The Genuine Progress Indicator

A new index of changes in well-being in Australia

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1. Introduction[1]

Raising the rate of economic growth is the principal objective of economic policy. Increasingly, social policy is also being formulated with a view to promoting economic growth, usually measured by growth of Gross Domestic Product (GDP) or sometimes Gross National Product (GNP).[2] The level of, and changes in, GDP per capita are used constantly as measures of the level of, and changes in, national well-being – by policy makers, politicians, media commentators and economists themselves. It is no defence to argue that some economists recognise that changes in GDP are not a good indicator of changes in national well-being, for in almost every case the practice belies the formal acknowledgment. In the words of Cobb and Cobb (1994: 251), who have been heavily involved in developing alternative indexes for the USA, the 'normative usage of GNP is the central dogma of the economic faith'.

In Australia's case, not only are the trends in GDP used as a measure of the success or otherwise of the current government but we frequently hear economists and business people bewailing the fact that since the Second World War Australia has fallen from 3rd to 16th in the international ranking of countries by GDP per capita. This decline is seen universally as a bad thing, a source of national shame and something we must devote all efforts to reverse. But no-one stops to ask what these rankings actually mean. The unstated assumption is that whereas Australians used to enjoy about the third highest level of well-being in the world, now we have only the 16th highest. Stating it in such a stark way makes it look absurd, but that is precisely how these figures are used.

It has long been recognised that GDP growth does not correlate well with changes in social welfare, i.e. national well-being. The principal shortcomings of GDP as a measure of changes in national well-being are:

- the failure to account for the way in which increases in output are distributed within the community;
- the failure to account for the contribution of household work;
- the incorrect counting of defensive expenditures as positive contributions to GDP; and
- the failure to account for changes in the value of stocks of both built and natural capital.

There have been several attempts to construct indicators of changes in well-being that are more comprehensive than GDP. A well-known earlier index was built by Nordhaus and Tobin (1972). In more recent years Daly and Cobb (1990) have constructed the Index of Sustainable Economic Welfare (ISEW) in an influential appendix to their book, *For the*

[1] We would like to thank John Nevile and Max Neutze for comments on a draft version, Phan Dinh The for excellent research assistance and Noel Semple for editorial assistance. Financial support for this work has been provided by the Oikoumene Foundation, the CSIRO's Division of Wildlife and Ecology and the National Citizenship Project. Officers of the Australian Bureau of Statistics have been very helpful in providing advice on data.

[2] GDP is defined as the total monetary value of final goods and services produced in a country in a year. It can also be measured by the total value added at each stage of production or by the payments to the factors of production used to produce goods and services. GNP is defined as the total value of wages, rent, interest and profits (including depreciation and indirect taxes) of a nation's residents. Unlike GDP, GNP includes returns on overseas investments and excludes dividends and interest accruing in Australia to foreign capital.

Common Good (1990). The Daly and Cobb index has led to a lively debate on a series of methodological and measurement issues (much of which is presented in Cobb and Cobb 1994), and construction of similar indexes for several other countries.[3] These later efforts have placed a particular emphasis on accounting for environmental costs in the new measure of welfare. The initial Daly and Cobb index for the USA has been refined and developed by Cobb, Halstead and Rowe (1995) and renamed the Genuine Progress Indicator (GPI), the name adopted for the Australian index.

Construction of the GPI is based on the recognition that we do not live in an economy but in a society, and that the society itself is embedded in a natural environment. The GPI does not claim to be a perfect, or even an adequate, indicator of changes in national well-being; it claims only to be a better – and possibly a much better – indicator than GDP. We now explore these issues in the context of describing the methodological approach of the Australian GPI.

[3] Including the UK (Jackson and Marks 1994), Germany (Diefenbacher 1994) and Sweden (Jackson and Stymne 1996).

2. Methodological issues

2.1 The broad approach

The methodological foundations of the GPI have not previously been clearly laid out. This is partly because the GPI attempts to incorporate into a single measure a number of conceptually disparate impacts on well-being. It combines impacts that derive from changes in the natural environment and in social conditions, and it incorporates impacts due to both changes in flows and changes in stocks.

The key to understanding the attempts to develop the GPI lies in the notion of sustainability. The best starting point is John Hicks' 1939 definition of income. What is now known as 'Hicksian income' is defined as the maximum amount that a person or a nation could consume over some time period and still be as well off at the end of the period as at the beginning (Hicks 1946: 172).[4] Thus income is maximum *sustainable* consumption. Sustaining consumption over a given period depends on maintaining the productive potential of the capital stocks that are needed to generate the flow of goods and services that are consumed.

The GPI takes this idea and sets itself two tasks:

1. to define and measure 'consumption' in a way that provides a better approximation of actual well-being than the simple measure of marketed goods and services that appears in the national accounts; and

2. to account for the sustainability of consumption by incorporating measures of changes in the value of capital stocks.

Taking account of these two classes of influence on welfare over time, we may end up with a situation in which GDP is increasing while consumption (more broadly defined) is rising or falling, and while capital stocks are growing or declining.

The GPI combines changes in the value of stocks and the values of flows of current consumption. Consistent with the definition of Hicksian income, capital stocks perform two functions in the GPI method of measuring changes in welfare – they yield an annual flow of services and they contribute to the sustainability or otherwise of levels of consumption in the future. In order to prevent the depreciation or depletion of capital stocks a portion of current consumption needs to be 'set aside' to replenish the stocks. The implication of this is that, unlike the way in which changes in GDP are used, year-on-year changes in the GPI are not very meaningful. The purpose of the GPI is to illustrate trends over time.

We now look more closely at the two tasks that the GPI sets itself and then consider some of the further methodological issues it gives rise to.

2.2 Measuring 'consumption' more comprehensively

For individuals or households, consumption may be defined as annual flows of marketed and non-marketed goods and services. Perhaps the biggest category of non-marketed goods and

[4] Hicks also wrote that 'the practical purpose of income is to serve as a guide for prudent conduct' (Hicks 1946: 172), a comment that has particular relevance for today's concern with ecological sustainability.

services comprises those produced in the home by unpaid household work. Non-marketed goods and services also include services provided by the natural environment, such as the aesthetic and recreational services of old-growth forests and the health-sustaining properties of clean air.

A more comprehensive definition of consumption that takes account of non-marketed goods and services is particularly important because measured GDP growth may reflect nothing more than the transfer of activity from the non-market to the market sector, a problem long recognised in the development literature. This is most apparent in the case of household work, but applies equally to any other 'free' service. Just as, in the well-known observation, GDP declines 'if a man marries his housekeeper', GDP rises if an entrance fee is levied on visits to a national park or a family decides to eat out more often.

Consumption includes negative flows or 'bads'. Some monetary expenditures by final consumers – which are therefore included as expenditures in GDP – represent not additions to welfare but attempts to offset some change in social, environmental or individual circumstances which is causing a decline in welfare. These are known as defensive expenditures and are deducted from the value of personal consumption expenditure which provides the starting point of the GPI.

These observations apply to consumption by individuals. At a national level it is important to take account of differences in the welfare impact of consumption between households or individuals. One of the most frequently heard criticisms of the use of GDP growth as a measure of national welfare is that it assumes that an extra $1 million of consumption by wealthy households has the same impact on national welfare as an extra $1 million of consumption by impoverished households. The GPI rejects this assumption and adjusts consumption flows by a measure of income distribution.

The GPI assumes that personal consumption spending by individuals on marketed goods and services is the major component of welfare and that an increase in this spending represents, *ceteris paribus*, a corresponding increase in welfare. There is a large literature critical of the assumption that there is a close relationship between changes in consumption spending and changes in individual welfare (see e.g. Dodds 1997). Many studies have shown that, at least beyond a certain level of income, perceived well-being depends more on the level of one's income relative to other people's incomes, or to previous or expected levels, than on absolute levels.[5] But the purpose of the GPI is to demonstrate that, even using conventional economic methods, a more comprehensive attempt to account for changes in welfare may show large deviations from GDP over time. Consequently, we adopt the assumption that increases in personal consumption (adjusted for the distribution of income) reflect increases in welfare.

It is appropriate at this point to put to rest a common misunderstanding about the GPI. The procedure does not arbitrarily assign 'weights' to each component before adding them up to arrive at the final index. The GPI includes only variables that can be measured in monetary terms. Thus, while the selection of measurement method will influence the dollar estimates for each component, the 'weights' look after themselves in the simple process of aggregating the various dollar values.

2.3 Accounting for changes in the value of capital stocks

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[5] For a formal treatment of the roles of relative incomes, aspirations and environmental quality in welfare see Ng and Wang (1993).

Sustaining levels of consumption requires that the productive potential of capital stocks be maintained. Capital stocks can be divided into five forms which we discuss in turn. While GDP accounts for changes in none of them, the GPI attempts to incorporate changes in the value of the first three.

Built capital This covers the stocks of physical machinery, buildings and infrastructure that are essential to sustaining levels of GDP. These stocks deteriorate and a portion of income must be set aside each year to invest in them to maintain and improve their productive potential. The GPI adjusts consumption spending to take account of net capital growth which, if positive, adds to sustainable economic welfare.

Financial assets A nation's ability to sustain investment in built capital assets is diminished if it is accumulating foreign debts, since some part of future income must be devoted to repaying the debts. If those loans are being invested productively then future income will be higher and it will be possible to repay the debts without additional burden. To the extent that foreign debt has been invested productively in the past, current consumption will be higher. The GPI adjusts consumption spending to account for net foreign liabilities.

Natural capital Maintaining the stocks of natural capital is essential to sustaining consumption in the future, especially when consumption is defined more broadly. These stocks take two forms. The first are stocks of renewable and non-renewable resources used as inputs in production, such as minerals, fossil fuels and soils. The second take the form of waste sinks which are provided by the natural environment and are essential for dissipating waste products so that they do not represent a danger to humans. The GPI takes account of the depletion of natural capital. However there are some difficult methodological issues concerning the substitutability of built for natural capital that are discussed in the next section.

Human capital This represents the accumulation of health, skills, knowledge and experience in humans that makes them more productive than brute labourers. Technology is partly embodied in humans. The GPI does not account for human capital because of the conceptual and measurement difficulties involved. If it did, the GPI would be adjusted to account not for annual investments in human capital but for the annual services provided by the stock of human capital. This is an area for future work.

Social capital A nation that possesses sound and stable political, legal and commercial institutions and cohesive, supportive and trusting communities will be in a better position to generate flows of goods and services than one that does not. However, this form of 'capital' is difficult to define precisely and to measure and is thus excluded from the GPI.

2.4 Substitutability among capital assets

The depletion of one form of capital does not represent a decline in sustainable consumption if other forms of capital are accumulating and can be substituted for the disappearing asset. Thus the issue of substitutability within and between these classes of assets is critical. For instance, the run-down in physical capital is not necessarily a problem if financial wealth that could be used to rebuild it (or could be used to invest in assets in other countries) is being accumulated outside of the country.

More controversially, the run-down of one type of natural asset will not necessarily impose a cost if built capital or another type of natural asset can perform, at the same or similar cost, the same functions. The question of the degree of substitutability of built for natural capital is perhaps the most strongly contested issue in the economics of the environment. We have taken the view that for three classes of natural assets perfect substitutability between built and natural assets is not a valid assumption. These classes are:

1. certain natural resources that are irreplaceable and form essential inputs to continued productive activity – soils and supplies of fresh water are examples;

2. waste sinks, i.e. those components of the natural environment which absorb or process wastes and render them benign, particularly the atmosphere (covering the climate system and the ozone layer) and the oceans; and

3. assets whose services are consumed directly by final consumers and which are valuable because of their unique natural features – old-growth forests and the Great Barrier Reef are examples.

In addition to these, there may be some natural resources for which there are, or probably will be, substitutes, but for which the substitutes are likely to be significantly more expensive. Fossil fuel based energy is the most pertinent category here. Energy is essential for economic activity, yet the evidence (discussed under Column T in Section 3 below) suggests that the market for energy may not adequately reflect the likely scarcity of fossil fuels (especially oil and natural gas).

The next question is that of the valuation methods to be used. To what extent does a run-down in this year's stock of capital diminish this year's consumption? If an irreplaceable capital asset is depleted by $1 million in a year, should we deduct that amount from the actual income/consumption to obtain sustainable income? Since the maintenance of the capital stock would require that $1 million be diverted from current income, the answer is 'yes'.

In the case of irreplaceable assets (such as soil and old-growth forests), any decline in the capital stock in one year will generate not only a consumption loss in that year but a stream of future losses, so that the cumulative losses must be taken into account.

2.5 The treatment of public spending

The base for the original and subsequent GPIs has been personal consumption (private final consumption expenditure). Various adjustments are made to personal consumption to arrive at the GPI. In the national accounts, the difference between personal consumption and expenditure on GDP comprise three principal components: public final consumption expenditure, gross fixed capital expenditure (private and public) and exports less imports.[6] In the GPI, trade effects are dealt with under 'Net foreign lending' (Column Y) and capital spending (public and private) is dealt with under 'Net capital growth' (Column X) and 'Services of public capital' (Column J).[7]

How is public spending treated in the GPI? The GPI could be constructed either by beginning with expenditure on GDP and deducting items of public spending that do not contribute to

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[6] GDP also includes changes in stocks, but since they more or less balance out over time, changes in stocks are not considered in the GPI.

[7] An additional accounting issue is associated with indirect taxation. Indirect taxes increase prices and thus personal consumption expenditure. If market prices reflect the full value of the goods and services to consumers because that is what they are willing to pay for them, then the publicly provided goods and services funded by indirect taxes are a bonus. We therefore simply need to assess the extent to which the public services funded by indirect taxes add to welfare.

welfare (i.e. items that are defensive expenditures) or by beginning with personal consumption and adding items of public spending that do contribute to welfare. The latter route has become standard. In principle each method will result in the same index. However, in practice it makes quite a difference to be asking which items of public expenditure add to welfare as opposed to which items do not add to welfare. The decision to assume that public services are 'guilty until proven innocent' seems to reflect a peculiarly American suspicion of government. The Australian GPI breaks with tradition by assuming that each component of public spending adds to welfare unless we argue otherwise and deduct it.

While the details are discussed under Column D below, some discussion of the treatment of public spending on health and education is warranted here. In principle, the appropriate way to treat spending on education (and perhaps some aspects of health) would be as an investment in the stock of human capital, reflected in increased earning ability. Accretions in the net stock of human capital would add to sustainable economic welfare, just as net capital growth does. However, despite its apparent importance to economic sustainability, for methodological and measurement reasons human capital has to date been excluded from the GPI.[8]

With the exclusion of investment in human capital from the GPI, expenditures on health and education are counted only to the extent that they can be construed as *consumption*, that is, they augment welfare in the year of the expenditure. Public spending on primary and secondary education is assumed to be investment in human capital. The Swedish and UK GPIs and the Daly and Cobb index count half of expenditure on further education as contributing to consumption because that part of it may be considered to be undertaken purely for enjoyment. We adopt the same, somewhat arbitrary, set of assumptions here.

On the other hand, some part of spending on health and education can be regarded as defensive. Daly and Cobb (1990) argue that some expenditure on education is undertaken only to protect or improve people's relative position in the labour market rather than to add to the overall productive potential of the stock of human capital. In the case of health spending, the practice has been to assume that half of public spending can be regarded as non-defensive and therefore a net contribution to welfare. This assumption is also adopted for the Australian GPI.

2.6 The treatment of consumer durables

An established set of items and valuation procedures is now used in the international literature on GPIs. In addition to the treatment of public spending discussed in Section 2.5 above, the Australian version introduces a number of variations. One is the treatment of consumer durables.

Each year a portion of consumer spending is devoted to consumer durables. Such goods, which by definition last for more than a year, provide increases in welfare over their lifetimes rather than just in the year of purchase. Thus this portion of consumer spending is a form of capital investment. Other GPIs have corrected for this by deducting spending on consumer

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[8] See Cobb and Cobb (1994: 261, 279). These authors question the assumption that expenditure on education contributes to the stock of human capital.

durables from personal consumption and adding the estimate of the flow of services each year from the net stock of consumer durables.[9]

The flow of services from consumer durables is made up of two components. The first is the depreciation charges calculated using an appropriate depreciation rate (usually straight line depreciation based on assumed lifetimes for each type of durable good). The second is an interest charge on the capital tied up in the current value of the stock of consumer durables. This is designed to reflect the opportunity cost of capital tied up in consumer durables each year (Jackson and Stymne 1996: 19).

These adjustments to consumer expenditure seem to us to be unnecessary. The first component, that relating to the flow of services of the goods, is effectively a smoothing device to eliminate the effects of the lumpiness of consumer spending on durables. The welfare gain from money spent in a year on durables is experienced in full in subsequent years until the goods are scrapped. The only conceptual benefit of deducting spending and adding in the flow of services may be in trying to estimate the effects of changes in product lifetimes to account for inbuilt obsolescence or declining product quality. However, the relationship between these and prices paid is not at all clear. It would be difficult to maintain that prices paid were 'excessive' for products that had shorter life-spans. Moreover, the life-span of the major consumer durable, vehicles, has been increasing in Australia over the last 20 years (BTCE 1996).

The second component – and the one that results in a net reduction in the GPI calculated for other countries due to their treatment of consumer durables – is the interest component. When consumers decide to purchase a capital item, it is reasonable to assume that their decision reflects an assessment of the effects on their welfare over time, including any forgone interest on money spent. Deducting an interest component therefore seems illegitimate.

If these arguments apply to consumer durables, why do the same arguments not also apply to the capital stocks of firms and public infrastructure? In other words, why not count only current expenditures on capital stocks and infrastructure? The reason lies in the idea of sustainability, which requires that each generation leaves the capital stock in at least as good a shape as when it inherited the stock. Whereas consumer durables are consumed by the households that purchase them, the nation's capital stocks, especially buildings and infrastructure, are passed on. It is quite conceivable for one generation to 'eat its capital', running down the stock of capital and thereby reducing the opportunity for future generations to generate income. Therefore we need to take account of changes in the value of capital stocks in the GPI.

2.7 Depletion of non-renewable natural resources

From an environmental point of view, depletion of non-renewable natural resources is a crucial issue, and estimates of the value of this depletion are dominating factors in previous GPIs. However, in estimating the likely economic costs of depletion of non-renewables it matters a great deal which non-renewables we have in mind. We need to distinguish between 'critical capital', i.e., assets that are irreplaceable, and assets for which substitutes are likely to be found at similar cost to those being depleted.

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9 Note that privately owned housing is not classed as a form of consumer durable. Consumer spending on housing is incorporated into the national accounts through the estimated imputed rent for owner-occupied homes.

Other GPIs, led by Cobb and Cobb (1994), have costed the depletion of fuel resources only. The US GPI used a replacement value for fossil fuel resources 'designed to reflect the cost of replacing each barrel of oil equivalent of energy consumed with renewable energy resources' (Jackson and Marks 1994: 23). On this basis an arbitrary, and very high, unit cost of a barrel of oil equivalent has been assigned, and the resulting estimate of the costs of depletion of non-renewables has been one of the largest components of the GPI – 27% of the 1994 value of consumer spending in the US index (Cobb, Halstead and Rowe 1995) and 33% in the Swedish case. We find these figures implausible for reasons explained under Column T.

2.8 Defensive expenditures

Whereas GDP counts them as additions to output, the GPI deducts defensive expenditures undertaken by consumers and governments because, by definition, they are undertaken to offset some decline in social welfare. One issue that has not been canvassed to date is the question of the relationship between economic growth and defensive expenditure. If defensive expenditures are made to offset the effects of something that is unrelated to the growth process (i.e. economic activity captured in the national accounts) is it legitimate to deduct these expenditures in the GPI?

In the GPI, defensive expenditures are deducted from private and public consumption expenditure as the latter should unambiguously confer welfare benefits on citizens. Thus, if some part of consumption expenditure does not represent an addition to welfare, but is undertaken to offset some other impact, it is quite legitimate to deduct it irrespective of whether the decline can be attributed to the growth process itself.

In principle, most defensive expenditures are reactions to a decline in the value of the stock of social, human or natural capital, as long as they are broadly defined. This applies to private defensive expenditures on health and personal security and public defensive expenditure on social welfare. If we could adequately account for changes in stocks of human and social capital then it would not be necessary to deduct defensive spending.[10]

A more difficult question is that of how much of a given expenditure is defensive and how much makes a net contribution to welfare. This is particularly relevant to some public expenditures, on social security and law and order for instance. An increase in spending on policing, courts and prisons due to a crime wave is clearly defensive, yet some basic level of spending on crime prevention and punishment is essential and makes a large contribution to national well-being. Ultimately judgements about how much spending is defensive and how much makes a positive contribution to welfare will be somewhat arbitrary.

Note finally that the US GPI (Cobb, Halstead and Rowe 1995) treats household pollution control expenditure as a defensive expenditure. This is legitimate. However, in the Australian GPI we do not include this item due to lack of data.

2.9 Time accounting

The Australian GPI attempts a more systematic approach to valuing time than previous GPIs. The value of time is a very important aspect of various components of the GPI, including the value of household and community work and the costs of unemployment and of overwork. In the Australian GPI we have adopted the principle that the value of time devoted to voluntary activities counts as a positive in the GPI and the value of time engaged in involuntary

[10] We are indebted to Max Neutze for this point.

activities counts as a negative. The following activities contribute to our welfare. They all have the characteristic that they are 'voluntary' – that is, we could choose not to do them or to devote less time to them:

- paid work, except the involuntary component referred to below as 'overwork';
- household work;
- community work; and
- leisure activities.

The following activities diminish welfare and, as such, impose costs on the community:

- involuntary leisure, i.e. the times when we are unemployed but want to be employed; and
- involuntary work, i.e. the times when we are doing paid work but would prefer not to be.

The distribution of these activities varies between different groups inside and outside the labour force, partly by choice and partly involuntarily. For our purposes, the groups in question are the fully employed full-time workers (who may be overworked), fully unemployed workers, underemployed part-time workers, fully employed part-time workers, and those outside the labour force. A notional distribution of activities among these groups is illustrated in Figure 1. It represents the allocation of time between activities for the 14 hours of an average weekday when we are not occupied by sleep or personal care.

In Figure 1, the activities that add to welfare have paler patterns while those that detract from welfare have darker patterns. How is each of these treated in the GPI? The values of household work and community work are assessed directly (Column E). The value of paid work is included in the GPI by way of the starting point of the index – consumer spending (Column A). The rationale is that people take on paid employment in order to earn money to spend on consumer goods.[11] This is not a good assumption since work serves a variety of personal and social functions beyond income generation, but for the purposes of the GPI there is no alternative.

The value of leisure is not included in the Australian GPI. This departs from the US GPI (Cobb, Halstead and Rowe 1995) but is consistent with the UK and Swedish GPIs (Jackson and Marks, 1994; Jackson and Stymne 1996). Cobb, Halstead and Rowe justify their inclusion of loss of leisure time by arguing that working hours in the USA have been getting longer and that this represents an involuntary loss of leisure. To measure this cost they deduct from the GPI the value of the leisure hours lost relative to leisure enjoyed in 1969, the year of greatest leisure since 1950. While the Australian GPI does not include an estimate of the value of lost leisure time, it does include the obverse – an estimate of the costs of overwork. The costs of overwork are discussed below (Column H). This leaves us with the costs of unemployment and underemployment which are included in the Australia GPI (Columns F and G).

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[11] They may, of course, save a part of their income. This saving, however, can be regarded as deferred consumption.

Figure 1 Notional allocation of time (hours per weekday)

3. The Australian GPI column by column

The full list of components of the Australian GPI appears in Table 1 along with an indication of which components are added to, and which are deducted from, the index and a brief description of the indicator. The references to columns below refer to Appendix Table 1, which contains the full set of final estimates used to construct the Australian GPI.

Year

The index has been calculated for the period 1949-50 to 1995-96. The financial year has been used as a basis for calculations because the national accounts which provide much of the data are presented that way. For simplicity of presentation, however, the years are identified only by a single date. Thus for the financial year 1995-96 we simply write 1996. All components of the GPI are converted to 1989-90 constant prices using appropriate deflators.

Column A Personal consumption

This is measured by private final consumption expenditure at constant 1989-90 prices as compiled by the Australian Bureau of Statistics (ABS). The series for the period 1949-50 to 1995-96 has been compiled and adjusted for inflation by the Reserve Bank of Australia (RBA 1996: Table 5.2a).[12] The RBA has deflated using the relevant implicit price deflator for expenditure on GDP (RBA 1996: Table 5.6a).

Column B Income distribution

The standard measures of welfare, GDP and GNP, treat each additional dollar of expenditure as an equal contribution to national well-being irrespective of who spends it. Yet most people would agree that an extra dollar to a poor family will increase national welfare by more than an extra dollar to a wealthy family. Economics recognises this in the notion of the diminishing marginal utility of income.

In the GPI, personal consumption spending is adjusted for the distribution of income. In the US and UK GPIs inclusion of a measure of changes in distributional inequality has been a major factor explaining the divergence of the estimated GPI from real GDP per capita. In the Swedish GPI it has had the opposite effect.

Measurement of changes in distributional equality is often difficult; it is particularly awkward when an index covering the period 1950 to 1996 is required since no robust data are available prior to the 1979-80. Saunders (1993) summarises the evidence on distribution since then.

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[12] These data have been updated on disk for the year 1995-96.

Table 1 Components of the Australian GPI

	Column name		Description of indicator
A	Personal consumption	+	Private final consumption expenditure
B	Income distribution		Share of lowest quintile in total income
C	Weighted personal consumption		Personal consumption weighted by index of changing income distribution
D	Public consumption expenditure (non-defensive)	+	Value of non-defensive government consumption spending
E	Value of household and community work	+	Hours of household and community work performed each year valued by the housekeeper replacement method
F	Costs of unemployment	–	Value of hours of idleness of the unemployed
G	Costs of underemployment	–	Value of hours of idleness of part-time employees who want to work full-time
H	Costs of overwork	–	Value of hours of work done involuntarily
I	Private defensive spending on health and education	–	Health and education spending that offsets declining conditions
J	Services of public capital	+	Contribution of public investment in non-defensive works (eg. roads)
K	Costs of commuting	–	Time spent commuting valued at opportunity cost
L	Costs of noise pollution	–	Excess noise levels valued by cost of reducing noise to acceptable level
M	Costs of transport accidents	–	Costs of repairs and pain and suffering
N	Costs of industrial accidents	–	Costs of pain and suffering etc.
O	Costs of irrigation water use	–	Damage to environment measured by the opportunity cost of environmental flows
P	Costs of urban water pollution	–	Damage to environment measured by the control cost of improving water quality
Q	Costs of air pollution	–	Damage to humans and environment from noxious emissions measuring mainly by health costs
R	Costs of land degradation	–	Costs to current and future generations from soil erosion etc. measured by forgone output
S	Costs of loss of native forests	–	Environmental values denied to future generations measured by willingness to pay
T	Costs of depletion of non-renewable energy resources	–	Costs of shifting from oil and gas to renewables
U	Costs of climate change	–	Annual emissions valued by future impacts on humans and environment
V	Costs of ozone depletion	–	Annual emissions valued by future impacts on humans and environment

W	Costs of crime	–	Measured by property losses and household spending on crime prevention
X	Net capital growth	+	Growth in net capital stocks per worker
Y	Net foreign lending	–	Change in net foreign liabilities

The only available source of information that can provide a measure of income distribution is the annual publication *Taxation Statistics* produced by the Australian Taxation Office.[13] The procedure used for the GPI has been to measure income distribution by the share of total income received by the bottom quintile of taxpayers. Using tax data carries problems for estimating changes in distribution. The main ones are as follows.

- Many poor households are not taxpayers, so our measure will be biased in a way that suggests more equality than is the case.

- Tax statistics are based on income statistics which exclude social security payments and public housing, factors that can significantly alter the living standards of poorer households.

- Tax statistics refer to individuals rather than households. Second-income earners in households with a high primary income earner will appear to be poor.

- The tax statistics are sensitive to changes in the tax structure, including the definition of taxable income (such as fringe benefits and capital gains) and tax rates.

- Tax statistics may be influenced by changes in the labour market. For example, increases in part-time work may take low income earners from just below to just above the tax threshold so that people who once did not appear in the tax statistics may subsequently do so giving the impression of an increase in inequality.[14]

The results of this new index of income distribution in Australia are reported in Figure 2 which shows that income distribution remained largely unchanged from the early 1950s through to the early 1970s. There was a sharp improvement in income equality from 1972 to 1979. Inequality worsened from 1980 until around 1989, at which point it levelled out and has since remained stable at a level a little worse than it was through the 1950s and 1960s. These trends receive some corroboration from other studies which indicate that:

- income inequality in Australia was about the same at the end of the 1980s as it was in the early 1940s; and

- distribution worsened in the 1980s (Saunders 1993).

Our new measure confirms that distribution improved in the 1970s.

Despite this corroboration, the new measure of income inequality has several serious flaws and should be regarded with caution. It was developed because of the absence of any alternative. In the final section of this paper, the results of the GPI calculations are presented both with and without the impact of estimated changes in distribution so that the effect of the new estimate can be seen.

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[13] Prior to 1958-59 the source of data is Commissioner of Taxation Report (Australian Taxation Office).

[14] We are indebted to Peter Saunders for these observations.

Figure 2 Income distribution in Australia 1950-1996 (share of lowest quintile, 1950=100)

Column C Weighted personal consumption

This column weights personal consumption in Column A by the index of income distribution in Column B.

Column D Public consumption expenditure (non-defensive)

As discussed in Section 2.5 above, some components of public consumption expenditure are deducted, either because they contribute to capital stocks (and are considered under Column J) or because they are defensive expenditures.

Public sector outlays are divided by function into the following categories: general government services, defence, public order and safety, education, health, social security and welfare, housing and community amenities, recreation and culture, transport and communication, and other (RBA 1996: Table 2.12). These outlays include capital and recurrent expenditure. Some part of the recurrent expenditure is comprised of transfer payments, which are excluded from GDP.[15]

Clearly, some government functions do make a net contribution to national well-being. What are they? Expenditure on *defence, public order and safety,* and *social security* (which account for around 35% of total expenditure) are best regarded as for the most part defensive expenditures. Although a base level of outlays undoubtedly contributes to national well-being, increases in these expenditures are generally responses to a deterioration in national well-being – increasing insecurity or rising unemployment. The question is thus whether decisions to increase spending are made in order to provide a net increase in levels of well-being or are made to offset declining levels of well-being. This is almost impossible to determine, but we feel that treating these expenditures as mostly defensive is more justifiable than not, particularly given rising levels of perceived insecurity and rising levels of unemployment since the 1970s. It is assumed that 25% of spending on *defence* and *public order and safety* advances well-being rather than offsets increasing insecurity. The great bulk of outlays on *social security* are in the form of transfer payments, which already appear under personal consumption.

Expenditure on *housing and community amenities* and *transport and communication* (around 11% of total outlays) are in large measure capital spending (adding to both physical and social capital) and are recorded in the GPI under 'Net capital growth' (Column X) and 'Services of public capital' (Column J) or are excluded from the index. However we include 50% of spending on transport and communications as consumption.

Expenditure on *education* and *health* account for around 27% of total outlays. The first issue to consider is whether expenditures on education and health contribute to current consumption (and add to well-being experienced at the time of the expenditure) or represent accumulation of human and social capital. To the extent that they add to stocks of human capital we should in principle count, not the annual expenditures, but the services yielded by the stocks. Since the GPI does not account for stocks of human and social capital we exclude the value of their services.

[15] One can think of transfer payments being deducted (through taxation) from the income, and thus the expenditure, of some final consumers and being added to the income and thus expenditure of other final consumers.

To the extent that spending on education and health can be considered to be consumption spending, that is, adding to annual welfare, we need to deduct from the GPI the share of that spending that is defensive. To what extent do increases in consumption spending on health and education make a net addition to well-being rather than compensate for declining well-being due to other factors? Consistent with the treatment of private spending on health and education (Column I), essentially we count most *public education* spending as investment in human capital (and therefore excluded from the index) while public *health* spending is treated as consumption spending, but 50% of it is considered to be defensive (and is thus deducted).

Spending on *recreation and culture* is regarded as wholly consumptive and wholly non-defensive and is therefore fully included in the GPI.

In the case of spending on *general government services*, these expenditures cover general administrative costs of government – including basic functions such as tax collection and policy advice – that are essential for good government. However, part of this expenditure is devoted to servicing defensive expenditures and should therefore not be included. We assume that 50% of spending on general government services makes a positive contribution to welfare rather than simply off-setting falling conditions.[16]

Column E Value of household and community work

Unpaid household work has always made a large contribution to human welfare. Indeed, the history of industrialisation has been the history of transferring activities out of the household sector into the market sector. This trend continues. With changes in the workforce – and in particular the entry of women into paid labour – more tasks that were previously performed unpaid and in the home are now purchased in the market. These include housekeeping, take-away food, restaurant meals, gardening services and paid childcare. Transfers from the household to the market sector are recorded as increases in GDP, but this exaggerates the true increase in well-being. The GPI is therefore adjusted to account for the value of household labour in Australia.

The question of what to include in household work involves some difficult choices. The key question is which activities in the household are properly considered to produce household goods and services rather than to contribute to leisure. Researchers in this area have generally adopted the rule, developed by Margaret Reid in 1934, that household work includes those activities which 'might be replaced by market goods or paid services, if circumstances such as income, market conditions and personal inclinations permit the service being delegated to someone outside the household group' (quoted in ABS 1994).

Thus meal preparation is work while consumption of meals is not. Shopping for household items is work but window shopping is not. Some elements of childcare involving parental love cannot be bought in the marketplace. Under the heading 'household work' Jackson and Stymne's (1996) Swedish GPI includes childcare, housework, odd jobs and shopping for necessities but excludes recreational shopping, travel for shopping and gardening. The latter are regarded as essentially leisure activities.

The source for data on amounts of household and community work in Australia is Ironmonger (1994), which provides data for the years 1974, 1987 and 1992, the only years for which comprehensive data on household work in Australia are available. Ironmonger chooses to

[16] The *other* category (RBA 1996: Table 2.12) is made up mostly of interest payments and is not included here.

include all forms of household work, including all hours devoted to shopping, childcare, gardening and voluntary community work. Table 2 records Ironmonger's estimates and converts them to hours per person per week for the adult population.

Table 2 Hours of household and community work in Australia

Year	*1974*	*1987*	*1992*
Total hours per week (million)	249	322	380
Population 15+ (million)	9.899	12.577	13.679
Hours per person per week	25.15	26.60	27.78

Source: Derived from Ironmonger (1994)

To cover the GPI study period, estimates of total hours of household work per annum are derived from interpolation and extrapolation of the estimates in Table 2 for hours per person per week and from changes in the population over 15. For the years between 1974 and 1992 we interpolate linearly. For the years after 1992 we assume that weekly hours remain constant at 27.78. For the years prior to 1974 the evidence is thin, but as it seems likely that weekly hours declined slightly in the 1950s and 1960s we assume that they declined in a secular trend from 28 hours per person per week in 1950 (D. Ironmonger, *pers. comm.*). The adult population is from RBA (1996 Table 4.2).

There is a good case for arguing that the comprehensiveness of Ironmonger's definition overstates what may reasonably be regarded as 'household work' under the definition given by Reid. GPIs for other countries have excluded certain activities from their definitions of household work because they are better defined as leisure activities which confer value on the household through the activity of performing them rather than by way of the product at the end. It would be difficult to argue that parents regard an hour of looking after their own children as in all cases equivalent to an hour of paid childcare. Some gardening (whether for ornamental or vegetable reasons) and some household repairs may also fall into this category (the shed is a sanctuary as well as a workplace), as would window shopping. In constructing the Swedish GPI, Jackson and Stymne (1996) exclude gardening and recreational shopping. They also omit travel, arguing that travel for shopping does not represent an increase in welfare.[17] Indeed, elsewhere in the GPI (Column K) we *deduct* the costs of commuting, regarding them as defensive expenditures. The same exclusions have been made in constructing the GPI for the UK (Jackson and Marks 1994).

The Australian GPI excludes 100% of gardening, lawn care and pool care, and 50% of home maintenance, pet care, shopping and associated travel and childcare. According to the breakdown of household work by activity in ABS (1994: Table B) these proportions account for around 30% of total household work in 1992. Assuming that this proportion remained constant from 1950 to 1996 (a strong assumption), we adjust our estimate of the value of household labour downward by 30%.

[17] They conclude that the 'average time spent in domestic labour fell by over 15% from about 23 hours per week in 1963 to about 19 hours in 1984/85' and remained stable thereafter (Jackson and Stymne 1996: 16).

The value of household and community work is derived from the number of hours worked per annum and a 'shadow wage rate' representing the value of an hour of work. There are a number of ways of deriving such a shadow wage rate. They are reviewed and applied to 1992 data in ABS (1994). We have adopted the 'housekeeper replacement cost method', derived by applying the wage rate for housekeepers to the hours worked.

Note that we have valued household work by the real wage rate of housekeepers for each relevant year (sourced from ABS 1992). There is a dispute in the literature over whether this is the correct method. The US GPI assumes a constant real wage applied over the whole period, on the argument that the real contribution of household activities to household welfare has not changed. However this would see the value of household work decline substantially over time relative to other activities (especially paid work), for which there appears to be little justification. The use of the housekeeper replacement cost method introduces an element of opportunity cost into the valuation, without going the whole way and valuing household work at the forgone wage of the householder. Although there is scope for debate, the choice here of a variable real shadow wage rate seems to be a reasonable one.

Column F Costs of unemployment

The costs of unemployment are several, and in this component of the GPI we need to be particularly mindful of the dangers of double counting. The costs of unemployment are the following:[18]

1. loss of output in the economy due to underutilisation of factors of production;

2. loss of human capital due to declines in levels of skills, especially as a result of long-term unemployment;

3. declining levels of health and increasing suicide among the unemployed;

4. increasing levels of crime associated with higher unemployment;

5. increasing rates of family breakdown;

6. psychological impacts on the families of unemployed people; and

7. trauma, stress and loss of self-esteem associated with being unemployed.

The first two of these factors, the resource costs of unemployment, are already reflected in the GPI through personal consumption and public consumption (via lower tax revenues). The next two (health and crime) are partly accounted for elsewhere in the index, under public and private defensive spending on health (Columns D and I) and the costs of crime (Column W).

This leaves us with the last three factors, which might be characterised as the psychological costs of unemployment. Some of the evidence relating unemployment to various personal and social problems is reviewed in Junankar and Kapuscinski (1992). These effects are extremely difficult to measure in monetary terms. However they represent large costs in

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[18] Sometimes it is argued that these costs are partly offset by benefits, including a more efficient economy due to lower inflation and current account deficits, and increased leisure for the unemployed. The former is the subject of considerable debate among macroeconomists, and in any case the efficiency effects are recorded elsewhere in the GPI. It is doubtful that the unemployed count increased leisure as a benefit.

social and personal terms and should be taken into account in any attempt to assess changes in national well-being.

The US GPI assigns a value of US$8 (about A$10.80) to each hour of unemployment, but the rationale is opaque. The authors argue that an hour of involuntary leisure should be valued the same way, but with a negative sign, as an hour of forgone leisure (Cobb, Halstead and Rowe 1995: 23). Thus, if the unemployed derive benefits of leisure but are willing to give them up to obtain a job, the price of an hour of leisure might be seen as the 'willingness to pay' to obtain work (assuming that the wage received is compensation for the work actually performed).

Elsewhere in the Australian GPI we have used an assessment of the value of forgone leisure in measuring the time component of the costs of commuting. The Bureau of Transport and Communications Economics (BTCE 1996: 484) values a person-hour of travel time at $15.19 across major Australian cities in 1995-96. (In the same publication it also uses $9 per hour.)

Another method of obtaining a rough estimate of the monetary value of an hour of unemployment may be to consider the costs of attempting to overcome some of the psychological damage caused by unemployment. If an unemployed person decided to visit a counsellor once a week, the cost would be at least $50. On this basis (an admittedly crude one), the psychological costs of an hour of unemployment have a value of at least $1.25.

Thus we have a number of methods of evaluating the psychological costs of unemployment, and a range of estimates from $1.25 to $15.19. In the Australian GPI we adopt a middle figure of $8 per hour for 1995-96.

The next step is to apply this figure to the amount of unemployment over time. Only unemployment in excess of a rate of 1.7% is considered to be costly. This figure can be regarded as the rate of 'frictional' unemployment arising from the normal processes of job change in a full-employment economy. It is the approximate rate for most of the 1950s and 1960s. Thus unemployment that imposes a cost is estimated by adjusting the number unemployed by this rate. Under this definition, unemployment among those seeking full-time work does not start to impose a cost until 1972 (although according to Commonwealth Employment Service data the rate of unemployment exceeded 1.7% in the period 1961-1963 (RBA 1996)). Unemployment among those seeking part-time work began to impose a cost in 1965.

To calculate the number of unemployed hours we assume that an unemployed person seeking full-time work forgoes 40 hours of work each week while an unemployed person seeking part-time work forgoes 20 hours of work per week. (Note that the shortest average working week for full-time workers was 39.9 hours in 1982.)

However it is well-known that official unemployment statistics significantly underestimate the true level of unemployment, principally because of the discouraged worker effect. We therefore use estimates of the full 'labour underutilisation rate' to scale up the official levels of unemployment. Estimates of labour underutilisation are derived from Ross (1997).

Column G Costs of underemployment

Underemployed workers are defined as those who work part-time but would like to work full-time. We assume that these part-time workers work 20 hours per week but would like to work 40 hours. Note that in 1996 of those part-time workers looking for full-time work, 60%

worked for 20 hours or less, with the largest group working 6-10 hours per week (ABS *Labour Force*, Cat. No. 6204.0), so our assumption will tend to understate the costs of underemployment.

It would be unreasonable to assume that the cost of an hour of unemployment for a partly employed person is the same as that of an hour of unemployment for a wholly unemployed person. On the other hand, many part-time employees are employed in casual jobs for short periods. We therefore value an hour of unemployment for an underemployed person at half of the rate for a fully unemployed person, i.e. $4.

Column H Costs of overwork

Contrary to the post-war trend – which saw average working hours decline – in recent years full-time employees have been working longer hours each week. There is strong evidence that much of this additional work is involuntary (Australia Institute 1996). In other words, these workers would prefer to be engaged in other activities, mainly leisure or household work, during these hours.

This overwork imposes a cost on workers and their families. The cost of overwork in the GPI is measured by assessing the amount of involuntary work and applying the appropriate wage rate to the hours worked. The extent of overwork is estimated by totalling the hours worked each year per full-time worker over and above the annual hours worked by full-time workers in the year of lowest hours of work. That year was 1982 when full-time workers worked an average of 39.9 hours each week. In other words, we assume that when the downward trend in hours worked turned upward, it did so not because workers wanted to work longer but because they were forced to by changes in the labour market or by economic insecurity.

The data do not permit a detailed breakdown by occupation and wage rate so we assume that the value of an hour worked involuntarily is approximated by the average hourly wage rate. One difficulty with this is that some of the extra hours worked are paid at overtime rates. The additional payment might be seen as reflecting the additional cost in terms of leisure foregone. On the other hand, to count all of the value of involuntary work as a cost fails to account for the benefits workers obtain from the wages earned. However in 1995 two-thirds of overtime work was unpaid, so there would be no financial cost for not working these hours (ACIRRT 1996). In addition, it is not valid to assume that workers were induced to work extra time by employers offering an hourly wage just high enough to compensate for lost leisure. Most workers have no choice but to work longer because their jobs would be jeopardised if they refused. Thus the 'reservation wage' that would be required to induce them to work longer if they had a free choice may well by substantially higher than the wage they actually receive (where they receive any additional wage at all). Thus valuing overwork at the average wage rate does not seem to be an unreasonably approximation.

Column I Private defensive expenditure on health and education

Consistent with the approach taken with public spending on health and education, we count 50% of private spending on health and 50% of private spending on post-secondary education as defensive and deduct these amounts from the index (since these expenditures have been included in personal consumption).

Information on private spending on health and education are from ABS consumer expenditure data.

Column J Services of public capital

The discussion of this component should be considered in conjunction with the discussion of net capital growth in Column X. There we note that the services of private capital stocks are reflected in the national accounts through the prices paid by consumers for goods and services produced by firms using the capital. In the case of public capital stocks, where these stocks are owned by public trading enterprises which sell goods or services to consumers – such as electricity, gas, water and publicly owned housing – the services rendered each year by the capital are captured in the national accounts in consumption spending (directly in final consumption or indirectly to the extent that these items are purchased by firms as intermediate inputs).

This leaves us with the capital stocks owned by government and provided free of charge to the public. These stocks are covered more or less by the items described in the national accounts as general government capital stocks in the form of 'roads' and 'other non-dwelling construction' (ABS Cat. No. 5221.0 1994-95 Table 8). Over the period of the 1980s and first half of the 1990s, these items accounted for approximately 45% of total capital stock owned by general government and public enterprises.

However, the story does not end there. Some part of this capital stock will have been created to sustain various defensive expenditures discussed in Section 2.5 and Column D above. Thus their services to national welfare should be excluded from the GPI. Data for attributing capital investments by function are not available, so (bearing in mind that only 45% of public capital is owned by general government as opposed to public enterprises) we assume that the services of only 25% of publicly owned capital stocks should be added to the GPI. In other words, the benefits conferred by this public investment contribute to national welfare and have not been accounted for elsewhere in the GPI.

We must now ask how much this public capital contributes to national well-being each year. These forms of capital are assessed by the ABS as having life-spans of around 50 years (Walters and Dippelsman 1985), so, if we assume a straight-line depreciation function, these capital stocks contribute 2% of their value each year. Cobb, Halstead and Rowe (1995) argue that we should also include the opportunity cost of funds tied up in these fixed assets and apply an interest rate of 7.5%. A real interest rate of 5% is closer to the cost of capital for government, and is the one used here. This means that the community benefits each year to the tune of 7% of the non-defensive freely provided stock of public capital.

Note that all of the capital stock must be maintained to ensure that income flows are sustainable, including the part devoted to defensive purposes. In its absence, the welfare of future generations would decline.

Column K Costs of commuting

The costs of commuting can be divided into two components. The first is the costs associated with travel to work due to urban sprawl. In order to have the same quality of housing and private space at comparable prices, households have had to move further away from city centres where a large proportion of workers continue to work. These costs can be seen as the defensive expenditures aimed at maintaining a lifestyle.

The second component is the costs associated with urban congestion, i.e., the additional time and financial expense of travelling to work due to congestion on the roads. We will refer to the first as the costs of commuting and the second as the costs of congestion. Commuting costs are those associated with travelling to work even if all traffic were to run smoothly.

The financial costs associated with commuting and congestion are recorded in the national accounts as additions to GDP. Thus the financial and time costs incurred by consumers in getting to work are deducted from the GPI.

A number of studies have estimated the costs of congestion in Australia by comparing the additional vehicle costs and the travel time incurred by commuters due to traffic congestion. The BTCE (1995) estimates the costs of congestion in Australia at $5.164 billion per annum, while another estimate puts it at $5 billion per annum (ABS 1997: 121). The Victorian Transport Externalities Study (EPA 1994) puts the cost for Melbourne at $2.0 billion in 1991, suggesting a national figure in the order of $5-6 billion.

However some of these congestion costs fall on businesses rather than final consumers and are therefore intermediate input costs that are reflected in the national accounts through higher prices for goods and services. The Victorian study (EPA 1994) estimates that 70% of congestion costs fall on business and commercial vehicles. This is largely due to the fact that the value of time dominates the cost estimates and the value of a vehicle-hour is estimated at $6 for private cars, $33 for business cars and $13 for trucks. However a large share of the travel done in business vehicles is in fact commuting time by employees in company cars. These costs fall on commuters, in the form of erosion of leisure time, rather than on businesses. On the other hand, as they fall on commuters, the value of each hour is that for an individual rather than for a business. We will assume that two-thirds of the travel time spent in business cars (but none of the travel in other commercial vehicles) is expended by commuters, but that this time is valued at $6 per hour. This means that the overall estimate of congestion costs is reduced by 26% but the share that falls in private commuters increases to 50% We thus estimate the costs of congestion imposed on private commuters at $1.85 billion in 1991.

To this we must add the costs of commuting. In the absence of information on the amount of commuting time we will make the conservative assumption that the travel time (and financial expenses) of commuting to work on uncongested roads is equal to the addition travel time (and financial expenses) due to congestion, i.e. half of travel time is due to congestion. Thus we double our point estimate to obtain an estimate of the total costs of commuting (including congestion) in 1991 at $3.7 billion.

EPA (1994) indicates that congestion costs were rising at a rate of 8% per annum. Thus our point estimate (for 1991) of the costs of commuting and congestion is $3.7 billion, rising at 8% per annum thereafter. For years prior to 1991 we note that vehicle kilometres travelled by cars increased at a flat rate of around 4.6% per annum from 1971 to 1991 (ABS 1997: Table I.2). We will assume that the costs of commuting rose at a rate of 7% in the 1980s, 6% in the 1970s, 4% in the 1960s and 2% in the 1950s.

Column L Costs of noise pollution

Noise is an uncompensated cost imposed on people mostly as a result of increasing traffic volumes, especially heavy vehicles. The costs take the form of costs of building noise barriers along roads and in homes, and falling property values of homes as well as the loss of amenity.

Various point estimates are available for the costs of noise. They are summarised in ABS (1997: 120). A detailed study for Melbourne can be found in EPA (1994). The Interstate Commission estimated the cost of noise to be $534 million in 1990, but the NRMA estimated in 1991 that traffic noise in Sydney could be reduced so that all private houses would experience noise levels at close to the OECD recommended level of 57 dB at a cost of $750-880 million (ABS 1997: 120). This suggests a national figure of around $2.4 billion, the figure used in the GPI. A series is formed by indexing this number by vehicle kilometres travelled by trucks, buses and light commercial vehicles.

Column M Costs of transport accidents

A nation that has more accidents is worse off; yet additional economic activity generated by accidents is recorded as an addition to GDP. The classic case is the damage caused by the Exxon-Valdez oil spill disaster. In this section we account for the costs of transport accidents. In principle we should account for all accidents but, with the notable exception of industrial accidents evaluated in the next section, data limitations prevent this.

The monetary costs associated with transport accidents are defensive as they involve repairing damage to both property and humans. These costs, which are added to national income, should be deducted. Non-market costs include losses to victims and their families from pain and suffering. To the extent that monetary values can be assigned to these, they too are deducted from the GPI because they represent a decline in welfare. However, not all costs of accidents should be deducted as that would involve double counting. Thus lost earnings and medical expenses are already reflected in the national accounts and, in the case of health costs, have been dealt with elsewhere in the GPI.

A number of studies of the costs of transport accidents have been conducted by the the BTCE and the results are summarised in ABS (1997: 109-110). For 1993, the cost of road, air, rail and sea accidents in Australia amounted to $6.597 billion, of which $6.136 billion was due to road accidents. Excluding the costs of lost earnings and hospital, medical and rehabilitation costs,[19] the cost of accidents in 1993 was $4.858 billion.[20] Deflating by the price index for private final consumption, this is $4.428 in 1989-90 prices. To form a time series, we assume that the real cost per accident has varied with changes in real GDP. A consistent series on the number of accidents is not available as the definition changed in 1980, so we employ number of deaths as a proxy. This may be preferable because a large part of the costs of accidents are due to deaths and because the relationship between number of accidents and number of deaths has diverged in the early 1980s (Vamplew 1987: 174; ABS 1997: 106).

Column N Costs of industrial accidents

In Australia, up to 2700 people are killed each year through workplace accidents – more fatalities than on the roads. In addition, around 650 000 workers each year suffer a work-related injury (Industry Commission 1995: 9-10). The costs of these deaths and injuries are enormous. Excluding pain and suffering, work-related accidents are estimated to cost between $20 billion and $37 billion each year.[21]

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[19] The data also exclude costs associated with search and rescue, accident investigation and losses to non-victims.

[20] Made up of family and community losses ($0.629 billion), pain and suffering ($1.531 billion), vehicle damage ($2.064 billion) and insurance administration ($0.635 billion).

[21] The first figure is from the Industry Commission (1995: 17), the second from WorkSafe Australia (1994).

Some of these costs are reflected in the national accounts. The Industry Commission (1995: 18-19) divides the costs into three groups.

Costs borne by employers. These include workers' compensation, loss of productivity and additional overtime, damage to equipment and legal penalties. They amount to around 40% of total costs but are best regarded as 'intermediate inputs' that are reflected in prices paid by consumers and are thus already included in the GPI.

Costs borne by the community. These include social welfare payments, medical and health costs and loss of human capital and are estimated to account for 30% of the total. They are for the most part dealt with elsewhere in the GPI, in the treatment of public health spending and social security.

Costs borne by injured workers. These include loss of income, pain and suffering, loss of future earnings, medical costs, losses of leisure, self-esteem and social status, and costs imposed on family members. They are estimated to amount to about 30% of the total. While medical costs and loss of income are reflected elsewhere in the GPI, the other costs are not measured in the Industry Commission's estimate of $20 billion per annum. In the case of road accidents, these costs, along with family and community losses, amount to a third of the total.[22]

We therefore estimate that the costs of work-related injuries in 1992-93 was 30% of $20 billion, or $6 billion ($6.384 in 1989-90 prices). In the absence of historical data, this figure is indexed by the size of the labour force. It is also indexed by real GDP to reflect changes in the real cost of an accident.

Column O Costs of irrigation water use

The costs of water use measured here are those associated with environmental damage due to diversions of water for irrigation purposes from Australia's river systems, particularly the Murray-Darling Basin which accounts for 75% of irrigation water in Australia (ABS 1996a, Table 6.5.3). The costs of water pollution included in the next component (Column P) are those associated with waste water disposal in urban areas.

The environmental impacts of water diversions from Australia's rivers include:

- loss and degradation of habitat resulting in disturbance to flora and fauna;
- declining conservation and recreational values associated with riverine ecosystems;
- downstream impacts of salinisation on household water users; and
- downstream impacts on industrial and other agricultural water users.

The last-mentioned set of costs includes loss of forest growth and grazing productivity, and additional costs due to salt build-up in industrial boilers, reduced service life of pipes, fittings and machinery and the costs of softening and demineralising water. These are intermediate costs that will be reflected in the prices of final goods produced.

[22] Only a small proportion of work-related accidents are road accidents (Industry Commission 1994: J2), so double counting with the costs of transport accidents is minimal.

Downstream impacts of salinisation on households include reduced service lives of pipes, fittings and machinery, increased use of household cleaning products (soaps, detergents and water softeners), and reduction in yields of garden produce (River Murray Commission 1984). These require defensive expenditures that in principle should be deducted from the estimate of the GPI.

The only feasible way of estimating the environmental costs of water use and salinisation is by use of the control cost method. This involves estimating the loss in agricultural output from reductions in water diverted to irrigation. The rationale behind the control cost method is that by agreeing to spend a given amount on controlling an environmental problem society 'effectively' demonstrates a willingness to pay for a certain amount of reduction in environmental damage. One implication of this is that amelioration measures will be adopted from an array of possibilities from the cheapest to the most expensive up to the point where the control cost is equal to the damage avoided.

In this case the argument is that the value of the environmental damage done by the diversion of the last gigalitre of water is equal to the value of the additional agricultural output. This would be a far-fetched interpretation since in the past the environment has been treated effectively as a free good, so that the environmental costs greatly exceed the economic benefits. Nevertheless, the control cost approach may be considered to provide a lower bound to the environmental costs of excessive water use.

In order to provide for adequate environmental flows in the Murray-Darling Basin, it is estimated that current diversions will need to be reduced by around 30%, from 10 684 GL/year (the mean for 1988-89 to 1992-93) to 7500 GL/year (Hamilton, Hundloe and Quiggin 1997: 22-3). If diversions are reduced to around 7500 GL/year (along with some changes to the seasonal flows to make them more in harmony with natural cycles) then a high proportion (perhaps 80%) of the environmental damage will in time be ameliorated. We thus assume that environmental costs began to exceed 'acceptable' levels (a form of safe minimum standard) when diversions began to exceed 7500 GL/year, an event that occurred for the first time in 1968.

Using farm budgets, the Murray-Darling Basin Commission estimated the value of water to irrigators at $56.40/ML in 1988 (MDBC 1989: 4). To estimate the costs of water use we apply this figure, adjusted for inflation, to each megalitre in excess of 7500 gigalitres for each year since 1967. Using this procedure, the cost of environmental damage from excessive water use for 1996 is estimated at $233 million. This is a very low figure.

In order to obtain a better approximation we make two adjustments to our estimate so far. First of all, since the Murray-Darling Basin accounts for only 75% of total irrigation water in Australia, we scale up our estimate by 33%. Secondly, since the control cost method is likely to seriously underestimate the environmental damage (for the reason given above) we arbitrarily double our estimate. This gives an estimated cost of environmental damage from irrigation water diversions in 1996 of $621 million. As a justification for the doubling of the initial estimate it might be pointed out that one study which evaluated the costs and benefits of reduced diversions in the Barmah-Millewa red gum forests of the Murray-Darling Basin concluded that the costs to agriculture from managed floods involving additional dam releases are exceeded by the benefits to the timber industry *alone* (MDBC 1992). In other words, using our control cost valuation, the increase in the health of forests reflected in higher timber yields – without any account of ecological and recreational values – is alone enough to account for the forgone agricultural output.

Column P Costs of urban water pollution

The environmental costs of urban water pollution include damage to habitat, decline in conservation and recreational values and impacts on downstream users. After reviewing the available information on the environmental costs associated with waste water treatment and disposal, a study by the National Institute for Economic and Industry Research (NIEIR) settled on a control cost approach as the only feasible method. Extrapolating from data for Sydney, NIEIR estimates the annual cost of internalising waste-water externalities in Australia in 1994 at $3.5 billion (DEST 1996a: 80-81). This estimate – $3.58 billion in 1989-90 dollars – is adopted for the GPI. It translates into a cost of $2.20/ML.

To derive a series for 1950-1996 we make the assumption that the real environmental cost of a litre of waste water remains constant over the period. The series is thus derived from estimates of the volume of waste water in Australia and a price deflator. The price deflator employed is the implicit price deflator for public expenditure on fixed capital (RBA 1996: Table 5.6a).

Estimates of the volume of waste water in Australia are difficult as until recently no national figures have been collected. As a rule of thumb, each person generates 250 L of waste water per day (Chris Davis, Australian Water and Wastewater Association, *pers. comm.*). Currently around 85% of households are sewered. In 1950, around 50% of households were sewered. However the environmental problems associated with waste water disposal from non-sewered households are worse than those from sewered households. Therefore the volume of waste water used to form a series is taken to be 250 L per day for the whole population. Note that this method of estimating total sewage volumes gives a figure for 1993-94 of 1.63 million ML, which compares with the estimate by the Australian Water and Wastewater Association of 1.67 ML, of which 1.18 million ML is metropolitan and 0.49 million ML non-metropolitan (AWWA 1996).

Column Q Costs of air pollution

This component is concerned with the costs of so-called noxious air pollutants, which are poisonous or otherwise damaging to humans, other animals and plants and therefore damage human health, agricultural production and natural ecosystems. Some of these pollutants also cause corrosion and aesthetic degradation (e.g. soot deposition) to buildings and other structures. The most important pollutants in this group include sulfur dioxide, carbon monoxide, lead, particles of various sizes and compositions, oxides of nitrogen, and volatile organic compounds other than methane (DEST 1996b: 5-7). The two last-named groups of pollutants are joint precursors of photochemical smog, the most important constituent of which is ozone. The principal sources of these pollutants are combustion of fuels (including both fossil fuels and biomass fuels such as wood) and some specific industrial processes, such as the smelting of metal ores and the manufacture of certain chemical products.

In general terms, as with other pollutants, these noxious air pollutants only impose measurable costs when the quantities emitted by human activities clearly exceed the capacity of the natural environment to absorb them. In Australia, both human populations and sources of emissions are both highly concentrated in a relatively small number of discrete areas within which measurable costs are imposed. These areas include the larger cities and a small number of non-urban regions which contain a high concentration of power stations, metal smelting and other large polluting industries.

The National Environment Protection Council has recently released a lengthy discussion paper, which draws on a series of commissioned studies to examine the costs and benefits of proposed new uniform national ambient air quality standards for the principal noxious pollutants (NEPC 1997). The discussion paper contains estimates of the annual health and other human costs that would be avoided if concentrations of the major air pollutants throughout Australia were reduced to the levels specified in the proposed new standards. In very general terms, the data presented in the paper suggest that the proposed new standards approximate the levels at which the marginal cost of further control of each pollutant would equal the marginal avoided health cost. Therefore the estimates of avoided costs given in the discussion paper approximate the human costs of air pollution not included in conventional national accounting aggregates.

The six pollutants proposed to be subject to stricter standards are carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulates and lead. The estimated annual avoided health cost from the first five of these is approximately $1.1 billion. Particles account for about three quarters of this total. In addition, it is estimated that reducing ambient particle levels would result in more than 500 avoided deaths each year. One study quoted in the discussion paper values these avoided deaths at $3.8 billion.

In the case of the sixth pollutant for which new standards are proposed – lead – the major human cost is reduced measured intelligence, resulting in loss of lifetime earnings. The NEPC discussion paper presents data derived from a 1995 national survey of lead in Australian children, from which it can be calculated that the current cost of reduced IQ caused by lead pollution is approximately $1.5 billion per annum.

Allowance has already been made for defensive expenditure on health, which include the direct health costs of all sources of air pollution. However this adjustment does not make allowance for the costs of additional deaths caused by particulates, or for the cost of reduced IQ caused by lead pollution, or for any of the other damage costs of noxious air pollution, such as to crops, garden plants, natural vegetation and buildings. Such damage arises not only from pollutants, such as ozone, included in the proposed new ambient air quality standards, but also from other pollutants such as fluoride. There are no published estimates at the national level of the costs of damage to crops and other vegetation, or to buildings and the like.

We have assumed that the costs of air pollution are made up of the above three components, and that the current annual value of these costs is $7 billion. This is a point estimate derived from current or recently past ambient levels of the various pollutants. To obtain cost estimates for previous years we have used total consumption of fossil fuels (coal, petroleum and natural gas) plus biomass fuels (wood and bagasse) as a proxy. This measure of pollutant level has been chosen because combustion of these fuels is by far the largest single source of emissions. Data sources used are Bush, Harris and Ho Trieu (1997) for the period 1974-1996, Department of National Development and Energy (1982) for the period 1961-1973, and Saddler (1981) and the sources referenced therein for the period 1950-1960.

Finally, we note that current ambient levels of air pollutants in some areas are much lower than they were in previous decades, as a result of previous control measures imposed on sources of pollution. These measures include both successively stricter motor vehicle exhaust emission standards, and control measures imposed on major point sources of air pollution, such as power stations and factories. Our figures may therefore underestimate the cost of air pollution in earlier years.

It should be noted that global costs of air pollutants, including greenhouse gas emissions and depletion of the stratospheric ozone layer, are not included in this column but are costed separately in Columns U and V respectively.

Column R Costs of land degradation

Soil is a resource for which there is no substitute. Moreover soil loss and changes in soil structure are effectively irreversible. As such the soil may be classified as 'critical capital' (Diesendorf 1997: 90). Current agricultural practices are unsustainable; the current generation is leaving a depleted and less productive resource for future generations, a resource that is essential for maintained living standards and ecological processes. The Standing Committee on Agriculture defined sustainable agriculture as 'the use of farming practices and systems which maintain or enhance:

- the economic viability of agricultural production;
- the natural resource base; and
- other ecosystems which are influenced by agricultural activities' (quoted in Derrick and Dann 1997: 189).

While there is a continuing debate over the economic viability of some types of farms, it is clear that the natural resource base is being depleted and other ecosystems have been seriously degraded.

The principal environmental problems associated with the land use in Australia are soil structure decline, salinity and waterlogging, acidification, nutrient loss, weed infestation, habitat loss and various forms of erosion. Some of the environmental impacts have already been assessed in our evaluation of the environmental costs of irrigation water use. The costs of degradation of native forests are also assessed elsewhere (Column S).

Some of the environmental costs associated with land use are reflected directly in lower agricultural outputs and higher costs of inputs – the on-farm costs. For example, weed infestation costs around $3.3 billion annually (excluding the health and environmental costs associated with weeds), mainly due to lost production and control costs (DEST 1996b: 6-23). The control costs are intermediate inputs that are reflected in final prices.

The off-farm costs include both costs imposed on other farmers – through, for example, the spread of weeds or salinisation of waterways – and damage to natural systems.

The question of how to value the loss of natural capital of the land is difficult. There are two types of costs – loss of productive potential, and environmental damage. One method of estimating the loss of productive potential would be to use the proportion of the value of agricultural output that is denied future generations through irreplaceable soil loss. Estimates of the annual losses have been made in the form of the production equivalent of land degradation. In a recent review, the Industry Commission reports a number of studies for the early to mid-1990s which indicate that land degradation across Australia results in an annual loss of output equivalent to around 5-6% of the value of agricultural production (Gretton and Salma 1996: E4-E7). This amounted to around $1.2 billion in 1992-93 (RBA 1996: Table 5.18).

The figure of 5-6% is an underestimate because it takes account of only some forms of land degradation – acidification, soil structure loss and erosion – and accounts only for production losses and not ecological damage. We therefore estimate total damage at double that amount, i.e. $2.4 billion in 1992-93 (although farm prices and output were low in that year due to recession). The figure is $2.6 billion in our base year 1989-90.

In addition to the annual loss of environmental quality experienced by the current generation, we need to account for the losses imposed on future generations by the irreversible depletion of a critical resource. The costs imposed on future generations are estimated by the present value of the future losses, which at a discount rate of 5% amount to 20 times current losses ($52 billion), distributed back over the years according to the contribution of each year to the current level of depletion. Very little data exist to indicate the trends over time in land degradation. In the absence of data, we assume that land degradation has proceeded at a rate of 2% per annum over the study period, so that for each year of the study period the capitalised future costs of land degradation amount to $1.04 billion at 1989-90 prices. This can be thought of as the amount that the population would have needed to set aside each year to compensate future generations for losses due to land degradation. This same rate of change of land degradation is used to estimate the losses in each year to the current generation.

We saw above that weed infestation costs around $3.3 billion annually (1986 data). Around $3 billion of this is reflected in lost or contaminated production (DEST 1996b: 6-23). This represented 19.4% of gross farm production in 1986. Since weed infestation does not represent an irreplaceable loss, its costs represent annual costs only. In addition, the cost of weeds is already reflected in the national accounts through a lower value of output. Weed control expenditures are defensive, but since they are intermediate inputs they too are reflected in the accounts.

Column S Costs of loss of native forests

When forests are cut the value of the timber products made from the logs is added to GDP. But the environmental costs associated with logging are not recorded anywhere. These costs include loss of biological diversity, falls in aesthetic and recreational values and diminution of non-use values, which are characterised by environmental economists as existence, bequest and option values.[23] To the extent that old-growth forests are able to return to their original state, the process may take 200 years or more. In Australia, the length and bitterness of the dispute over logging of old-growth forests (where conservation values are particularly high) suggest that Australians place a high value on these losses.

How should these losses be valued for the purposes of the GPI? Cobb, Halstead and Rowe (1995: 36) arbitrarily assume that the annual loss of ecological services from logging was US$30 billion in 1950, a value based on the estimated difference in ecological values between and old-growth an a regrowth forest.

We take the view that it is inappropriate to place economic values on loss of biodiversity and the losses experienced by people when they see an old-growth forest destroyed. These are ethical issues rather than economic ones (Hamilton 1994).

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[23] In addition, where it occurs, overcutting diminishes the productivity of the forests and reduces the future timber values of the forest. The ability of the forests to renew their timber values is damaged. This factor is not included in the analysis.

However, since loss of old-growth forests may represent a large impact on well-being, we have decided to include a monetary estimate of the losses for comparison with the GDP measures of changes in welfare. Rather than attempting to value each component of loss, a comprehensive approach to monetary valuation can be obtained by estimates of willingness to pay for preservation of environmental values. (This approach is based on an anthropocentric ethic, one that many would regard as inappropriate.)

In 1991, the Resource Assessment Commission carried out a study of the environmental values of National Estate forests in Southeast NSW and East Gippsland. These forests cover an area of 130 000 hectares and had been declared by the Australian Heritage Commission to be of high conservation value. A contingent valuation survey revealed that adult residents of NSW and Victoria were willing to pay $22 per annum to preserve these forests (RAC 1992: U15).[24] This translates into a total valuation for these forests of $156 million, or $1700/ha/annum, by the residents of the states in which the forests are located. Loss of old-growth forests is also felt by residents in other states, as campaigns over logging in Tasmania and the Queensland wet tropics illustrate. We might then scale up this amount by, say, 100%. On the other hand, these National Estate forests are of particularly high value, so a conservative approach may be to halve this estimate of the environmental values of a hectare of old-growth. Thus we estimate that the logging of each hectare of old-growth forest results in a loss of environmental values of $1700 per annum. Since the losses are effectively irreversible, the value of each hectare lost needs to be capitalised. At a 5% discount rate, the present value of the environmental losses from each hectare logged is $34 000.

Remarkably, data on areas of old-growth forest logged over the study period, or indeed for any year, are not available. We have therefore been forced to make some rough estimates. The area of native forest available for logging in 1990 was around 22 million hectares (ABS 1995: Table 4.3). However, not all of this area is suitable for logging, so we estimate that only 15 million hectares are available in practice. If these forests are managed on a 100-year rotation,[25] this means that 150 000 hectares are logged each year. We assume that when logging of native forests reached its peak in the late 1980s this was the area logged. For other years we are forced to make a rough estimate using data on timber volumes extracted from native forests as reported in DEST (1996b: 6-41). The estimated value for 1996 is $4.81 billion (in 1989-90 prices). As a result of the uncertainties in estimating both the areas logged and the environmental values lost due to logging, the estimates of the costs of logging native forests should be viewed as only very rough approximations.

Column T Costs of depletion of non-renewable energy resources

It is often argued by environmental economists that economic growth will run into constraints imposed by depletion of finite natural resources such as minerals and fossil fuels and that therefore current consumption patterns are unsustainable (e.g. Daly and Cobb 1990). This claim is the subject of vigorous and continuing debate amongst some environmental economists and scientists on the one hand and more conventional neoclassical economists on the other. The latter argue that, while it is true that some natural resources that are vital to continued economic growth are finite, we will never run out of resources since the price mechanism will ensure that substitutes will always be found for inputs in short supply. More specifically, price movements and technological change will do one or more of three things: increase the available reserves through new discoveries, permit substitution of new resources

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24 This figure is a median willingness to pay rather than a mean. The mean is not reported.

25 See Streeting and Hamilton (1991).

for old ones, and induce greater economy of usage (Hamilton 1997a). While particular resources may become scarce, there will never be any general resource constraint. Thus current market prices adequately reflect the current and expected future scarcities of these resources.

The debate is not so much about whether substitutes will be found as about what the costs will be of the substitutes (including the requirement for consumers to change their consumption patterns) that must be used when resources approach full depletion.

In other GPIs, the assessed costs of depletion of non-renewable resources comprise the largest, or one of the largest, 'deductions' from the index. Yet the methodological foundations employed are shaky. Cobb and Cobb (1994: 264) reject the use of current market prices as a proper measure of future scarcity on the grounds that the current discount rate fails adequately to express the interests of future generations. This may be so, but the use of discount rates in dealing with intergenerational equity is an area littered with methodological traps (see, for example, Norgaard and Howarth 1991).

In the US GPI, Cobb, Halstead and Rowe (1995) also reject the view that current prices adequately reflect future scarcity. In their estimate of the costs of depletion of non-renewable resources, they include only energy and not minerals because of the importance of energy as an input and the ease of aggregating across energy resources. To measure the cost of depletion of non-renewable energy resources the authors use an estimate of the cost of replacing fossil fuels and nuclear energy with renewable alternatives, in particular the costs of producing 'gasohol' from biomass. The price they settle on is US$75 per barrel of oil equivalent (boe) in 1988, a figure that increases at a rate of 3% per annum from 1950 to 1994 around the 1988 figure (Cobb, Halstead and Rowe 1995: 31). The UK and Swedish GPIs adopt the same approach and the same unit value.[26]

This debate revolves around opinions based on two sets of beliefs:

- whether one believes that 'competitive' markets adequately reflect future scarcities well beyond the time frames of any actual discount rate (beyond around 30 years); and
- related to this, whether one takes an optimistic or pessimistic view of the ability of technological change to solve any emerging scarcities.

If one believes in the efficacy of markets then one is *ipso facto* a technological optimist. Thus one must take a position on the spectrum in order to decide how to assess the costs of depletion of non-renewables, one in which the optimists assess the costs at zero. Our own view is that current prices fail to reflect adequately future scarcities but that, nevertheless, both induced and autonomous technological change have provided, and will continue to provide, many substitutes to emerging scarcities.

These considerations apply especially in the case of minerals. There is a much stronger case for arguing that substitutes for, and efficiency in the use of, minerals such as iron ore, bauxite and copper ore (three of the non-energy mineral products used in greatest quantity in Australia) will mean that no binding or serious constraint will be imposed on global consumption growth. Already there is a significant shift towards the dematerialisation of

[26] Although in the Swedish GPI the replacement cost in 1988 (US$75/boe) is in 1972 dollars rather than in 1988 dollars (Jackson and Stymne 1996: 29).

consumption activity in developed countries, and recycling technologies are advancing rapidly in some activities which remain resource intensive.

We take a less optimistic position with regard to energy resources. While a continuously growing economy in the absence of any particular non-energy mineral resource is conceivable, consumption of energy is essential to all economic activity, including those activities required for the most basic level of subsistence,. Many renewable energy substitution possibilities for finite fossil fuels clearly are available, and there are also many options to extend the life of fossil fuel resources by increasing the efficiency with which they are used. Moreover, the unit cost of renewable energy has fallen substantially over the last decade or two and will continue to do so (see the examples in Grubb *et al.* 1991). The replacement cost used in the US GPI is thus a significant overestimate if applied, as it is, to consumption of all fossil fuels.

On the other hand, it is difficult to envisage that an economy based entirely on renewable energy will be able to use energy in such quantities and at such low cost as our present fossil fuel based society (Trainer 1995). Finding alternative energy sources which do not contain fossil carbon for cars and aircraft will provide a particular challenge. Although some authors suggest that fuel cell vehicles powered by hydrogen produced with solar electricity may one day be cost competitive with current petrol fuelled internal combustion engine powered vehicles (e.g. Lenssen and Flavin, 1996; Johansson *et al.* 1996), most authors are much less optimistic (e.g. Michaelis and Davidson 1996; Chapman 1996). In 1995, after fifteen years of industrial development and a nearly three-fold reduction in cost, sugar cane fuel ethanol in Brazil still costs around US$57 per barrel, which is approximately twice the international price of petrol (Goldemberg 1996). It seems unlikely that this gap will ever be fully closed. Moreover, Brazil is uniquely well-endowed with abundant low-cost, fertile land. It is conceivable that the world's entire current consumption of transport fuels could be supplied by synthetic fuels sourced from biomass on a sustainable basis, but if so it would be at a significantly higher price.

Michaelis and Davidson (1996) present vehicle operating cost figures from a variety of recent studies. The studies compare a conventional petrol-fuelled car with vehicles using fuels derived from renewable energy sources, including methanol from wood, ethanol from sugar cane and wood, solar hydrogen used in either internal combustion engine or fuel cell vehicles, and electric vehicles. The data presented imply additional costs for these fuel/vehicle systems, ranging from about US$60/boe for methanol from wood to several hundred dollars for the hydrogen-fuelled and electric-powered vehicles. In the long run it is only this latter group of fuels which could be considered to be truly sustainable, in that they would be ultimately sourced from renewable electricity.

It should be noted that much of the additional cost of using these sustainable fuels derives from the higher costs of the vehicle and supporting infrastructure and only part is attributable to the hydrogen or electrical energy.

These considerations have led us to adopt a middle position between the energy pessimists, who attribute a replacement cost of US$75/boe (1988 prices) to all fossil fuels, and the optimists, who attribute a replacement cost of zero. For the Australian GPI we have attributed a depletion cost of US$75/boe in 1995 dollars to the consumption of petroleum and natural gas, but not to coal. This approach recognises the uniquely valuable attributes of petroleum as a transport fuel, for which no truly sustainable substitutes would appear to be available except at much higher costs, as detailed above. This figure converts to approximately A$17.4 million/petajoule in 1990 prices (1 petajoule equals approximately 158 000 boe).

We should add one more vital point in this debate. The discussion in the GPI literature about the finiteness of resources focuses entirely on limits to those resources that are inputs into production processes. In our view, by far the most serious environmental constraints on continued growth are not provided by inputs but by the absorptive capacity of waste sinks. These are the aspects of 'natural capital' that most need to be accounted for in an evaluation of sustainability. While the atmosphere and the waterways are renewable resources, their assimilative capacities are in many cases being greatly exceeded. As these 'resources', or rather life-support systems, lie outside of markets, the accuracy or otherwise of current prices is largely irrelevant and the available evidence suggests that an attitude of technological pessimism is well founded. We have attempted to assess the environmental costs of the depletion of these systems elsewhere in the index.

The immediate relevance of this issue to considerations of fossil fuel depletion is that large-scale use of one of the three major fossil fuels, coal, imposes such severe damage on the assimilative capacity of the global atmosphere, in the form of greenhouse gas emissions, that it is most improbable that we will ever be able to use all known resources of coal. Moreover, relative to present rates of consumption, known resources of coal, both globally and within Australia, are far larger than known resources of the other two major fossil fuels, petroleum and natural gas. These considerations provide a further rationale for applying a depletion cost only to consumption of petroleum and natural gas.

Petroleum consumption figures are derived from the same sources as used for Column Q (Costs of air pollution).

Column U Costs of climate change

Emissions of carbon dioxide, methane and other gases resulting from human activities are beginning to cause an increase in average global temperature and thereby to change the climate of the earth. Even if emissions were reduced overnight to a fraction of their current rate, so that there were no further increase in atmospheric concentration of these gases, further climate change would occur.

The largest source of greenhouse gas emissions in Australia, as in most other countries, is the combustion of fossil fuels. However, many other activities make significant contributions, including:

- enteric fermentation in the gut of domestic animals (cattle, sheep etc.);
- breakdown of animal manure;
- application of nitrogenous fertilisers;
- clearing of native vegetation;
- breakdown of organic waste material in landfills;
- cement manufacture and other industrial processes; and
- fugitive emissions (leakage) of methane and other gases derived from fossil fuels.

Emissions from fossil fuel consumption can be estimated over the entire period covered by this study much more readily than emissions from any other source. We have compiled a time series for consumption of black coal, brown coal, petroleum and natural gas from the same sources used to compile the similar series for estimating the costs of air pollution (Column Q).

Emissions of greenhouse gases associated with combustion of each of these fossil fuels are calculated by use of emission factors for each fuel. Emission factors take account of emissions not only of carbon dioxide but also the two other principal greenhouse gases, methane and nitrous oxide, which are equated to carbon dioxide by use of the global warming potential for each gas. Total emissions per unit of each fuel consumed are expressed in terms of carbon dioxide equivalent (CO_2-e). The unit for emission factors is kilotonnes of CO_2-e per petajoule (equivalent to kilograms per gigajoule). Emission factors used are the averages reported for fossil fuel combustion in Australia over the seven years 1988 to 1994 (National Greenhouse Gas Inventory Committee 1996). It should be noted that carbon dioxide arising from oxidation of the carbon atoms contained in fossil fuels accounts for by far the largest proportion of all greenhouse gas emissions resulting from fossil fuel combustion. Some fossil fuel consumption arises from the use of petroleum and natural gas as feedstock for the manufacture of chemical products and some carbon in fuels is not oxidised. Emission factors were therefore reduced by 5% to allow for this effect.

Fossil fuel consumption figures are derived from the same sources as used for Column Q (Costs of air pollution). Over the period 1988-1994 the contribution of fossil fuel combustion to estimated total Australian greenhouse gas emissions rose steadily from 46.3% to 48.7% (National Greenhouse Gas Inventory Committee 1996). This implies that fossil fuel combustion grew more rapidly over the period than did other activities which make major contributions to emissions, such as livestock production, vegetation clearing and use of nitrogenous fertilisers. Examination of the time series data shows that over 1988-1994 consumption of fossil fuels grew at a modest rate compared with some earlier periods, such as 1962-1973, and again for 1982-1989. In the light of these considerations we have assumed that, on average, over the period from 1950-1987, fossil fuel combustion accounted for 45% of total Australian greenhouse gas emissions, i.e. we multiplied estimated fossil fuel combustion emissions by 1/0.45 to obtain an estimate of total emissions in each year. For the years 1988 to 1994 we used the estimates of total national greenhouse gas emissions as published by the National Greenhouse Gas Inventory Committee (1996).

The final step in calculating the cost of greenhouse gas emissions is to attribute a unit cost to each tonne of CO_2-e emitted. The analysis and data do not exist to estimate the damage avoided by reducing emissions by a tonne. However, we can derive an approximation using a control cost approach. If policies are introduced requiring, say, stabilisation of emissions at 1990 levels by the year 2010 then we can calculate the implicit price of carbon in an economy, a price that can be thought of as the cost of buying a permit to emit a certain amount of carbon. A number of studies suggest that such a restriction would result in a tonne of carbon (not carbon dioxide) being priced at around US$100. A recent study commissioned by the US Government confirmed that this would be the approximate price (Interagency Analytical Team 1997).[27] This translates into a price of A$133/tonne of carbon or

[27] Note that the Interagency Analytical Team concluded that this price could be approximately halved if trading in emissions permits among OECD countries occurred.

A$36.40/tonne of CO_2.[28] This is the unit price of emissions of carbon dioxide used in the GPI.

How does this estimate compare with others? A Canadian company is selling CO_2 credits generated from renewable energy sources for C$35/tonne of CO_2, equal to around A$35/tonne of CO_2.

A number of modelling studies in Australia have estimated the carbon tax rate that would need to be applied in order to reduce Australia's greenhouse gas emissions by enough to meet our obligations under the Montreal Protocol (Common and Hamilton 1996; McDougall and Dixon 1996; Industry Commission 1991). In other words we approximate the future damage from climate change by the control cost of reducing emissions. The ORANI model generates a tax rate of around $23/tonne of CO_2 in 1992, or around $25 in 1995.

There are two significant problems with these estimates. The first is that it is known that greenhouse gas emissions will need to be reduced to around 30-40% of current levels in order to stabilise climate change, suggesting that a much higher tax or implicit price of carbon will be needed. The second problem, one that offsets the first, is that there may be cheaper ways of reducing emissions than imposing a carbon tax or allowing emissions trading within a country.

It might be noted that the US, UK and Swedish GPIs adopt a different approach, one of assigning a tax of US$0.50 (in 1972 prices) to each barrel of oil equivalent, a tax which operates cumulatively. Proportionately, the estimated cost of Australia's greenhouse gas emissions is only around 25-30% of the estimated costs for these other countries. Thus the Australian estimate is very conservative compared to other GPIs.

Column V Costs of ozone depletion

Depletion of the ozone layer, principally as a result of the release of chlorofluorocarbons (CFCs) into the atmosphere, presents a serious environmental problem. The *State of the Environment Report* notes that increased levels of UV radiation reaching the land increase the incidence of sunburn, eye damage, skin cancer and damage to immune systems, especially among fair-skinned people. Many other organisms, including plants and insects, are also at risk (DEST 1996b: 5-11). Australia may be particularly prone to the impacts of ozone depletion because the largest of the 'holes' in the ozone layer form in the Antarctic and sometimes subsequently pass across southern Australia (the most populated areas) in late spring (DEST 1996b: 5-18).

CFCs have been used since the 1930s as refrigerants, propellants and industrial solvents. Once released into the atmosphere they are dispersed globally and remain airborne for many decades. Thus the annual release of CFCs has a cumulative environmental impact.

Global concern about ozone depletion led to the Montreal Protocol of 1987, which introduced a timetable for phasing out ozone-depleting substances. Consumption of CFCs has declined sharply since 1989 and should cease by the end of 1997. However, it will take several decades before UV radiation returns to its natural level (DEST 1996b: 5-45).

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[28] The price of a tonne of carbon is converted into a price for a tonne of carbon dioxide by multiplying by a factor of 0.273.

How do we estimate the costs of ozone depletion? The US GPI multiplies US production of CFCs by US$30/kg (in 1982 prices). The authors do not have a persuasive reason for this choice. They observe that no definitive studies of the impacts of ozone depletion exist but that, given the potentially catastrophic effects, 'we made an estimate reflecting our expectation of the order of magnitude of the problems' (Cobb, Halstead and Rowe 1995: 34n). Cobb and Cobb (1994: 273) note that the total costs estimated this way 'may be thought of as the amount that would need to be set aside to compensate future generations for having made their planet less habitable'. The US GPI cost estimate has been adopted for the UK and Swedish indexes, although in the Swedish case the unit cost is applied to consumption rather than production of CFCs, which seems more appropriate since the damage is done by the release into the atmosphere from appliances that use CFCs in their manufacture.

In the Australian GPI we have adopted a different approach, by using data from a study of the estimated health costs of enhanced UV-B radiation in Australia in each year over the period 1990-2030, measured in constant 1990 dollars (Bryant *et al.* 1992). This study assumed that the level of UV-B would remain constant at the level in 2010 for every year thereafter. This level, although higher than the peak of a few years earlier, was estimated to be considerably higher than the 1990 level, with consequent continuation of significantly higher health costs. Following the adoption in 1992 of the Copenhagen Amendment to the Montreal Protocol, it is now expected that restoration of the ozone layer will occur more quickly and that UV-B levels will therefore fall more rapidly (DEST 1996b: 5-44). We have therefore amended the annual health costs estimated by Bryant *et al.* by assuming they will fall steadily after 2010, reaching zero by 2030. We then summed costs over the whole 1990 to 2030 period to obtain an estimate of total costs over the entire period in 1990 dollars. This figure is $37.3 billion.

Two further adjustments were then made. Firstly, measurable damage to the ozone layer, and consequent increase in UV-B radiation, began some years before 1990. The use of 1990 as the base for the study therefore both fails to include the costs incurred in earlier years and, more significantly, measures the *increase* in health costs against a base which already includes some increased costs. It is also highly likely that increased costs will continue to be incurred for many years after 2030. We have therefore doubled the estimate of total costs to take account of these factors.

Secondly, we recognised the need to take account of the damage caused by enhanced UV-B radiation to plants, including both terrestrial and aquatic plants, and hence to agricultural and fisheries production and to natural terrestrial and marine ecosystems. In the absence of any readily identifiable estimates for these costs, we have assumed that they would equal the cost to human health, i.e. we doubled the estimate of health costs to obtain a total cost estimate.

The next step in the calculation was to relate these costs to emissions of CFCs. We based our estimate on the assumption that damage to the ozone layer affecting Australia is caused by emissions of CFCs and other ozone-depleting compounds from Australia. This is clearly invalid, in that ozone layer depletion is a global phenomenon caused by the world-wide increase in atmospheric concentrations of ozone-depleting compounds. To the extent that, to date, ozone layer depletion has been mainly a southern hemisphere phenomenon, it might be argued that Australia is suffering damage disproportionate to other countries, i.e. that part of the damage imposed on Australia is imposed by emissions from other countries. However an offsetting factor is that Australia contains only a small proportion of the total world population and plant production. Therefore, in the absence of any guidance as to an alternative relationship between Australian CFC emissions and Australian damage costs from ozone layer depletion, we have assumed that the costs are directly related to the emissions.

Estimated annual emissions of CFCs are derived from CFC consumption data provided by Dr Paul Fraser of the CSIRO Division of Atmospheric Research (*pers. comm.*). These are the data which are presented graphically in the *State of the Environment Report* (DEST 1996b: 5-44). These data extend back to 1975 and are disaggregated into consumption from aerosols and from all other applications. For a few years the latter category is further broken down to show consumption in refrigeration. We made the following further assumptions to construct an estimated set of annual emissions figures stretching back to 1950.

- 'All other' consumption is separated into refrigeration and the remainder (mainly foams and solvents) by assuming the same proportionate split as in the years for which data are available.

- Consumption prior to 1975 is estimated by assuming that aerosol use rose by equal annual increments from zero in 1960 to the 1975 level, that non-aerosol use rose similarly from zero in 1950, and that refrigeration use accounted for all consumption up to 1960, and then increased by equal annual increments to 1987 (the earliest year for which a specific refrigeration consumption figure is available).

- To estimate emissions from consumption we assumed that in all uses other than refrigeration CFCs were emitted to the atmosphere in the same year in which they were consumed. For refrigeration it was assumed that in each year 10% of the stock of CFCs in refrigerators leaked to the atmosphere; replacement of this leakage accounted for part of the consumption of CFCs for refrigeration. The balance of consumption went into new refrigerators, and thus contributed to the build up of stock. It was further assumed that all refrigerators were scrapped upon reaching 20 years of age and that their whole content of CFCs was emitted to the atmosphere. Finally, it was assumed that from 1996 onward no further leakage of CFCs from refrigerators occurs and that CFCs are salvaged when refrigerators are scrapped; emissions therefore fall to zero.

By this means estimates were made of total emissions in each year from 1950 to 1996. It was assumed that these account for the total of all emissions ever occurring from Australia, and they were then summed over the whole period. By dividing this sum into the estimated total costs, a unit cost of $214 per kilogram of CFC (in 1990 dollars) was obtained (considerably higher than the US estimate). This figure was applied to the estimated emissions in each year to yield an estimated cost for each year.

Column W Costs of crime

The costs of crime are various. They include property loss, medical expenses, pain and suffering, feelings of insecurity, and lost opportunities to undertake various activities because of risks of exposure to criminal acts. There are also considerable resources devoted to defending persons and property against crime – locks, alarms and security guards.

Some of these costs, notably medical costs, have been deducted elsewhere in the GPI or are reflected in lower economic growth (such as the lost income of victims of violent crime). Property loss is a 'transfer' and might be thought to confer as much benefit on the thief as on the legal owner. However it is more accurate to regard stolen property as invalid contributions to well-being because society deems them so. Alternatively, we might use the proceeds of crime as a proxy (perhaps a lower bound) for the pain and suffering caused by crime, a factor which is undoubtedly large but not accounted for in estimates of the costs of crime.

Walker (1995) has made the most comprehensive estimates of the costs of crime in Australia. The total for 1994-95 is around $19 billion, but some of these costs have been counted elsewhere in the GPI. Thus we deduct from this total the expenditure on the criminal justice system (police, courts and prisons) ($6.4 billion) and the costs of violent crime ($1.25 billion) since the latter are mostly in the form of medical expenses and lost income. We also deduct half of the costs attributed to drug offences ($1.0 billion) as these too are medical expenses. The remainder, $10.3 billion, includes property losses, insurance costs, and the costs of crime prevention and 'target hardening' (mostly non-government). The latter are thought to be seriously under-estimated, so the figure of $10.3 billion, or 2.3% of GDP, should be seen as a lower bound.

How have these costs changed over time? There are no time series available for the costs of crime. It is not possible to say whether the costs of crime as a proportion of GDP have changed over time, although it is possible that the scope for fraud involving very large sums of money has increased in more recent years (John Walker, *pers. comm.*). Therefore we assume that the costs of crime have been 2.3% of GDP over the whole study period.

Column X Net capital growth

The notion of Hicksian income requires that the value of a nation's capital stocks be maintained. Capital stocks yield two potential benefits – they contribute to the current year's production of goods and services (measured by their depreciation) and they contribute to the sustainability of income for future generations. We consider each of these, beginning with the latter.

In the GPI, the sustainability function is measured by net capital growth (i.e. net of depreciation). In addition to providing for depreciation, the growth of the capital stock must be enough to accommodate the growth of the labour force each year. Thus the net capital stock is estimated from changes in the series of capital stocks net of depreciation adjusted to account for growth in the labour force. Estimates of the real value of the net capital stock for the years 1966-67 to 1993-94 are from RBA (1996: Table 5.23) and updated from ABS (Cat No. 5221.0) for 1994-95 with the 1995-96 figure derived by extrapolation. For the years 1949-50 to 1966-67 we have extrapolated backwards from an index derived from estimates of Australia's capital stocks taken from Butlin (1977).

Let us now consider the annual services provided by the capital stock. The services of private capital stocks are reflected in the national accounts through the prices paid by consumers for goods and services produced by firms with the capital, so there is no need to consider it further. But what about the contribution of public capital stocks? Where these stocks are owned by public trading enterprises which sell goods or services to consumers – such as electricity, gas, water and publicly owned housing – the services rendered each year by the capital are captured in the national accounts in consumption spending (directly in final consumption or indirectly to the extent that these items are purchased by firms as intermediate inputs).

This leaves us with the capital stocks owned by government and provided free of charge to the public. These are discussed under Column J (Services of public capital). In summary, Column X is a measure of the annual growth in the value of the nation's built capital stocks net of depreciation and adjusted for growth in the labour force.

Column Y Net foreign lending

Sustainable consumption requires that a nation does not accumulate debts over a long period. Foreign borrowing can contribute to sustainable consumption if it is invested productively. But if it is used for consumption purposes then a debt is left for future generations to repay without the increased capacity to pay for it. This component of the index interacts with Column X (Net capital growth) in a way that takes account of the productive contribution of foreign investment in Australia, since the latter adds to the stock of national capital. Thus the net foreign lending column reflects net foreign borrowing for the purposes of consumption. This column is measured by the real value of net foreign liabilities (borrowing less lending) taken from RBA (1996).

Columns Z-AE Aggregate indexes

Column Z is the Australian GPI weighted by changes in income distribution and is arrived at by adding Columns C, D, E, J and X and subtracting Columns F to I, K to W and Y.

Column AA is the weighted GPI per capita derived by dividing Column Z by population in each year. Column Z is measured in billions of dollars while Column AA is measured in dollars, both at constant 1989-90 prices.

Column AB and AC are simply GDP and GDP per capita in constant 1989-90 prices measured in billions of dollars and dollars respectively.

Columns AD and AE are the unweighted GPI and GPI per capita measured in the same way as Columns Z and AA except that Column A is substituted for Column C in the aggregation.

4. Results and discussion

The results of the calculation of the GPI per capita are shown in Figure 3, where the trend can be compared with the growth of per capita GDP. The full results are contained in Appendix Table 1. The absolute levels of the GPI and GDP are not comparable because GDP measures economic activity while the GPI is a measure of changes in welfare. The fact that they begin at around the same level of $9000 is a convenient accident. It is convenient because it allows us more easily to compare changes in the indexes over time. It is an accident because of the fact that in 1950 the sum of the various components added to and subtracted from the personal consumption base (mainly the addition of the value of household work and net capital growth) were approximately equal to the difference between personal consumption and GDP.

Before discussing the results it is worth commenting on the fact that human capital, a potentially major factor in the sustainability of income levels, has been excluded from the index for methodological and data reasons. Over the study period we would expect there to have been continuing net growth in the value of human capital. In order to measure this value we would need to define human capital in a way that reflects its contribution to future well-being. This is no easy task. Net growth in human capital would be measured in part by investments in education and health care. Other components may be regarded as replenishment of a 'depreciating stock' or expenditure on current consumption (such as tertiary courses taken for enjoyment). If we included some part of education and health spending as investments in human capital then the effect would be to shift the GPI curve upwards by a small amount.

Returning to our results in Figure 3, between 1950 and 1996 real GDP per person in Australia increased from a little over $9000 to over $23 000, reflecting steady economic growth over the period. This is usually interpreted as showing that Australians have become progressively better off.

Using the much broader accounting framework of the GPI reveals a very different picture of the changing levels of well-being of the Australian people. Starting at a little under $9000 in 1950, the GPI rises over the period by an average of 1.3% each year, compared to 2.1% for GDP, reaching approximately $16 000 in 1996.

However from the late 1970s the pattern changed markedly. In effect, the GPI does not increase at all from the late 1970s to 1996. It is important to isolate the influence on this pattern of measured changes in income distribution. Figure 4 shows the GPI both with and without weighting for changes in income distribution. The decline in the index of well-being since the late 1970s would have started sooner except for the impact of a substantial measured improvement in income distribution in the 1970s. Thus the measured improvement in income distribution in the 1970s masked the divergence of the GPI from GDP that began around 1972.

The improving trend in the GPI in the 1970s was reversed at the end of the decade, and the result has been a sharp divergence between GDP and the GPI. These results suggest that for the last two decades the benefits of economic growth to society have been offset by the costs. The principal factors explaining the failure of measured well-being in Australia to continue to rise since the late 1970s have been as follows:

- unsustainable levels of foreign debt;
- the growing costs of unemployment and overwork;
- the combined impact of a number of environmental problems;
- the escalating costs of energy resource depletion and greenhouse gas emissions; and
- a failure to maintain investments in the national capital stock.

The impact of these various factors are illustrated in Figures 5 and 6, which show, respectively, the components added to and subtracted from personal consumption to arrive at the (unweighted) GPI.[29]

The first three factors listed above are numerically the most important overall. However, the significant dip in the GPI in the years 1987-1989 was due to the sudden decline in net capital growth and a jump in net foreign liabilities as a result of policies that saw a sharp fall in public investment and an expansion of the current account deficit. Together these changes represent a significant set-back in the value of Australia's capital stocks.

The GPI results indicate that continued growth in Australia is relying ever more heavily on the run-down of stocks of built, social and natural capital. They suggest that the living conditions of Australians are not improving and that we are borrowing from the future to prevent our living standards falling further.

The divergence of the Australian GPI from GDP in the 1970s is mirrored by the indexes calculated for Britain, the USA and some European countries. The 1970s saw some historic changes in the world economy and in economic policies in the leading economies, including the floating of major currencies, the development of often unstable international capital markets, the emergence of stagflation and persistent high unemployment in OECD countries, the oil shocks and economic policies based on a belief in 'small government'. These are summarised in the term 'globalisation', a process which may explain the divergence between continued GDP growth and perceived declines in living standards reflected in the GPI.

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[29] In Figure 6 showing the negative contributions to the GPI, several groups of negative effects have been successively deducted from GDP per capita. The groups are: costs of work (Columns F, G and H), environmental damage and depletion (Columns O, P, Q, R, S and T), climate change and ozone depletion (Columns U and V), net lending (Column Y) and other (Columns I, K, L, M, N and W).

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