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# Structural decomposition analysis of Australia's greenhouse gas emissions

Richard Wood [a,b,*]

[a] Centre for Integrated Sustainability Analysis, A28, The University of Sydney NSW 2006, Australia
[b] Industrial Ecology Programme, Norwegian University of Science and Technology (NTNU), Norway

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ABSTRACT

A complex system of production links our greenhouse gas emissions to our consumer demands. Whilst progress may be made in improving efficiency, other changes in the production structure may easily annul global improvements. Utilising a structural decomposition analysis, a comparative-static technique of input–output analysis, over a time period of around 30 years, net greenhouse emissions are decomposed in this study into the effects, due to changes in industrial efficiency, forward linkages, inter-industry structure, backward linkages, type of final demand, cause of final demand, population affluence, population size, and mix and level of exports.

Historically, significant competing forces at both the whole of economy and industrial scale have been mitigating potential improvements. Key sectors and structural influences are identified that have historically shown the greatest potential for change, and would likely have the greatest net impact. Results clearly reinforce that the current dichotomy of growth and exports are the key problems in need of address.



## 1. Introduction

A complex system of production embedded in our economic structure links our levels of greenhouse gas emissions to our consumer demands. Whilst progress may be made in curtailing consumption or improving efficiency, elsewhere changes within the economy may have a nullifying effect. Thus, policy formed from a whole of production/consumption perspective will likely be most effective. The macro-economic tool of input–output analysis is utilised in this in order study to capture the economy in these terms, whilst incorporating greenhouse gas emissions, and decomposing net impacts into different structural effects.

This study seeks to understand the changes in the factors that influence greenhouse gas emissions by decomposing overall emissions into a number of key determinants over a period of almost 30 years. A detailed model is developed using the macro-economic tool of input–output analysis. This model makes it possible to investigate inter-relationships and intra-relationships between and within sectors of the economy, levels of consumption, exports, emissions production and population. An important facet of the model is the micro-level breakdown of economic structure and energy use, with a disaggregation to 344 industries and a residential sector. This enables insight to be gained on sections of the economy which are most responsible for emissions growth, and which could be easily addressed to reduce aggregate emissions.

The use of input–output analysis in studying environmental effects stemmed from the late 1960s (see Daly (1968); Isard et al. (1967); Ayres and Kneese (1969); Leontief and Ford (1971)). Its subsequent use in structural decomposition studies initially focussed on energy studies (Proops, 1988; Rose and Chen, 1991; Chen and Rose, 1990), but has been extended to greenhouse studies as the importance of climate change has become apparent (Casler and Rose, 1998; Common and Salma, 1992; Proops et al., 1993; Wier, 1998; Chang and Lin, 1998; De Haan, 2001; de Nooij et al., 2003; Roca and Serrano, 2007; Llop, 2007; Lim et al., 2009; Wachsmann et al., 2009; Weber, 2009; Zhang, 2009). The point of departure of this study is a level of decomposition investigating 11 different factors—;including industrial efficiency, forward linkage, industrial structure, backward linkage, mix of final demand, destination of final demand, affluence, per-capita residential emissions, population, export mix and export level. This is a novel separation of forward and backward linkages, and affluence and population growth, for a temporal study—(compare de Nooij et al. (2003) for an inter-country study); and over a 30-year time frame. Investigation is performed at a highly detailed level for the economy (breakdown to 344 industrial sectors before subsequent aggregation).

The basic methodology and sources of data of this study is included in Section 2. Results of the decomposition for Australia's emissions from 1976–2005 are presented in Section 3, with subsequent analysis, before conclusions are drawn in Section 4.

* Tel.: +61 0 2/9351 2627.
*E-mail address:* rwood@physics.usyd.edu.au

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## 2. Methodology

### 2.1. Input–output analysis

Input–output analysis is a top–down macro-economic technique, which uses sectoral transaction data to account for the complex interdependencies of industries in modern economies. Generalisation of the basic form of input–output analysis for factors external to inter-industry transactions results in a $1\times n$ vector of factor multipliers, i.e., embodiments of a production factor (greenhouse emissions) per unit of final consumption of commodities produced by $n$ industry sectors. A multiplier matrix $\mathbf{M}$ is calculated from a $1\times n$ matrix $\mathbf{c}$ containing sectoral production factor usage, and from an $n\times n$ direct requirements matrix $\mathbf{A}$ according to

$$\mathbf{M}=\mathbf{c}(\mathbf{I}-\mathbf{A})^{-1}, \tag{1}$$

where $\mathbf{I}$ is the $n\times n$ unity matrix. $\mathbf{A}$ comprises requirements from current as well as capital intermediate demand of domestically produced and imported commodities. $(\mathbf{I}–\mathbf{A})^{-1}$ is known as the Leontief Inverse, $\mathbf{L}$. i.e.,

$$\mathbf{M}=\mathbf{cL}. \tag{2}$$

The factor inventory $C$ of a given functional unit represented by an $n\times 1$ commodity inputs vector $\mathbf{y}$ and a scalar $C_d$ of direct factor usages is then simply

$$C=\mathbf{My}+C_d. \tag{3}$$

$\mathbf{My}$ represents the indirect usage of factors embodied in all inputs into the functional unit.

An introduction into the input–output method and its application to environmental problems can be found in Leontief and Ford (1971). The mathematical formalism used to derive Eqs. (1) and (2) are described in detail elsewhere.

In this study, we are interested in decomposing the overall factor $C$ into structurally important factors for overall greenhouse emissions. Hence, beginning with the original formulation

$$C=\mathbf{cLy}+C_d, \tag{4}$$

$\mathbf{L}$ is decomposed into forward linkages, $\mathbf{f}$, which represent the sales of a producer to its industrial consumers, $\mathbf{S}$, industrial structure and $\mathbf{b}$, backward linkages, or purchases of a producer from its suppliers (Lenzen, 2003). Hence, defining

$$\mathbf{f}=\widehat{\sum\nolimits_{\imath=1:n}L_{\imath J}}, \tag{5}$$

$$\mathbf{S}=\frac{\mathbf{L}}{\sum_{i=1:n}L_{ij}*\sum_{j=1:n}L_{ij}}, \tag{6}$$

$$b=\widehat{\sum\nolimits_{J=1:n}L_{\imath J}}, \tag{7}$$

$\mathbf{L}$ is decomposed as

$$L=\widehat{\sum\nolimits_{\imath=1:n}L_{\imath J}}*\frac{\mathbf{L}}{\sum_{i=1:n}L_{ij}*\sum_{j=1:n}L_{ij}}*\widehat{\sum\nolimits_{J=1:n}L_{\imath J}}. \tag{8}$$

So

$$\mathbf{L}=\mathbf{fSb}. \tag{9}$$

A hat signifies diagonal. $\mathbf{y}$ is decomposed into $\mathbf{uv}YP+\mathbf{g}Z$, where $\mathbf{u}$ is the $(n\times d)$ matrix of $d$ categories of final demand (excluding exports) relating individual components of final demand to absolute levels of final demand for each category ($u_{n,d}=y_{n,d}/y_d$); $\mathbf{v}$ the vector of length $d$ relating categories of final demand (excluding exports) to gross national expenditure (GNE) ($v_d=y_d/Y$); $Y$ the per-capita measure of economic activity (GNE); $P$ the population; $\mathbf{g}$ the mix of exports (length $n$) and $Z$ the magnitude of total exports. Finally, direct emissions, $C_d$, representing residential emissions, is decomposed into the factor $c_{\mathrm{res}}P$, where $c_{\mathrm{res}}$ represents the per-capita greenhouse emission factors for residential use. In Summary, Eq. (3) becomes

$$C=\mathbf{cfSb}(\mathbf{uv}YP+\mathbf{g}Z)+c_{res}P. \tag{10}$$

### 2.2. Structural decomposition analysis

The basic approach to additive (Hoekstra and van den Bergh, 2003; Choi and Ang, 2003) structural decompositions of a function $y(x_1, x_2, \ldots, x_m)$ of $m$ determinants is through its total differential

$$\mathrm{d}y=\frac{\partial y}{\partial x_1}\mathrm{d}x_1+\frac{\partial y}{\partial x_2}\mathrm{d}x_2+\ldots+\frac{\partial y}{\partial x_m}\mathrm{d}x_m. \tag{11}$$

In this case, $y(x_1, x_2, \ldots, x_m)=x_1\cdot x_2\cdot\ldots\cdot x_m$ (with the $x_i$ being scalars, vectors or matrices)

$$\begin{aligned}\mathrm{d}y&=\prod_{j=1,j\neq 1}^{m}x_j\,\mathrm{d}x_1+\prod_{j=1,j\neq 2}^{m}x_j\,\mathrm{d}x_2+\ldots+\prod_{j=1,j\neq m}^{m}x_j\,\mathrm{d}x_n\\&=\sum_{i=1}^{m}\left(\prod_{j=1,j\neq i}^{m}x_j\,\mathrm{d}x_i\right).\end{aligned} \tag{12}$$

Analysing discrete time series with a Divisia decomposition approach, differences $\Delta y$ are obtained by integrating infinitesimal changes d$y$

$$\begin{aligned}\Delta y&=\int_{y_0}^{y_1}\mathrm{d}y\\&=\int_{x_{1,0}}^{x_{1,1}}\prod_{j=1,j\neq 1}^{m}x_j\,\mathrm{d}x_1+\int_{x_{2,0}}^{x_{2,1}}\prod_{j=1,j\neq 2}^{m}x_j\,\mathrm{d}x_2+\ldots\\&\quad+\int_{x_{n,0}}^{x_{n,1}}\prod_{j=1,j\neq m}^{m}x_j\,\mathrm{d}x_m\\&=\sum_{i=1}^{m}\left(\int_{x_{i,0}}^{x_{i,1}}\prod_{j=1,j\neq i}^{m}x_j\,\mathrm{d}x_i\right).\end{aligned} \tag{13}$$

In order to compute the integral, one has to know what average values $y$ assumes, while the $x_i$ change from $x_{i,0}$ to $x_{i,1}$ (the "integral path"). Conventional Parametrical Divisia methods assume a parametrical average $\bar{y}^{\alpha}=y_0+\alpha(y_2-y_1)=y_0+\alpha\Delta y$, with $0\le\alpha\le 1$. Searching for a non-parametric method, Ang and Choi (1997) and Ang and Liu (2001) propose the logarithmic mean $\bar{y}^{\lambda}=\Delta y/\Delta(\ln y)$. The resulting logarithmic mean Divisia (LMD) formulation

$$\Delta y^L=\sum_{i=1}^{n}\frac{\Delta y}{\Delta(\ln y)}\ln\frac{x_{i,1}}{x_{i,0}} \tag{14}$$

is non-parametric, exact and time-reversible (for proofs see (Ang and Choi, 1997) and (Ang et al., 1998), for overview see (Lenzen, 2006) and (Hoekstra and van den Bergh, 2002) and (Janssen et al., 2001). The issue of handling zero and negative values in the logarithmic term has been addressed in Wood and Lenzen (2006); Ang and Liu (2007a, b)).

Applying Eq. (13) to (3), gives

$$\begin{aligned}\Delta C = &\ \Delta \mathbf{cfSb}(\mathbf{uv}YP + \mathbf{g}Z) + \mathbf{c}\Delta \mathbf{fSb}(\mathbf{uv}YP + \mathbf{g}Z) \\ &+ \mathbf{cf}\Delta \mathbf{Sb}(\mathbf{uv}YP + \mathbf{g}Z) + \mathbf{cfS}\Delta \mathbf{b}(\mathbf{uv}YP + \mathbf{g}Z) \\ &+ \mathbf{cfSb}(\Delta \mathbf{uv}YP) + \mathbf{cfSb}(\mathbf{u}\Delta \mathbf{v}YP) + \mathbf{cfSb}(\mathbf{uv}\Delta YP) \\ &+ \mathbf{cfSb}(\Delta \mathbf{g}Z) + \mathbf{cfSb}(\mathbf{g}\Delta Z) + \Delta c_{res}P \\ &+ (\mathbf{cfSbuv}Y + c_{res})\Delta P, \end{aligned} \quad (15)$$

where each factor change (the delta term) is calculated according to Eq. (14).

The terms of Eq (14) are named by their difference factor (i.e., the first term, is hence named $\Delta\mathbf{c}$), and described in Table 1.

### 2.3. Data sources

Data sources for economic data (**f**, **S**, **b**, **u**, **v**, **g**, $Z$) was the Australian Bureau of Statistics publication 5209.0. Seventeen sets of tables have been published by the Australian Bureau of Statistics (ABS), with the years being 1974–75, 1977–78, 1979–79, 1979–80, 1980–81, 1981–82, 1982–83, 1983–84, 1986–87, 1989–90, 1992–93, 1993–94, 1994–95, 1996–97, 1998–99, 2001–02 and 2004–05. These tables were moulded into a true time series by combining supply/use information and National Accounts data. This was done to smooth out any changes in classification and methodology. A full description of the process is outlined in Wood (2009). The implementation of supply/use tables in 1994–5, and the change in SNA for the 1994–5 tables resulted in quite a significant change that introduced too much error, and this change has been omitted from this analysis. Price Indices by industry were needed to deflate subsequent years data, and national accounts data was further used to balance estimates (Wood, 2009). The source for the data on greenhouse gas emissions was the National Greenhouse Gas Inventory (NGGI) (Australian Greenhouse Office, 2007), and the application to the input–output system has previously been defined. A description of allocation techniques used is available elsewhere (Wood et al., 2008). Population data was obtained from the ABS (Australian Bureau of Statistics, 2008).

## 3. Results and analysis

A summary of the decomposition of the total change in greenhouse gas emissions over time according to Eq. (7) is presented in Fig. 1, and for a rolling average coverage of years, and under accounting schemes of fuel combustion only and Kyoto in Table 2. Each column corresponds to the parameters of the decomposition described in Table 1.

At this macro-level, changes in industrial efficiency, final demand mix, final demand destination and export mix were found to generally have a negative forcing on emissions. The change in industrial efficiency was the strongest component of this group, particularly when only referring to fuel combustion emissions. In contrast, changes in structural inter-relationships, overall economic growth, population and export level had large positive forcing on emission levels. The effect of the oil crisis in the late 1970s was seen to have a significant reduction in the direct energy use by industry ($\Delta\mathbf{c}$). The residential effect over the whole time series was less pronounced, with per-capita emissions slightly decreasing. Overall, the influence of population on emission levels was a fairly consistent 1%. Diverging results occur for some factors between fuel combustion results and all types of greenhouse gases (Table 2). These differences occur mainly in the structural component of the economy, and in the type of final demand and are due to the changing importance of agricultural and land-use change emissions across certain years. Where negative changes are seen under the Kyoto accounting but not fuel combustion, this shows less demand for the goods and services with high embodiments of non-energy emissions.

A further decomposition was performed at the final demand level over the time series. A graphical representation of the all factors by industry is included in Fig. 2 for the last decade (1995–2005). Industries are ordered such that primary industries are left most, and service (tertiary) industries are rightmost. Industries are aggregated to 30 sectors.

One of the main results out of the analysis is that the majority of these changes (in terms of both number and magnitude) are occurring in 'end use' sectors such as services and transport, depicted on the right of Fig. 2. Thus, to achieve easy emission reductions, policy focus should be placed on these sectors, both in terms of the inputs into production for the industries (particularly, the structural effects of **f** and **S**), and in terms of final demand for their products ($\Delta\mathbf{u}$), as these parameters contributed most to change, independent of the affluence and population effects.

In the utilities sector, electricity supply is strongly represented, consistently representing the largest contribution to change in overall emissions across each period of the full time series. Construction is also consistently represented, as are the transport sectors. Within the service sector, government administration, defence, education, health and community (or welfare) services have consistently contributed to change, often forcing emissions higher.

For exports, the significant industries are meat products, which in earlier years had a negative forcing on emissions, and in later years had more of a positive forcing. Petroleum and coal products

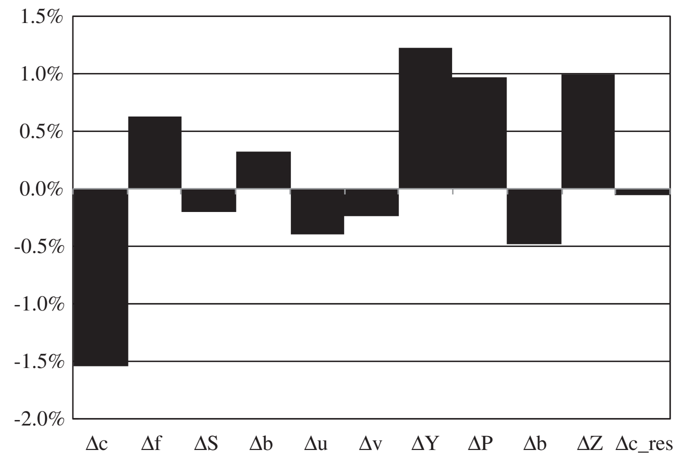


**Fig. 1.** Decomposition parameters contributing to total change in emissions, both fuel combustion and other emissions, Australia, 1976–2005.

**Table 1**
Description of structural decomposition components.

| Factor | Description<br>The change in total greenhouse gas emissions reflected in the changes in: |
|---|---|
| $\Delta\mathbf{c}$ | Greenhouse gas efficiency (intensity) of industrial production. |
| $\Delta\mathbf{f}$ | Forward linkage. |
| $\Delta\mathbf{S}$ | Industrial structure. |
| $\Delta\mathbf{b}$ | Backward linkage. |
| $\Delta\mathbf{u}$ | In the mix of final demand of goods and services from the industries. |
| $\Delta\mathbf{v}$ | The relative change in destination of final demand. |
| $\Delta Y$ | The change in the per-capita GNE. |
| $\Delta c_{res}$ | Per-capita direct greenhouse gas emissions. |
| $\Delta P$ | Population. |
| $\Delta\mathbf{g}$ | The mix of exports. |
| $\Delta Z$ | The total level of exports. |
| $\Delta C$ | The total change in emissions (summation of above terms). |

**Table 2**
Decomposition of parameters contributing to total change in emissions, Australia, 1976–2005.

| | Industrial | | | | Expenditure | | | Population | Export | | Residential |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Δ**c** (%) | Δ**f** (%) | Δ**S** (%) | Δ**b** (%) | Δ**u** (%) | Δ**v** (%) | Δ*Y* (%) | Δ*P* (%) | Δ**g** (%) | Δ*Z* (%) | Δ**c**_res (%) |
| Fuel combustion emissions only | | | | | | | | | | | |
| 1976–1981 | **−4.5** | 7.8 | **−4.8** | 3.2 | 0.2 | **−0.2** | 0.6 | 1.0 | **−0.1** | **−0.1** | **−0.1** |
| 1978–1983 | **−2.4** | 2.4 | **−0.3** | **−0.1** | **−0.9** | 0.2 | 1.1 | 1.1 | 0.4 | 0.1 | **−0.1** |
| 1980–1985 | **−3.6** | **−0.2** | 0.1 | 1.1 | 1.8 | **−0.3** | 1.5 | 1.2 | 0.1 | **0.0** | **−0.1** |
| 1982–1987 | **−0.4** | **−0.1** | 0.4 | 0.1 | 0.3 | **−0.2** | 0.5 | 1.1 | **−0.7** | 0.9 | **0.0** |
| 1984–1989 | **−1.1** | 2.6 | **−0.5** | **−0.1** | **−2.2** | **0.0** | 2.6 | 1.3 | **−0.2** | 1.2 | **0.0** |
| 1986–1991 | **0.0** | 1.4 | **−0.3** | **−0.7** | **−1.1** | 0.4 | 1.2 | 1.2 | **−0.1** | 1.3 | 0.0 |
| 1988–1993 | 0.2 | **−2.7** | 0.7 | **−0.7** | 2.5 | **−0.6** | 0.6 | 1.1 | 0.2 | 0.9 | 0.1 |
| 1990–1995 | **−0.8** | **−0.6** | **−1.6** | 2.1 | 3.6 | **−0.2** | 0.8 | 0.9 | 0.2 | 0.9 | 0.1 |
| 1992–1997 | **−0.5** | 1.9 | **−2.7** | 2.1 | **−0.8** | **−0.4** | 2.2 | 0.9 | **−0.9** | 1.2 | 0.0 |
| 1994–1999 | **−3.5** | 4.2 | **−4.5** | 3.4 | **−0.4** | 0.4 | 2.5 | 0.9 | **−1.2** | 1.2 | **0.0** |
| 1996–2001 | **−0.9** | 0.7 | **−0.8** | **0.0** | **−1.7** | **−0.4** | 1.8 | 0.9 | **−0.3** | 1.4 | **0.0** |
| 1998–2003 | **−1.0** | 0.4 | **−1.2** | 0.4 | **−0.6** | **−0.1** | 1.7 | 0.9 | 0.3 | 1.1 | **−0.1** |
| 2000–2005 | **0.0** | 0.5 | **−0.6** | 0.2 | **−1.1** | 0.1 | 1.4 | 0.7 | 0.2 | 0.4 | **−0.1** |
| All types of GHG emissions (Kyoto accounting) | | | | | | | | | | | |
| 1990–1993 | **0.0** | **−5.6** | 2.5 | **−1.0** | 2.9 | **−2.4** | **−0.6** | 0.8 | **−0.4** | 1.5 | **−0.2** |
| 1992–1995 | 2.6 | **−1.4** | 1.9 | **−2.0** | **−2.9** | **−1.8** | 1.2 | 0.5 | **−0.7** | 0.8 | **0.0** |
| 1994–1997 | 1.5 | **−2.8** | **−0.6** | 0.2 | **−1.8** | **−0.5** | 0.8 | 0.6 | **−0.5** | 1.7 | **0.0** |
| 1996–1999 | **−1.2** | 2.8 | **−0.7** | **−0.6** | **−3.6** | 0.4 | 2.3 | 0.8 | **−0.6** | 1.2 | **0.0** |
| 1998–2001 | **−3.3** | 0.7 | **−0.7** | 0.5 | 2.7 | **−1.2** | 1.1 | 0.9 | **−1.0** | 2.3 | **−0.1** |
| 2000–2003 | **−0.4** | 0.8 | **−1.2** | 0.8 | **−1.6** | 0.2 | 1.1 | 0.9 | **−0.8** | 0.9 | **−0.1** |
| 2002–2005 | **−1.5** | **−4.0** | 4.0 | 0.3 | **−5.8** | 4.8 | 2.8 | 0.8 | **−0.8** | **−0.1** | 0.1 |
| Average | | | | | | | | | | | |
| Fuel combustion | **−1.7** | 1.0 | **−1.0** | 0.8 | 0.1 | **−0.1** | 1.4 | 1.0 | **−0.2** | 0.8 | **0.0** |
| Average | | | | | | | | | | | |
| All GHG | **−0.5** | **−2.1** | 1.6 | **−0.4** | **−1.1** | **−0.3** | 1.3 | 0.8 | **−0.7** | 1.4 | **−0.1** |

Negative changes are in bold.

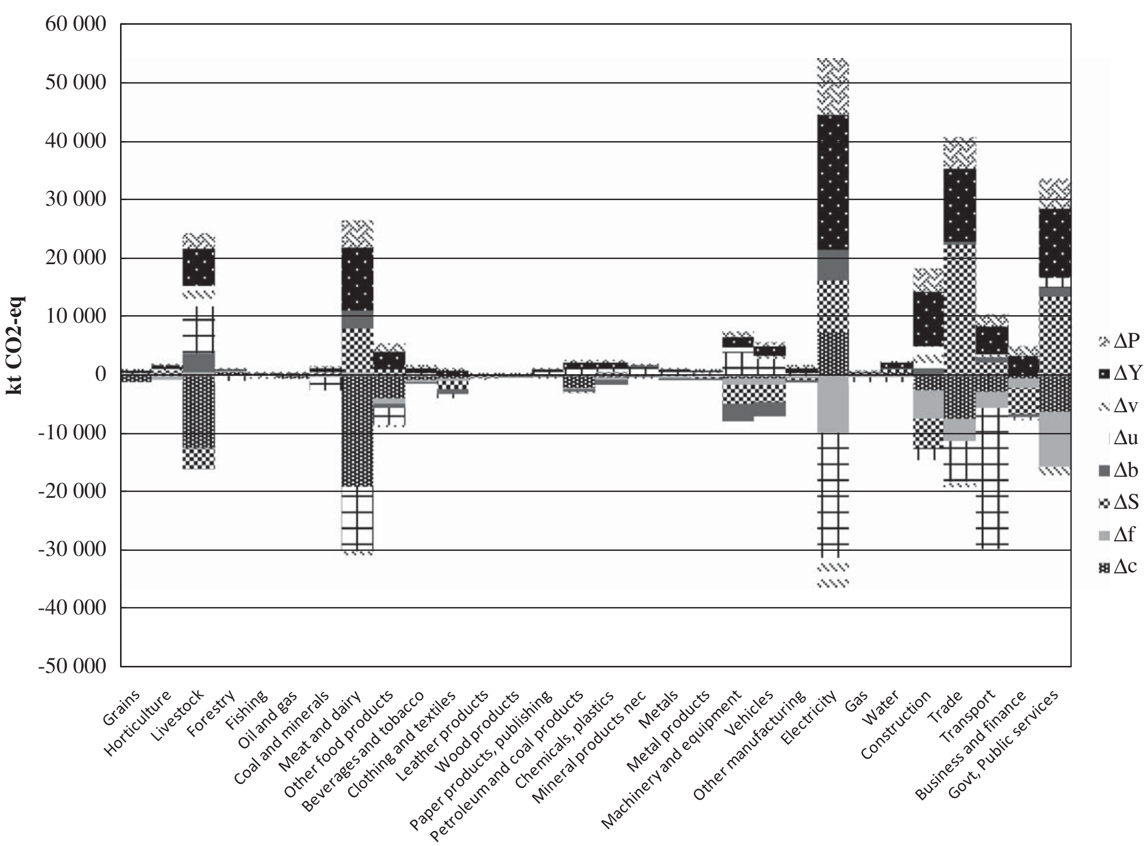


**Fig. 2.** Summary of contribution to change in emissions by industry, 1995–2005, domestic final demand only.

had a perceptible but intermittent effect, whilst the transport industries, particularly road transport consistently influenced the levels of emissions. Industries that were more primary in production showed their importance in this decomposition, due to the nature of most of the Australia's exports.

It was also found that variances in the influence of factors at the industrial level were considerable over the time series, implying that considerable gains could be made in reducing emissions by developing policy that exploits the maximum influence of the different parameters at the same time.

A final important result was that the influence of the industrial efficiency ($\Delta \mathbf{c}$) and overall industrial structure ($\Delta \mathbf{L} = \Delta \mathbf{f} + \Delta \mathbf{S} + \Delta \mathbf{b}$) parameters often showed large and opposite impacts in the same period (specifically when looking at fuel combustion emissions only—Fig. 3). This is a result of the substitution of direct energy inputs for non-energy inputs, which still embody high levels of emissions. In order to have an aggregate negative impact on emission levels, it is important that both these considerations are taken into account. This result also shows the importance of using the methodology employed, which is able to account for embodied emissions in the production process, whereas a normal intensity analysis of emissions production would not capture this effect.

## 4. Discussion

This analysis adds further weight to the fact that efficiency measures are not making up for our increasing demands from the economy. If we want to stabilise emissions, we cannot continue growing population and consumption levels at a rate that the economy cannot adapt to. Improvements in emissions intensity of 0.5–1.7% p.a. (depending on accounting) have not so far been sufficient to make up for our evolving economy and levels of consumption. The current dichotomy of pushing products with high resource and greenhouse gas emissions embodied straight to export must be changed for Australia to move towards any semblance of sustainability (compare Wood et al. (2009)).

Further, these results show how important it is to act in a life cycle context. Action on greening energy technologies will only have limited benefit if industry substitutes from greener energy providers to dirtier industrial providers. This was most evident in the oil crisis of the 1970s, but also in most other years, when consistent improvements in greenhouse gas intensity closely matched opposite effects in 'burden shifting' within the technology of the economy (represented here by the Leontief matrix). Whilst cap and trade policies should prevent this type of activity from happening, we need to be observant of not only burden shifting from one industry to another, but also to other environmental and social impacts not explicitly included in carbon frameworks.

## 5. Conclusion

In this study, the extent to which structural economic change has influenced levels of greenhouse gas emissions has been investigated for Australia's recent history. A disaggregation of total changes by inter-industrial and environmental–industrial inter-relationships was undertaken through the development of a model based on input–output and structural decomposition analysis.

At a macro-level, changes in industrial efficiency, final demand mix, final demand destination and export mix were found to decrease emissions. The change in industrial efficiency was the strongest component of this group, particularly for fuel combustion emissions. In contrast, changes in structural interrelationships, affluence and export level strongly increased emissions. The residential effect was less pronounced, with emissions per-capita slightly reducing. Overall, the influence of population growth on emission levels was around a fairly consistent +1% p.a.

At the disaggregated level, the importance of the electricity supply, construction, transport and service industries to changing emission levels was confirmed, but no industry showed a constant effect over the full time series. A further important result was that there appeared to be a high level of substitution between energy and structural inputs, with diminished effect on total emissions. This suggests that the real gains in energy efficiency would not be as great as an energy intensity analysis would show, and that the consideration of impacts embodied in production was needed to capture all effects.

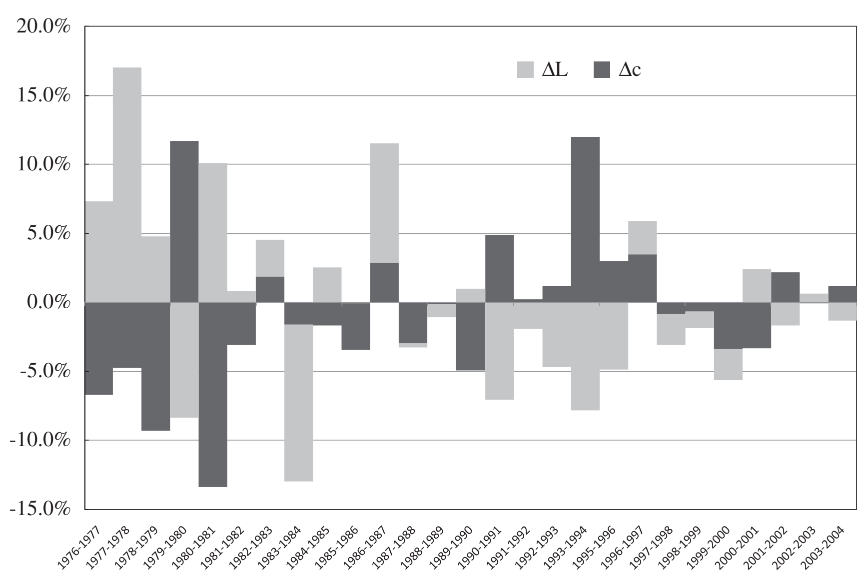


**Fig. 3.** Percentage contributions of structural change and industrial efficiency to overall emissions, by year.

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