Endogenising Capital:
A comparison of Two Methods

By

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Abstract

Two methods for endogenising capital transactions into a static input-output system — the augmentation method and the flow matrix method — are compared. While the first method treats all types of capital as one homogeneous commodity, the latter distinguishes capital transactions by origin and destination industry. Multipliers including capital requirements are calculated for the Australian economy of 1996-97, for the factors energy, CO_2, water, and intermediate demand. In these cases, the augmentation method leads to a systematic overestimation of low- and mid-range multipliers, and to a substantial underestimation of high-range multipliers. The magnitude of this error is factor-dependent, and increases with increasing variance and range of the corresponding factor intensities. On the other hand, the flow matrix method avoids these systematic errors, but has the disadvantage of high data requirements.

1. Introduction

It is general knowledge amongst practitioners of input-output analysis, that there is a whole range of input-output systems, tailored to answer particular questions. One distinction between different systems is their degree and type of closure. A system can be closed by endogenising particular parts of primary inputs and final demand into current intermediate transactions (the use matrix). Examples for such closures are the endogenisation of trade with foreign regions, or of household expenditure and income. Any kind of closure leads to an increase in magnitude of the multipliers.

In this work, we are concerned with closing a static input-output system with respect to fixed capital: production of fixed capital *by* industries and inputs of fixed capital *into* industries are transferred from final demand and primary inputs respectively, and added to current intermediate demand. In this case, the increase in multipliers reflects a transition from a short-term to a long-term perspective: Current transactions as published in use matrices represent a more or less constant stream of inputs that is turned over at least annually. In contrast, capital demand often fluctuates highly between

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years, and is effective as an input into production until many years after purchase.

Input-output analysis can address questions of the likely impact of (1) final demand shocks on quantities demanded throughout the economy (the Leontief model), or (2) primary input price shocks on consumer prices (the Ghosh model). In both models, impacts can be determined as including or excluding the effects of capital. In this paper, we examine the effect that closing the input-output system with respect to capital has on static, *ex-post* Leontief-type multipliers, in monetary terms as well as in terms of energy consumption, CO_2 emissions, water use, and intermediate demand. We examine two approaches for endogenising capital: the augmentation technique, and the flow matrix method. The following sections explain the methodology, the data preparation, and the results of the comparison. The paper is then concluded.

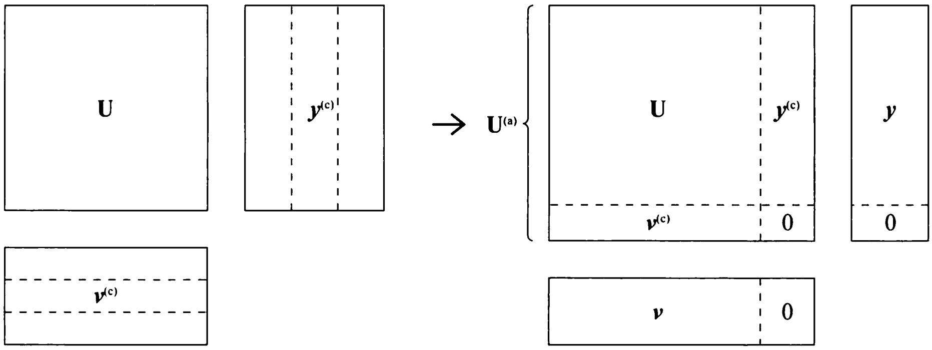
2. Methodology

It is a convention in National Accounts that purchases of capital goods are counted as primary inputs and final outputs of the economic system rather than as intermediate inputs into production. In the Australian input-output tables, the primary input category 'gross operating surplus' contains inputs of fixed capital into production, while final demand includes gross fixed capital expenditure as a category. As a consequence, the use matrix only describes "current" intermediate, but not "capital" transactions, and the multipliers in the corresponding Leontief or Ghosh inverses do not include effects of capital. Since capital investment ultimately occurs to facilitate production (for infrastructure replacement and capacity expansion), it can be regarded as an intermediate input (compare Bullard and Herendeen 1975). Accordingly, transactions involving fixed capital can be separated from primary inputs and final demand, and endogenised into intermediate transactions. In the input-output literature this process is referred to as "closing an open input-output system". Not many input-output studies incorporate capital effects. Within those that do, there appear to be two dominant approaches: the augmentation technique, and the flow matrix method (see also Lee 1971, Casler 1983, Wolff 1985, Gowdy 1992, Hohmeyer 1992, Wenzel and Pick 1997).

2.1 Augmentation method

Within most published input-output tables, gross fixed capital expenditure is available as a column vector $\boldsymbol{y}^{(c)}$ as part of final demand $\boldsymbol{y}$, while gross fixed capital input (for capacity expansion or replacement) appears as a row vector $\boldsymbol{v}^{(c)}$ as part of primary inputs $\boldsymbol{v}$. It is therefore in most cases straightforward to move these vectors as an additional column and row into the intermediate demand field, thus augmenting the existing array of sectors by one (see Fig. 1). This artificially created additional sector is assumed to produce one homogeneous commodity – 'capital' – which is produced using inputs according to $\boldsymbol{y}^{(c)}$, and consumed by other sectors according to $\boldsymbol{v}^{(c)}$.

Figure 1: Endogenising capital expenditure $y^{(c)}$ and capital investment $v^{(c)}$ into the intermediate use matrix U, to form an augmented use matrix $U^{(a)}$.



A Leontief inverse $\mathbf{L}^{(a)}$ is then calculated using the augmented use matrix $\mathbf{U}^{(a)}$:

$$\mathbf{L}^{(a)} = [\mathbf{I} - \mathbf{S}^{(a)t}\, \mathbf{U}^{(a)}\, \hat{\boldsymbol{x}}^{(a)-1}]^{-1} = [\mathbf{I} - \mathbf{A}^{(a)}]^{-1} \tag{1}$$

where $\mathbf{I}$ is a suitable unity matrix. $\mathbf{S}^{(a)\,t}$ is a transposed augmented market share matrix (resulting from an augmented supply matrix $\mathbf{V}^{(a)} = \begin{pmatrix} \mathbf{V} & 0 \\ 0 & \sum_i v_i^{(c)} \end{pmatrix}$ according to $\mathbf{S}^{(a)}_{ij} = \mathbf{V}^{(a)}_{ij} / \sum_i \mathbf{V}^{(a)}_{ij}$, so that $\mathbf{S}^{(a)} = \begin{pmatrix} \mathbf{S} & \mathbf{0} \\ \mathbf{0} & \mathbf{1} \end{pmatrix}$, where $\mathbf{V}$ and $\mathbf{S}$ are the original make and market share matrices, respectively). The diagonal-only augmentation of $\mathbf{V}$ shows that the additional capital sector is assumed to have no by-products, and that no other sector directly produces capital, but instead delivers into the "capital sector". Augmented total output is $\boldsymbol{x}^{(a)} = \begin{pmatrix} \mathbf{V} & \boldsymbol{x} \\ 0 & \sum_i v_i^{(c)} \end{pmatrix} = \begin{pmatrix} \boldsymbol{x} \\ V^{(c)} \end{pmatrix}$, with $\hat{\boldsymbol{x}}^{(a)}$ being its diagonalised version. $\mathbf{A}^{(a)} = \mathbf{S}^{(a)t}\mathbf{U}^{(a)t}\hat{\boldsymbol{x}}^{(a)-1} = \begin{pmatrix} \mathbf{A} & \boldsymbol{y}^{(c)}\mathbf{V}^{(c)-1} \\ \boldsymbol{v}^{(c)}\hat{\boldsymbol{x}}^{-1} & \mathbf{0} \end{pmatrix} = \begin{pmatrix} \mathbf{A} & \boldsymbol{a}_y^{(c)} \\ \boldsymbol{a}_v^{(c)} & \mathbf{0} \end{pmatrix}$ is the augmented direct requirements matrix.

This formulation is "blind" with regard to the type of capital, meaning that livestock, machinery, buildings or artwork are not distinguished as different commodities. While this is less of a problem in a purely monetary impact study operating in value terms, different types of capital can exhibit significantly different factor intensities $\boldsymbol{q}$ in terms of physical factors, for example energy intensities $\boldsymbol{q}_e$, CO_2 intensities $\boldsymbol{q}_c$, or water use intensities $\boldsymbol{q}_w$. Therefore, determining factor multipliers

$$\boldsymbol{m}^{(a)} = \boldsymbol{q}^{(a)}\, \mathbf{L}^{(a)} \tag{2}$$

in a generalised input-output study, an indiscriminate allocation of different types of capital can lead to distortions of factor multipliers $\boldsymbol{m}^{(a)}$, because particular types of capital are generally only used by some, but not all sectors (for example livestock is used as capital input only within agriculture).

Following Miyazawa et al. (1963), an analytical formulation of Eq. 1 can be written as

$$\mathbf{L}^{(a)} = \begin{pmatrix} \mathbf{I}-\mathbf{A} & -\boldsymbol{a}_y^{(c)} \\ -\boldsymbol{a}_v^{(c)} & 0 \end{pmatrix} = \begin{pmatrix} \mathbf{B}\,(\mathbf{I}+\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)}\mathbf{B}) & \mathbf{B}\boldsymbol{a}_y^{(c)}K \\ K\boldsymbol{a}_v^{(c)}\mathbf{B} & K \end{pmatrix} \tag{3}$$

with $\mathbf{B}=(\mathbf{I}-\mathbf{A})^{-1}$ and the scalar $K=(1-\boldsymbol{a}_v^{(c)}\,\mathbf{B}\boldsymbol{a}_y^{(c)})^{-1}$. The upper left term can be transformed into

$$\begin{aligned}
\mathbf{B}\,(\,\mathbf{I}+\boldsymbol{a}_v^{(c)}K\boldsymbol{a}_v^{(c)}\,\mathbf{B}\,) &= (\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)})\,\mathbf{B} = \left[\,\mathbf{B}^{-1}(\,\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)})^{-1}\right]^{-1} \\
&= \left[\mathbf{B}^{-1}\left\{\mathbf{I}-\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)}(\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)})^{-1}\right\}\right]^{-1} = \left[\mathbf{B}^{-1}-\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)}(\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)})^{-1}\right\}\Big]^{-1} \\
&= \left[\mathbf{I}-\mathbf{A}-\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)}(\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)})^{-1}\right]^{-1}
\end{aligned} \tag{4}$$

2.2 Flow matrix method

An obvious solution to this shortcoming is to disaggregate capital input $\boldsymbol{v}^{(c)}$ by supplying sector, and to disaggregate capital expenditure $\boldsymbol{y}^{(c)}$ by using sector. This disaggregation results in a capital flow matrix $\mathbf{K}$ that, as the current flow matrix $\mathbf{A}=\mathbf{S}'\mathbf{U}\,\hat{\boldsymbol{x}}^{-1}$, shows producing sectors in its rows and using sectors in its columns, and that maps the flow of capital commodities according to their type and origin. Factor multipliers are then

$$\boldsymbol{m}^{(f)} = \boldsymbol{q}\mathbf{L} = \boldsymbol{q}\,[\,\mathbf{I}-(\mathbf{A}+\mathbf{K})]^{-1} \tag{5}$$

While in the augmentation method the dimension of all matrices increases by 1, it remains unchanged in the flow matrix method. Comparing Eqs. 4 and 5, one can interpret that the term $\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)}(\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)}K\boldsymbol{a}_v^{(c)})^{-1}$ in Eq. 4 is an approximation of $\mathbf{K}$ in Eq. 5.

In Section 4, we present results of Leontief-type multipliers $\boldsymbol{m}^{(a)}$ and $\boldsymbol{m}^{(f)}$, in terms of energy, CO_2 emissions, water use, and intermediate demand. We compare sets of multipliers from open and semi-closed models, as well as sets of semi-closed multipliers resulting from different closure methods. Note that the formalism holds equally for a Ghosh-type calculus.

3. Data preparation and estimation of flow matrices

A disadvantage of the flow matrix method is that most statistical bureaux do not estimate capital flow matrices regularly, or at all. Therefore, in our work, a 1996-97 capital flow matrix for Australia was estimated in a semi-survey approach, combining spot samples of industry survey data with the RAS balancing technique. This estimation involved

1) separating total capital input $v^{(c)}$ by industry from gross operating surplus in the Australian input-output tables (Australian Bureau of Statistics 2001), using auxiliary data (Australian Bureau of Statistics 1996). Since the model is generalised to physical quantities, capital input includes only physical capital; the sum over v is actually equal to the sum over y. The remaining part of gross operating surplus contains profits that represent income of economic agents, and may be invested in some monetary form or other;
2) inserting spot samples of survey data (from Australian Bureau of Statistics 1994; 1995; 1996; 1999a; c; b) into a preliminary flow matrix;
3) adding the remaining elements based on informed judgment: for example manufacturing and services do not use livestock, hence the respective values are set to zero;
4) netting the preliminary flow matrix as well as row and column totals $y^{(c)}$ and $v^{(c)}$ of fixed survey-based elements;
5) RAS-balancing the net **K** matrix, adjusting to net row and column totals; and
6) adding fixed survey-based elements to balanced matrix.

There are other approaches to constructing a capital flow matrix. For example, Casler (1983) suggests determining a representative mix of capital stock held by industries through time, and calculating a capital corrections matrix from the depreciation rates of capital stock items. This approach has the advantage of evening out fluctuations in rather sporadical capital purchases, and hence avoids atypically small or large coefficients for any one year. The resulting capital flow matrices, however, would not comprise a growth component of investment.

In the case of the augmentation method, only step 1) was performed, and $v^{(c)}$ and $y^{(c)}$ were then simply added as a separate row and column to the use matrix. Multipliers were then calculated according to Equations 2 and 5.

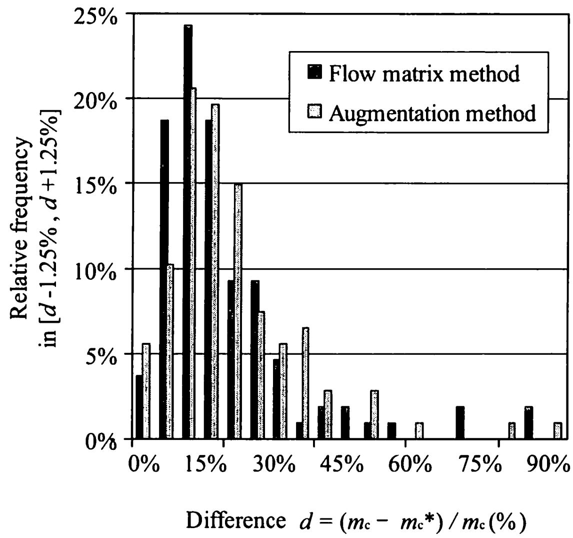
The factor data for q for energy consumption, CO_2 emissions and water use were taken from national energy statistics (Australian Bureau of Agricultural and Resource Economics 1997, see also Lenzen 1998), the national greenhouse gas inventory (National Greenhouse Gas Inventory Committee 1998, see also Lenzen 1998), and the national water accounts (Australian Bureau of Statistics 2000, see also Lenzen and Foran 2001). In the case of multipliers for total intermediate demand, $q_i = \{1, 1, ..., 1\}$.

4. Results: CO_2, energy, water and intermediate demand multipliers including capital

Closing the input-output system by endogenising transactions involving fixed capital into intermediate demand increases the size of matrix elements in the direct requirements matrix **A**, and therefore the internal feedback in the system. Multipliers are therefore larger in this closed system than in the open one.

In the case of the 1996-97 Australian input-output system, and for the example of CO_2 emissions, multipliers increase on average by about 10%-15% when capital is endogenised (Fig. 2). This magnitude is reasonable, considering that in Australia in 1996-97 capital expenditure constituted about 10% of total output. The relative frequency of differences between CO_2 multipliers $m_c^* = q(\mathbf{I} - \mathbf{A})^{-1}$ excluding capital flow and m_c including capital flow depends however on which method was used: In general, multipli-

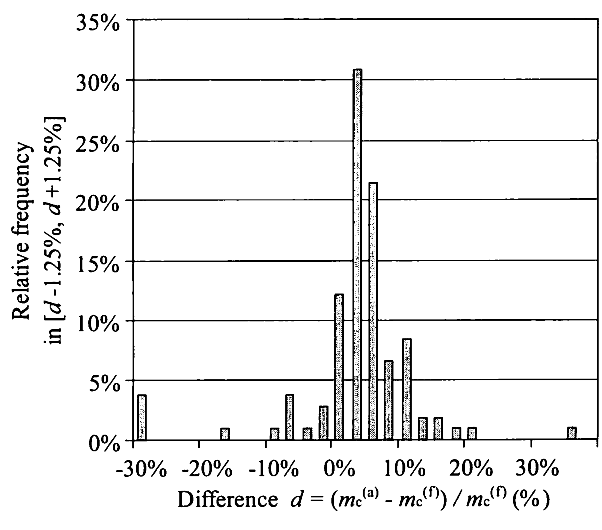
Figure 2: Relative frequency of differences between CO_2 multipliers m_c^* excluding capital flow, and m_c including capital flow obtained from the flow matrix and the augmentation method.



ers that were obtained using the augmentation method tend to be larger than those obtained by the flow matrix method. This phenomenon is examined further in the following.

Given that the flow matrix method provides a more accurate picture of the origin and destination of different types of capital commodities, the relative difference between CO_2 multipliers $m_c^{(f)}$ from the flow matrix and multipliers $m_c^{(a)}$ from the augmentation method can be regarded as a measure for the error that is associated with using the augmentation method. The relative frequency distribution for this error centres

Figure 3: Relative frequency of differences between CO_2 multipliers $m_c^{(f)}$ from the flow matrix method and multipliers $m_c^{(a)}$ from the augmentation method.



around 2%, with the bulk of samples contained between –1% and +12% (Fig. 3). This indicates once again that the augmentation method tends to overestimate most CO_2 multipliers.

This behaviour can be explained by the fact that the augmentation method does not distinguish between different types of capital. For example, because of associated emissions from land clearing, Australian livestock embodies a larger amount of CO_2 emissions than all other capital commodities. Correctly, these emissions should be allocated to a few agricultural industries that use livestock as a capital input for breeding. However, in the augmentation method these livestock-related emissions get lumped together with those related to other capital commodities, and distributed across all industries according to total capital input value, thus overstating the corresponding CO_2 mul-

Table 1: CO_2 multipliers (kg/A$) for the open and the semi-closed system, the flow matrix and augmentation techniques, and relative changes (%) between the two techniques, for selected Australian industries.

Industry	CO_2 multipliers (kg/A$)			
	excluding capital flow	flow matrix technique	augmenta tion technique	relative change (%)
Dairy cattle	0.96	1.39	1.16	–17.1
Meat and meat products	7.17	7.97	7.32	–8.1
Dairy products	0.87	1.13	1.04	–7.3
Beef cattle	27.56	29.4	27.78	–5.5
Textile products	0.69	0.81	0.79	–1.5
Electricity supply	11.31	11.47	11.53	0.5
Pulp, paper and paperboard	6.43	6.54	6.58	0.7
Accommodation, cafes and restaurants	0.76	0.88	0.89	0.8
Basic chemicals	2.39	2.49	2.51	1.1
Iron and steel	3.02	3.13	3.17	1.3
Residential building	0.76	0.92	0.94	2.0
Petroleum and coal products	1.23	1.32	1.36	2.5
Road transport	1.20	1.29	1.32	2.6
Ships and boats	0.84	0.92	0.95	3.3
Commercial fishing	0.83	0.93	0.96	3.3
Plastic products	0.77	0.85	0.88	3.7
Coal oil and gas	1.17	1.34	1.40	4.3
Electronic equipment	0.61	0.69	0.72	4.8
Motor vehicles and parts	0.59	0.67	0.70	4.9
Education	0.15	0.19	0.20	6.5
Iron ores	0.52	0.67	0.72	8.0
Communication services	0.31	0.42	0.47	10.0
Health services	0.11	0.16	0.18	11.8
Libraries, museums and the arts	0.14	0.20	0.23	15.2
Banking	0.14	0.24	0.28	17.2
Insurance	0.06	0.13	0.15	21.0

Figure 4: Relative frequency of differences between water multipliers $m_w^{(f)}$ from the flow matrix method and multipliers $m_w^{(a)}$ from the augmentation method.

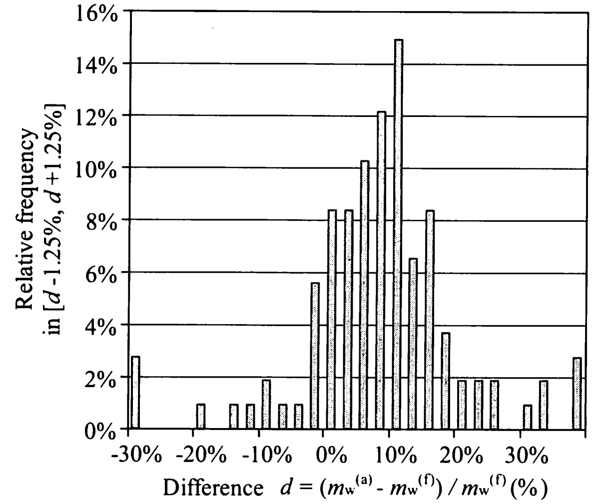
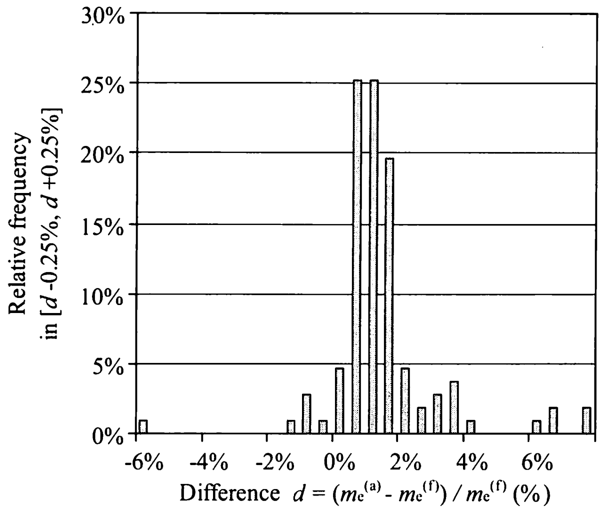


Figure 5: Relative frequency of differences between energy multipliers $m_e^{(f)}$ from the flow matrix method and multipliers $m_e^{(a)}$ from the augmentation method.



tipliers of all non-livestock-using industries. In contrast, the CO_2 multipliers of agricultural industries are significantly underestimated (see Tab. 1). The more the augmentation technique underestimates the CO_2 multiplier, the more CO_2-intensive the capital input of the respective industry is compared to the average commodity "capital". Agricultural and agriculture-related industries receive — directly and indirectly — relatively CO_2-intensive capital inputs (livestock), while most other industries, especially services, receive less CO_2-intensive capital (for example office equipment).

If instead of CO_2, water use is examined, the deviation of multipliers $m_w^{(a)}$ obtained from the augmentation from multipliers $m_w^{(f)}$ obtained using the flow matrix method is even larger: The relative frequency distribution of the error associated with the aug-

Figure 6: Relative frequency of differences between intermediate demand multipliers $m_i^{(f)}$ from the flow matrix method and multipliers $m_i^{(a)}$ from the augmentation method.

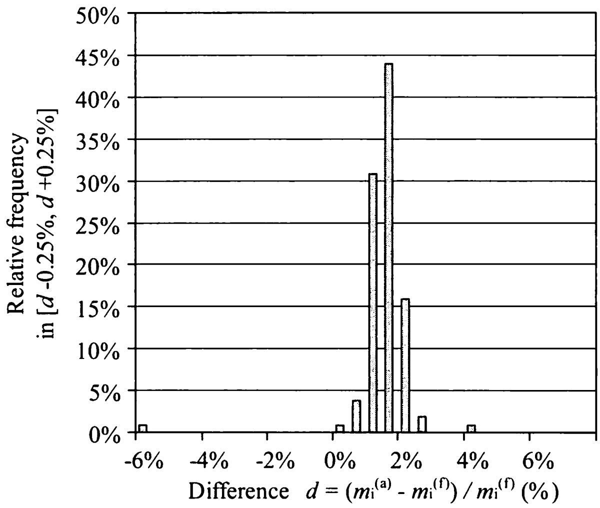


Table 2: Comparative measures for variation in factor multiplier and differences between flow matrix and augmentation method.

	Var(q) / Mean(q)	Max(q) / Min(q)	Mean(d)	Var(d)
Water	899.3	7,839,496	7.8%	2.45%
CO2	28.1	2,148,357	2.2%	1.53%
Energy	38.4	339,299	1.1%	0.05%
Intermediate demand	0	1	1.1%	0.01%

mentation method is centred around 8% and ranges roughly from –5% to +25% (Fig. 4). A few percent of multipliers are overestimated by more than 40%, and those of water-intensive industries (largely dairy cattle and products, rice growing, water supply and electricity generation) are underestimated by more than 30%.

In contrast, both methods produce similar results if energy and intermediate demand are considered. Here, errors of the augmentation method range only from –0.5% to 1.5%, and 0 to 1.5%, respectively. A summary of results from numerical experiments (Tab. 2) shows that the magnitude of the error d, and its variance across industries, is related to the type of factor: Generally speaking, the larger the relative variance of intensities q across industries, the larger the error of the augmentation method.

It is however also intuitively clear that the range of intensities must play a role for this error too, since in the augmentation method factor content from intensive industries is distributed across all industries. A comparison of CO_2 and energy multipliers demonstrates that the larger the factor range (expressed as the ratio between the largest and the smallest factor intensity), the larger the error. An example of two factors that feature the same range but different variances could not be found.

The error does however not disappear for a factor with zero variance and range 1, as shown in the example of intermediate demand. The remaining "baseline" error of about 1.1% is factor-independent, and must be attributed entirely to the differences in the coefficients of $\mathbf{A}^{(a)}$ and $\mathbf{A}+\mathbf{K}$.[3]

5. Conclusions

Comparing the two methods for endogenising capital introduced in this paper, it can be concluded that the augmentation method leads to a systematic overestimation of low- and mid-range multipliers, and to a substantial underestimation of high-range multipliers. The magnitude of this error is factor-dependent, and increases with increasing variance and range of the corresponding factor intensities.

In order to calculate interindustry effects of capital expenditure, it is therefore under most circumstances preferable to employ the flow matrix method. However, a drawback of this approach is its relatively high data requirements: In many countries, capital flow matrices are not estimated by statistical bureaux at all, so that these have to be constructed based on disparate, and often incomplete and inconsistent data sources. If capital transactions data are not available at all, the augmentation method has to be used. In this case, some estimate of the magnitude of the error in the multiplier values can be obtained by computing the variance and range of the factor intensities under consideration.

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References

Australian Bureau of Agricultural and Resource Economics (1997). *Australian energy consumption and production*. ABARE Research Report 97.2, Commonwealth of Australia, Canberra, Australia.

Australian Bureau of Statistics (1994). *Australian National Accounts, Capital Stock*, 1992-93. ABS Catalogue No.5221.0, Australian Bureau of Statistics, Canberra, Australia.

Australian Bureau of Statistics (1995). *Private New Capital Expenditure and Expected Expenditure to June 1996*. ABS Catalogue No.5625.0, Australian Bureau of Statistics, Canberra, Australia.

Australian Bureau of Statistics (1996). *Australian National Accounts, Capital Stock, 1994-95*. ABS Catalogue No.5221.0, Australian Bureau of Statistics, Canberra, Australia.

Australian Bureau of Statistics (1999a). Capital flow estimates for the OECD Structural

[3] It can be conjectured that this baseline error is related to the difference $\boldsymbol{a}_y^{(c)} K\boldsymbol{a}_v^{(c)}(\mathbf{I}+\mathbf{B}\boldsymbol{a}_y^{(c)} K\boldsymbol{a}_v^{(c)})^{-1}$ between the terms in Eqs. 4 and $\mathbf{K}$ in Eq. 5, but we have not investigated this any further.

Analysis (STAN) Database for Industrial Analysis, OECD, Paris 1992. Electronic file (unpublished working estimates)(electronic source).

Australian Bureau of Statistics (1999b). Capital Stock Estimates. Electronic file (unpublished working estimates) (electronic source).

Australian Bureau of Statistics (1999c). Private New Capital Expenditure: Total Assets, by 3 digit ANZSIC Industry. Electronic file (unpublished working estimates) (electronic source).

Australian Bureau of Statistics (2000). *Water Account for Australia*. ABS Catalogue No.4610.0, Australian Bureau of Statistics, Canberra, Australia.

Australian Bureau of Statistics (2001). *Australian National Accounts, Input-Output Tables, 1996-97*. ABS Catalogue No.5209.0, Australian Bureau of Statistics, Canberra, Australia.

Bullard C.W. and Herendeen R.A. (1975). Energy impact of consumption decisions. *Proceedings of the IEEE* **63**(3), 484-493.

Casler S. (1983). Correcting input-output coefficients for capital depreciation. *Energy Systems and Policy* **7**(3), 171-193.

Gowdy, J.M. (1992). Labour productivity and energy intensity in Australia 1974-87. *Energy Economics* **14**(1), 43-48.

Hohmeyer O. (1992). The analysis of indirect emissions due to intermediate production. In: *Expert workshop on life-cycle analysis of energy systems, methods and experience*, Paris, France, Organisation for Economic Co-Operation and Development (OECD), International Energy Agency (IEA).

Lee T.H. (1971). *Intersectoral capital flows in the economic development of Taiwan, 1895-1960*. Cornell University Press Ithaca, USA.

Lenzen M. (1998). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. *Energy Policy* **26**(6), 495-506.

Lenzen M. and Foran B. (2001). An input-output analysis of Australian water usage. *Water Policy* **3**(4), 321-340.

Miyazawa, K. and Masegi, S., 1963. Interindustry analysis and the structure of income-distribution. *Metroeconomica* **XV**, 89-103.

National Greenhouse Gas Inventory Committee (1998). *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks*. Workbooks 1.1 to 8.1, Australian Greenhouse Office, Canberra, Australia.

Wenzel B. and Pick E. (1997). *Energetische Input-Output-Analyse – Verschiedene Ansätze zur Berücksichtigung von Abschreibungen*. Arbeitsbericht Juli 1997, Fachgebiet Ökologisch verträgliche Energiewirtschaft, Universität GH, Essen, Germany.

Wolff, E.N. (1985). Industrial composition, interindustry effects, and the U.S. productivity slowdown. *Review of Economics and Statistics* **67**(2), 268-277.