Monitoring Utilisation of Nonrenewable Natural Resources: A Shift-Share Analysis

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Summary

Economists well understand the need to make rational choices about the costs and benefits accruing to society from the exploitation of stocks of nonrenewable natural resources, although this understanding seems to have rarely guided government policy. In this paper we present a simple, but comprehensive approach to developing indicators of the speed with which nonrenewable natural resources are being depleted that might be used to impress policy makers of the urgency of more appropriate policy. The approach we use combines shift-share analysis with the reserve life index concept. This approach is then applied to some Australian data and the results are discussed. We conclude that Australia needs to develop a resource depletion plan that modifies the interests of private sector mining firms by reference to the interests of future generations.

Key words: nonrenewable resources, shift-share analysis, reserve life index.

INTRODUCTION

In general, natural resources are divided into stocks that are renewable or capable of regenerating, such as fish and forestry, and those that are nonrenewable or depletable, such as fossil fuels and minerals. Although nonrenewable resources are capable of regeneration over very long time periods, from the perspective of human life expectancies, the rate of regeneration is approximately zero. Therefore, present consumption of nonrenewable resources implies that stocks for future consumption are depleted forever. Nevertheless, it is difficult to imagine industrialisation of modern economies without fossil fuels such as oil and gas, or uranium or metals such as aluminium, lead and iron.

In economic terms stocks of natural resources are properly considered as capital assets. Reducing them represents disinvestment. When nonrenewable natural resources are considered, rational choices have to be made with regard to the costs and benefits accruing as a result of their exploitation at different time periods or among different generations. Furthermore, it must be understood that some nonrenewable resources consumption leads to pollution and this can create economic costs through damage to the environment, which is itself composed of natural resources. There are two implications of pollution created by the use of nonrenewable resources. One is that efficient pollution control is impossible when the rate of utilisation of the resources is too high. The other is that economic analysis of the effects of pollution requires intertemporal studies that involve accounting for welfare effects on future generations.

These issues are generally well-understood by economists (Turner, *et al*, 1994; Hanley, 1995), but seem to have too rarely been integrated into decision making at the political level in Australia. In this paper, we present a simple approach to developing indicators of the speed with which nonrenewable resources are being depleted that might be used to impress policy makers of the urgency of more appropriate natural resource utilisation policy. The approach we present is based on shift-share analysis and provides a handy means of monitoring their utilisation.

The paper is structured as follows. In the next section the contribution of the nonrenewable resource sector to the Australian economy is summarised. This is followed by discussion of the methodology we have used to develop our indicators. Essentially the methodology uses shift-share analysis as a basis for defining reserve life indices that are useful in indicating the relative sustainability of present rates of nonrenewable resource depletion. Then, results of the application of this methodology using Australian data are summarised. Finally, some concluding comments are made.

CONTRIBUTION OF NONRENEWABLE RESOURCES TO THE AUSTRALIAN ECONOMY

The pattern of utilisation of nonrenewable resources in Australia provides an indication of their contribution to Australia's economic growth. For instance, in 1992, the mining and basic metal products sector alone contributed over 6% to gross domestic product. Furthermore, as figure 1 below illustrates, Australia's exports are very heavily dependent on natural resources. For instance, merchandise exports of Australia comprised around 50% nonrenewable resources in 1992, which is an increase of approximately 10 percentage points over 1975. Exports of coal and coke alone amounted to 13% of our merchandise exports. During the period between 1975 and 1992 basic metals, metalliferous and other ore exports increased from 19% to 30% of merchandise exports.

[Figure 1 should go about here]

In capitalist economies such as Australia in which export led economic growth is considered as one of the main, if not the main objective, overutilisation of nonrenewable resources in a myopic manner can threaten seriously future economic growth. The obvious reason for this is that the availability of nonrenewable resources is a constraint on growth. In other words, the rate of extraction of nonrenewable resources by profit maximising mining firms in the current time period can impose a burden on the welfare of future generations. Furthermore, because extraction and export of nonrenewable resources is properly considered as disinvestment, there should be a depreciation cost charged in the national accounts.

Protagonists for conservation often assert that economic growth and protection of the natural environment are mutually exclusive objectives. In contrast, protagonists for economic growth typically assert that innovation induced by diminution of any resource, natural or otherwise, will protect societies from catastrophic collapse. Nevertheless, few would argue that national accounting practice in Australia and elsewhere appropriately charges the economy for consumption or degradation (or improvement) of its natural resource endowment. Solow (1992) has argued that the right way in which to calculate the correction to national income is to assume that it is always possible to substitute greater inputs of labour, reproducible capital and renewable natural resources for lesser inputs of nonrenewable natural resources. Thus society must not only decide how much to save and invest, but also how much of its stock of nonrenewable natural resources to consume. Investment in reproducible capital substitutes for consumption of nonrenewable natural resources. Sustainability can then be defined as preserving productive capacity for the future. There is nothing very innovative in this suggestion. It merely transfers John Hicks' famous definition of personal income* into the macroeconomic context. It's about time! Thus sustainability is compatible with the use of nonrenewable natural resources only if society replaces resources consumed with reproducible capital. On the basis of this discussion, it must be admitted that Australia's true rate of economic growth has been lower than published figures indicate, largely because commodity exports are concentrated among a few nonrenewable resources.

Sustainability of the nonrenewable resources sector in Australia is heavily dependent on the structure of domestic tradables production. However, exports of nonrenewable resources themselves will influence that structure. Whenever the value of nonrenewable resource exports rises, either because commodity prices increase or because export volumes increase, there will be upward pressure on the exchange rate. Consequently, there will be a 'Dutch disease' or 'Gregory thesis' effect as other tradable production is squeezed out. This actually happened in the early 1980s when the output shares of manufacturing and agriculture fell relative to mining, although there were factors other than 'Dutch disease' at work (for example, the raising of barriers to agricultural trade, particularly in Europe). If other, nonmining, sectors are not restructured to increase their contributions to exports, depletion of nonrenewable resources will eventually increase beyond sustainable levels as Australia strives to maintain its export income. Hence, there is a clear need to develop a simple way of indicating the relative sustainability of present rates of utilisation of nonrenewable resources.

* 'A person's income is what he can consume during the week and still expect to be as well off at the end of the week as he was at the beginning'.

METHODOLOGY

In order to indicate relative intensity of the depletion of nonrenewable natural resources a simple and reliable comparative indicator is desirable. The reserve life index is one indicator that is very commonly used. In this paper we graft the reserve life index onto a shift-share analysis to give a simple, but comprehensive, overview of nonrenewable resource depletion.

Shift-share analysis

Shift-share analysis is a well-known technique that has been used in a wide range of disciplines such as geography (Hoare, 1986), international trade (Green, 1985; Green and Larsen 1991; Brownie and Dalziel, 1993) and regional economics (Scott 1980; Patterson, 1989). Good descriptions of shift-share analysis may be found in standard textbook outlines of quantitative regional analysis (see for example, Krueckeberg and Silvers, 1974; Dunn, 1980; and Nijkamp, *et al*, 1986). Shift-share analysis provides quick, inexpensive, and useful indications of past performance and helps to identify problems that require attention by policy makers. Although some researchers have attempted to use shift-share analysis for policy making and prediction purposes, it is generally agreed that the technique is not sufficiently robust for such uses (Steven and Moore, 1980; Nijkamp, et al, 1986; and Patterson, 1989). This is mainly because the results are sensitive to factors such as degree of disaggregation and the choice of time interval. Nevertheless, it is a simple technique that summarises the outcomes of complex processes and it has policy relevance if the degree of disaggregation and time period are chosen appropriately.

To the best of our knowledge shift-share analysis has not been used in the area of nonrenewable resource management, but we believe that it can serve a useful purpose. Shift-share analysis separates changes in nonrenewable resource utilisation into proportional (or world), structural and differential changes. Proportional change is defined as the depletion rate for a specific nonrenewable resource that would be recorded if it was depleted at the same rate as world depletion of that resource. Structural change is defined as the additional depletion rate for a specific nonrenewable resource that would be recorded if it was depleted at the rate of depletion of all nonrenewable resources in aggregate in the rest of the world. This rate may be positive or negative. If a country has an actual change over and above the proportional and structural changes it can be concluded that it has depleted its nonrenewable resources at a faster rate than rest of the world. This excess production is measured as a residual and is known as the differential change.

The starting point for this study is 1987 and the end point is 1992. Detailed results are set out in table 1. Data in each column are as follows:

1. Quantity produced in the base year 1987;
2. Actual change in production between 1987 and 1992;
3. Proportional or world change, describing the increase (or decrease) in production that would have been expected if production of that commodity type had grown at the same rate as production of that commodity type in the rest of the world;
4. Structural change describing the additional increase (or decrease) in production of that commodity type if its production had grown at the same rate as the whole nonrenewable resources sector of rest of the world. The additional increase (or decrease) in production represents a structural change in utilisation of the resource; and
5. Differential or residual change, given by the actual change less sum of the proportional change and structural change, describing the change in domestic production that cannot be 'explained'

by the relevant production share held at the beginning of the study period. The sum of the proportional change and structural change is defined as the warranted change.

Reserve life index

The reserve life index (RLI) is commonly used to provide an indication of the intensity of production in relation to available stocks of nonrenewable resources. This is expressed in terms of years remaining. It is computed by dividing the available reserves (or, in some cases the reserve base - see appendix) of a particular resource by the production rate of that resource for a given year. The underlying assumptions in these calculations are that the rate production will continue at current levels and that no new reserves will become available. The RLI provides a snapshot of perceived abundance of a nonrenewable resource at a given time. Changes in the index over time measure whether perceived abundance is increasing or decreasing.

Using the shift-share analysis results, reserve life indices were calculated (see table 2). The actual reserve life index (ARLI) shows the number of years remaining to exhaust the stock of mineral reserves of that category if production is carried out at the current (1992) rate of production. The estimated reserve life index (ERLI) is calculated assuming that Australia will follow a 'warranted' production path based on world trends. As stated above, the warranted production level is found by summing the proportional and structural changes. The ERLI shows the number of years remaining to exhaust the mineral reserves of that category if production is carried out according to world trends. If the value of ARLI is smaller than the value of ERLI, nonrenewable resources are going to be exhausted earlier than anticipated, that is, perceived abundance is decreasing.

Data

As discussed previously, choice of the period selected for the study can have considerable influence on the outcome of the analysis. Therefore, a stable period should be selected to obtain accurate measures in the analysis. During the period between 1987 and 1992 mineral production trends appear to be stable. Based on this observation, 1987 and 1992 were selected as end points. Data used for this study covered a selected range of nonrenewable natural mineral resources. The data were collected from three sources. Most of the Australian and world production data were collected from *World Resources: A Guide to the Global Environment (1994-95)* and *Commodity Statistical Bulletin (1994)* published by the Australian Bureau of Agricultural and Resources Economics. Gaps in world statistics (such as gold, silver, titanium, uranium) were filled using information provided in *Phillip Crowson's Minerals Handbook (1994-95)*. Information on data selected for the study is presented in the appendix. In all cases except crude steel and cadmium, production data are based on mine production.

The following assumptions were made with regard to the study period:

1. Australia followed the 'muddling through scenario' (ABARE 1987) during the study period and will continue to do so. The basic feature of this scenario is that production will continue to be carried out at the current level (ABARE assigned a 0.40 probability to this scenario). Other features are that the world trading system will continue roughly as it has in the recent past, with slow adjustment to exchange rate or other pressures for change; there will be steady growth in world GDP at approximately 3 percent per year; and investment in resource extraction will be positive, but the processing sector will remain weak;
2. No new stocks of nonrenewable resources will become available; and
3. No changes in geological information, technology, or costs of extraction and production will occur.

RESULTS

The results of shift-share analysis are set out in table 1. Actual changes are negative in the cases of manganese, nickel, tin and uranium. Proportional change is negative in all cases except aluminium, coal, copper, gold, gypsum and nickel. Negative proportional change indicates that production in the rest of the world has fallen during this period. Structural change was negative in the case of copper, gold and gypsum. Production of these metals in Australia has fallen below the rate of production for the mineral sector overall in Australia.

[Table 1 should go about here]

Warranted change is less than actual change in production in all cases except manganese, nickel and tin. Therefore, most residual or differential changes are positive, implying that Australia has depleted its reserves faster than what would have been expected given the initial situation in 1987 and world trends between 1987 and 1992. Positive residual changes were substantial in the cases of aluminium, coal, crude steel, iron ore and uranium. In the case of uranium, Australia, being the world's leading miner, has mined almost twice the amount that might have been expected based on mine production of the rest of the world. These results challenge the anti-nuclear policy stance of Australia.

[Table 2 should go about here]

Table 2 presents the computed reserve life indices. The warranted production for 1992 is calculated using proportional and structural changes from table 1. It provides an indication of how much of each mineral we 'should' have produced if we followed world production trends. Columns 4 and 5 provide the information on ARLI and ERLI which are computed by the dividing the reserve base by the first two columns respectively. The differences are shown in the last column. Negative values indicate that the reserves are going to be exhausted faster than anticipated based on the rate of production of the rest of the world. It is very clear from this column that during the period from 1987 to 1992, uranium has been mined excessively. So, too, have gold and aluminium. Copper and iron ore have also been mined excessively. Only in the cases of aluminium, coal and uranium might this be justified on the ground of very substantial reserve lives.

CONCLUDING COMMENTS

In this paper we have employed shift-share analysis to define reserve life indices for the major nonrenewable natural resources that Australia relies upon for the generation of export income. We have argued that this approach, although simple, gives a comprehensive picture of the utilisation of such resources that might be useful in the formulation of policy. Although RLIs are quite high for some resources (aluminium, coal, iron ore and uranium) this is not the case for most. This implies that Australia will not be able to rely on minerals to trigger export led economic growth for much longer. Australia needs to develop a nonrenewable natural resource depletion plan that modifies the interests of private sector mining firms by reference to the interests of future generations. This plan needs to be comprehensive enough to include strategies to develop nonmineral exports in the twenty-first century. Unless this is done, when the minerals run out, so too will export led economic growth

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APPENDIX

DATA

Aluminium. Production refers to Bauxite only and is expressed in gross weights of ore mined. The quantity is given in tonnes. Australia ranks first in world production.

Cadmium: Production refers to the production of refined metal. Quantity is given in kilotonnes. Australia ranks sixth in world production.

Coal: Production refers to hard coal (anthracite and bituminous coal) only. Quantities are given in megatonnes. Australia ranks sixth in world production.

Copper: Production refers to total metallic content of production and is based on mine production. This excludes primary and secondary (scrap) production of blister copper. Quantities are given in kilotonnes. Australia ranks tenth in world production.

Gold: Production refers to metallic content of mine production. Quantity is given in tonnes. Australia ranks seventh in world production.

Iron Ore. Production includes iron ore, iron ore concentrates and iron agglomerates (sinter and pellets). Quantity is given in kilotonnes and expressed in terms of dry gross weights. Australia ranks third in world production.

Crude Steel: Production is defined as total useable ingots, continuously cast semi-finished products and liquid steel for casting. Quantity is given in kilotonnes. Australia ranks below tenth in world production.

Gypsum: Production is given on the basis of bulk and bagged product. Quantity is given in kilotonnes.

Lead: Production refers to metallic content of mine production. Quantity is given in kilotonnes. Australia ranks first in world production.

Manganese: Production refers to manganese ore. Quantity is given in kilotonnes. Australia ranks seventh in world production.

Nickel. Production refers to metallic content of mine production. Quantity is given in kilotonnes. Australia ranks fifth in world production.

Silver: Production refers to metallic content of mine production. Quantity is given in tonnes. Australia ranks fourth in world production.

Tin: Production refers to metallic content of mine production. Quantity is given in kilotonnes. Australia ranks ninth in world production.

Titanium: Production refers to mine production and includes both rutile and ilmenite concentrates. Quantity is given in kilotonnes. Australia ranks first in world production.

Uranium: Production refers to Uranium Oxide (U_3O_8) . Quantity is given in tonnes. Australia ranks first in world production.

Zinc: Production refers to metal content of mine production. Quantity is given in kilotonnes. Australia ranks third in world production.

DEFINITIONS

Mineral reserves

Mineral reserves are that part of the reserve base that could be economically extracted or produced at the time of the assessment. Reserves do not signify that extraction facilities are in place and operative. These are deposits whose quantity and grade have been determined by samples and measurements. Changes in geological information, technology, cost of extraction and production, and prices of mined product can affect estimates.

Reserve base

The reserve base is the portion of the mineral resource that meets grade, quality, thickness and depth criteria defined by current mining and production practices. It includes both measured and indicated reserves and refers to those resources that are currently economic, marginally economic and some of those that are currently subeconomic

Reserve life index and reserve base life index

These are expressed in terms of years remaining. They are computed by dividing reserves and reserve base for a given year by the respective production rate for that year. The underlying assumptions in these calculations are that world production will continue at the current rate and that no new reserves become available.

Estimated reserve life index and actual reserve life index for Australia

The estimated reserve life index is calculated assuming that Australia will follow the world trend in production. It shows the number of years remaining to exhaust reserves of that category if production is carried out according to world trends. The actual reserve life index shows the number of years remaining to exhaust the mineral reserves of that category, if production is carried out at the current rate of production of that mineral in Australia. If the ERLI is below the ARLI, mineral reserves are going to be exhausted earlier than otherwise anticipated.

Figure 1 Shares of Australian Merchandise Exports By Nonrenewable Resource Sector

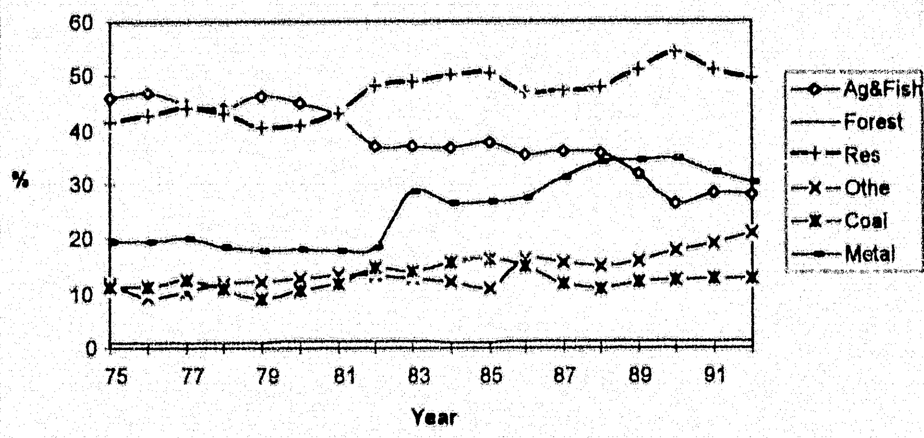

Table 1: Result of the Shift-Share Analysis

1 Commodity Type	2 Production 1987	3 Actual Change 1987-1992	4 Proportional Change	5 Structural Change	6 Differential Change
Aluminium (t)	34,101.7	5,848.3	2,169.4	303.3	3,375.6
Coal (mt)	145.0	35.0	4.3	6.4	24.3
Copper (kt)	232.7	93 3	25.7	-8.5	76.1
Cadmium (kt)	0.9	0.1	-0.02	0.09	0.9
Crude Steel (kt)	6,125.0	865.0	-118.9	570.2	413.7
Gold (t)	111.0	133.0	25.5	-17.2	124.7
Gypsum (kt)	1,580.0	420.0	168.1	-51.7	303.6
Iron Ore (kt)	101,748.0	15,422.0	-4,213.9	11,711.2	7,924.7
Lead (kt)	489.1	58.9	-10.6	46.6	22.9
Manganese (kt)	1,854.0	-569.0	-217.9	354.6	-432.3
Nickel (kt)	74.6	-10.6	3.6	1.8	-5.2
Silver (t)	1,119.0	99.0	-45.4	127.9	16.5
Tin (kt)	7.7	-1.3	-0.02	0.6	-0.7
Titanium (kt)	1,755.0	219.0	-179.4	308.7	89.7
Uranium (t)	4349	-822.5	-1,501.4	414.2	264.7
Zinc (kt)	778.4	249.6	-41.6	98.9	192.3

Quantities are given in parentheses: t = tonnes, kt = kilotonnes and mt = megatonnes.

Table 2: Reserve Life Indices

1 Commodity Type	2 Actual Production 1992	3 Warranted Production 1992	4 ARLI	5 ERLI	6 ARLE - ERLI
Aluminium	39,950.0	36,574.4	106	115	-9
Coal	180 0	155.7	620	717	-97
Copper	326.0	249.8	19	25	-6
Cadmium	1.0	0 97	55	56	-1
Gold	244.0	119.3	10	21	-11
Iron Ore	117,170.0	109,245.2	87	93	-6
Lead	548.0	525.1	23	24	-1
Manganese	1,285.0	1,990.6	28	18	10
Nickel	64.0	80	18	14	4
Silver	1,218.0	1,201.4	20	20	0
Tin	6.4	8.3	29	23	6
Titanium	1,974	1,884.2	15	16	-1
Uranium	3,526.5	3,261.7	148	160	-12
Zinc	1,028.0	835.7	16	20	-4