Input-output analysis for business planning: a case study of the University of Sydney

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**Abstract**:

We present a multi-region input-output (MRIO) model of the University of Sydney embedded in the Australian economy, which forms the centrepiece of a new data-driven framework for strategic forecasting and planning of the university’s financial operations. This framework incorporates both Leontief’s well-known demand-pull, as well as Ghosh’s supply-push exercise. It is therefore able to estimate the immediate financial implications for the university, and the economy-wide flow-on effects, for example as a result of changes in demand for courses by students, or as a result of supply-side changes such as wage increases. We report on recent scenario studies on the financial performance of the teaching and research functions of the university, and the lessons learned for management practice.

1. **Introduction**

The idea of assessing the wider impacts of a university is not new. Already in the 1970s, researchers used input-output analysis to study the immediate and regional economic flow-on effects of a university’s operations (Brownrigg 1973; Wilson and Raymond 1973; Lichty and Jesswein 1978). More recently the emphasis has been on environmental implications of running a university, both on campus and beyond through the complex supply-chain network (Viebahn 2000; Venetoulis 2001). Wood and Lenzen 2003 carried out the first comprehensive life-cycle assessment for the University of Sydney, using the School of Physics as a case study. In 2009, the University released its first corporate Triple Bottom Line report based on input-output analysis, as successfully piloted by the Australian Government a few years prior (Foran *et al.* 2005a; Foran *et al.* 2005b).

In funding this work the aim of the University of Sydney is twofold:

1. To quantify the economic, environmental and social impacts of its operations, and in doing so, to set a high methodology standard by reporting on impacts in its entire supply-chain network that extends across Australia and beyond.
2. To investigate the interactions and interdependencies between the various business units within the University of Sydney, and to use this information for scenario exercises.

Both aims can be met by using input-output analysis in general, by enterprise input-output models in particular. Enterprise models have been published extensively in this journal (for example Grubbstrom and Tang 2000; Marangoni and Fezzi 2002; Albino *et al.* 2003). This work breaks new grounds in a number of ways. According to our knowledge, our enterprise model

* is the largest so far in terms of its number of sectors,
* is the first subjected to the Ghosh supply-push calculus,
* is the first to investigate system closure, and
* is the first to feature an application of Structural Path Analysis.

Thus, the novelty of this work lies not so much in the techniques used, but in their application to a very large enterprise input-output model. The purposes of this paper are twofold: a) to describe the construction of the University’s enterprise input-output table, and its embedding into a multi-region table including the Australian economy, and b) to demonstrate the usefulness of enterprise models for basic input-output modelling. In particular this paper shows how demand-pull and supply-push exercises, as well as closed-system model results can be interpreted and used for internal decision-making. The paper unravels as follows: In Section 2 we explain the methodology used to generate the results discussed in Section 3. Section 4 then illustrates how these results can be applied in strategic financial planning, and Section 5 concludes.

**Methodology**

Enterprise input-output models have been constructed previously, but mostly as single-region models for one enterprise only (for example Farag 1967; Lin and Polenske 1998; Correa and Craft 1999; Albino and Kühtz 2004; Lave 2006), or as extended single-region models of an economy with an enterprise represented by one additional sector (Tiebout 1967; Billings and Katz 1982; Lenzen 2008), but rarely as nested multi-region models, as done by Polenske 1997 and Li et al. 2008. Polenske’s basic idea was taken up again in recent input-output-based hybrid life-cycle approaches, where a so-called foreground system containing interdependent production processes, is embedded in a national input-output table (Heijungs and Suh 2002; Suh 2004). These research approaches reflect the fundamental equivalence of business data and National Accounts (UNSD 2000).

In order to be able to capture both the interdependencies of business units within the University of Sydney as well as the University’s interactions with the rest of the economy, we use a nested multi-region input-output model, where the university and its “sectors” represent region 1, and the Australian economy represents region 2. The resulting input-output table is a four-quadrant industry-by-industry table (Fig. 1), with quadrant **T**UU containing the intra-university transactions, and quadrant **T**AA containing the intra-economy transactions including final demand and primary inputs, but excluding the university. Quadrant **T**UA contains the revenue of the university either from industry sectors of the economy, or from final demanders such as students paying fees. Finally, quadrant **T**AU contains the expenditure or the university on commodities produced in the Australian economy and on primary inputs such as wages, surplus and taxes. Final demand and primary inputs are separate blocks labelled **y** and **v**.[[1]](#footnote-1) The model is open with regard to the rest of the world, that is exports are a part of final demand, and imports are a part of primary inputs.



Fig. 1: Schematic of the four-quadrant nested MRIO, with the University accounts (**T**UU) embedded into the Australian National Accounts (**T**AA), bilateral trade blocks (**T**AU and **T**UA), and primary inputs (**v**) and final demand (**y**). Subscripts U stand for University, and A for Australia. The dotted line separates components of final demand, for example private final consumption, or expenditure on gross fixed capital.

Quadrants **T**UU and **T**UA plus **y**U were constructed using the University’s revenue accounts, and quadrants I and III plus **v**U were constructed from the expenditure accounts, This involved two steps: First, a concordance matrix was constructed, linking the University’s class codes (CCs are used to label every purchase and income) with the Input-Output Product Classification (IOPC) of the Australian Bureau of Statistics (ABS). This concordance matrix was then used to re-classify the entire General Ledger of the University from its CC classification into the Australian IOPC system. Second, quadrant **T**UU was balanced by reconciling the University’s internal transfers, that is, internal revenues and expenditures were first matched at the detailed transaction level, and then the quadrant was balanced using a Quadratic Programming algorithm (Yu *et al.* 2009). This part of our nested MRIO distinguishes the University’s 639 business units, which are mainly its faculties[[2]](#footnote-2), but also non-academic units such as campus infrastructure and services, libraries, or IT. By far the most important intra-university transactions in the **T**UU quadrant are transfers from ‘Central Accounts’ to faculties. These transactions represent research and teaching income that is pooled within Central Accounts, part of which is then re-distributed across research and teaching purposes according to a funding formula (evidence for this mechanism is in Tab. 9). Also importantly, albeit to a lesser extent, capital investment and management units are also responsible for transfers of funds to faculties, for infrastructure replacement and expansion purposes.

Quadrant **T**AA plus **v**A and **y**A is an expanded version of the Australian input-output tables (ABS 2008). These tables are published at the 109-sector level of detail, but were extended to 344 sectors by using a large amount of unpublished superior information and re-balancing using a RAS variant, as described by Gallego and Lenzen 2008 and Lenzen *et al.* 2009. Before final balancing, the Australian National Accounts were netted by subtracting the turnover of the university. There are 7 final demand and primary input categories, so that the entire system is sized (639+344+7)2 = 9902 = 980,100 entries. The intersection of primary inputs and final demand (field labelled 0) is empty, showing that our MRIO is not a Social Accounting Matrix.

Because of its nested form, the model allows for several variants of input-output analysis, characterised by different system closures (Fig 2). All variants are characterised by a distinction between endogenous (bold) and exogenous (dashed) parts, with the exogenous sectors driving change, and the endogenous sectors facilitating flow-on effects. In the classical demand-pull and supply-push exercises (Dietzenbacher 1989; 1997), final demand and primary inputs, respectively, of both the university and the economy are exogenous, and flow-on effects are traced throughout the linked university-economy inter-regional intermediate demand system. In what we call the “open” variant, the industry sectors of the economy are also made exogenous, and there are only intra-university flow-on effects. In a “closed” variant, wages and salaries as well as final consumption are endogenised, leading to the well-known type-II systems that feature a large amount of internal feedback (Miyazawa 1968; Katz 1980; Miller 1980; Round 1988; Lenzen and Schaeffer 2004).[[3]](#footnote-3) Further closures are possible, for example with regard to capital transactions (Lenzen and Treloar 2005), or with regard to the rest of the world, into a true international MRIO. Because of increasing internal, or in our case inter-regional feedback, the magnitude of multipliers calculated from such models usually increases with the degree of closure. For the sake of brevity, in this article we only report on open and classical demand-pull and supply-push exercises. These variants were considered the most appropriate, given that the questions asked by university decision makers included the enumeration of internal financial flows, as well as the economy-wide flow-on effects as a result of the university’s operations.







Fig. 2: Illustration of open (top), classical (middle) and closed (bottom) input-output demand-pull model variants. The endogenous and exogenous parts are delineated by bold and dashed lines, respectively. The more closed the model, the larger the endogenous part that is facilitating the flow-on effects, and the smaller the exogenous part that is exerting the pull.

In the following Section we will show two types of results: First we will subject the system to demand-pull and supply-push shocks propagated by the Leontief and Ghosh inverses in the usual way (Leontief 1936; Ghosh 1958), and then examine the total effects of these shocks on the respective opposite supply and demand sides. Expressed mathematically: Let **T** be the input-output transactions matrix represented for each model by the bold rectangles in Fig. 2, and **y** the remaining exogenous demand represented by the dashed rectangle. Let **1** = {1,...,1} be a summation operator, and **T1** + **y**= **x** be gross output. The Leontief inverse is then **L** = [$\hat{1}$- **T**$\hat{x}$-1]-1, where the hat symbol denotes diagonalisation of a vector, and $\hat{1}$ = **I** is the identity matrix. Effects **Q** of demand-side shocks **y** on exogenous inputs **v** are then determined by **v** = **v**$\hat{x}$-1**L** **y**. The supply-push model formulation can be derived in a similar way from **v** + **1T**= **x**’, where the prime denotes transposition, and the Ghosh inverse **G** = [$\hat{1}$- $\hat{x}$-1**T**]-1.

In particular, for open-model demand-pull we use $T^{o}=T\_{UU}$,$ A^{o}=T\_{UU}\hat{x\_{U}}^{-1}$, and demand-side shocks $∆y^{o}=∆T\_{UA}1+∆y\_{U}1$ to enumerate supply-side effects $∆v^{o}=\left[\begin{matrix}T\_{AU}\hat{x\_{U}}^{-1}\\v\_{U}\hat{x\_{U}}^{-1}\end{matrix}\right]\left(I-A^{o}\right)^{-1}∆y^{o}=\left[\begin{matrix}A\_{AU}\\φ\_{U}\end{matrix}\right]L^{o}∆y^{o}$. We call $A\_{AU}L^{o}∆y^{o}$ the “university supply-side requirements in terms of operating inputs”, and $φ\_{U}L^{o}∆y^{o}$ the “university supply-side requirements in terms of primary inputs”, that are necessary to meet the demand-side shock.

For classical-model demand-pull we use $T^{c}=\left[\begin{matrix}T\_{UU}&T\_{UA}\\T\_{AU}&T\_{AA}\end{matrix}\right]$,$ A^{c}=T^{c}\hat{\left[\begin{matrix}x\_{U}\\x\_{A}\end{matrix}\right]}^{-1}$, and demand-side shocks $∆y^{c}=\left[\begin{matrix}∆y\_{U}\\0\end{matrix}\right]1$ to enumerate supply-side effects $∆v^{c}=\left[\begin{matrix}v\_{U}\hat{x\_{U}}^{-1}&v\_{A}\hat{x\_{A}}^{-1}\end{matrix}\right]\left(I-A^{c}\right)^{-1}∆y^{c}=\left[\begin{matrix}φ\_{U}&φ\_{A}\end{matrix}\right]L^{c}∆y^{c}$. We call $\left[\begin{matrix}φ\_{U}&0\end{matrix}\right]L^{c}∆y^{c}$ the “university supply-side requirements in terms of primary inputs”, and $\left[\begin{matrix}0&φ\_{A}\end{matrix}\right]L^{c}∆y^{c}$ the “economy supply-side requirements in terms of primary inputs”, that are necessary to meet the demand-side shock.

For open-model supply-push we use$ A^{\*o}=\hat{x\_{U}}^{-1}T\_{UU}$ and supply-side shocks $∆v^{\*o}=1^{'}∆T\_{AU}+1^{'}∆v\_{U}$ to enumerate demand-side effects $∆y^{\*o}=∆v^{\*o}\left(I-A^{\*o}\right)^{-1}\left[\begin{matrix}\hat{x\_{U}}^{-1}T\_{UA}&\hat{x\_{U}}^{-1}y\_{U}\end{matrix}\right]=∆v^{\*o}G^{o}\left[\begin{matrix}A\_{UA}^{\*}&ψ\_{U}^{\*}\end{matrix}\right]$. We call $∆v^{\*o}G^{o}A\_{UA}^{\*}$ the “university demand-side requirements in terms of industry revenue”, and $∆v^{\*o}G^{o}ψ\_{U}^{\*}$ the “university demand-side requirements in terms of final demand”, that are necessary to absorb the supply-side shock.

For classical-model supply-push we use $A^{\*c}=\hat{\left[\begin{matrix}x\_{U}\\x\_{A}\end{matrix}\right]}^{-1}T^{c}$ and supply-side shocks $∆v^{\*c}=1^{'}\left[\begin{matrix}∆v\_{U}&0\end{matrix}\right]$ to enumerate demand-side effects $∆v^{c}=∆v^{\*c}\left(I-A^{\*c}\right)^{-1}\left[\begin{matrix}\hat{x\_{U}}^{-1}y\_{U}\\\hat{x\_{A}}^{-1}y\_{A}\end{matrix}\right]=∆v^{\*c}G^{c}\left[\begin{matrix}ψ\_{U}^{\*}\\ψ\_{A}^{\*}\end{matrix}\right]$. We call $∆v^{\*c}G^{c}\left[\begin{matrix}ψ\_{U}^{\*}\\0\end{matrix}\right]$ the “university demand-side requirements in terms of final demand”, and $∆v^{\*c}G^{c}\left[\begin{matrix}0\\ψ\_{A}^{\*}\end{matrix}\right]$ the “economy demand-side requirements in terms of final demand”, that are necessary to absorb the supply-side shock.

The usual qualifications made in input-output analysis apply here as well. Requirements coefficients **A = T**$\hat{x}$-1 and sales coefficients **A**\*= $\hat{x}$-1**T** are assumed constant in the demand-pull, and supply-push scenarios, respectively. Effects are linear functions of exogenous percentage changes. The demand-pull scenario is a quantity model, whilst the supply-push scenario can – at least *ex-ante* – only be interpreted as a price model (price/wage changes, see Dietzenbacher 1989; 1997).[[4]](#footnote-4)

Second, we will decompose the total requirements into different production rounds[[5]](#footnote-5) and important paths, by using Structural Path Analysis (SPA, Crama *et al.* 1984; Defourny and Thorbecke 1984; Treloar 1997; Lenzen 2002; 2006; Peters and Hertwich 2006; Suh and Heijungs 2007). In essence, SPA unravels the Leontief and Ghosh inverses into contributions from transaction chains, using their series expansion (**I**-**A**)-1 = **I** + **A** + **A**2 + **A**3 + … . For example, a Leontief element *Lji* can be written as , where *i*, *j*, *k*, and *l* denote industries, and *ij*=1 if *i*=*j* and *ij*=0 otherwise. A first-order structural path from industry *j* into industry *i* of first order is represented by a coefficient *Aji*, while a second-order structural path from industry *k* via industry *j* into industry *i* is represented by a product *AkjAji*, and so on. There are *N* structural paths of first order, *N*2 paths of second order, and, in general, *Nn* paths of *n*th order.

1. **Results**
	1. Overall results for the university

In the classical demand-pull exercise, each dollar of revenue received from final demand initiates intermediate transactions within the university and the Australian economy, ultimately resulting in payments of primary input categories, as defined by the Australian Bureau of Statistics (Tab. 1). Overall, of each dollar of revenue received by the university, 61¢ end up paid as wages and salaries, within the university, or elsewhere in Australia, 14¢ as operating surplus, 4¢ as taxes, 7¢ increase reserves, and 11¢ leave the economy for imports. Before rounding, the total over those multipliers is 100 ¢/$, since every dollar of revenue has to be accounted for somewhere as an expenditure.[[6]](#footnote-6)

|  |  |
| --- | --- |
| Primary input category | Multiplier (¢/$) |
| Wages and salaries | 61 |
| Gross operating surplus | 14 |
| Taxes  | 4 |
| Increases in inventories | 7 |
| Imports | 11 |

Tab. 1: Primary input multipliers for the University of Sydney, calculated using the Leontief inverse of the classical system in Fig. 2. The total does not equal 100 ¢/$ due to rounding.

From a supply-push perspective, *ex post*, each dollar of primary inputs was paid because of intermediate demand from within the university and the Australian economy, but ultimately because of final demand from categories defined by the Australian Bureau of Statistics (Tab. 2). Overall, each dollar of primary inputs spent by the university as a result of its activities, was met by 46¢ of dividends from, and sales of capital assets within the university and the Australian economy, by 29¢ of government final consumption (grants in the case of the university), by 12¢ of private final consumption (domestic student contributions and private donations in the case of the university), by drawing 6¢ from existing reserves, and by earning 8¢ in exports (overseas students fees in the case of the university). Before rounding, the sum over those multipliers is 100 ¢/$, since every dollar of expenditure on primary inputs has to be met in revenue somewhere.[[7]](#footnote-7)

|  |  |
| --- | --- |
| Final demand category | Multiplier (¢/$) |
| Private final consumption |  12  |
| Government final consumption |  29  |
| Gross fixed capital |  46  |
| Decreases in inventories |  6  |
| Exports |  8  |

Tab. 2: Final demand multipliers for the University of Sydney, calculated using the Ghosh inverse of the classical system in Fig. 2. The total does not equal 100 ¢/$ due to rounding.

How these multiplier effects split between the university and the economy will be shown in the following Section on scenarios. Also, we will use “revenue” instead of the ABS term “final consumption” so it is clearer that these categories represent revenue to the university. Finally, the terms “inventories”, “assets” and “reserves” are used synonymously.

* 1. Scenarios

We examine four case studies – two demand-pull and two supply-push scenarios – comparing the teaching and research functions of the University of Sydney. We investigate

1. the effects of a 5% increase in research demand (through government and industry grants) in terms of additional salaries and operating inputs required to meet the demand increase, as well as associated taxes levied, and gross surplus recorded (demand-pull on quantities),
2. the effects of a 5% increase in teaching demand (through student fees and matching government support) in terms of additional salaries and operating inputs required to meet the demand increase, as well as associated taxes levied, and gross surplus recorded (demand-pull on quantities),
3. the effects of a 5% increase in research cost or capacity (salaries, equipment and consumables) in terms of additional revenue (for example increased student fees) required to absorb the cost increase, from all domestic and overseas sources (supply-push on prices), and
4. the effects of a 5% increase in teaching cost or capacity (salaries, equipment and consumables) in terms of additional revenue required to absorb the cost or capacity increase, from all domestic and overseas sources (supply-push on prices).

The mechanisms of the supply-push scenarios have to be understood as changes in transactions values facilitated by price changes, and not by quantity changes. The implausibility of the *ex-ante* quantity interpretation has been convincingly argued by Oosterhaven 1988; 1989.

In the following four sub-sections we present results from the classical and the open model. We use the terms “university requirements” and “economy requirements” as defined in the previous Section. In addition, for the open model, we split university requirements into 2 parts. “Research requirements” or “teaching requirements” describe effects that arise in the same area of the University where the shock occurred. The terms “intra-university spillover” and “intra-university cross-financing” denote the carrying of cost by teaching to satisfy demand for research or the diversion of revenue generated by teaching to cover cost of research, and vice versa.

In the classical model, transactions within both the university and the economy are endogenous, and requirements in terms of primary inputs and final demand arise as university and economy requirements (sectors outside the solid box in Fig. 2, middle part). In the open model, only transactions within the university are endogenous, and requirements in terms of primary inputs and final demand arise only as university requirements (sectors outside the solid box in Fig. 2, top part).

Since the economy is exogenous in the open model, university requirements arise as well as in terms of operating inputs or industry revenue. In the following four tables the link between the classical and open demand-pull model can be seen in that *total economy supply-side requirements in terms of primary inputs in the classical model are about equal to total university supply-side requirements in terms of operating inputs in the open model*. Intuitively, this is clear because all payments made by the University for operating inputs are used in the selling industry sectors ultimately to pay for primary inputs. Similarly, in the supply-push models, *total economy demand-side requirements in terms of final demand in the classical model are about equal to total university demand-side requirements in terms of industry revenue in the open model*. This is clear because all industry revenue received by the University must have been generated in the paying industry sectors ultimately by final demand.[[8]](#footnote-8)

Moreover, we make a distinction between “real cost” and “surplus”; the former are paid out and leave the university, the latter are surplus available for investment and increases in capital assets. Cost are paid for by what we call “real revenue” where this arises from fees and grants received in exchange for university teaching and research. If this real revenue is insufficient to meet cost, “deficits” have to be covered by drawing on reserves.

Total real cost and demand are represented in the ‘Real cost/revenue’ columns of the four tables below. Real cost/revenue in the open model are equal to real cost/revenue are the sum of classical-model real cost/revenue plus operating cost /industry revenue, which is equal to the sum of classical-model real cost/revenue plus all economy requirements. This is because – as explained above – economy requirements in the classical model are equal to university requirements in terms of operating inputs/industry revenue in the open model.

* + 1. Increase in research demand

In this sub-section, we will explicitly refer to rows (r) and columns (c) in Tab. 3 in order to ease interpretation. The descriptions of Tabs. 4-6 proceed in an identical manner, so the row/column reference has been omitted in the corresponding sub-sections.

Assuming a constant input-output structure, a 5% increase in demand for research through government and industry funding leads, in the open model, on a per-dollar of revenue basis, to an increased requirement for university wages and salaries of 49¢ (row 3 / column 1, or rows 7+8 / column 1 in Tab. 3), an increase in the production tax bill of 3¢ (r3/c3, or r7+8/c3), and an increase in operating inputs from the rest of the economy of 45¢ (r4/c7+8 or r7+8/c6). Total real cost are hence 97¢ (r7+8/c7), and net surplus is only 3¢ (r7+8/c8). These 3¢ net surplus are the balance of a 5¢ increase in inventories (mainly accrued within the Faculties that undertake the research, as unspent research funds), and a 2¢ decrease in surplus (affecting the University’s Central Accounts). The negative effect is due to the structure of research funding at the University of Sydney, where research and teaching income is pooled within Central Accounts, part of which is then re-distributed across research and teaching purposes according to a funding formula (see Section 2.3.2). In essence, a lot of research is not fully self-funded, and draws on teaching revenue as well as other surplus. Hence, an increase in research activities reduces surplus. This is further evidenced in the following sub-sections.

The input-output calculus in the classical model traces the 45¢ operating inputs spilling throughout the Australian economy and shows that these end up in a diverse mix of industries – mostly service sectors – as 23¢ wages and salaries, 11¢ imports, 10¢ surplus, and a further 2¢ of taxes (r4/c1-6).

The 5% demand increase in research is worth $6.9m (r5+6/c7+8) in absolute terms, of which for the University $6.7m (r5+6/c7) are incurred as real cost, and $0.2m (r5+6/c8) as net surplus.

Most of the total real cost for research – 94¢ (r7/c7) out of the total real cost of 97¢ for every dollar of funded research activities – are incurred within the research units that received the funding in the first place, and only 3¢ (r8/c7) spill over into other university units, such as Human Resources, Campus Property and Services, and ICT.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Wages and salaries | + Gross operating surplus | + Taxes | + Increases in inventories | + Imports | + Operating inputs | = Real cost a | + Surplus, to reserves b |
|  |  |  |  |  |  |  |  |  |
| **Classical model** |  |  |  |  |  |  |  |  |
| University requirement ($m) c | 3.40 | -0.17 | 0.18 | 0.40 | 0.00 |  | 3.57 | 0.23 |
| Economy requirement ($m) d | 1.57 | 0.67 | 0.13 | 0.01 | 0.75 |  | **2.45** | **0.68** |
|  |  |  |  |  |  |  |  |  |
| University requirement (¢/$) c | 49 | -2 | 3 | 5 | 0 |  | 51 | 3 |
| Economy requirement (¢/$) d | 23 | 10 | 2 | 0 | 11 |  | **35** | **10** |
|  |  |  |  |  |  |  |   |  |
| **Open model** | ┌─── |  | University | e | ───┐ | Economy f |  |  |
| Research requirement ($m) | 3.27 | -0.17 | 0.17 | 0.38 | 0.00 | **3.06** | 6.50 | 0.21 |
| Intra-university spillover ($m) | 0.13 | 0.00 | 0.01 | 0.02 | 0.00 | **0.07** | 0.20 | 0.02 |
|  |  |  |  |  |  |  |  |  |
| Research requirement (¢/$) | 47 | -2 | 3 | 5 | 0 | **44** | 94 | 3 |
| Intra-university spillover (¢/$) | 2 | 0 | 0 | 0 | 0 | **1** | 3 | 0 |
|  |  |  |  |  |  |  |  |  |

a Real cost = Wages and salaries + Taxes + Imports; b Surplus = Gross operating surplus + Increases in inventories; c university supply-side requirements in terms of primary inputs $\left[\begin{matrix}φ\_{U}&0\end{matrix}\right]L^{c}∆y^{c}$, by components in $φ\_{U}$; d economy supply-side requirements in terms of primary inputs $\left[\begin{matrix}0&φ\_{A}\end{matrix}\right]L^{c}∆y^{c}$, by components in $φ\_{A};$ e university supply-side requirements in terms of primary inputs $φ\_{U}L^{o}∆y^{o}$, by components in $φ\_{U}$; f university supply-side requirements in terms of operating inputs $A\_{AU}L^{o}∆y^{o}$, total. Note that requirements labelled d are about equal to those labelled f (both in bold print), as shown in the previous Section. Values may not add up due to rounding.

Tab. 3: Supply-side requirements of a 5% increase in research demand.

* + 1. Increase in teaching demand

Assuming a constant input-output structure, a 5% increase in demand for teaching through student enrolments leads, in the open model, on a per-dollar of revenue basis, to an increased requirement for university wages and salaries of 53¢, an increase in the production tax bill of 3¢, and an increase in operating inputs from the rest of the economy of 16¢ (Tab. 4). Total real cost are hence 72¢, and net surplus is 28¢. The input-output calculus in the classical model traces the 16¢ operating inputs spilling into the Australian economy and shows that these end up – again mostly in service sectors – as 7¢ wages and salaries, 4¢ imports, and 5¢ surplus, and a further 1¢ of taxes.

The 5% demand increase in teaching is worth $15.5m in absolute terms, of which $11.2m are incurred as real cost, and $4.3m as net surplus.

Most of the total real cost for research – 61¢ out of the total real cost of 72¢ for every dollar of student revenue – are met by the accounts of the units that received the student fees in the first place, but 11¢ spill over into other university units, mostly into Human Resources, but also for Student Administration and Support, Campus Property and Services, ICT, and Senior Management.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Wages and salaries | + Gross operating surplus | + Taxes | + Increases in inventories | + Imports | + Operating inputs | = Real cost a | + Surplus, to reserves b |
|  |  |  |  |  |  |  |  |  |
| **Classical model** |  |  |  |  |  |  |  |  |
| University requirement ($m) c | 8.27 | 1.50 | 0.42 | 2.80 | 0.01 |  | 8.70 | 4.30 |
| Economy requirement ($m) d | 1.06 | 0.73 | 0.13 | 0.01 | 0.55 |  | **1.75** | **0.73** |
|  |  |  |  |  |  |  |  |  |
| University requirement (¢/$) c | 53 | 10 | 3 | 18 | 0 |  | 56 | 28 |
| Economy requirement (¢/$) d | 7 | 5 | 1 | 0 | 4 |  | **11** | **5** |
|  |  |  |  |  |  |  |  |  |
| **Open model** | ┌─── |  | University | e | ───┐ | Economy f |  |  |
| Teaching requirement ($m) | 7.22 | 1.50 | 0.36 | 2.62 | 0.01 | **1.93** | 9.52 | 4.12 |
| Intra-university spillover ($m) | 1.05 | 0.00 | 0.06 | 0.18 | 0.00 | **0.55** | 1.65 | 0.18 |
|  |  |  |  |  |  |  |  |  |
| Teaching requirement (¢/$) | 47 | 10 | 2 | 17 | 0 | **12** | 61 | 27 |
| Intra-university spillover (¢/$) | 7 | 0 | 0 | 1 | 0 | **4** | 11 | 1 |
|  |  |  |  |  |  |  |  |  |

a Real cost = Wages and salaries + Taxes + Imports; b Surplus = Gross operating surplus + Increases in inventories; c university supply-side requirements in terms of primary inputs $\left[\begin{matrix}φ\_{U}&0\end{matrix}\right]L^{c}∆y^{c}$, by components in $φ\_{U}$; d economy supply-side requirements in terms of primary inputs $\left[\begin{matrix}0&φ\_{A}\end{matrix}\right]L^{c}∆y^{c}$, by components in $φ\_{A};$ e university supply-side requirements in terms of primary inputs $φ\_{U}L^{o}∆y^{o}$, by components in $φ\_{U}$; f university supply-side requirements in terms of operating inputs $A\_{AU}L^{o}∆y^{o}$, total. Note that requirements labelled d are about equal to those labelled f (both in bold print), as shown in the previous Section. Values may not add up due to rounding.

 Tab. 4: Supply-side requirements of a 5% increase in demand for teaching.

* + 1. Increase in research expenditure

The previous two demand-pull scenarios provided information about the extent of increased cost to meet increased demand, the extent of surplus, the sectors bearing those cost, and possible cost spillovers. The following two supply-push scenarios look the other way: They provide information about the extent of revenue required to absorb increased cost, and whether this revenue can be provided by increasing fees for final demanders, or whether a part of cost increases have to be met by drawing from reserves and cross-unit financing.

Assuming a constant input-output structure, a 5% increase in expenditure for research either through price/wage hikes or capacity expansion requires, in the open model, on a per-dollar of revenue basis, the forthcoming of 60¢ of government funding, 11¢ of overseas research contracts, 8¢ of funding by private individuals, and 14¢ of research grants from Australian industry (Tab. 5). Total real revenue required to meet the increased expenditure is hence 92¢, and the remaining 7¢ in every dollar of expenditure needs to be drawn from existing reserves. The input-output calculus in the classical model traces the 14¢ industry funding through the Australian economy and shows that these are likely to come mostly from service sectors that pay for this research through 7¢ of sales to private individuals, 3¢ sales to government, and 2¢ of dividends from, and sales of capital assets.

The 5% expenditure increase in research is worth $6.8m in absolute terms, of which $6.3m are absorbed by real revenue, and $0.5m must be financed from existing reserves.

For every dollar of their increased research expenditure, the research units are able to generate 86¢ out of 92¢ of real revenue. They need to draw 2¢ from reserves directly, and need other units (mostly through Central Accounts) to generate 5¢ of real revenue and draw additional 5¢ from reserves. Total intra-university cross-financing for every dollar of research may therefore be up to 12¢ (underlined figures).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Private revenue | + Government revenue | + Gross fixed capital | + Decreases in inventories | + Exports | + Industry revenue | = Real revenue a | + Deficit, from reserves b |
|  |  |  |  |  |  |  |  |  |
| **Classical model** |  |  |  |  |  |  |  |  |
| University requirement ($m) c | 0.55 | 4.09 | 0.21 | 0.25 | 0.73 |  | 5.37 | 0.45 |
| Economy requirement ($m) d | 0.46 | 0.20 | 0.17 | 0.01 | 0.02 |  | **0.68** | **0.18** |
|  |  |  |  |  |  |  |  |  |
| University requirement (¢/$) c | 8 | 60 | 3 | 4 | 11 |  | 79 | 7 |
| Economy requirement (¢/$) d | 7 | 3 | 2 | 0 | 0 |  | **10** | **3** |
|  |  |  |  |  |  |  |  |  |
| **Open model** | ┌─── |  | University | e | ───┐ | Economy f |  |  |
| Research requirement ($m) | 0.43 | 3.81 | 0.00 | 0.14 | 0.67 | **0.97** | 5.88 | 0.15 |
| Intra-university cross-financing ($m) | 0.10 | 0.29 | 0.20 | 0.10 | 0.06 | **-0.10** | 0.35 | 0.31 |
|  |  |  |  |  |  |  |  |  |
| Research requirement (¢/$) | 6 | 56 | 0 | 2 | 10 | **14** | 86 | 2 |
| Intra-university cross-financing (¢/$) | 1 | 4 | 3 | 2 | 1 | **-1** | 5 | 5 |
|  |  |  |  |  |  |  |  |  |

a Real revenue = Private revenue + Government revenue + Exports; b Deficit = Gross fixed capital + Decreases in inventories; c university demand-side requirements in terms of final demand $∆v^{\*c}G^{c}\left[\begin{matrix}ψ\_{U}^{\*}\\0\end{matrix}\right]$, by components in $ψ\_{U}^{\*}$; d economy demand-side requirements in terms of final demand $∆v^{\*c}G^{c}\left[\begin{matrix}0\\ψ\_{A}^{\*}\end{matrix}\right]$, by components in $ψ\_{A}^{\*};$ e university demand-side requirements in terms of final demand $∆v^{\*o}G^{o}ψ\_{U}^{\*}$, by components in $ψ\_{U}^{\*}$; f university demand-side requirements in terms of industry revenue $∆v^{\*o}G^{o}A\_{UA}^{\*}$, total. Note that requirements labelled d are about equal to those labelled f (both in bold print), as shown in the previous Section. Values may not add up due to rounding.

 Tab. 5: Demand-side requirements of a 5% increase in research expenditure.

* + 1. Increase in teaching expenditure

Assuming a constant input-output structure, a 5% increase in expenditure for teaching either through price/wage hikes or capacity expansion requires, in the open model, on a per-dollar of revenue basis, the forthcoming of 33¢ of government funding, 24¢ from overseas students, 19¢ from domestic students, and 4¢ from Australian industry (Tab. 6). Total real revenue required to meet the increased expenditure is hence 81¢, and the remaining 19¢ in every dollar of expenditure needs to be drawn from existing reserves. The input-output calculus in the classical model traces the 4¢ industry funding through the Australian economy and shows that these are likely to come mostly from construction, trade and service sectors that pay for this research through 2¢ of sales to private individuals, 1¢ sales to government, and 1¢ of dividends from, and sales of capital assets.

The 5% expenditure increase in research is worth $15.4m in absolute terms, of which $12.4m are absorbed by real revenue, and $3m must be financed from existing reserves.

For every dollar of their increased teaching expenditure, the teaching units are able to generate 76¢ out of 81¢ of real revenue. They need to draw 16¢ from reserves directly, and need other units (mostly through Central Accounts) to generate 4¢ of real revenue and draw additional 3¢ from reserves. Total intra-university cross-financing for every dollar of research may theoretically be up to 24¢, however given the results from Sections 2.2.1 and 2.2.2, reserves are likely to have been built up through teaching revenues, so that realistically, only about 4¢ of cross-financing occurs (underlined).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Private revenue | + Government revenue | + Gross fixed capital | + Decreases in inventories | + Exports | + Industry revenue | = Real revenue a | + Deficit, from reserves b |
|  |  |  |  |  |  |  |  |  |
| **Classical model** |  |  |  |  |  |  |  |  |
| University requirement ($m) c | 2.91 | 5.12 | 2.11 | 0.91 | 3.78 |  | 11.81 | 3.02 |
| Economy requirement ($m) d | 0.27 | 0.15 | 0.15 | 0.01 | 0.01 |  | **0.44** | **0.15** |
|  |  |  |  |  |  |  |  |  |
| University requirement (¢/$) c | 19 | 33 | 14 | 6 | 24 |  | 76 | 19 |
| Economy requirement (¢/$) d | 2 | 1 | 1 | 0 | 0 |  | **3** | **1** |
|  |  |  |  |  |  |  |  |  |
| **Open model** | ┌─── |  | University | e | ───┐ | Economy f |  |  |
| Teaching requirement ($m) | 2.61 | 4.82 | 1.71 | 0.78 | 3.69 | **0.60** | 11.72 | 2.49 |
| Intra-university cross-financing ($m) | 0.29 | 0.30 | 0.40 | 0.13 | 0.09 | **-0.01** | 0.68 | 0.53 |
|  |  |  |  |  |  |  |  |  |
| Teaching requirement (¢/$) | 17 | 31 | 11 | 5 | 24 | **4** | 76 | 16 |
| Intra-university cross-financing (¢/$) | 2 | 2 | 3 | 1 | 1 | **0** | 4 | 3 |
|  |  |  |  |  |  |  |  |  |

a Real revenue = Private revenue + Government revenue + Exports; b Deficit = Gross fixed capital + Decreases in inventories; c university demand-side requirements in terms of final demand $∆v^{\*c}G^{c}\left[\begin{matrix}ψ\_{U}^{\*}\\0\end{matrix}\right]$, by components in $ψ\_{U}^{\*}$; d economy demand-side requirements in terms of final demand $∆v^{\*c}G^{c}\left[\begin{matrix}0\\ψ\_{A}^{\*}\end{matrix}\right]$, by components in $ψ\_{A}^{\*};$ e university demand-side requirements in terms of final demand $∆v^{\*o}G^{o}ψ\_{U}^{\*}$, by components in $ψ\_{U}^{\*}$; f university demand-side requirements in terms of industry revenue $∆v^{\*o}G^{o}A\_{UA}^{\*}$, total. Note that requirements labelled d are about equal to those labelled f (both in bold print), as shown in the previous Section. Values may not add up due to rounding.

 Tab. 6: Demand-side requirements of a 5% increase in teaching expenditure.

* + 1. Summary of scenarios

Increases in demand for research lead to about equal increases in wages and operating inputs, whereas increases in demand for teaching lead mainly to increases in wages, and also to surplus (Tab. 7). On a per-dollar basis, teaching’s surplus is about nine times higher at 28¢/$ than that of research, where instead 97¢/$ of revenues are spent.

Note that in applying input-output analysis, these total effects are the sum of direct transactions occurring in the unit that experiences the demand increase, and indirect repercussions throughout the university, facilitated by interdependences between the university’s business units. This is demonstrated by the internal transfers in Tab. 7, which are especially high in the case of teaching revenues, which are collected to a large extent by Central Accounts, and then distributed amongst university faculties according to an internal funding model. Almost 60¢ in every dollar of teaching revenues undergo intermediate transactions, whilst for research it is 7¢. This circumstance underlines the need for an input-output model that can deal with the complexities of such a highly cross-financing business system.

On a per-dollar basis, increases in expenditure for research require 93¢ to come forth as revenue for services, and need to meet the deficit of 7¢/$ from reserves. Increases in teaching expenditure are matched by only 81¢/$ of fees and grants, and hence need to draw another 19¢/$ from reserves. Once again, these effects include direct transactions and indirect repercussions.

After subtracting deficits from surpluses, teaching makes a net surplus of about 9¢ for every dollar of turnover, whilst research runs up a net deficit of about 4¢/$. These figures agree well with the more detailed estimates of cross-financing flows in Tabs. 5 and 6.

These scenario results hold for research and business units as a whole; results may vary substantially if single faculties are examined. Finally, neither research nor teaching supply-pushes rely as much on capital revenue as university activities in general. The high capital multiplier of 46¢/$ in Tab. 2 stems from significant infrastructure works that are financed mainly through revenues from capital assets.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **University requirements** |  | **Economy requirements** |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Demand-pull** |  | ┌─── **Real cost** ───┐ | **Surplus** |  |  |   |  |  |  |
|  |  | **Classical** |  | **Open** |  |  |  |  |  |  |  |
|  | 1 =10 | 2 | 3 |  | 4 = 8 + 9 | 5 = 2 + 3 + 4 | 6 | 7 |  | 8 | 9 |  | 10 = 5 + 6 = 1 |
|  | Total pull | Wages and salaries |  + Taxes |  |  + Operating inputs |  = Total real cost | Surplus, to reserves | Internal transfers |  | Economy primary inputs | Economy imports |  | Total input-output requirement |
|  |  |  |  |  |  |  |  |  |  |   |  |  |  |
| 5% Research demand | $m 6.9 | $m 3.4 | $m 0.2 |  | $m 3.1 | $m 6.7 | $m 0.2 | $m 0.5 |  | $m 2.4 | $m 0.7 |  | $m 6.9 |
| 49¢/$ | 3¢/$ |  | 45¢/$ | 97¢/$ | 3¢/$ |  |  | 34¢/$ | 11¢/$ |  | 100¢/$ |
|  |  |  |  |  |  |  |  |  |  |   |  |  |  |
| 5% Teaching demand | $m 15.5 | $m 8.3 | $m 0.4 |  | $m 2.5 | $m 11.2 | $m 4.3 | $m 9.2 |  | $m 1.9 | $m 0.6 |  | $m 15.5 |
| 53¢/$ | 3¢/$ |  | 16¢/$ | 72¢/$ | 28¢/$ |  |  | 12¢/$ | 4¢/$ |  | 100¢/$ |
|  |  |  |  |  |  |  |  |  |  |   |  |  |  |
| **Supply-push** |  | ┌─── **Real revenue** ───┐ | **Deficit** |  |  |   |  |  |  |
|  |  | **classical** |  | **Open** |  |  |  |  |  |  |  |
|  | 1 =10 | 2 | 3 |  | 4 = 8 + 9 | 5 = 2 + 3 + 4 | 6 | 7 |  | 8 | 9 |  | 10 = 5 + 6 = 1 |
|  | Total push | Private revenue & exports |  + Government revenue |  |  + Industry revenue |  = Total real revenue | Deficit, from reserves | Internal transfers |  | Economy final demand | Economy exports |  | Total input-output requirement |
|  |  |  |  |  |  |  |  |  |  |   |  |  |  |
| 5% Research expenditure | $m 6.8 | $m 1.3 | $m 4.1 |  | $m 1.0 | $m 6.4 | $m 0.5 | $m 1.3 |  | $m 0.8 | $m 0.1 |  | $m 6.8 |
| 19¢/$ | 60¢/$ |  | 14¢/$ | 93¢/$ | 7¢/$ |  |  | 12¢/$ | 2¢/$ |  | 100¢/$ |
|  |  |  |  |  |  |  |  |  |  |   |  |  |  |
| 5% Teaching expenditure | $m 15.5 | $m 6.7 | $m 5.1 |  | $m 0.7 | $m 12.5 | $m 3.0 | $m 9.7 |  | $m 0.6 | $m 0.1 |  | $m 15.5 |
| 43¢/$ | 33¢/$ |  | 4¢/$ | 81¢/$ | 19¢/$ |  |  | 4¢/$ | 0¢/$ |  | 100¢/$ |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Tab. 7: Summary of scenarios.

* 1. Structural Path Analysis

The results presented in the previous Section can be decomposed further in order to evaluate in which sub-sectors of the university or the economy the financial effects occur, and via which supply chains they are facilitated. As explained in the methodology Section, this decomposition can be carried out using Structural Path Analysis (SPA). For the sake of brevity, we will only show the two demand-push scenarios. For detailed examples of supply-push SPAs and possible interpretations see Lenzen and Murray 2010.

SPA results are usually presented as ranked lists, showing the ranked supply chains as a succession of nodes, connected with arrows (‘<’), starting from the right with the sector exerting the demand pull, followed by the sector that initially bears, and then passes on this pull, and so on, until the final, exogenous primary input requirement. The value of the path is expressed in terms of that primary input, for example $ of wages and salaries. A path of order 1 contains one node between the sector exerting the demand-pull and the primary input, and so on. The ‘percentages in the total’ refer to the sum of the university and economy requirements (in $m), listed in the rightmost two columns (real cost and surplus) in Tabs. 3 and 4, respectively.

* + 1. Increase in research demand

A 5% in research demand is overwhelmingly financed by the government through research grants, and to a lesser extent by private individuals through donations by individuals and foundations, and sales of university assets and publications (Tab. 8). The injected funds are mostly used directly by the receiving research unit to pay for wages and salaries. The paths ranking 5th, 11th and 18th are funds that the Faculty of Medicine receives for collaborative research projects where part of the funds are passed on to other universities (‘Education’ sector of the economy), community health centres and hospitals. Similar effects are recorded in paths ranked 12th and 13th. The 10th- and 17th-ranking paths represent funding received by university units, which is temporarily held to pay for future expenses. Paths 14 and 16 represent the tax burden of the two faculties with the highest turnover. The path ranked 20th reflects the equipment-intensive nature of science research as well as the fact that Australia imports much specialised equipment, rather than producing it domestically.



Tab. 8: Structural Path Analysis of research demand-pull.

* + 1. Increase in teaching demand

As with research, university teaching is overwhelmingly financed through government operating grants that, in the case of the University of Sydney, are passed through Central Accounts before disbursed to the various teaching units according to a funding formula (paths ranked 4th and lower in Tab. 9). Central Accounts is also responsible for distributing funds to centralised university services such as human resources, Senior Executives (PVCc, DVCs, VCs, CFO), ICT services, campus property, and student support. The path ranked 2nd are wages paid centrally for a whole range of campus functions. The top and third paths show the surplus the University has recorded during the 2007 financial year, which is earmarked for expanding building and other capital. These expenditures are probably not linked to the operating grant revenue, but these paths appear because these operating grants for teaching are pooled with other income, for example investment income. The top three paths demonstrate a shortcoming of the university’s accounting system in that the pooling of various revenues before their disbursement for different internal purposes hinders the unambiguous allocation of expenditures to particular revenues, and thus creates obstacles for activity-based accounting.



Tab. 9: Structural Path Analysis of teaching demand-pull.

1. **Application to strategic planning – outlook and conclusions**

Whilst the technical part of this paper has concentrated on the construction and usage of a monetary enterprise input-output model, its implications go beyond financial analyses. Recent ambitions to enhance the attractiveness of universities to students have resulted in university performance not being measured solely in financial terms, but more and more importantly in terms of environmental sustainability and social responsibility. For example, Clarke and Kouri 2009 report on stakeholder surveys conducted by KPMG and others, demonstrating that higher education institutions are driven towards more effective environmental management systems by diverse factors such as compliance and liability, student and employee pressure for change, financial donor requirements, community concerns, and initiatives at competing universities. In response, organisations were placing more emphasis on assuming leadership, on becoming role models in research and teaching, and on improving their community and student image. The long-term perception was that initial investments were paid off by tangible benefits, such as high employee morale, increase in market shares, reduced liability, and cost savings. Clarke and Kouri 2009 also found that successful management systems in a range of countries included policy vision, expert planning, organised implementation, continuous checking including audits, monitoring, management review, and preventive and corrective action, and that these tasks involved students, staff, faculty, and senior management alike. Such shifts in focus call for a broadening and integration of organisational financial accounting and responsibility, to include social and environmental objectives, cross-campus as well as for the wider economy. Hierarchically nested, multi-region enterprise input-output models with social and environmental satellite accounts are ideal frameworks to meet these needs.

In fact, our enterprise model has already been generalised by adding physical satellite accounts as in Leontief’s basic idea (Baboulet and Lenzen 2009, for a list of available physical data see ISA 2010), and the University of Sydney has already published its Triple Bottom Line report based on input-output analysis (Dey and Lenzen 2008). Physical quantities in most recent generalised input-output models often include greenhouse gas emissions and other environmental information, however in the case of a university, one could envisage analysing knowledge flow-on effects, for example in the form of R&D expenditure (Hauknes and Knell 2009), or patents (Hanel 1994).

Governments are equally important to students in being a stakeholder in universities, and it is as well in governments’ interest to ensure that higher education contributes to strengthening national skill bases and competitiveness. In this respect, the capability of the enterprise input-output model described above was used by the University of Sydney in responding to the Australian Federal Government on the findings of the Bradley review of higher education and the Cutler review of the national innovation system. Bradley's report provided indicative costs of proposals to boost Australia’s higher education sector, for example an increase of 10% in the government's grants to institutions for teaching and learning. Considering that the government was facing difficult economic conditions, and hence had to borrow for any increased funding for higher education, a battle ensued in general over the size of the total package, and in particular over the funding rate per student, more adequate indexation, increased stipends, and more adequate funding of the indirect costs of research.

With regard to the last issue – indirect costs but also benefits of research – the government did not want mere illustrations of the problems resulting from lack of full funding for research, teaching and learning, or examples for initiatives that would be carried out with more adequate funding. Required were authoritative estimates of the extent to which inadequate funding was affecting research, teaching and learning, and the wider economic benefits of adopting the Bradley proposals, with emphasis on long-term systemic sustainability. To this end, especially the results in Tabs. 3-7 represented striking evidence for under- and cross-funding of research. Hence, the input-output analyses presented in the previous Section proved to be an ideal tool, and were hence used in preparing the University of Sydney’s response to the government.

Finally, the Australian Government requested similarly sound estimates of indirect effects of projects that applied for funding from its Education Investment Fund (DEEWR 2010). Once again, the enterprise model was used to strengthen the University’s applications.

These examples may highlight the usefulness of enterprise input-output models in meeting market challenges as well as in negotiating with government. Obviously, the results in this paper are reported at an aggregated, university-wide level only for the sake of brevity; scenario exercises can be undertaken at the faculty, school, or even account level. In addition to financial modelling, input-output analysis can form the backbone of an integrated approach to measure not only a university’s carbon footprint, but also other environmental indicators (water, land, biodiversity, etc), as well as its social outcomes (employment, degrees, publications, etc). Because of their mathematical structure, input-output accounting ensures that these environmental and social objectives are measured in consistency with the financial accounts, thus providing comparability, and allowing decision-makers to identify trade-offs between different aspects of a university’s Triple Bottom Line. In fact, Sydney University’s financial reporting and planning systems and its environmental and social reporting systems are seen to become one consistent unit, which reflects the very spirit of the integration that the United Nations envisaged in the creation of the System of Environmental and Economic Accounts (SEEA; UNSD 2003), and their integration with business accounts (UNSD 2000).

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1. Final demand consists of private final consumption, government final consumption, gross fixed capital expenditure, decreases in inventories, and exports. Primary inputs consist of wages & salaries, gross operating surplus, taxes, increases in inventories, and imports. These categories are the same for the University and the Australian economy. [↑](#footnote-ref-1)
2. Dentistry, medicine, nursing, pharmacy, science, agriculture, architecture, engineering, economics, arts, education, law, each split into research, teaching, consulting, community outreach and administrative functions. [↑](#footnote-ref-2)
3. We do not examine a final-demand closure on the open, intra-University model. Such a model would examine intra-University flows plus household feedback loops. For these loops one would need to assume that the staff members earning their wages and salaries at the University are also students enrolling in courses. This is unlikely to be the case. [↑](#footnote-ref-3)
4. The supply-push model can however be interpreted as an *ex-post* quantity model (Gallego and Lenzen 2005). [↑](#footnote-ref-4)
5. Also sometimes referred to as production layers, or tiers. [↑](#footnote-ref-5)
6. This can be shown mathematically, using the basic input-output relationship **x** = **Ly**, where **x** is gross output, **L** is the Leontief inverse, and **y** is final demand, and the National Accounting Identity *P* = *GDP* + *M* = *GNE* + *X* = *Y*, where *P* are primary inputs, *GDP* is Gross Domestic Product, *M* are imports, *GNE* is Gross National Expenditure, *X* are exports, and *Y* is final demand. Denoting wages with **W**, surplus and inventory changes with **S**, and taxes with **T**, and their intensities with corresponding lowercase letters (**w**t = **W**t$\hat{x}$-1, etc), we find *P* = ( **W** + **S** + **T** + **M** )t **1** = ( **w** + **s** + **t** + **m** )t **x** = ( **w** + **s** + **t** + **m** )t **Ly** = ( **w**t**L** + **s**t**L** + **t**t**L** + **m**t**L** ) **y** = *Y*, which is equivalent to (**w**t**L** + **s**t**L** + **t**t**L** + **m**t**L** ) = **1**t= {1,1,…,1}, where the superscript t denotes transposition, and the hat symbol ^ denotes a diagonal matrix. [↑](#footnote-ref-6)
7. This can be shown mathematically, as in the demand-pull case. [↑](#footnote-ref-7)
8. Mathematically the above relationships are expressed as $1'\left[\begin{matrix}0&φ\_{A}\end{matrix}\right]L^{c}∆y^{c}≈1'A\_{AU}L^{o}∆y^{o}$ and $∆v^{\*c}G^{c}\left[\begin{matrix}0\\ψ\_{A}^{\*}\end{matrix}\right]1 ≈∆v^{\*o}G^{o}A\_{UA}^{\*}1$. They can be proven using partitioned inverses. For example, Miyazawa 1966 has shown that the Leontief inverse can be partitioned as

$L^{c}=\left(I-\left[\begin{matrix}T\_{UU}&T\_{UA}\\T\_{AU}&T\_{AA}\end{matrix}\right]\hat{\left[\begin{matrix}x\_{U}\\x\_{A}\end{matrix}\right]}^{-1}\right)^{-1}=\left(\begin{matrix}I-A\_{UU}&-A\_{UA}\\-A\_{AU}&I-A\_{AA}\end{matrix}\right)^{-1}=\left[\begin{matrix}L^{o}\left(I+A\_{UA}KA\_{AU}L^{o}\right)&L^{o}A\_{UA}K\\KA\_{AU}L^{o}&K\end{matrix}\right]$,

where $K=\left(I-A\_{AA}-A\_{AU}L^{o}A\_{UA}\right)^{-1}$. In our application the mean values for the **A** coefficients are $\overbar{A\_{UU}}=0.001, \overbar{A\_{UA}}=0.005, \overbar{A\_{AU}}=0.01, and \overbar{A\_{AA}}=0.03$, so that the interregional feedback loops represented by $A\_{AU}L^{o}A\_{UA}$are small compared to intermediate demand in Australia, and $K≈\left(I-A\_{AA}\right)^{-1}=L\_{AA}$. Similarly, we encounter $\overbar{T\_{UA}}\ll \overbar{y\_{U}}$ so that $∆y^{o}≈∆y\_{U}1$.Therefore, $1'\left[\begin{matrix}0&φ\_{A}\end{matrix}\right]L^{c}∆y^{c}≈1'φ\_{A}L\_{AA}A\_{AU}L^{o}∆y\_{U}1=1'A\_{AU}L^{o}∆y\_{U}1≈ 1'A\_{AU}L^{o}∆y^{o}$, which had to be shown. The proof for the supply-push relationship proceeds correspondingly. [↑](#footnote-ref-8)