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Natural Resources: Curse or Blessing?

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Are natural resources a "curse" or a "blessing"? The empirical evidence suggests that either outcome is possible. This paper surveys a variety of hypotheses and supporting evidence for why some countries benefit and others lose from the presence of natural resources. These include that a resource bonanza induces appreciation of the real exchange rate, deindustrialization, and bad growth prospects, and that these adverse effects are more severe in volatile countries with bad institutions and lack of rule of law, corruption, presidential democracies, and underdeveloped financial systems. Another hypothesis is that a resource boom reinforces rent grabbing and civil conflict especially if institutions are bad, induces corruption especially in nondemocratic countries, and keeps in place bad policies. Finally, resource rich developing economies seem unable to successfully convert their depleting exhaustible resources into other productive assets. The survey also offers some welfare-based fiscal rules for harnessing resource windfalls in developed and developing economies. (*JEL* O47, Q32, Q33)

1. *Introduction*

Many recognize the opportunities natural resources provide for economic growth and development and thus the challenge of ensuring that natural resource wealth leads to sustained economic growth and development. Still, many countries are cursed by natural resource wealth. The key question is why resource rich economies, such as Botswana or Norway, are more successful while others perform badly despite their immense natural wealth. Is it because resource booms induce appreciation of the real exchange rate and makes nonresource sectors less competitive (Dutch disease)? Are learning by doing and other spill-over effects strong enough in those nonresource traded sectors to warrant government intervention? Or do the riches of a resource

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bonanza induce a shift from profit-making entrepreneurship toward socially inefficient rent seeking? How much of this depends on the quality of institutions, the rule of law and the degree of financial development? Is resource wealth plundered by corruption, rent grabbing, and civil war at the expense of widespread inequality and poverty? Does a resource boom maintain unsustainable, bad policies for too long? Is depleting natural wealth sufficiently reinvested in other productive assets?

To shed light on these important questions, I first present the relevant stylized facts (case studies, historical and statistical) on the heterogeneous experiences of resource rich economies in section 2. I then put forward, in section 3, eight hypotheses and offer supporting theory and the best cross-country, panel-data, and quasi-experimental evidence that is available on each hypothesis. What transpires is not only how much the experiences of resource rich economies differ from other economies but also the wide variety of experiences of different resource rich economies. In section 4, I give detailed attention to the question why so many resource rich developing economies deviate from the so-called Hartwick rule and do not fully reinvest their resource rents in foreign assets or productive capital (e.g., buildings, roads, machines, human capital, or health) even though saving is an essential part of economic development. The puzzle is why observed and optimal saving rates do not seem to differ much in nonresource economies but differ sharply in resource rich economies. I put forward the "anticipation of better times" and the "voracious rent seeking" hypotheses to help explain this puzzle. Section 5 offers welfare-based fiscal rules for harnessing resource windfalls in developing economies paying special attention to capital scarcity, absorption problems, and volatile revenue streams. Section 6 concludes.

2. *Stylized Facts: Is the Natural Resource Curse Inevitable?*

Although some resource rich countries benefit from their natural wealth, others are in a terrible state. I discuss some well-known examples of countries whose dependence on natural resources have gone together with bad macroeconomic performance and growing inequality among its citizens and contrast these with others that have benefited from their natural resource wealth (section 2.1). I also discuss historical evidence on how natural resources have led to establishment of property rights and contributed to economic development (section 2.2). I then discuss some cross-country stylized facts on the effects of resources on economic and social outcomes (section 2.3). Finally, I discuss saving statistics to see to what extent natural resource wealth is converted into physical, human, and other wealth (section 2.4). The main point of these stylized facts is to point out the enormous variety of experiences of resource rich countries and the puzzles that they suggest. I leave theories for the effects of resources on growth and conflict and the testing thereof to section 3.

2.1 *Diverse Experiences of Illustrative Resource Rich Countries*

Accounts of the resource curse are available for many countries (e.g., Alan Gelb 1988; Terry Lynn Karl 1997, 1999; Adrian J. B. Wood 1999; Richard M. Auty 2001b). The most dramatic example is perhaps Nigeria (David Bevan, Paul Collier, and Jan Willem Gunning 1999; Xavier Sala-i-Martin and Arvind Subramanian 2003). Oil revenues per capita in Nigeria increased from US$33 in 1965 to US$325 in 2000, but income per capita has stagnated at around US$1,100 in PPP terms since its independence in 1960 putting Nigeria among the fifteen poorest countries in the world. Between 1970 and 2000, the part of the population that has to survive on less than US$1 per day shot up from 26 to almost 70 percent. In 1970, the top 2 percent had the same share of income as the bottom 17 percent but, in 2000, the same share as the bottom 55 percent. Clearly, huge oil exports have not benefited the average Nigerian. Although Nigeria has experienced rapid growth of physical capital at 6.7 percent per year since independence, it has suffered a declining TFP of 1.2 percent per year. Capacity utilization in manufacturing hovers around a third. Two thirds of capacity, often owned by the government, thus goes to waste. Successive military dictatorships have plundered oil wealth and Nigeria is known for its anecdotes about transfers of large amounts of undisclosed wealth. Oil wealth has fundamentally altered politics and governance in Nigeria. It is hard to maintain that the standard Dutch disease story of worsening competitiveness of the non-oil-export sector fully explains its miserable economic performance. Instead, exchange rate policy seemed to be driven by rent and fiscal imperatives and relative price movements were almost a by-product of the resource boom (Sala-i-Martin and Subramanian 2003).

Other oil exporters (Iran, Venezuela, Libya, Iraq, Kuwait, Qatar) experienced negative growth during the last few decades. OPEC as a whole saw a decline in GNP per capita while other countries with comparable GNP per capita enjoyed growth. The deindustrialization and disappointing growth experience of South Africa following the boom in gold prices can be explained by the appreciation of the real exchange rate in the 1970s followed by gradual depreciations together with increased barriers to technological adoption (Hildegunn E. Stokke 2008). The disruption of the "air bridge" from 1994 onwards shifted the production of coca paste from Peru and Bolivia to Colombia and led to a huge boom in the demand for Colombian coca leaf. This has led to more self-employment and work for teenage boys in rural areas but not to widespread economic spill-over effects, and the financial opportunities that coca provided have fueled violence and civilian conflict especially outside the major cities (Joshua D. Angrist and Adriana D. Kugler 2008). Greenland benefits from a large annual grant from Denmark to ensure a similar GDP per capita to the Danish one. As a result, it has suffered from an appreciated real exchange rate as well as rent seeking from a comprehensive system of state firms and price regulations (Martin Paldam 1997).

Others discuss more positive experiences. Forty percent of Botswana's GDP stems from diamonds, but Botswana has managed to beat the resource curse. It has the second highest public expenditure on education as a fraction of GNP, enjoys the world's highest growth rate since 1965, and its GDP per capita is at least ten times that of Nigeria (Maria Sarraf and Moortaza Jiwanji 2001). The Botswana experience is noteworthy since it started its postcolonial experience with minimal investment and substantial inequality. Of sixty-five resource rich, developing countries, only four managed to achieve long-term investment exceeding 25 percent of GDP and an average GDP growth exceeding 4 percent—namely Botswana, Indonesia, Malaysia, and Thailand (Thorvaldur Gylfason 2001). These three resource rich Asian countries have achieved this by economic diversification and industrialization. Still, they fared less well than their neighbors Hong Kong, Singapore, and South Korea with little raw material wealth. Norway has shown remarkable growth of manufacturing and the rest of the economy compared with its neighbors despite phenomenal growth in oil exports since 1971 (Svein S. Andersen 1993; Erling Roed Larsen 2006). Norway is the world's third largest petroleum exporter after Saudi Arabia and Russia, but is one of the least corrupt countries in the world and enjoys well developed institutions, far sighted management and market friendly policies.

United Arab Emirates account for close to 10 percent of the world's crude oil and 4 percent of the world's natural gas reserves but has turned its resource curse into a blessing (Ugo Fasano 2002). Its government debt is very small, inflation is low, and hydrocarbon wealth has been used to modernize infrastructure, create jobs, and establish a generous welfare system. Major strides in life expectancy and literacy have been made through universal and free access to education and health care. In anticipation of depletion of its natural resources, oil-rich Abu Dhabi has emphasized petrochemical and fertilizers, Dubai has diversified into light manufacturing, telecommunications, finance, and tourism, and the other emirates have focused on small-scale manufacturing, agriculture, quarrying, cement, and shipping services. Many Latin American countries have abandoned misguided state policies, encouraged foreign investment in mining, and increased the security of mining investment. Since the 1990s, Latin America appears to be the fastest growing mining region, well ahead of Australia, Canada, Africa, and the United States in terms of spending on exploitation. Chile has recently achieved remarkable annual growth rates of 8.5 percent while the mining industry accounted for almost half of total exports. Peru ranks second in the world in the production of silver and tin, fourth in zinc and lead, and eighth in gold and its mineral sectors enjoy prospects for further growth. Another leader in this region is Brazil. Argentina seems to be moving ahead as well.

2.2 *Historical Evidence: Natural Resources, Evolution of Property Rights, and Innovation*

Successful resource-based development does not primarily depend on geological endowment. The United States developed its mineral potential ahead of other countries and continents, including Latin America. The positive experiences of the United States with its mineral abundance from the mid-nineteenth to the mid-twentieth century explain much of subsequent economic growth (H. J. Habakkuk 1962; Paul A. David and Gavin Wright 1997). It was a choice driven by collective learning and leading education in mining engineering and metallurgy, geological knowledge, transportation, increasing returns, and an accommodating legal environment where the U.S. government claimed no ultimate title to the nation's minerals (Wright and Jesse Czelusta 2002, 2003, 2004). The main lesson is that one has to learn to make the most of one's resources (cf., Jean-Philippe C. Stijns 2005). The role of *private* extraction and mining companies was crucial in this learning process. The United States was the world's leading mineral economy in the very period that the country became the world leader in manufacturing. Linkages and complementarities of the nonresource sectors of the economy to the private resource sectors were vital to the American economic success. Governments provided weak oversight. High wages may have contributed to returns being dispersed throughout the U.S. economy.

In 1913, the United States was the world's dominant producer of virtually every major industrial mineral even though other countries initially seemed to have more mineral reserves. New deposits were continuously discovered. The U.S. share of world mineral production in 1913 was far in excess of its share of world reserves; mineral rich countries like Brazil, Chile, Russia, Canada, and Australia did much worse in developing new reserves and cheaper techniques (David and Wright 1997). The U.S. experience suggests that impending scarcity of natural resources can be compensated by technical progress in exploration, extraction, and substitution and privatization of reserves. Many resource rich economies may have performed badly, not because they relied too much on resources, but because they failed in developing their mineral potential through appropriate policies. Investment in minerals-related knowledge seems a legitimate component of a forward-looking development program.

Coal and iron ore deposits spurred industrial development of Germany and the United Kingdom during the late nineteenth century. South Korea and Japan have taken advantage of fallen transport costs and have become important steel producers despite relying on import of iron ore. Still, history shows that good experiences of resource rich economies are not always replicated. In the seventeenth century, resource poor Netherlands outpaced Spain, even though the latter obtained much gold and silver from its colonies in the New World. More recently, resource poor Switzerland has enjoyed an excellent economic performance compared with resource rich Russia. In sum, the effects of natural resources on the economy vary from country to country and across different episodes in history.

More work is required on the changing role of natural resources throughout history. The resource curse features especially during the last four decades, but before countries such as the United States seemed to have harnessed resources for growth. Is this because those countries that industrialized first also had good institutions and those countries that remained underdeveloped had bad institutions and when resources were exploited at a later stage they led to corruption, rent seeking, and strife? Key is the contractual basis for exchange. Natural resources may be underproduced due to lack of effective property rights and high transaction costs (Terry L. Anderson and Gary D. Libecap 2005). The Coase theorem says that with well-defined property rights private, voluntary negotiations yield efficient outcomes, but high transactions costs may preclude such outcomes. More valuable resources tend to have more precise property rights because the larger benefits from defining and enforcing rights offset the higher costs of doing so (Harold Demsetz 1967). Private mineral rights indeed became more explicit as mine values increased. They evolved from local property rules within the mining camps to formal territorial and state statutes and judicial opinions as the extent and value of the deposits in the regions became more apparent (Libecap 1978). With increased competition for valuable resources, informal rules were insufficient to reduce risk and support long-term investment to develop the mines. Making property rights more formal boosted mining investment. However, in case of the Western timberlands, the transaction costs were more than the government price of land and timber depredations continued (Libecap and Ronald N. Johnson 1979).

These case studies suggest interesting hypotheses about transactions costs and the implications of property rights for turning the resource curse into a blessing. For example, if transport costs are high relative to those of manufactured goods, extra resources lower the domestic price for a key input to manufacturing giving domestic manufacturers a comparative advantage. For example, car producers in Detroit had cheap access to iron ore. Another hypothesis is that those exploiting the natural resource can sell their rights and consume the entire present value of their reserves, thus causing an initial consumption boom. Otherwise, their consumption possibilities seem more limited leading to a higher saving rate. Another interesting question is whether the more widespread ownership of resources in the nineteenth century had something to do with a smaller minimum efficient scale of production.

2.3 *Cross-Country Correlations*

Figure 1 indicates a negative correlation between growth performance and the share of natural resources in merchandise exports, but this does not tell us anything about causation. Natural resource dependence may

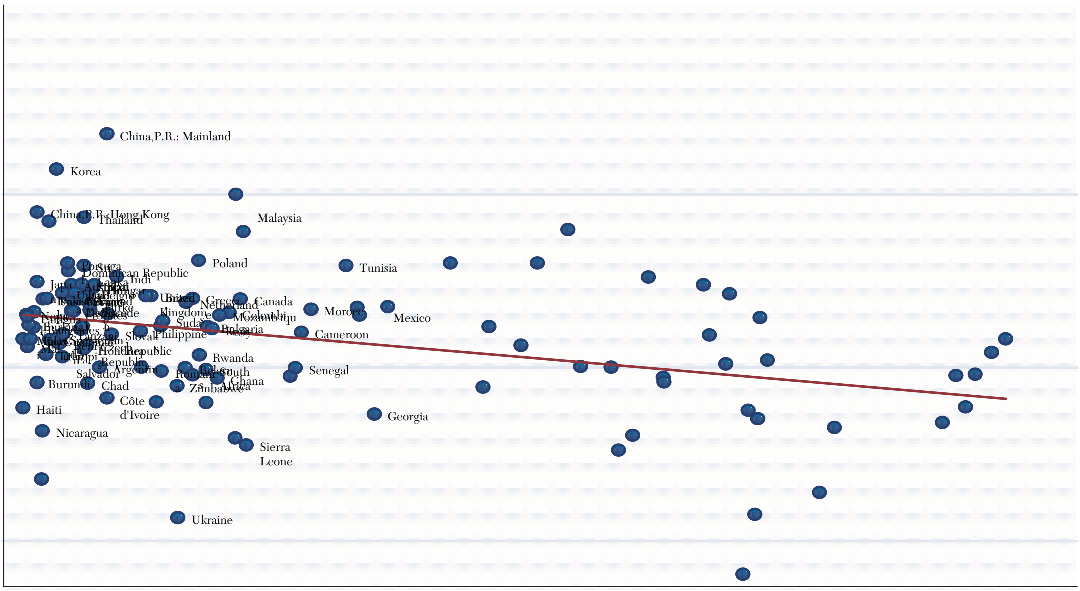

Figure 1. Growth and Natural Resource Dependence

Source: World Development Indicators, 2004, World Bank

harm the economy through other variables than lower growth (e.g., Gylfason, Tryggvi Thor Herbertsson, and Gylfi Zoega 1999; Gylfason 2001, 2004). For example, partial cross-country correlations for oil exporters in the Arab world and elsewhere suggest that resource dependence is associated with less nonresource exports and foreign direct investment. Evidence of a sample of eighty-seven countries suggest that resource wealth is associated with less openness to foreign trade and less openness to gross foreign direct investment, which in turn may harm growth prospects. Also, in a sample of eighty-five countries the share of natural resource wealth in national capital is negatively correlated with both gross domestic investment as percentage of GDP and the average ratio of broad money (M2) to GDP (a measure of financial development). Furthermore, although there are exceptions such as Botswana, there is an inverse correlation between resource dependence and school enrollment at all levels, expected years of schooling, and public spending on education. This may matter as there is a positive correlation between education and growth. Finally, empirically there is a positive correlation between natural resource dependence and macroeconomic volatility and a negative correlation between macroeconomic volatility and growth (e.g., Frederick van der Ploeg and Steven Poelhekke 2009). These partial correlations are not inconsistent with the suggestion that resource dependence crowds out foreign, social, human, real, and financial capital, each effect tending to depress growth.

TABLE 1
Total, Natural, Produced and Intangible Capital, 2000
(*$ per Capita and Percentage Shares*)

Income group	Natural capital	Produced capital	Intangible capital	Total wealth	Natural capital share	Produced capital share	Intangible capital share
Low-income countries	1,925	1,174	4,434	7,532	26%	16%	59%
Middle-income countries	3,496	5,347	18,773	27,616	13%	19%	68%
High-income OECD countries	9,531	76,193	353,339	439,063	2%	17%	80%
World	4,011	16,850	74,998	95,860	4%	18%	78%

Note: All dollars at nominal exchange rates. Oil states excluded.

Source: World Bank 2006, table 2.1.

2.4 *World Bank Data on Natural Capital and Wealth of Nations*

Various components of national wealth for the year 2000 (approximated by the present value of sustainable consumption during 2000–25 using a social discount rate of 4 percent) have been calculated for nearly 120 countries in the world (World Bank 2006). Produced capital is estimated from historical investment data with the perpetual inventory method. Natural capital consists of subsoil assets, timber resources, nontimber forest resources, protected areas, cropland, and pastureland. Due to data problems, fisheries, subsoil water, and diamonds are excluded. The explicit value of ecosystems is not evaluated either. The value of natural capital is estimated from world prices and local costs. Intangible capital reflects the contribution of raw labor, human capital, R&D, social capital, and other factors such as institutions and rule of law. It is calculated residually as the excess of total national wealth over the sum of produced and natural capital and is well explained by school years per capita, a rule of law index, and remittances per capita. For example, an extra year of schooling yields extra intangible capital varying from $840 for low-income to $16,430 for high-income countries. Tables 1 and 2 give a flavor of the detailed results.[1] Although global wealth per capita is $96,000, this masks huge variety across countries. The share of produced assets in total wealth is more or less the same irrespective of how poor or rich a country is. However, the share of natural capital in total wealth is much higher in poorer countries while the share of intangible capital in total wealth is substantially higher in richer economies. Interestingly, richer countries have a substantially higher value of natural capital per capita despite having lower shares of natural capital in total wealth. The results confirm what we know from the literature on economic growth that intangible capital is the main engine of growth and wealth. Richer countries focus relatively more on dynamic sectors such as manufacturing and services, whereas poorer countries specialize in the more static primary sectors.

[1] One of the referees pointed out that these estimates of the share of resources in national wealth include human wealth, so that countries with a high wage level such as Norway are measured as having a relatively small fraction of their wealth in natural resources. Also, it is more difficult to control for initial conditions than with the ratio of resource exports to GDP.

TABLE 2
COMPONENTS OF NATURAL CAPITA, 2000 ($ *per Capita*)

Income group	Subsoil assets	Timber resources	NTFR	Protected areas	Cropland	Pastureland	Total natural capital
Low-income countries	325	109	48	111	1,143	189	1,925
Middle-income countries	1,089	169	120	129	1,583	407	3,496
High-income countries (OECD)	3,825	747	183	1,215	2,008	1,552	9,531
World	1,302	252	104	322	1,496	536	4,011

Note: NTFR stands for non-timber forest resources. Oil states excluded.
Source: World Bank 2006, table 1.2.

Table 2 indicates that the poorer countries rely relatively heavily on land resources (more than two thirds of natural wealth in low-income countries). In the ten wealthiest countries, only Norway has a natural capital share of more than 3 percent (namely 12 percent). On the other hand, the bottom ten countries all have shares of natural capital in total wealth exceeding 30 percent. Table 3 indicates that highly resource rich economies, such as the oil exporters Nigeria, Venezuela, and Algeria, sometimes even have negative shares of intangible capital in total wealth. This suggests that these countries have extremely low levels of GNI as their returns on productive and intangible capital are very low and possibly even negative. Consequently, they have very low total wealth and can sustain only very low levels of consumption per capita. This is another manifestation of the resource curse.

3. *Popular Explanations of the Natural Resource Curse*

The stylized facts discussed in section 2 suggest that the experiences of resource rich countries have been very heterogeneous. Some have harnessed their resource wealth to boost their economic performance and others have done worse. Here we discuss the theoretical support and evidence where available for a wide range of hypotheses about the effects of natural resources on the economy and society.[2] Section 3.1 puts forward the hypothesis that a resource bonanza induces appreciation of the real exchange rate, contraction of the traded sector, and expansion of the nontraded sectors and offers some evidence for Brazil on this hypothesis. Section 3.2 shows that, if the traded sector is the engine of growth, a resource bonanza will lead to a temporary fall in growth. Early cross-country evidence indeed indicates a negative link between resources and growth. Subsequent panel-data and quasi-experimental tests of this hypothesis are also discussed. Section 3.3 puts forward the hypothesis that the resource curse can be turned into

[2] Earlier empirical work attempts to identify the potential channels of transmission for the resource curse by regressing institutional quality, human capital, etc. on natural resource dependence only and calculating the indirect effects of resource dependence on growth from the coefficients of these intermediate variables on growth (Elissaios Papyrakis and Reyer Gerlagh 2004; Jann Lay and Toman Omar Mahmoud 2004), but this approach suffers from potential omitted variable bias and other econometric problems.

TABLE 3
Intangible Capital and Wealth Composition in Highly Resource-Rich Countries

Country	Intangible capital per capita ($)	Percentage share of total wealth: Natural capital	Produced capital	Intangible capital
Russian Federation	6,029	44	40	16
Guyana	2,176	65	21	14
Moldova	1,173	37	49	13
Venezuela	4,360	60	30	10
Gabon	–3,215	66	41	–7
Syrian Arab Republic	–1,598	84	32	–15
Algeria	–3,418	71	47	–18
Nigeria	–1,959	147	24	–71
Congo	–12,158	265	180	–346

Source: World Bank 2006, p. 29.

a blessing for countries with good institutions and provides some evidence in support thereof. Section 3.4 discusses the hypothesis that presidential democracies are more likely to suffer a negative effect of resources on growth. Section 3.5 reviews econometric and quasi-experimental evidence for the hypothesis that resource windfalls increase corruption, especially in countries with nondemocratic regimes. Section 3.6 offers econometric support for the hypothesis that volatility of resource windfalls is the quintessence of the resource curse and also for the hypothesis that the negative effect on growth is less in countries with well developed financial systems. Section 3.7 puts forward the hypothesis that resources induces voracious rent seeking and armed conflict, and examines cross-country, panel-data, and quasi-experimental evidence for this hypothesis. Section 3.8 discusses the hypothesis that resource windfalls encourage unsustainable and unwise policies. Section 4 is entirely devoted to two hypotheses that might explain why many resource rich developing countries experience negative genuine saving. Of course, there may be other hypotheses which we do not touch upon.[3]

3.1 *Dutch Disease: Natural Resource Windfalls Cause Deindustrialization*

Early policy contributions highlight the appreciation of the real exchange rate and the resulting process of deindustrialization induced by the increase in oil exports in Britain (Peter J. Forsyth and John A. Kay 1980, 1981). There has also been a relative decline of Dutch manufacturing as a result of worsening of competitiveness associated with the export

[3] For example, resource dependence seems to be correlated with a bigger Gini index of inequality and less political liberties, which in turn are correlated with lower growth (Gylfason and Zoega 2003). Empirical evidence suggests that resources increase income inequality only in ethnically polarized societies, after controlling for GDP, schooling, and constraints on the executive (Ruikang Marcus Fum and Roland Hodler 2010). Income inequality also reduces immediately after an oil or mineral boom and increases gradually thereafter; uncertainty about future commodity export prices seems to increase long-run inequality (Benedikt Goderis and Samuel W. Malone forthcoming).

of natural gas found in Slochteren (M. Ellman 1981). The idea behind this Dutch disease is that the extra wealth generated by the sale of natural resources induces appreciation of the real exchange rate and an ensuing contraction of the traded sector (W. Max Corden and J. Peter Neary 1982; Corden 1984).

We illustrate this with the Salter–Swan model of a two-sector economy with a resource windfall, abstracting from capital accumulation, international investment, and financial assets. Export of resources thus equals net imports of traded goods, that is $H_T QE = C_T - H_T F(L_T)$ where Q denotes the world price of natural resources, E the volume of exports of natural resources, C_T consumption of traded goods, L_T employment in the traded sector, H_T productivity in the traded and natural resource sectors, and $H_T F(L_T)$ output of the traded sector (with $F' > 0$, $F'' \leq 0$). Nontraded goods market equilibrium requires $C_N = H_N G(L_N)$, where C_N denotes consumption of nontraded goods, L_N employment in the nontraded sector, H_N productivity in the nontraded sector, and $H_N G(L_N)$ output of the nontraded sector (with $G' > 0, G'' \leq 0$). With exogenous labor supply of one unit and labor mobility between traded and nontraded sectors, labor market equilibrium requires $L_T + L_N = 1$. Households maximize utility $U(C_N, C_T)$ subject to the budget constraint $PC_N + C_T = Y$, where P is the relative price of nontraded goods in terms of traded goods and national income is defined by $Y \equiv PH_N G(L_N) + H_T F(L_T) + H_T QE$. Optimality requires $U_N/U_T = P$. With CES utility, we have $C_N = Y/(1 + P^{\varepsilon-1})P$, where ε is the elasticity of substitution between traded and nontraded goods. The condition for equilibrium in the market for nontraded goods,

$$H_N G(L_N) = C_N = Y/(1 + P^{\varepsilon-1})$$

$$= \frac{[PH_N G(L_N) + H_T F(L_T) + H_T QE]}{(P + P^{\varepsilon})},$$

yields $P^{\varepsilon} = H[F(1 - L_N) + QE]/G(L_N)$, where $H \equiv H_T/H_N$ is the productivity of the traded and resource sectors relative to that of the nontraded sector. This equation corresponds to the *NTGME*-locus in figure 2 and describes those combinations of the real exchange rate P and the share of labor employed in the nontraded sector L_N that ensure clearing of the market for nontraded goods. The *NTGME*-locus slopes downwards, since a higher P is associated with relatively lower demand for nontraded goods and, thus, with fewer workers employed in the nontraded sector. Labor mobility between traded and nontraded sectors requires that labor is paid the same in each sector, so that the value of the marginal product of labor is equalized. This yields the *LM*-curve $PG'(L_N) = HF'(1 - L_N)$, which gives those combinations of the real exchange rate P and the share of labor employed in the nontraded sector L_N that ensure labor market equilibrium. The *LM*-curve slopes upward. A higher relative price of nontraded goods P pushes up the value of the marginal product of employment in the nontraded sector, so employment in the traded sector must decline in order to push up the marginal product of labor in the traded sector.

Higher natural resource revenue QE boosts national income and demand. Hence, the *NTGME*-locus shifts upwards, the *LM*-locus is unaffected and equilibrium in figure 2 shifts from A to A'. The short-run consequences of higher resource revenues are thus appreciation of the real exchange rate (a higher relative price of nontraded goods P), decline of the traded sector and expansion of the nontraded sector. Labor shifts from the exposed to the sheltered sectors. This boosts both consumption and output of nontraded goods. The rise in consumption of traded goods and the contraction in the production of traded goods is made possible by additional imports financed by the increase in resource revenues. National income rises

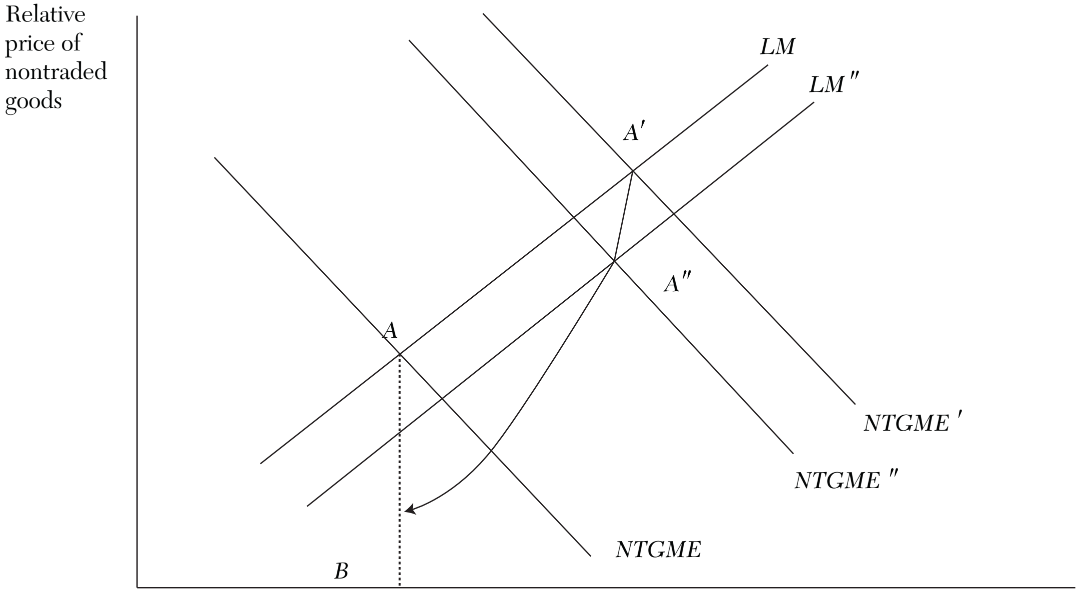

Figure 2. Natural Resource Dependence Reduces Competitiveness

Note: A resource boom shifts A to A', so a shift from the traded to nontraded sector and real appreciation. With time, relative productivity of the traded declines if the elasticity of substitution in demand goods is less than unity. This shifts the equilibrium from A' to A'' and eventually to B. In the long run, there is real depreciation and the allocation of labor is returned to its original level.

by more than natural resource revenues ($dY = H_T\, d(QE) + C_N\, dP > H_T\, d(QE)$). The natural resource bonanza thus increases welfare.[4] The short-run effects of the Dutch disease on unemployment are discussed in appendix 1.

For the longer run effects one must allow capital and labor to be mobile across sectors and move beyond the specific factors framework. In an open economy Heckscher–Ohlin framework with competitive labor, capital, and product markets, no resource use in production and constant returns to scale in the production of traded and nontraded goods, a natural resource windfall induces a higher (lower) wage-rental ratio if the nontraded sector is more (less) labor-intensive than the traded sector. In any case, there is a rise in the relative price of nontraded goods leading to an expansion of the nontraded sector and a contraction of the traded sector. Labor and capital shift from the traded to the nontraded sectors. More interesting may be to study the effects of a resource boom in a dynamic dependent economy with adjustment costs

[4] More elegant is to use duality (Neary 1988). Let $Z(p)$ denote nonresource national income, so that $Z'(P)$ equals nontraded output. Equilibrium in traded and nontraded goods is given by $Z(P) + QE = e(P)U$ and $Z'(P) = e'(P)\ U$, respectively, where $e(P) = Y/U$ indicates the CPI and U denotes real consumption (utility). It follows that $dU/d(QE) = 1/e(P) > 0$ and $dP/d(QE) = (PC_N/Y)/(\varepsilon_S + \varepsilon_D)$, so that windfall revenue from abroad boosts utility. It also leads to an appreciation of the real exchange rate, especially if the share of nontraded goods in the consumption basket is large, the supply elasticity $\varepsilon_S \equiv PY''/C_N > 0$ is small, and the demand elasticity $\varepsilon_D \equiv -Pe''U/C_N > 0$ is small. If labor supply increases with the real consumption wage (migrants, informal labor), the real exchange rate appreciates less.

for investment and allow for costly sectoral reallocation of capital between nontraded and traded sectors (A. K. M. Mahbub Morshed and Stephen J. Turnovsky 2004). It is then more costly to transform one form of existing capital into another, since this involves demolition. This way one has factor specificity for each sector in the short run and factor mobility across sectors in the long run. An advantage of this approach is that in the short and medium run the real exchange rate is no longer fully determined by the supply side and does not adjust instantaneously. If a greater fraction of resource revenues is saved, the initial appreciation of the real exchange rate will be less and will eventually be reversed (see appendix 4). One could also use a model of endogenous growth in the dependent economy (e.g., Turnovsky 1996) to explore the implications of a resource boom on economic growth.

What happens if the exploitation sector uses labor and capital as factor inputs? Apart from the hitherto discussed *spending* effects of a resource boom, there are also *resource movement* effects (Corden and Neary 1982). Deindustrialization occurs on account of the usual appreciation of the real exchange rate (the *spending* effect), but also due to the labor drawn out of both the nontraded and traded sectors toward the resource sector (the *resource movement* effect). Looking at the longer run where both factors of production (labor and capital) are mobile between the traded and nontraded sectors and the resource sector only uses labor, it helps to consider a mini-Heckscher–Ohlin economy for the traded and nontraded sectors. The Rybczinski theorem states that the movement of labor out of the nonresource toward the resource sectors causes output of the capital-intensive nonresource sector to expand. This may lead to the paradoxical result of pro-industrialization if capital-intensive manufacturing constitutes the traded sector, despite some offsetting effects arising from the deindustrialization effects arising from an appreciation of the real exchange rate (Corden and Neary 1982). If the nontraded sector is more capital intensive, the real exchange rate depreciates if labor is needed to secure the resource windfall; the Rybczinski theorem then says that the nontraded sector expands and the traded sector contracts. This increase in relative supply of nontraded goods fuels depreciation of the real exchange rate. Real exchange depreciation may also result from a boost to natural resource exports if the traded sector is relatively capital intensive and capital is needed for the exploitation of natural resources (Neary and Douglas Purvis 1982). Since less capital is available for the traded sector, less labor is needed and thus more labor is available for the nontraded sector. This may lead to a depreciation of the real exchange rate. This also occurs if the income distribution is shifted to consumers with a low propensity to consume nontraded goods (Corden 1984).

3.1.1 *Empirical Evidence for Dutch Disease Effects*

Although early evidence for a shrinking manufacturing sector in response to terms of trade shocks and real appreciation has been mixed (Sala-i-Martin and Subramanian 2003), more recent evidence for 135 countries for the period 1975–2007 indicates that the response to a resource windfall is to save about 30 percent, decrease nonresource exports by 35–70 percent, and increase nonresource imports by 0–35 percent (Torfinn Harding and Anthony J. Venables 2010). These findings hold in pure cross-sections of countries (averages across one, two, three, or four decades), in pooled panels of countries, and in panel estimations including dynamics and country fixed effects. Another study uses detailed, disaggregated sectoral data for manufacturing and obtains similar results: a 10.0 percent oil windfall is on average associated with a 3.4 percent fall in value added across manufacturing, but less so in countries that have restrictions on capital flows and for sectors that are more capital intensive (Kareem Ismail 2010). Using as a counterfactual the Chenery–Syrquin (1975) norm for the size of tradables (manufacturing and agriculture), countries in which the resource sector accounts for more than 30 percent of GDP have a tradables sector 15 percentage points lower than the norm (Milan Brahmbhatt, Otaviano Canuto, and Ekaterina Vostroknutova 2010). The macroeconomic and sectoral evidence thus seems to offer support for Dutch disease effects. Interestingly, macro cross-country and micro U.S. county level evidence suggests that resource rich countries experience despecialization as the least skilled employees move from manufacturing to the nontraded sectors thus leading their traded sectors to be much more productive than resource poor countries (Karlygash Kuralbayeva and Radosław Stefánski 2010).

Quasi-experimental, within-country evidence on the Dutch disease for Brazil has recently also become available (Francesco Caselli and Guy Michaels 2009). This study exploits a dataset on oil dependence for Brazilian municipalities, which is useful as oil fields are highly concentrated geographically and local resource dependence is more likely to be exogenous as it is decided by the national oil company, Petrobras. It turns out that oil discoveries and exploitation do not affect non-oil GDP very much, albeit that in line with the Dutch disease hypothesis services expand and industry shrinks somewhat. But they do boost local public revenue, 20–25 percent (rather than 10 percent) going to housing and urban development, 15 percent to education, 10 percent to health, and 5 percent on welfare. Interestingly, household income only rises by 10 percent, mostly through higher government wages. The lack of migration to oil-rich communities also suggests that oil does not really benefit local communities much. The evidence for Brazil thus offers support for the Dutch disease hypothesis, but also to waste in local government and corruption (see section 3.3).

3.2 *Temporary Loss in Learning by Doing Curbs Economic Growth*

A declining traded sector is the appropriate market response to a resource windfall. In itself this does not justify government intervention since it is optimal to specialize in one's comparative advantage. Why are resource windfalls then perceived to be a problem? One popular answer is that the traded sector is the engine of growth and benefits most from learning by doing and other positive externalities, hence nonresource export sectors temporarily hit by worsening competitiveness are unable to fully recover when resources run out. This can be demonstrated in a two-period, two-good Salter–Swan model where learning by doing is captured by future productivity of the traded sector increasing with current production of traded goods (Sweder J. G. van Wijnbergen 1984a) or with cumulative experience (Paul Krugman 1987).[5] If manufacturing rather than agriculture enjoys learning by doing and the income elasticity of demand for agricultural goods is less than unity, shifting from manufacturing toward agriculture curbs growth in an open economy (Kiminori Matsuyama 1992). Similarly, if human capital spillover effects in production are generated only by employment in the traded sector and induce endogenous growth in both traded and nontraded sectors, natural resource exports lower employment in the traded sector, hamper learning by doing, and thus stunt economic growth (Jeffrey D. Sachs and Andrew M. Warner

[5] Similarly, giving aid to developing countries may lead to appreciation of the real exchange rate and decline of manufacturing (Christopher S. Adam and Bevan 2006; Adam and Stephen O'Connell 2004).

1995; Gylfason, Herbertsson, and Zoega 1999).

With perfect international capital mobility and no specific factors of production, the wage, the relative price of nontraded goods, and the capital intensities in the traded and nontraded sectors are pinned down by the world interest rate. Higher resource revenue then induces gradual movement of labor from the traded to the nontraded sector. This reduces learning by doing and thus lowers the rate of labor-augmenting technical progress so that the resource boom permanently lowers the rate of growth. One can show that nonresource GDP falls on impact after a resource discovery if the traded sector is capital-intensive (see appendix 2). However, if production of traded goods requires natural resources as factor input, a higher world price of natural resources leads to depreciation of the real exchange rate and a lower capital intensity in the production of nontraded goods which accentuates the fall in traded sector employment and throttles learning by doing and growth even more.

To illustrate how a resource boom affects *relative* productivity growth of the traded and nontraded sector, the adverse effects of the Dutch disease on growth are illustrated with a dynamic two-sector economy without capital accumulation, absence of current account dynamics and balanced trade (Ragnar Torvik 2001). Both traded and nontraded sectors contribute to learning. A foreign exchange windfall arising from resource exports then leads to appreciation of the real exchange rate in the short run but real depreciation in the long run. To illustrate, allow productivity growth in each sector to increase with the number employed in that sector and suppose that learning by doing is more substantial in the traded than nontraded sector. Suppose also that the elasticity of substitution between traded and nontraded goods in consumption ε is less than unity. A fall in relative productivity of the traded sector $H \equiv H_T/H_N$ induces real depreciation (lower P) and, given $\varepsilon < 1$, a smaller nontraded sector (lower L_N). After an increase in QE, the economy gradually converges to the lower steady-state value of H, so over time productivity of the traded sector declines relative to that of the nontraded sector.

We have already seen in section 3.1 that higher natural resource exports lead initially to real appreciation and expansion of the nontraded sector (the shift from A to A' in figure 2). Over time, relative productivity of the traded relative to that of the nontraded sector H declines gradually. This induces gradual depreciations of the real exchange rate and falls in labor use in the nontraded sector, and corresponds to the movement from A' to A'' and eventually B in figure 2. In the end, this completely chokes off the initial expansion of the nontraded sector and eliminates the boom of the traded sector through gradual depreciation of the real exchange rate. The new steady-state level of production has also moved in favor of the nontraded sector, not due to reallocation of labor but due to the relative fall in the productivity of the traded sector.

3.2.1 *Empirical Evidence for Negative Effect of Natural Resources on Economic Growth*

The pioneering study on the empirical cross-country evidence shows that resource rich countries indeed grow on average about one percentage point less during 1970–89 even after controlling for initial income per capita, investments during the period, openness, and rule of law (Sachs and Warner 1995). The revised cross-country regressions explaining average growth in real GDP per capita during 1970–90 are reported in the first regression of table 4. There is evidence of conditional convergence since countries with a low (log of the) level of initial real GDP per active member of the population catch up and grow relatively fast. Countries

TABLE 4
Effects of Resource Dependence and Institutional Quality on Economic Growth

Annual growth in real GDP per capita	Sachs and Warner (1997a)	Based on data in Sachs and Warner (1997b)	Mehlum, Moene, and Torvik (2006b)
Initial income	–1.76 (8.56)	–1.28 (6.65)	–1.26 (6.70)
Openness	1.33 (3.35)	1.45 (3.36)	1.66 (3.87)
Resource dependence	–10.57 (7.01)	–6.69 (5.43)	–14.34 (4.21)
Rule of law	0.36 (3.54)	—	—
Institutional quality	—	0.6 (0.64)	–1.3 (1.13)
Investments	1.02 (3.45)	0.15 (6.73)	0.16 (7.15)
Interaction term	—	—	15.40 (2.40)
Number of countries	71	87	87
Adjusted R^2	0.72	0.69	0.71

with a high log ratio of real public and private gross domestic investment to real GDP averaged over 1970–89 grow faster. Countries with a large number of years in which their economy is rated as open and whose citizens accept the rule of law more easily (on a scale from 1 to 6) grow faster. Even taking account of these traditional growth determinants, there is a strong negative effect of resource dependence (measured by the share of exports of primary products in GNP in 1970) on growth. This is what has become known as the resource curse. This pioneering study gives no role for institutions or bureaucratic quality in explaining the curse. The second regression reported in table 4 uses more countries, more years, and an index of institutional quality (on a scale from 0 to 1). Using the starting year 1965 rather than 1970, it confirms that resource rich economies experience slower growth and that institutional quality is not significant at the 5 percent level (see, however, section 3.3).

These regressions are the cornerstone of many discussions of the resource curse but can be criticized on econometric grounds. For example, the share of resources in GNP (dependence) is potentially endogenous and, if instrumented, it does not significantly affect growth whereas subsoil resource wealth (abundance) does have a significant positive effect on growth (Christa N. Brunnschweiler and Erwin H. Bulte 2008). However, natural resource wealth is also endogenous as it is calculated as the present value of natural resource rents. If it is instrumented with the more exogenous measure of economically recoverable reserves, there is no evidence for either a curse or a blessing unless one allows for an indirect effect via volatility (van der Ploeg and Poelhekke 2010). Another issue is the negative correlation between growth performance and resource dependence, which may merely be picking up cross-country variations in income per capita. Alternatively, if the nonresource traded sector declines and the wage premium for education falls, resource rich economies might invest less in education and thus the growth rate falls. Hence, adding a control for education implies that the negative coefficient on resource dependence should fall. Similar points apply to intermediate variables such as wars or institutional quality, so one should be careful about drawing inferences about the speed of convergence from the coefficient on initial income. There may also be some omitted variable bias if a third factor say "underdevelopment" is driving income as then countries with a low income potential are measured as resource rich.

It is crucial to move from cross-country to panel data evidence to avoid omitted variable bias arising from correlation between initial income per capita and the omitted initial level of productivity (Stephen L. Parente and Edward C. Prescott 1994; Nazrul Islam 1995). If resource dependence is expressed as a fraction of national income, cross-country regressions that do not control properly for initial productivity underestimate the speed of convergence and overestimate the share of capital in value added. Even though this requires reliable data on changing quality of institutions, school attainment, resource dependence, etc., such problems need not arise with panel data regressions. One panel study investigating the link between resources, institutional development and growth in ninety-one developing countries during 1970–2000 finds that point-source type natural resources (minerals, coffee, coca) retard democratic and institutional development, measured by the degree of democracy for each country over time, and this stunts growth (George S. Mavrotas, S. Mansoob Murshed, and Sebastian Torres 2006; also see Michael L. Ross 1999, 2001a). Another panel data study finds that the impact of resources on growth found in cross-country regressions disappears once one allows for fixed effects; resource dependence (primary exports as fraction of GNP) may be correlated with unobservable characteristics (Osmel Manzano and Roberto Rigobon 2001).

Cross-country and panel-data results are sensitive to changing the sample period, the sample of countries, or the definition of various explanatory variables. The data may simply not allow one to distinguish, for example, whether it is openness to international trade, quality of institutions, or financial development since these variables are highly correlated. The road forward might be to exploit variation within a country where variables that might confound the relationship between resources and macroeconomic outcomes do not vary and the danger of spurious correlation is minimized (cf., Caselli and Michaels 2009).

3.3 *Turning the Resource Curse into a Blessing: Good Institutions and No Corruption*

Increased corruption hampers economic growth (Paolo Mauro 1995; Pranab Bardhan 1997; Carlos Leite and Jens Weidmann 1999). Mineral wealth may prevent redistribution of political power toward the middle classes and thus prevent adoption of growth-promoting policies (Francois Bourguignon and Thierry Verdier 2000). Resource wealth worsens quality of institutions since it allows governments to pacify dissent, avoid accountability, and resist modernization (Isham et al. 2005). Corruption and granting of import licenses and other privileges to cronies rather than Dutch disease seem to be why oil riches have ruined long-run performance of the Nigerian economy (Sala-i-Martin and Subramanian 2003). Resource wealth makes it easier for dictators to buy off political challengers as President Mobuto has done in Congo with its wealth in copper, diamonds, zinc, gold, silver, and oil (Daron Acemoglu, James A. Robinson, and Verdier 2004). Resource riches raise the value of being in power and induce politicians to expand public sectors, bribe voters by offering them well paid but unproductive jobs and inefficient subsidies and tax handouts, especially if accountability and state competence are lacking (Robinson, Torvik, and Verdier 2006). Those profiting from the resource sector may bribe politicians to provide specific semi-public goods at the expense of manufacturing, which curbs welfare if manufacturing enjoys returns to scale (Bulte and Richard Damania 2008). Natural resources also make it attractive for political elites to block technological and institutional improvements since this can weaken their power (Acemoglu and Robinson 2006).

Depending on how resource rents affect the leader's probability of survival, they can induce a self-interested leader to invest more or less in assets that favor growth such as rule of law or infrastructure, so the effects of resources on economic performance can be highly non-monotonic (Caselli and Tom Cunningham 2009). On the one hand, the "busy" leader faces budget and time constraints. Hence, if a resource boom raises the value of staying in office, he shifts from productive toward unproductive activities and patronage, contributing to a resource curse. On the other hand, the "strategic" leader uses the windfall to keep citizens happy and stay longer in power, so the windfall becomes a blessing. A "fatalistic" leader realizes that a windfall boosts chances of rebellion and thus is more short-sighted and puts less effort into developing the nonresource economy and more into inefficient self-preservation. However, if the leader responds by offering better and more outside opportunities to rebel groups, the windfall may become a blessing.

A natural resource bonanza encourages productive entrepreneurs to shift to rent seeking. With an aggregate demand externality (and a constant tax rate and no external trade), this lowers income by more than the extra income from the resource revenues and thus lowers welfare (Torvik 2002). It helps to make a difference between countries with production-friendly institutions and others with rent grabbing-friendly institutions (Halvor Mehlum, Karl Moene, and Torvik 2006a, 2006b). Suppose there is a fixed supply of people that can direct their talent to either rent seeking or productive entrepreneurship. Both are thus competing activities. If there are more productive entrepreneurs, demand in the economy and profits of each entrepreneur increase provided there are demand complementarities in production (Kevin M. Murphy, Andrei Shleifer, and Robert W. Vishny 1989). In contrast, if a greater fraction of talented people is rent seeker (political insider, bureaucrat, oligarch, war lord, etc.), the gain per rent seeker declines. One can then distinguish two outcomes following a resource bonanza. If institutions are strong and encourage productive entrepreneurship, profits of entrepreneurs increase. This means that, in equilibrium, less people engage in rent seeking and more in productive activities (see outcome A″ in figure 3). The rent of the resource bonanza is more than dissipated. Examples of resource rich countries with strong institutions are Australia, Canada, the United States, New Zealand, Iceland, and Norway and also Botswana (Acemoglu, Simon Johnson, and Robinson 2003; Acemoglu et al. 2003). However, if institutions are weak, the legal system dysfunctions and transparency is low, rent seeking has a higher return and unfair takeovers, shady dealings, corruption, crime, etc. pay off. A natural resource bonanza thus elicits more rent seekers and there will be less productive entrepreneurs. In equilibrium, profits fall and as a result the economy is worse off (see outcome A′ in figure 3). Weak institutions may explain poor performance of oil-rich states such as Angola, Nigeria, Sudan, and Venezuela, diamond-rich Sierra Leone, Liberia, and Congo, and drug states Colombia and Afghanistan. There institutions are often destroyed by civil wars over control of resources. Dependency on oil and other resources hinders democracy and quality of governance (e.g., Ross 1999). Also, timber booms have induced members of political elites to dissolve forestry management and destroy institutions in Southeast Asia (Ross 2001b).

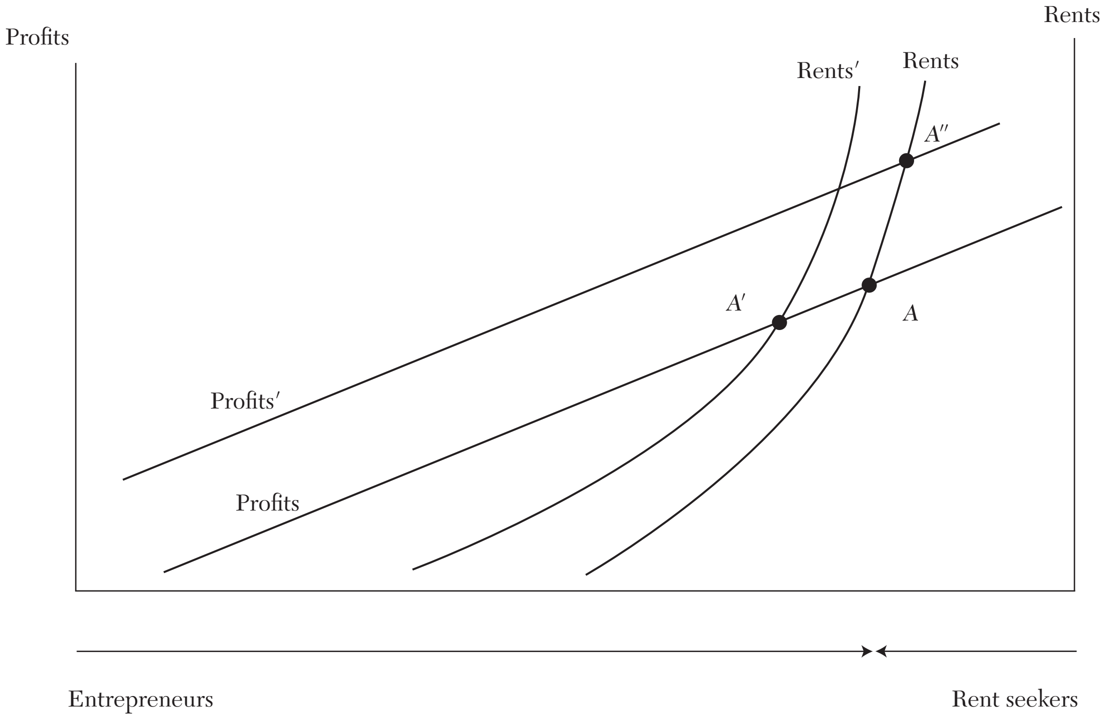

Figure 3. Rent Grabbing and Producer Friendly Institutions

Note: A resource bonanza shifts equilibrium from A to A'' if there are strong institutions, which means higher profits and more entrepreneurs. In case of weak institutions, the equilibrium shifts from A to A', so profits decline and number of rent seekers increases.

Source: Mehlum, Moene, and Torvik 2006b.

3.3.1 *Empirical Evidence on How Institutional Quality Transforms Effect of Resources on Growth*

The estimates reported in section 3.2 imply that the curse is cast in stone. But subsequent evidence offers support for the hypothesis that with good institutions the curse can be turned into a blessing (Mehlum, Moene, and Torvik 2006a, 2006b). The third regression in table 4 indicates that countries with a high enough index of institutional quality $(> 14.34/15.4 = 0.93)$ experience no curse. This holds for fifteen out of the eighty-seven countries (including the United States, Canada, Norway, the Netherlands, New Zealand, and Australia). Five countries belong both to the top eight according to natural resource wealth and to the top fifteen according to per capita income. Resource rich countries with bad institutions typically are poor and remain poor. Related cross-country evidence strongly suggests that natural resources—oil and minerals in particular—exert a negative and nonlinear impact on growth via their deleterious impact

TABLE 5
MARGINAL EFFECTS OF DIFFERENT RESOURCES ON GROWTH FOR VARYING INSTITUTIONAL QUALITY

	Primary exports share of GDP	Ores and metals exports as share of GDP	Mineral production as share of GNP	Production of gold, silver and diamonds as share of GDP
Worst institutions	–0.548	–0.946	–1.127	–1.145
Average institutions	–0.378	0.425	0.304	0.279
Average + one s.d. institutions	–0.288	1.152	1.062	1.183
Best institutions	–0.228	1.629	1.560	1.776

Note: Institutional quality is an average of the indexes for bureaucracy, corruption, rule of law, risk of expropriation of private investment and repudiation of contracts by government.

Source: Boschini et. al. (2007).

on institutional quality[6] rather than through worsening of competitiveness of the nonresource export sectors (Sala-i-Martin and Subramanian 2003). The adverse effect of resource dependence on institutional quality and growth is particularly strong for easily appropriable "point-source" resources with concentrated production and revenues and massive rents such as oil, diamonds, minerals, and plantation crops rather than agriculture (rice, wheat, and animals) whose rents are more dispersed throughout the economy, and with easy appropriation of rents through state institutions (Auty 1997, 2001b; Michael Woolcock, Lant Pritchett, and Jonathan Isham 2001; Isham et al. 2005; Anne D. Boschini, Jan Pettersson, and Jesper Roine 2007; Mavrotas, Murshed, and Torres 2006).

Appropriability matters since it indicates the ease of realizing large financial gains within a short period and having control over resources. Two types can be distinguished (Boschini, Pettersson, and Roine 2007). *Institutional* appropriability implies that resource dependence only has an adverse effect on economic development when institutions are poor. *Technical* appropriability states that the impact of institutional quality and resource dependence is more pronounced the more technically appropriable the country's resources are. Table 5 calculates the marginal effects of one standard deviation change in various measures of resource dependence that are increasingly technically appropriable on the average yearly growth rate of GDP during 1975–88 for different levels of institutional quality (from cross-country regressions with a sample of eighty industrialized and developed countries, controlling for trade openness, average share of investment in GDP, and initial level of income per capita). Going from top to bottom in table 5, we see that better institutions are conducive to growth indicating *institutional* appropriability. Reading table 5 left to right, the importance of good institutions

6 This variable is instrumented by mortality rates of colonial settlers (cf., Acemoglu, Johnson, and Robinson 2001) and the fraction of the population speaking English and European languages (cf., Robert E. Hall and Charles I. Jones 1999).

increases in technical appropriability of resources confirming *technical* appropriability. The curse is thus not cast in stone.

Bad institutions clearly have an adverse effect on growth. They may also be more powerful explanations of cross-country variations in income per capita than geography, trade, or economic policies (Douglass C. North 1990; Hall and Jones 1999; Acemoglu, Johnson, and Robinson 2001, 2003; Acemoglu et al. 2003; Dani Rodrik, Subramanian, and Francesco Trebbi 2004; William Easterly and Ross Levine 2002), but not everybody agrees fully (Edward L. Glaeser et al. 2004). Cross-country evidence also suggests a significant negative impact of natural resources on income per capita after controlling for institutional quality, trade openness, and geography, and the curse seems particularly severe in countries with bad institutions and low degrees of trade openness (Rabah Arezki and van der Ploeg forthcoming).[7] Moving toward more trade openness and improving institutional quality may thus turn the curse into a blessing. Cross-country evidence suggests that resource dependence weakens institutions and thus leads to worse outcomes for indicators of welfare such as the human development index, availability of water, nourishment of the population, or life expectancy (Bulte, Damania, and Robert T. Deacon 2005).

3.4 *Natural Resource Curse Stronger in Presidential Democracies*

The average effect of natural resources on growth across a sample of countries is thus not very informative. Depending on quality of institutions and degree of openness, there are huge variations. Following Torsten Persson and Guido Tabellini (2003) and using a cross-country sample of ninety countries, estimates suggest that the resource curse occurs in presidential, not parliamentary democracies (Jorgen Juel Andersen and Silje Aslaksen 2008). Presidential systems are less accountable and less representative and thus offer more scope for resource rent extraction. In contrast, parliamentary systems seem better able at using resource revenues to promote growth. The nature of the constitutional system is empirically more important than democratic rule itself for the link between resource dependence and growth. The empirically observed resource curse seems to be mostly driven by presidential countries and nondemocratic regimes.

The adverse effects of resource dependence on growth survive controlling for geography such as kilometers to closest airport, percentage land in tropics or incidence of malaria (Sachs and Warner 2001). Natural resources can permanently boost income and welfare through higher human capital, and this can offset the direct negative effect of natural resources on the growth rate (Claudio Bravo-Ortega and Jose de Gregorio 2005).[8] This may explain why Norway has fared better than most resource-dependent Latin American countries. It is thus important to ascertain whether a low growth rate with a high level of income per capita is a normal state of affairs or induced by a resource curse. There is a host of further cross-country econometric evidence on the curse (e.g., Leite and Weidmann 1999; Gylfason, Herbertsson, and Zoega 1999; Isham 2005). An influential study states that primary commodities exports and fraction of GDP in mining belong to the twenty-two most robust variables out of a list of fifty-nine variables in explaining cross-country variations in economic growth (Sala-i-Martin 1997).

[7] Gravity equations for bilateral trade flows are used as instruments for international trade (Jeffrey A. Frankel and David Romer 1999) and the fraction of the population speaking English and Western European languages as the first language (Hall and Jones 1999) and colonial origins and settler mortality (Acemoglu, Johnson, and Robinson 2001) as instrument for institutional quality.

[8] Human capital does not appear in the growth regressions but the interaction term with resources does.

3.5 *Resource Windfalls Increase Corruption, Especially in Nondemocratic Regimes*

Resource dependence elicits corruption and rent seeking via protection, exclusive licenses to exploit and export resources by the political elite, oligarchs and their cronies to capture wealth and political power. In a sample of fifty-five countries, resource dependence is indeed strongly associated with a worse corruption perceptions index (from Transparency International, Berlin) which in turn is associated with lower growth (Mauro 1995). Cross-country regressions also suggest that natural resource wealth stimulates corruption among bureaucrats and politicians (Alberto Ades and Rafael Di Tella 1999). It also crowds out social capital, erodes the legal system and elicits armed conflicts and civil wars (see section 3.7).

Panel evidence covering ninety-nine countries during 1980–2004 suggests that natural resources only induce corruption in countries that have endured a nondemocratic regime for more than 60 percent of the years since 1956 controlling for income, time-varying common shocks, regional fixed effects, and some other covariates (Sambit Bhattacharyya and Hodler 2010). Effectively, "bad" politicians have a bigger incentive to mimic "good" politicians in democracies. Democratization may thus be a powerful instrument to curb corruption in resource rich countries. Another study suggests that the combination of high natural resource rents and open democratic systems retards growth unless there are sufficient checks and balances which is not the case in many new resource rich democracies (Collier and Anke Hoeffler 2009).[9] However, the best evidence for the effect of windfalls on corruption can be found in quasi-experimental studies. One recent study compares changes in perceived corruption in the island São Tomé, which had a significant oil discovery announcement in 1997–99, with the island Cape Verde which did not find oil, both with similar histories, culture, and political institutions, and uses a unique dataset of the characteristics of all scholarship applicants during 1995–2005 and tailored household surveys (Pedro C. Vicente 2010). It finds that corruption increased by close to 10 percent after the announcements of the oil discovery but decreased slightly after 2004. Another study uses data on Brazilian municipalities, a political agency theory of career concerns with endogenous entry of candidates, and regression discontinuity design (Fernanda Brollo et al. 2010). It finds that a municipal windfall of 10 percent increases corruption by 17–24 percent, raises the chances of the incumbent holding on to office by 7 percent, and shrinks the fraction of its opponents holding a college degree by 7 percent. Such experimental studies pave the way for more convincing evidence on natural resources and corruption.

3.6 *Volatility of World Resource Prices Harms Exports and Output Growth*

During the 1970s when commodity prices were high, resource rich countries used them as collateral for debt but during the 1980s commodity prices fell significantly. Panel data estimation suggests that this has thrown many resource rich countries into debt crises. Indeed, if debt is also an explanatory variable in the panel data estimation, the effect of resource dependence disappears. The empirical results suggest that the effect

[9] However, longitudinally truncated, pooled cross-sectional evidence may be misleading. Recent longitudinal evidence exploits within-country variations in resource dependence and regime types to obtain explicit counterfactuals and suggests that oil and mineral dependence may not be associated with undermining of democracy or less complete transitions to democracy (Stephen Haber and Victor Menaldo 2008).

of resource dependence is mainly driven by boom–bust cycles induced by volatile commodity prices, debt overhang, and credit constraints, and much less by quality of bureaucracy (data from Stephen Knack and Philip Keefer 1995) or degree of financial development (Manzano and Rigobon 2001).

Changes in natural resource wealth are triggered by sudden changes in commodity prices or resource discoveries, which can lead to boom and bust cycles. Resource revenues are highly volatile (much more so than GDP) because their supply exhibits a low price elasticity. Dutch disease can also induce real exchange rate volatility and thus to less investment in physical capital and learning, further contraction of the traded sector, and lower productivity growth (Gylfason, Herbertsson, and Zoega 1999). Cross-country evidence suggests that real exchange rate volatility can seriously harm the long-term productivity growth, especially in countries with low levels of financial development (Aghion et al. 2009). For a monetary growth model, it can be shown that real exchange rate uncertainty can exacerbate the negative investment effects of domestic credit market constraints.[10] Empirically, IMF data on forty-four commodities and national commodity export shares and monthly indices on national commodity export prices for fifty-eight countries during 1980–2002 suggest that there is a long-run relationship between real commodity prices and real exchange rates in about one-third of these commodity-exporting countries (Paul Cashin, Luis F. Céspedes, and Ratna Sahay 2004). However, many countries with abundant natural resources are likely to experience volatile real exchange rates that might explain observed volatile growth rates of growth that cannot be explained by the conventional, relatively stable determinants such as institutions, geography, and culture. Historical evidence for the period 1870–1939 indeed suggests that volatility harms growth for the commodity-dependent "periphery" nations rather than for Europe or the United States (Christopher Blattman, Jason Hwang, and Jeffrey G. Williamson 2007). Resource rich countries also suffer from poorly developed financial systems and from financial remoteness, so that they are likely to experience bigger macroeconomic volatility (Andrew K. Rose and Mark M. Spiegel 2009).

Building on Aghion et al. (2009), van der Ploeg and Poelhekke (2009) show that with commodity price volatility liquidity constraints are more likely to bite and thus innovation and growth will fall. Extending Garey Ramey and Valerie A. Ramey (1995), they offer evidence that the adverse growth effect of natural resources results mainly from volatility of commodity prices, especially for point-based resources (oil, diamonds) and in landlocked, ethnically polarized economies with weak financial institutions, current account restrictions, and high capital account mobility. Instrumenting resource exports with subsoil resource stocks, estimates suggest a strong negative and significant effect of macroeconomic volatility on growth and a strong and positive effect of exports of especially point-source resources on macroeconomic volatility (van der Ploeg and Poelhekke 2010).[11] The *indirect* negative

[10] With endogenous growth, if firms face tight credit constraints, long-term investment is pro-cyclical, amplifies aggregate volatility and lowers mean growth for a given total investment rate (Philippe Aghion et al. 2005). Under complete financial markets, investment is countercyclical and mitigates volatility.

[11] The IV estimates yield an insignificant coefficient for the effect of point-source natural resources on mean growth in GDP per capita, but a significant coefficient of −0.394 at the 1 percent level for the effect of the standard deviation of unanticipated growth in GDP per capita, and a significant coefficient of 11.8 and 5.3 at the 1 percent level for the effects of point-source and diffuse natural resource dependence on the variance of unanticipated growth in GDP per capita. The effects of financial development, openness, the distance to nearest coast or navigable river on the variance of unanticipated growth in GDP per capita are also significant at the 1 percent level.

effect of resource exports on growth via the volatility channel outweighs any *direct* positive effect of resources on growth. A nonlinear specification suggests that the resource curse is operative only for countries with a volatility of unanticipated growth exceeding 2.45 percent per annum. So it is operative for Bolivia but not for Norway (both have a dependence of about 15 percent on point-source resource exports over the sample). Volatility thus seems the quintessence of the resource curse, but is offset somewhat in countries with a high degree of financial development.

Volatile resource revenues hurt risk-averse households, but welfare losses induced by consumption risk are tiny compared with those from imperfect financial markets. If only debt contracts are available and bankruptcy is costly, the economy and the real exchange rate become more volatile when there is specialization in traded goods and services and the nonresource traded sector is small (Ricardo Hausmann and Rigobon 2003). Effectively, shocks to demand for nontraded goods and services—driven by shocks to resource income—are not accommodated by movements in the allocation of labor but by expenditure switching. This demands much higher relative price movements. Due to bankruptcy costs, interest rates increase with relative price volatility. This causes specialization away from nonresource traded goods and services, which is inefficient. The less it produces of these traded goods and services, the more volatile the economy becomes and the higher the interest rate has to be. This causes the traded sector to shrink further until it vanishes.

Volatility is bad for growth but also for investment, income distribution, poverty, and educational attainment (Joshua Aizenman and Nancy Marion 1999; Karnit Flug, Antonio Spilimbergo, and Erik Wachtenheim 1998). To get round these curses, one could resort to stabilization and saving policies and improve efficiency of financial markets. It also helps to have a fully diversified economy since then shocks to nontraded demand can be accommodated through changes in structure of production rather than expenditure switching. This is important for inefficiently specialized countries such as Nigeria and Venezuela, but less so for diversified countries like Mexico or Indonesia or naturally specialized countries such as some Gulf States. Many resource rich economies have highly specialized production structures and thus are very volatile.

3.7 *Natural Resource Wealth Induces Voracious Rent Seeking*[12] *and Armed Conflict*

The political economy of massive resource rents combined with badly defined property rights, imperfect markets, and poorly functioning legal systems provide ideal opportunities for rent seeking behavior of producers, thus diverting resources away from more productive activities (Gelb 1988; Auty 2001a, 2001b, 2004; Ross 2001a, 2001b). Economists demonstrate that resource revenues are prone to rent seeking and wastage. Indeed, self-reinforcing effects of rent seeking if rent seekers compete and prey on productive entrepreneurs can explain wide cross-country differences in rent seeking (Murphy, Shleifer, and Vishny 1993; Acemoglu 1995). More rent seekers lower returns to both rent seeking and entrepreneurship with possibly large marginal effects on production. Since more entrepreneurs switch to rent seeking in times of a resource boom, multiple (good and bad) equilibrium outcomes arise. More

[12] Rent seeking is also relevant when countries receive foreign aid (Jakob Svensson 2000). Aid can remove pressure to reform, induce recipients to overstretch themselves, cause a Samaritan's dilemma with the donor expected to bail out bad policies, siphon skilled workers away from government and thus weaken institutions, and spark conflict over aid rents (Deborah A. Brautigam and Knack 2004; Tim Harford and Michael Klein 2005).

rent seekers induce negative external effects that depress profits for remaining entrepreneurs, which stimulate even more people to shift from productive entrepreneurship to wasteful rent seeking. Increased entrepreneurship can also crowd out rent seeking. For example, private business can invent and supply new substitutes for restricted imports and thus destroy the rents of quota licenses (Jean-Marie Baland and Patrick Francois 2000).

The "voracity effect" also causes a drag on growth as seen after the oil windfalls in Nigeria, Venezuela, and Mexico (Philip R. Lane and Aaron Tornell 1996; Tornell and Lane 1999). This effect implies that dysfunctional institutions and poorly defined property rights lead to a classical commons problem whereby there is too much grabbing and rapacious rent seeking of natural resource revenues. It supposes a fixed number of rent seekers. Capital can be allocated either to a formal sector where rents derived from a common-good stock may be appropriated or to an informal sector with lower returns and no rent seeking. During a natural resource boom returns to capital investment in the formal sector rise, so rent seekers appropriate proportionately more without destroying the incentive to invest in the formal sector. This happens if there is sectoral reallocation or if the elasticity of intertemporal substitution is sufficiently high so that groups do not refrain from excessively increasing appropriation. Rapacious rent seeking in a Markov-perfect equilibrium outcome of a differential game lowers the capital left for investment in the formal sector and thus curbs growth. The higher profitability of investment is more than undermined by each group of rent seekers grabbing a greater share of national wealth by demanding more transfers. As the number of rent seeking groups increases, the voracity effect dampens.

Production and resource income have differential impact on armed conflict. Higher production income makes warfare less attractive and conflict less likely to occur, whereas higher resource income makes warfare more attractive as there is more to fight over. Indeed, cross-country evidence suggests a negative relationship between shocks in the growth of production income and the risk of civil war (Collier and Hoeffler 2004; James D. Fearon and David D. Laitin 2003; Edward Miguel, Shanker Satyanath, and Ernest Sergenti 2004) and a positive relationship between resource income and conflict (Collier and Hoeffler 2004; Fearon 2005). The export share of primary commodities is the largest single influence on the risk of conflict and the effect is nonlinear (Collier and Hoeffler, 2004).[13] For instance, a country with no resources has a probability of civil conflict of merely 0.5 percent, but a country with a share of natural resources in GDP of a quarter has a probability of 23 percent. There is now a growing body of cross-country evidence that rents on resources and primary commodities, especially oil and other point-source resources, increase chances of civil conflicts and wars especially in sub-Saharan Africa through weakening of the state or financing of rebels, sometimes by corporations. Diamonds (Paivi Lujala 2010), oil (Fearon and Laitin 2003; Ross 2004; Fearon 2005; Macartan Humphreys 2005) and narcotics (Angrist and Kugler 2008) especially increase the risk of civil war onsets. Oil increases the likelihood of conflict, especially

[13] Katharina Wick and Bulte (2006) show analytically the possibility of a nonmonotonic relationship between resources and conflict intensity. Point-based resources can trigger intense contests but can also facilitate coordination on peaceful outcomes. They also demonstrate that contesting resources through violent conflict may yield superior outcomes than contests through rent seeking. Taking account of resource dependence being endogenous to conflict seems to remove the statistical correlation between resource dependence and conflict onset, since historically conflict-torn societies become more dependent on resources (Brunnschweiler and Bulte 2008). Resource abundance (reserves under the ground) is associated with higher income and reduced chance of onset of war.

separatist conflict. Lootable resources such as gemstones and drug tend to prolong conflict but do not increase the chances of the onset of conflict. There is no evidence for a significant link between (legal) agricultural production and conflict. It is onshore rather than offshore oil that is more difficult to protect, encourages rebel groups and increases the risk of violent conflict (Lujala 2010).

Some see conflict as reflecting limited capacity of poor countries to put rebellion down (Fearon and Laitin 2003) and others as lower opportunity cost of fighting (Collier and Hoeffler 2004). It matters whether civil strife and wars result from *grievance*, a sense of injustice about how a social group is treated (e.g., systematic economic discrimination), or *greed* possibly induced by massive rents of point-source resources as in Angola, Congo, and Sierra Leone (Murshed 2002; Ola Olsson and Heather Congdon Fors 2004). Furthermore, *feasibility* is important if resources lead to ideological leaders being crowded out by opportunistic, rebel leaders generating the worst civil wars (Jeremy M. Weinstein 2005; Collier and Hoeffler 2005).

However, cross-country evidence for the effect of resources on conflict suffers from being confounded by the effects of quality of institutions, rule of law, etc. on conflict. It is more insightful to examine determinants of conflict at the subnational level, thus eliminating such confounding influences. Exploiting variation across four types of violence (guerrilla attacks, paramilitary attacks, clashes, and war-related casualties) in 900 municipalities during 1988–2005 for Colombia and making use of individual-level wage data from rural household surveys, a recent study tests the hypothesis that a higher price of capital-intensive commodities increases the return on capital and lowers wages, so boosts conflict over the ownership of resource production; conversely, a higher price of labor-intensive commodities boosts wages and reduces conflict. This hypothesis can be derived from a Heckscher–Ohlin model of international trade extended with an appropriation sector (Ernesto Dal Bó and Pedro Dal Bó forthcoming). The empirical evidence indeed suggests that the sharp fall in coffee prices in the 1990s has increased violence in regions growing coffee by lowering wages and opportunity costs of joining army groups while the sharp increase in oil prices has fueled conflicts in oil regions by increasing municipal revenue through rapacity (Oeindrila Dube and Juan F. Vargas 2008). Hence, conflict indeed intensifies if the price of labor-intensive commodities such as coffee, sugar, banana, palm, and tobacco falls but weakens if the price of capital-intensive commodities such as oil, coal, and gold falls. The empirical evidence does not support the hypothesis that the state colludes with paramilitary groups and protects oil. Also, satellite evidence does not support the hypothesis that the fall in coffee prices has induced substitution toward coca that led to more violence in coffee regions; but violent deaths escalated differentially in coca regions during the 1990s (Angrist and Kugler 2008).

Worrisome is that the estimated effects of natural resources on the outbreak and duration of war may be flawed since it fails to take account of the potential impact of fighting and armaments accumulation on resource extraction itself. In the face of rebel attacks, rapacious depletion may be favored by nationalized mining companies to reduce the stake to be fought over despite its economic costs; furthermore, private mining companies invest less in unstable countries, especially if their mining investments are not well protected and the government's grip on office is weak; also commitment problems lead a government to underinvest in weapons and mining companies to underinvest in mining equipment; and there may be an incentive to bribe rebels to stave off war (van der Ploeg and Dominic Rohner 2010). Without binding agreements and sufficient military capacity of the resource-owning faction, war can be avoided if resource revenue is transferred to resource-poor rebels (Carmen Beviá and Luis C. Corchón 2010). State capacities should be modeled as forward-looking investments by governments that are affected by the risk of external or internal war, the degree of political instability, and dependence on natural resources; furthermore, repression and war may both be driven by resources and peace, repression and war could be modeled as an ordered probit (Timothy Besley and Persson 2010). More empirical work is needed on the relationship between natural resources and conflict that allows for endogeneity of mining investment and resource extraction, development of state capacity, and repression outcomes.

Especially point-source resource rents may, by inducing conflict, put democratic institutions to a survival test. Under democracy, politicians are less able to appropriate resource rents for their own ends, but violent competition with other political factions is costly as armies need to be paid and property may be destroyed. Theory suggests that higher resource rents biases political choice from democracy toward violent conflict especially if politicians are short-sighted; higher income induced by higher productivity makes democracy more likely (Aslaksen and Torvik 2006).

Governments of resource rich countries often seem unable to provide basic security to their citizens since natural resource wealth elicits violence, theft, and looting often financed by rebel groups and competing war lords (e.g., Stergios Skaperdas 2002; Mehlum, Moene, and Torvik 2002). The effect of resources on incidence and duration of civil wars features strongly in political science (e.g., Ross 2004; Fearon and Laitin 2003; Collier, Hoeffler, and Mans Soderbom 2004). Rival groups fighting about the control over natural resources may harm the quality of the legal system and thus undermine property rights. The resulting destruction of output can outweigh the increase in output due to the resource boom but not in homogenous countries. There will thus be an erosion of property rights and a resource curse if the number of rival factions is large and natural resource revenues are substantial. Fractionalization and fighting can thus lead to overdissipation of resource rents. Here we show that the presence of natural resources R can lead to erosion of property rights and a resource curse, especially if there are many rivaling factions (cf., Hodler 2006). Let group i either work for productive purposes l_i or fight f_i. Group i obtains utility:

$$U_i = \phi H l_i = R_i \text{ with}$$

$$R_i = \left(\frac{f_i}{\sum_{j=1}^{N} f_j}\right)\left[R + (1-\phi)\sum_{j=1}^{N} H l_j\right]$$

$$\text{and } \phi = 1 - \frac{1}{F}\sum_{j=1}^{N} f_j,$$

where H, N, ϕ, and F denote productivity, the number of rivaling groups, the quality of the legal system, and a measure of incorruptibility, respectively. The specification for R_i indicates that group i appropriates more resources if they fight more than others, and the resource windfall and "stolen" resources from productive activities are large. The specification of ϕ indicates that fighting undermines effective property rights (cf., Herschel Grossman 2001). The optimum outcome of this symmetric Nash game is:

$$Nf_i = \underbrace{\left(\frac{N-1}{N}\right)}_{\substack{\textit{rapacious}\\ \textit{rent seeking}}} \underbrace{\left(1 - \frac{N-1}{F}\right)^{-1}}_{\substack{\textit{erosion of}\\ \textit{property rights}}} \left(\frac{R}{H}\right)$$

$$\geq \underbrace{\left(\frac{N-1}{N}\right)}_{\substack{\textit{rapacious}\\ \textit{rent seeking}}} \left(\frac{R}{H}\right).$$

More effort is devoted to fighting (rent seeking, corruption or conflict) if resource revenues that are at stake R are high and the return on productive activities H is low. In "incorruptible" countries (very large value of F, ϕ close to one), there can still be rapacious rent seeking, especially if the number of competing factions N is large, even though the erosion of property rights is insignificant. In "corruptible" countries (with low value of F), rent seeking is much more severe and may even erupt into corruption or outright conflict. Here fighting causes erosion of property rights (higher $1 - \phi = Nf_i/F$), which in turn induces even more fighting, especially if "corruption culture" is strong (low F). Both the "rapacious rent seeking" and the "erosion of property rights" effect is stronger if there are more rival factions (high N). Fighting implies that there are fewer resources available for productive activities; hence, utility of each group is lower. If the country is homogenous ($N = 1$), there is no fighting and no undermining of property rights so that a natural resource bonanza always benefits consumption of its citizens. Indeed, empirical evidence suggests that the resource curse is more severe in countries that have many ethnic or religious factions and many languages (Hodler 2006; van der Ploeg and Poelhekke 2009).

Caselli and Wilbur John Coleman (2006) provide a richer theory of coalitions formed along ethnic lines competing for natural resources. In ethnically homogenous societies, members of the losing coalition can defect to winners at low cost, which rules out conflict as an equilibrium outcome. Of course, rent of each member of the winning coalition is diluted. In ethnically heterogeneous societies, members of winning coalitions more easily recognize potential infiltrators by skin color or other physical characteristics and exclude them. We should therefore see more conflict in ethnically heterogeneous societies such as Rwanda, Sudan, Indonesia, Afghanistan, etc. and less violent resource conflicts in homogenous societies like Botswana. Religion or language is not such a good marker since people can easily acquire such characteristics. Caselli (2006) argues that resource dependence generates power struggles and political instability, which increases the effective discount rate of the governing group. Consequently, the elite invest less in long-run development.

3.8 *Natural Resource Wealth Leads to Unsustainable Government Policies*

Natural resource wealth may encourage countries to engage in "excessive" borrowing, which harms the economy in the short and long run (Arman Mansoorian 1991). Heavy borrowing on the world market induces depreciation of the real exchange rate in the long run. In an economy with overlapping generations of households without a bequest motive, the generations alive at the time of the exploitation of the resource borrow against future resource income and future generations bear the burden of servicing the debt. The consequent fall of aggregate demand causes depreciation of the real exchange rate in the long run. Others also find that resource rich countries have an incentive to borrow excessively (Manzano and Rigobon 2001).

In general, a sudden resource bonanza tends to erode critical faculties of politicians and induce a false sense of security. This encourages them to invest in projects that are unnecessary, keep bad policies in force, and dress up the welfare state so that it is impossible to finance once natural resource revenues dry up. Politicians are likely to lose sight of growth-promoting policies, free trade, and "value for money" management. For example, after the discovery of natural gas in the Netherlands, the global oil price shocks during the 1970s and 1980s and the consequent sharp rise in unemployment, successive Dutch governments responded irresponsibly. They expanded public employment and consumption, made unemployment and disability benefits more generous, weakened eligibility conditions for benefits, raised the minimum wage, and implemented protective labor market legislation (Neary and van Wijnbergen 1986). Starting in 1989, it has taken more than twenty years to put the Dutch welfare state on a financially sustainable footing again.

Many developing countries erred by trying in vain to encourage industrialization through prolonged import substitution using tariffs, import quota, and subsidies for manufacturing. Neo-Marxist policymakers in these countries, but also many other economists during the 1970s and 1980s, found inspiration from the Prebisch-Singer hypothesis, namely the secular decline of world prices of primary exports (David I. Harvey et al. 2010), to attempt to avoid resource dependency through state-led industrialization and import substitution. These policies may also have been a reaction to the appreciation of the real exchange rate and the decline of the traded manufacturing sectors caused by natural resource wealth. The substantial resource wealth in many of those countries may thus have prolonged bad policies. Political scientists have advanced several reasons why states have a proclivity to adopt and maintain suboptimal policies (e.g., Ross 1999). Cognitive theories blame policy failures on short-sightedness of state actors who fail to take account of the adverse effects of their actions on generations that come after the resource is exhausted, thus leading to myopic sloth and exuberance. These cognitive theories also stress a get-rich-quick mentality among businessmen and a boom-and-bust psychology among policymakers. Political scientists point the finger at abuse of resource wealth by privileged classes, sectors, client networks, and interest groups. They also emphasize the rentier state and fault a state's institutional weakness to extract and deploy resources, enforce property rights, and resist demands of rent seekers.

4. *Why Do Many Resource Rich Developing Countries Experience Negative Saving?*

Section 3 has put forward eight important hypotheses on how natural resources affect the economy, institutions, rent seeking, conflict, and policy. Here I put forward two further hypotheses to explain the stylized fact discussed in section 2.4 that many resource rich developing countries are unable to fully transform their large stocks of natural wealth into other forms of wealth. To set the scene, section 4.1 discusses the Hotelling rule for optimal intertemporal depletion of natural resources and the resulting utilitarian outcome for transforming depleting exhaustible natural resource assets into financial capital in a small open economy. I suppose throughout that countries have some power on the market for natural resources but are price takers in all other markets. Section 4.2 adopts a Rawlsian max–min social welfare perspective to discuss the optimal level of sustainable consumption and the Hartwick rule for reinvesting resource rents into durable, nonexhaustible assets. It also offers some evidence that many resource rich countries experience negative genuine saving. Section 4.3 then puts forward the "anticipation of better times" hypothesis, which suggests that resource rich countries should borrow in anticipation of higher world prices for resources and improvements in extraction technology in the future. Section 4.4 puts forward the "rapacious extraction" hypothesis to explain how, in absence of effective government intervention, conflict among rival factions induces excessive resource extraction and investment and negative genuine saving when there is wasteful rent seeking, investment in "white elephants" and short-sighted politicians.

4.1 *Preamble: Optimal Conversion of Depleting Natural Resources into Foreign Assets*

Most discussions of the resource curse and Dutch disease take the windfall as manna from heaven. Earlier literature, however, deals with the optimal intertemporal depletion of exhaustible resources (e.g., Partha Dasgupta and Geoffrey M. Heal 1979). The main result is the Hotelling rule, which states that the rate of increase in the marginal rent of resources must equal the world interest rate (possibly including a risk premium). With no extraction costs and constant elasticity of demand for resources, the Hotelling rule states that the capital gain on resources must equal the world interest rate. This is based on the arbitrage principle, which says that one should be indifferent between keeping the resource under the ground (in which case the return is the capital gain on reserves) and extracting, selling, and getting a market return on it. The rate of increase in marginal resource rents should thus equal the world interest rate. Since marginal extraction costs differ widely across countries, optimal depletion rates vary widely as well even if each country is a price taker.

Consider the optimal conversion of depleting exhaustible resources into foreign assets for a small open economy that uses capital and resources in production, obtains an exogenous return on investment abroad, and faces elastic demand for its resources on the global market (Dasgupta, Robert Eastwood, and Heal 1978). Maximizing social welfare yields the Hotelling rule and the efficiency conditions that the marginal product of capital must equal the world interest rate and that of resources the world price of resources. The optimal rate of resource depletion thus equals the elasticity of world demand for its resources times the interest rate. The initial price and the resulting depletion path of natural resources are set so that reserves are eventually completely exhausted. A resource discovery thus leads to an immediate fall in the resource price and increase in the rate of resource depletion. Suppose world demand for resources is given by $E = E(Q)$, where Q is the price of natural resources and $\varepsilon \equiv -QE'/E > 1$ the constant elasticity of demand. The social planner maximizes utilitarian social welfare, $\int_0^\infty U(C(t)) \exp(-\rho t)\, dt$, subject to the equations describing natural resource depletion, the dynamics of the current account and the Cobb–Douglas production function, i.e.,

$$\dot{S} = -E - R,$$

$$\dot{A} = r(A - K) + Y + QE(Q) - C \text{ and}$$

$$Y = F(K, R) = K^{\alpha} R^{\beta},$$

where C, S, R, A, K, Y, r, and ρ denote consumption, the resource stock, resource use in production, national assets, the capital stock, domestic production, the exogenous world interest rate, and the subjective rate of time preference, respectively. The production function has decreasing returns to scale with respect to K and R $(0 < \alpha + \beta < 1)$. It follows that:

$$F_K = r, \quad F_R = Q(1 - 1/\varepsilon), \quad \dot{Q}/Q = r,$$

$$\dot{E}/E = -\varepsilon r, \quad \dot{C}/C = \sigma(r - \rho),$$

where σ is the elasticity of intertemporal substitution. The first and second equation equate the marginal products of capital and resource to the interest rate and the marginal revenue of natural resources, the third equation is the Hotelling rule that (given that demand for resources is iso-elastic) says that capital gains on natural resources must equal the rate of interest r, and the fourth equation is the Keynes–Ramsey rule. Effectively, the first three equations result from maximizing the present value of natural resource and other income while the fourth equation results from choosing the timing of consumption to maximize utility. It follows that capital and natural resource use must decline over time:

$$\dot{Y}/Y = \dot{K}/K = -\left(\frac{\beta}{1-\alpha-\beta}\right)r < 0,$$

$$\dot{R}/R = -\left(\frac{1-\alpha}{1-\alpha-\beta}\right)r < 0.$$

Substituting the rates of decline of E and R into the resource depletion equation, using the marginal factor productivity conditions, and integrating over time gives two equations relating $E(0)$ and $R(0)$ to $S(0)$:

$$\frac{E(0)}{\varepsilon r} + \frac{(1-\alpha-\beta)R(0)}{(1-\alpha)r} = S(0)$$

$$\text{and } R(0)^{-(1-\alpha-\beta)} = \left(\frac{r}{\alpha}\right)^{\alpha}\left[E^{-1}(E(0))\left(1-\frac{1}{\varepsilon}\right)\right]^{1-\alpha}.$$

Hence, a resource bonanza (higher $S(0)$) lifts the declining paths of resource use and resource exports up (higher $R(0)$ and $E(0)$), also lifts the declining paths of capital and production, and depresses the price trajectory (higher $Q(0)$). Since the optimum production in this small open economy depends only on world prices, the optimal trajectories of E, R, K, and Y are independent of consumer preferences (σ and ρ). Substituting these together with the Euler equation into the present-value national wealth constraint, one gets initial consumption:

$$C(0) = [(1-\sigma)r + \sigma\rho] \times \left(A(0) + \left(\frac{1-\alpha-\beta}{1-\alpha}\right)\left(\frac{Y(0)}{r} - K(0)\right) + \frac{Q(0)E(0)}{\varepsilon r}\right),$$

where $Y(0)$, $K(0)$, and $Q(0)$ directly follow from $E(0)$ and $R(0)$. Since $Y(0) - rK(0)$ equals $W(0) + (1 - 1/\varepsilon)Q(0)E(0)$ and the wage W grows at the same rate as output, households consume a constant fraction of the sum of financial, human, and natural resource wealth. Clearly, a higher σ or lower ρ boosts consumption growth but lowers $C(0)$. The expression for initial consumption holds for all instants of time. Natural resource wealth ($QE/r\varepsilon$) declines over time at the rate $(\varepsilon - 1)r$ and human wealth declines at the rate $\beta r/(1-\alpha-\beta)$. Hence, supposing that $r = \rho$, a constant level of consumption can be sustained by accumulating sufficient foreign assets, A, to compensate for the continually declining levels of natural resource and human wealth. It is easy to extend the results to a return that declines with the level of foreign investment, e.g, $r = r(A - K)$, $r' < 0$, or to allow for some uncertain date in the future at which prices fall due to invention of some new alternative technology or source of resources (Dasgupta, Eastwood, and Heal 1978).

These pioneering insights on optimally converting natural resources into financial assets have not yet been extended to take account of resource windfalls harming competitiveness, provoking corruption, rent seeking, and other distortions.[14] But analysis of a

[14] Appendix 3 shows how to optimally convert depleting exhaustible resources into physical capital for a closed economy.

basic Dutch disease model without capital accumulation albeit with learning by doing indicates that, after a windfall, one should gradually adjust the optimal share of national wealth consumed downward and accept some adverse Dutch disease effects (Egil Matsen and Torvik 2005). Lower growth in resource rich economies may thus be part of an optimal growth path. The challenge is to reinvestigate these issues for a dependent economy with capital accumulation, specific factors or intrasectoral adjustment costs, and learning by doing, where wages and capital intensities are not fixed by technology and the world interest rate.

Nonrenewable or exhaustible resources typically imply steady declines in income per capita. With environmental resources being a production factor and production displaying constant returns to scale, capital and labor run into jointly diminishing returns (William D. Nordhaus 1992). In the AK-model of endogenous growth with natural resources as production factor, a positive growth rate of consumption cannot be sustained forever either (Aghion and Peter Howitt 1998, chapter 5). Faster population growth increases pressure on the finite resource and thus reduces per capita growth. However, resources such as fisheries, forests, and agricultural land are renewable. This raises questions about how a limited renewable resource sector can coexist with a growing sector in balanced growth equilibrium. Typically, this requires technological progress in use of the resource to be sufficiently faster than in use of other inputs. If proper account is taken of renewable resources, ongoing growth is feasible (e.g., A. Lans Bovenberg and Sjak A. Smulders 1996; Ludvik Elíasson and Turnovsky 2004).

The literature on optimal oil exploitation pays ample attention to the market structure of oil producers. Typically, the monopolist OPEC is considered together with a competitive fringe of price-following oil producers. One feedback Nash outcome is an initial phase where the monopolist sets prices low enough to exhaust the fringe and a final phase where the monopolist enjoys higher monopoly profits; the price at the end of the first phase is then not high enough to incite the fringe to postpone extraction (David M. G. Newbery 1981; Fons Groot, Cees Withagen, and Aart de Zeeuw 2003).

4.2 *Genuine Saving and the Wealth of Nations: A Pragmatic Guide*

The Hartwick rule of investing all resource rents in other forms of capital provides a pragmatic guide for sustainable development. Genuine saving is the traditional concept of net saving, namely public and private saving minus depreciation of public and private investment, *plus* current spending on education to capture the change in intangible (human) wealth, *minus* the value of net depletion of exhaustible natural resources and renewable resources (forests), *minus* damages of stock pollutants (carbon dioxide and particulate matter) (Kirk Hamilton and Michael Clemens 1999; Hamilton and John M. Hartwick 2005). Alas, fisheries, diamonds, subsoil water, and soil erosion are not dealt with due to data problems. With positive genuine saving, a nation becomes richer and social welfare increases, and with negative genuine saving, a nation loses wealth and social welfare falls (Dasgupta and Karl-Goran Mäler 2000). Wealth per capita is the correct measure of social welfare if the population growth rate is constant, per capita consumption is independent of population size, production has constant returns to scale, and current saving is the present value of future changes in consumption (Dasgupta 2001a).

Genuine saving estimates calculated by World Bank (2006), based on Giles Atkinson and Hamilton (2003), presented in figure 4 show an alarming picture. Countries with a large percentage of mineral and energy rents of GNI typically have lower genuine saving

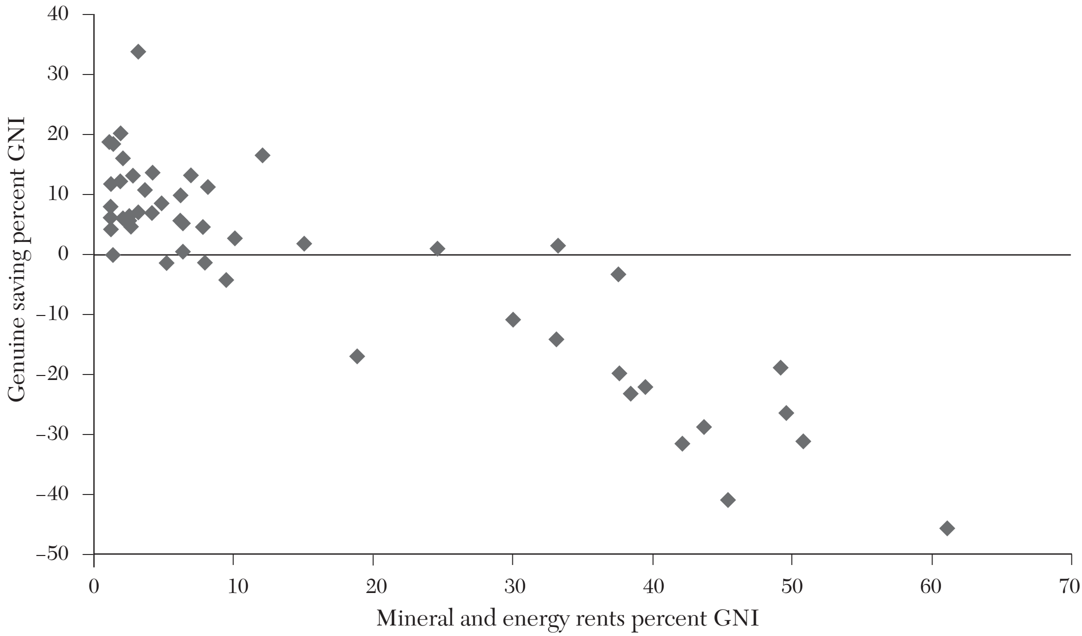

Figure 4. Genuine Saving and Exhaustible Resource Share

Source: World Bank 2006, figure 3.4.

rates. This means that many resource rich countries become poorer each year despite the presence of large natural resources. They do not fully reinvest their resources at the expense of future generations by not investing in intangible or productive wealth. For example, Venezuela combines negative economic growth with negative genuine saving while Botswana, Ghana, and China with positive genuine rates enjoy substantial growth in the year 2003. Highly resource dependent Nigeria and Angola have genuine saving rates of minus 30 percent, which impoverishes future generations despite having some GDP growth. The oil/gas states of Azerbaijan, Kazakhstan, Uzbekistan, Turkmenistan, and the Russian Federation all have negative genuine saving rates; they seem to be consuming or wasting rather than reinvesting their natural resource rents.

Figure 5 calculates by how much productive capital would increase by 2000 if countries would have invested their rents from crude oil, natural gas, coal, bauxite, copper, gold, iron, lead, nickel, phosphate, silver, and zinc in productive capital since 1970. The calculations provide an upper bound since they abstract from marginal extraction costs due to data problems. High resource dependence is defined as minimally a 5 percent share of resource rents in GDP. We see that resource rich countries with negative genuine saving, such as Nigeria or Venezuela, could have boosted their nonresource capital stocks by a factor of five or four if the Hartwick rule would have been followed. This is also true for oil/gas rich Trinidad and Tobago and copper rich Zambia. All the countries in the top right quadrant (except Trinidad and Tobago) have experienced

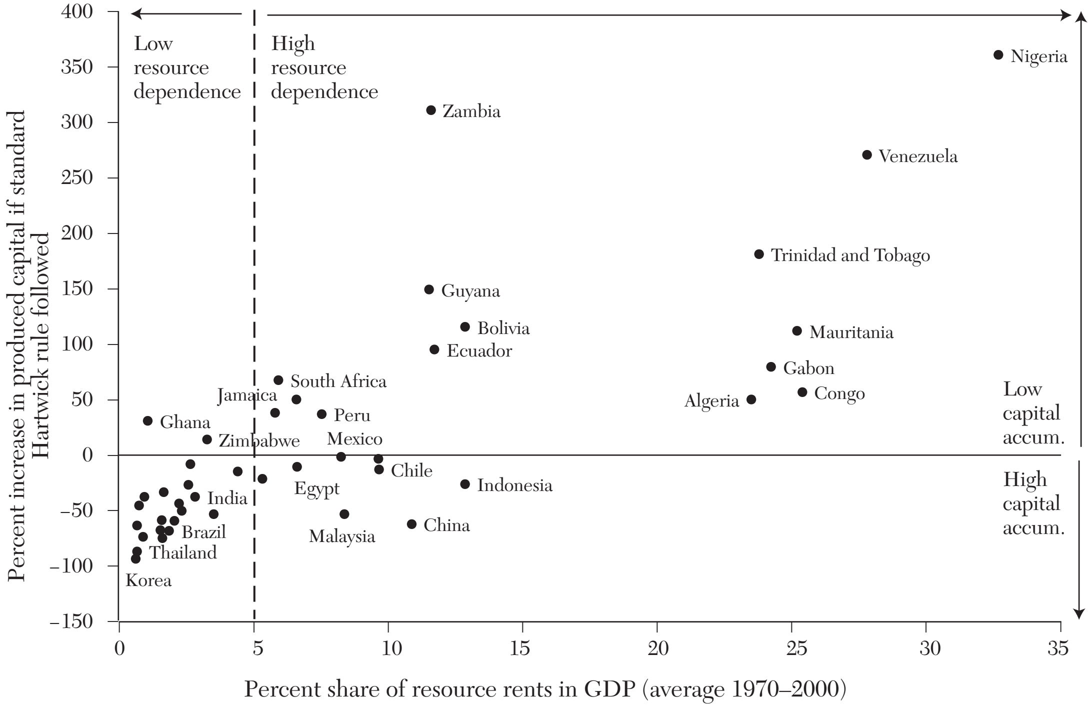

Figure 5. Counterfactual Hartwick Rule

Source: World Bank 2006, figure 4.1.

declines in per capita income from 1970 to 2000. If the Hartwick rule would have been followed during the last few decades, these economies would have been much less dependent on oil and other resources than they are.

The Solow–Swan neoclassical model of economic growth predicts that countries with high population growth have lower capital intensities and thus lower income per capita. Similarly, in countries with high population growth rates, genuine saving can be positive while wealth per capita declines (World Bank 2006, table 5.2). Such countries are on a treadmill and need to create new wealth to maintain existing levels of wealth per capita. They thus need to save more than their resource rents.[15] Sub-Saharan Africa has high population growth and shows substantial saving gaps typically of 10 to 50 percent of GNP. For Congo and Nigeria, the saving gaps are as high as 110 percent and 71 percent, respectively.

Even countries that save a large part of their natural resource wealth can fare badly. An early influential study found that about half of the windfall income of six oil-producing countries (Algeria, Ecuador, Indonesia, Nigeria, Trinidad and Tobago,

[15] Positive population growth gives a negative shadow price of time and thus positive genuine saving; technical progress gives a positive shadow price of time and negative genuine saving (Y. Hossein Farzin 2010).

and Venezuela) after the oil price hikes of 1973 and 1979 was invested domestically (overwhelmingly by the public sector), but that nevertheless all countries experienced prolonged periods of real exchange appreciation and negative growth (Gelb 1988). The roots of this puzzling feature may be investment in socially undesirable public investment projects or "white elephants" (Robinson and Torvik 2005) and high population growth. I show in the next section that, even without such "white elephants," it may not be optimal for such countries to save less than their resource rents if world resource prices are expected to increase and improvements in exploration technology are anticipated in the future.

4.3 *Anticipation of Better Times Can Induce Negative Genuine Saving*

Consider a small resource-exporting economy that takes the world interest and world price for its final products as given but exerts some monopoly power on the world market for natural resources. I investigate max–min social welfare and investigate what needs to be done to sustain a constant level of per capita consumption.[16] To do this, suppose that there is no use of exhaustible resources in production and no population growth. The production function is $f(K)$ with $f' > 0$ and $f'' < 0$, and there is no depreciation of the capital stock. The cost of extracting E units of resources is $TC(E)$ with $C' > 0$ and $C'' \geq 0$, where a fall in T indicates a boost to extraction productivity. World demand for oil equals $E = E(Q/Q^*)$ with $\varepsilon \equiv -QE'(Q)/E > 1$, where Q^* is the world price of oil sold by its competitors. Saving of the nation is given by

$$\dot{A} = r(A - K) + [QE - TC(E)] + f(K) - C.$$

The initial stock of oil S_0 defines the maximum amount of oil that can be depleted:

$$\dot{S} = -E,\ S(0) = S_0 \text{ or } \int_0^\infty E(t)\,dt = S_0.$$

There are two efficiency conditions:

$$f'(K) = r \quad \text{and}$$

$$\frac{d[Q(1-\varepsilon^{-1}) - TC'(E)]/dt}{Q(1-\varepsilon^{-1}) - TC'(E)} = r.$$

The first one states that the marginal product of capital is set to the interest charge. The second requires that the marginal resource rents must increase at a rate equal to the world interest rate. An anticipated positive rate of increase in the world resource price or in the rate of technical progress in extraction technology thus induces resource depletion to be postponed:

$$\frac{\dot{E}}{E} = [(1+\mu)\pi + \mu\tau - r]/\varepsilon^E\,\mu,$$

$$\text{where } \tau \equiv -\left(\frac{\dot{T}}{T}\right) \geq 0,\ \pi \equiv \frac{\dot{Q}}{Q},$$

$$\mu \equiv \frac{AC'(E)}{Q(1-\varepsilon^{-1}) - AC'(E)} > 0$$

$$\text{and } \varepsilon^E \equiv \frac{EC''(E)}{C'(E)} > 0.$$

With exogenous continual improvements in extraction technology ($\tau > 0$), it pays to delay depletion of reserves to reap the benefits of technical progress. The rate of

[16] Although the Keynes–Ramsey rule, $\dot{C}/C = \sigma(r-\rho)$, suggests that it is feasible to sustain a constant level of per capita consumption in the small resource-exporting economy even if there is no max–min welfare (i.e., $\sigma \neq 0$) provided that $r^* = \rho$, this is not the case for the closed economy. The optimal path for the closed economy first has per capita consumption rising and then falling and vanishing asymptotically; the first phase may not occur (Dasgupta and Heal 1979, chapter 10 and appendix 3).

increase in the price of resources and the rate of change in resource depletion are then reduced even further. Now consider the case $\pi^* \equiv \dot{Q}^*/Q^* > 0$. This pushes up the rate of increase in the price of resources charged by the country and postpones resource depletion. I assume $r - \pi^* > \mu(\pi^* + \tau)$, so $\pi > \pi^*$ and reserves are not exhausted in finite time. With a constant r^* and π^* and no costs of extraction, one has $E(0) = \varepsilon(\pi - \pi^*)S_0 = \varepsilon(r - \pi^*)S_0$. Reserves are exhausted relatively slowly if the world interest rate is low and the world rate of increase in the world price is high. In general, this is also true if the rate of technical improvements in exploration technology is high. Sustaining the max–min level of constant consumption requires:

$$\dot{A}(t) = [Q(t)(1 - \varepsilon^{-1}) - A(t)C'(E(t))]E(t) - \int_t^\infty \exp\left(-\int_t^s r(v)\,dv\right) \times [\tau(s)T(s)C(E(s)) + \pi(s)Q(s)E(s) + \dot{r}(s)(A(s) - K(s))]\,ds.$$

This saving rule extends the Hartwick rule to an open economy. The first term says that the nation saves the marginal resource rents valued at the world resource price minus marginal extraction costs, so depletion of natural resource reserves must be compensated by increases in foreign assets. The second term is the "anticipation of better times" term. It says that the nation saves less if it expects the world interest rate (provided $A > K$) or the price of its resources to increase in the future. The country then saves less and postpones extraction. The nation also saves less if it expects positive technical progress in future oil extraction technology. A special case arises if extraction costs are zero and the world price of resources follows the Hotelling rule because then the depletion rate is given by $\dot{E}/E = -\varepsilon(r - \pi^*)$and the max–min saving rule becomes $\dot{A} = Q(1 - 1/\varepsilon)E - \pi^* QS$. Saving marginal resource rents *minus* imputed interest on the value of natural resource reserves thus sustains a constant level of consumption. Countries with abundant reserves of exhaustible resources should thus run a current account deficit if resource rents fall short of the imputed rent on the value of resource reserves. Genuine saving is thus negative, i.e., $\dot{A} + Q(1 - \varepsilon^{-1})\dot{S} = -\pi^* QS < 0$.

Since the country saves *less* than its marginal resource rents and postpones extraction of exhaustible resources if it expects extraction technology to continually improve or the price it can fetch for its resources to continually increase in the future (cf., Geir B. Asheim 1986; Jeffrey R. Vincent, Theodore Panayotou, and Hartwick 1997; van der Ploeg 2010b),[17] it is a priori unclear whether observed negative genuine saving for resource-rich economies are due to poor institutions, badly functioning capital markets, corruption, or mismanagement or due to anticipation of better times. It is optimal for a country with substantial oil reserves to save less than a country with almost no reserves because it makes sense to sell more of its reserves in the future when the price of oil is higher.

4.3.1 *The Hartwick Rule in the Global Economy*

To examine the Hartwick rule for the global economy, consider a world consisting of natural resource (say, oil) exporters and oil importers. With free international trade in oil and goods, perfect capital mobility, zero

[17] Similar arguments can be applied to deforestation in a small open economy with a large endowment of forest land and small endowment of agricultural land (Hartwick, Ngo Van Long, and Huilan Tian 2001). The early phases of clearing forest land are then governed by the high price of agriculture while later phases are driven by profits from marketing timber from cleared land.

labor mobility, no technical progress, no population growth, and identical technologies for both blocks, the max–min egalitarian outcome can be characterized (Asheim 1986, 1996). Factor intensities are determined by the world interest rate and price of oil. The ratios of output, capital, and resource use in oil-exporting economies relative to those in oil-importing economies are then identical and equal to the ratio of the labor force of oil exporters relative to that of oil importers.

On the efficient max–min path, oil exporters consume the full marginal product of their human capital plus their oil rents, but consume only a fraction of the marginal product of physical capital and the remainder is used to accumulate national wealth to compensate for the decreasing rate of return on capital. This fraction equals one minus the ratio of the share of resource rents to the share of capital income in value added. Oil importers consume less since they have no oil rents. If oil exporters owned all physical capital, they would be investing all oil rents in physical capital. They would then use all natural resource rents for consumption and run a foreign financial debt. Oil has no marginal productivity as a stock but oil exporters can consume a fraction of the capital gains. Oil exporters can thus indefinitely sustain positive consumption by consuming only a fraction of their resource rents, especially if these are large relative to capital income. Since the Hotelling rule implies that oil exporters enjoy a growing income from oil revenues over time, they need to save less than the Hartwick rule to keep consumption constant. Conversely, oil importers need to save more to afford the increasing cost of oil imports and sustain a constant level of consumption. Resource rich economies thus sustain consumption by consuming a fraction of their marginal resource rents. Alas, no empirical tests of this proposition are available yet.

4.4 *Fractionalization, Voracious Depletion, Excessive Investment, and Genuine Saving*

Section 4.3 advanced the hypothesis that resource rich economies may not save all of their resource rents in anticipation of better times (e.g., higher rate of increase in the prices for its resource products or ongoing technical progress in resource extraction). An alternative hypothesis is that resource rich countries have to contend with rival factions competing for natural resource rents. The modern political economy of macroeconomics literature, surveyed in Persson and Tabellini (2000), abstracts from the intertemporal aspects of natural resource depletion but is of obvious relevance to the crucial question of why countries seem to be impatient and do not reinvest all their resource rents. This literature highlights deficit biases in the absence of a strong minister of finance due to government debt being a common pool (Andres Velasco 1999), debt biases if political parties have partisan preferences over public goods and the probability of removing the government from office is high (Alberto Alesina and Tabellini 1990), and delayed stabilization resulting from different groups in a "war of attrition" attempting to shift the burden of higher taxes or spending cuts to other groups (Alesina and Allan Drazen 1991). A common insight of this literature is that the rate of discount used by politicians may be higher than the rate of interest by, for example, the probability of being removed from office. Indeed, if a faction worries it may not be in office in the near future, it will extract natural resources much faster than is socially optimal and will borrow against future resource income (or accumulate less assets than is socially optimal) in order to gain at the expense of future successors. This could show up as capital flight and higher private consumption for the faction in power or higher public spending of the type that primarily benefits those in power.

There are no studies available yet that attempt to apply these political economy insights to a formal model addressing the optimal depletion of natural resources. This is an interesting area for further research and some of these issues are discussed in section 5 that deals with optimal harnessing of given natural resource windfalls. Here I offer, as a first step, a simple analysis of how common-pool problems induce competing factions to use a discount rate greater than the interest rate in the Hotelling rule which in turn leads to voracious natural resource depletion, excessive investment rates, less build-up of foreign assets, and lower consumption than is socially optimal for the small open economy of section 4.3.[18,19] This analysis also allows me to illustrate how natural resources are gradually transformed into foreign assets. Although I do not offer a full political economy analysis, I do clarify some conceptual issues to do with measuring genuine saving in noncompetitive environments and suggest that World Bank figures may underestimate genuine saving.

The dynamics of the stock of natural resources owned by each faction i is given by $\dot{S}_i = -E_i + \sum_{j \neq i} \xi(E_j - E_i)$, $S_i(0) = S_{i0}$. Here $\xi > 0$ indicates the speed by which oil, gas or water seeps from one field to another or the degree of imperfection of property rights on natural resources (van der Ploeg 2010c). No seepage (as is the case for gold, silver, or diamonds) or perfect property rights corresponds to $\xi = 0$. In general, we have $\xi > 0$. As in Lane and Tornell (1996) and Tornell and Lane (1999), I make a distinction between *uncontested* stocks of foreign assets (bonds and capital) and *contested* stocks of natural resources.[20] Furthermore, extraction costs are zero, the production function of each group is given by $f(K_i) = K_i^{\alpha}(1/N)^{1-\alpha}$, $Q(\cdot) = E^{-1}(\cdot)$, and the saving equation of each faction equals $\dot{A}_i = r(A_i - K_i) + Q(\sum_{j=1}^{N} E_j)E_i + f(K_i) - C_i$. Resources of each competing faction are perfect substitutes in demand. A homogenous society with perfect property rights has the usual Hotelling rule $\dot{Q}/Q = r$. The Hotelling rule under fractionalization $(N > 1)$ becomes $\dot{Q}/Q = r + \xi(N-1) > r$, so resource prices rise faster than the rate of interest if there are factions contesting resource rents, seepage is strong, or property rights imperfect. As a consequence of the higher discount rate used by competing factions, resource extraction is more voracious and the rate of decline of natural resource revenues, $(\dot{QE})/(QE) = -(\varepsilon - 1)[r + \xi(N-1)]$, is higher in more fractionalized societies. Although fractionalized societies save a greater fraction of their natural resource revenues, $\dot{A}/QE = [1 + (\xi(N-1)/(\varepsilon r + (\varepsilon - 1) \times \xi(N-1)))](1 - (1/\varepsilon)) \geq 1 - (1/\varepsilon)$ they end up with less wealth in the long run.

Hence, $SWF \equiv \lim_{t\to\infty} A(t) - A_0 = [1 + (\xi(N-1)/(\varepsilon r + (\varepsilon - 1)\xi(N-1)))]\, Q(\varepsilon(r + \xi(N-1)))\, S_0 < Q(\varepsilon r) S_0$ if $N > 1$, especially if N is large and world demand for resources is more elastic. The sustainable level of consumption equals interest on initial foreign assets *plus* wage income *plus* interest on accumulated wealth, $C = rA_0 + (1-\alpha)(\alpha/r)^{\alpha/(1-\alpha)} + rSWF$, and is thus lower in fractionalized societies where resources suffer from weak property rights

[18] With a max–min specification of social welfare ($\sigma = 0$), consumption of each faction will be constant over time. With a positive elasticity of intertemporal substitution ($\sigma > 0$), short-sighted factions induce excessive resource extraction and less accumulation of foreign assets that will lead to a bias toward higher consumption in the short run and lower consumption in the long run.

[19] This can also be shown for a *closed* economy with capital accumulation where the subgame-perfect Nash equilibrium yields a suboptimally low level of sustainable consumption (van der Ploeg 2010b).

[20] The Keynes–Ramsey rule is again $\dot{C}/C = \sigma(r - \rho)$so that the rate of growth in consumption is not affected by conflict among factions. The analysis focuses on Rawlsian max–min outcomes ($\sigma = 0$).

and seepage. It is thus optimal to gradually transform natural resource reserves into interest-earning foreign assets. The wealth of the state, i.e., sovereign wealth, gradually grows from A_0 to $A_0 + SWF$. The final level of accumulated foreign assets in a fractionalized society is less than in a homogenous society despite the lower initial price of natural resources. Also, the speed of transformation is faster in a fractionalized society. It is the interest earned on sovereign wealth that makes up for dissipating resource revenues and thus makes it possible to sustain constant consumption as resources are depleted. Comparing the market with the socially optimal outcome suggests that benevolent governments redistribute from the lucky cohort that discovers resources to later cohorts by bequeathing them a large stock of foreign assets.

If there is an imperfect mechanism for resource allocation, one must use the true accounting prices $\mathcal{Q}_A$ when calculating genuine saving (Dasgupta and Mäler 2000; Dasgupta 2001b; Kenneth J. Arrow, Dasgupta, and Mäler 2003). These are the effect of a marginal increase in the initial stock of resources on social welfare divided by the effect of a marginal increase in initial foreign assets on social welfare. In the present context, this amounts to:

$$\left(1 - \frac{1}{\varepsilon}\right)\mathcal{Q}(0) \leq \mathcal{Q}_A(0) \equiv \frac{\partial C/\partial S_0}{\partial C/\partial A_0}$$

$$= \frac{\partial SWF}{\partial S_0} = \left[\frac{\varepsilon[r + \xi(N-1)]}{\varepsilon r + (\varepsilon - 1)\,\xi(N-1)}\right]$$

$$\times \left(1 - \frac{1}{\varepsilon}\right)\mathcal{Q}(0) \leq \mathcal{Q}(0).$$

In societies that are homogenous or have perfect property rights, the accounting price equals marginal resource revenue. In fractionalized societies with insecure property rights, however, the accounting price is higher and is closer to the world price of resources. Estimates of genuine saving should use accounting prices; if they use marginal revenues, they yield a too optimistic estimate, and if they use market prices of resources, they yield a too pessimistic estimate of genuine saving in fractionalized societies. Using true accounting prices, genuine saving is zero, $\dot{A}(0) + \mathcal{Q}_A(0)\dot{S}(0) = \dot{A}(0) - \mathcal{Q}_A(0)E(0) = 0$, even though the struggle over resources depresses consumption and welfare. Effectively, both resource extraction and investment in foreign assets occur at a rate that is from a social perspective too high, thereby leaving genuine saving unaffected.

Interestingly, rapacious rent seeking in itself does not explain the observed negative genuine saving rates of many developing resource rich countries (unless erroneously market rather than accounting prices are used to calculated genuine saving—a data artifact). The "anticipation of better times" hypothesis (see section 4.4) helps to explain observed negative genuine saving but a deeper analysis of the political distortions of rapacious rent seeking should offer a better explanation. Countries with a lot of fighting about natural resources suffer from corruption and erosion of the quality of the legal system, thus discouraging saving and investment in productive capital (see section 3.7), may overinvest in public investment projects as an inefficient form of distribution to the own group members as they are not so obviously corrupt within the context of a dynamic citizen–candidate model for a representative democracy (cf., Besley and Stephen Coate 1997, 1998), may overinvest in public investment projects with negative social surplus ("white elephants") as a form of credible redistribution as *all* politicians can commit to socially efficient public investment projects (cf., Robinson and Torvik 2005), and often attract short-sighted politicians. If added to my explanation of voracious resource depletion and excessive investment, these features

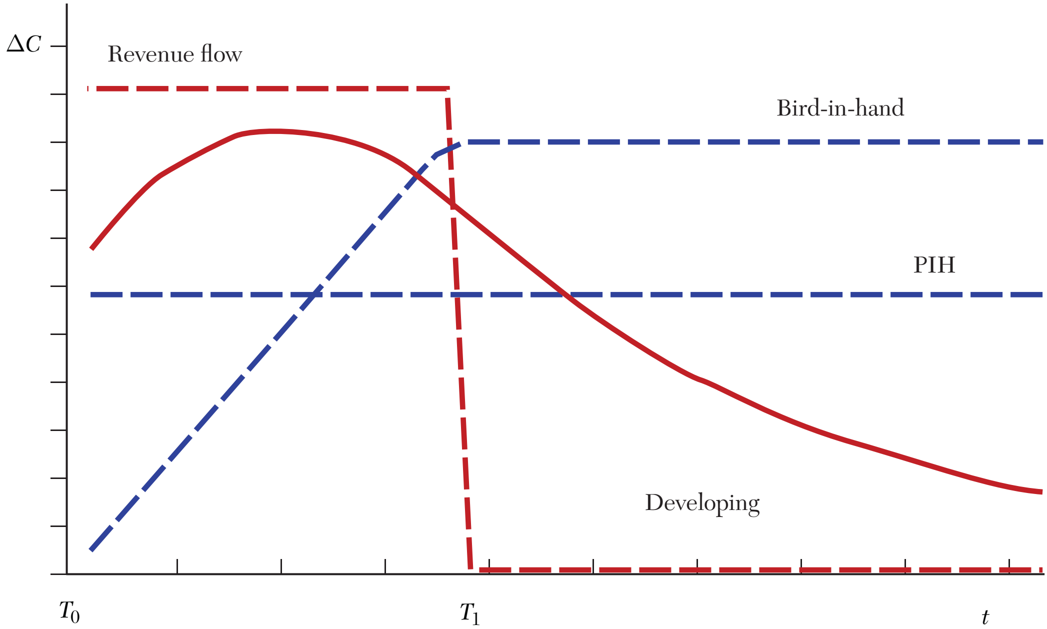

Figure 6. Alternative Prescriptions for Harnessing Natural Resource Windfalls

Note: The incremental consumption path indicated by "Developing" is the optimal path obtained by maximizing social welfare for a developing economy which suffers capital scarcity and has to pay an interest premium on its outstanding foreign debt.

Source: Collier et al. 2010.

should give a realistic explanation of the negative genuine saving rates observed in many developing resource rich economies.

5. *Harnessing Natural Resource Windfalls in Developing Economies*

Despite the normative and political analyses of converting depleting natural resources into productive assets discussed in section 4, there are good technical reasons to pump oil as fast as possible out of the ground once a field has been opened. So it may be better to focus at the optimal way of harnessing a *given* windfall (e.g., Collier et al. 2010). Such windfalls are typically anticipated (five years or so) and temporary (say, twenty years). The benchmark for harnessing such a windfall is based on the permanent income hypothesis, which says that countries should borrow ahead of the windfall, pay back incurred debt, and build up sovereign wealth during the windfall and finance the permanent increase in consumption out of the interest on the accumulated sovereign wealth after the windfall has ceased. Indeed, the IMF has often recommended resource rich countries to put their windfalls in a sovereign wealth fund (e.g., Jeffrey Davis et al. 2001). Figure 6 shows how the permanent income hypothesis and the consequent building up of such a fund are used to optimally harness unanticipated windfalls. In practice countries such as Norway prefer to restrict incremental consumption to interest earned on the fund and not to use the windfall until it is banked, which gives the conservative bird-in-hand rule. Estimation of fiscal reaction functions for non-hydrocarbon tax and public spending using official projections for hydrocarbon revenues and the pension burden for Norway suggests that fiscal reactions have been partially forward-looking with respect to the pension bill, but indeed not with respect to hydrocarbon revenues (Harding and van der Ploeg 2009). The primary non-hydrocarbon deficit should according to the permanent income hypothesis react only to permanent oil/gas revenues, but in practice it also reacts to current revenues. This suggests that Norway has used the bird-in-hand rule rather than the permanent income rule. VAR analysis of a DSGE model of oil-rich economies with a traded and nontraded sector suggests that the fiscal rules of Mexico and Norway with respectively a small and big emphasis on saving windfalls can explain the Mexican hump-shaped impulse responses for output, the real exchange rate, and private consumption and the flat responses for Norway (Anamaría Pieschacón 2009). More DSGE work is needed on resource rich economies, also paying attention to monetary policy rules, sterilization of foreign exchange windfalls, and unemployment in the light of natural resource windfalls.

One must take account of the special features of resource rich developing countries. Many of them are converging on a development path, suffer capital scarcity and high interest rates resulting from premium on high levels of foreign debt, and households do not have access to perfect capital markets. In that case, the permanent income hypothesis is inappropriate. In contrast to transferring much of the increment to future generations (as with the permanent-income and bird-in-hand rules), the optimal time path for incremental consumption should be skewed toward present generations and saving should be directed toward accumulating of domestic private and public capital and cutting debt rather than accumulating foreign assets (van der Ploeg and Venables 2010). The resulting optimal micro-founded path for incremental consumption is given in figure 6. Effectively, the windfall brings forward the development path of the economy. Although the hypothesis of learning-by-doing in the traded sector may be relevant for advanced industrialized economies, developing economies are more likely to suffer from absorption constraints in the nontraded sector especially as it is unlikely that capital in the traded sector can easily be unbolted and shunted to the nontraded sector. This cuts the other way, since it is then optimal to temporarily park some of the windfall in a sovereign wealth fund until the nontraded sector has produced enough home-grown capital (infrastructure, teachers, nurses, etc.) to alleviate absorption bottlenecks and allow a gradual rise in consumption (see appendix 4). The economy experiences temporary appreciation of the real exchange rate and other Dutch disease symptoms. However, these are reversed as home-grown capital is accumulated.

There are many other resource management issues. First, governments should realize that, if imports are mostly financed by an exogenous stream of foreign exchange coming from resource rents, revenue generated by tariffs is illusory as the increase in tariff revenue is offset by reducing real resource revenue (Collier and Venables forthcoming). Tariffs effectively reduce the domestic purchasing power of the windfall of foreign exchange. Second, tax capacity typically erodes quickly during windfalls. Since legal and fiscal capacity are likely to be complements (Besley and Persson 2009), this leads to grave concerns about the adequate supply of common-interest public goods such as fighting external wars or inclusive political institutions. Third, the political economy of windfalls dictates that incumbents may avoid putting resource revenues in a liquid sovereign wealth fund that can be easily raided by political rivals. There is thus a bias to excessive investment in illiquid, partisan projects, especially if the probability of being kicked out of office is high (Collier et al. 2010). There may also be a tendency to overinvest in partisan projects with negative social surplus ("white elephants") if politicians find it hard to credibly commit to socially efficient projects (Robinson and Torvik 2005). Fourth, harnessing windfalls in face of the notorious volatility of commodity prices implies that governments build precautionary and liquidity buffers (by postponing spending and bringing taxes forward) and extract natural resources excessively fast (compared with the certainty-equivalent Hotelling rule) to minimize the commodity price risk of future remaining reserves, especially if the degree of prudence is high and commodity price shocks are persistent and have high variance (van der Ploeg 2010a). Future work needs to extend existing results on uncertainty about future demand for the resource and about exploration and reserves that will ultimately be available for exploitation (e.g., Robert S. Pindyck 1980) to a setting where governments must decide on their intra- and intertemporal allocation of public goods and setting of tax rates. It is also necessary to investigate how options and other financial instruments can be used to shield economies from commodity price volatility and what political constraints prevent these instruments from being used in practice.

6. *Concluding Remarks*

A quasi-experimental within-country study of the districts of Brazil suggests that the economic argument that a resource bonanza induces appreciation of the real exchange rate and a decline of nonresource export sectors may have some relevance, but much more panel-data and quasi-experimental studies are needed to shed light on this key issue. The best available empirical evidence suggests that countries with a large share of primary exports in GNP have bad growth records and high inequality, especially if quality of institutions, rule of law, and corruption are bad. This potential curse is particularly severe for point-source resources such as diamonds and precious metals. The resource curse is, however, not cast in stone. Resource rich countries with good institutions, trade openness, and high investments in exploration technology seem to enjoy the fruits of their natural resource wealth. On the other hand, the curse seems more severe in presidential democracies. Resource rich countries are also vulnerable to the notorious volatility of commodity prices, especially if their financial system is not well developed. Recent research, taking account of the endogeneity of resource dependence, suggests that volatility may be the quintessence of the resource curse. Of course, there is also cross-country and panel-data econometric evidence that natural resource dependence may undermine the quality of institutions. And there is an interesting quasi-experimental study on São Tomé, using Cape Verde as control, which suggests that announcements of oil discoveries lead to corruption. Resource bonanzas also reinforce rent grabbing, especially if institutions are bad, and keep in place bad policies (debt overhang, building a too generous welfare state, etc.). There is also evidence that dependence of point-source resources makes countries prone to civil conflict and war, although these results fail to convincingly take account of the effect of conflict on natural resource production. A recent quasi-experimental study on the districts of Colombia offer evidence that capital-intensive resources such as oil are much more prone to civil conflict than labor-intensive resources such as coffee, rice, or bananas.

Although, from a normative perspective, countries should invest their natural resource rents into reproducible assets such as physical capital, human capital, infrastructure, or foreign assets, World Bank data suggest that resource rich economies do not fully reinvest their resource wealth and therefore have negative genuine saving rates. But resource rich countries may grow less simply because they save less than other countries. However, if these countries anticipate a positive rate of increases in future resource prices or continual improvements in exploration technology, it may make sense for them to borrow. Rival factions competing for control of resources will speed up extraction and may well lead to overinvestment. To explain negative genuine saving, more is needed; for example, rapacious resource extraction being associated with erosion of the legal system, inefficient rent seeking, investment in "white elephants," and short-sighted politicians. In well developed economies, it may be optimal to put natural resource revenues in a sovereign wealth fund. In contrast, developing countries often face capital scarcity in which case it is more appropriate to use the windfall to pay off debt and lower interest rates to boost private and domestic capital accumulation and speed up the process of economic development. Many countries find it hard to absorb a substantial and prolonged windfall of foreign exchange since it takes time for the nontraded sectors to accumulate "homegrown" capital. Whilst these Dutch disease bottlenecks are being resolved, it is optimal to park the windfall revenue abroad until there is enough capacity to sensibly invest in the domestic economy. However, fear of the fund being raided by political rivals can induce a suboptimal political bias toward too much partisan, illiquid investment.

An interesting option is to change the constitution to guarantee that resource revenues are handed to the public. The government has to subsequently tax its citizens to finance its spending programs. The advantage is that the burden of proof for spending resource revenues is with the government. Most important is for countries to learn from the U.S. history and adopt an optimistic, forward-looking approach to technological innovation in resource exploration and the search for new reserves. Predatory governments induce mining companies to be less transparent about their natural resource revenues and become less efficient.[21]

The analysis of resource rich countries draws on macroeconomics, public finance, public policy, international economics, resource economics, economic history, and applied econometrics. It also benefits from collaboration with political scientists and historians. More research needs to be directed at the changing role of institutions throughout history and in particular to understand why the resource curse seems to be something of the last four or five decades whereas before natural resources were harnessed to promote growth. Also, future work should apply the insights from contract theory to design good incentive-compatible contracts between governments and exploration companies. Future research should also be directed at appropriate design of auctioning mineral rights. Work is also needed on the question of whether resource rich countries have different saving patterns, e.g., in world financial markets ("petrodollars") rather than in domestic productive capital, and on how this might affect their rate of economic growth if reserves are privately owned. The

[21] Using a panel of seventy-two industries from fifty-one countries over sixteen years, the negative effect of expropriation risk on corporate transparency appears to be strongest for industries whose profits are highly correlated with oil prices and transparency is lower if oil prices are high and property rights are bad (Artyom Durnev and Sergei Guriev 2007). Lack of transparency may lead oil-rich countries to overreport reserves to raise expected future supply, discourage rival development of oil substitutes, and thus improve future market conditions (Philip Sauré 2010).

answers should be contrasted with the situation where reserves are publicly owned and managed by politicians who may be voted out of office soon. The answers will undoubtedly depend on whether there is presidential or a parliamentary system. Future research should tackle these questions with rich political economy models.

The wide diversity in experiences of countries with substantial natural resources means that comparative analysis and exchange of experiences of managing resource rich economies could be very fruitful and that real progress can be made in advancing the plight of poor countries with abundant natural resources. Future empirical work should move from cross-section to panel-data regressions to overcome problems of omitted variable bias and to allow for the changing quality of institutions (see International Monetary Fund 2005). At the same time, detailed country studies and quasi-experimental studies are necessary as often the devil is in the detail and results are often clouded by confounding factors. The discovery of natural resources has often been associated with devastating conflicts and disastrous economic performance. Future research should thus extend the normative theories of optimally converting depleting natural resources into productive assets to allow for rent seeking, corruption, and conflict. More generally, more work is needed on how to manage natural resource revenues in a way that promotes sustainable growth, alleviates poverty, and avoids conflict. This challenge is particularly relevant for the resource rich, volatile, and conflict prone economies of Africa with their high population growth rates and poor institutions.

Appendix 1: Unemployment and Dutch Disease

A higher world price of natural resources has, in the presence of short-run nominal rigidities, significant effects on unemployment and inflation (Eastwood and Venables 1982; Willem H. Buiter and Purvis 1983; van Wijnbergen 1984b). Although a higher oil price boosts demand for the domestic manufacturing good, that effect may be swamped by the real appreciation created by increased demand for the home currency. The result may be a decline in domestic manufacturing output and higher unemployment as well as a temporary rise in inflation. The oil price shock has elements of both a demand and supply shock but an increase in resource reserves is mainly a demand shock. Natural resource discoveries generate permanent income effects well beyond the productive life of the new natural resource reserve. The initial increase in income above its permanent level leads to a current account surplus but is reversed when reserves run out. Natural resource windfalls do not necessarily imply a shrinking of manufacturing exports or output and an increase in unemployment but, if a windfall is anticipated, the real exchange will appreciate and unemployment will rise ahead of the windfall. Other simulations of Dutch disease effects and unemployment use perfect-foresight, intertemporal general equilibrium models with temporary real wage rigidity, short-run capital specificity, long-run capital mobility between sectors, international capital mobility, intermediate inputs, adjustment costs of investment, dynamics of capital accumulation, government debt, current account imbalances, and far-sighted behavior of firms and households (Michael Bruno and Sachs 1982). With overlapping generations or household liquidity constraints, it matters whether the government uses the resource windfall to cut public debt or increase transfers. Oil price shocks then induce real appreciation and transient unemployment. It is worthwhile to investigate further the effects of resource dependence on wage formation in competitive and noncompetitive labor markets (Monojit Chatterji and Simon Price 1988; Rolf Jens Brunstad and Jan Morten Dyrstad 1997). Capital market imperfections may also generate adverse growth effects of resource booms. For example, if resource income cannot be invested in international capital markets, resource rich economies may experience slower steady-state growth as people live beyond their means and are overshooting their steady-state levels (Francisco Rodriguez and Sachs 1999).

Appendix 2: Endogenous Growth and Dutch Disease

I extend Sachs and Warner (1995) to allow for natural resource use in production of traded goods, R_T. The traded and nontraded sectors have the same labor-augmenting productivity growth, fully determined by the share of employment in the traded sector L_T. The production functions of the two sectors in extensive and intensive form are thus given by:

$$X_T = F(L_T H, K_T, R_T) \text{ and}$$

$$X_N = G(L_N H, K_N) \text{ with}$$

$$H_t = (1 + \theta L_{Tt-1}) H_{t-1}, \theta > 0 \text{ and}$$

$$x_T = X_T / L_T H = F(1, k_T, r_T)$$

$$\equiv f(k_T, r_T) \text{ and}$$

$$x_N = X_N / L_N H = G(1, k_N) \equiv g(k_N).$$

The zero profit conditions are $1 = c_W(W, r, Q)W + c_r(W, r, Q)r + c_Q(W, r, Q)Q$ and $d_W(W, r)W + d_r(W, r)r = P$, where W indicates the wage, r the exogenous world interest rate, and $c(\cdot)$ and $d(\cdot)$ are the unit-cost functions homogenous of degree one associated with the CRTS production functions $G(\cdot)$ and $F(\cdot)$. They give the price of nontraded goods P and the wage W in terms of the world interest rate r and the world resource price Q. Capital market equilibrium demands $Pg(k_N) = f(k_T, r_T) = r$ and gives, together with the condition $f_r(k_T, r_T) = Q$, k_N, k_T and r_T in terms of r and P (or Q). I obtain (suppressing r) that $r_T = r_T(Q)$, $r_T' < 0$ and:

$$W = W(Q), P = P(Q), k_N = k_N(Q) \text{ with}$$

$$P' = d_W W' = -c_Q / c_W < 0 \text{ and}$$

$$k_N' = -g' P_Q / g'' < 0.$$

Along the factor price frontier, the wage and the price of nontraded goods decrease if the world price of natural resources increases. The latter induces a fall in capital intensity of the nontraded sector. Overlapping households with logarithmic utility and discount factor $1/(1 + \rho) < 1$ enjoy wage w when young and receive a natural resource dividend per effective worker of e. It follows that aggregate consumption per effective young worker is given by:

$$c_{Nt} = \left(\frac{\mu}{P(Q_t)}\right)\left(\frac{1+\rho}{2+\rho}\right) \times \left[W_t + Q_t e_t + \left(\frac{(1 + r_{t-1})}{(1+\rho)(1 + L_{Tt-1})}\right) \times (W_{t-1} + Q_{t-1} e_{t-1})\right]$$

$$= (1 - L_{Tt}) g(k_N(Q_t)),$$

where μ indicates the relative utility weight (and budget share) of nontraded consumption. The factor $(1 + L_{Nt-1})$ is necessary to convert from old to young workers, the factor $(1 - L_{Nt})$ is to convert output per worker to output per young worker in the nontraded sector, and the labor market equilibrium condition $L_{Tt} + L_{Nt} = 1$ has been used. This condition for nontraded goods market equilibrium can be written as a stable difference equation $L_{Tt} = \Omega(L_{Tt-1}, e_t, e_{t-1}, Q_t, Q_{t-1})$ with $0 < \Omega_1 < 1$, $\Omega_i < 0$, $i = 2, 3, 4, 5$. An increase in resource dividend induces a gradual shift of employment from the nontraded to the traded sector (L_T falls), so there is less learning by doing and the growth rate is permanently lowered ($(H_t - H_{t-1})/H_{t-1}$ falls). In this setup, the resource dividend cannot affect relative productivity. If this dividend is driven by a higher world price of resources, depreciation of the real exchange rate and the lower capital intensity in production of nontraded goods lead to even bigger falls in traded sector employment, learning by doing, and the rate of growth. GDP is given by $Qe + WH + r(K_T + K_N) = QE + (W + r) \times H[k_N + L_T(k_T - k_N)]$. Hence, GDP grows at the rate $\xi\theta L_T$ where the nonresource share of GDP is ξ. Nonresource GDP falls on impact after a shock in Qe_1 if the traded sector is capital-intensive, that is

$$\partial \text{GDP}/\partial(Qe_1) = 1$$

$$+ (W + r)H_1(\partial L_{T1}/\partial(Qe_1))(k_T - k_N) < 1)$$

$$\text{as } \partial L_{T1}/\partial(Qe_1) < 0.$$

Appendix 3: Hartwick Rule for Reinvesting Natural Resource Rents in a Closed Economy

Does exhaustibility of natural resources constrain the growth potential if resources are essential in production? The answer depends on the ease with which reproducible inputs can be substituted for exhaustible natural resources. Utilitarian social welfare implies that consumption first rises and then vanishes in the long run (e.g., Dasgupta and Heal 1979). It is difficult to defend from an ethical point of view that the consumption level of future generations vanishes asymptotically. Hence, the normative focus in the literature on natural resources has been on max–min egalitarianism which leads to a constant level of per capita consumption. Nondecreasing per capita consumption is infeasible under exponential population growth if resources are essential inputs in production and there is no technical progress (Dasgupta and Heal 1974; Robert M. Solow 1974; Joseph E. Stiglitz 1974), but feasible with quasi-arithmetic population growth (Tapan Mitra 1983; Asheim et al. 2007). The so-called Hartwick rule states that natural resource rents should be fully reinvested in reproducible capital under max–min social welfare. This entails in the absence of population growth a constant savings rate equal to the constant functional share of resource inputs (Hartwick 1977). With no population growth and no technical progress, the economy features constant consumption and is thus a max–min optimum. If there is positive population growth, a max–min optimum requires constant consumption per head. If consumption per head were rising (falling) over time, welfare could be raised if earlier (later) generations saved and invested less or consumed capital at the expense of later (earlier) generations. A max–min optimum then requires that investment in reproducible capital *exceeds* natural resource rents.

Consider a closed economy with resource depletion $\int_0^\infty R(t)\,dt = S_0$ zero depreciation, savings rate $s \equiv \dot{K}/Y$, Cobb–Douglas production $Y = F(K, R) = K^\alpha R^\beta L^{1-\alpha-\beta}$, and population growth rate equal to η. Firms set marginal products to factor prices, that is $F_R = Q$ and $F_K = r$. The Hotelling rule in absence of extraction costs is $\dot{F}_R/F_R = \dot{Y}/Y - \dot{R}/R = F_K = \alpha Y/K$. The following saving rate sustains a stable income per capita:

$$\dot{Y}/Y - \eta = sr - \alpha\eta + \beta(\dot{Y}/Y - \eta - r)$$

$$= \frac{(s - \beta)r - \alpha\eta}{1 - \beta} = 0$$

$$\Rightarrow s = \beta + (\alpha/r)\eta \equiv s^*.$$

If there is no population growth ($\eta = 0$), all resource rents must be invested in capital to sustain a constant income per capita (i.e., $QR = sY$ or $s = \beta$). This is the well-known Hartwick rule and holds for general production functions.[22] It corresponds to a max–min optimum, since it sustains constant consumption per capita. With population growth ($\eta > 0$), the country must invest *more* than the resource rents to sustain constant income and constant consumption per capita ($s^* > \beta$). The interest rate then declines while the capital–output ratio rises with time, so the saving rate rises over time. The steady-state depletion rate is $r - \eta$, so societies with fast growing populations should deplete their resources less rapidly.

Without population growth and technical progress, the Hartwick rule also results in a max–min optimum in economies with many consumption goods, heterogeneous capital goods and endogenous labor supplies provided there is free disposal and stock reversal (Avinash Dixit, Peter Hammond, and Michael Hoel 1980). The conditions under which a max–min optimum implies adherence to the Hartwick rule are also known (e.g., Withagen and Asheim 1998; Mitra 2002).

The Hartwick rule is related to the Hicksian definition of real income, that is "the maximum amount a man can spend and still be as well off at the end of the week as at the beginning." The general equilibrium features of such a Hicksian definition of real income, defined as zero change in the present discounted value of current and future utility, are well understood (Asheim and Martin L. Weitzman 1991; J. A. Sefton and M. R. Weale 2006). In contrast to national accounting practice, income must be deflated with the Divisia consumption price index rather than the price index of output. Aggregation across multiple infinitely lived households with heterogeneous consumption preferences is feasible under constant returns to scale. The return on the increasingly scarce natural resource increases at the expense of the increasingly abundant other factors of production. Capital gains then represent capitalization of those future changes in factor prices and are effectively a transfer from one factor to another rather than a change in resources available to the whole economy. As a result, in a closed economy where all factors are entirely owned by households, the net gains are zero and capital gains should *not* be included in real income.

[22] Differentiating $\dot{K} = F(K, R, L) - C = F_R R$ and using the Hotelling and Hartwick rules, $\dot{K} = F_R R$ yields $\ddot{K} = F_K \dot{K} + F_R \dot{R} - \dot{C} = (\dot{F}_R/F_R) F_R R + F_R \dot{R} - \dot{C} = \ddot{K} - C$, so $\dot{C} = 0$.

Appendix 4: Absorption Constraints and Dutch Disease Dynamics

Assume a small open dependent economy with perfect access to the international capital market. The traded good is the numeraire. Production in the traded sector only used labor, so normalizing productivity at one we have $Y_T = L_T$ and $W = 1$. The nontraded sector has a Cobb–Douglas production function, $Y_N = K^{\alpha} L_N^{1-\alpha}$, $0 < \alpha < 1$. Profit maximization yields the demand for labor in the nontraded sector, $L_N = K[(1 - \alpha)P]^{1/\alpha}$, where P is the relative price of nontraded goods. Labor market equilibrium then gives $L_T = 1 - K[(1 - \alpha)P]^{1/\alpha}$. Output of nontraded goods is given by $Y_N = K[(1 - \alpha)P]^{(1-\alpha)/\alpha}$. Denoting the unit-cost function for producing capital goods by $c(P) = P^{\gamma}$ with $0 < \gamma < 1$ the share of nontraded goods in the production of home-grown capital, profit maximization requires that the marginal product of capital, $r(P) = \alpha[(1 - \alpha)P]^{(1-\alpha)/\alpha}$, must equal the rental change, r^*, plus the depreciation charge, δ, minus the expected capital gains, $\dot{c}(P)/c(P)$.

Preferences are homothetic and $e(P) = P^{\beta}$, $0 < \beta < 1$, denotes the unit-expenditure function, hence consumption in nontraded goods is given by $C_N = e'(P)U$, where U denotes real consumption (or utility). Equilibrium on the market for nontraded goods is given by $C_N + c'(P)I = Y_N$, where $I = \dot{K} + \delta K$ denotes gross investment. The representative consumer maximizes utility, $\int_0^{\infty} \ln(U) \exp(-\rho t)\, dt$, subject to the constraint, $\int_0^{\infty} [e(P)U + c(P)I] \exp(-r^* t)\, dt \le F_0 + V_0 + \int_0^{\infty} (Y_T + PY_N) \exp(-r^* t)\, dt$, where F indicates foreign assets (bonds) and V the present value of natural resource revenues (i.e., natural resource wealth). The budget constraint states that the present value of the stream of current and future consumption and investment spending on traded and nontraded goods cannot exceed initial foreign assets plus initial resource wealth plus the present value of current and future traded and nontraded production. If we suppose that $r^* = \rho$, the optimality condition for the consumer is $1/U = \lambda\, e(P)$, where the marginal utility of wealth λ has to be constant over time. At the time the resource windfall becomes known (upward jump in V_0), λ jumps down and stays at this lower value forever after. A resource windfall thus corresponds to an unanticipated, permanent fall in the marginal utility of wealth λ.

The adjustment path follows from the system of differential equations describing, respectively, equilibrium in the market for nontraded goods and equity arbitrage:

$$\dot{K} = \left[K((1-\alpha)P)^{\frac{1-\alpha}{\alpha}} - \frac{\beta}{\lambda P}\right]\frac{P^{1-\gamma}}{\gamma} - \delta K,$$

$$K(0) = K_0,$$

$$\dot{P} = \left[r^* + \delta - \alpha((1-\alpha)P)^{\frac{1-\alpha}{\alpha}}\right]\frac{P}{\gamma},$$

$$P(0) \text{ free.}$$

The steady-state value of P is independent of λ but the steady-state value of K increases after downward and permanent jump in λ induced by a windfall of foreign exchange. Note that as the share of traded goods in capital goods vanishes, $\gamma \to 0$, the capital stock adjusts immediately to a natural resource windfall. As a result of the downward jump in λ, there is an immediate and permanent upward jump in K and there is no need for the real exchange rate to appreciate whatsoever. However, much capital (think of nurses and teachers as well as infrastructure) must be homegrown and cannot be imported. Consequently, γ is closer to one and absorption constraints will manifest themselves. This may be seen from the saddle-path diagram given in figure 7. The optimal response to a windfall is for the real exchange to appreciate on impact signaling labor to shift from the traded to the nontraded sector and shifting demand from nontraded to traded goods. Over time, investment induces a gradual expansion in homegrown capital that permits a gradual reversal of the initial appreciation of the real exchange rate. The resulting temporary boost to the return on capital in the nontraded sector $r(P)$ is in line with the anticipated capital losses on those capital goods (as over time the relative price of investment goods $c(P)$ will fall and return to its original level). The windfall results in an immediate and permanent increase in the consumption of traded goods, but consumption of nontraded goods increases on impact and subsequently continues to increase toward its new steady-state level. Homegrown capital also jumps up on impact and then continues to rise to its new steady-state level. Due to the gradual increase in consumption as supply constraints are gradually relaxed, the total stock of assets increases by more than the windfall. Hence, there is initial saving (parking funds abroad) relative to the permanent income hypothesis. Van der Ploeg and Venables (2010) provide a much more general analysis allowing for capital accumulation in the traded sector

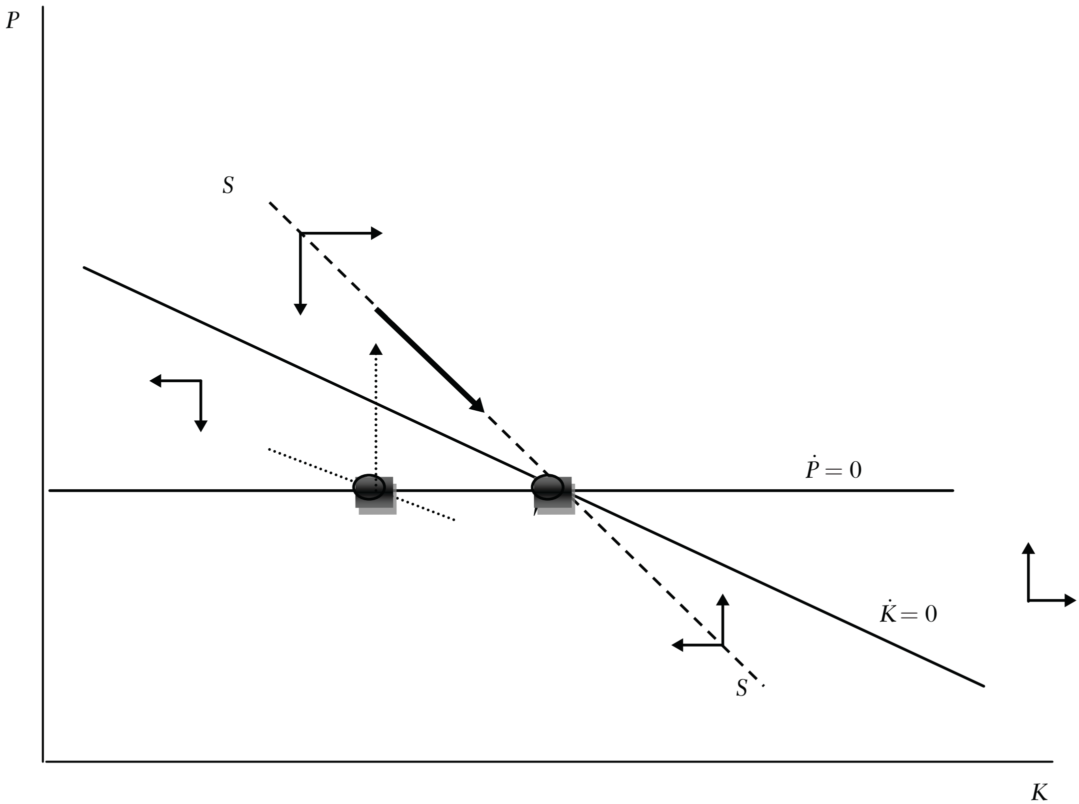

Figure 7. Absorption Constraints and Dutch Disease Dynamics

as well and highlighting the impossibility of shifting capital between the two sectors once it has been installed.

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