



Sustainability Accounting for business

–

a new international software based on input-output tables

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ABSTRACT

Triple-Bottom-Line (TBL) accounting is a wide-spread concept for firms wishing to realise broader societal objectives in addition to increasing shareholder value. TBL Accounts routinely cover social and economic indicators in addition to environmental indicators, and enable decision-makers to quantify trade-offs between different facets of sustainability. For example, a recent analysis of the Australian economy (www.isa.org.usyd.edu.au/publications/balance.shtml) integrates financial input-output tables that describe the inter-dependencies between economic sectors, with national social and environmental accounts to construct numerate 'triple bottom line' accounts for 135 discrete sectors. The accounts are portrayed against the numeraire of 'one dollar of final demand'. Thus for a sector of the economy, financial aspects of performance can be expressed for example as dollars of export earnings per dollar of GDP. Social aspects such as employment can be portrayed as minutes of employment generated per dollar. Climate change issues can be portrayed as kilograms of carbon dioxide emitted per dollar.

Since these indicators of 'triple bottom line' performance are referenced against financial units and are consistent with the System of National Accounts, they can be applied to financial accounts of a firm, a service or a product, and allow a robust triple bottom line account to be developed across a range of scales. The critical advantage of this approach is that it includes both the direct or immediate effects as well as the indirect or diffuse effects associated with a large and distant chain of supply paths. The incorporation of all the indirect or upstream effects therefore removes any problems from a choice of boundary and imports and exports are also included. Both products and firms can then be assessed properly in sustainable chain management terms. Thus a firm that uses a key intermediate input that requires a large amount of water for example, cannot hide the environmental implications since they are revealed in the analysis of the full production chain. This revelation can also underpin progress when firms acknowledge both the direct and indirect effects, and improve their selection of key inputs on a wider range of criteria, rather than on price alone.

At the University of Sydney, TBL Accounting has been formulated as a quantitative framework using an input-output-based LCA method. This framework has been applied to dozens of organisations in reporting on their sustainability performance - companies, government departments, NGOs. Experiences were collected in a 3-year pilot project. It became clear that the data collection burden for the organisation has to be as small as possible. As a result, a software tool was developed in collaboration with the using organisations, enabling users to create a comprehensive sustainability report solely by importing their existing financial accounts (www.bottomline3.com). Software outputs include aggregate figures, detailed breakdowns and rankings of indicators into supply chain contributions. Users had no difficulty in understanding and accepting indirect impacts occurring off-site, in addition to on-site direct impacts. Users felt that assessing their organisation's



indirect impacts was a valuable feature because it increases abatement options, enables meaningful benchmarking, avoids loopholes in reporting and informs about real risk. Sydney University's TBL software has been designed so it can readily be implemented for any economy that for which input-output data complemented with physical data are available. Trial versions include Australia, the UK, Japan, the US, and Germany. In principle it is possible to develop a version based on a multi-national IO framework that covers international trade flows.

1. INTRODUCTION

Governments at all levels, corporations, non-governmental organisations and the general public are all engaging with the concept of sustainability. The environmental movement first brought the issue of tensions between economic development and environmental quality to the attention of the public over 30 years ago. More recently the developed world has been struggling with expanding the original concept of sustainable development from one of meeting environmental concerns whilst maintaining economic development to a more holistic concept where economic, environmental and social considerations are given more equal weighting.

The broadly agreed definition of sustainability is: practices and development that meets the needs of the current generation without compromising the ability of future generations to meet their needs. Although this definition has been widely accepted, applying it in a meaningful way to all levels of society is a major intellectual and governance challenge. Sustainability is ultimately an absolute condition: a country, community or company is either sustainable or it is not. However, un-sustainability may be less recognisable over immediate or short time scales that are at odds with the accepted principle of sustainability defined in terms of future generations. Therefore, in an operational sense and with our current limited knowledge, sustainability is best viewed as a process. It is likely therefore that the sustainability 'goal posts' will be continually moved as our understanding of the importance of social and natural capital increases. Whilst it is difficult to make an absolute assessment of what sustainability means, proxy indicators of sustainability, many of which are currently in use, are essential for determining relative performance.

Corporations are beginning to apply the concept of sustainability at a practical level in terms of corporate citizenship or corporate social responsibility (CSR). CSR is currently dominated by the notion of the triple bottom line. Triple bottom line (TBL) was a term originally coined by John Elkington in the early 1980s to describe corporations moving beyond reporting only on their financial "bottom line" to assessing and reporting on the three



spheres of sustainability: economic, social and environmental. The notion of the triple bottom line has many meanings to many people, and can be applied at different levels in society by different stakeholders. However, there is general agreement that the triple bottom line principle is a useful approach for examining the operations of an entity, from a local council to a major corporation.



2. ANALYTICAL APPROACH

In this study, the principle of the triple bottom line is assessed using input-output analysis (IOA). Input-output analysis is a top-down economic technique, which uses sectoral monetary transactions data to account in a “snap-shot” - like manner for the complex interdependencies of industries in modern economies. The result of generalised input-output analyses is a $f \times n$ matrix of TBL *factor multipliers*, that is embodiments of f TBL indicators (such as exports, labour, energy, etc) per unit of final demand of commodities produced by n industry sectors. A multiplier matrix \mathbf{M} can be calculated from a $f \times n$ matrix \mathbf{F} containing sectoral TBL indicator scores, and from a $n \times n$ *direct requirements* matrix \mathbf{A} according to

$$\mathbf{M} = \mathbf{F} (\mathbf{I} - \mathbf{A})^{-1} , \quad (1)$$

where \mathbf{I} is the $n \times n$ unity matrix. The $f \times 1$ TBL *inventory* Φ of a given sectoral final demand represented by a $n \times 1$ commodity vector \mathbf{y} is then simply

$$\Phi = \mathbf{M} \mathbf{y} . \quad (2)$$

For many countries, the direct requirements matrix \mathbf{A} can be compiled from the Input Output Tables published by the National Statistical Agencies.

Input-output theory was pioneered by Nobel Prize winning economist Wassily Leontief in the 1940s and applied by Herendeen and others (Herendeen, 1973; Herendeen, 1974; Herendeen et al., 1975; Herendeen et al., 1976; Herendeen, 1981), to many energy analyses problems from the mid-1970s to today. It was always Leontief's intention that IOA be extended from purely financial considerations to a range of social and physical elements (Leontief et al., 1970). However, such methods have not been widely employed in government planning and policy circles, except for the European NAMEA movement, in which physical tables are set up as satellite accounts to the National Accounts (de Haan et al., 1996; de Haan, 1999). The NAMEA accounts as well as our work aim at integrating the structure and function of the financial economy (as described by the national IO tables) with other national social and physical accounts such as energy, greenhouse emissions, water, land disturbance, employment and so on.

There is a well-known precedent for IO analysis techniques improving assessment processes: In life cycle assessment (LCA), which aims to calculate the total



environmental burdens associated with a product, IO has experienced a significant role in overcoming what is known as the boundary problem, or the problem of incompleteness of an LCA inventory due to the arbitrary truncation of the system by a subjectively set boundary (Suh et al., 2004), thus preventing decision-makers from overlooking important hidden upstream impacts.

The ISA team at the University of Sydney has compiled national- and state-level economic sector level data for 344 sectors of the Australian economy, using input-output tables and additional data. A part of these accounts are published (www.isa.org.usyd.edu.au/publications/balance.shtml), and contain information on the aggregate and average performance of 135 economic sectors for ten TBL indicators together with their main data sources (Table 1). The synthesis of disparate data sources is a major component of the development of a generalised IOA framework.

Table 1: Brief list of the 10 macro TBL indicators developed in this work.

Macro Indicator (and unit)	Brief description
Primary energy (MJ)	Combustion of all non-renewable fossil fuels
Greenhouse gas emissions (kg CO ₂ -e)	Carbon dioxide equivalent impact of all gases affecting climate
Water use (L)	Consumption of all mains and self-extracted surface water
Land disturbance (hectares - ha)	Land use, weighted by intensity of impact
Imports (m\$)	Value of all goods and services purchased from foreign residents
Exports (m\$)	Australian production destined for consumption outside Australia
Surplus (m\$)	Operating profits and expenditure on fixed capital
Government revenue (m\$)	All taxes less subsidies
Employment (hours)	Full time equivalent employment
Income (m\$)	Total compensation for employees

By applying the IO formalism to the Australian TBL accounts we are able to allocate TBL loadings from producing industries to final demanders of commodities in a mutually exclusive and collectively exhaustive way, that is without double counting of any flows. We are also able to describe in hard numbers a number of economic, social and environmental outcomes against a common unit of one dollar of final demand (Table 1). The latter constitutes a convenient and meaningful numeraire, because it is the destination of GDP, the



common measure of national economic performance, and as Adam Smith concluded already in 1776, it is “the sole end and purpose of all production. Thus economic indicators of surplus, exports and imports can be reported as “dollars of surplus per dollar of final demand”. Social indicators such as employment, wages and government revenue can be described as “the minutes of employment generated per dollar of final demand”. Environmental indicators such as greenhouse gas emissions, water requirement and land disturbance can be described as “kilograms of carbon dioxide equivalent emissions per dollar of final demand” or the like. The quantities reported in this paper are referred to as intensities and can be described and discussed for each economic sector. The presentation of such complex analyses is always fraught with the tension between simplicity and complexity.

The extended data set features many more indicators than the published set: In addition to the ten indicators in Table 1, the ISA framework includes material flow, the ecological footprint, emissions of more than 100 toxic, ozone-depleting, acidifying and eutrophivating substances to air, water and soil, and two prominent Dutch LCA sets (the CML midpoint set and PRé’s endpoint Eco-indicator99). In total the whole database distinguishes 1270 indicators for 344 industry sectors in 8 Australian States and Territories.



3. AN EXAMPLE TRIPLE BOTTOM LINE ACCOUNT FOR AUSTRALIAN MINING

3.1 Bauxite mining

The bauxite mining sector ranks 108th out of 135 sectors in terms of value adding in the economy, and contributes 0.09% of GDP in this analysis. The sector supplies 2000 employment years to the downstream processing industries of alumina production and aluminium smelting. It has relatively small resource requirements with less than one tenth of one percent of national energy use, greenhouse emissions, and land disturbance, and less than two tenths of one percent of national water use. In financial terms, exports are approximately equal to imports. In this embodied product analysis, most of the physical processing liabilities are passed on to the value adding stages of alumina production and aluminium smelting, from where the product is sold, and thus enters final demand (see Table 2).

Table 2: TBL factors of the Australian bauxite mining industry: On-site impacts in terms of indicators listed in Table 1.

TBL factors	in supplying industry (% of national)
Gross operating surplus (\$m)	\$m 277.0 (0.14%)
Exports (\$m)	\$m 85.1 (0.10%)
Imports (\$m)	\$m 67.2 (0.07%)
Employment (e-y)	2,293 e-y (0.03%)
Income (\$m)*	\$m 74.3 (0.04%)
Government revenue (\$m)†	\$m 46.0 (0.04%)
GHG emissions (kt CO ₂ -e)	209 kt (0.04%)
Water use (ML)	287,297 ML (1.37%)
Land disturbance (kha)	7 kha (0.00%)
Primary energy (TJ)	2,980 TJ (0.08%)
*excludes income tax	† includes net commodity taxes on final demand and income tax

The spider diagram (Figure 1) portrays a TBL account with significant outliers for the environmental indicators of water and primary energy, and the three social indicators of employment, income, and government revenue. Environmental issues relating to bauxite mining, especially those of mine reclamation, have been addressed by the development and application of leading edge ecologically based approaches. The key downstream issues, outside the scope of this analysis, relate to the carbon intensity of the eventual product aluminium, and potential health impacts of emissions from alumina and aluminium refineries.

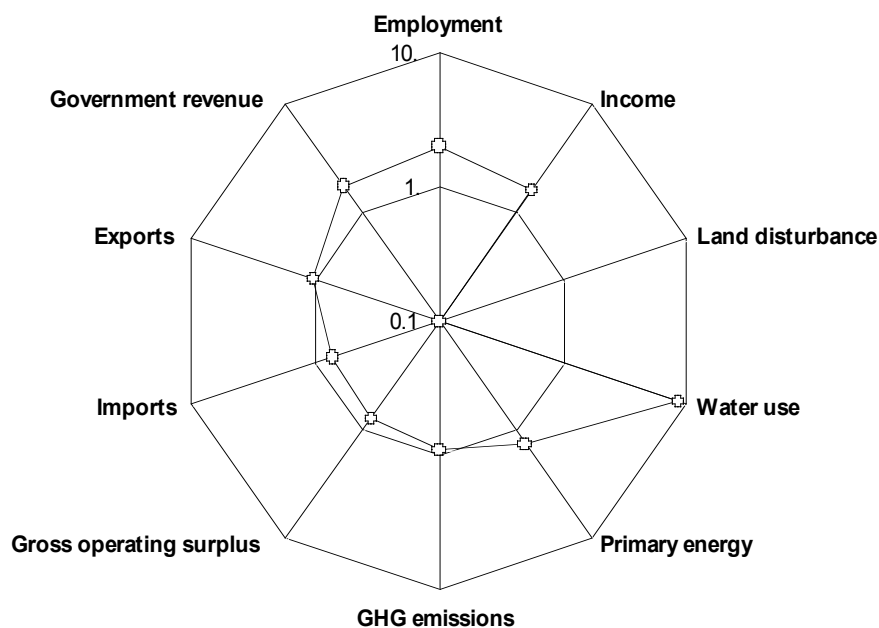


Figure 1. A spider diagram presentation of triple bottom line performance for financial, social and environmental indicators, in the bauxite mining sector. The economy-wide scaled average (=1) is the regular polygon in the centre of the diagram. Indicators with above average performance are closer to the centre, while below average indicators are positioned closer to the outside boundary.

Apart from the three social indicators which are outliers in most primary mining sectors due to the capital intensive nature of the industry, the issues that warrant analysis in bauxite mining relate to the water use and primary energy indicators. The structural pathway for the water indicator shows that the direct sector effect represents 97% of the total with minor additions from electricity production, services to mining, and the water delivery sectors (Table 3). Water is used in bauxite mining to dampen strip mine surfaces and reduce blowing dust and to separate dust from bauxite pebbles, so purifying the ore and increasing the chemical efficiency of the alumina production process. Industry sources suggest that 500 to 1000 litres per tonne are required, with this analysis giving 750 litres per tonne. Industry sources also suggest that considerable improvements have been implemented in new bauxite washing plants and one mining group has reduced its water use from 2000 litres per tonne of ore treated, to 500 litres per tonne in a three year period. The energy outlier is composed of electricity (36%), fuel combusted directly within the sector, presumably mainly for mining machines (35%), diesel refining (4%), basic chemicals (1%) and wholesale trade (1%). The electricity and diesel engine fuel together make up 71% of total energy consumption. Bauxite extraction, treatment

and crushing are physical activities and energy efficiency may be approaching the process limit.

Table 3: Structural Path Analysis of Eq. 1 for the Australian bauxite mining industry. For abbreviations, see <http://www.isa.org.usyd.edu.au/publications/balance.shtml>.

Gross operating surplus (\$/\$)			Employment (min/\$)			GHG emissions (kg CO ₂ -e/\$)		
Bx	0.338	(0; 70.%)	Bx	0.349	(0; 41.%)	El Bx	0.332	(1; 36.%)
Mn Bx	0.0193	(1; 4.%)	Wt Bx	0.0409	(1; 4.7%)	Bx	0.255	(0; 28.%)
El Bx	0.0134	(1; 2.8%)	Mn Bx	0.0405	(1; 4.7%)	Fr Bx	0.044	(1; 4.8%)
Wt Bx	0.00568	(1; 1.2%)	Nb Bx	0.0218	(1; 2.5%)	Fo Bx	0.0279	(1; 3.%)
Cm Bx	0.00523	(1; 1.1%)	Ts Mn Bx	0.0193	(2; 2.2%)	Ch Bx	0.00856	(1; 0.93%)
Ts Mn Bx	0.00428	(2; 0.88%)	El Bx	0.0149	(1; 1.7%)	Oi Fo Bx	0.00842	(2; 0.91%)
Oi Fo Bx	0.00397	(2; 0.82%)	Cm Bx	0.0145	(1; 1.7%)	Bl El Bx	0.00837	(2; 0.91%)
Bk Bx	0.00303	(1; 0.62%)	Eq Bx	0.0131	(1; 1.5%)	Wt Bx	0.00566	(1; 0.61%)
Sg Bx	0.0027	(1; 0.56%)	Ma Bx	0.012	(1; 1.4%)	Is Bx	0.00483	(1; 0.52%)
Bl El Bx	0.00214	(2; 0.44%)	Bk Bx	0.012	(1; 1.4%)	Ce Bx	0.00455	(1; 0.49%)
Nb Bx	0.00214	(1; 0.44%)	Rd Bx	0.0105	(1; 1.2%)	Is Ma Bx	0.0033	(2; 0.36%)
Sf Bx	0.00213	(1; 0.44%)	Rh Bx	0.00826	(1; 0.96%)	Pc Bx	0.00327	(1; 0.35%)
Rd Bx	0.00178	(1; 0.37%)	Sm Bx	0.00583	(1; 0.68%)	Lm Bx	0.00306	(1; 0.33%)
Fo Bx	0.00154	(1; 0.32%)	Bs Bx	0.00511	(1; 0.59%)	Rd Bx	0.00283	(1; 0.31%)
Rh Bx	0.00135	(1; 0.28%)	Gv Bx	0.00499	(1; 0.58%)	Bl Bx	0.00261	(1; 0.28%)
Pd Bx	0.00134	(1; 0.28%)	Sh Bx	0.00457	(1; 0.53%)	Ga Bx	0.00249	(1; 0.27%)
Eq Bx	0.00133	(1; 0.27%)	Rf Bx	0.0045	(1; 0.52%)	Mn Bx	0.00225	(1; 0.24%)

Exports (\$/\$)			Income (\$/\$)			Water use (L/\$)		
Bx	0.104	(0; 66.%)	Bx	0.0906	(0; 44.%)	Bx	350.3	(0; 97.%)
Wt Bx	0.00464	(1; 2.9%)	Mn Bx	0.0136	(1; 6.6%)	El Bx	1.84	(1; 0.51%)
Bl El Bx	0.00325	(2; 2.1%)	Wt Bx	0.00877	(1; 4.3%)	Mn Bx	1.28	(1; 0.36%)
Oi Fo Bx	0.00272	(2; 1.7%)	Ts Mn Bx	0.00451	(2; 2.2%)	Wa Bx	0.538	(1; 0.15%)
Eq Bx	0.00234	(1; 1.5%)	El Bx	0.00404	(1; 2.%)	Wa El Bx	0.106	(2; 0.03%)
Ma Bx	0.00177	(1; 1.1%)	Cm Bx	0.00328	(1; 1.6%)	Sg Bx	0.0684	(1; 0.019%)
Sg Bx	0.00134	(1; 0.85%)	Nb Bx	0.00325	(1; 1.6%)	Wa Ts Mn Bx	0.0577	(3; 0.016%)
Fo Bx	0.00113	(1; 0.72%)	Bk Bx	0.00297	(1; 1.4%)	Bl El Bx	0.0435	(2; 0.012%)
Bl Bx	0.00101	(1; 0.64%)	Eq Bx	0.00231	(1; 1.1%)	Sm Bx	0.037	(1; 0.01%)
Ch Bx	0.000996	(1; 0.63%)	Ma Bx	0.00226	(1; 1.1%)	Wa Pd Bx	0.0367	(2; 0.01%)
Rf Bx	0.000922	(1; 0.58%)	Rd Bx	0.0018	(1; 0.88%)	Fo Bx	0.0334	(1; 0.0093%)
Pc Bx	0.000771	(1; 0.49%)	Rf Bx	0.00126	(1; 0.62%)	Ws Bx	0.0287	(1; 0.008%)
Oc Bx	0.000723	(1; 0.46%)	Gv Bx	0.00126	(1; 0.61%)	Ch Bx	0.0261	(1; 0.0073%)
Cm Bx	0.000698	(1; 0.44%)	Pd Bx	0.00121	(1; 0.59%)	Wa Ms Bx	0.0233	(2; 0.0065%)
At Bx	0.000694	(1; 0.44%)	Sm Bx	0.001	(1; 0.49%)	Wt Bx	0.0229	(1; 0.0064%)
Ts Mn Bx	0.000679	(2; 0.43%)	In Bx	0.000984	(1; 0.48%)	Wa Ms Wt Bx	0.0212	(3; 0.0059%)
Nf Bx	0.000653	(1; 0.41%)	Ms Bx	0.000945	(1; 0.46%)	Oi Fo Bx	0.0201	(2; 0.0056%)

Imports (\$/\$)			Government revenue (\$/\$)			Land disturbance (m ² /)\$)		
Bx	0.082	(0; 58.%)	Bx	0.0561	(0; 47.%)	Bx	0.0826	(0; 45.%)
Fo Bx	0.00915	(1; 6.5%)	Mn Bx	0.00923	(1; 7.8%)	Fr Bx	0.0141	(1; 7.8%)
Mn Bx	0.00882	(1; 6.2%)	Wt Bx	0.0041	(1; 3.5%)	El Bx	0.00537	(1; 2.9%)
Ma Bx	0.00209	(1; 1.5%)	El Bx	0.00252	(1; 2.1%)	Bc Mp Ho Bx	0.00358	(3; 2.%)
Pc Bx	0.00164	(1; 1.2%)	Ts Mn Bx	0.00222	(2; 1.9%)	Bc Mp Ch Bx	0.0034	(3; 1.9%)
Eq Bx	0.00154	(1; 1.1%)	Bk Bx	0.00164	(1; 1.4%)	Wo Tx Bx	0.00312	(2; 1.7%)
Wt Bx	0.00132	(1; 0.93%)	Cm Bx	0.00157	(1; 1.3%)	Bc Mp Ho Mn	0.00202	(4; 1.1%)
Ts Mn Bx	0.00123	(2; 0.87%)	Nb Bx	0.00137	(1; 1.2%)	Bc Ch Bx	0.00171	(2; 0.94%)
Oc Bx	0.00112	(1; 0.79%)	Rd Bx	0.00128	(1; 1.1%)	Wo Tx Wt Bx	0.00145	(3; 0.8%)
Ch Bx	0.000997	(1; 0.71%)	Eq Bx	0.00115	(1; 0.97%)	Wo Tx Ru Bx	0.000957	(3; 0.53%)
El Bx	0.000932	(1; 0.66%)	Ma Bx	0.00109	(1; 0.92%)	Bc Mp Ho Wt	0.00084	(4; 0.46%)
Cm Bx	0.000895	(1; 0.63%)	In Bx	0.00106	(1; 0.89%)	Ba Bm Bx	0.000798	(2; 0.44%)
Sg Bx	0.000845	(1; 0.6%)	Pd Bx	0.000793	(1; 0.67%)	Wo Ts Mn Bx	0.00074	(3; 0.41%)
Nb Bx	0.000725	(1; 0.51%)	Sf Bx	0.000595	(1; 0.5%)	Bc Mp Bp Bx	0.000672	(3; 0.37%)
Rh Bx	0.000697	(1; 0.49%)	Rf Bx	0.000581	(1; 0.49%)	Rf Bx	0.000633	(1; 0.35%)
Ru Bx	0.000687	(1; 0.49%)	Oi Fo Bx	0.000483	(2; 0.41%)	Bc Mp Oc Bx	0.000606	(3; 0.33%)
Sh Bx	0.000529	(1; 0.37%)	Ms Bx	0.000449	(1; 0.38%)	Bc Mp Ts Mn	0.000605	(4; 0.33%)

3.2 Mining overview

The primary mining sector portrays advantaged outcomes for the environmental and financial indicators, but below average performance for the social indicators of employment generation, income and government revenue. The export propensity indicator is four times the average reflecting the industry's contribution to helping improve the international trade balance. The lower than average contribution to government revenue may be an overestimate since resource rents paid for mineral and petroleum extraction to state and federal governments are not included as 'payments to government' in the internationally implemented 'System of National Accounts,' and thereby the national input-output tables. The lower than average indicators for employment generation and income are essentially structural due to the scale, capital intensity, and economic efficiency, required by each mine that exports to a competitive international marketplace. However there is some justification to claims from mining regions, that a significant component of resource rents be pledged to long term structural investments in those areas from which minerals are extracted, rather than being directed towards the maintenance of major urban centres where the political power lies.

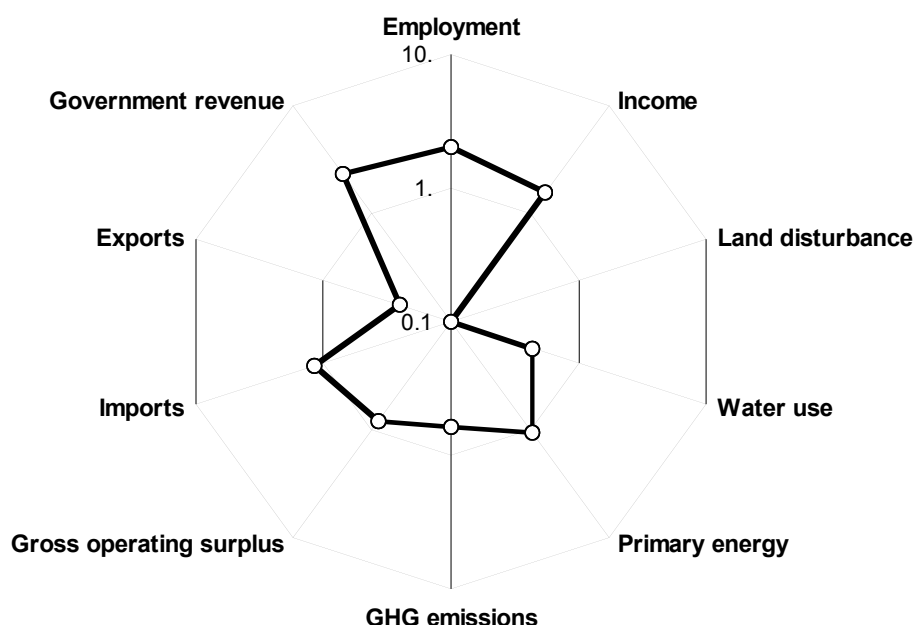


Figure 2: A spider diagram presentation of triple bottom line performance for financial, social and environmental indicators, in the aggregated macro-sectors of 'mining' (13 sectors). The economy-wide scaled average (=1) is the regular polygon in the centre of the diagram. Indicators with above



average performance are closer to the centre, while below average indicators are positioned closer to the outside boundary.

3.2.1 Options for Change

Given an emerging concern on the energy, greenhouse emissions and material transactions embodied in the acquisition of virgin metals, and their accumulation and eventual release from urban-industrial complexes, the concept of 'cradle to cradle' stewardship is moving steadily towards full implementation. The concept is already well developed for aluminium drink containers and steel recycling through electric arc 'mini mills', but is now moving into metals of concern such as lead, copper, zinc and some small volume but high toxicity metals such as mercury and cadmium. A new vision might transform a typical commodity miner to a metal steward who manages a metal stock that is based on the metals embodied in human artefacts, the collection and recycling chain, and the supplementation of metal stocks from virgin ores. Implementing this wider boundary for mining will improve its social indicators and, if industry and consumers buy into the full stewardship concept, its financial indicators as well. For industry, the challenges are more complex but two issues stand out. The first is to focus procurement for intermediate inputs into production, towards items with low environmental loadings certified through established conventions of life cycle analysis. The second more challenging option is to reduce the energy and material content of manufacturing by co-location of many industries into 'industrial ecology' complexes where waste materials are inputs into other products, process heat can be shared, and lower carbon electricity can be generated, so enabling manufacturing synergies while reducing fossil carbon content.

5. SOFTWARE DEVELOPMENT

At the University of Sydney, TBL Accounting has been formulated as a quantitative framework using an input-output-based LCA method. This framework has been applied to dozens of organisations in reporting on their sustainability performance - companies, government departments, NGOs. Experiences were collected in a 3-year pilot project (www.isa.org.usyd.edu.au/research/TBLEPA.shtml). It became clear that the data collection burden for the organisation has to be as small as possible. As a result, a software tool was developed in collaboration with the using organisations, enabling users to create a comprehensive sustainability report solely by importing their existing financial accounts (www.bottomline3.com).

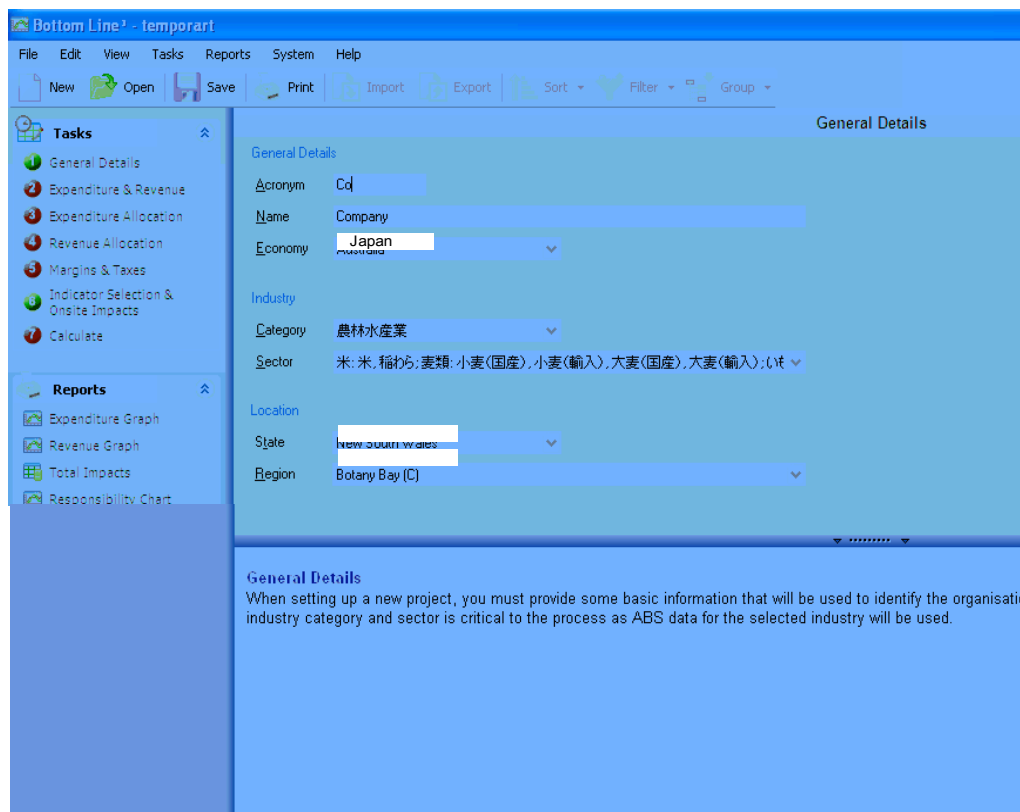


Figure 2. General page of the BottomLine³ software

This software tool is called BottomLine³, or short BL³ (“BL-cubed”). It accepts any organisation’s financial accounts as imported input, and uses this financial information to calculate upstream, indirect impacts in terms of physical indicators chosen by the user. On-site physical impacts are entered separately. BL-cubed’s indicator set features all indicators in Table 1, plus material flow (<http://abareonlineshop.com/product.asp?prodid=13315>), energy use (<http://abareonlineshop.com/product.asp?prodid=1327>), water use (www.abs.gov.au/AUSSTATS/), land disturbance (Lenzen et al., 2001), greenhouse gas emissions (www.greenhouse.gov.au), the ecological footprint (www.isa.org.usyd.edu.au/publications/documents/Ecological_Footprint_Issues_and_Trends.pdf), emissions of more than 100 toxic, ozone-depleting, acidifying and eutrophating substances to air, water and soil from the Australian National Pollutant Inventory (www.npi.gov.au), and two prominent Dutch LCA sets (the CML midpoint set www.leidenuniv.nl/cml/ssp/databases/cmlia/, and PRé’s endpoint Eco-indicator99 www.pre.nl/eco-indicator99/ei99-reports.htm). In total the whole database distinguishes 1270 indicators for 344 industry sectors.

Within the software “engine”, the financial accounts of companies or other organisations are incorporated into national input-output tables (A in Eqn. 1),

as an additional sector. Users choose their “own” sector (i.e. the classified sector that their organisation belongs to), and the software a) converts the user’s financial data from purchasers’ prices into basic prices, and b) subtracts their expenditures and revenues from this sector’s input-output table entries. Furthermore the user inputs data on their organisation’s on-site impacts which the software embeds in the national exogenous data (F in Eqn. 1). Thereafter, the Leontief inverse, the Taylor expansion, and total multipliers are calculated, and presented in various graphs.

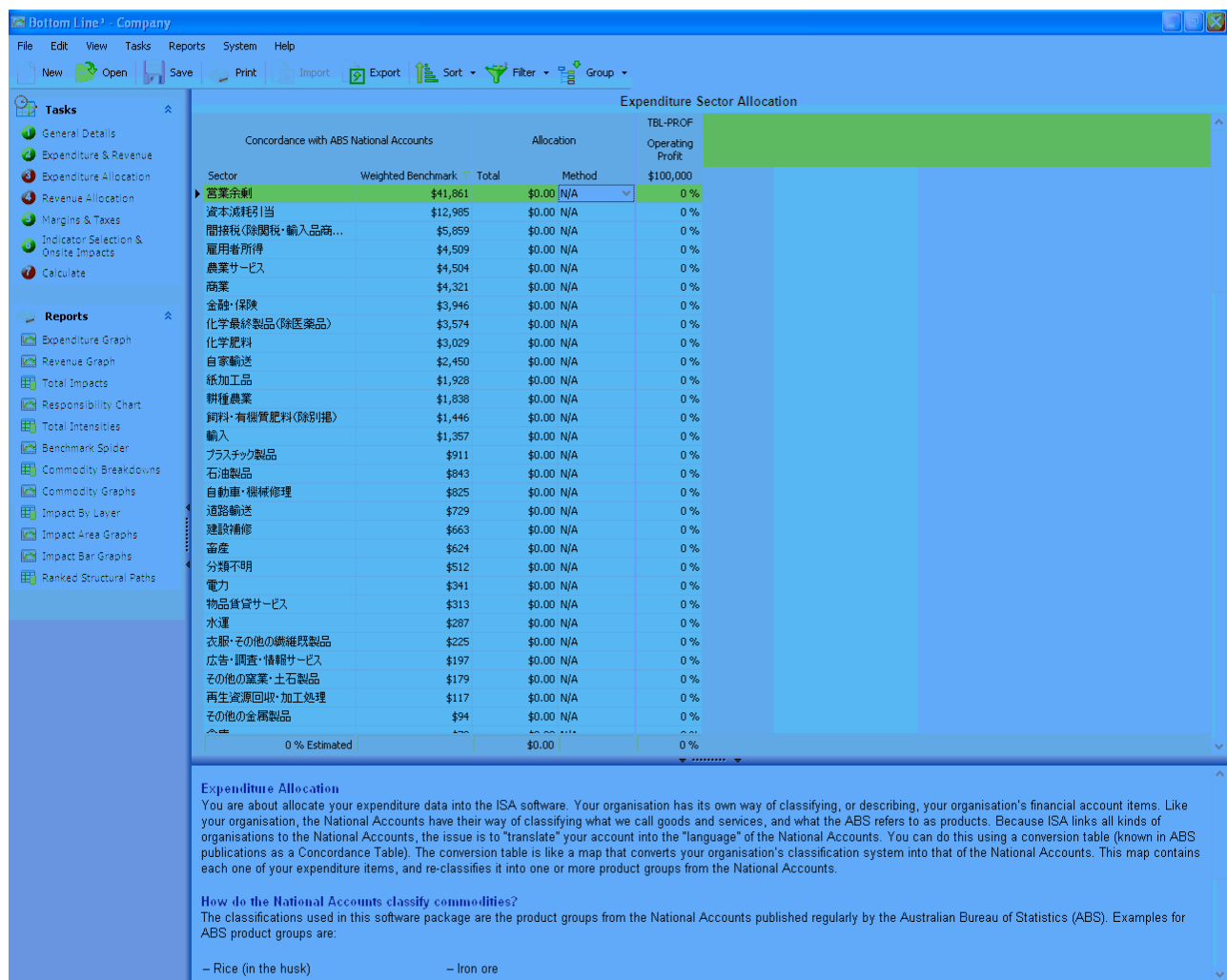


Figure 3. User input page of the BottomLine³ software

Software outputs include aggregate figures, detailed breakdowns and rankings of indicators into supply chain contributions. These outputs enable the user to determine

- which of the operating inputs embody the largest impacts,
- whether these impacts occur at direct suppliers, or at more remote supply chain locations (the Taylor expansion of the Leontief inverse), and
- which single input paths carry the largest impacts (Structural Path Analysis, SPA; Lenzen, 2002).

Users perceive especially the latter information as very helpful, because it can be used for organisational planning and priority setting for informed action towards financial, social and environmental sustainability. In particular, it shows organisations alternatives for effective procurement policy changes, which may be applied instead of perhaps costly on-site measures.

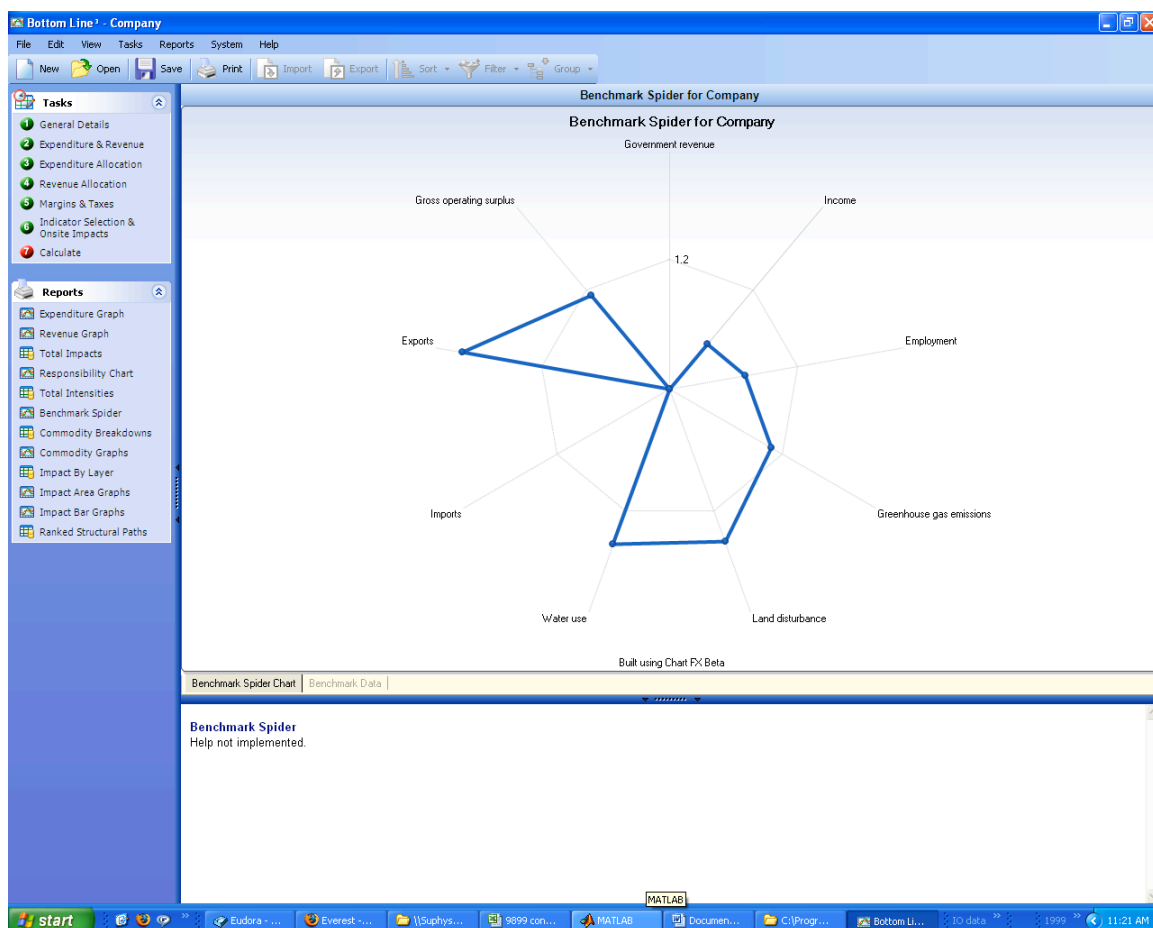


Figure 4. Example output page of the BottomLine³ software



The BL-cubed software has been extensively road-tested over three years. Users had no difficulty in understanding and accepting indirect impacts occurring off-site, in addition to on-site direct impacts. Users felt that assessing their organisation's indirect impacts was a valuable feature because it increases abatement options, enables meaningful benchmarking, avoids loopholes in reporting and informs about real risk. Sydney University's TBL software has been designed so it can readily be implemented for any economy that for which input-output data complemented with physical data are available. Trial versions include Australia, the UK, Japan, the US, and Germany. In principle it is possible to develop a version based on a multi-national IO framework that covers international trade flows.

5. CONCLUSIONS AND FURTHER WORK

Numerate triple bottom line accounting at the whole-economy level has highlighted a number of key issues for the Australian economy. Given the high likelihood of incremental change as a policy constant in today's democracies, technological innovation faces significant challenges as it attempts to reduce the environmental intensities in many sectors. Improving the social indicators is more of a challenge since sector aggregates such as mining for example, have evolved over many decades to be capital intense, skill rich and employment poor.

More radical interpretations of these Triple Bottom Line Accounts suggest a number of directions many of which will not find ready acceptance in today's policy debate. Nevertheless there is sufficient support in statements such as 'charging the real price for water' and 'including environmental externalities in the full cost of production' to suggest that some movement is possible. For example, improving the social indicators for mining by moving to a full life cycle 'metal stewardship' approach, may seem extreme in today's marketplace, but recycling programs for copper, lead, steel and aluminium are commonplace and the main challenge is moving to much higher levels of recycling while extraction of virgin ore stabilises and then decreases. This will allow the concept of a sustainable metals industry to bridge the current gap between rhetoric and reality.

There is a significant policy tension between implementing the changes suggested by this aggregated and macro-analysis, and stimulating those changes at a sector by sector level. The challenge of harmonising the effects across the whole economy are immense, particularly when international institutions and the global business cycle could be focused on goals that are completely



opposite. The concept of fully free and open trade is still in reality a hypothetical one. However if, within the current international trading regimes, the farm gate price of Australian food and fibre products were substantially increased to internalise the environmental externalities, much domestically produced food could be replaced by imports, none of which were assessed by the same full chain analyses presented here. Allowing trade officials and industry blocks access to these domestic analyses, as well as similar ones for trading countries, would allow scope for informed trade negotiations based on triple bottom line concepts.

It is important to harmonise this analytical approach, with its strengths of integration and lack of boundaries, with international approaches rapidly gaining headway such as 'The Global Reporting Initiative' and 'The Equator Principles'. These approaches have widespread support through many globalised companies and national governments. However they are currently orientated to a 'within the factory fence' approach, but do acknowledge a number of first order issues such as the origin of water and energy, and some second and third order effects particularly the labour practices used to supply intermediate inputs to production. Part of the harmonisation process will require the development of indicator datasets that match the requirements of these initiatives, as well as collaborating in the development of multi-national input-output frameworks and corresponding international software tools that enable the fluent use of whole economy accounting without boundaries.

Inevitably, today's production chains reach across many countries and production processes and embody a wide range of positives and negatives in social and environmental areas. This current analysis focuses only on production processes that occur within the boundary of Australia's continental shelf. To adequately represent imports of both final and intermediate demand both of goods and services, will require this level of analysis for five to ten of Australia's main trading partners, predominantly Japan, China, New Zealand, and the US, and an aggregated 'rest of world' category. With appropriate collaboration between countries, this may be feasible.



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