Indicators and Environmental Valuation

# Estimating National Wealth: Methodology and Results

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# Contents

Abstract v

Foreword vii

***Chapter 1***
***Introduction*** 1

***Chapter 2***
***Natural Capital*** 4
- Discount Rates 5
- Agricultural Cropland 5
- Pasture Land 7
- Timber Resources 7
- Non-Timber Forest Benefits 7
- Protected Areas 8
- Sub-Soil Assets 8
- The Unfinished Agenda for Natural Capital 10

***Chapter 3***
***Produced Assets*** 11

***Chapter 4***
***Human Resources*** 13

***Chapter 5***
***Caveats*** 15

***Chapter 6***
***Conclusions and Policy Implications*** 17

***Appendix A***
***Estimates of National Wealth: Total and Components*** 19

***Appendix B***
***Estimating Rental Values for Timber and Sub-Soil Assets*** 27
Rent from Oil 27
Rent from Natural Gas 28
Rent from Metals and Minerals 30
Rent from Hard Coal 32
Rent from Brown Coal (Lignite) 34
Timber Rent and Mean Annual Increments 36

***References 39***

***Figures***
1 Composition of wealth in low-income natural resource exporters, 1994 3
2 Components of natural capital, 1994 6
3 Human resources and years of education 14
B1 A comparison of several natural gas export prices from around the world 29

***Tables***
1 Wealth per capita by geographic region, 1994 2
A1 Estimates of national wealth: Total and components 19
A2 Natural capital estimates, 1994 22
B1 "Surrogate" countries used to estimate oil production costs 28
B2 "Surrogate" countries used to estimate natural gas production costs 30

# Abstract

As the nations of the world move from commitment to action in achieving sustainable development the need for measuring progress toward this end is heightened. This paper builds on the concept of wealth (or the asset base) as the foundation of generating well-being. National wealth takes on a much broader definition and is embodied in natural capital; human resources that include education, raw labor, and social capital; and produced assets (machinery, equipment, buildings, and urban land). The paper provides details on the methodology and assumptions used in estimating these magnitudes. The results show that human resources play a predominant role, thus lending support to investments in education and health. They also highlight the importance of agricultural cropland and pasture land, pointing to the need for sustainable land management practices. The estimates support our intuitive understanding of the importance of people and the environment in development.

# Foreword

To estimate the total wealth of nearly 100 nations, as presented in summary form in *Expanding the Measure of Wealth: Indicators of Environmentally Sustainable Development* (World Bank 1997b), a number of strong assumptions are required. If these estimates are to be credible, it is vitally important that these assumptions be spelled out carefully. This is the prime motivation for this working paper.

In addition, this paper demonstrates that expanding the national accounts to include the environment and natural resources is a practical exercise, even when working within the limits imposed by the availability of international data sets. This raises a key point however: while the economic *concepts* applied below are applicable in any context, the *methods* applied are often constrained by the data. *Analysts working in a given country can generally employ more copious and pertinent data, and so should be able to apply the conceptual approach more directly than we have below.* While we have espoused sound economics in what follows, the details of the methods applied should not be construed as the last word in expanded wealth accounting.

The final key point is inherent in the title of this working paper: the numerical results presented are *estimates* and so do not carry the authority of the World Bank to the extent of the development data appearing in *World Development Indicators* or the *World Development Report*.

# 1 Introduction

In the five years since the Rio Earth summit much has been achieved not only in terms of raising awareness of environmental concerns, but also in instituting specific innovative policies that capitalize on the potentially positive link between economic development and the environment (World Bank 1997a, Steer 1996). If governments are indeed moving from commitment to action it is important to be able to measure and assess the results of such actions. Recent years have seen much attention devoted to measuring progress toward sustainable development. Indicators to measure the pace and direction of environmental change have ranged from improved physical indicators of environmental resources, to measures linking the macro-economy and the environment.

Prominent among indicators linking the macro-economy and the environment are measures of "green" net national product (green NNP), genuine saving, and wealth accounts. The field of integrated economic and environmental accounting has made significant advances in improving NNP as an indicator of sustainable development by suggesting adjustments that bring the environmental effects of economic activity into the mainstream. NNP measures the annual flow of economic production based on market transactions, thereby leaving out the impact of economic activity on a very important national asset—natural capital. By accounting for the degradation and depletion of natural capital, green NNP reflects the productive services of labor, capital, and natural resources and also presents a complete picture of the costs incurred in the process (Hamilton and Lutz, 1996). Building on the same concept, "genuine" savings measure the true rate of savings in an economy after taking into account depletion of natural resources and damage caused by pollution. For greater detail on green NNP and genuine savings, interested readers are referred to Hamilton and Lutz (1996) and World Bank (1997b, chapter 2) respectively.

The motivation of this paper is to elaborate on wealth accounting as a measure of sustainable development. As defined by the report of the Brundtland Commission (World Commission on Environment and Development, 1987), sustainable development is development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs. The simplest interpretation of this (and the one adopted here) is to leave future generations as many opportunities as we ourselves have had, if not more. Here opportunity is measured by the capital stock which forms the basis for well-being (Serageldin 1996). To the extent that the available stock of assets—produced assets, natural capital, and human resources and social capital—empowers economic actors (in this and future generations) to create well-being, it is central to comprehending and operationalizing the concept of sustainable development. Maintaining, and/or enhancing the productive potential of an economic entity requires the creation, maintenance and sound management of wealth, broadly defined.

Our approach is to seek the answers to two questions. First, what are the components and contributing factors to national wealth? Since the sustainable performance of an economy is influenced by the portfolio of assets over time, this leads to the second question: how best to manage and maintain this portfolio to promote sustainable economic development? The wealth estimates are the sum of the following three major components:

- *Natural capital*. This is calculated as the sum of the stock value of the following renewable and non-renewable resources—agricultural land, pasture land, timber, non-timber forest benefits, protected areas, oil, coal, natural gas, metals, and minerals.
- *Produced assets*. This is the sum of the value of a country's stock of machinery and equipment, structures and urban land.
- *Human resources*. This is calculated as a residual by estimating the percentage of gross national product that can be considered "returns to labor" in agricultural and non-agricultural sectors, taking the present value of this stream over the mean productive years of the population, and then subtracting the stock of produced assets and urban land. Included in this component is the return to social capital.

Not surprisingly, the human resources component which combines returns to raw labor, human capital, and social capital is the most important constituent of wealth. It should be mentioned at the outset that natural capital values are primarily based on instrumental or use values of the environment and that important ecological and life support functions of natural systems have not been valued. This is in part due to the fact that methods of valuation are more well developed for instrumental values. We have, however, included the value of protected areas and some non-timber forest benefits such as minor forest products and recreation.

**Table 1. Wealth per capita by geographic region, 1994**

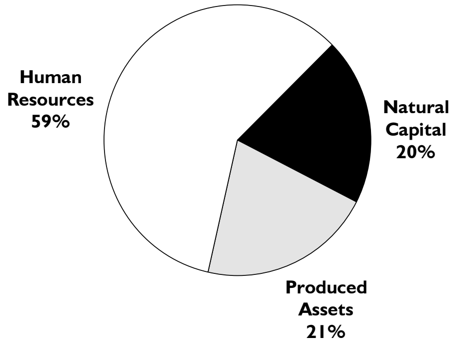
| | Total wealth | Human resources | Produced assets | Natural capital | Human resources | Produced assets | Natural capital |
|---|---|---|---|---|---|---|---|
| | *dollars per capita* | | | | *percent share of total wealth* | | |
| North America | 326,000 | 249,000 | 62,000 | 16,000 | 76 | 19 | 5 |
| Pacific OECD | 302,000 | 205,000 | 90,000 | 8,000 | 68 | 30 | 2 |
| Western Europe | 237,000 | 177,000 | 55,000 | 6,000 | 74 | 23 | 2 |
| Middle East | 150,000 | 65,000 | 27,000 | 58,000 | 43 | 18 | 39 |
| South America | 95,000 | 70,000 | 16,000 | 9,000 | 74 | 17 | 9 |
| North Africa | 55,000 | 38,000 | 14,000 | 3,000 | 69 | 26 | 5 |
| Central America | 52,000 | 41,000 | 8,000 | 3,000 | 79 | 15 | 6 |
| Caribbean | 48,000 | 33,000 | 10,000 | 5,000 | 69 | 21 | 11 |
| East Asia | 47,000 | 36,000 | 7,000 | 4,000 | 77 | 15 | 8 |
| East and Southern Africa | 30,000 | 20,000 | 7,000 | 3,000 | 66 | 25 | 10 |
| West Africa | 22,000 | 13,000 | 4,000 | 5,000 | 60 | 18 | 21 |
| South Asia | 22,000 | 14,000 | 4,000 | 4,000 | 65 | 19 | 16 |

*Notes:* The aggregate figures for West Africa do not include Nigeria because of data quality issues. Similarly, figures for North Africa do not include Algeria. Pacific OECD includes Japan, Australia, and New Zealand.
*Source:* Authors' estimates.

The different components of wealth were estimated for nearly one hundred countries and aggregate results are presented below (see tables 1 and 2 in Appendix A for details on wealth estimates and the various components of natural capital for each country). The selection of countries was governed wholly by considerations of data availability and quality. Since we used consolidated sources this was a particular concern. A greater investment of time and resources in collecting and validating data from countries would certainly improve the coverage of countries and the reliability of estimates. The main results are presented in table 1 which shows wealth and its components in dollars per capita and the relative shares in different regions of the world.

We observe that in all regions of the world human resources form the lion's share of wealth. Across regions the relative share of human resources ranges from 40 to 80 percent. The share of natural capital also varies considerably (2 to 40 percent). The small share of natural capital in industrialized economies is deceptive and does not imply that natural capital is insignificant. The preponderance of human resources and produced assets in high income countries masks the percentage share of natural capital. For example, although Canada has only 11 percent of total wealth per capita in natural capital, in dollar per capita terms it ranks in the top five. In contrast Figure 1 shows that low income economies that depend primarily on revenues from the export of natural resource commodities have a much larger percentage share in natural capital (this does not include countries dependent on petroleum revenues). Interestingly the relative share of produced assets, the main focus of national planners in the past, shows the least variation across income groups and regions (15 to 30 percent).

**Figure 1**
**Composition of wealth in low-income natural resource exporters, 1994**




*Source*: Authors' estimates.

An exercise of this nature necessarily involves several strong assumptions and the details are critical to understanding the results. In what follows we discuss the methodologies and assumptions used. The next chapter takes each component of natural capital and presents the valuation methodology adopted. Chapters 3 and 4 deal with produced assets and human resources respectively and the final chapter presents some important conclusions and guidance for public policy.

Most of these results reinforce our intuitive understanding of the development process. By explicitly accounting for the different components of wealth, these estimates have brought to the fore the concept of portfolio management where a nation's portfolio consists of natural capital, produced assets, and human resources. It is hoped that this endeavor will first and foremost strengthen the emerging view of the importance of people and the environment by supporting intuition with numbers, and secondly, spur improvements in the measurement of these critical components.

# 2 Natural Capital

The environmental resource base is comprised of regenerative resources—atmosphere, animal, bird, plant, fish populations, land (arable and grazing land), underground basins of water—and non-renewable resources—oil, coal, natural gas, metals, minerals. Economic development in both industrialized and developing economies, but particularly so in agrarian economies, relies crucially on environmental resources, and yet they "make but perfunctory appearances in government planning models" (Dasgupta 1993). Natural capital, like any other asset, contributes a flow of services to the economy. These services can be direct contributions to economic activity via inputs (raw materials, energy) or goods and services for final consumption. Capturing the economic value of the latter and bringing it into mainstream economic analysis has been the raison d'être of environmental economics. Services provided by the environment range from current values such as extractive uses (fish, pharmaceuticals), non-extractive uses (recreation, aesthetic), maintenance of life-support systems (watershed protection, nutrient cycling), to future values (options and existence values). All of these contribute to well-being, and it is this *total* economic value of environmental goods (over and above its value as resource inputs) that ought to be reflected in a measure of natural capital. Several methods have been identified and used to monetize these different values.

To capture the total economic value of all environmental goods is a huge endeavor and we have primarily considered the value of natural capital as *resource inputs* into production: land as an input into agricultural crops and animal husbandry, forests as a source of timber, and sub-soil assets as a source of metals, minerals, and fossil fuels. We have also considered certain extractive and non-extractive values embodied in the component of non-timber forest benefits. Also included is an estimate of the values people place on keeping open the option of such extractive and non-extractive uses in the future, as revealed in the establishment of protected areas. Clearly, there are other environmental resources and types of values missing from the calculus.

Having identified environmental resources and types of values, we have used the concept of *economic rent* to place a value on natural capital. Economic rent is the return on a commodity in excess of the minimum required to bring forth its services. Rental value is therefore the difference between the market price and cost of production / extraction.[1] To ease international comparability, we have used international market prices for all the components of natural capital where rental values are used – agricultural crop and pasture land, timber, and sub-soil assets.

The capital value of an asset is the present value of the stream of services it generates over its life time. This is the method we have used to calculate the stock of natural capital based on the above-mentioned streams of services.

Concerns about sustainable management of resources enter the calculation through the choice of the time horizon over which present value is computed. The extractive and non-extractive uses of the environment and the use of environmental resources as inputs into production can be enjoyed in a sustainable or unsustainable manner. Since the (un)sustainability of current use patterns affects the stock of capital being left for the future, this ought to enter a measure of natural capital. Thus, for renewable resources and non-renewable resources the calculation makes adjustments for (un)sustainable use patterns. The precise adjustments are discussed below with the detailed calculations for each component of natural capital.

## Discount Rates

In computing present values the choice of the discount rate is critical to the calculation. There are several reasons suggested in the literature for choosing a positive discount rate such as social rate of return on investment, pure time preference, and opportunity cost of capital (for a more detailed discussion see Pearce and Turner, 1990). The relevant discount rate for resource allocation decisions over time is the social rate of return on investment (SRRI). The SRRI is defined as $s = r + \mu c$, where $r$ is the pure rate of time preference (people prefer their benefits now rather than later because they are impatient), $\mu$ is the elasticity of marginal utility of consumption, and $c$ the rate of growth of real consumption per capita. Pearce and Ulph (1995) have estimated the SRRI for developed countries to be in the range of 2 to 4 percent. Clearly for fast growing developing economies this rate should be higher and for those experiencing weak or declining per capita consumption growth, the rate should be lower.

Although the SRRI varies from country to country, we have chosen to use a standard discount factor of 4 percent, because one of the objectives of this exercise is to enable cross country comparisons. This discount rate is applied to all assets including human resources.

We will now go into greater detail on the calculation of each component of natural capital and the data sources used.

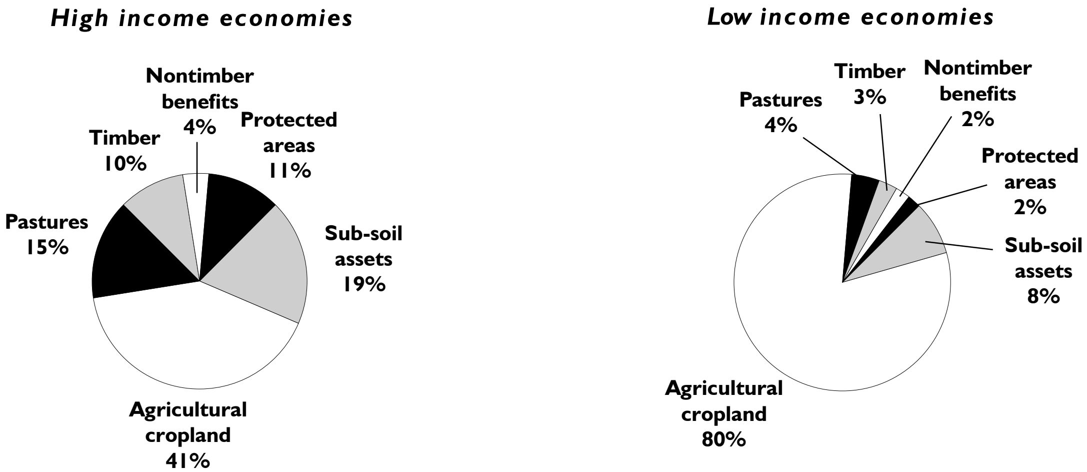
## Agricultural Cropland

The quality of land, not often thought of as a renewable resource, can be maintained only by careful management. It is an important factor in generating well-being particularly in countries where a large part of the population is involved in agricultural and pastoral activities. Indeed our results show that agricultural crop and pasture land account for a little over 80 percent of natural capital in low income economies (Figure 2).

Country-level data on agricultural land prices are not widely published, and so an estimation methodology for land asset values is required. Even if local price data were available, it is arguable that land markets are often so distorted that meaningful comparisons across countries would be difficult. We have chosen therefore to estimate land values based on the present discounted value of land rents, assuming the products of the land are sold at world prices.

The return to land is computed as the difference between the market value of the output crops and crop-specific production costs. We have considered the production of three major cereals—maize, wheat and rice—and valued each at international prices. The annual economic return to land is measured as a percentage of crop value—34 percent for maize, 31 percent for wheat, and 50 percent for rice (World Bank 1992, 1993a, 1995). These percentages are based on farm-level crop budgets from World Bank agricultural sector reports, and include the return to irrigation

**Figure 2**
**Components of natural capital, 1994**




*Source:* Authors' estimates.

but exclude return to other inputs such as labor and fertilizers. Therefore, implicit in this calculation is the economic value of water in agricultural production.

These crop-specific ratios of economic rent to world prices are then multiplied by values of production at world prices for the major cereal croplands in each country. This has the effect of assigning higher land rents to more productive soils, which makes perfect sense. However, applying average crop-specific ratios in this manner probably understates the value of the most productive lands, and overstates the value of the least productive.

To calculate the return to land on which crops other than maize, wheat and rice are being grown we use a weighted average of the per hectare return to land under maize, wheat and rice cultivation (weighted by the area sown to each crop in any individual country). Eighty percent of this weighted average is then used to value land on which other crops are being grown (calculated by subtracting the area under maize, wheat, and rice from arable and permanent crop area). Land under crops other than maize, wheat, and rice has been valued at 80 percent of the average per hectare return to the major cereals on the assumption that these crops will yield lower returns per hectare. While this is a reasonable assumption for coarse grains and tubers, this is less accurate for higher value crops such as coffee, tea, rubber, and cocoa. Therefore, for countries that cultivate large amounts of high-value non-grain crops this methodology underestimates the value of land.

In order to reflect the sustainability of current cultivation practices, the annual return for 1994 is projected to the year 2020 based on country-specific and crop-specific projected annual growth rates of cereal yields and area under cultivation (Rosegrant, Agcaoili-Sombilla, and Perez, 1995). The growth rate of production is therefore estimated as $(1+G_{at})*(1+G_{yt})$, where $G_{at}$ is the growth rate of area under cultivation and $G_{yt}$ is the growth rate of yields. After 2020 the value of production is held constant to infinity. The discounted present value of this flow was then calculated using a discount rate of 4 percent to arrive at an estimate of the asset value of agricultural land.

*Data sources*. The percentage of crop value attributable to land as an input is based on World Bank agriculture sector reports (World Bank 1992, 1993a, 1995). Data on land areas under cultivation of different crops is taken from the Food and Agricultural Organization's (FAO) Production Yearbook. Data on crop production in metric tons were taken from BESD's[1] FAO-Production database. To smooth fluctuations in production we use average production over the period 1990-94. Data on international prices are from the "Pink Sheet" put out by the Commodity Prices and Analysis Unit of the World Bank.

### Pasture Land

Returns to pasture land are assumed to be a fixed proportion of the value of output based on a study of sheep and bovine budgets (World Bank, 1993a). On average, costs of production are 55 percent of revenues, and therefore returns to pasture land are assumed to be 45 percent of output value. Value of output is based on the production of milk, beef, mutton, lamb, and wool valued at international prices. As with croplands, this rental share of output values is applied to country-specific outputs of pastureland valued at world prices. The present value of this flow is then calculated using a 4 percent discount rate over an infinite time horizon.

In countries where there are significant feed-lot operations, we find that the apparent per hectare return to pasture land is greater than the return to cropland. Lacking data on the animal feed that 'subsidizes' the returns to pasture land in these situations, we have simply capped the maximum value of pasture land to be less or equal to that of cropland.

*Data sources*. Production volumes (averaged over 1990-94) for dairy and meat products are taken from BESD's FAO/Production database. As with crop output, we use an average over 1990-94 to smooth out fluctuations in production. Data on international prices (1994) are from the "Pink Sheet" published by the Commodity Prices and Analysis Unit of the World Bank. Milk is valued at $500 per metric ton. Area of pasture land (1994) is from BESD's FAO/Fertilizers database.

### Timber Resources

The predominant economic use of forests has been as a source of timber. The annual flow of roundwood production is valued using timber rents (price minus average production costs) and then capitalized using a 4 percent discount rate to arrive at a stock of timber resources. The concept of sustainable use of forest resources is introduced via the choice of the time horizon over which the stream is capitalized. If roundwood production is greater than net annual increments, then the time to exhaustion is calculated based on estimates of forest volume divided by the difference between production and increment. Forest volume is calculated as 80 percent of forest area multiplied by an area-to-volume factor for tropical and non-tropical forests taken from Mather (1990). If, however, logging rates are below net annual increments, timber flows are capitalized over an infinite time horizon.

*Data sources*. Roundwood production data (averaged over 1990-94) are taken from the BESD/FAO-Forestry database. For further details on the calculation of timber rents and net annual increments see Appendix B. Forest area data for 1994 are taken from the World Resources Institute database 1996-97.

### Non-Timber Forest Benefits

Timber revenues are not the only contribution forests make. Non-timber forest benefits such as minor forest products, hunting and fishing, recreation, watershed regulation, options and existence values are significant benefits not explicitly accounted for. This fact leads to undervaluing of forest resources and could explain much of the difference in deforestation rates in developed and developing countries. A comparison of non-timber forest benefits in developed and developing countries reveals that returns per hectare per year from such benefits vary from $145 per hectare in developed countries to $112 per hectare in developing countries (Lampietti and Dixon, 1995). Assuming that only a tenth of forest area is accessible, this per hectare value is multiplied by one-tenth of the forest area in each country.

*Data sources*. Forest area data (1994) are taken from the World Resources Institute database 1996-97.

### Protected Areas

Protected areas provide a number of benefits that range from existence values to recreational values. They can be a significant source of income from a thriving tourist industry. These values are revealed by a high willingness to pay for such benefits. The establishment and good maintenance of protected areas preserves an asset for the future and therefore protected areas form an important part of the natural capital estimates.

We have valued protected areas at the opportunity cost of preservation—that is, the costs of demarcating these regions as protected areas are the foregone benefits from converting them to pasture or agricultural land. The willingness to pay to preserve specific natural regions varies considerably, and there is no comprehensive data set on this. Limiting the value of protected areas to the opportunity cost of preservation probably captures the minimum value, and not the complete value, of protected areas.

Area protected (IUCN categories I-V) is valued at the lower of per hectare returns to pasture land and cropland. This is then capitalized over an infinite time horizon, using a 4 percent discount rate.

*Data sources*. Data on protected areas, IUCN categories I-V for 1994 are from the World Resources database 1996-97.

### Sub-soil Assets

Sub-soil assets—metals, minerals, oil, coal, and gas—form a large share of natural capital in oil-rich countries such as Saudi Arabia, Norway, and Mexico and mineral-rich countries such as South Africa. In the absence of competitive markets for stocks of sub-soil assets, our approach to valuing these assets is to calculate present values of the economic profits on extraction (net operating surplus less a "normal" return on produced assets) over the life of the resource deposit.

Calculating the value of subsoil assets requires some strong assumptions. Assuming a constant stream of resource rents, the value of the stock of sub-soil assets, $V(0)$, is calculated based on the following expression:

$$V(0) = \pi_0 q_0 \cdot \left(1 + \frac{1}{r}\right)\left(1 - \frac{1}{(1+r)^{T_0}}\right) \quad . \qquad (1)$$

Here $\pi_0$ is the total rent per unit of resource, $q_0$ is the production of the exhaustible resource smoothed over a 5 year period, $r$ is the discount rate, and $T_0$ the time to exhaustion. Expression (1) is just the present value of a constant stream of total resource rents over a finite time horizon.

The unit total resource rent ($\pi_0$) is the same as that used in the genuine savings estimates of chapter 2 of *Expanding the Measure of Wealth* (World Bank 1997b). It is calculated as the difference between the international price and the average cost of extraction for the year 1994 as detailed in Appendix B. The production of sub-soil assets is smoothed over a 5 year time period to eliminate sudden fluctuations. In most cases it is smoothed over 1990-94, but for some countries data were not available for these years and an average for the most recent five year period was used. Again, a discount rate of 4 percent is employed.

Optimal extraction of a subsoil resource requires the Hotelling rule to hold: unit scarcity rents (price minus *marginal* cost of extraction) must rise at a percentage rate equal to the discount rate. By adding one more assumption, an isoelastic extraction cost function with increasing marginal extraction costs, it is possible to define the path that the percentage change in unit total resource rents ($\pi$) must follow:

$$\frac{\dot{\pi}}{\pi} = \frac{r}{\varepsilon} \cdot \frac{p - \varepsilon c / q}{p - c / q} \text{ for } c(q) = aq^{\varepsilon}, \varepsilon > 1.$$

Denoting this growth rate of total rents as $\gamma$, it is easy to see that this rate varies over time as the ratio of scarcity rent ($p$ - $c/q$) to total rent ($p$ - $c/q$) varies. However, under an optimal extraction program we know that these two rent measures will be equal at the point of exhaustion, and so a further simplifying assumption is made: $\gamma$ is assumed to be constant and equal to its average value over the extraction program, so that,

$$\gamma = \frac{1}{2}\left( \frac{r}{\varepsilon} + \frac{r}{\varepsilon} \cdot \frac{p - \varepsilon c / q}{p - c / q} \right). \qquad (2)$$

In calculating expression (2) we assume that the elasticity of the extraction cost function equals 1.15[3]. The assumption of constant resource rents over the extraction program implies that the quantity extracted, $q$, must fall at the same percentage rate $\gamma$ as unit total rents are rising. Time to exhaustion $T_0$ is therefore calculated by solving the following equation:

$$\sum_{i=0}^{T_0 - 1} \frac{q_0}{(1+\gamma)^i} = S \quad . \qquad (3)$$

Here $S$ is the stock of proven recoverable reserves as reported in *World Resources* (World Resources Institute 1993). This is a conservative measure of resource extent—more elaborate estimates of subsoil assets could include probable and possible reserves, but these would have to be adjusted to reflect the probability of the resources being available in these quantities and the likely extraction costs associated with them.

In some cases the margin between price and average production costs is very thin, yielding a negative unit scarcity rent for the chosen value of the elasticity of the extraction cost function. For these cases we assume scarcity rents are equal to half of total rents and calculate the appropriate value for from expression (2). In short hand:

$p - \varepsilon c/q = 0.5 * (p - c/q)$
$\Rightarrow \quad \varepsilon = q/c * (p - \pi/2)$
and $\gamma = 3/4 * (r/\varepsilon)$

In countries with large stocks of subsoil resources we find that the assumed constant rate of decline in the quantity extracted yields no solution to expression (3). This is equivalent to saying that the resource stock will not be exhausted in finite time. Therefore in countries where $T_0$ tends to infinity we use the following equation to estimate the present value of the resource stock:

$$V(0) = \pi_0 q_0 \cdot (1 + 1/r).$$

Where we have no data on reserves we assume the time to exhaustion $T_0$ is 20 years. In our estimates countries that are not extracting their reserves are assumed to have a stock value of zero.

A comparison of this valuation methodology (based on the assumption of rising scarcity rents and a constant revenue stream) with others reveals that these estimates are greater than those from a simple present value approach (implicit in the method of El Serafy 1989) and lower than the values from the net price approach (as employed in Repetto and others 1989). Unlike these alternative methods, our 'constant revenue' approach is consistent with optimal resource extraction and the currently observed flat long term trend in prices of sub-soil assets.

*Data sources for metals and minerals*.
Production data on the following metals and minerals — Bauxite, Copper, Iron Ore, Lead, Nickel, Phosphate Rock, Tin, and Zinc — are from BESD's METMIN database. Estimates of metals and minerals reserves (1990) are from the World Resources Database 1992-93. For greater detail on the methodology used to estimate resource rents see Appendix B.

*Data sources for crude oil, soft and hard coal, natural gas*. Production data are from BESD's UN Energy Statistics database. Estimates of proved recoverable oil, coal, and natural gas reserves are for 1993 and are taken from the World Resources Database 1992-93. For greater detail on the methodology used to estimate rents see Appendix B.

## The Unfinished Agenda for Natural Capital

A prominent element for future consideration is the explicit valuation of water resources. At present the value of water as an input in agricultural production (the predominant utilization of water in most countries) enters implicitly via the value of agricultural cropland (see above). It should be possible to value industrial and household uses of water by estimating economic values, based on willingness to pay, for different uses. However, finding consistent international data sets with sufficient country coverage is problematic. Moreover, there are significant conceptual issues associated with trying to assign a stock value to what is inherently a flow resource.

Valuing fish resources is another clear gap in our estimates of natural wealth. However, both conceptual and practical issues stand in the way. While the ownership of many inland fisheries is fairly unambiguous, this is not the case for pelagic marine species. An overriding issue is the fact that resource rents appear to have been driven to zero in many fisheries, a clear indication of the mismanagement of these resources.

## Endnotes

1. The difference between output measured at world prices and production costs is, strictly speaking, the total economic rent. The scarcity or 'Hotelling' rent is measured as price minus marginal cost—see the discussion of subsoil assets below.
2. BESD is the World Bank's Economic and Social Database that draws upon consolidated data sources of other international institutions such as the Food Agriculture Organization, and International Energy Agency.
3. Vincent (1996) estimates this value for oil extraction in Malaysia.

# 3 Produced Assets

Produced assets (or physical capital) have been the focus of national economic planning for years. Physical capital was thought to be the bottleneck to development hence warranting high rates of capital accumulation and a great emphasis on the optimum rate of accumulation. While no doubt an important factor of production, physical capital is not necessarily the limiting factor and we increasingly find that natural capital is taking on this role. For instance, in the fisheries sector it is the availability of fish and not fishing boats that is the problem. When we look across different regions, the estimates show that the percentage share of physical capital in total wealth does not vary very much, ranging from a high of 30 percent in Pacific OECD countries to a low of 15 percent in East Asia and Central America. However, the variation in human resources is far greater.

The effective use of physical capital itself is dependent upon human capital. If there is under-investment in human capital the rate at which additional physical capital can be productively utilized will be limited.

The estimates of produced assets include buildings and structures, machinery and equipment, and urban land (as a natural asset whose value is closely related to the value of produced assets), and are based on physical capital stock estimates taken from Nehru and Dhareshwar (1993). Their database of physical capital stock is created by a perpetual inventory method from investment rates, assumed asset lives and an initial assumption about the capital stock (based on an assumed initial capital-output ratio). The estimates of physical capital stock for 1990 are in constant 1987 local currency. These have been converted to 1990 US dollars using 1987 exchange rates and the US GDP deflator. The 1990 estimates are then extrapolated to 1994 by adding gross domestic investment in the current year to the previous year's stock and subtracting depreciation. The depreciation series until 1990 have been derived from the same physical capital stock database and then extrapolated to 1994 assuming that for a given country the proportion of depreciation in GNP is the same as the average for the period 1980-90.

To account for the fact that not all components of a country's physical capital stock are tradable, these are separated out as follows. The non-tradable components, namely structures and urban land, are valued using purchasing power parity (PPP) exchange rates while tradable components are valued at nominal exchange rates.

Structures = $s$ * produced assets * (PPP/nominal exchange rate)

Machinery and equipment = (1-$s$) * produced assets

Urban land = $s$ * produced assets * (PPP/nominal exchange rate) * $u$

where, $s$ (share of structures in total produced assets) and $u$ (ratio of the value of urban land to the value of structures) are assumed to be 72 percent and 33 percent respectively.

*Data sources*. Physical capital stock estimates for 1990 were provided by the Development Data Division of the International Economics Department of the World Bank. The GDP deflator is taken from BESD's International Financial Statistics database. Data on gross domestic investment in current US dollars are from BESD's World Bank National Accounts database. Values for $s$ and $u$ are based on detailed national balance sheet information for the Canadian economy (Statistics Canada, 1985). On average these balance sheet accounts show structures accounting for roughly 72 percent of total produced assets, while urban land in turn is 33 percent of structures. While this introduces a likely bias, Canada being a land-rich country, the Canadian balance sheet accounts are among the most detailed in the world. PPP exchange rates are from the Development Data Division of the International Economics Department of the World Bank.

# 4 Human Resources

Estimating the asset value of the return to human resources is the most difficult and contentious aspect of the wealth estimates. We use the term ‘human resources’ as distinct from ‘human capital’ because the latter is generally considered to be the return to education. Aiming to be more inclusive, the wealth estimates place a value on the returns to education, raw labor, and ‘social capital’ (the value that is added by institutions and other social structures—for a more comprehensive treatment of the concept of social capital the reader is referred to chapter 6 of *Expanding the Measure of Wealth* (World Bank 1997b)).

While ‘development’ was at one time synonymous with accumulation of produced assets, recent thinking has emphasized the importance of human resources in the development process. Evidence suggests that expenditures on education, training, and health contribute to development outcomes. Moreover, such expenditures yield a sustained return in the future. Improvement in the quality of the human factor of production is at least as important as investment in physical capital.

We have used a residual approach, similar to pioneering efforts in Norway (Central Bureau of Statistics of Norway, 1992), in estimating human resources. The calculation proceeds in three stages: (i) returns to natural resources are stripped out of NNP; (ii) the present value of non-resource NNP is taken over the mean remaining years of productive life of the population; and (iii) the value of produced assets is subtracted from this present value of non-resource NNP — the residual is defined to be the value of human resources.

These calculations can be represented by the following equation system:

R = Present value (agricultural wages + non-agricultural GNP - sub-soil rents - depreciation)

$K_p$ = stock value of structures, and machinery and equipment

Human Resources = (R - $K_p$ - urban land) * (PPP/nominal exchange rate)

The share of wages in agricultural value added is calculated to be 45 percent, based on information on crop budgets from agricultural sector reports (World Bank, 1992). Data on agricultural and non-agricultural shares of GDP and GNP are from *World Development Indicators* (World Bank, 1996). Because ‘agricultural GDP’ in these data includes forestry and fishing, the only resource rents remaining to be subtracted from GNP are those for subsoil assets.

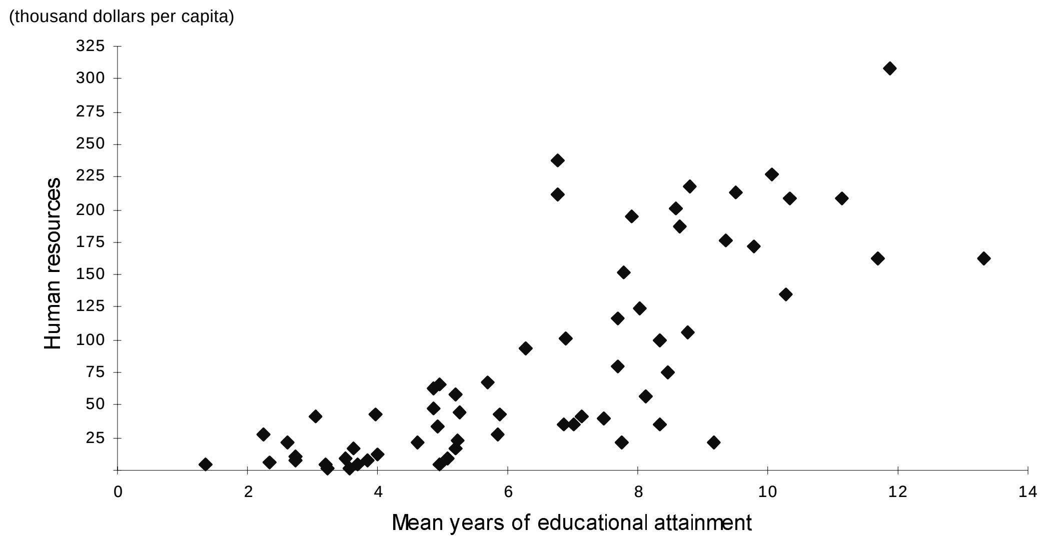
For purposes of taking the present value, remaining years of productive life are calculated as: age 65 or life expectancy at age 1 (whichever is lower) *minus* mean (average) age of the population. Mean age is calculated using the detailed age distribution of the population. The lower of age 65 or the life expectancy at age 1 is taken on the assumption that beyond 65 individuals are no longer working and producing. For example, in India life expectancy at age 1 is 61 years and the average age of the population is 27 years, yielding remaining years of productive activity of 34 years. In Sweden life expectancy at age 1 is 78 and the mean age of the population is 40. Using an upper bound value of 65 to reflect productive life rather than life expectancy, yields a time horizon of 25 years. Note that we take life expectancy at age 1 and not at birth because in many developing countries the highest risk of death is in the first year.

Recall that the non-tradable portions of produced assets—buildings and structures—were valued at purchasing power parity (PPP) rather than nominal exchange rates. Human resources are similarly valued at PPP exchange rates, in an effort to reflect the consumption possibilities presented by the returns to human resources.

The wealth calculations begin with net *national* product (GNP minus depreciation of produced assets) because the question of ownership is important in wealth accounting. The residual approach to valuing human resources is biased to an extent, however, because some of the net flows of wages and property income from abroad in national product should properly be attributed to produced assets. For countries where there is a net outflow of wages and property income to abroad, therefore, the value of produced assets is overstated and the value of human resources is understated in the wealth calculations.

Because the residual approach to valuing human resources stacks so many assumptions on top of one another, it is important to corroborate the resulting valuations. Human capital is undoubtedly the largest component of the value of human resources. If the residual approach makes sense, therefore, the resulting values for human resources should correlate well with independent measures of the quantities of human capital in different countries. To test this, Figure 3 plots mean years of education per capita in a sample of countries on the x-axis against the estimated value of human resources per capita on the y-axis.

**Figure 3**
**Human resources and years of education**




*Source*: Authors' estimates.

# 5 Caveats

While the foregoing description has been careful to highlight many of the intricacies and controversial aspects of the wealth estimation methodology, it is worth re-emphasizing the key points and adding some new caveats. As noted in the Preface, the divergences between best practice and the methods actually applied in estimation are dictated by inadequacies in the data.

The first point to note is that, while *arbitrary* assumptions have been kept to a minimum, there are still a few 'expert judgements' that were used. Non-cereal croplands are assumed to have 80% of the average value of land under cereals. Ten percent of forested land is assumed to be accessible to provide non-timber forest benefits. For subsoil resources, either the elasticity of the cost function was assumed to be 1.15, or scarcity rents were assumed to be half of total rents. Where the data show production of subsoil resources but no corresponding reserve estimates could be found, the reserve to production ratio was assumed to be 20 years. The latter two assumptions in particular are fairly innocuous—the assumed proportionality of scarcity to total rents only applies when rental margins are particularly thin, and missing reserves data only occurred for very minor producers of resources.

The lacunae, notably water and fishery resources, have already been highlighted. For countries with extremely large forest resources there is another type of missing element. Because timber harvest occurs only where there is infrastructure to support it, and not over the whole extent of the forest, our methods value only the economic margin of the forest. Moreover, as documented above, only 10% of the forested area is assumed to provide non-timber forest benefits. As a result, the largest forested countries (Brazil, Indonesia, Malaysia and Canada are the obvious examples) have some portion of their forest resource valued at zero. To the extent that we are valuing commercial resources in this exercise, this is not a problem. But sequestering carbon, harboring biodiversity and regulating flow in watersheds all have economic value as well, and to that extent the wealth of these countries is underestimated by our methodology.

Cases of under-valuation of natural resources are most obvious for protected areas. While the opportunity cost approach applied is probably quite adequate for the most remote protected areas, the more accessible areas are certainly undervalued. Willingness to pay to visit the most popular natural parks, even in developing countries, is substantial and is not captured by our methodology.

The estimates of total wealth are pessimistic to the extent that existing under- and unemployment of production factors is extrapolated into the future. Where capable human resources have been idled by bad policies, therefore, their potential value is not reflected in the wealth estimates. This is an inherent byproduct of 'pulling apart' existing

GNP figures as the basis for calculating total wealth.

The use of purchasing power parities (PPP) to value both non-traded assets (buildings and structures) and human resources is at one level simply following the logic of international economic comparisons, by valuing relatively non-mobile production factors at local prices. However, the resulting mixing of exchange-rate based and PPP-based valuations is not particularly satisfying from a theoretical point of view. That point being granted, the alternative of using only exchange-rate based valuations gives results that violate our intuitions: the countries with the most overvalued exchange rates and inflated price levels end up appearing to be the richest nations on Earth.

As the foregoing indicates, there are reasons to believe that we have undervalued nature and natural resources in the methods applied. Many of the limitations highlighted disappear when truly local data are available. Working at the country level to overcome these limitations seems a better way forward than by introducing more arbitrary assumptions and extrapolating from extremely shaky foundations in order to arrive at larger numbers for natural, and national, wealth.

# 6 Conclusions and Policy Implications

The process by which nations combine and employ their assets to generate well-being is a complex one. Unquestionably, human resources and natural capital are major contributors to this process. The wealth estimates provide many noteworthy findings and policy messages.

First, agricultural crop and pasture land are a very important component of natural capital in all income groups, with a relative share of 50 percent or more. The implication for policy making is clearly the overriding importance of judicious management of land resources. Unsustainable cultivation practices could imperil the agricultural production system itself and its supporting ecosystems, effectively curtailing opportunities for future generations. This is particularly true of low income countries where the relative share of agricultural cropland and pasture land is as high as 84 percent of total wealth.

Second, human resources — the return to education, raw labor, and to social capital — dominate the portfolio overall. This yields an optimistic message for policy-making. A nation's wealth lies predominantly in its people and the amalgam of individual and institutional relationships that we have termed 'social capital'. Building people's capabilities through education and health can enhance a nation's human resources and help in realizing a sustainable path to development. We need to learn more about building social capital; at a minimum we must be careful not to destroy it through poor policies.

Third, for countries rich in sub-soil assets the importance of investing, rather than consuming, returns from extraction of oil, minerals, coal, gas and other exhaustible resources needs to be stressed.

In conclusion, our analysis suggests the need for a more holistic approach to development planning, an approach that places due emphasis on all the different components of wealth. While investments in and maintenance of infrastructure are important, this is equally the case for agricultural land or people. Economies have available to them an initial endowment of natural resources, raw labor and social capital. This initial endowment together with investments in produced assets and human capital form the foundation of the development process. The sustainability of this process relies crucially on sound management.

# *Appendix A*

# Estimates of National Wealth: Total and Components

**Table A1. Estimates of national wealth: Total and components**

| Wealth rank | Country | Total wealth | Human resources | Natural capital | Produced assets | Human resources | Natural capital | Produced assets |
|---|---|---|---|---|---|---|---|---|
| | | *dollars per capita* | | | | *percent share of total wealth* | | |
| 24 | ArgenWina | 147,000 | 124,000 | 10,000 | 13,000 | 84 | 7 | 9 |
| 6 | AusWralia | 297,000 | 195,000 | 35,000 | 67,000 | 66 | 12 | 23 |
| 10 | AusWria | 286,000 | 201,000 | 8,000 | 78,000 | 70 | 3 | 27 |
| 70 | Bangladesh | 22,000 | 17,000 | 3,000 | 2,000 | 76 | 14 | 10 |
| 9 | Belgium | 287,000 | 225,000 | 2,000 | 62,000 | 79 | 1 | 21 |
| 67 | Benin | 25,000 | 19,000 | 2,000 | 4,000 | 76 | 8 | 16 |
| 57 | Bolivia | 36,000 | 21,000 | 6,000 | 9,000 | 59 | 17 | 25 |
| 35 | BoWswana | 89,000 | 68,000 | 6,000 | 15,000 | 76 | 6 | 17 |
| 35 | Brazil | 89,000 | 66,000 | 7,000 | 16,000 | 74 | 8 | 18 |
| 84 | BurNina Faso | 14,000 | 10,000 | 2,000 | 2,000 | 68 | 17 | 15 |
| 88 | Burundi | 10,000 | 6,000 | 2,000 | 2,000 | 58 | 20 | 22 |
| 60 | Cameroon | 32,000 | 17,000 | 7,000 | 8,000 | 53 | 21 | 26 |
| 3 | Canada | 331,000 | 227,000 | 37,000 | 67,000 | 69 | 11 | 20 |
| 71 | CAR* | 21,000 | 12,000 | 6,000 | 3,000 | 55 | 30 | 15 |
| 81 | Chad | 15,000 | 8,000 | 6,000 | 2,000 | 51 | 37 | 12 |
| 23 | Chile | 148,000 | 116,000 | 14,000 | 17,000 | 79 | 10 | 12 |
| 56 | China | 37,000 | 28,000 | 3,000 | 6,000 | 77 | 7 | 16 |
| 37 | ColomEia | 85,000 | 67,000 | 6,000 | 12,000 | 79 | 7 | 14 |
| 62 | Congo | 31,000 | 17,000 | 4,000 | 9,000 | 55 | 14 | 30 |
| 34 | CosWa Rica | 96,000 | 73,000 | 8,000 | 15,000 | 77 | 8 | 15 |
| 71 | CoWe d'Ivoire | 21,000 | 11,000 | 4,000 | 6,000 | 52 | 18 | 30 |
| 8 | DenmarN | 295,000 | 213,000 | 11,000 | 71,000 | 72 | 4 | 24 |
| 42 | Dom. RepuElic | 68,000 | 51,000 | 8,000 | 8,000 | 76 | 12 | 12 |
| 43 | Ecuador | 67,000 | 41,000 | 11,000 | 14,000 | 61 | 17 | 22 |
| 49 | EgypW | 52,000 | 33,000 | 2,000 | 16,000 | 64 | 5 | 31 |
| 54 | El Salvador | 40,000 | 35,000 | 1,000 | 5,000 | 86 | 3 | 12 |
| 17 | Finland | 241,000 | 135,000 | 16,000 | 90,000 | 56 | 7 | 37 |
| 6 | France | 297,000 | 218,000 | 8,000 | 70,000 | 74 | 3 | 24 |
| 74 | GamEia, The | 18,000 | 13,000 | 2,000 | 3,000 | 73 | 12 | 15 |
| 11 | Germany | 281,000 | 211,000 | 4,000 | 66,000 | 75 | 1 | 23 |
| 65 | Ghana | 27,000 | 21,000 | 2,000 | 4,000 | 78 | 7 | 15 |
| 25 | Greece | 142,000 | 106,000 | 5,000 | 31,000 | 75 | 4 | 22 |
| 49 | GuaWemala | 52,000 | 43,000 | 2,000 | 7,000 | 84 | 3 | 13 |
| 74 | Guinea-Bissau | 18,000 | 8,000 | 8,000 | 2,000 | 43 | 44 | 13 |
| 85 | HaiWi | 13,000 | 9,000 | 1,000 | 3,000 | 70 | 7 | 23 |
| 58 | Honduras | 34,000 | 23,000 | 3,000 | 8,000 | 66 | 10 | 24 |

**Table A1. Estimates of national wealth: Total and components** *(continued)*

| Wealth rank | Country | Total wealth | Human resources | Natural capital | Produced assets | Human resources | Natural capital | Produced assets |
|---|---|---|---|---|---|---|---|---|
| | | *dollars per capita* | | | | *percent share of total wealth* | | |
| 73 | India | 20,000 | 12,000 | 4,000 | 4,000 | 58 | 20 | 22 |
| 46 | Indonesia | 60,000 | 45,000 | 7,000 | 8,000 | 75 | 12 | 13 |
| 18 | Ireland | 219,000 | 162,000 | 18,000 | 39,000 | 74 | 8 | 18 |
| 16 | Italy | 257,000 | 187,000 | 3,000 | 67,000 | 73 | 1 | 26 |
| 52 | Jamaica | 45,000 | 22,000 | 3,000 | 20,000 | 49 | 7 | 44 |
| 4 | Japan | 304,000 | 208,000 | 2,000 | 94,000 | 68 | 1 | 31 |
| 44 | Jordan | 64,000 | 48,000 | 1,000 | 16,000 | 74 | 2 | 24 |
| 74 | Kenya | 18,000 | 9,000 | 2,000 | 7,000 | 51 | 9 | 39 |
| 22 | Korea, Republic Of | 168,000 | 138,000 | 3,000 | 27,000 | 82 | 2 | 16 |
| 64 | Lesotho | 28,000 | 22,000 | 1,000 | 5,000 | 80 | 3 | 17 |
| 79 | Madagascar | 16,000 | 8,000 | 7,000 | 1,000 | 49 | 42 | 9 |
| 91 | Malawi | 7,000 | 5,000 | 1,000 | 2,000 | 61 | 12 | 28 |
| 26 | Malaysia | 137,000 | 101,000 | 12,000 | 25,000 | 73 | 9 | 18 |
| 86 | Mali | 12,000 | 5,000 | 5,000 | 2,000 | 43 | 41 | 15 |
| 68 | Mauritania | 24,000 | 14,000 | 5,000 | 4,000 | 60 | 22 | 18 |
| 32 | Mauritius | 99,000 | 80,000 | 1,000 | 18,000 | 80 | 1 | 18 |
| 30 | Mexico | 113,000 | 87,000 | 7,000 | 19,000 | 77 | 6 | 17 |
| 48 | Morocco | 54,000 | 42,000 | 2,000 | 9,000 | 78 | 4 | 18 |
| 89 | Mozambique | 9,000 | 5,000 | 1,000 | 3,000 | 53 | 13 | 35 |
| 41 | Namibia | 71,000 | 54,000 | 7,000 | 10,000 | 76 | 10 | 14 |
| 79 | Nepal | 16,000 | 11,000 | 3,000 | 2,000 | 68 | 18 | 15 |
| 13 | Netherlands | 272,000 | 196,000 | 4,000 | 71,000 | 72 | 2 | 26 |
| 12 | New Zealand | 277,000 | 162,000 | 51,000 | 63,000 | 59 | 18 | 23 |
| 65 | Nicaragua | 27,000 | 19,000 | 4,000 | 4,000 | 71 | 14 | 15 |
| 69 | Niger | 23,000 | 8,000 | 12,000 | 2,000 | 36 | 54 | 10 |
| 5 | Norway | 302,000 | 172,000 | 30,000 | 99,000 | 57 | 10 | 33 |
| 58 | Pakistan | 34,000 | 28,000 | 2,000 | 4,000 | 83 | 6 | 12 |
| 33 | Panama | 97,000 | 75,000 | 6,000 | 16,000 | 77 | 6 | 17 |
| 55 | Papua New Guinea | 39,000 | 25,000 | 7,000 | 6,000 | 64 | 19 | 17 |
| 45 | Paraguay | 61,000 | 43,000 | 7,000 | 10,000 | 72 | 12 | 17 |
| 47 | Peru | 59,000 | 40,000 | 5,000 | 15,000 | 67 | 8 | 25 |
| 53 | Philippines | 44,000 | 35,000 | 3,000 | 7,000 | 79 | 6 | 15 |
| 20 | Portugal | 175,000 | 137,000 | 4,000 | 34,000 | 78 | 2 | 19 |
| 92 | Rwanda | 5,000 | 2,000 | 1,000 | 2,000 | 39 | 22 | 39 |
| 21 | Saudi Arabia | 171,000 | 69,000 | 72,000 | 30,000 | 40 | 42 | 18 |
| 60 | Senegal | 32,000 | 22,000 | 5,000 | 4,000 | 70 | 17 | 13 |
| 87 | Sierra Leone | 11,000 | 6,000 | 3,000 | 2,000 | 58 | 28 | 14 |
| 38 | South Africa | 83,000 | 62,000 | 4,000 | 17,000 | 75 | 5 | 20 |
| 19 | Spain | 201,000 | 152,000 | 6,000 | 43,000 | 76 | 3 | 22 |
| 51 | Sri Lanka | 47,000 | 36,000 | 3,000 | 8,000 | 76 | 7 | 17 |
| 15 | Sweden | 260,000 | 176,000 | 15,000 | 70,000 | 68 | 6 | 27 |
| 2 | Switzerland | 352,000 | 237,000 | 3,000 | 111,000 | 68 | 1 | 32 |
| 90 | Tanzania | 8,000 | 2,000 | 2,000 | 4,000 | 21 | 27 | 52 |
| 29 | Thailand | 117,000 | 93,000 | 8,000 | 17,000 | 79 | 6 | 14 |
| 74 | Togo | 18,000 | 11,000 | 3,000 | 4,000 | 64 | 15 | 21 |
| 27 | Trinidad & Tobago | 128,000 | 77,000 | 12,000 | 39,000 | 60 | 9 | 30 |

**Table A1. Estimates of national wealth: Total and components** *(continued)*

| Wealth rank | Country | Total wealth | Human resources | Natural capital | Produced assets | Human resources | Natural capital | Produced assets |
|---|---|---|---|---|---|---|---|---|
| | | *dollars per capita* | | | | *percent share of total wealth* | | |
| 39 | Tunisia | 81,000 | 58,000 | 6,000 | 17,000 | 71 | 8 | 21 |
| 40 | Turkey | 79,000 | 63,000 | 4,000 | 11,000 | 81 | 5 | 14 |
| 81 | Uganda | 15,000 | 8,000 | 2,000 | 6,000 | 49 | 15 | 37 |
| 14 | United Kingdom | 266,000 | 209,000 | 5,000 | 51,000 | 79 | 2 | 19 |
| 1 | United States | 401,000 | 308,000 | 17,000 | 76,000 | 77 | 4 | 19 |
| 28 | Uruguay | 127,000 | 99,000 | 15,000 | 13,000 | 78 | 12 | 11 |
| 31 | Venezuela | 110,000 | 57,000 | 21,000 | 32,000 | 52 | 19 | 29 |
| 74 | Vietnam | 18,000 | 12,000 | 4,000 | 2,000 | 68 | 22 | 10 |
| 81 | Zambia | 15,000 | 5,000 | 5,000 | 4,000 | 38 | 38 | 25 |
| 63 | Zimbabwe | 30,000 | 17,000 | 3,000 | 10,000 | 59 | 8 | 33 |

*Note:*
Estimates for Eastern Europe and countries of the former Soviet Union are not included because of uncertainty about data quality. Similar problems exist for Nigeria and Algeria.
* CAR is Central African Republic

**Table A2. Natural capital estimates, 1994, total and components**

| | Natural capital | Pasture land | Crop land | Timber resources | Non-timber forest resources | Protected areas | Subsoil assets |
|---|---|---|---|---|---|---|---|
| | | | | *$ per capita (percent of total)* | | | |
| Argentina | 9,850 | 3,270 | 5,200 | 280 | 480 | 100 | 520 |
| | | (33) | (53) | (3) | (5) | (1) | (5) |
| Australia | 35,340 | 7,270 | 14,150 | 1,030 | 2,150 | 1,650 | 9,080 |
| | | (21) | (40) | (3) | (6) | (5) | (26) |
| Austria | 7,570 | 1,480 | 2,410 | 1,720 | 150 | 1,580 | 230 |
| | | (20) | (32) | (23) | (2) | (21) | (3) |
| Bangladesh | 3,110 | 60 | 3,000 | 0 | 0 | 10 | 20 |
| | | (2) | (97) | (0) | (0) | (0) | (1) |
| Belgium | 1,750 | 470 | 1,110 | 100 | 20 | 50 | 10 |
| | | (27) | (63) | (6) | (1) | (3) | (1) |
| Benin | 1,930 | 70 | 1,030 | 440 | 250 | 120 | 10 |
| | | (4) | (54) | (23) | (13) | (6) | (1) |
| Bolivia | 6,060 | 690 | 2,520 | 160 | 1,820 | 240 | 640 |
| | | (11) | (42) | (3) | (30) | (4) | (11) |
| Botswana | 5,620 | 1,180 | 260 | 420 | 2,700 | 490 | 570 |
| | | (21) | (5) | (8) | (48) | (9) | (10) |
| Brazil | 7,060 | 1,070 | 2,740 | 1,200 | 960 | 190 | 910 |
| | | (15) | (39) | (17) | (14) | (3) | (13) |
| Burkina Faso | 2,400 | 210 | 1,870 | 100 | 120 | 90 | .. |
| | | (9) | (78) | (4) | (5) | (4) | .. |
| Burundi | 1,940 | 90 | 1,820 | 10 | 10 | 10 | 0 |
| | | (5) | (94) | (0) | (1) | (0) | (0) |
| Cameroon | 6,800 | 270 | 4,840 | 650 | 430 | 270 | 340 |
| | | (4) | (71) | (10) | (6) | (4) | (5) |
| Canada | 36,590 | 2,310 | 9,910 | 6,230 | 4,560 | 6,830 | 6,750 |
| | | (6) | (27) | (17) | (12) | (19) | (18) |
| Central African Republic | 6,470 | 440 | 2,010 | 520 | 2,600 | 900 | .. |
| | | (7) | (31) | (8) | (40) | (14) | .. |
| Chad | 5,550 | 470 | 4,110 | 340 | 500 | 120 | .. |
| | | (9) | (74) | (6) | (9) | (2) | .. |
| Chile | 14,440 | 1,100 | 4,910 | 1,560 | 180 | 1,110 | 5,580 |
| | | (8) | (34) | (11) | (1) | (8) | (39) |
| China | 2,670 | 100 | 2,010 | 90 | 30 | 10 | 420 |
| | | (4) | (75) | (3) | (1) | (1) | (16) |
| Colombia | 6,100 | 1,160 | 2,490 | 390 | 410 | 270 | 1,380 |
| | | (19) | (41) | (6) | (7) | (4) | (23) |
| Congo | 4,420 | 20 | 200 | 1,040 | 2,200 | 0 | 960 |
| | | (1) | (4) | (24) | (50) | (0) | (22) |
| Costa Rica | 7,860 | 1,480 | 5,690 | 180 | 100 | 410 | .. |
| | | (19) | (72) | (2) | (1) | (5) | .. |

**Table A2. Natural capital estimates, 1994, total and components** *(continued)*

| | Natural capital | Pasture land | Crop land | Timber resources | Non-timber forest resources | Protected areas | Subsoil assets |
|---|---|---|---|---|---|---|---|
| | | *$ per capita (percent of total)* | | | | | |
| Cote d'Ivoire | 3,790 | 80 | 2,870 | 570 | 210 | 10 | 30 |
| | | (2) | (76) | (15) | (6) | (0) | (1) |
| Denmark | 11,070 | 270 | 7,210 | 380 | 30 | 1,930 | 1,260 |
| | | (2) | (65) | (3) | (0) | (17) | (11) |
| Dominican Republic | 8,380 | 560 | 7,310 | 90 | 30 | 280 | 100 |
| | | (7) | (87) | (1) | (0) | (3) | (1) |
| Ecuador | 11,330 | 1,160 | 4,880 | 440 | 270 | 2,610 | 1,970 |
| | | (10) | (43) | (4) | (2) | (23) | (17) |
| Egypt | 2,360 | 420 | 1,540 | 0 | 0 | 70 | 330 |
| | | (18) | (65) | (0) | (0) | (3) | (14) |
| El Salvador | 1,150 | 250 | 890 | 10 | 10 | 0 | .. |
| | | (22) | (77) | (1) | (0) | (0) | .. |
| Finland | 15,930 | 90 | 4,670 | 6,970 | 1,660 | 2,420 | 110 |
| | | (1) | (29) | (44) | (10) | (15) | (1) |
| France | 8,120 | 1,350 | 5,210 | 700 | 90 | 700 | 60 |
| | | (17) | (64) | (9) | (1) | (9) | (1) |
| Gambia, The | 2,120 | 190 | 1,850 | 10 | 20 | 50 | .. |
| | | (9) | (87) | (1) | (1) | (2) | .. |
| Germany | 4,150 | 430 | 2,100 | 490 | 30 | 750 | 350 |
| | | (10) | (51) | (12) | (1) | (18) | (8) |
| Ghana | 1,920 | 60 | 1,510 | 190 | 150 | 10 | 10 |
| | | (3) | (78) | (10) | (8) | (1) | (1) |
| Greece | 5,210 | 1,490 | 3,080 | 170 | 90 | 60 | 320 |
| | | (29) | (59) | (3) | (2) | (1) | (6) |
| Guatemala | 1,720 | 300 | 930 | 170 | 110 | 150 | 60 |
| | | (18) | (54) | (10) | (6) | (9) | (4) |
| Guinea-Bissau | 7,970 | 200 | 7,440 | 330 | .. | .. | .. |
| | | (2) | (93) | (4) | .. | .. | .. |
| Haiti | 840 | 110 | 720 | 0 | 0 | 0 | 0 |
| | | (13) | (86) | (0) | (0) | (0) | (0) |
| Honduras | 3,380 | 410 | 1,610 | 820 | 210 | 230 | 100 |
| | | (12) | (47) | (24) | (6) | (7) | (3) |
| India | 3,910 | 90 | 3,440 | 50 | 20 | 110 | 210 |
| | | (2) | (88) | (1) | (0) | (3) | (5) |
| Indonesia | 7,480 | 60 | 5,780 | 720 | 150 | 100 | 670 |
| | | (1) | (77) | (10) | (2) | (1) | (9) |
| Ireland | 17,780 | 11,770 | 4,810 | 510 | 40 | 120 | 530 |
| | | (66) | (27) | (3) | (0) | (1) | (3) |
| Italy | 3,400 | 430 | 2,430 | 110 | 40 | 230 | 160 |
| | | (13) | (71) | (3) | (1) | (7) | (5) |

**Table A2. Natural capital estimates, 1994, total and components** *(continued)*

| | Natural capital | Pasture land | Crop land | Timber resources | Non-timber forest resources | Protected areas | Subsoil assets |
|---|---|---|---|---|---|---|---|
| | | *$ per capita (percent of total)* | | | | | |
| Jamaica | 3,080 | 110 | 280 | 50 | 10 | 0 | 2,630 |
| | | (4) | (9) | (2) | (0) | (0) | (85) |
| Japan | 2,300 | 120 | 1,360 | 220 | 70 | 490 | 40 |
| | | (5) | (59) | (10) | (3) | (21) | (2) |
| Jordan | 1,020 | 260 | 360 | 0 | 0 | 100 | 300 |
| | | (26) | (35) | (0) | (0) | (9) | (29) |
| Kenya | 1,730 | 740 | 840 | 10 | 10 | 120 | 0 |
| | | (43) | (49) | (1) | (1) | (7) | (0) |
| Korea, Republic Of | 2,940 | 50 | 2,290 | 120 | 40 | 390 | 50 |
| | | (2) | (78) | (4) | (1) | (13) | (2) |
| Lesotho | 940 | 340 | 600 | 0 | 0 | 0 | .. |
| | | (36) | (64) | (0) | (0) | (0) | .. |
| Madagascar | 6,510 | 500 | 5,350 | 310 | 330 | 20 | .. |
| | | (8) | (82) | (5) | (5) | (0) | .. |
| Malawi | 880 | 60 | 600 | 90 | 80 | 40 | .. |
| | | (7) | (68) | (11) | (10) | (4) | .. |
| Malaysia | 11,820 | 20 | 6,190 | 1,310 | 230 | 840 | 3,230 |
| | | (0) | (52) | (11) | (2) | (7) | (27) |
| Mali | 4,840 | 530 | 3,620 | 270 | 340 | 70 | .. |
| | | (11) | (75) | (6) | (7) | (1) | .. |
| Mauritania | 5,100 | 1,060 | 2,270 | 0 | 70 | 50 | 1,640 |
| | | (21) | (45) | (0) | (1) | (1) | (32) |
| Mauritius | 1,240 | 20 | 1,180 | 10 | 10 | 10 | .. |
| | | (2) | (95) | (1) | (1) | (1) | .. |
| Mexico | 6,630 | 810 | 1,520 | 200 | 140 | 110 | 3,860 |
| | | (12) | (23) | (3) | (2) | (2) | (58) |
| Morocco | 2,210 | 480 | 1,480 | 60 | 100 | 10 | 80 |
| | | (22) | (67) | (3) | (5) | (0) | (4) |
| Mozambique | 1,130 | 90 | 360 | 400 | 280 | 0 | 0 |
| | | (8) | (32) | (35) | (25) | (0) | (0) |
| Namibia | 7,180 | 1,400 | 1,230 | .. | 2,310 | 380 | 1,860 |
| | | (20) | (17) | .. | (32) | (5) | (26) |
| Nepal | 2,900 | 380 | 2,150 | 90 | 60 | 210 | 10 |
| | | (13) | (74) | (3) | (2) | (7) | (0) |
| Netherlands | 4,140 | 560 | 1,020 | 80 | 10 | 230 | 2,250 |
| | | (14) | (25) | (2) | (0) | (6) | (54) |
| New Zealand | 51,090 | 22,130 | 12,600 | 4,340 | 770 | 9,950 | 1,300 |
| | | (43) | (25) | (9) | (1) | (19) | (3) |

## Table A2. Natural capital estimates, 1994, total and components *(continued)*

| | Natural capital | Pasture land | Crop land | Timber resources | Non-timber forest resources | Protected areas | Subsoil assets |
|---|---|---|---|---|---|---|---|
| | | *$ per capita (percent of total)* | | | | | |
| Nicaragua | 3,690 | 540 | 2,110 | 580 | 360 | 90 | 0 |
| | | (15) | (57) | (16) | (10) | (2) | (0) |
| Niger | 12,340 | 310 | 11,600 | 50 | 80 | 300 | 0 |
| | | (3) | (94) | (0) | (1) | (2) | (0) |
| Norway | 30,220 | 110 | 1,680 | 2,520 | 700 | 5,110 | 20,090 |
| | | (0) | (6) | (8) | (2) | (17) | (66) |
| Pakistan | 1,880 | 140 | 1,480 | 0 | 0 | 100 | 150 |
| | | (7) | (79) | (0) | (0) | (6) | (8) |
| Panama | 6,300 | 930 | 3,960 | 270 | 310 | 830 | .. |
| | | (15) | (63) | (4) | (5) | (13) | .. |
| Papua New Guinea | 7,490 | 10 | 560 | 1,550 | 2,370 | 20 | 2,980 |
| | | (0) | (7) | (21) | (32) | (0) | (40) |
| Paraguay | 6,990 | 1,490 | 3,590 | 1,150 | 650 | 100 | .. |
| | | (21) | (51) | (16) | (9) | (1) | .. |
| Peru | 4,630 | 350 | 2,770 | 220 | 800 | 50 | 430 |
| | | (8) | (60) | (5) | (17) | (1) | (9) |
| Philippines | 2,730 | 50 | 2,400 | 140 | 30 | 30 | 80 |
| | | (2) | (88) | (5) | (1) | (1) | (3) |
| Portugal | 4,040 | 280 | 2,140 | 1,140 | 110 | 190 | 190 |
| | | (7) | (53) | (28) | (3) | (5) | (5) |
| Rwanda | 1,110 | 100 | 930 | 0 | 10 | 70 | 0 |
| | | (9) | (84) | (0) | (1) | (6) | (0) |
| Saudi Arabia | 71,880 | 330 | 3,600 | .. | 20 | 20 | 67,910 |
| | | (0) | (5) | .. | (0) | (0) | (94) |
| Senegal | 5,300 | 290 | 4,180 | 310 | 250 | 210 | 60 |
| | | (6) | (79) | (6) | (5) | (4) | (1) |
| Sierra Leone | 3,040 | 60 | 2,570 | 180 | 110 | 0 | 120 |
| | | (2) | (84) | (6) | (4) | (0) | (4) |
| South Africa | 4,200 | 880 | 1,790 | 90 | 30 | 80 | 1,340 |
| | | (21) | (43) | (2) | (1) | (2) | (32) |
| Spain | 5,740 | 940 | 3,690 | 430 | 140 | 390 | 140 |
| | | (16) | (64) | (8) | (3) | (7) | (3) |
| Sri Lanka | 3,480 | 140 | 2,970 | 90 | 30 | 250 | 0 |
| | | (4) | (85) | (3) | (1) | (7) | (0) |
| Sweden | 14,590 | 440 | 4,390 | 5,890 | 1,160 | 2,300 | 410 |
| | | (3) | (30) | (40) | (8) | (16) | (3) |

**Table A2. Natural capital estimates, 1994, total and components** *(continued)*

| | Natural capital | Pasture land | Crop land | Timber resources | Non-timber forest resources | Protected areas | Subsoil assets |
|---|---|---|---|---|---|---|---|
| | | *$ per capita (percent of total)* | | | | | |
| Switzerland | 3,050 | 950 | 820 | 600 | 50 | 620 | 0 |
| | | (31) | (27) | (20) | (2) | (20) | (0) |
| Tanzania | 2,200 | 310 | 920 | 530 | 310 | 120 | 0 |
| | | (14) | (42) | (24) | (14) | (6) | (0) |
| Thailand | 7,600 | 110 | 6,270 | 110 | 50 | 980 | 80 |
| | | (1) | (83) | (1) | (1) | (13) | (1) |
| Togo | 2,670 | 50 | 2,250 | 0 | 90 | 170 | 120 |
| | | (2) | (84) | (0) | (3) | (6) | (4) |
| Trinidad And Tobago | 12,110 | 70 | 2,540 | 40 | 40 | 100 | 9,310 |
| | | (1) | (21) | (0) | (0) | (1) | (77) |
| Tunisia | 6,370 | 550 | 5,070 | 10 | 20 | 10 | 710 |
| | | (9) | (80) | (0) | (0) | (0) | (11) |
| Turkey | 3,940 | 490 | 2,950 | 170 | 90 | 40 | 200 |
| | | (12) | (75) | (4) | (2) | (1) | (5) |
| Uganda | 2,230 | 120 | 1,680 | 210 | 90 | 130 | 0 |
| | | (5) | (75) | (9) | (4) | (6) | (0) |
| United Kingdom | 4,940 | 1,540 | 1,820 | 110 | 20 | 710 | 730 |
| | | (31) | (37) | (2) | (0) | (14) | (15) |
| United States | 16,500 | 2,570 | 7,210 | 1,730 | 410 | 1,400 | 3,180 |
| | | (16) | (44) | (10) | (2) | (8) | (19) |
| Uruguay | 14,810 | 6,040 | 8,530 | 160 | 60 | 10 | .. |
| | | (41) | (58) | (1) | (0) | (0) | .. |
| Venezuela | 20,820 | 860 | 3,130 | 40 | 570 | 1,270 | 14,960 |
| | | (4) | (15) | (0) | (3) | (6) | (72) |
| Viet Nam | 3,990 | 70 | 3,490 | 70 | 30 | 260 | 70 |
| | | (2) | (87) | (2) | (1) | (7) | (2) |
| Zambia | 5,490 | 160 | 3,330 | 660 | 940 | 30 | 360 |
| | | (3) | (61) | (12) | (17) | (1) | (7) |
| Zimbabwe | 2,520 | 450 | 990 | 400 | 220 | 280 | 170 |
| | | (18) | (39) | (16) | (9) | (11) | (7) |

*Notes:*

0 means less than 10 dollars per capita.
(0) means less than 1%.

.. means no data.

Estimates for Eastern Europe and countries of the former Soviet Union are not included because of uncertainty about data quality.

# *Appendix B*
# Estimating Rental Values for Timber and Sub-Soil Assets

What follows is a detailed account of methodology for calculating the rental value of sub-soil assets (oil, natural gas, metals and minerals, and coal) and timber. It documents all assumptions made, operations performed, and bibliographical sources utilized. These rental values were used in the wealth estimates and in the genuine savings estimates (Chapter 2, World Bank, 1997).

### Rent from Oil

As in the case of all other nonrenewable resources, rent was estimated as:

*Rent* = ( *Production Volume*) ( *International Market Price - Average Unit Production Cost* )

In other words, rent equals volume produced by a particular country in a particular year times the unit rent for that country in that year. Production volume data for 1970-1992 were taken from the Bank Economic and Social Database, or BESD, an internal on-line database of the World Bank Group ("UN-Energy Statistics" database, "CR Crude Petroleum" indicator, "production volume" transaction). Production volume data for 1993-1994 were obtained from West (1996). International price data came from UNCTAD (1989; 1993; 1996). Average production cost data were taken from from, by country: Ukraine (IEA, 1996a); Russia (IEA, 1994a; IEA 1995a; IEA 1995b; Sagers, 1995); Venezuela and Mexico (IEA 1995b; IADB 1981); Libya, Malaysia, Nigeria, USA, Gabon, Egypt, North Sea/Great Britain (IEA, 1995b); Norway (Adelman, 1987); Ecuador, Peru, Trinidad & Tobago, Argentina, Bolivia, Brazil, Chile and Colombia (IADB, 1981); Iran, Iraq, Saudi Arabia, Kuwait, United Arab Emirates, Oman (IEA, 1995b; Jenkins, 1989); Indonesia (IEA, 1995b; Repetto et al., 1989); Canada (IEA, 1995b; Smith, 1992); and Europe (EIA, 1995).

Because production cost data were frequently available for a single year only, one of two methods was used to obtain year-by-year estimates of production cost: 1) If data were available for a single year only, it was assumed that production costs remained constant in real terms. Production costs for each year in current dollars were obtained from the single data point and a times series GDP deflator (obtained from BESD, "WB-IEC Data" Database, "NY.GDP.MKTP.XU.E" indicator). 2) if data for two different years were available with an interval of no data, estimates for the intervening years were calculated as a linear interpolation between the two points. Those countries for which no production cost data were available were assigned a surrogate production cost from another country. The choice of surrogate country was made on the basis of 1) geographic proximity and 2) similarity between the ratios of offshore active drilling rigs to total active drilling rigs between the two countries. The numbers of active offshore and total drilling rigs were obtained from Meyer et al. (1994), and selected statistics on onshore vs. offshore production came from Whitehead (1983). Table B1 shows the resulting assignments of surrogate countries.

Additional, general references on accounting for the depletion of oil reserves include Dienes et al. (1994) and Stauffer (1984; 1986). Useful conversion factors came from the first page of Blackwell Energy Research (1996).

## Rent from Natural Gas

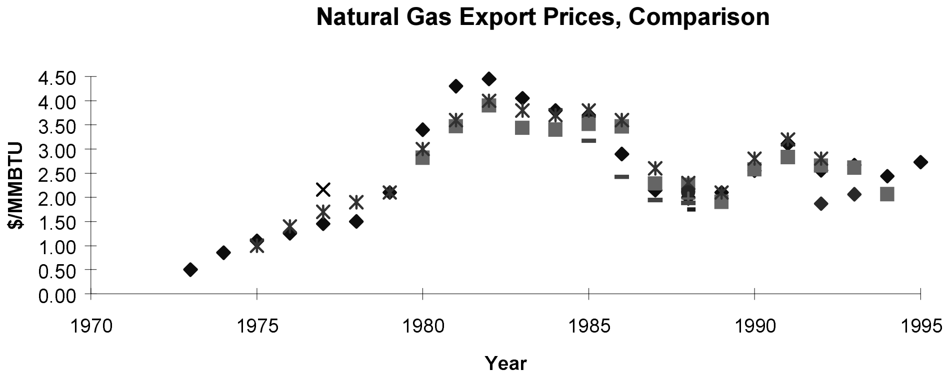
The most difficult aspect of the natural gas calculation was that natural gas, unlike crude oil, has no single *de facto* world price. Since the object of correcting saving rates is to measure opportunities foregone by current extraction, some estimate of this opportunity cost was required. Data on natural gas export prices from various countries were collected, and found to collectively follow a very similar historical trend. Figure B1 presents annual average export price data from the United States and Europe (Streifel, 1996; Meyer, 1994); the Netherlands, Norway (IEA, 1996b); Canada (Tiratsoo, 1979, McKeough, 1989, Government of Canada, 1996); and export from Algeria to Italy, France, Belgium, and Spain (McKeough, 1989). Due to the similar historical pattern in all of these prices, a world price for natural gas was estimated as the average of all available prices in this set in any given year.

Since this data set only extended back in time to 1973, some method of estimating the price on the period 1970-72 was required. Data were available for the US internal price for natural gas from 1970-1995 (Streifel, 1996), and when the international price on the period 1973-1995 was compared to the US internal price on the same period, the two were found to follow each other so closely that the international price could be estimated as a linear function of the US internal price with $R^2 = 0.90218$. This same linear function was then used to estimate the international price for 1970-1972 based on the US internal price for the same period. This function was:

**Table B1. "Surrogate" countries used to estimate oil production costs**

| Country | Surrogate | Country | Surrogate | Country | Surrogate | Country | Surrogate | Country | Surrogate |
|---|---|---|---|---|---|---|---|---|---|
| AGO | GAB | COG | GAB | HUN | EU | NOR | NOR | TKM | RUS |
| ALB | EU | COL | VEN | IDN | IDN | NZL | USA | TTO | TTO |
| ARE | ARE | CSK | EU | IND | IDN | OMN | OMN | TUN | LBY |
| ARG | ARG | CUB | TTO | IRN | IRN | PAK | IRN | TUR | IRN |
| AUS | USA | CZE | EU | IRQ | IRQ | PER | PER | UKR | UKR |
| AUT | EU | DDR | EU | ISR | SAU | PHL | IDN | USA | USA |
| AZE | RUS | DEU | EU | ITA | EU | POL | UKR | UZB | RUS |
| BEN | GAB | DFA | EU | JOR | SAU | PNG | IDN | VEN | VEN |
| BGD | MYS | DNK | NOR | JPN | EU | QAT | OMN | VNM | IDN |
| BGR | UKR | DZA | LBY | KAZ | RUS | ROM | UKR | YAR | OMN |
| BHR | SAU | ECU | ECU | KGZ | RUS | RUS | RUS | YEM | OMN |
| BLR | UKR | EGY | EGY | KWT | KWT | SAU | SAU | YMD | OMN |
| BOL | BOL | ESP | EU | LBY | LBY | SUN | RUS | YSR | EU |
| BRA | VEN | FRA | EU | LTU | RUS | SUR | VEN | YUG | EU |
| BRB | TTO | GAB | GAB | MAR | LBY | SVK | EU | ZAR | GAB |
| BRN | GAB | GBR | GBR | MEX | MEX | SVN | EU | | |
| CAN | CAN | GEO | RUS | MMR | IDN | SWE | NOR | | |
| CHL | ARG | GHA | NGA | MNG | RUS | SWK | MYS | | |
| CHN | RUS | GRC | EU | MYS | MYS | SYR | SAU | | |
| CIV | NGA | GTM | MEX | NGA | NGA | THA | IDN | | |
| CMR | NGA | HRV | EU | NLD | EU | TJK | RUS | | |

**Figure B1**
**A comparison of several natural gas export prices from around the world**




*International price* = (1.2436) (*US internal price*) + 0.53245, in $/MMBTU.

Production volumes for 1970-1992 were extracted from BESD ("UN Energy Statistics" database, "NG Natural Gas" indicator, "Production Volume" transaction). Production volumes for 1993-94 were taken from British Petroleum (1995). Average production cost estimates were obtained from, by country: Turkmenistan, Iran, Iraq, Qatar, Saudi Arabia, United Arab Emirates, Oman, Nigeria, Algeria, Libya, Venezuela, Trinidad & Tobago, Norway (IEA, 1995c); Tunisia, Cameroon, Morocco, Tanzania (Julius and Mashayekhi, 1990; Mashayekhi 1983); Egypt, Thailand, Bangladesh (Julius and Mashayekhi, 1990; Khan, 1986; Mashayekhi 1983); India, Pakistan (Mashayekhi, 1983); USA (Meyer, 1994; Adelman, 1991); South Asia region (Khan 1986); Europe region (Cornot-Gandolphe, 1994); Russia (IEA, 1995c; Liefert, 1988)—roubles were converted using data from The Economist Intelligence Unit (1989; 1991; 1992).

Single-year data for production costs were converted to a 1970-1994 time series exactly as described above for the calculation of oil rents. Those countries for which no production cost data were available were, as in the case of oil, assigned a "surrogate" country whose production cost would be used instead. These assignments, as before, were made on the basis of 1) geographic proximity and 2) similarity in the ratios of offshore gas production to total gas production between the two countries. These ratios were obtained from British Petroleum (1995). Table B2 shows the resulting assignments of surrogate countries. Note that "WD" denotes a world average production cost.

General references on the expanding international market for natural gas and the future of natural gas in developing countries include IEA (1996c), Conant (1986), and Homer (1993). Useful factors for converting between British Thermal Units, joules, cubic meters, cubic feet, tons of oil equivalent, and barrels of oil can be found in Valais (1977), Mashayekhi (1983), Varzi (1983) and Blackwell Energy Research (1996).

## Rent from Metals and Minerals

Metal production was measured as the metal content of ore production. With the exception of gold and silver, production volumes for 1970-1990 were extracted from BESD ("WB-Metals & Minerals" database; "BAUXITE_GW," "COPPER_OREMC," "IRONORE_MC," "LEAD_OREMC," "NICKEL_OREMC," "PHOSPHAT_ROCK," "TIN_OREMC," "ZINC_OREMC" indicators: "PROD_VOL" statistic). Production volumes for 1991-1994 came from World Bureau of Metal Statistics (1995), with the exception of iron ore (United Nations, 1995) and phosphate rock (FAO, 1995a). In the occasional case that no data for 1994 were available, a linear extrapolation of approximately the past four years was performed. For gold and silver, production volumes for 1970-1975 came from United Nations (1977a), for 1975-1984 came from United Nations (1986), for 1987-1991 came from United Nations (1995), and for 1992-1994 came from World Bureau of Metal Statistics (1995).

With the exception of Bauxite, international price data for all metals were obtained from UNCTAD (1989, 1993; 1996). In each case, the two or three prices presented (often a New York price and a London price) were averaged to arrive at an approximate international price. Bauxite prices for 1970-1991 were taken from World Bank (1993b). Since the approximate price ranges presented in Serjeantson (1996) show that bauxite price-at-mine did not vary significantly during the period 1991-1995, it was assumed that the World Bank (1993b) price for bauxite in 1991 held constant on 1992-1994. Since iron ore production volumes are reported as mass of metal content and iron ore prices are given by UNCTAD as mass of *ore*, an adjustment to the iron price was necessary. Assuming that iron metal is the only valuable component of iron ore, the iron ore prices were divided by their fractional metal content (reported by UNCTAD along with the price) to arrive at an approximate price per mass of metal content (e.g. Brazilian iron ore in 1980 was being exported at $28.12 per metric ton of ore, with

**Table B2. "Surrogate" countries used to estimate natural gas production costs**

| Country | Surrogate | Country | Surrogate | Country | Surrogate | Country | Surrogate |
|---|---|---|---|---|---|---|---|
| AFG | BGD | COL | VEN | IRL | EU | QAT | QAT |
| AGO | WD | CSK | EU | IRN | IRN | ROM | EU |
| ALB | EU | CUB | TTO | IRQ | IRQ | RUS | RUS |
| ARE | ARE | CZE | EU | ISR | IRQ | RWA | NGA |
| ARG | WD | DDR | EU | ITA | EU | SAU | SAU |
| AUS | THA | DEU | EU | JPN | EU | SUN | RUS |
| AUT | EU | DFA | EU | KAZ | RUS | SVK | EU |
| AZE | WD | DNK | EU | KGZ | RUS | SWK | IND |
| BEL | EU | DZA | DZA | KWT | IRQ | SYR | IRQ |
| BGD | BGD | ECU | WD | LBY | LBY | THA | THA |
| BGR | EU | EGY | EGY | MAR | MAR | TJK | RUS |
| BHR | SAU | ESP | EU | MEX | VEN | TKM | RUS |
| BLR | RUS | FRA | EU | MMR | BGD | TTO | TTO |
| BOL | WD | GAB | WD | MYS | IND | TUN | DZA |
| BRA | VEN | GBR | NOR | NGA | NGA | TUR | EU |
| BRB | TTO | GEO | RUS | NLD | EU | UKR | RUS |
| BRN | THA | GRC | EU | NOR | NOR | USA | USA |
| CAN | USA | GTM | VEN | NZL | WD | UZB | RUS |
| CHE | EU | HRV | EU | OMN | OMN | VEN | VEN |
| CHL | WD | HUN | EU | PAK | PAK | VNM | BGD |
| CHN | WD | IDN | PAK | PER | WD | YSR | EU |
| COG | NGA | IND | IND | POL | EU | YUG | EU |

an Fe content of 64.5%. The price used for the calculation was thus $28.12 / 0.645 = $43.60 per metric ton Fe).

Production costs for metals and minerals are proprietary information and very difficult to obtain for research purposes. In addition to bibliographical sources, the project received volunteer expert assistance from the US Geological Survey in Denver, Colorado (Bleiwas and Wagner, 1996). Sources for metal production costs, together with the dates of data presented therein, were: **Bauxite** 1984-1992 (World Bank, 1994), 1989 (Bleiwas, 1996) and 1985 (Bureau of Mines 1987); **Copper** 1975-1992 (World Bank, 1994), 1989 (World Bank, 1989), 1988 (Bleiwas, 1996), and 1985 (Bureau of Mines, 1987); **Gold** 1992 (World Bank, 1994), 1991-1992 (Bleiwas, 1996), and 1985 (Bureau of Mines, 1987); **Iron Ore** 1985 (Bureau of Mines, 1987); **Lead** 1988-1991 (World Bank, 1994), 1990 (Bleiwas, 1996), and 1985 (Bureau of Mines, 1987); **Nickel** 1990-1992 (World Bank, 1994) and 1981 (Bleiwas, 1996); **Phosphate Rock** 1985 (Bureau of Mines, 1987); **Silver** 1985 (Bureau of Mines, 1987); **Tin** 1989 (World Bank, 1991) and 1985 (Bureau of Mines, 1987); and **Zinc** 1988-1991 (World Bank, 1994), 1990 (Bleiwas, 1996), and 1985 (Bureau of Mines, 1987). In all cases, the most recent cost estimate for each country was used. A 1970-1994 time series of costs was constructed from each single-year figure, as for oil, by assuming constant real costs and adjusting with a GDP deflator. Cost data in most cases were the sum of mining costs, milling costs, smelting/refining/transportation costs, capital recovery (depreciation), and 15% Discounted Cash Flow Rate of Return, minus byproduct credit. In rare cases where data were presented in less detail (e.g. presented simply as a single, aggregate figure for "production cost"), that number, for lack of any other, was used.

In some cases, for certain country-years, the calculated result for unit rent (unit market price minus average unit production cost) was negative. Since the assumption of constant real production costs is rather strong, it is most likely that such numbers are errors indicative of the rough estimation employed. This problem was evident in cases of large price drops, such as the price of tin, which fell by approximately two thirds from 1980 to the early 1990's. Such a drop would probably force greater efficiency of production and lower unit production costs, but in the absence of complete production cost time-series data, a constant real production cost was assumed. The remedy selected was, for each country with "negative" unit rents, to calculate an average rental rate (the difference between market price and production cost, as a fraction of market price) for those years in which unit rent, as initially calculated, was positive. It was then assumed that the same rate would hold approximately constant in those years where initially calculated unit rents were negative, and for those years the unit rent was set equal to the average positive rental rate multiplied by the market price. Significant numbers of such corrections were necessary for nickel in 1992-1994, phosphate rock 1983-1994, tin 1970-71 and 1986-1994, and zinc 1970-71, 1985-87, and 1991-1994. In the absence of more precise production cost data, such approximations appear to be the most attractive alternative.

Similarly to the technique used for oil and gas rents, countries for which no production cost data were available were assigned a "surrogate" country's production cost. These assignments were made strictly on the basis of geographic proximity. A world average production cost was assigned to countries whose geography was dissimilar to all those for which cost data were available.

### Rent from Hard Coal

Excepting countries of the Former Soviet Union, production volumes for 1970-1992 were extracted from BESD ("UN Energy Statistics" database, "CL Hard Coal" indicator, "Production Volume" transaction). Production volumes for 1993-1994 were taken from National Mining Association (1996), except Former Yugoslavia which came from Blackwell Energy Research (1996). Data for the Former Soviet Union came from IEA (1994b) for the period 1985-1991, the same BESD database cited above for 1992, and Blackwell Energy Research (1996) for 1993-1994.

In the case of coal, the determination of price and production cost is complicated by 1) the fact that coal exists in different grades of different value and 2) the lack of a single, uniform world price even for the same grade of coal. The hard coal production volumes reported in BESD, which made up the vast majority of the volume figures used, were standardized at 29.3076 Terajoules per thousand metric tons (i.e., 0.6995 tons of oil equivalent per ton). Since hard coal includes both steam and coking coal, and a range of heat values within each type, the BESD production volumes are clearly adjusted to represent an average heat value and quality of the coal to which is referred. BESD indicates the heat value that was the norm of standardization, but not the quality. Steam coal, however, makes up more than three-quarters of global hard coal production (IEA, 1995d), and it was thus assumed that the BESD figures represented an aggregate of all steam and coking coal standardized to an average "coal equivalent" of *steam* coal with a heat value of 0.6995 toe/ton. It was assumed that all collected hard coal production volumes uniformly represented this type of coal.

Further difficulties arise because, although the hard coal production volumes are presented as an aggregate of steam coal and coking coal, prices and production costs are reported separately for steam coal and coking coal. It was necessary to establish a weighted average price and production cost for all hard coal, based on parallel figures for steam and coking coal. There would clearly be many ways to carry out this estimation; the methods below were chosen for their expediency and plausible conclusions.

The price estimation was carried out as follows. Data on export prices between 1985 and 1991 for steam coal from three Australian sites and one Canadian site were compared to export prices of coking coal from three Australian sites and two Canadian sites (IEA, 1995d). All were made commensurable by converting to US dollars (IMF, 1996). The heat values of steam coal from each site were obtained (IEA, 1995d) as were the heat values of average coking coal from each country (IEA, 1995e). This allowed the calculation of a price in US dollars per unit heat value (US$/1000 kcal) for each site in each year. For each of the two countries in each year, this value was averaged across all sites to obtain a country-average price per unit heat value for steam coal and a corresponding price for coking coal—in each year. For each country in each year, a ratio of the average price per unit heat value for steam coal to the average price per unit heat value for coking coal was determined. When averaged across all years (1985-1991) this ratio was 0.7677 for Australia, and 0.7756 for Canada—essentially identical. This means that after adjusting for the effects of heat value, the value of steam coal is approximately 77% of the value of coking coal, presumably because of its lower quality (ash content, sulfur content, utility in industry). This ratio was assumed to hold for all hard coal.

Next, data for free-on-board prices of coking coal were collected for exports from the United States, Former Soviet Union, Australia, Canada, China, South Africa, Indonesia, Poland, and New Zealand (IEA, 1995d) on the period 1970-1994 (for any given year, prices for between two and nine of the above countries were available). Again, all data were converted to US dollars (IMF, 1996). For each year, a world average export price was calculated as the average of available prices for that year, weighted by national average coking coal heat value (IEA, 1995e; IEA 1995f). This allowed the calculation of a complete time series of world average coking coal export price from 1970-1994. An identical process, utilizing the same bibliographical sources, was followed to obtain a time series for world average steam coal export price, the differences being that 1) Colombia was included in the country set and New Zealand was not, and 2) the final time series stretched only from 1980-1994 due to unavailability of steam coal export prices before 1980. To complete the steam coal series, prices on the period 1970-1979 were approximated from the coking coal world prices for the same period by 1) scaling the coking coal price down to reflect the difference between the average heat value of coking and steam coal in the countries included in the sample and 2) scaling down by an additional factor of 0.77 to reflect the difference in quality. Finally, after the steam coal prices for all years were scaled down to be commensurable in terms of dollars per kilocalorie with the coking coal prices, the *world average hard coal export price* in each year from 1970-1994 was approximated as the average of the export prices for steam and coking coal, with steam coal given a weight of three quarters and coking coal a weight of one quarter to reflect the aforementioned relative production of the two types at the global level. Note that in averaging steam coal and coking coal prices, the steam coal prices were adjusted to be commensurable in terms of heat value with the coking coal prices, meaning that the final hard coal price series is in terms of a mixed steam/coking coal with a standard heat content equal to the average heat content of coking coal in the nine countries included in the coking coal average price (i.e. 0.686583 tons of oil equivalent per ton). In order to make this final price commensurable with the standardized heat value in which hard coal production volumes were reported (0.699465 toe/ton), it was scaled up slightly by a factor of 0.699465/0.686583.

Since production costs were also separately reported for steam coal and coking coal, a similar method of estimating a single, aggregated hard coal production cost was required. Production costs for steam coal were obtained from, by country: Australia, USA, Canada, Colombia, South Africa, Indonesia (IEA, 1995d); Poland (IEA, 1995g); Czech Republic (IEA, 1994c); China (Doyle, 1987) [converted to US$ using IMF (1996)]; Russia (Tretyakova and Heinemeier, 1986) [converted to US$ using The Economist Intelligence Unit (1991; 1992)]; Mexico (World Bank, 1989); and India (Bhattacharya, 1995). Production costs for coking coal came from, by country: Australia, USA, Canada, South Africa (IEA 1995d); Poland (IEA, 1995c and 1995d); and India (Bhattacharya, 1995). Since coking coal data were scarce, only the steam coal data were utilized and an aggregate hard coal production cost was constructed by assuming production cost varies with the heat content and quality of coal just as the market price does. That is, it was assumed that after adjusting for heat value, the ratio of steam coal production cost to coking coal production cost is 0.77. Since the production cost figures came with no information on heat content, it was assumed that the heat content of steam coal for this calculation was 0.5943 toe/ton, the average heat content of the steam coal exports analyzed in the price calculation. To obtain an approximate aggregate steam-and-coking coal production cost for each country, the steam coal production cost was first scaled up to be commensurable in heat content with the production volumes (i.e. multiplied by 0.6995/0.5943) and a weighted average was found between the heat-adjusted steam coal figure and an estimated coking coal production cost, the latter being obtained by dividing the former by 0.77. The weights in this weighted average, as above, were three-quarters for steam coal and one-quarter for coking coal. In shorthand form, the estimated aggregate hard coal production cost for each country was derived from the steam coal production cost by multiplying by the following factor:

$$(0.699465/0.594342)(1+((1/4)((1/0.77)-1))).$$

As in the case of oil, this gave production costs for a single year only, in almost all cases. A time series of production costs from 1970-1994 was generated by assuming constant *real* production costs and adjusting the single-year figure by a GDP deflator. The assumption of constant real production costs is a strong but necessary one, and as in the case of metals & minerals described earlier, it resulted in a few falsely negative unit rents for certain country-years—mostly on the periods 1970-71 and 1993-1994. The same remedy that was applied to metals and minerals was applied again. Each negative unit rent was replaced by an estimated unit rent calculated by multiplying the average rental rate for all years in which calculated unit rent was positive by the market price in the year of the unit rent being replaced. As in the case of metals and minerals, countries for which no production cost data were available were assigned a "surrogate" country's production cost based on geographic proximity; when no such country was available, a world average production cost was used.

## Rent from Brown Coal (Lignite)

In most cases, production volumes for 1970-1992 came from BESD ("UN Energy Statistics" database, "LB Lignite/Brown Coal" indicator, "Production Volume" indicator) and for 1993-1994 came from Blackwell Energy Research (1996). Exceptions included: China 1984-1986 (Blackwell Energy Research, 1996); Albania, Austria, France, Italy, Japan and Myanmar 1993 (National Mining Association, 1995); all Former Soviet Union countries except Russia (IEA, 1994b). In certain cases where no production volume data for 1994 were available, 1994 volume was assumed equal to 1993 volume.

Estimating unit rents for lignite was a daunting task, since no export prices are available (it is only traded internationally in minute quantities), domestic prices are often distorted by subsidies, and production cost data were only available for a single country known to be a particularly heavy subsidizer at the time of the study (Bhattacharya, 1995). An estimation technique was required if lignite was to be included in the study. Again, as above, the following method was chosen for its expediency and plausible conclusions, and has the potential to be improved.

An international price for lignite was estimated as follows. It was assumed that the value of lignite is some affine function of the value of steam coal, and that the determining factors in this relationship are difference in heat value and some coefficient for "quality," which together determine the slope of the function. First, data on current free-on-board prices for exportable steam coal from 11 countries were compiled (*Coal Week International*, 1996). The heat values of each type were scatter-plotted against the f.o.b. value, giving a least-squares affine relationship of

$$\textit{price} = (0.0075)(\textit{heat value}) - 11.737$$

where price is in US$/ton and heat value in kcal/kg. This linear specification gave a higher correlation coefficient than an exponential, quadratic, or higher-order fit. Two different values were then compared: 1) the price obtained from inserting 2693 kcal/kg (the standardized heat content of lignite used for the production volumes in BESD) into the above affine function, i.e. $8.46/ton, and 2) for each country, the price that would result if the price of both brown and steam coal were assumed to be a simple linear function of heat content alone, with no effects from coal quality (average across 38 coal types in 11 countries of $15.16/ton). The comparison was thus between a price extrapolated from an observed downward trend in price as both heat content *and* quality decrease, and an imaginary price ignoring the effects of quality. The ratio of the former to the latter, averaged across the sample, was 0.562305, or approximately 0.56. That is, it was estimated that the value of brown coal would be 56% of the value which its lower heat content alone would imply, demonstrating the effects of higher sulfur content, higher ash content, and decreased utility to industry.

To verify this result, a separate analysis was performed. Statistics Canada provided the project with production volumes and values (internal prices) for Saskatchewan lignite and steam coal from Alberta on the period 1979-1994 (Born, 1996). Since the coal industry of western Canada faces a relatively free market, these prices were assumed to be competitive. Heat values for both types of coal came from IEA (1995e), and the prices were converted to dollars with IMF (1996). The price of steam coal in each year was adjusted, assuming that price varies strictly linearly with heat value, to obtain an imaginary price for brown coal in the absence of quality effects. The ratio of the true price of brown coal to this imaginary price, averaged over 1979-1994, was, strikingly, 0.562108, or approximately 0.56. The fact that this ratio was identical to the ratio derived above in a completely different fashion does not prove the analysis to be correct; however, 0.56 was therefore judged to be a reasonable estimate of a "quality deflator" for lignite. This index was assumed to hold true for all lignite. An identical analysis of Czech internal coal prices (IEA, 1994c) gave a value for this lignite "quality deflator" of 0.85, a figure which was discarded due to clear distortions in the prices presented. The Czech Republic's recent history of central planning makes all internal nominal price data suspect, and in fact it is clear from the source that steam coal was being sold below cost at the time of the study.

Lastly, a production cost for lignite was estimated. As for hard coal, production cost was assumed to vary with coal heat value and quality in the same manner as price. An analysis of lignite production costs identical to the above analysis of prices was performed. Lignite and steam coal production costs in Canada (World Bank, 1979) were compared with heat values (IEA, 1995e) to arrive at a "quality deflator" of 0.653; that is, lignite production costs were approximately 65% of the costs that would be expected from scaling down steam coal production costs solely to reflect the difference in heat value between the two types. In a similar analysis of Australia, hard coking, steam and brown coal production costs (Abelson, 1983), hard coking coal heat value (Abelson, 1983), and steam and brown coal heat value (IEA, 1995e) were compared to arrive at a "quality deflator" for lignite production costs of 0.645, essentially identical to the Canadian value. Note that in this analysis, coking and steam coal production costs were in 1983 Australian dollars and lignite costs were in 1980 US$, necessitating the use of a currency conversion factor (IMF, 1996) and a GDP deflator (from BESD, "WB-IEC Data" Database, "NY.GDP.MKTP.XU.E" indicator). An analysis of Czech coal production costs (IEA, 1994c) (note that production costs in the IEA study are estimates of real costs and therefore do not suffer from the aforementioned distortion of the prices in the same report) showed the "quality deflator" for lignite production cost to be approximately 0.60.

The only other study available that estimated brown coal production costs was for India (Bhattacharya, 1995), where the costs reported were indicated by the study's author to be distorted by overinvestment in the sector during the oil crisis and ineffective monitoring of inefficient, nationalized lignite producers. Based on the above, a figure of 0.65 was assumed to be a valid "quality deflator" for global lignite production costs.

The above assumptions and estimations allowed the calculation of a world price and estimated production costs for lignite. Lignite price was taken to be the world average export price for steam coal (calculated above) scaled down by a factor of 0.2693/0.5943 (the ratio of the BESD lignite standard heat value to the average heat value of steam coals used in the steam coal world price estimation) and scaled down again by a factor of 0.56. Lignite production cost was taken to be steam coal production cost (in each country-year for which those data were available) scaled down by a factor of 0.2693/ 0.5943 and again by a factor of 0.65. A time series for production costs in each country was made as it was for steam coal, and assignments of "surrogate" country production costs were made as for steam coal. In the minor case of two country-years, falsely "negative" unit rents were seen (both in 1970; see the metals & minerals section), and were corrected as described in metals & minerals.

## Timber Rent and Mean Annual Increments

Estimates of mean annual increment per hectare in commercial-quality wood mass ($m^3$/hectare/year), were calculated first by creating a table of "potential productivities" based on a map of the same created from soil, temperature and rainfall data (Mather, 1990). The resulting estimates were reviewed by a senior World Bank expert for substantial correction (Cassells, 1996). Estimates of mean annual increment for most temperate countries came from FAO/UNECE (1992), and for a small number of tropical countries from Kanowski et al. (1992), Lamprecht (1989), and Duvigneaud (1971). Forest areas for 1970, 1980, and 1990 were obtained, for most tropical countries, from the United Nations Food & Agriculture Organization (Singh, 1994), for most temperate countries from FAO (1994), and for Former Soviet Union countries from the International Institute for Applied Systems Analysis in Vienna (Nilsson, 1994). Some additional data were collected from WRI (1995). Nearly all area figures were multiplied by a factor of 0.8 to allow for the fact that roughly a fifth of any given country's forest area is not accessible for extraction due to steep slopes, rivers, etc. (Cassells, 1996). In most cases, forest areas in 1971-1979 and 1981-1989 were estimated by linear interpolation between the above figures and areas in 1991-1994 by extrapolation of the 1980-1990 trend. Where data for 1970 were unavailable, data on the period 1970-1979 were estimated by back-casting based on the 1980-1990 trend. Thus, the product of the mean annual increment per hectare in commercial quality wood, the factor of 0.8, and the forest area was determined for each country in each year from 1970-1994. This number will be called the *increment* for that country-year.

In certain countries, particularly in East Africa, a large portion of roundwood production comes from land which does not have sufficient tree density to be classified as a forest by FAO (Cassells, 1996). Table 6-5 in Millington et al. (1994) indicates that approximately 67% of roundwood production in East Africa comes from "forest" land, as opposed to 94% in Central Africa (Table 6-4 in Millington et al., 1994). The increment figures for certain countries were thus multiplied by a factor of 1/0.67 to reflect non-forestland increment. These countries were Rwanda, Burundi, Uganda, Kenya, Tanzania, Malawi, Haiti, Egypt, and Bangladesh.

Figures on total roundwood production on the period 1970-1992 were extracted from

BESD ("FAO Forestry" database, "RNDWOOD_TOT" forestry code), and figures for 1993-1994 were estimated as a linear extrapolation of the trend on 1988-1992. Figures for coniferous roundwood production were similarly obtained ("RNDWOOD_C" forestry code). These figures were used to calculate the fraction of total roundwood production that was coniferous wood in each country-year. A separate set of total roundwood production volumes and fuelwood production volumes for each country-year on the period 1970-1994 was obtained from WRI (1996) and used to calculate the percentage of total roundwood production that was fuelwood in each country-year (note that the WRI figures for total roundwood production were used for the calculation of this percentage only; the total roundwood figures used in the main calculation were those from BESD). The original BESD figures were modified for Malaysian roundwood production based on data in ITTO (1996). The average ratio between the ITTO figures and the BESD figures during the 1990's was assumed true for the rest of the period as well, and this ratio was used to scale down the BESD figures from 1970-1994.

Next, a shadow price for roundwood was required. This price, in each country, was estimated as a weighted average of three different prices: 1) the world average export price of coniferous logs, 2) an estimated world average price for fuelwood, and 3) a third price, which varied according to the region. In temperate countries, this third price was a world average export price for non-coniferous softwood logs. In tropical countries, this third price was an average tropical hardwood export price of which there were three versions for Asia, Africa, and Latin America. The weights in this average price were by relative proportion of total roundwood that was coniferous, fuelwood, and non-coniferous non-fuelwood. In precise terms, the price was calculated as:

$$P_s = (Q_f)(P_f) + (1\text{-}Q_f)[(Q_c)(P_c)+(1\text{-}Q_c)(P_o)]$$

where $P_s$ = Shadow price of roundwood
$P_f$ = Price of fuelwood
$P_c$ = Price of coniferous roundwood
$P_o$ = Price of "other" wood, depending on region:
if temperate country, then non-coniferous softwood price
if Latin America, then estimated Latin America tropical hardwood price
if Africa, then Africa tropical hardwood price
if Asia, then Asian tropical hardwood price
$Q_f$ = Fuelwood quotient, i.e. percentage of total roundwood production that is fuelwood
$Q_c$ = Coniferous quotient, i.e. percentage of total roundwood production that is coniferous

The technique of obtaining $Q_f$ and $Q_c$ has already been described. $P_c$ was the "coniferous logs average world export unit value" from FAO (1983; 1995b). $P_f$ was estimated as an average value of reported fuelwood prices in 21 developing countries (Barnes, 1992), Kenya (Openshaw and Feinstein, 1989), Costa Rica and Nicaragua (van Buren, 1990), which came to an average and relatively constant price of $25/cubic meter around the end of the late seventies. A time series of fuelwood prices was created by assuming constant real prices and adjusting with a GDP deflator, as was done previously for production costs. The assumption that fuelwood prices do not follow the same trends as timber prices and can be assumed relatively constant is supported by Barnes (1992). As was noted previously, $P_o$ varied depending on the region to which the country in question belonged; there were four different versions, and thus four different prices $P_s$ were applied to total roundwood production depending on the country. For temperate countries, $P_o$ was "non coniferous logs average world export unit value;" for Africa, $P_o$ was "tropical logs average export unit value Africa;" and for tropical Asia, $P_o$ was "tropical logs average export unit value Asia;" all from FAO (1983; 1995b). Since no time series data on Latin American tropical logs were available, an estimate was made: the ratio of average tropical log export unit value in Latin America to the same value for the Asia-Pacific region in 1993 (Table 3-3 in ITTO, 1996) was assumed to hold constant on the entire period 1970-1994. This allowed the Latin American price to be calculated from the Asian price.

Since all FAO prices only extended to 1991, prices for 1992-1994 had to be estimated. A time series for a single type of wood, the price of Okoume hardwood from Cameroon, was available for the entire period 1970-1994 (UNCTAD 1989; 1993; 1996). Each of the four types of primary roundwood price data was estimated as an affine function of the Okoume price based on the period 1970-1991. All five prices were found to follow similar trends on this period; the estimate of coniferous roundwood price as a function of Okoume price during 1970-1991 had an $R^2$ of 0.948, for the non-coniferous softwood price $R^2$ was 0.898, for Africa tropical hardwood price $R^2$ was 0.957, and for Asian tropical hardwood price it was 0.808. Since this set of four functions was a reasonable predictor of the prices of the four types of wood as a function of the Okoume price on 1970-1991, the same functions were used to estimate the prices of the four on the period 1992-1994, again based on the Okoume price for those years.

Rather than collect information on production costs, for the purposes of this study a set of *rental rate* estimates was collected from a group of experts and some previous research. Rental rate is defined as

((*Market Price - Production Cost*)/(*Market Price*)).

A rental rate of roughly 50% for Indonesia was estimated from World Bank data (Carbonnier, 1996; Douglas, 1996). Repetto et al. (1989) used a figure of 55% for Indonesia. A study on the Philippines by delos Angeles et al. (1988) found figures of 42% and 58% on two different sites (average 50%). Further World Bank data were employed to estimate 48% for Thailand (Sadoff, 1996). Based on these figures, an approximate rental rate of 50% was used for East Asia, Southeast Asia, and South Asia.

World Bank data suggest an approximate rental rate of 30% for the West African rainforest (Rietbergen, 1996). A study by Gillis (1988) found the rate in Ghana to be 26%. Based on these figures, a lower rate of 30% was used for all of Africa.

A study by Cottle et al. (1990) demonstrated a rental rate of approximately 55% for a Brazilian forestry operation. Solórzano et al. (1991) provide data on Costa Rican internal prices which show an average rental rate in recent years of 68% when sawmill costs are excluded (probably too high, but effects on the price of processing are difficult to separate since data on unprocessed logs are not presented). Kellenberg (1995) provides data that show an approximate rate of 52% in Ecuador. Based on these results, a rental rate of 55% was assumed for all of Latin America.

Finally, Carbonnier (1996) further estimated a rental rate of 40% for temperate country forestry operations.

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