Economic Growth, Employment, and Environmental Pressure: Insights from Australian experience 1951-2001

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Introduction and abstract

There is a general presumption among economists and the general public that economic growth is associated with increasing environmental pressure, but that rising incomes result in improved environmental quality as part of a more general process of social adaptation. This presumption of an eventual harmony of economic and environmental outcomes mitigates against attention to environmental pressure and investment in understanding and measuring environmental health. The presumption of harmony is not supported by economic theory, however (see Arrow et al 1995, Page 1995), or recent work on the dynamics of interdependent social and natural systems (Holling et al 2002).

This paper thus provides an empirical view on the relationships between economic activity and environmental pressure in Australia over the last five decades. Environmental pressure is indicated by total material throughput, throughput of renewable resources, energy-related greenhouse gas emissions, fresh water use, intensive land use and land degradation. Historical data is from the CSIRO Australian Stocks and Flows Framework (ASFF, see Foran and Poldy 2002). This data is provided for major industry sectors and Australia as a whole. Data is also provided on energy consumption by sector.

The analysis draws on the framework proposed by Lecomber (see Collard et al 1998) to examine the environmental pressure and environmental intensity (or pressure per dollar) of economic activity, and compare the relative importance of changes in technology, economic structure, and patterns of employment. The same data is used to examine the changing patterns of employment and environmental pressure in more detail, and contrast 'monetary economy' and 'material economy' views of economic development over the last fifty years. The paper concludes with a brief discussion of key insights arising from the analysis for public policy and the development of environmental indicators.

1. Theoretical outlook

Despite its reputation as the dismal science, economists have a strong presumption in favour of an underlying harmony in human affairs. Adam Smith laid the groundwork for this in arguing that the best strategy for raising living standards is to allow each person to pursue their individual interests (although noting a range of specific cases for government action, see Smith 1776). Concerns over population growth or the status of women in developing countries are met by economists with arguments that rising incomes naturally lead to lower birth rates, assisting the demographic transition and enhancing the independence of women (Page 1995). Early arguments by Turgot (1751) that the spread of market relations and rising incomes civilise society by moderating militarism find a modern echo in the logic of the Colombo Plan, which sought to reduce the risk of communist uprising by addressing poverty in South East Asia, and the continuing efforts of the international development community.

The prospects for harmony between economic and environmental goals

It is thus not surprising that conventional economic wisdom assumes that economic development and rising incomes will also tend to result in improved environmental quality (see WCED 1987). This proposition is often supported by the example of urban air quality, which tends to deteriorate in the early phases of industrialisation and then improve (see, for example, Pearce et al 1989).

Arrow et al (1995) point out, however, that this harmony between economic and environmental goals is the result of particular physical and social circumstances which do not apply to many important environmental problems. The impacts of urban air pollution are local, visible, well understood and easily reversed.

Together these circumstances imply:

(i) The costs and benefits of reduced pollution are born largely by the same community (as most of the economic costs are passed through to those employed in polluting industries, over time, through reduced wage growth);

(ii) The direct benefits of pollution control are easily understood by the general public;

(iii) There are a range of feasible methods for reducing emissions, which result in almost immediate improvements in air quality.

This combination of factors enables residents to express their relative preferences for income (or regional economic development) and air quality through various democratic mechanisms, so that the relevant market failure[1] is corrected for by responsive institutional arrangements. Importantly, environmental quality has strong public good characteristics, and so willingness to pay for environmental quality can often only be expressed through political processes. Yet political institutions are also subject to incentive effects. Where understanding or information is poor, or impacts occur elsewhere or in the future, communities are unlikely to demand (or accept) political action involving short terms costs for the sake of uncertain long term gains.[2]

The wider implication is that no harmony can be presumed between economic activity and environmental quality where the impacts of economic activity occur at a distance in time or space, or are not visible or well understood, or are not able to be reversed or ameliorated. Any one of these circumstances will militate against effective institutional responses to correct market failure: the first by undermining the incentive for a community to act (as they are unlikely to receive a sufficient share of the benefits to compensate for the costs involved, and so must act altruistically); the second by obscuring the case for action; and the third by preventing practical options for action.

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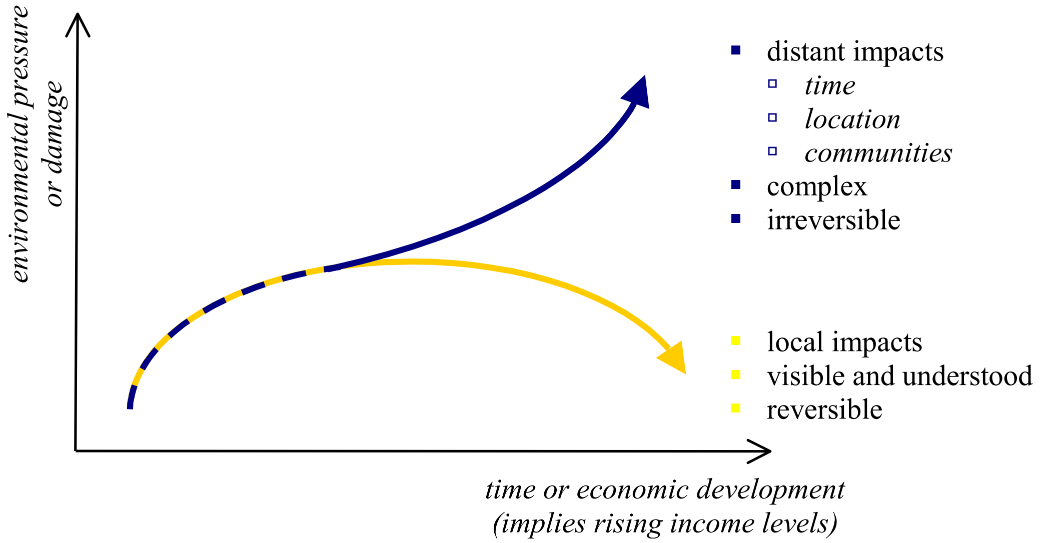
[1] The market failure in this case is that the marginal employment or income benefit of the polluting industry is less than the marginal cost imposed by the associated pollution, implying a potential net welfare gain from the introduction of higher levels of pollution control.

[2] While this explanation is typically framed in terms of environmental quality as a consumption item, it can also be framed in terms of protecting common pool environmental resources that provide basic needs or inputs to production (see Pearce and Warford 1993, Martínez-Alier 1995).

Figure 1 presents a stylised view of how these contrasting social and biophysical circumstances lead to different environmental trajectories.

Figure 1: Stylised view of economic growth and environmental pressure



In a sense, the lack of a natural harmony between economic and environmental outcomes underpins the need for deliberate (altruistic) action to achieve sustainable development, as well as representing the greatest barrier to its achievement.

It is this potential disharmony that motivates this paper to explore the historical relationships between economic growth and environmental pressure in Australia over the period 1951-2001.

Assessing human impacts on ecological systems

Ecological systems are complex and respond to disturbances in ways that are difficult to predict. Human systems are also complex, and are using resources at exponentially increasing rates. The resultant biophysical and social uncertainties interact. Human resource management tends to focus on maintaining key variables (or aspects of system performance) within a desired target range without fully understanding wider system impacts or the proximity of the interlinked system to key thresholds. Actions leading to undesirable or catastrophic outcomes – such as famine (due to a loss of crop diversity) or the collapse of major fishery – are often only identified in hindsight (see Holling et al 2002).

Ecologists often focus on impacts rather than causes in assessing environmental pressure. These may include various indicators of 'ecological health', such as loss of biological diversity, increases in exotic species, nutrient leakage, and extreme variation in primary production or ecosystem stability (see ANZECC 2000). Such indicators are often difficult to incorporate into models seeking to analyse the impact of economic activity across a range of different ecosystems, however. Industrial or human ecology typically draws attention to both material throughput and toxicity. Boyden and Dovers (1992) examine human numbers, the quantity and type of energy use, levels of resource extraction, and the production of different types of wastes (including radioactive wastes, atmospheric emissions, and other chemical outputs).

Ecological economists (such as Ayres 1995) often suggest that energy use or an index of greenhouse gas emissions may be used as a key indicator of the environmental impact of economic activity. Energy – particularly the use of fossil fuels – plays a key role in extracting, transforming and transporting natural resources, and makes a significant contribution to local and global environmental degradation. Furthermore, detailed data on extrasomatic energy use is reliable and readily available.

Although more difficult to estimate, it has also been suggested that the mass of material throughput can provide valuable information about the environmental impact of economic activity and importance of environmental resources to economic activity. Ayres and Kneese (1989), for example, estimated that commercial resource extraction exceeded 10 tons per person in the United States between 1960 and 1975, but that only 6 per cent of this material was embodied in products and capital goods with an estimated life span of 10 years or more. These authors also note that the mass of residuals discarded was greater than the recorded mass of inputs of raw materials, as the contribution of air and water to chemical processes (including combustion) is largely unpriced and unmeasured. Significantly, the wastes associated with this colossal throughput tend to disappear from the market domain, as do the true costs of disposal, resulting in massive underpricing of environmental resources (see also Hinterberger 1997). Ayres et al (2003) apply similar techniques to explore the extent to which energy analysis can explain the determinants of economic growth (particularly in relation to the nature of technical change and its contribution to enhancing factor productivity).

A growing body of researchers and analysts calculate ecological footprints for different jurisdictions (such as cities, regions or nations) or other entities (such as a specific firm). This approach inverts the ecological notion of carrying capacity, which calculates the maximum human or animal population that can be sustained by a defined geographic area(see Brookfield 1992), and instead estimates the land area that would be required to sustain the resource demands of a specific human population using only renewable resources (see, for example, WWF 2004).

Linking economic activity and environmental pressure

The environmental impact of human activity thus depends on the quantity of materials extracted from the environment and returned as wastes, the qualities of these materials, and the modification of ecosystems through farming and other changes in land use.

Paul and Anne Ehrlich's (1990) well known I = P*A*T equation suggests that environmental impact (I) is a function of population (P), affluence or per capita consumption levels (A), and technology (T). This implies that, if consumption is supplied through market mechanisms and measured in monetary terms, that technology is effectively the 'environmental efficiency' of per capita economic activity, or environmental impact per dollar. Technology in this sense is very broad, encompassing production and waste disposal practices, the distribution of human artefacts and activities in relation to ecosystem carrying capacities, and the cultural norms influencing the types of goods and services produced and consumed. In principle, this interpretation of technology also encompasses the effect of the distribution of income and power in shaping environmental impacts (see Bromley 1990).

Lecomber identifies three ways in which the environmental impact of a given value of economic activity may be reduced: by increasing the efficiency of resource use, by substituting less damaging inputs and processes for more damaging ones, and by changing the composition of economic activity towards goods and services which are less damaging over their life cycles (see Collard et al 1988).[3]

From this perspective, GDP – measured in dollars – could increase while there was a decrease environmental pressure (as indicated by energy consumption or material throughput or some measure of ecological load reflecting toxicity). This could occur, for example, through a shift to less toxic or resource intensive economic activities, a fall in the relative prices of resource intensive or damaging products, or the adoption of less damaging or more resource and energy efficient products and processes. The first involves a change in the pattern of activity with no change in production technology, the second involves a change in the money values (used to aggregate across commodity types) but no change in physical activity, the third involves a change in production technology.

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[3] This treats the monetary value and biophysical scale of economic activity separate, at least in principle, in contrast to Daly's suggestion that economic growth should be interpreted as an increase in the physical scale of economic activity (see Daly 1987). This paper adopts the conventional definition of growth as an increase in the measured value of economic activity. Most of the analysis uses GDP in constant prices.

This approach implies that total environmental impact is a function to the value of economic activity, the volume and toxicity of resource throughput per dollar, and the distribution of production and consumption in relation to the sensitivities of the ecosystems involved. Furthermore, the environmental intensity of total economic activity may change due to technical change within an industry, or through changes in the relative size of different industries, or through a combination of both. This may be summarised in the following key relationships:

$$I = f(ES, EP)$$

$$EP = GDP * EI$$

$$EI = EP / GDP = f(TC, VS, GDP)$$

Where:
I = Impact
EP = Environmental Pressure
ES = Environmental Sensitivity
EI = Environmental Intensity
GDP = Gross Domestic Product, or the measured value of economic activity (adjusted for inflation)
TC = Technological Change within sectors
VS = Value Shares of different sectors

Environmental reporting commonly adopts a condition-pressure-response framework (also referred to as pressure-state-response, originally developed by the OECD (see ANZECC 2000). This avoids the need for a comprehensive understanding of environmental systems by separately reporting on outcomes (the current conditions resulting from pressure in relation to sensitivity), pressures, and responses (institutional measures taken to reduce pressures).

This paper focuses on environmental pressure, rather than impact or condition (although it reports one condition indicator).

As discussed below, it constructs six indicators of environmental pressure, drawing on data for relevant major industry sectors and Australia as a whole. This allows the calculation of environmental pressure and environmental intensity for each of the indicators examined, and an assessment of the relative importance of technological change within industry sectors versus changes in economic structure. The paper also explores the relationships between environmental pressure and levels and patterns of employment.

2. Data on Australian environmental pressures

The analysis of environmental pressure focuses on six indicators: total material flows, renewable resource material flows, greenhouse gas emissions from fossil fuels, land disturbance and degradation, and fresh water use.

These six indicators have been chosen because they are available from the historical dataset included in the CSIRO Australian Stocks and Flows Framework (ASFF), as described by Foran and Poldy (2002, see Poldy and Foran 1998). This data is arranged in five year intervals from 1946, matching the time step of the forward looking component of the ASFF, based on historical information for 1946-1991 and estimates for the years 1996 and 2001. (The ASFF modelling framework is designed to model physically consistent national scenarios with a forecast horizon of up to 100 years.) Major advantages of this data set include that is internally consistent and provides significant sector level detail, although the degree of disaggregation that is relevant and achievable varies across the different types of pressure. Data is also available on energy consumption by sector and urban air pollution for selected cities.

The six indicators chosen are consistent with most headline environmental reporting frameworks (see ANZECC 2000, ABS 2002), although there is no direct measure of biodiversity or biodiversity loss. Attention to material flows is uncommon in current official practice, although implied in the calculations of 'ecological footprint' measures and similar aggregate measures of environmental pressure or environmental health (see WWF 2004). Attention has also been given to flows of specific pollutants, including weighting these for toxicity (see CECNA 2002, Hintenberger et al

1997). Moldan et al (2004) provides an excellent discussion of the use of environmental indicators, and the construction of composite indicators.

Importantly in the context of testing for evidence of some harmony between economic and environmental goals, and related social feedback processes, these indicators chosen relate to environmental issues where there are likely to be long lags in institutional responses due to the distance between causes and impacts, poor understanding of environmental processes, and difficulties in reversing or ameliorating past environmental damage.

Intensive land use and land degradation

The ASFF data on land use does not provide information on the level or extent of land clearing for grazing purposes (a major driver of habitat and biodiversity loss), and so land disturbance is indicated by 'intensive land use'. This is defined as land classed as urban, cropping (both in use and fallow), and sown pasture.

As shown in Table 1, intensive land use increased by 48 percent over the period, driven by increases in the area of land used for cropping (81 percent) and sown pasture (408 percent, from a low base). The area of urban land increases in line with land use generally, but accounts for only a small share, with agriculture accounting for around 99 percent of Australian intensive land use (and an even larger share of land use including grazing on unsown pasture). For this reason the land use data is only disaggregated into agriculture and 'other industries'. Total land use, including grazing, does not change significantly over the period. Data is not available on the land area used for mining, but would not impact on these results as the area is significantly smaller than that used for urban purposes.

The ASFF data also identifies degraded agricultural land, defined as land where productivity has declined by 20 percent or more. A longer time series (see Dunlop 2001, Gordon et al 2003) identifies the first human induced land degradation appearing around 1900, although the area of land is less than and becoming significant in the 1920s. By the early 1950s, around 2 million hectares are identified as degraded, rising to 9 million hectares by 2001. These figures are broadly consistent with the findings of the Natural Land and Water Resource Audit, which found that at least 5 percent of our cultivated land is currently affected by dryland salinity, and estimates that this will rise to 15 to 20 percent over the next 50 years (NLWRA 2000b). Dryland salinity results in reduced agricultural production and infrastructure damage, and is closely associated with other resource degradation issues, such as soil erosion, eutrophication of streams and waterways, and native vegetation loss. Estimates of current costs of resource degradation range from \$1.7 billion to \$3.5 billion per annum (ACG 2001), equivalent to around a fifth of the value of agricultural value added, with salinity related costs expected to increase dramatically over time. Available studies suggest around half of these costs are born by agricultural producers, a third by households, and the remainder by state and local government agencies (ACG 2001).

Water use

Total water use has grown more rapidly than intensive land use, rising by around two thirds over the five decades. As shown in Table 1, around 60 percent of this increase is accounted for by increased diversions for irrigation, which rose more than six-fold over the period. The service sector accounts for a further 20 percent of the total increase in use. In contrast to land use, 13 to 20 percent of total human water use is accounted for by manufacturing, processing and services (including household consumption).

It is now widely accepted that levels of water use are endangering ecosystem health in some regions, particularly in the Murray Darling Basin. According to the Audit, more than a quarter of Australia's water management areas – accounting for more than half of our surface water use – are approaching or beyond sustainable levels of water use (NLWRA 2001a).

Carbon dioxide emissions from fossil fuels

The ASFF provides considerable detail on material and energy flows, allowing the calculation of robust estimates of energy related carbon dioxide (CO_2) emissions. These are presented in Table 2. These figures include emissions from international air transport (ex-Australia) but not bunker fuel supplied to international shipping.[4] Emissions are attributed directly to emitting sectors (where combustion occurs), rather than down stream beneficiaries. The nature of the ASFF maps well to standard ABS industry sectors for primary and secondary industry. The analysis in this paper effectively expands the secondary industries to include transport, which is usually considered a service. This group of industry sectors is referred to as 'other material intensive industry'. Other service sectors – such as finance, insurance, wholesale and retail trade, education, and health – are not differentiated in the ASFF data set, and so are reported here as a single service sector.

Total CO_2 emissions from fossil fuel use have risen around 370 percent over the period, equivalent to a compound growth rate of 3.2 percent a year. This increase was driven almost equally by the transport, manufacturing and electricity sectors (each accounting for around 30 percent of the total increase). The mining sector exhibits the highest rate of emissions growth, from a very low base, followed by road transport (up almost ten-fold) and manufacturing (up more than eight-fold).

There is an emerging international consensus, based on the work of the International Panel on Climate Change (IPCC), that policy makers should seek to stabilize greenhouse gas concentrations at around 550 parts per million (up from the present level of around 380 parts per million). This would – on the best current science – arrest global warming with a rise in temperatures of 2-3 degrees Celsius (see WBCSD 2004). Achieving this target requires a reduction in future global emissions growth by around 50 percent, which is likely to involve deep reductions in emissions by developed nations over the next fifty years. A number of opinion leaders, including Tony Blair in the UK and the Pew Centre in the USA, have proposed target reductions by developed nations of 60 percent below 1990 levels.

Total and renewable material flows

Attention to material flows, or throughput, reflects a thermodynamic perspective on the economy as an open dissipative system, drawing in resources (matter and energy) which are transformed and then discarded as waste. These wastes may impact on the quality of future resource inputs as well as direct enjoyment of environmental amenity (see Pearce and Warford 1993, Ayres and Kneese 1989).

The ASFF calculates material throughput on the basis of different types of flows, including forestry products, crops, animal products, metals, construction materials, energy resources and other minerals. These flows have been mapped to economic sectors. Where a type of flow is not uniquely associated with one sector, such as metal (which is used in mining, manufacturing and construction), the flow has been apportioned on the basis of the ratio of primary energy use by these sectors in each year (as reported in Table 2). Consistent with the work of Adriaanse et al (1997), the estimates of material flows include both direct material flows (where the materials are traded) and indirect or hidden flows. This paper focuses on total material flows, ignoring the distinction between direct (market) and hidden (non-market) flows, but distinguishes between total flows of all materials and total flows of renewable resources.

The data contained in Table 3 indicates that total material flows have increased almost six-fold over the last half century, more than an of the other environmental pressure indicators. This is equivalent to a compound growth rate of 3.6 percent per annum for fifty years, and is the only pressure indicator that has grown more rapidly than real GDP over the period.[5] Three quarters of the increase in material flows is accounted for by manufacturing (48 percent of the total increase), mining (16 percent) and agriculture (12 percent). Direct material flows (not reported in Table 3) have increased even more rapidly, rising more than thirteen-fold over the period, equivalent to a compound growth rate of 5.4 percent per annum. Total material flows of renewable natural resources (forestry and agricultural products) grow more slowly, with an average annual compound growth rate of 1.7 percent, and account for around a third of total flows over the period.

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[4] Emissions from bunker fuel would increase total emissions by around 4 percent over the period if included.

[5] Real GDP data is available for 40 years from 1961. The average compound growth rate for GDP over this period is 3.56 percent, compared with 3.72 percent for material flows over the same period.

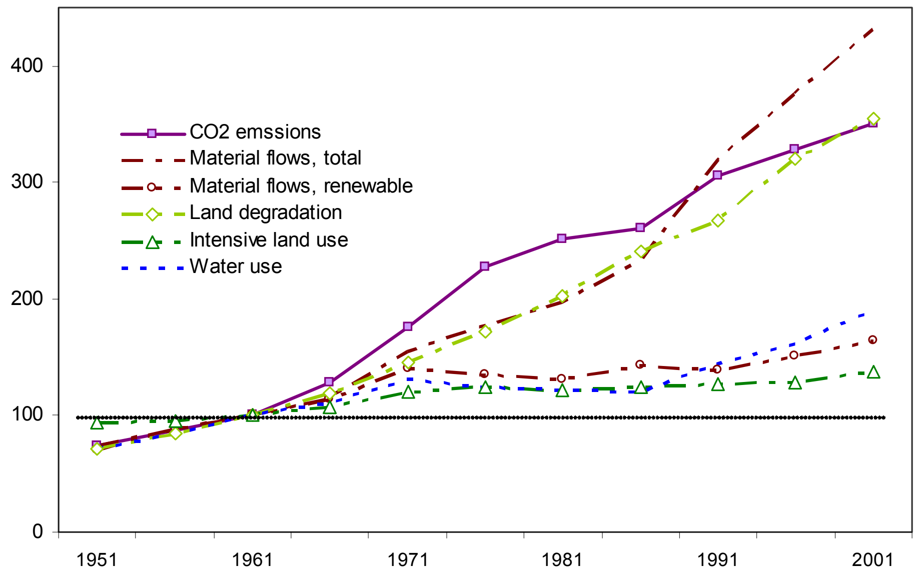
3. Analysis of environmental pressure and environmental intensity

The environmental data described above has been used to calculate indexes of environmental pressure (EP), reported in Table 4.

As shown in Figure 2, the measures indicate that all the types of environmental pressure examined in this paper have risen over the last fifty years, although the rate and extent of increase varies. The six measures fall into two groups. The first group effectively represents activity based primarily on drawing down natural capital stocks: the combustion of fossil fuels, total material throughput (two thirds of which is made up of non-renewable resources), and land degradation. These indexes increase around five fold (rising 372 to 478 percent) over the five decades. The second group faces a stricter supply-side constraint, with a tighter link to the availability of renewable resources – represented by intensive land use, water use, and material throughput of forest and agricultural products. This group exhibits much more modest growth, ranging from increases of 48 to 165 percent over fifty years.

Figure 2 Indicators of Australian environmental pressure, 1951-2001

Index: 1961 = 100



Source: Calculated from ASFF data, CSIRO

The same environmental data allows calculation of four environmental pressure ratios for each of the six indicator series. These ratios represent the relationships between environmental pressure and (a) the value of economic activity, (b) payments to employees, (c) employment levels, and (d) total population. The ratio estimates are draw on ABS data for real GDP (2001-02 dollars) and RBA employment time series, and cover the period 1961-2001, as estimates of real GDP are not available for the preceding years. The economic and demographic data used are summarised in second panel in Table 4.

As shown in Figure 3, the environmental pressure ratios also split into two groups, mirroring the underlying environmental pressure data. (Table 5 provides detail of the indexes.)

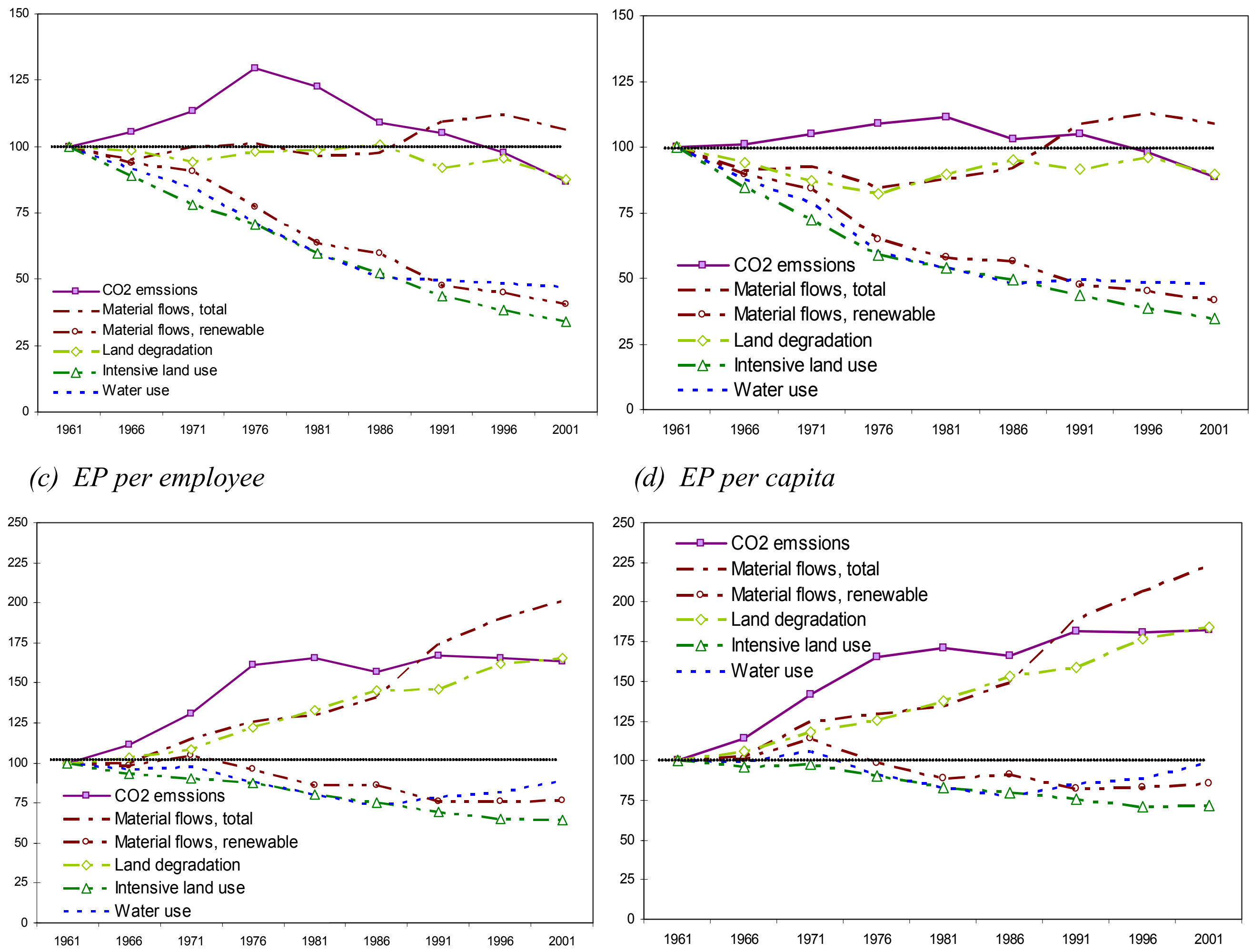
Examining first environmental intensity and pressure in relation to payments to employees, the three 'natural capital consuming' indicators show little or no trend decline, while the 'renewable resource' intensity indicators show a reduction of half to two thirds over the period. The environmental intensity of total material flows and CO2 fossil energy emission both increase for significant portions of the forty year time series, consistent with resource extensive economic growth driven by increased inputs rather than more efficient resource use. The intensity of energy emissions grows 30 percent to a peak in the mid 70's, and then declines to end 13 percent below the 1961 level by 2001. Total material flows trend weakly up to end slightly higher than in 1961.

Figure 3 Environmental pressure ratios, 1961-2001

Index: 1961 = 100

(a) Environmental intensity (EP per dollar) *(b) EP per dollar paid to employees*

(c) EP per employee *(d) EP per capita*



Source: Calculated from ASFF data, CSIRO; ABS Catalogue 5204.0, 2002-03; RBA employment data

The ratios of environmental pressure to employment and population numbers show increases in pressure ratios for the three natural capital consuming indicators and moderate trend declines for the other three indicators. This reflects the increase in real income, with average employment and population growth rates are lower than the increase in the value of economic activity and wages.

Importance of technology and structural change

The above analysis explores relationships between environmental pressure and the following:

- economic growth, increasing the real value of economic activity, as measured by GDP adjusted for inflation);
- employment and wages growth; and
- population growth.

Consistent the analytical framework derived from Lecomber (described in Section 1), the sectoral detail provided by the ASFF and ABS data also allows exploration of the relative importance of the following:

- technological change within broad industry groups, as reflected in changes in the environmental pressure per dollar for a specific sector over time;
- changes in economic structure, reflected in changes in the share of GDP accounted for by different sectors;
- changes in employment patterns (a different measure of structure, based on sector employment shares).

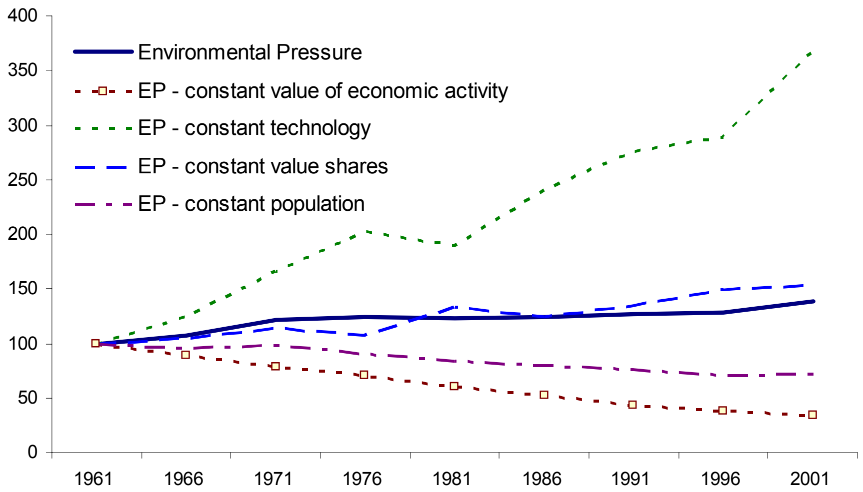
This analysis is intended to provide a clearer understanding of the interplay of forces and key relationships involved in changes in environmental pressure. These may be thought of as the proximate factors through which the underlying determinants of environmental pressure operate. (Potential deeper causal factors, such as underpricing of environmental resources and assimilative capacity, are discussed in Section 6 below.) The identification of the relative role played by different contributors to changes in environmental intensity (the second three points above) involves calculating a counterfactuals, such as the environmental pressure Australia would have experienced in the absence of technical change within sectors (that is, if the environmental intensity of each sector remained constant over the period).

Figure 4 and Table 5 provide the results of this decomposition for the environmental pressure represented by the extent of intensive land use. (The impact of changes in employment shares is not shown in the figure because employment shares data is not available for the full period.)

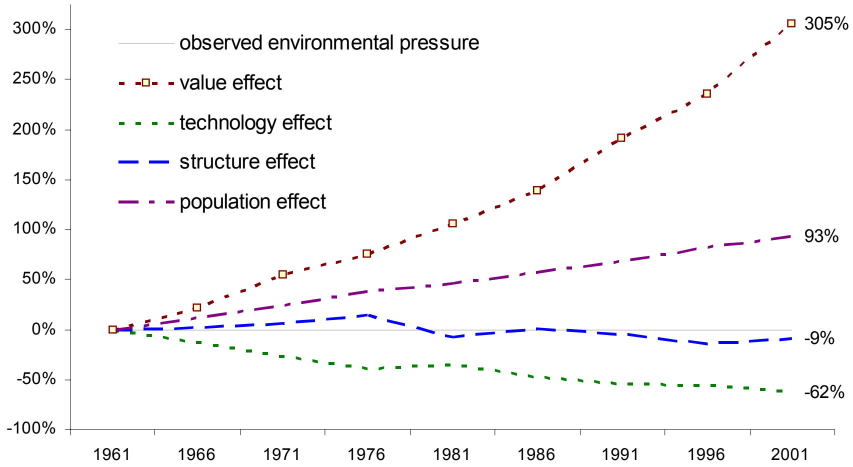
Figure 4 Decomposition of environmental pressure, Australian intensive land use, 1961-2001

(a) Environmental pressure counterfactuals

Index: 1961 = 100



(b) Difference between observed environmental pressure and counterfactuals



Source: Calculated from ASFF data, CSIRO, and ABS Catalogue 5204.0, 2002-03, and RBA employment data

Changes in both technology and economic structure (as measured by value shares) both reduce environmental intensity. The impact of technical changes is particularly dramatic, reducing pressure by over 60 percent relative to that which was actually observed. Economic growth is the largest single influence, increasing pressure by around 300 percent (in relation to the no-growth case), while population growth is associated with around a 90 percent increase in pressure. These effects may be treated as approximately multiplicative.

Figure 5 provides the results of the same calculations for total material flows. In contrast to the environmental pressure indicated by intensive land use, total material flows would have increased slightly even in the absence of economic growth. Indeed, the major contrast with the land use case is that none of the factors provide a strong moderating effect (reflected in none of the counterfactuals portraying a world with significantly higher environmental pressure.

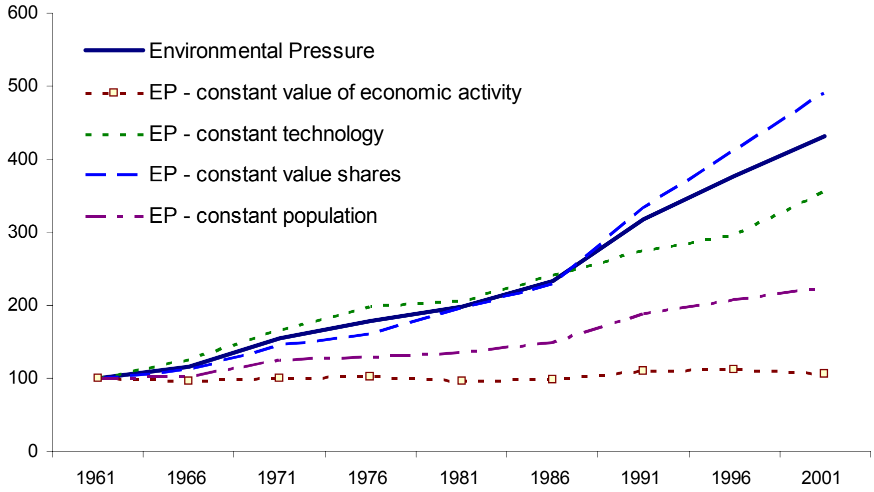
The only factor that acted to reduce the level of increase in environmental pressure was the change in economic structure. This occurs because the counterfactual reduces the impact of strong growth in the environmental intensity of services (with pressure per dollar increasing by around twice the economy-wide average), as the service sector is assumed to remain at 50 percent of the economy by value, rather than increasing to 55 percent of the economy in 2001.

All other factors contribute to increased environmental pressure from total material flows, which rose more than four fold over the period.

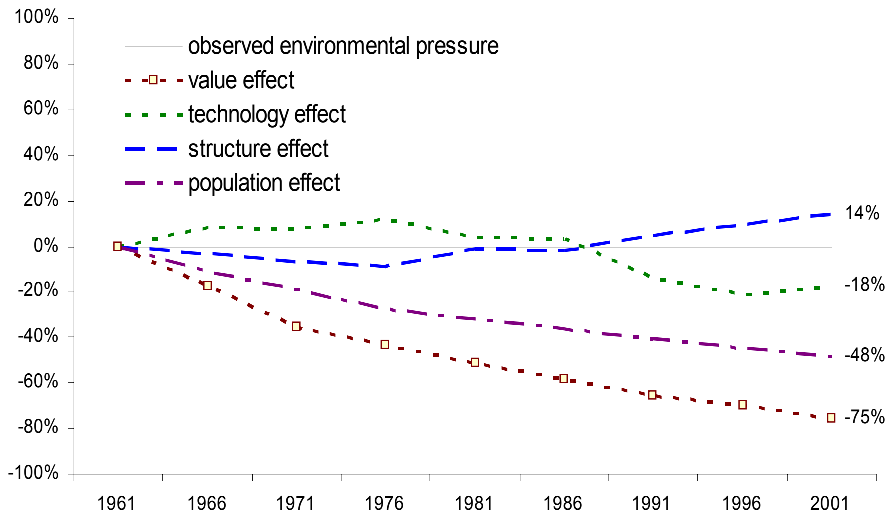
Figure 5 Decomposition of environmental pressure, Australian total material flows, 1961-2001

(a) Environmental pressure counterfactuals

Index: 1961 = 100



(b) Difference between observed environmental pressure and counterfactuals



Source: Calculated from ASFF data, CSIRO, and ABS Catalogue 5204.0, 2002-03, and RBA employment data

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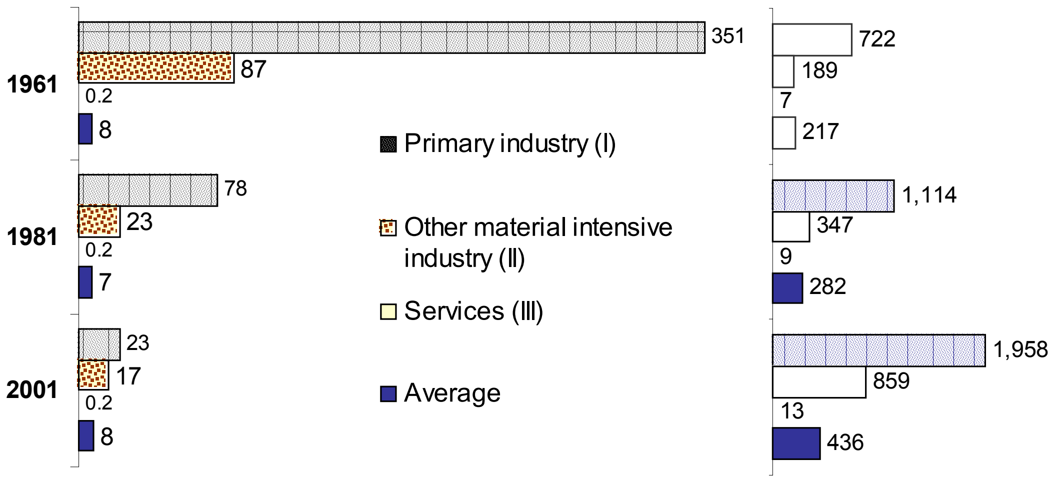
4. Employment and environmental pressure

The data presented in Figure 3 and Table 5 indicate that environmental pressure per employee and per dollar of wages and salaries has grown strongly for at least natural capital consuming resource use. Figure 6 complements this information with a comparison of the structure of environmental pressure per employee over the period. The figure indicates very different patterns in pressure per dollar and pressure per employee, with dramatic declines in pressure per dollar in primary and secondary industry, and a marked increase in pressure per employee in these sectors. (The pressure per employee figures for 1961 are estimated and should only be treated as broadly indicative.)

The environmental pressure associated with services is very low, but is growing rapidly relative to the rest of the economy. Nevertheless, lower growth in primary and secondary industries and an expansion of the service sector would help moderate growth in environmental pressures.

Figure 6 Comparison of environmental pressure per dollar and per employee, Australian total material flows by sector, 1961-2001

(a) Environmental intensity ('000 per dollar)   *(b) Environmental pressure per employee (tonnes per employee)*



The ASFF data does not distinguish between different types of services (other than various forms of transport activity, which here are treated as part of secondary industry).

5. Perspectives on economic structure and development

The data and analysis described above also provides a basis for contrasting a 'material economy' perspective on economic development with that provided by a 'monetary economy' perspective.

Figure 7 sets out a conventional view of the change economic structure associated with the last four decades of economic growth. It portrays an economy with relatively stable sectoral shares and a large service sector, accounting for around half of total economic activity. Gross value added grows at an average compound rate of 3.6 percent, while employment grows around 1.9 percent. Per capita GDP grows at 1.9 percent per annum over the period, rising to $26,375 per person by 2001.

This may be compared with Figure 8, which reports the change in the total material flows associated with economic activity.[6] In contrast to the conventional view, the service sector is almost non-existent, accounting for 1 to 2 percent of material flows, while secondary industry accounts for a large and increasing share of economic activity (rising from half to two thirds of

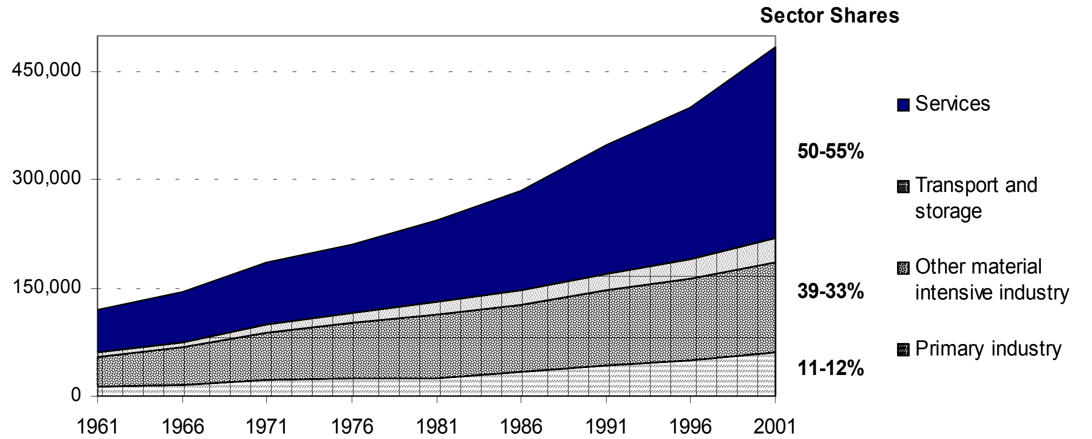
[6] The data presented in Figure 8 includes material flows associated with imports, which are equal to around 2 percent of total flows. Imports are excluded from the environmental pressure calculations presented elsewhere in the paper because of difficulties attributing them to specific sectors.

total throughput over the period). Primary industry throughput grows in absolute terms but declines as share of total material flows over the period.

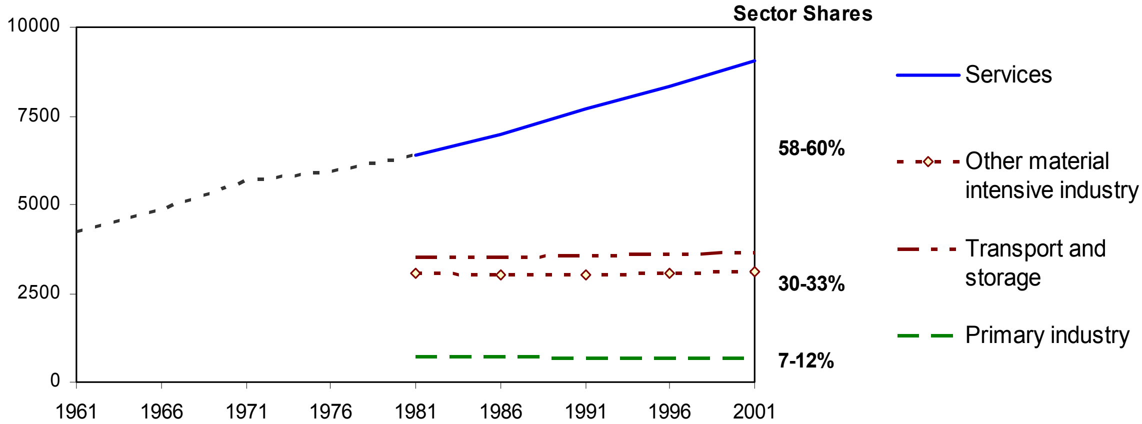
Material flows grow faster than both value added and employment, with an average compound growth rate of 3.7 percent. In terms of living standards, the closest approximation to GDP per capita is direct material flows per capita, representing the physical flow of traded resources per person. These grow at an average compound growth rate of 2.8 percent per annum. Total material flows increased from 86 tonnes per person in 1961 to 204 tonnes per person in 2001, representing a compound growth rate of 2.2 percent per annum over the period. Total material flows are around four times the size direct flows.

Figure 7 Australian economic structure, 1961-2001 – value added perspective

(a) Sectors as a share of total economic value (GDP, in constant prices, $m 2001-02)



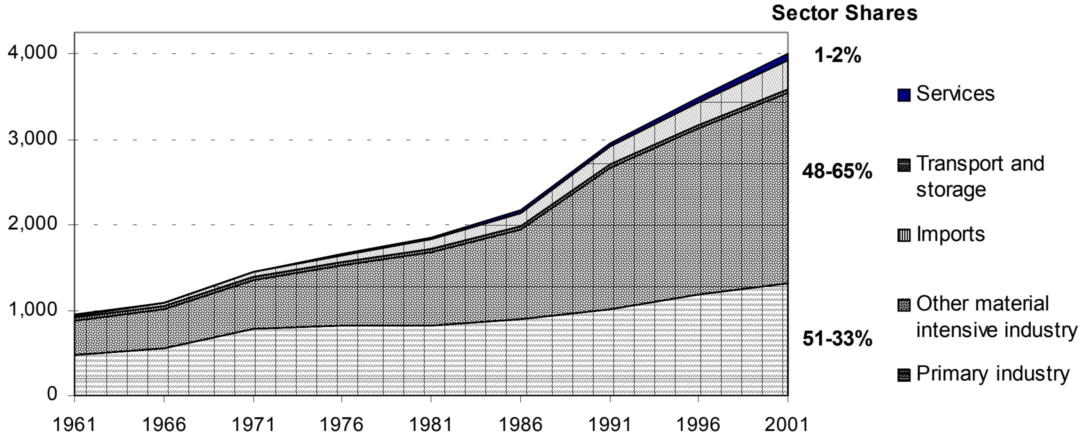
(b) Sectors as a share of total employment ('000 people)



Source: Calculated from ABS Catalogue 5204.0, RBA employment data

Figure 8 Australian economic structure, 1961-2001 – material flow perspective

Total material flows (million tonnes)



Source: Calculated from ASFF data, CSIRO

6. Interpretation and concluding comments

The analysis presented above represents an opportunistic examination of a rich new data set that is able to be coupled with standard national accounts data. This final section explores three types of insights that might be drawn from this initial analysis:

(i) potential lessons for the selection and use of environmental indicators

(ii) preliminary insights or hypotheses related to the underlying determinants of observed changes in environmental pressure

(iii) implications for public policy.

These are discussed in turn below.

Insights into development of indicators of environmental pressure

Environmental reporting is cursed by the importance of context and the complexity of environmental systems. This makes it extraordinarily difficult to identify or construct high level indicators that are well based scientifically, relevant and simple to use, and can be maintained at reasonable cost. The Australian Bureau of Statistics (ABS 2002) *Measuring Australia's Progress* notes that it difficult to encapsulate environmental performance in a small number of indicators, and identifies six environmental themes – biodiversity, land clearing, land degradation, inland waters, air quality and greenhouse gas emissions. Biodiversity is not able to be measured comprehensively and detailed national time series data is not available for inland waters. On available data, Australian environmental quality has declined in all areas other than urban air quality.

The ANZECC State of the Environment Reporting task Force identifies 75 indicators in six groups (ANZECC 2000). This indictor set casts a wider net than the ABS (2002) headline approach, including information on estuaries and marine ecosystems and on human settlements, as well as providing more depth and detail in each area. Consistent with the condition-pressure-response framework and the objective of describing the 'state of the environment', the proposed set of indicators is dominated by condition indicators, such as exceedance measures (where a measure is above the relevant regulatory standard) and descriptions of the quality and extent of particular ecological communities.

The measures of environmental pressure presented in this analysis cannot hope to compete with this level of detail on actual impact. This shortcoming is illustrated by the lack of indication of a (regional) water crisis in the historical data presented above, although a regionally disaggregated approach may be able to generate corse indicators of environmental pressure in relation to defined thresholds (such as water use relative to ecological capacity). Indeed, indicators of environmental pressure are of little concrete use in the absence of information on system thresholds, such as the sustainable yield of a renewable resource. Where we know at least the desired direction of change it may be possible to include additional data – such as on land clearing – to provide useful estimates of sector level environmental pressure and intensity.

Overall, however, the potential utility of the approach demonstrated here relates to insights that might be provided into the underlying forces shaping future environmental impacts, along with its ability to connect environmental and physical outcomes to established social and economic statistics.

Underling determinants of trends in environmental pressure and intensity

The data presented on environmental pressure and intensity represents the outcomes of complex causal factors. It is the habit of economists to think in terms of prices shaping behaviour, noting that prices are themselves shaped by institutional arrangements and the wider social and physical context of market activity.

The information presented in Figures 2 and 3 is consistent with a number of well known trends or events in recent economic history:

- The agricultural cost-price squeeze is reflected in the rising intensification of agricultural land use and increased physical output (measured by tonnes of material flows of renewable resources), along with a sharp decline in the unit value of this output.
- The rise in real energy prices triggered by the first OPEC crisis is mirrored in the sharp downturn in the environmental intensity of CO_2 fossil fuel emissions from the mid-1970s (although emission levels continued to grow throughout the period). Interestingly, emissions per dollar continue to decline due to technological change despite long periods of declining real energy prices since the 1970s.
- The more general contrast between rapidly growing 'natural capital consuming' activities and slower growth in 'renewable resource dependent' activity resonates with conventional views that the harnessing of non-renewable resources (particularly energy resources) was a key element in overcoming the Malthusian limits on agriculturally based economies and allowing the emergence of modern industrial society (see, for example, Wrigley 1989).

All of these reflect the interaction of social and environmental factors, including the relative scarcity of different types of resources (including stock and flow issues for renewable resources), the distribution of specific resources (and implications for social control in the OPEC example), and the differential opportunities for technical advances in the efficiency of using different natural resources. Perhaps more importantly, all of them reflect the importance of social processes – particularly behaviour shaped by markets – in determining environmental outcomes.

Policy implications

The analysis presented appears to have three main policy implications.

The first is to confirm that relationship between environmental quality and income (or economic development) is neither straightforward nor – on the evidence examined here – harmonious. All of the indicators of environmental pressure increase over the period, implying at least decreased environmental resilience and – in some cases – reduced environmental quality or reductions in the physical natural capital stock. These increases in pressure were reduced but not reversed by changes in technology and economic structure.

The second is that that Australian economy is 'materialising' rather than 'dematerialising'. Material flows and environmental pressure are increasing, and resource extensive growth appears to remain an important part of the increases in economic activity achieved over the last fifty years. While the agriculture's share of material flows has fallen, absolute levels of agricultural throughput has risen, and physical throughput and CO_2 emissions from material intensive secondary industry have grown strongly (with average increases of 4.4 and 3.2 percent per year, compared to a

3.1 percent annual increase in the value of this sector). Indeed, the growth of material throughput for the economy as a whole exceeded economic growth over this period, implying that environmental pressure would have risen on this indicator even in the absence of economic growth. That is, if the Australian economy was 75 percent smaller than it is today – equivalent to the value of economic activity in 1961 – total material throughput would still be greater than forty years ago.

These two insights are of concern because it is clear that continuing growth in environmental pressure is not sustainable (see Boyden and Dovers 1992). Ayres (1995:99) argues that our lack of knowledge about the ecological thresholds of the global system in which we live suggests that the only reasonable policy is to ensure that the biosphere is not perturbed more than it has been by natural events in the past. "Unfortunately", he observes, "there is no indication that the world's policy makers are willing to acknowledge any such limits." The analysis presented in this paper suggests that this challenge will become more difficult the longer we wait.

The third and final insight that emerges from the analysis is the dramatic potential of technological change for reducing environmental pressure, even in the face of weak price signals. None of the environmental issues examined in the paper is completely unpriced – material throughput involves extraction and disposal costs, energy resources giving rise to CO_2 emissions are priced and traded, access to land and water also involve costs – although all are underpriced from a social perspective. Despite these weak institutional signals, the ratio of environmental pressure per dollar of activity has fallen in most cases (the exception being material flows, with the weakest links to environmental damage), and appears to have fallen most where institutions and understanding have provided the strongest signals.[7]

This suggests that well crafted environmental policies that signal the need for reduced environmental pressure would be likely to have significant environmental benefits over time. While such policies do not need to be intrusive or onerous, they do need to provide a stronger 'sustainability signal' than was present over the last fifty years if we wish to continue the pursuit of economic growth while recognising the need to avoid indefinite increases in environmental pressure. Additional targeted action will be required to reduce environmental pressure where resource use is already approaching significant environmental thresholds.

Overall, the approach demonstrated appears to play a useful complementary role in understanding environmental pressure and potential impacts, and in helping to identify potential policy approaches and interventions that might assist the transition to a sustainable and happy society.

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This paper would not have been possible without the willing assistance of Franzy Poldy, Barney Foran and Mike Dunlop (CSIRO Sustainable Ecosystems) in providing ASFF data, and research assistance from Tanjua Doss (The Allen Consulting Group) in compiling relevant ABS data.

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[7] Note the causes of dryland salinity – the major form of land degradation – were only well understood at the very end of the period examined, while CO2 emissions have declined by third since the mid 1970s' despite trend reductions in real energy prices for much of this time.

Wentworth Group – were recognized by his inclusion in *The Bulletin* magazine's inaugural 'Smart 100' list of leading Australian innovators (October 2003).

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Table 1: Environmental Pressure indicators – intensive land use, land degradation, and water use, 1951-2001

	1951	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001
ENVIRONMENTAL PRESSURE INDICATORS											
Intensive land use ('000 hectare)											
Primary industry (I)											
Agriculture, forestry and fishing											
Cropping	19,112	19,457	20,036	23,099	28,575	28,925	30,049	32,721	32,837	33,193	34,608
Grazing (sown pasture)	7,117	9,280	13,462	17,716	24,516	27,428	25,888	26,256	28,972	29,672	36,257
Forestry	51,852	50,899	49,956	49,011	48,063	47,108	46,152	45,196	44,240	44,323	44,423
Mining	-	-	-	-	-	-	-	-	-	-	-
Other industry and services (II & III)	682	698	715	734	761	785	811	846	887	927	970
Total	**78,763**	**80,334**	**84,169**	**90,560**	**101,915**	**104,246**	**102,899**	**105,018**	**106,936**	**108,116**	**116,258**
including degraded land	1,814	2,120	2,520	3,000	3,680	4,340	5,100	6,060	6,740	8,080	8,940
Water use (GL/year)											
Primary industry (I)											
Agriculture, forestry and fishing											
Cropping	1,190	1,748	2,421	3,391	4,654	4,294	4,754	4,304	6,205	7,026	8,718
Grazing & animal production	5,220	5,748	6,469	6,361	6,832	6,264	5,240	5,157	5,255	5,814	6,588
Forestry	0	0	0	0	0	0	0	0	0	0	0
Mining	18	31	43	67	116	190	228	258	319	361	411
Other material intensive industry (II)											
Manufacturing	137	175	235	308	357	329	339	380	344	379	399
Utilities, construction and transport	96	119	141	171	202	213	248	289	347	382	418
Services (III)	746	877	1,002	1,144	1,364	1,593	1,792	2,075	2,408	2,732	3,077
Total	**7,407**	**8,696**	**10,311**	**11,443**	**13,526**	**12,883**	**12,601**	**12,463**	**14,878**	**16,693**	**19,610**

from:
Economic growth, employment and environmental pressure: Insights from Australian experience, 1951-2001

Source: CSIRO Australian Stocks and Flows Framework (ASFF) data

Steve.HatfieldDodds@csiro.au November 2004

Table 2: Environmental Pressure indicators – CO_2 emissions from fossil fuels and primary energy, 1951-2001

	1951	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001
ENVIRONMENTAL PRESSURE INDICATORS											
CO2 emissions from fosil fuels (tonnes/year)											
Primary industry (I)											
Agriculture, forestry and fishing	2,055	2,069	2,132	2,311	2,594	2,644	3,150	3,519	3,638	3,925	4,233
Mining	60	78	97	135	2,432	5,634	6,249	6,416	9,467	12,286	13,947
Other material intensive industry (II)											
Manufacturing	9,774	11,719	16,604	34,023	63,754	97,222	90,593	75,857	82,549	87,138	92,211
Electricity, gas and water supply	40,197	45,140	44,752	45,627	50,000	53,176	71,592	88,141	110,325	112,526	116,737
Construction	1,185	1,374	1,564	1,753	1,954	2,146	2,775	2,491	2,927	2,867	3,018
Transport and storage											
Transport - domestic non-road	7,473	9,534	11,690	13,748	15,382	18,092	22,527	26,122	28,652	33,634	39,371
Transport - road	3,941	6,563	9,944	14,276	19,008	23,992	28,218	30,915	36,100	39,072	41,265
Transport - international air	112	341	668	1,014	1,562	1,921	2,500	2,965	4,522	6,805	8,084
Bunker (international marine)	10,505	10,615	10,497	10,046	9,428	8,210	7,180	4,771	4,054	3,702	3,439
Services (III)	5,467	6,182	6,931	7,762	8,887	9,932	9,629	9,123	10,212	11,308	12,730
Total (excl. bunker)	**70,264**	**83,000**	**94,381**	**120,649**	**165,575**	**214,758**	**237,233**	**245,550**	**288,391**	**309,560**	**331,596**
Primary energy (Petajoules/year)											
Primary industry (I)											
Agriculture, forestry and fishing	28	29	30	32	36	37	44	49	51	56	59
Mining	1	1	1	2	32	77	86	93	140	184	210
Other material intensive industry (II)											
Manufacturing	121	144	195	366	655	1020	977	855	940	1011	1058
Electricity, gas and water supply	453	509	505	515	570	623	851	1053	1304	1337	1382
Construction	16	19	21	24	26	29	38	34	40	39	41
Transport and storage											
Transport - domestic non-road	101	129	158	186	208	245	305	354	388	454	528
Transport - road	53	89	134	193	257	324	381	418	488	529	560
Transport - international air	2	5	9	14	21	26	34	40	61	92	109
Bunker (international marine)	142	143	142	136	127	111	97	64	54	49	45
Services (III)	86	98	112	130	150	171	178	176	198	222	252
Total (excl. bunker)	**862**	**1021**	**1165**	**1461**	**1956**	**2551**	**2893**	**3070**	**3609**	**3925**	**4198**

from:

Economic growth, employment and environmental pressure: Insights from Australian experience, 1951-2001

Source: CSIRO Australian Stocks and Flows Framework (ASFF) data

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Table 3 Environmental Pressure Indicators - total and renewable material flows (by sector and by type of material), 1951-2001

	1951	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001
ENVIRONMENTAL PRESSURE INDICATORS											
Material flows, excluding imports (million tonnes/year)											
Flows by sector											
Primary industry (I)											
Agriculture, forestry and fishing											
Cropping	126	135	159	205	261	243	270	310	282	315	358
Grazing & animal production	235	265	290	308	386	379	324	339	346	369	389
Forestry	19	24	29	30	27	27	31	34	37	36	39
Mining	2	3	5	8	100	176	187	215	345	458	537
Other material intensive industry (II)											
Manufacturing	131	159	181	211	330	536	607	715	1,234	1,493	1,693
Electricity, gas and water supply	33	40	42	47	59	78	126	212	292	330	389
Construction	118	162	175	197	186	92	131	114	126	126	136
Transport and storage											
Transport - domestic non-road	7	10	13	17	22	31	45	71	87	112	149
Transport - road	4	7	11	18	27	41	56	84	109	131	158
Transport - international air	0	0	1	1	2	3	5	8	14	23	31
Bunker (international marine)	10	11	12	12	13	14	14	13	12	12	13
Services (III)	6	8	9	12	16	21	26	35	44	55	71
Total (excl. bunker)	**682**	**813**	**916**	**1,055**	**1,415**	**1,627**	**1,809**	**2,136**	**2,915**	**3,447**	**3,949**
inc. renewable resource flows	*380*	*424*	*479*	*543*	*674*	*649*	*624*	*683*	*664*	*719*	*786*
Flows by type of material											
Cropping	126	135	159	205	261	243	270	310	282	315	358
Animal production	235	265	290	308	386	379	324	339	346	369	389
Forestry	19	24	29	30	27	27	31	34	37	36	39
Excavation	84	96	87	77	105	26	49	36	29	29	32
Construction materials	18	49	73	114	152	187	192	187	206	226	241
Other minerals	1	1	1	1	3	7	9	13	26	32	37
Energy materials	71	89	105	143	212	329	436	620	808	968	1,179
Metals	138	166	183	188	283	443	512	610	1,193	1,484	1,687
Total	**692**	**825**	**927**	**1,067**	**1,429**	**1,641**	**1,823**	**2,149**	**2,927**	**3,459**	**3,962**
Imports (not included above)	20	22	28	37	42	35	39	37	37	40	44

from:
Economic growth, employment and environmental pressure: Insights from Australian experience, 1951-2001

Source: CSIRO Australian Stocks and Flows Framework (ASFF) data

Steve.HatfieldDodds@csiro.au November 2004

Table 4: Overview of environmental pressure and key economic and social data, Australia, 1951-2001

	1951	1956	1961	1966	1971	1976	1981	1986	1991	1996	2001
ENVIRONMENTAL PRESSURE											
Environmental pressure (EP)											
Intensive land use	94	95	100	108	121	124	122	125	127	128	138
Land degradation	72	84	100	119	146	172	202	240	267	321	355
Water use	72	84	100	111	131	125	122	121	144	162	190
CO2 emssions	74	88	100	128	175	228	251	260	306	328	351
Material flows, total	74	89	100	115	155	178	198	233	318	376	431
Material flows, renewable	69	89	100	114	141	136	130	143	139	150	164
Average	**76**	**88**	**100**	**116**	**145**	**160**	**171**	**187**	**217**	**244**	**272**
Direct material flows, total	*49*	*76*	*100*	*147*	*226*	*333*	*379*	*430*	*515*	*581*	*663*
ECONOMIC AND SOCIAL DATA											
Key indicators											
GDP (constant prices, 2001-02, $b)			119	145	185	210	245	285	348	401	484
GDP (constant prices) index			100	121	155	176	205	239	291	335	405
Population ('000 persons)	7,511	8,419	9,511	10,664	11,783	13,081	13,966	14,923	16,018	17,284	18,352
Population index	79	89	100	112	124	138	147	157	168	182	193
Employment ('000 persons)	3,411	3,725	4,222	4,862	5,677	5,966	6,415	6,990	7,722	8,356	9,066
Employment index, number of people	81	88	100	115	134	141	152	166	183	198	215
Employment index, hours worked (1981 = 152)							152	161	183	197	213
Payments to employees (constant prices, 2001-02, $b)			68	86	114	142	153	172	198	227	269
Payments to employees index			100	127	167	209	226	253	292	334	397
Living standards											
GDP per capita ($2001-02)			12,562	13,562	15,714	16,040	17,552	19,104	21,726	23,184	26,379
Average payment to employees ($2001-02)			16,087	17,707	20,000	23,837	23,917	24,558	25,668	27,134	29,711
Direct material flows per capita (tonnes)	11	15	17	22	29	37	39	41	45	47	50

from:
Economic growth, employment and environmental pressure: Insights from Australian experience, 1951-2001
Steve.HatfieldDodds@csiro.au November 2004

Source: CSIRO Australian Stocks and Flows Framework (ASFF) data
ABS Catalogue 5204.0, 2002-03; RBA employment data

Table 5: Environmental pressure ratios, all indicators, 1961-2001

	1961	1966	1971	1976	1981	1986	1991	1996	2001
ENVIRONMENTAL PRESSURE RATIOS									
(a) Environmental intensity (EI) *(environmental pressure per dollar)*									
Intensive land use	100	89	78	71	60	52	44	38	34
Land degradation	100	98	94	98	99	101	92	96	88
Water use	100	92	85	71	60	51	50	48	47
CO2 emssions	100	106	113	130	123	109	105	98	87
Material flows, total	100	95	100	101	96	98	109	112	106
Material flows, renewable	100	94	91	77	64	60	48	45	41
Average	100	96	93	91	83	78	74	73	67
(b) Environmental pressure per person employed									
Intensive land use	100	93	90	88	80	75	69	65	64
Land degradation	100	103	109	122	133	145	146	162	165
Water use	100	96	98	88	80	73	79	82	89
CO2 emssions	100	111	130	161	165	157	167	166	164
Material flows, total	100	100	115	126	130	141	174	190	201
Material flows, renewable	100	99	105	96	86	86	76	76	76
Average	**100**	**100**	**108**	**113**	**113**	**113**	**119**	**123**	**127**
(c) Environmental pressure per dollar paid to employees									
Intensive land use	100	85	72	59	54	49	44	38	35
Land degradation	100	94	87	82	90	95	92	96	89
Water use	100	88	78	60	54	48	49	49	48
CO2 emssions	100	101	105	109	111	103	105	98	89
Material flows, total	100	91	92	85	87	92	109	113	109
Material flows, renewable	100	90	84	65	58	56	48	45	41
Average	**100**	**91**	**87**	**77**	**76**	**74**	**74**	**73**	**69**
(d) Environmental pressure per capita									
Intensive land use	100	96	98	90	83	80	75	71	72
Land degradation	100	106	118	125	138	153	159	176	184
Water use	100	99	106	91	83	77	86	89	99
CO2 emssions	100	114	142	165	171	166	181	180	182
Material flows, total	100	103	125	129	135	149	189	207	223
Material flows, renewable	100	101	114	99	89	91	82	83	85
Average	**100**	**103**	**117**	**117**	**116**	**119**	**129**	**134**	**141**

from:
Economic growth, employment and environmental pressure: Insights from Australian experience, 1951-2001
Steve.HatfieldDodds@csiro.au November 2004

Source: CSIRO Australian Stocks and Flows Framework (ASFF) data
ABS Catalogue 5204.0, 2002-03; RBA employment data

Table 6: Decomposition of environmental pressure, all indicators, 1961-2001

	1961	1966	1971	1976	1981	1986	1991	1996	2001
ENVIRONMETNAL PRESSURE - DECOMPOSITION									
Intensive Land Use									
Environmental Pressure	**100**	**108**	**121**	**124**	**122**	**125**	**127**	**128**	**138**
EP - constant value of economic activity	100	89	78	71	60	52	44	38	34
EP - constant technology	100	124	166	203	189	240	276	289	368
EP - constant value shares	100	105	114	108	133	124	134	149	152
EP - constant job shares	n.a.	n.a.	n.a.	n.a.	122	114	105	97	98
EP - constant population	100	96	98	90	83	80	75	71	72
Material flows, total									
Environmental Pressure	**100**	**115**	**155**	**178**	**198**	**233**	**318**	**376**	**431**
EP - constant value of economic activity	100	95	100	101	96	98	109	112	106
EP - constant technology	100	125	166	198	206	240	275	296	354
EP - constant value shares	100	112	144	161	196	230	334	412	491
EP - constant job shares	n.a.	n.a.	n.a.	n.a.	198	214	264	286	305
EP - constant population	100	103	125	129	135	149	189	207	223

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