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Is a negative correlation between resource abundance and growth sufficient evidence that there is a "resource curse"? ☆

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ABSTRACT

Evidence from cross-sectional growth regressions suggests that economies dependent on natural resource exports have had slower growth than resource scarce economies. Explanations for this "curse of resources" focus on institutional and market failures caused by resource abundance. With a simple two sector model exhaustible resource model, we demonstrate that the correlation between growth and natural resource abundance can be negative in the absence of market and institutional failures. Since there is no way to distinguish between efficient and inefficient equilibria on the basis of the negative correlation between growth and resource abundance, finding that correlation is not sufficient to conclude resources are a curse, nor is it necessary to find a positive correlation between growth and resources to overturn the resource curse interpretation. We show whether resources are a curse or a blessing for an economy can only be determined by an investigation of the correlation between resource abundance and income levels. Using panel data for U.S. states for the period 1970–2001, we show that resource abundance is negatively correlated with growth rates but positively correlated with income levels.

Introduction

Evidence from cross-sectional growth regressions suggests that economies dependent on natural resource exports have had slower growth than resource scarce economies. Consequently, Sachs and Warner (1995, 1999, 2001) and many others have concluded that resource abundance is a "curse" for economies, and a growing literature seeks to identify the way in which natural resource exploitation crowds out growth promoting institutions, investments or productive activities which in turn reduces welfare by lowering long run income levels.[2] Peretto (2008) notes that it would appear that to dispel the curse one must demonstrate that the correlation between resource abundance and growth is non-negative. A sizeable literature has emerged assessing the robustness of the resource curse correlation to alternative measures resource abundance and estimation methods.[3]

In this paper, we argue that the welfare interpretation of growth rates in this literature, and the expectation that resource abundance can only be good for an economy if it is positively correlated with growth, are both misleading for two reasons. First, the normative evaluation of resource abundance for economies has suffered from an insufficiently specified counter-factual

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[2] Neary and Van Wijnbergen (1986) and Sachs and Warner (2001) argue that natural resource intensive economies have high labor costs which tend to make manufacturing uncompetitive. Other authors have modeled the harm to the economy as arising from the manufacturing sector being characterized by external economies in production. For example, learning by doing in Matsuyama (1992), Torvik (2001), and Matsen and Torvik (2005), and increasing returns to scale in manufacturing in Sachs and Warner (1999) and Mehlum et al. (2006). Gylfason et al. (1999), Gylfason (2001) and Bravo-Ortega and De Gregorio (2005, 2007) argue that low growth and income levels could be due to low human capital accumulation. Gelb (1988), Rodriguez and Sachs (1999), Auty (2001) and Atkinson and Hamilton (2003) argue that resource windfalls result in inefficient use of resource rents. There has been a great amount of focus in the literature on identifying the effects of natural resources on institutions and of the effect of institutions on growth. See Leite and Weidmann (1999), Atkinson and Hamilton (2003), Sala-i-Martin and Subramanian (2003), Bulte et al. (2005), Papyrakis and Gerlagh (2004, 2007), Mehlum et al. (2006), Robinson et al. (2006), Brunnschweiler (2008), and Brunnschweiler and Bulte (2008).

[3] Evidence for the curse has also been shown in Leite and Weidmann (1999), Atkinson and Hamilton (2003), Bulte et al. (2005), Sala-i-Martin and Subramanian (2003), and Papyrakis and Gerlagh (2004, 2007). There are, however, a number of papers question whether the curse of resources exists. See Davis (1995, 2008a, 2008b), Wright and Czelusta (2004), Stijns (2005), Bravo-Ortega and De Gregorio (2005, 2007), Lederman and Maloney (2007), Brunnschweiler (2008), Brunnschweiler and Bulte (2008), and Alexeev and Conrad (2009).

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benchmark to inform us as to what we should expect to observe when natural resource exploitation occurs in the context of well-functioning markets and institutions. Second, because natural resource production inherently involves intertemporal tradeoffs, the cross-sectional estimation strategies prominent in this literature are incapable of assessing the welfare implications of resource abundance.

We extend the analysis of the dynamic causes of the resource curse by considering what we believe is a surprising omission from models of the curse of natural resources, namely that of a well-specified natural resource market.[4] As the resource curse is generally thought to be a phenomenon associated primarily with exhaustible resources,[5] we show that the basic Hotelling (1931) model of a competitive well-functioning exhaustible resource industry predicts a negative correlation between resource abundance and income growth and a positive correlation between resource abundance and income levels.[6] The economic rents earned in the exhaustible resource sector explain the differences in levels, while the dynamics of the intertemporal tradeoffs faced by exhaustible resource owners explain the growth effects. As our model assumes that the natural resource markets are well functioning, we show that market and institutional failures—the standard arguments in the literature—are not necessary to explain the slower growth implication of the resource curse. Our model also shows that finding a negative correlation between resource abundance is not sufficient to conclude that resource abundance reduces incomes over the long run, as is implied in the resource curse interpretation.

To discriminate between whether resources are a blessing or a curse requires an estimation strategy that can distinguish between the effects of resource abundance on income levels and income growth.[7] We show that cross-sectional growth equations cannot identify distinct effects of resource abundance on income levels and income growth since any growth specification can be respecified in terms of income levels where the only important change is a rescaling of the coefficient on the initial income regressor. This suggests that panel data estimation methods are necessary to identify distinct effects of natural resources on income levels and growth.[8]

We examine data for U.S. states over the period 1970–2001 using the same empirical strategy of Sachs and Warner (1995) and Papyrakis and Gerlagh (2004, 2007). We show that in a cross-sectional estimation, resource abundant U.S. states exhibit the slower growth that is associated with the "curse of natural resources". While the U.S. states in our data do display variety in the institutional arrangements for extractive industries (e.g., Libecap and Wiggins, 1985) and in general (e.g., Mitchener and McLean, 2003), it is unlikely that market or institutional failure is behind this result. This is in direct contrast to the conclusions drawn by Papyrakis and Gerlagh (2004, 2007) and counter to the expectations of Mehlum et al. (2006, p. 3).[9] When we specify a theoretically consistent panel estimation model for U.S. states, we find that predictions about the effects of natural resources on per capita income levels and per capita income growth from a simple two-sector exhaustible resource economy model are broadly supported. That is, resource abundance is correlated with slower per capita income growth but resource rents raise per capita income levels. In the model we consider, per capita income is higher all along the equilibrium path. Thus, like a number of authors before us, we conclude that resources are a blessing, not a curse.

Theory

Is a negative correlation between growth rates and resource abundance sufficient evidence for concluding natural resources are a curse? Is it obvious that in the absence of market or institutional failures, that there would be a positive correlation between growth and natural resource abundance? In this section we demonstrate that the answer to both these questions is no. With a simple two sector model that includes an exhaustible resource, we demonstrate that the correlation between growth and natural resource abundance can be negative in the absence of market and institutional failures. Since there is no way to distinguish between efficient and inefficient equilibria on the basis of a negative correlation between growth and resource abundance, finding that correlation is not sufficient to conclude resources are a curse, nor is it necessary to find a positive correlation to overturn the resource curse interpretation. Whether resources are a curse or a blessing for an economy can only be determined with an investigation of the correlation between resource abundance and income levels.

A model of a two-sector small open economy producing an exhaustible resource

We build on the model in Chambers and Gordon (1966) to consider a simple dynamic specific-factor model of a small open

[4] Bravo-Ortega and De Gregorio (2007) and Davis (2008a) both highlight this omission in the literature. With the exception of Barbier (2005), we have found no papers that model endogenous decisions occurring in the natural resource sector. Sachs and Warner (1999) and Rodriguez and Sachs (1999) have dynamics in the resource rents, but neither paper has the flow of rents being determined endogenously. Bravo-Ortega and De Gregorio (2007), like us, have an endogenous allocation of labor between the resource and alternative sectors. They do not use the size of, or changes in, the size of the resource sector in their econometric analysis.

[5] The literature does not find this regularity for renewable resources (e.g., Bulte et al., 2005), which is why we do not emphasize them here.

[6] Without modeling the dynamics of resource production several papers in the literature predict "convergence from above": resource economies have higher levels of income but lower rates of growth in income. In Bravo-Ortega and De Gregorio (2005, 2007) resource rents are fixed in magnitude, but technological change in the manufacturing sector due to human capital accumulation makes the relative contribution of economic rents shrink over time. In Rodriguez and Sachs (1999), resource rents also decline, but at an exogenous rate of change. In contrast, the decline in resource rents occurs endogenously, in our model, and its rate of decline is affected by the rates of change in technology, population growth, and resource prices.

[7] These distinct predictions for the impact of resource abundance on income growth and income levels reconciles the empirical finding in the resource curse literature that resource abundance is negatively correlated with per capita income growth rates with a growing body of empirical evidence that finds that natural resource abundance is positively correlated with income levels. For evidence that natural resources make economies richer suggesting that resources are a blessing for an economy see Davis (1995), Sala-i-Martin (1997), Hall and Jones (1999), Keay (2007), and Sachs (2007). Using cross-sectional analysis with instrumental variables for institutional quality, Brunnschweiler (2008), and Brunnschweiler and Bulte (2008) find that natural resources are associated with higher levels of growth.

[8] Lederman and Maloney (2007), Bravo-Ortega and De Gregorio (2007), and Manzano and Rigobon (2001, 2007) find that the negative correlation between annual growth rates and the share of natural resource exports in GDP found in cross-sectional estimation is not produced in panel estimation.

[9] Mehlum et al. (2006) claim "that natural resources put the institutional arrangements to a test, so that the resource curse only appears in countries with inferior institutions". Papyrakis and Gerlagh (2007), using a two-equation cross-sectional model of U.S. states data, find that resources negatively affect institutional quality and that institutional quality affects economic growth. However, to identify the effect that resources have upon growth, they use the strong assumption that errors in explaining institutional quality with resource intensity are uncorrelated with the errors in explaining economic growth. Brunnschweiler and Bulte (2008) discuss alternative forms of identification of the resource intensity, institutional quality link.

economy with an exhaustible resource sector and a manufacturing sector. Following Chambers and Gordon (1966, pp. 320–321), in a small open economy model with capital perfectly elastic in supply, economic growth can be expressed entirely in terms of the labor allocation.[10] At any point in time, t, production in the resource and manufacturing sectors are given by

$$Q_R(t) = [L_R(t)A(t)]^{\alpha}, \tag{1}$$

and

$$Q_M(t) = L_M(t)B(t). \tag{2}$$

Manufacturing is a constant-returns-to-scale industry, with output depending upon the amount of labor, $L_M(t)$, used in the manufacturing sector.[11] Labor used in the resource sector, $L_R(t)$, is subject to positive but diminishing marginal product of labor since $0<\alpha<1$, reflecting an unspecified specific factor, e.g., "land", which is fixed in magnitude.[12] $A(t)$ and $B(t)$ denote the exogenous levels of labor augmenting technological change in the resource and manufacturing sectors. Let $g_A = \dot{A}/A > 0$ and $g_B = \dot{B}/B > 0$ denote the exogenous rates of technological change in each sector, where the "dot" derivative means $\dot{x} \equiv dx(t)/dt$ for any variable $x(t)$. Thus, $A(t) = A(0)e^{g_A t}$ and $B(t) = B(0)e^{g_B t}$.

The quantities of labor available for use in the two sectors is constrained by the size of the population,

$$L_R(t) + L_M(t) = L(t), \tag{3}$$

where $L(t)$ grows at rate $\dot{L}/L = n > 0$, so that $L(t) = L(0)e^{nt}$.

In this small open economy, producers in both sectors treat output prices as exogenous. The price of output in the resource sector is $p_R(t)$ and the price of output in the manufacturing sector is $p_M(t)$. The manufacturing price is chosen as the numeraire so $p_M(t)=1$ for all t. Let $g_R \equiv \dot{p}_R/p_R$ denote the rate of change in the relative price of the natural resource. Thus, $p_R(t) = p_R(0)e^{g_R t}$.

Our substantive extension to the Chambers and Gordon (1966) model described to this point is to specify Hotelling (1931) production of an exhaustible resource. The natural resource stock, $S(t)$, declines at the rate of production,

$$\dot{S}(t) = -Q_R(t), \quad S(0) = S_0. \tag{4}$$

Together with (1), (4) implies that one unit of the natural resource stock is required to produce one unit of the natural resource output. Since the extraction costs are independent of the stock level, there exists some $T<\infty$ at which

$$S(0) = \int_0^T [L_R(t)A(t)]^{\alpha}\, dt. \tag{5}$$

Therefore, at time T, when the stock is exhausted, the economy reverts entirely to manufacturing production.

The profits a resource producer earns at any instant in time depend upon the exogenous resource price, $p_R(t)$, and the endogenous labor demand, $L_R(t)$, where labor is paid its opportunity cost, $w(t)=B(t)$, the marginal product of labor in the manufacturing sector. Natural resource producers also compete for the rights to exploit the resource stock. Let $\lambda e^{\rho t}$ denote the current value of the user cost of the resource stock when the market for the resource stock is perfectly competitive. This is comprised of two parts: λ is the present value of the *in situ* price firms must pay the owner of the resource for rights to extract a unit of the resource stock, and ρ is the rate of return that the resource owner could earn by investing the proceeds of his sale in international capital markets. For the resource owner to be indifferent between selling at any two points along the equilibrium path, the current value of the sales price, $\lambda e^{\rho t}$, must rise at the rate of interest. In addition, in order that the resource owner does not wish to wait and simply earn capital gains forever, it must be that $\rho > g_R$, so that the resource price grows more slowly than the rate of interest.

The resource producer's flow of profits at any point in time t are

$$\pi_R(t) = p_R(t)[L_R(t)A(t)]^{\alpha} - B(t)L_R(t) - \lambda e^{\rho t}[L_R(t)A(t)]^{\alpha}. \tag{6}$$

Along the equilibrium path, firms choose labor $L_R(t)$ to maximize (6), taking as given the resource price, $p_R(t)$, the labor productivity, $A(t)$, the *in situ* cost, $\lambda e^{\rho t}$, and the wage rate, $B(t)$. Choosing $L_R(t)$ to maximize (6) yields

$$\alpha p_R(t)L_R(t)^{\alpha-1}A(t)^{\alpha} = B(t) + \alpha\lambda e^{\rho t}L_R(t)^{\alpha-1}A(t)^{\alpha}, \tag{7}$$

which states that firms set the value of the marginal product of labor equal to the sum of marginal labor costs plus the current value of the marginal scarcity rent from the marginal unit of labor hired. Re-writing (7) as a condition that must hold over some interval dt yields:

$$\begin{aligned}&[\alpha p_R(t)L_R(t)^{\alpha-1}A(t)^{\alpha} - B(t)](1-\rho\, dt)\\ &\quad = \alpha p_R(t+dt)L_R(t+dt)^{\alpha-1}A(t+dt)^{\alpha} - B(t+dt).\end{aligned} \tag{8}$$

The left-hand side of (8) is what a resource firm could earn by selling the marginal unit of resource output at time t and investing those proceeds in the international capital market, earning interest ρ over the interval dt. For the owner of the resource to be indifferent between selling at time t and at time t+dt, it must be that the marginal profits at time t+dt equal the right-hand side of this expression. Eq. (8) is the basic intertemporal arbitrage equation for a firm in the resource extraction industry. It describes how a resource firm's labor demand changes over time because of arbitrage across competing assets, when all other assets earn a return of ρ. Eq. (8) does not require the price of the resource to be rising (as in Hotelling, 1931), nor does it require technological change to occur in either sector.

Since someone in society earns the payment for the use rights of the resource, the firm profits, and the labor income, it is convenient for measures of per capita income to sum these together into industry gross income, $Y_R(t) = p_R(t)[L_R(t)A(t)]^{\alpha}$, for the resource sector, and $Y_M(t)=B(t)L_M(t)$ for the manufacturing sector. Then the average product of labor in the resource sector, $y_R(t)$, and the manufacturing sector, $y_M(t)$, equal

$$y_R(t) \equiv \frac{Y_R}{L_R} = p_R(t)L_R(t)^{\alpha-1}A(t)^{\alpha} \quad \text{and} \quad y_M(t) \equiv \frac{Y_M}{L_M} = B(t). \tag{9}$$

Thus, we can write (8) as

$$[\alpha y_R(t) - y_M(t)](1+\rho\, dt) = \alpha y_R(t+dt) - y_M(t+dt), \tag{10}$$

where the marginal product of labor in the resource sector is simply α times the average product of labor in that sector. Thus, (10) (and hence (8)) imply a relationship between how the average product of labor in each sector changes over time. Let dt approach zero and express (10) in terms of rates of change. From (9) and (10), the rate at which labor demand in the resource sector

[10] To see this, suppose that $Q_R = (A_R L_R)^{\alpha} K_R^{1-\alpha}$ and $Q_M = (A_M L_M)^{\beta} K_M^{1-\beta}$ (where $0<\beta<1$). Note that the assumption on β makes the marginal product of labor in manufacturing to be diminishing. Then with capital elastically supplied, the firm's first-order-conditions imply that $K_R = L_R(1-\alpha)/\alpha$ and $K_M = L_M(1-\beta)/\beta$.

[11] All of the qualitative conclusions can be reached in a model in which the marginal product of labor is diminishing in manufacturing as well. Constant-returns-to-scale in manufacturing simplifies the presentation.

[12] In Chambers and Gordon (1966) land is an input into the production of wheat. It might be thought that the resource stock is the specific factor but Livernois and Uhler (1987) have shown that including the resource stock into the production function is appropriate only at the mine level, not at the aggregate level.

changes obeys (where we have dropped the time notation)

$$\frac{\dot{L}_R}{L_R}=\frac{-\rho}{1-\alpha}\left(\frac{\alpha y_R-y_M}{y_M}\right)+\frac{\alpha g_A}{1-\alpha}-\frac{g_B}{1-\alpha}+\frac{\alpha y_R g_R}{(1-\alpha)y_M}. \quad (11)$$

Eq. (11) shows that there are four separate forces at work in determining the net flow of labor into the resource sector. The first term is the Hotelling effect caused by the intertemporal optimization of resource owners in the presence of an international capital market which yields a rate of return ρ. Since (10) implies that the numerator of the term in brackets is positive, the intertemporal optimization of resource producers causes labor to exit the resource sector, all else constant. The second force is the rate of technological change in the resource sector, g_A, which causes labor demand in the resource sector to increase. The third force is the rate of technological change in the manufacturing sector, g_B, which raises the opportunity cost of labor in the resource sector thereby causing labor to flow out of the resource sector. Finally, when the resource price growth, g_R, is positive, it increases the value of labor in the resource sector, so labor flows into the resource sector, and when g_R is negative, labor flows out the resource sector.

In addition, the time T when reserves are exhausted is endogenous. Firms continue to harvest from the stock so long as the profit from extraction is positive in value and is feasible. Thus, at time T, reserves are exhausted, so that (5) is satisfied, and, if competitive markets exist for the ownership rights to the resource, then at time T, profits must also vanishes, from which (6) implies that

$$\pi_R(T)=p_R(T)[L_R(T)A(T)]^{\alpha}-B(T)L_R(T)-\lambda e^{\rho T}[L_R(T)A(T)]^{\alpha}=0. \quad (12)$$

Substituting from (7) to eliminate $\lambda e^{\rho T}$ and simplifying yields

$$\alpha L_R(T)=L_R(T). \quad (13)$$

Since $0<\alpha<1$, this equality can hold only if $L_R(T)=0$. Hence, solving (7) for $L_R(t)=[\alpha(p_R-\lambda e^{\rho t})A^{\alpha}B^{-1}]^{1/(1-\alpha)}$ and evaluating at time T yields

$$\lambda=p_R(T)e^{-\rho T}. \quad (14)$$

Substituting the value of $L_R(t)$ into (5) yields two equations, (5) and (14), which implicitly define T and λ. It can be shown that $d\lambda/dS_0<0$, $d\lambda/dB_0<0$, $d\lambda/dA_0>0$, and $d\lambda/dp_R^0>0$. Thus, the scarcity rental price, λ is decreasing in the stock size and in the productivity of manufacturing, and increasing in the productivity in the resource sector and in the resource price. By (14), the time to exhaustion, T, is decreasing in λ.

Thus every natural resource abundant economy is on its way to becoming a resource poor manufacturing economy. How long this takes depends on the size of the resource stock, S_0, the relative price of natural resources to manufactured goods, $p_R(t)$ (and its expected growth, g_R), the rates of technological change in the two sectors, g_A and g_B, and the rate of return to capital, ρ. We can also see from (9) that as $t\to T$, y_R tends to infinity and Y_R tends to zero, since L_R approaches zero at a faster rate than y_R approaches infinity.[13]

Effect of natural resources on per capita income growth

Since the "curse of natural resources" is usually presented as a relationship between resource abundance or resource intensity of an economy and the growth rate of per capita income (Sachs and Warner, 2001), we first investigate the dynamics of per capita income growth.

[13] From (8), $y_R=p_RA^{\alpha}/L_R^{1-\alpha}$. So as $L_R\to 0$, y_R tends to infinity. However, $Y_R=p_RA^{\alpha}L_R^{\alpha}$, so as $L_R\to 0$, total resource sector income goes to zero.

Define per capita income in a mixed resource/manufacturing economy as the weighted sum of the average product of labor in each sector:

$$y=y_R\left(\frac{L_R}{L}\right)+y_M\left(\frac{L-L_R}{L}\right)=p_RA^{\alpha}L_R^{\alpha-1}\left(\frac{L_R}{L}\right)+B\left(\frac{L-L_R}{L}\right). \quad (15)$$

Time differentiating per capita income from (15) and writing it in terms of percentage rate of growth yields:

$$\frac{\dot{y}}{y}=\frac{g_By_M}{y}+\frac{g_Ry_RL_R}{yL}+\frac{(\alpha g_Ay_R-g_By_M)L_R}{yL}-\frac{n(y_R-y_M)L_R}{yL}+\frac{(\alpha y_R-y_M)L_R}{yL}\left(\frac{\dot{L}_R}{L_R}\right). \quad (16)$$

To show the effect natural resources have on growth relative to a non-natural resource producing economy, we substitute for $\dot{L}_R/L_R$ from (11) into (16) and subtract $\dot{y}_M/y_M=g_B$ to yield

$$\frac{\dot{y}}{y}-\frac{\dot{y}_M}{y_M}=\frac{-\rho(\alpha y_R-y_M)^2L_R}{(1-\alpha)y_MyL}-\frac{n(y_R-y_M)L_R}{yL}+\frac{\alpha(y_R-y_M)(g_A-g_B)L_R}{(1-\alpha)yL}+\frac{g_Ry_RL_R[(1-\alpha)y_M+\alpha(\alpha y_R-y_M)]}{(1-\alpha)y_MyL}. \quad (17)$$

There are four forces at work in determining the growth in a resource economy relative to a non-resource economy identified in (17). The first term is due to the intertemporal optimization of resource owners who face an opportunity cost ρ in the international capital markets. This causes per capita income growth to be lower in a natural resource producing economy relative to a non-natural resource producing economy. The second effect also reduces income growth in a natural resource economy relative to a non-resource economy, since population growth spreads the resource rents over a larger population. The third force is the effect of the relative rates of technological change in the resource and manufacturing sectors. This effect reduces the relative growth of a natural resource economy if the rate of technological change in manufacturing exceeds the rate of technological change in the resource sector, and is increases relative growth otherwise. The final effect is due to growth in the real resource price level. When the real resource price level is growing, resource economies grow relatively more quickly, all else equal, and when the real resource price level is falling, resource economies grow relatively more slowly.

If technological change in manufacturing has been the source of economic growth in most western countries, and real resource prices have been falling, then the curse of natural resources immediately follows, since every term on the right-hand side of (17) is then negative, which means that growth is slower when natural resources are abundant. Thus our first result is:

Proposition 1. *With each factor paid its marginal product, with technology defined by* (1) *and* (2), *with a higher rate of technological change in manufacturing than in resource extraction, and with constant or declining real resource prices,* (i) *an economy with natural resources grows more slowly than a pure manufacturing economy, and* (ii) *labor flows out of the resource sector over time.*

Proof. (i) If $g_A\le g_B$ and $g_R\le 0$, each term on the right-hand side in (17) is non-positive in sign, so a resource economy grows more slowly than a non-resource economy. (ii) Similarly, if $g_A\le g_B$ and $g_R\le 0$, then each term on the right-hand side of (11) is negative, which implies that labor is flowing out of the resource sector over time. This proves the proposition. □

Per capita income in a pure manufacturing economy grows at rate g_B, the rate of growth in manufacturing productivity. This is shown in Fig. 1 as the percentage change in the effective wage of

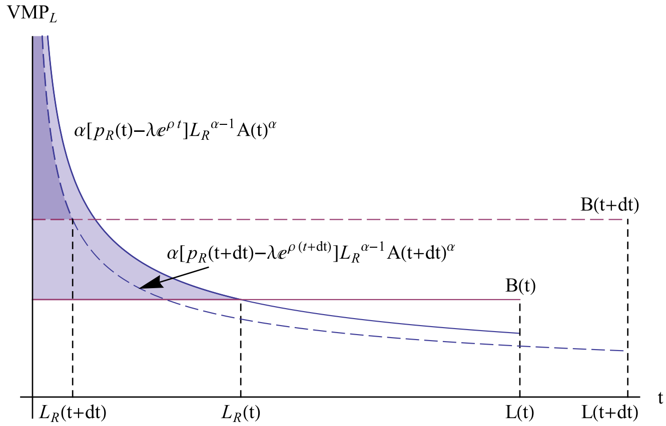

Fig. 1. The positive level effect and the negative growth effect from natural resources.

labor from $w(t)=B(t)$ to $w(t+dt)=B(t+dt)$. Thus the total gain to a manufacturing economy is equal to the difference between the rectangles $L(t+dt)B(t+dt)$ and $L(t)B(t)$. This difference involves a gain in productivity for all workers of $B(t+dt)-B(t)$, which measures the per capita increase in income in a pure manufacturing economy, and an increase due to an increase in the size of the labor force to $L(t+dt)$ from $L(t)$. An exhaustible resource economy, in contrast, will grow more slowly for two reasons. First, an exhaustible resource economy already earned surplus equal to the shaded areas between $B(t)$ and $B(t+dt)$, because these were part of economic rents when the wage was $w(t)=B(t)$. These are now higher wages to all workers—including the $L_R(t)-L_R(t+dt)$ workers who left to go to the manufacturing sector and the $L_R(t+dt)$ workers who remain the resource sector—but at the expense of lower rents to the owners and producers of the resource. So even if there were no Hotelling dynamic effects due to an increase in the scarcity rental price, the natural resource economy would grow less in total by an amount equal to the shaded area of former resource rents between $B(t)$ and $B(t+dt)$.[14] Second, when there are Hotelling scarcity effects, the economic rents to the natural resource sector decline from the entire shaded area to just the dark shaded area above the $B(t+dt)$ wage curve and below the new net value of marginal product of labor curve in the resource sector (the downward sloping dashed curve). Thus, the light shaded area above $B(t+dt)$ is also lost, relative to the growth in a pure manufacturing economy. This is due to the scarcity rental price of the exhaustible resource rising, which causes the NVMP$_L$ in the resource sector to shift down, resulting in lower resource labor demand of $L_R(t+dt) < L_R(t)$. Even if this second effect were offset by technological progress in the natural resource sector, the first effect, that increases in manufacturing productivity are spread over a smaller labor base, would still inhibit per capita income growth in a natural resource economy. When both effects are observed, growth in the resource intensive economy is lower by the light shaded area in Fig. 1.

Proposition 1 shows that the slower growth aspect of the “curse of natural resources” can occur in perfectly functioning competitive markets. Thus the explanations emphasized in the literature, including corruption, rent-seeking, increasing-returns-to-scale in manufacturing, may all contribute to the resource curse, but none of these is necessary to explain the slower growth of resource abundant economies.[15] Since market and/or institutional failures are not necessary for there to be a negative correlation between resource abundance and income growth, it follows that observing a negative correlation between resource abundance and growth is not sufficient to conclude that an economy suffers from market and institutional failures that reduce long run income.[16] To show that resource abundance is a “curse” requires evidence that there is a negative correlation between resource abundance and income levels.

Effect of natural resources on per capita income levels

Since the negative correlation between resource abundance and income growth can occur in the absence of market and institutional failures, to conclude that there is a resource curse one needs to demonstrate that resource abundance is correlated with lower income levels.

Inspection of (15) shows that an economy which has no resources has per capita income y_M and provides our second result:

Proposition 2. *With each factor paid its marginal product and technology defined by* (1) *and* (2), *per capita income is always higher in an economy with a resource base than in a pure manufacturing economy.*

Proof. The difference in per capita income in a mixed resource/manufacturing economy and a pure manufacturing economy equals

$$y-y_M=(y_R-y_M)\left(\frac{L_R}{L}\right)>(\alpha y_R-y_M)\left(\frac{L_R}{L}\right)=\lambda e^{\rho t}y_R\left(\frac{L_R}{L}\right)>0. \qquad (18)$$

The expression after the first equality is the average rents earned in the resource sector multiplied by the share of labor in the resource sector. The first inequality in (18) occurs because $\alpha<1$, so that the marginal product of labor is less than the average product of labor. The second inequality follows from (7), which requires that the economic rents in the resource sector be equal to the scarcity rental value of the marginal product of labor in the resource sector. Since $\lambda>0$ by (14), this proves the proposition. □

Note that Proposition 2, as simple as it is, turns the “curse of natural resources” on its head. If natural resources are a curse, how can their presence cause per capita income to be larger? The answer is that if the resource sector earns economic rents, which it will so long as property rights are well defined, then by definition, these are returns above what it costs to bring the good to market, which is the foregone manufacturing output. Fig. 1 shows the level effect. At time t, an economy with no natural resources has per capita income equal to $B(t)$, as all labor is engaged in manufacturing, so total income in the economy is $B(t)L(t)$. However, economies with natural resources have income in the resource sector that is higher by the shaded area between the net value of marginal product curve, $\alpha(p_R(t)-\lambda e^{\rho t})L_R^{\alpha-1}A^\alpha$, and the opportunity cost of labor, $w(t)=B(t)$, for each unit of labor employed in the resource sector.[17] The average difference

[14] This effect was first noted by Chambers and Gordon (1966).

[15] This is counter to the claim of Mehlum et al. (2006) that the resource curse should only occur in economies with “grabber friendly” institutions.

[16] Nor is the correlation useful for identifying economic underperformance. Sachs (2007) suggests that resource abundant economies suffer from problems of under-performance rather than lower incomes. This notion is similar to Barbier's (2005) examination of “frontier” economies where too much consumption crowds out long run investment diminishing the sustainability of the high consumption levels of the resource boom. Barbier's analysis ignores the important role of external sources of capital for frontier economies which can substitute for domestic savings (see McLean, 1994).

[17] Note that even if the marginal product of labor were decreasing in the manufacturing sector, there would exist an economic rent area, as the marginal product of labor, $\alpha L_R^{\alpha-1}A^\alpha$, approaches infinity as L_R approaches zero, since $0<\alpha<1$.

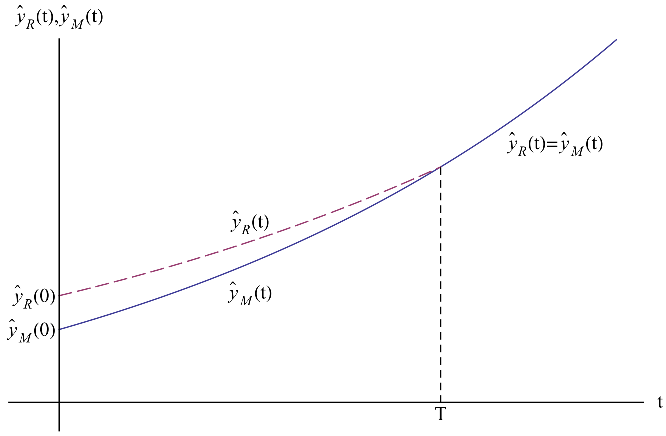

Fig. 2. Natural resources are a blessing, not a curse.

between per capita income in the two sectors, $y_R - y_M$, is given by dividing the rents triangle by the number of workers in the resource sector.[18]

The net result of having natural resources in a well functioning economy is shown in Fig. 2. This figure shows the per capita income path in an economy that has, at time 0 begun to exploit a newly discovered exhaustible natural resource stock of size S_0 (shown by the dashed line, labeled $\hat{y}_R(t)$), compared to an economy that has made no such discovery (the solid curve, labeled $\hat{y}_M(t)$). The natural resource economy has a higher level of income during the entire natural resource production phase, [0,T], than does an economy with no natural resources, but has a lower growth in per capita income. Once the resource is exhausted, the natural resource economy reverts to behaving like an economy that never made a natural resource discovery.[19] Thus, the per capita income gain to having natural resources occurs during the period of natural resource production.[20]

The level effect from natural resources does not depend upon increasing real resource prices, technological change, or any other rates of growth. All that is required is a system of property rights where rents are captured in the resource sector. Indeed, it is not even necessary that all of the rents be captured for this proposition to hold. Even if only a fraction $0<s<1$ of the rents are captured, the first equality in (18) can be written as $y-y_M = s(y_R-y_M)L_R/L$, and it is clear that $s\lambda e^{\rho t}$ is still positive. Thus, for this result to be reversed, one must postulate not only that the economic rents are not captured, but the rents must be *over* dissipated. This is not possible in a rent-seeking model with rational rent-seekers.[21] Unlike with income growth, our model shows that resource abundance cannot cause income levels to be lower unless there are market and/or institutional failures. Consequently, to show that there is a "resource curse" one needs to show that there is a negative correlation between resource abundance and per capita income levels.

There are a number of models in which the resource curse has been argued to be due to market failure, either due to increasing returns to manufacturing (e.g., Sachs and Warner, 1999; Mehlum et al., 2006) or due to learning-by-doing in manufacturing (e.g., Sachs and Warner, 1995; Torvik, 2001; Matsen and Torvik, 2005). Our model shows that high rates of growth in manufacturing do lower per capita income growth rates, as suggested by these models, but again, this is not the only effect at work. But a more serious criticism of these models is that if welfare is reduced by one of these market failures, then not only should one observe a lower growth rate, but one should also observe an negative per capita income *level effect* from natural resources. Thus, to distinguish between our model from models with market—or institutional—failures, one has to examine whether or not there is a positive level effect. The growth effect is not sufficient to distinguish between these hypotheses.

Empirics

We now turn to an empirical analysis of growth and level effects from natural resources using a panel of data from the U.S. states over the period 1970–2001. This economy would be judged by most observers to be both institutionally sophisticated and economically advanced.[22] We begin by applying the cross-sectional growth models employed by much of the resource curse literature to demonstrate the U.S. states are suitable to use for considering specification issues in the resource curse literature. Using and different sample period and measure of resource abundance, we confirm the results of Papyrakis and Gerlagh (2007) that resource abundant states do exhibit the slower growth properties of the resource curse. We then estimate income level, and income growth equations using panel data to uncover the dynamic forces at work and to demonstrate that slower growth in resource abundant states is not indicative of lower income levels.

Specification issues

The standard approach for estimating the effect of natural resource abundance on growth involves using a single equation growth model to capture both a level and a growth effect. Consider the conditional convergence estimating equation used by Sachs and Warner (2001):

$$\ln\left(\frac{y_{i\tau}}{y_{i0}}\right)\frac{1}{\tau} = \delta_0 + \delta_1 \ln(y_{i0}) + \delta_2 R_{i0} + \delta_3 Z_i + \varepsilon_i, \quad i=1,\ldots,N, \tag{19}$$

where $y_{i\tau}$ and y_{i0} are per capita incomes measured at τ periods apart, R_{i0} is a measure of the natural resource abundance at time 0, Z_i is a set of other control variables, and ε_i is the unobserved error for each state, $i=1,\ldots,N$, in the regression. The parameters to be estimated are $\delta_j, j=0,\ldots,3$. Rearranging this equation to look at level effects yields

$$\ln(y_{i\tau}) = \delta_0\tau + (\delta_1\tau+1)\ln(y_{i0}) + \delta_2\tau R_{i0} + \delta_3\tau Z_i + \tau\varepsilon_i, \quad i=1,\ldots,N. \tag{20}$$

Thus, the signs of each of the coefficients in the level effects regression, except the coefficient on the initial per capita income, are exactly the same sign in the growth equation as in the level

[18] It might be thought that an increase in B could cause the resource sector to disappear. However, λ, which is endogenous, appears in the $\alpha(p_R(t)-\lambda e^{\rho t})L_R^{\alpha-1}A^{\alpha}$ curve. An increase in B_0 causes λ to decrease—i.e., the rent from resources is measured as the difference between the marginal productivity in the two sectors—thus, economies with higher B, all else equal, will also have lower λ, which causes both the opportunity cost, $w(t)$, and the $NVMP_L^R$ to shift upwards. Indeed, as shown by (14), the scarcity rental price, λ, is positive for any finite level of the stock.

[19] Sachs and Warner (1995, Fig. B1) and Gylfason (2000, Fig. 1, p. 546) each assume that there is a temporary positive level effect, but that growth in the long-run is lower. In Sachs and Warner growth eventually returns to the no-resource rate g_B, but the long-run level is everywhere lower. In Gylfason, both the level and growth are lower in the long run. Bravo-Ortega and DeGregorio (2007, Fig. 4.1, p. 80) draw an income path similar to ours, and Rodriguez and Sachs (1999, Fig. 2, p. 283) have a capital stock that overshoots its long-run potential.

[20] Of course, by using capital markets to facilitate savings, such an economy would be able to sustain a higher level of consumption forever as a result of the natural resource windfall, so welfare must also be improved.

[21] For example see Mueller (2003, pp. 335–337).

[22] Albeit, see Papyrakis and Gerlagh (2007).

equation (Mehlum et al., 2006, p. 16). They differ in magnitude, but not in sign. Thus, if the effect of resources is negative in (19), it must be negative in (20) as well. Therefore, it is impossible to use this method of estimation to obtain different effects of natural resources on levels and growth.

To test the predictions of our model, we need an empirical specification that can distinguish between the effects of resource abundance on income growth and income levels. A useful starting point is the definition of income in a two-sector economy, given by (15). This can be re-written as

$$y = y_M + (y_R - y_M)\left(\frac{L_R}{L}\right). \tag{21}$$

This implies the following empirical specification:

$$y_{it} = \alpha_0 + \alpha_1\left(\frac{L_{it}^R}{L_{it}}\right) + v_{it}, \quad i = 1, \ldots, N, \ t = 1970, \ldots, 2001, \tag{22}$$

where in state i in period t, y_{it} is the observed income level, L_{it}^R is employment in the resource sector, and L_{it} employment in the economy. Thus, L_{it}^R/L_{it} is the share of employment in the resource sector in state i in period t.[23] Given that the share of resource employment is available for U.S. states, we can estimate the model in (22) with standard linear regression methods. The value of the intercept $\alpha_0 = y_M$ is a measure of average per capita gross state product (GSP) in the manufacturing sector over the period, and the slope parameter $\alpha_1 = y_R - y_M$ measures the difference in GSP per capita in the two sectors. Since y_M and y_R change over time, the parameters α_0 and α_1 measure the sample averages for manufacturing income and the difference between resource and manufacturing income. The error structure can be written as $v_{it} = u_i + e_{it}$, where u_i is the component specific to each state and e_{it} is white noise. In a fixed effects model, the u_i are estimated as dummy variables for each state. In a random effects specification, the u_i are mean zero white noise, with variances that differ across states.

Next, consider the specification of the growth dynamics. The equation governing growth in per capita income is (16). We can re-write this as

$$\frac{\dot{y}}{y} = \frac{g_B y_M}{y} + \left[\frac{\alpha g_A y_R - g_B y_M}{y}\right]\left(\frac{L_R}{L}\right) + \left[\frac{y_R}{y}\right]\left(g_R \times \frac{L_R}{L}\right) - \left[\frac{y_R - y_M}{y}\right]\left(n \times \frac{L_R}{L}\right) + \left[\frac{\alpha y_R - y_M}{y}\right]\left(\frac{L_R}{L} \times \frac{\dot{L}_R}{L_R}\right). \tag{23}$$

Given that we observe the growth rate in per capita GSP, $\dot{y}/y$, the share of employment in the resource sector, L_R/L, the growth rate in resource prices, g_R, the growth rate in population, n, and the growth rate in the employment in the resource sector, $\dot{L}_R/L_R$, we may estimate this growth equation econometrically by treating the terms in square brackets in (23) as parameters to be estimated:

$$\ln\left(\frac{y_{it}}{y_{it-1}}\right) = \beta_0 + \beta_1\left(\frac{L_{it}^R}{L_{it}}\right) + \beta_2 \ln\left(\frac{p_t^R}{p_{t-1}^R}\right)\left(\frac{L_{it}^R}{L_{it}}\right) + \beta_3 \ln\left(\frac{N_{it}}{N_{it-1}}\right)\left(\frac{L_{it}^R}{L_{it}}\right) + \beta_4 \ln\left(\frac{L_{it}^R}{L_{it-1}^R}\right)\left(\frac{L_{it}^R}{L_{it}}\right) + \varepsilon_{it}, \tag{24}$$

where N_{it} is the population in state i in period t, p_t^R is the real price of natural resources (relative to manufactured goods) in period t.[24] We approximate rates of growth by log annual first differences and measure the shares of employment in their natural units. The error structure can be written as it $\varepsilon_{it} = u_i + e_{it}$, where u_i is the component specific to each state and e_{it} is white noise. The β_j's are parameters to be estimated. Because each of the parameters measures an economic variable that changes over the sample, the parameters measure the sample average for each economic variable.

Since (24) comes directly from our specification of the growth dynamics, the interpretation of the parameters is straightforward. The intercept, β_0, is equal to sample average of $g_B y_M/y$, so β_0 should be positive in value. The slope parameter β_1 is equal to the sample average of $(\alpha g_A y_R - g_B y_M)/y$. This is expected to be negative if the rate of technological change in the manufacturing sector is large relative to the rate of technological change in the resource sector, and positive if Wright and Czelusta's (2004) hypothesis that technological change in natural resources is large relative to manufacturing. The parameter β_2, which equals the sample mean of y_R/y, measures the premium earned in the resource sector, so it should be positive. When β_2 is greater than one, it indicates a positive premium. The parameter β_3, which equals to the sample mean of $-(y_R - y_M)/y$, is expected to be negative. The parameter β_4, which equals the sample mean of $(\alpha y_R - y_M)/y$, is expected to be positive.

The specification in (24) contains variables one might expect to see in a standard curse of natural resources econometric model, but their interaction with the employment share in the resource sector is derived from our two-sector model. While all curse of natural resource models contain some measure of the size of the resource sector, in (24) it is not just the size of the resource sector that matters, but how the size of the resource sector interacts with the rate of growth of the resource sector, the rate of growth in population, and the rate of growth in real resource prices. This is because the resource sector share of employment scales the influence of these other variables. As the share of resource employment approaches zero, an increase in these variables has less effect on the economy.

The panel of U.S. states, 1970–2001

We consider a panel of the fifty U.S. states over the period 1970–2001. The employment and income data are drawn from the Bureau of Economic Analysis and national and regional price indices available from the Bureau of Labor Statistics.[25] We observe per capita Gross State Product (GSP), the population size, mining employment,[26] total non-farm employment, and total employment in each state for each year of this period. We calculate the share of employment in the exhaustible resource sector as the mining employment divided by total employment for each state. We also calculate growth rates in the share of employment in the mining sector and of the population using log first differences. Each of these measures varies both across states and across time. However, resource prices vary only across time. As a measure of the relative resource price, we use the producer price index for "crude materials for further processing" divided by the index by the producer price index for "finished goods" (*cf.* Kellard and Wohar,

[23] This measure of resource abundance does not suffer the problem that a GDP based measure would have. Mehlum et al. (2006) argue that in a specification like (22), if resource abundance is measured relative to GDP, all else equal, economies with high GDP would appear resource scarce while low GDP economies would appear resource abundant.

[24] We made no distinction between L_{it} and N_{it} in Section 2, but since per capita income divides by N_{it}, we let n measure population growth rather than using employment growth. We use L_{it} in the denominator of the resource employment share rather than N_{it} to take remove business cycle effects from the resource employment share.

[25] See the notes to Table 1 for descriptions of the data sources.

[26] Mining employment includes "metal mining", "coal mining", "oil and gas extraction", and "non-metal mining".

Table 1
Summary statistics, U.S. states, 1970–2001.

Variable	Observations	Mean	Std. dev.
State identifier	1650	25.5	14
Year	1650	1985	10
Real per capita GSP (1982 dollars, deflated by state CPI)	1650	15,831	4080
Nominal per capita GSP[a]	1650	14,465	8146.80
Annual real per capita GSP growth (100)	1600	1.3	4.22
State level consumer price index[b] (1982 = 100)	1650	104.7	44.8
Producer price index, crude materials[b] (1982 = 100)	1650	86.9	25
Producer price index, finished goods[b] (1982 = 100)	1650	95.8	33.1
Resource price level, finished goods (100)	1650	93.2	11.5
Resource price level, finished goods excl. food (100)	1650	97	13.6
Population[a] (1000s)	1650	4791	5167
Annual population growth rate (Percent)	1600	0.69	0.39
Total employment[a] (1000s)	1650	2499	2736
Non-farm employment[a] (1000s)	1650	2429	2695
Mining employment[a] (1000s)	1645	20.1	40.9
Forest and fishery employment[a] (1000s)	1566	2.8	3.3
Mining employment share of non-farm employment (Percent)	1645	1.24	1.94
Mining employment share of total employment (Percent)	1645	1.18	1.84
Annual mining employment growth rate	1593	0.004	0.098

[a] *Notes*: Source: Tables SA25, SA04, and SA05, Bureau of Economic Analysis, U.S. Department of Commerce (http://www.bea.doc.gov/bea/regional/spi/default.cfm).
[b] Source: Tables CUUR0000SA0, WPUSOP1000, WPUSOP3000, and WPUSOP3500, Bureau of Labor Statistics, U.S. Department of Labor (http://www.bls.gov/). All other data is calculated. Annual percentage growth variables are calculated as $x_t = \ln(X_t/X_{t-1})$, where X_t is the raw data and x_t is the growth rate.

2006).[27] We calculated the growth in resource prices using log first differences in the ratio of these indices. All income measures are converted to constant 1982 purchasing power by dividing by the state level consumer price indices that we constructed using selected M.S.A. level consumer price indices following Mitchener and McLean (1999, 2003).[28]

Tables 1 and 2 summarize the data used in the analysis. Table 1 reports the sample averages of all of the data. Table 2 reports the sample average of a subset of the variables by state. In Table 1, real per capita income based on state-level consumer price indices averaged $15,831 in 1982 dollars. Annual real per capita income growth averaged 1.3% over this period. Our proxy measure for the real price of natural resources shows that natural resource prices were an average of 93% of the price of finished goods over the sample period, and ranged from 73% to 119%, with the period of high resource prices occurring with the oil price shocks in 1973. On average the average relative resource price declined between 0.1% and 0.3% per annum between 1969 and 2001, depending on the specification, although there are significant time variations as well, with the 1973 price shock increasing the relative resource price by over 20%. Employment in the mining sector averaged between 1.2% to 1.4% of total employment, depending upon the measurement. While mining sector employment grew on average, the share of mining employment in total employment declined between one and two percent over this period.

The theory developed in Section 2 suggests that interactions of the resource price growth rate and the resource sector employment, interactions of the population growth rate and resource sector employment, and interactions of the rate of change of resource sector employment and the level of resource sector employment are important. The means of these variables reflect that resource prices and the share of resource sector employment were declining while the population was growing.

Table 2 shows that there is considerable variation across the states. Per capita income in Alaska is almost twice that of Mississippi. The growth rates in per capita income range from 0.3% per year in the mining state Montana to 1.4% in Mississippi, almost a five-fold difference. The population growth rates range from 0.08% in North Dakota to 4.61% in Nevada, almost a 60-fold difference. The mining share of employment ranges from 0.05% in Hawaii to 8.79% in Wyoming, over a two-hundred fold difference. The mining share of income averaged over thirteen percent in Wyoming and was less than one tenth of a percent in Hawaii. The ratio of income per worker to per capita income ranges from a high of over five times higher in Delaware, probably because of corporate headquarters being located there, down to barely 1.1 times in Kansas. Minnesota experienced the largest decline in mining employment (−2.19%) and Hawaii accounted for the largest growth in mining employment. Thus, there is ample variation across states that might account for the smaller variations in growth in per capita incomes.

Fig. 3 plots the mean real per capita GSP growth rate over the period 1970–2001 against the natural log of the mean mining employment share for the state. While our choice of resource abundance is driven by our theoretical model, it produces a similar negative correlation between growth and natural resources that has been shown in the literature using other measures. For example, this graph is similar to Fig. 1 in Sachs and

[27] The "crude materials for further processing" PPI index is not a perfect match to mining as it includes agricultural products, forestry products, and fishery products as well. However, Kellard and Wohar (2006) show that commodity prices for these goods have generally been declining, as have mining commodity prices. Thus this index is probably highly correlated with an ideal index for exhaustible resources. We also tried using the PPI for "finished goods excluding food and energy" in the denominator of the relative resource price and found similar results.

[28] The state price indices each have a base of 100 in 1982. Since these price indexes are not spatially adjusted, systematic differences in the levels of cost of living will be captured in state fixed effects. The state level consumer price indices are constructed using city level consumer price indexes published by the Bureau of Labor Statistics. Since this data is only available for a subset of cities, the consumer price index for states that are not represented by a major city is assumed to be the index for the state closest to an available city. Thus, Atlanta is used as the measure for most of the south outside of Florida, Denver for the mountain states, and Boston for the New England states. States with more than one city measure used the CPI for an arbitrary city: Los Angeles for California, Philadelphia for Pennsylvania, Cincinnati for Ohio; Miami for Florida, St. Louis for Missouri, and Dallas for Texas.

Table 2
Summary statistics by state, 1970–2001.

State	Real per capita GSP		Population	Mining employment		Mining income	
	(1982 Dollars)	Growth rate	Growth rate	Share (%)	Growth rate	y_R/y	$100 \times Y_R/Y$
Alabama	12,569	1.47	0.82	0.69	0.44	3.33	1.09
Alaska	32,203	1.36	2.37	2.86	3.84	3.24	5.49
Arizona	15,144	0.79	3.48	1.47	−1.53	2.6	1.86
Arkansas	11,994	1.53	1.07	0.73	0	1.84	0.63
California	17,817	1.14	1.75	0.36	0.13	2.45	0.46
Colorado	17,705	1.52	2.23	1.7	0.97	2.53	2.47
Connecticut	18,947	1.84	0.42	0.13	1.75	3.15	0.22
Delaware	20,172	2.25	1.21	0.07	2.2	5.29	0.17
Florida	14,281	1.4	2.82	0.25	1.41	2.43	0.31
Georgia	15,247	1.93	1.91	0.29	0.72	2.26	0.34
Hawaii	17,589	0.87	1.55	0.05	5.83	4.14	0.08
Idaho	13,900	0.64	1.95	0.85	−0.63	2.83	1.18
Illinois	17,632	1.1	0.39	0.55	−1.38	2.02	0.58
Indiana	14,878	1.03	0.55	0.4	−0.12	2.54	0.52
Iowa	14,899	1.24	0.14	0.2	−1.44	2.16	0.24
Kansas	15,432	1.61	0.59	2.07	0.06	1.1	1.21
Kentucky	14,039	1.18	0.75	2.38	−0.7	3.31	3.85
Louisiana	16,063	1.03	0.66	3.75	0.33	2.8	4.81
Maine	12,380	1.33	0.81	0.06	0.05	3.68	0.12
Maryland	15,450	1.6	1.03	0.13	0.25	2.44	0.16
Massachusetts	17,208	1.82	0.39	0.07	1.45	3.51	0.12
Michigan	15,928	0.84	0.41	0.35	−0.11	2.14	0.35
Minnesota	17,078	1.51	0.88	0.53	−2.19	2.53	0.74
Mississippi	11,201	1.38	0.79	0.93	0.29	2.13	0.9
Missouri	15,284	1.32	0.61	0.32	−1.26	2.43	0.44
Montana	13,774	0.31	0.83	1.91	0.01	2.56	2.51
Nebraska	16,391	0.9	0.48	0.3	−0.85	1.84	0.31
North Carolina	14,930	1.73	1.53	0.16	0.95	2.19	1.88
North Dakota	14,572	1.58	0.08	1.31	2.07	2.45	0.16
Nevada	18,685	0.69	4.61	1.48	3.14	2.19	1.88
New Hampshire	14,500	1.79	1.73	0.12	1.59	2.45	0.16
New Jersey	17,478	1.7	0.57	0.12	−1.54	2.77	0.17
New Mexico	15,039	0.63	1.86	3.45	0.12	2.59	4.24
New York	18,249	1.2	0.16	0.14	−0.47	2.62	0.19
Ohio	16,047	1	0.23	0.56	−0.36	2.22	0.64
Oklahoma	14,251	1.27	0.98	4.97	0.34	2.17	5.28
Oregon	14,962	1.12	1.63	0.19	1.53	2.11	0.21
Pennsylvania	14,553	1.25	0.14	0.71	−1.62	2.82	1
Rhode Island	14,059	1.23	0.4	0.06	2.21	3.85	0.1
South Carolina	12,879	1.72	1.43	0.13	0.71	2.53	0.17
South Dakota	13,961	1.9	0.4	0.75	−2.13	2.38	0.98
Tennessee	14,176	1.61	1.21	0.36	−0.49	2.72	0.54
Texas	17,278	1.64	2.06	3.16	1.7	2.53	4.02
Utah	14,416	1.06	2.43	1.72	−1.14	2.91	2.5
Virginia	16,210	1.96	1.38	0.61	−0.62	2.24	0.36
Vermont	13,281	1.19	1.06	0.29	−0.79	2.79	0.96
Washington	17,092	1.08	1.82	0.18	2.97	2.43	0.22
West Virginia	12,185	0.93	0.1	6.25	−1.71	3.49	9.09
Wisconsin	15,522	1.39	0.66	0.14	−0.01	2.45	0.19
Wyoming	22,034	0.67	1.27	8.79	1.61	2.72	13.61
Average	15,831	1.3	0.69	1.18	0.004	2.66	1.59

Notes: Data is the mean for each state for the sample for which data is available. Mining share is of total employment. The mining income ratio y_R/y is GSP per worker in the mining sector relative to GSP per worker generally. The mining share of total income ($100 \times Y_R/Y$) is the percentage of total income due to mining. Growth rates are mean of log first differences across years. All values in 1982 dollars.

Warner (2001), which uses the share of exports as the resource abundance measure for a set of international countries and it is also similar to Papyrakis and Gerlagh's (2007) Fig. 2 showing growth in per capita GSP 1986–2000 for U.S. states, using the share of the primary sector in state GSP as their measure of resource abundance.[29]

[29] See Papyrakis and Gerlagh (2007, Appendix 2) for an excellent discussion of alternative resource abundance proxy variables that are available for U.S. states.

Cross-sectional growth estimates

We begin by showing that U.S. states exhibit the "curse of natural resources" result using the standard specification in the resource curse literature, (19). In Table 3, the dependent variable is the annual percentage rate of growth in per capita income over the period 1970–2001, calculated as $\ln(y_{2001}/y_{1970})/31$. Models (1) and (2) include the share of employment in the resource sector (mining plus forestry and fishing), and the share of mining employment, both as shares in total (non-farm

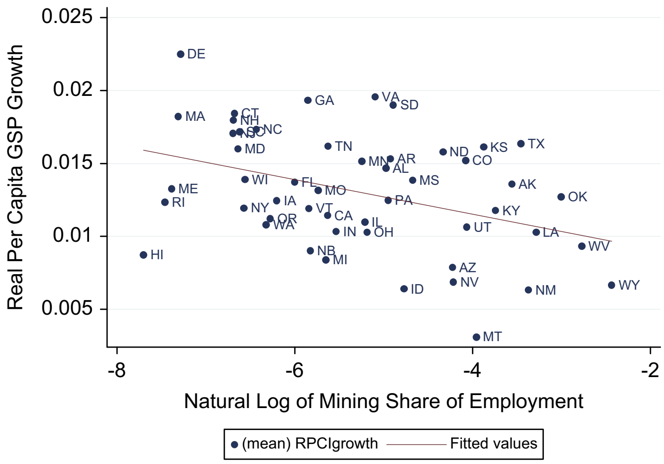

Fig. 3. Average annual real per capita GSP growth rate and mining employment share, 1970–2001, by State.

employment).[30] Models (3) and (4) add the initial real per capita income level to capture convergence effects.

The standard test of the "curse of natural resources" is a test of whether some measure of the size of the resource sector, here the share of employment in the resource sector, has a negative effect on growth in per capita income. Consistent with what Papyrakis and Gerlagh (2004, 2007) have previously shown for U.S. states using different proxies of resource abundance (primary sector's share of state GSP) and a shorter time period (1986–2000), the sign of the estimated coefficient on the resource abundance measure is negative and is statistically different from zero in all five specifications. When the initial per capita income is added in models (3) and (4), that variable is negative in sign and statistically different from zero, supporting the convergence hypothesis that states with lower initial incomes have higher rates of growth.

Panel estimation of level effects of resources

Next we turn to the estimation of the level specifications suggested by our model. The estimation of the level of per capita income equation results using (22) are presented in Table 4. These equations are estimated using the panel structure of the U.S. states data, with observations from 1970–2001 included for each of the fifty states where available. We present six specifications of the model, based on whether or not OLS, fixed, or random effects estimation methods are used. Following the literature, the dependent variable is the logarithm of real per capita income, $\ln(y_{it})$.[31] Given that real per capita income is increasing over time and the resource share of employment is decreasing over time, dummy variables for years are included in the even numbered specifications. Statistical tests indicate that the set of dummy variables for years should not be excluded, and a Hausman test supports the fixed effects specification over the random effects specification.

The results of Table 4 are broadly supportive of the hypothesis that states with higher natural resource employment shares have higher per capita incomes, all else constant. The magnitudes of the level differences are also quite interesting. At the upper bound, for a state such as Wyoming, which has averaged over 8% employment in the resource sector, this translates into around a 50% premium in income levels. For a typical state averaging around 1.3% resource employment, this yields almost a 8% increase in per capita income. These sizeable increases in per capita income associated with higher resource abundance do not support the interpretation that resource abundance is a negative influence on the standard of living in U.S. states.

Panel estimation of growth effects of resources

Next, let us turn to the growth estimates for the specification (24). The results for growth in the panel of U.S. states from 1970–2001 are presented in Table 5. We present six specifications of the model, based on whether or not OLS, fixed, or random effects estimation methods are used. The dependent variable in each regression is the one year growth rate, $\ln(y_{it}/y_{it-1})$. Hausman tests suggest that the random effects specifications are supported by the data over the fixed effects model. Based on the Hausman tests, we focus our discussion on the random effects specifications.

The coefficient β_1 on the resource employment share, L_R/L, is negative in each specification in Table 5. However, it is statistically significant in only the fixed effects specifications in columns (3) and (4) which are rejected by the Hausman test as the correct specifications. The negative coefficient estimates suggest that $\alpha g_A y_R < g_B y_M$, which, if $\alpha y_R > y_M$, as is implied by the sign of β_4, implies that the rate of technological change in the manufacturing sector has exceeded the rate of technological change in the resource sector in this data. This does not support the hypothesis of Wright and Czelusta (2004), at least for this sample period.

As expected, the coefficient β_2 on the variable $g_R(L_R/L)$, the interaction of the resource price growth and the share of labor in the resource sector, is greater than one in magnitude and is statistically different from one in every case. The coefficient β_3 on the interaction of the population growth rate and the resource employment share, $n(L_R/L)$ is expected to be negative in sign. It is negative and statistically different from zero in all six specifications in Table 5. The coefficient β_4 is predicted to be positive in sign, since it measures the share of economic rents to per capita income. This coefficient is positive and statistically different from zero in every specification. Finally, the coefficient β_0 is expected to be positive in sign. It is positive and statistically different from zero in each model estimated. In terms of signs and significance, therefore, the results in Table 5 are supportive of the growth specification in (15).

In all specifications, we find support for our theoretical conclusion that while growth in per capita income is slower in resource intensive states, per capita income levels are higher in those states with large natural resource sectors than in the economy as a whole, all else constant. In their work, Papyrakis and Gerlagh (2004, 2007) concluded that the resource curse occurs even in the highly developed U.S. states and they went on to argue that this reflected the negative indirect influences of resource abundance on growth via influences on investment, corruption and schooling. This in itself should give pause to those who argue for institutional or market failure explanations of the curse, particularly Mehlum et al. (2006, p. 3) who argue that a strong test of institutional arrangements as the cause of the curse would be that it should only be apparent in economies with inferior institutions. With their cross-sectional analysis, Papyrakis and Gerlagh (2004, 2007), however, do not, and cannot, determine if the negative influence of resource abundance on growth results in long run lower income levels.

[30] These variables are suggested by the specification in (24), although we have not interacted them with the resource employment share. Note that it is not possible to include the growth in resource price as a variable in these cross-state regressions, since the resource price does not vary across states.

[31] See Sala-i-Martin (1997) and Hall and Jones (1999). We also estimated models using the value of real per capita income as the dependent variable and those results agree with the results presented here.

Table 3
Cross-sectional growth regressions, U.S. states 1970–2001.

	(1)	(2)	(3)	(4)
1970 mining employment share, L_R/L (×100)	***−0.117		***−0.109	
	(0.030)		(0.029)	
1970 resource employment share, L_R/L (×100)		***−0.107		**−0.096
		(0.028)		(0.028)
1970 log of (real per capita income)			*−0.007	*−0.006
			(0.003)	(0.003)
Constant	***0.015	***0.016	*0.08	*0.076
	(0.001)	(0.001)	(0.030)	(0.030)
Observations	50	50	50	50
Adjusted-R^2	0.246	0.242	0.313	0.307

Notes: The dependent variable is the average annual real per capita GSP growth in state i over the period 1970–2001, $\ln(y_{i,2001}/y_{i,1970})/(2001–1970)$. The estimation method is ordinary least squares. Employment in the resource sector is measured as employment in mining, or in resource sectors, in the numerator, and total employment in the denominator. The ratio of producer price indices, p_R/p_M, are crude materials in the numerator and finished goods in the denominator. Standard Errors in parentheses. "***" statistically significant at 1% confidence level; "**" statistically significant at 5% confidence level; "*" statistically significant at 10% confidence level.

Table 4
Panel level effect regressions, U.S. states 1970–2001.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	FE	FE	RE	RE
α_1: Mining employment share, L_R/L	***1.407	***2.201	*−0.971	***6.143	−0.603	***5.93
	(0.292)	(0.247)	(0.542)	(0.308)	(0.504)	(0.301)
α_0: Constant	***9.625	***9.385	***9.654	***9.333	***9.65	***9.337
	(0.006)	(0.026)	(0.007)	(0.011)	(0.024)	(0.026)
Observations	1645	1645	1645	1645	1645	1645
Year effects	No	Yes	No	Yes	No	Yes
R^2	0.014	0.327				
R^2 within groups			0.002	0.752	0.002	0.752
R^2 between groups			0.033	0.031	0.033	0.031
R^2 Overall			0.014	0.271	0.014	0.275
σ_u			0.171	0.182	0.164	0.166
σ_e			0.146	0.073	0.146	0.073
ρ (% of variation in u_i)			0.579	0.86	0.559	0.836
Degrees of freedom, ν_2	1	33	50	82	1	33
$\chi^2(\nu_2)$, $H_O:\beta_i=0$					1.428	***4692.761
$F(\nu_2, N-50-\nu_2)$, $H_O:\beta_i=0$	***23.307	***23.678	3.211	***143.265		
$F(49, N-50-\nu_2)$ Test, H_O: $u_i=0$			***42.17	***169.02		
Hausman Test $\chi^2(\nu_2)$, $H_O:u_i\perp X$					*3.44	11.15
Breusch–Pagan Test $\chi^2(\nu_2)$, $H_O:\sigma_u=0$					***7797	***17558

Notes: The dependent variable is the average annual real per capita GSP in state i over the period 1970–2001, $\ln(y_{i,t})$. The errors are assumed to be of the form $\varepsilon_{it}=u_i+e_{it}$, where u_i varies with state and e_{it} is white noise. The variance of u_i is σ_u, and the variance of e_{it} is σ_e. The estimation method is either least squares (OLS), fixed effects (FE), or random effects (RE). Employment in the resource sector is measured as employment in the mining sectors, in the numerator, and total employment in the denominator. Standard Errors in parentheses. "***" statistically significant at 1% confidence level; "**" statistically significant at 5% confidence level; "*" statistically significant at 10% confidence level.

Discussion and conclusions

A number of economists have sought to explain the "curse of natural resources". In this paper, we show that well functioning natural resource markets require that the marginal profit be equalized across time. This means that the quantity of inputs used in production declines over time, as does the production of that resource. This fact alone makes it possible to observe lower growth of per capita income in resource abundant economies than in resource scarce economies even in the absence of market and institutional failures. Slower growth in resource abundant economies, therefore, does not inform about the long run income implications of resource abundance. Whether resources are a blessing or a curse is an empirical issue that can only be addressed by determining if resource abundance increases or decreases per capita incomes.

We find that each of these effects, lower growth and higher levels of per capita income, are observed when we examine a panel of U.S. states over the period 1970–2001. These effects cannot all be explained by institutional failure, as these would be correlated with lower levels of per capita income. Our empirical evidence adds to the mounting evidence that there is slower growth in resource abundant U.S. states (see also Mitchener and McLean, 1999, 2003; Papyrakis and Gerlagh, 2007). However, unlike those papers, we also find that there is a positive level effect from natural resources.

We believe that the explanation we have offered is complementary to the institutional failure argument. It is clear that institutions in many developed countries are woefully inadequate. The explanation we have offered suggests that it is possible to observe slower growth in resource abundant economies with good institutions and no market failures. The lesson we draw from

Table 5
Panel growth effect regressions, U.S. states, 1970–2001 (annual growth).

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	FE	FE	RE	RE
β_1: mining employment share, L_R/L	−0.044	−0.071	** −0.373	*** −0.48	−0.044	−0.071
	(0.067)	(0.054)	(0.183)	(0.162)	(0.067)	(0.054)
β_2: mining employment share × real price growth, $(L_R/L)\times g_R$	***6.239	***2.515	***6.048	***2.269	***6.239	***2.515
	(0.741)	(0.705)	(0.758)	(0.718)	(0.741)	(0.705)
β_3: mining employment share × population growth, $(L_R/L)\times n$	*** −9.171	*** −9.91	** −7.209	*** −7.302	*** −9.171	*** −9.91
	(2.809)	(2.287)	(3.260)	(2.682)	(2.809)	(2.287)
β_4: mining employment share × mining employment Growth, $(L_R/L)\times(\dot{L}_R/L_R)$	***4.77	***6.466	***4.823	***6.516	***4.77	***6.466
	(0.484)	(0.415)	(0.496)	(0.424)	(0.484)	(0.415)
β_0: Constant	***0.015	* −0.008	***0.018	−0.003	***0.015	* −0.008
	(0.001)	(0.004)	(0.002)	(0.005)	(0.001)	(0.004)
Observations	1593	1593	1593	1593	1593	1593
Year effects	No	Yes	No	Yes	No	Yes
R^2	0.108	0.456				
R^2 within groups			0.109	0.46	0.108	0.458
R^2 between groups			0.149	0.161	0.188	0.233
R^2 overall			0.095	0.433	0.108	0.456
σ_u			0.007	0.008	0	0
σ_e			0.04	0.032	0.04	0.032
ρ (% of variation in u_i)			0.029	0.059	0	0
Degrees of freedom, ν_2	4	35	53	84	4	35
$\chi^2(\nu_2)$, $H_O:\beta_i=0$					***192.374	***1303.9
$F(\nu_2, N-50-\nu_2)$, $H_O:\beta_i=0$	***48.093	*** 7.257	***47.281	***36.747		
$F(49, N-50-\nu_2)$ Test, H_O: $u_i=0$			0.34	0.54		
Hausman test $\chi^2(\nu_2)$, $H_O: u_i \perp X$					3.87	7.37
Breusch–Pagan test $\chi^2(\nu_2)$, $H_O:\sigma_u=0$					***13.85	***8.85

Notes: The dependent variable is the average annual real per capita GSP growth in state i over the period 1970–2001, $\ln(y_{i,t}/y_{it-1})$. The errors are assumed to be of the form $\varepsilon_{it}=u_i+e_{it}$, where u_i varies with state and e_{it} is white noise. The variance of u_i is σ_u, and the variance of e_{it} is σ_e. The estimation method is either least squares (OLS), fixed effects (FE), or random effects (RE). Employment in the resource sector is measured as employment in the mining sectors, in the numerator, and total employment in the denominator. Standard Errors in parentheses. "***" statistically significant at 1% confidence level; "**" statistically significant at 5% confidence level; "*" statistically significant at 10% confidence level.

this exercise is that it is important to specify very clearly the underlying theoretical model before doing growth regressions and assessing the welfare implications on the estimated coefficient for the resource abundance measure.

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