Inter industry linkages in New Zealand

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Abstract

This paper investigates the production structure of the New Zealand business sector using the recently released 1996 input output tables. The analysis is undertaken at the most disaggregated level for which data are available, 126 industries. Indices of backward and forward linkages, measures of industry interconnectedness and a value added production multiplier are calculated. The ranking of industries by degree of connectedness depends on whether direct transactions or both direct and indirect transactions are considered. In 1996, wholesale and retail trade, air transport, services to transport and storage, central government administration, meat processing, and dairy product manufacturing had the strongest backward and forward links with other industries.

JEL CLASSIFICATION C67 (input output models), L16 (macroeconomic industrial structure)

KEYWORDS Input output models, inter industry dependencies

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1 Introduction

The purpose of this paper is to examine the structure of production of the New Zealand economy using the 1996 input output tables (National Accounts Division Statistics New Zealand 2001). Input output data contain detailed information about the process of production, the use of goods and services (products) and the income generated in that production of an economy (United Nations 1993). They can be used to assess the degree of specialisation in the economy. Specialisation is important as it leads to increased division of labour and productivity – one of the key sources of economic growth.

The methodology in this paper adopts a technological definition of production structure. This definition refers to "the input coefficients of an input output model derived from Leontief-type fixed-proportion production functions" (Soofi 1992). In the production model, a change in output results from changes in final demand, whereas in the allocation model, the causal element is the level and composition of primary inputs (Adamou and Gowdy 1990).

The remainder of this paper proceeds as follows. Section 2 discusses the 1996 input output tables. The methodology used to examine the production structure of the New Zealand economy in 1996 is described in section 3. Three types of measure are used: (i) backward and forward linkages, (ii) industry interconnectedness, and (iii) a value added production multiplier. The analysis is undertaken at the most disaggregated level for which data are available, the 126 industry level. Section 4 presents the results. The main findings are summarised in section 5 and section 6 contains some concluding remarks.

2 Input output tables[1]

With the release of the 1996 input output tables, Statistics New Zealand has completed the ninth inter industry study for New Zealand.[2] The 1996 tables are based on the 1993 System of National Accounts (SNA93) and Australian and New Zealand Standard

1 (United Nations 1993) provides a useful reference.

2 Tables are also available for 1952-53, 1954-55, 1959-60, 1965-66, 1971-72, 1976-77, 1981-82 and 1986-87. No official tables were produced for the early 1990s.

Industrial Classification (ANZIC) to define industries and Australian and New Zealand Standard Commodity Classification (ANZSCC) for commodity definitions.[3]

Input output tables provide information on the values of flows of goods and services between industries and sectors of an economy. There are two types of input output table (matrix): supply and use tables, and square input output (or Leontief) tables. Supply and use tables are *product by industry* tables. The focus of input output analysis tends to be on the inter industry transactions table or (square) *industry by industry* flow matrices.

All commodity and industry flows in the input output tables are in dollar millions and recorded at *basic prices*. The basic price of a good or service is the amount receivable by the producer from the purchaser minus any tax payable and plus any subsidy receivable. The p*roducer price* is the amount receivable by the producer from the purchaser minus any deductible goods and services tax (GST) invoiced to the purchaser. The *purchaser's price* is the amount paid by the purchaser, excluding any deductible GST in order to take delivery of a unit of a good or service. In the case of goods, the purchaser's price includes any trade margins and transport charges paid by the purchaser. Both basic and producer prices exclude transport charges invoiced separately by the producer.

Table 1 shows (parts of) the 1996 industry by industry transactions matrix.[4] The rows of the table describe the distribution of an industry's output throughout the economy (forward linkages). The columns describe the composition of inputs required by a particular industry to produce its output (backward linkages). These inter industry transactions of products constitute the shaded portion of Table 1.

The column labelled "total industry" shows the total of intermediate products supplied by a particular industry.[5] The additional columns record the sales by each sector for final demand, i.e. final consumption expenditure (by households, private non-profit institutions serving households, central and local government), gross capital formation and exports, where gross capital formation consists of gross fixed capital formation and change in inventories. The column labelled "total economy" is the sum of sales of intermediate and final demand products. It is equal to the row labelled "total supply in basic prices".

The row labelled "total use in purchasers' prices" is the sum of inputs purchased from domestic producers and imports required by a particular industry to produce its output. The other rows account for other inputs to production, such as labour. Compensation of employees, operating surplus, consumption of fixed capital, other taxes on production and subsidies add up to total value added.

Table 1 also shows the link between total use in basic prices and purchasers' prices.

From Table 1 gross domestic product (GDP) can be calculated. The sum of total use in purchasers' prices of final consumption expenditure ($M 71,965), gross capital formation ($M 21,073) and exports ($M 27,350) less total economy imports ($M 26,641) is equal to GDP at market prices ($M 93,747). Total industry total value added ($M 84,120) plus total economy taxes on products ($M 9,626) is also equal to GDP ($M 93,746).

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3 The input output tables for the years 1971-72, 1976-77, 1981-82 and 1986-87 are based on the 1968 System of National Accounts (SNA68). The 1996 tables are hence not directly comparable to earlier data.

4 For more details and an excellent introduction to inter industry transactions and input output analysis see (Dixon 1996).

5 The total value of intermediate output is equal to the total value of intermediate inputs; that is, aggregate intermediate supply is equal to aggregate intermediate demand.

Table 1: Inter industry transactions in basic prices (dollar millions)

	Other horticulture	…	Waste disposal, sewerage and drainage services	Total Industry	Final consumption expenditure	Gross capital formation	Exports	Total economy
Other horticulture	7	…		427	125	9	188	749
…	…	…	…	…	…	…	…	…
Waste disposal, sewerage and drainage services		…	65	258	6	3	3	271
Imports	40	…	7	15,468	6,051	4,620	503	**26,641**
Total use in basic prices	385	…	135	101,054	65,801	20,304	27,002	214,161
Taxes on products	8	…	4	2,346	6,164	768	348	**9,626**
Total use in purchasers' prices	394	…	139	103,400	**71,965**	**21,073**	**27,350**	**223,788**
Total value added	355	…	132	**84,120**				
Compensation of employees	151	…	46	39,450				
Operating surplus	125	…	65	29,621				
Consumption of fixed capital	67	…	17	12,407				
Other taxes on production	15	…	4	2,957				
Subsidies	-3	…		-315				
Total supply in basic prices	749	…	271	187,520				

The inter industry transactions table can be used to construct input output *coefficients*. The matrix of *technical or input coefficients* reports the value of inputs directly required from one industry in order to produce one dollar's worth of output of another industry. The matrix of *total requirements coefficients* shows how much extra output is needed by every industry if a particular industry is to produce one more dollar worth of final output.

Total requirements coefficients can be used to evaluate the effects of a change in the circumstances of one industry upon all other industries as long as the coefficients are constant. The coefficients will be constant if:

- both relative prices and quantities are constant;
- industry composition is constant;
- technical coefficients (i.e. quantities of inputs per unit of output) are constant; this implies that inputs cannot be substituted for each other.

In reality, total requirement coefficients are unlikely to be constant. However, they are generally only changing slowly and hence are still useful.

3 Measures of inter industry linkages

The production structure is examined using three types of measure: (i) backward and forward linkages, (ii) industry interconnectedness, and (iii) a value added production multiplier. These are described in more detail in this section.

Backward and forward linkages, which were first proposed by (Rasmussen 1956), are descriptive measures of the economic interdependence of industries, while industry interconnectedness refers to the number of direct and indirect inter industry transactions. The value added production multiplier is a measure of dispersion and shows the relative direct and indirect contribution of a unit increase in final demand to value added by each sector.

3.1 Measures of backward and forward linkages[6]

The input output model in its most basic form consists of a system of linear equations, each of which describes the distribution of an industry's product through the economy. The basic input output identity can be expressed in value terms as follows

$$x = Ax + f \qquad (1)$$

where $x = [x_1,\ldots,x_N]'$ is the vector of gross output, N denotes the number of industries, $A = [a_{ij}]$ is the matrix of technical coefficients and $f = [f_1,\ldots,f_N]'$ is the vector of final demand. Technical or input coefficients are the inputs directly required from one industry in order to

6 Sections 3.1 and 3.2 follow (Chatterjee 1989) and (Soofi1992).

produce one dollar's worth of output of another industry. Equation (1) states that gross output, x, is the sum of all intermediary output, Ax, and final demand, f.

Equation (1) can be solved for x to obtain

$$x = [I - A]^{-1} f \qquad (2)$$

if $[I - A]$ is non-singular and where I is the identity matrix.[7] The matrix $[I - A]^{-1}$ is called the inverted Leontief matrix or total requirement matrix. Total requirement coefficients show how much output is required directly and indirectly from each industry in the economy for every dollar's worth of output produced for final use. The elements of $[I - A]^{-1}$ are denoted b_{ij}, where i refers to the industry in the i^{th} row and j to the industry in the j^{th} column. The elements of the final demand weighted Leontief inverse are denoted by b_{ij}^{w}, where

$$b_{ij}^{w} = b_{ij} \frac{f_i}{\sum_{i=1}^{N} f_i} \qquad (3)$$

The total requirement coefficient matrix is weighted by final demand to avoid a possible bias (discussed further below).

The sum of the elements in column j[8]

$$b_{.j}^{w} = \sum_{i=1}^{N} b_{ij}^{w} \qquad (4)$$

shows the input requirements for a unit increase in the final demand for sector j's output given each sector's share in total final demand. It is called the *backward linkage* as it measures the impact on the supplier industries of a unit increase in the final demand.[9] Expressing the backward linkage as an index

$$U_{.j}^{w} = \frac{(1/N) b_{.j}^{w}}{(1/N^2) \sum_{j=1}^{N} b_{.j}^{w}} = \frac{b_{.j}^{w}}{(1/N) \sum_{j=1}^{N} b_{.j}^{w}} \qquad (5)$$

allows inter industry comparisons to be made. The numerator in equation (5) measures the average stimulus to other sectors, according to each sector's share in total final demand, resulting from a unit increase in the final demand for sector j's output. The denominator measures the average stimulus to the whole economy resulting from a unit increase in the final demand for the output of all sectors.

Conversely, the index of *forward* linkage is given by

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7 The condition that $[I - A]$ is non-singular means that $\lim_{T \to \infty} A^{T} = 0$ and the economic system produces the intermediate inputs needed to produce the intermediate inputs needed to produce the intermediate inputs needed, and so on … .

8 Subscripts .j and i. denote column and row sums respectively.

9 (Hirschman 1958) labelled $U_{.j}^{w}$ and $U_{i.}^{w}$ (discussed further below) backward and forward linkages. (Rasmussen 1956) used the term power of dispersion for $U_{.j}^{w}$ and sensitivity of dispersion for $U_{i.}^{w}$.

$$U_{i.}^{w} = \frac{(1/N)b_{i.}^{w}}{(1/N^{2})\sum_{i=1}^{N} b_{i.}^{w}} = \frac{b_{i.}^{w}}{(1/N)\sum_{i=1}^{N} b_{i.}^{w}} \qquad (6)$$

where the sum of the elements in row i

$$b_{i.}^{w} = \sum_{j=1}^{N} b_{ij}^{w} \qquad (7)$$

shows the increase in the output of sector i needed to supply the inputs required to produce an additional unit of final demand output, given each sector's share in total final demand.

The forward linkage would be subject to a bias noted in (Chatterjee 1989) if the total requirement matrix wasn't weighted. This is because "for the row sum to measure the forward linkage in an unbiased fashion, it is necessary to make the assumption that the demands for all sectors increase by one unit. All sectors are unlikely in practice to be of equal importance in the structure of demand, so if a small sector j uses inputs from sector i disproportionately largely, the forward linkage index will be blown up artificially by the assumption of equal expansion of all sectors" (Chatterjee 1989, p. 96). Weighting the total requirement matrix avoids this problem.

Indices (5) and (6) are averages and hence sensitive to extreme values. For example, a sector with high forward linkages could be selling large amounts of output to only a few sectors. To account for extreme values, (Rasmussen 1956) supplements the linkage indices with coefficient of variation indices. They measure the dispersion of an increase in final demand and are given by

$$V_{.j}^{w} = \frac{\left[(1/N)\sum_{i=1}^{N}\left[b_{ij}^{w} - (1/N)b_{.j}^{w}\right]^{2}\right]^{\frac{1}{2}}}{(1/N)b_{.j}^{w}} \qquad (8)$$

and

$$V_{i.}^{w} = \frac{\left[(1/N)\sum_{j=1}^{N}\left[b_{ij}^{w} - (1/N)b_{i.}^{w}\right]^{2}\right]^{\frac{1}{2}}}{(1/N)b_{i.}^{w}} \qquad (9)$$

The numerators in equations (8) and (9) are the standard deviations and the denominators the averages.

The index $V_{.j}^{w}$ ($V_{i.}^{w}$) measures the relative evenness with which industry j (i) purchases from (sells to) other sectors. A relatively large value of $V_{.j}^{w}$ implies that sector j purchases inputs from only a few industries in the economy. Conversely a large $V_{i.}^{w}$ means that sector i sells output to only a few industries in the economy.

3.2 Measures of industry interconnectedness

Backward and forward linkages assess the magnitude of transactions between industries. Measures of industry interconnectedness, on the other hand, focus on the number of direct and indirect industry sales or purchases. They are related to coefficients of variation.

To determine the degree of industry interconnectedness, following (Soofi 1992), two measures are used: (i) a measure of concentration, and (ii) entropy as a measure of variation. Measures of concentration focus on the intermediate sector, while entropy based measures of dispersion of inter industry transactions are more descriptive of the characteristics of the economy as a whole.

To derive the measure of concentration, suppose that final demand is zero, i.e.

$$x_i = \sum_{j=1}^{N} a_{ij} x_j \qquad (10)$$

This allows normalising the elements of the matrix of technical coefficients A with the corresponding row sums $a_{i.} = \sum_{j=1}^{N} a_{ij}$ and column sums $a_{.j} = \sum_{i=1}^{N} a_{ij}$ for all i and j respectively. This results in matrices $c_{i.} = [c_{i.,ij}]$ and $c_{.j} = [c_{.j,ij}]$, where $c_{i.,ij} = a_{ij} / a_{i.}$ and $c_{.j,ij} = a_{ij} / a_{.j}$.[10]

Measures of concentration are then defined as

$$G_{i.}(a_{ij}) = \left[N\left(1 - \sum_{j=1}^{N} (c_{i.,ij})^2 \right) \right]^{1/2} \qquad (11)$$

and

$$G_{.j}(a_{ij}) = \left[N\left(1 - \sum_{i=1}^{N} (c_{.j,ij})^2 \right) \right]^{1/2} \qquad (12)$$

where equation (11) is the forward concentration index and (12) the backward index.

When sector i sells the same proportion of output to all sectors j, i.e. $c_{i.,ij} = 1/N$ for all j, $G_{i.}(a_{ij}) = [N-1]^{1/2}$ and complete *uniformity* of intersectoral distribution prevails. Complete *skewness* of intersectoral distribution occurs when sector i sells all the output to one sector j, i.e. $c_{i.,ij} = 1$ for one j and $c_{i.,ij} = 0$ for all other j and $G_{i.}(a_{ij}) = 0$.

Conversely, when sector j buys the same quantity of inputs from all sectors i, i.e. $c_{.j,ij} = 1/N$ for all i, complete uniformity of intersectoral distribution occurs and $G_{.j}(a_{ij}) = [N-1]^{1/2}$. In contrast, complete skewness of intersectoral distribution occurs when sector j purchases all the inputs from industry i, i.e. $c_{.j,ij} = 1$ for one i and $c_{.j,ij} = 0$ for all other i. This implies $G_{.j}(a_{ij}) = 0$.

10 The matrix of technical coefficients is given by $A = \hat{A}\hat{x}^{-1}$, where $\hat{A}$ is the intermediate input flow matrix and $\hat{x}$ is the diagonal matrix containing on its diagonal the elements for the vector of gross output x.

The larger is the measure of concentration, the more industries ties. Conversely, the smaller the measure of concentration is, the fewer inter industry sales or purchases. The index would thus probably be more adequately called a "de-concentration" index.

Measures of concentration can also be calculated for total requirement matrices, taking into account both direct and indirect transactions.

An alternative measure of industry interconnectedness is entropy. Entropy has its origin in physics and is a measure of disorder. Consider, for example, two gases, one with all A molecules and one with all B molecules. Mixing the two gases will lead to a final mixture of A and B molecules that is less ordered than the initial system of pure A and B molecules. The mixed state is more probable than the unmixed state, i.e. it has a higher entropy, because there are more ways of distributing the molecules of A and B so as to yield mixed states than there are ways to yield pure states. The two gases in the example can be interpreted as the industries in an economy. The higher is the entropy, the more integrated and thus specialised industries are. The more integrated and specialised industries are, the less probable that the economy returns to its initial state (of barter).

The entropy of sector i is calculated as follows

$$H_{i.}(a_{ij}) = \sum_{i=1}^{N} c_{i.,ij} \log\left(\frac{1}{c_{i.,ij}}\right) \tag{13}$$

and of sector j as

$$H_{.j}(a_{ij}) = \sum_{j=1}^{N} c_{.j,ij} \log\left(\frac{1}{c_{.j,ij}}\right) \tag{14}$$

Note that $c_{..,ij} \log\left(\frac{1}{c_{..,ij}}\right)$ is generally replaced by $\lim_{c_{..,ij} \to 0}\left[c_{..,ij} \log\left(\frac{1}{c_{..,ij}}\right)\right] = 0$ for $c_{..,ij} = 0$ (Theil 1971).

The (row) entropy $H_{i.}(a_{ij})$ is zero when sector j is the only sector that purchases additional output from sector i following a one dollar increase in sector i's delivery of output to final demand. $H_{i.}(a_{ij}) = \log(N)$ when all sectors of the economy purchase an equal amount of output after sector i delivers one dollar's worth of its output to final demand.

Similarly, the (column) entropy $H_{.j}(a_{ij})$ is zero if sector j purchases additional output from only one industry in response to a one dollar increase in sector i's delivery of output to final demand. $H_{.j}(a_{ij}) = \log(N)$ if sector j uniformly increases its intra industry and inter industry purchases in response to a change in sector i's delivery of output to final demand.

The entropies for the weighted total requirement coefficients matrices, b_{ij}^{w}, taking into account direct and indirect linkages, are calculated accordingly.

Entropy can also be measured taking into account inter industry sales as well as sales to final demand. To measure the impact of deliveries to both the intermediate and final demand sectors normalise

$$x_i = a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{iN}x_N + f_i \tag{15}$$

by dividing both sides of (15) by x_i and applying the entropy formula in equation (13) to the proportions. $H_{i.} = 0$ if sector i sells to one sector only and $H_{i.} = \log(N+1)$ when sector i sells an equal amount of output to all intermediate and final demand sectors.

3.3 Value added production multiplier[11]

Industry interconnectedness measures the relative dispersion of inter industry transactions. To assess the effect of changes in final demand on value added, and hence gross domestic product, taking into account inter industry linkages, the value added production multiplier can be used. It is measured as follows

$$D_{.j} = v_j b^w_{.j} \qquad (16)$$

where $b^w_{.j} = \sum_{i=1}^{N} b^w_{ij}$ is the input requirement for a unit increase in the final demand for sector j's output, weighted by each sector's share in total final demand, and v_j is the share of value added in industry j's output. The sum of value added production multipliers across industries is one. $D_{.j}$ hence shows the direct and indirect contribution of a unit increase in final demand to value added in industry j relative to other industries.

4 Empirical results

This section presents the results of backward and forward linkages, measures of industry interconnectedness and the value added production multiplier after a brief discussion of some descriptive statistics of the New Zealand business sector in 1996.

4.1 Some descriptive statistics

In 1996, slightly less than half (47.2 percent) of total gross output in New Zealand consisted of intermediate products, i.e. inputs into other industries' production. The remainder (52.8 percent) went to final demand, of which 58.2 percent were for final consumption expenditure, 18 percent for gross capital formation and 23.9 percent were exported abroad. The share of value added in gross output was 44.9 percent.[12]

Table 2 shows the industry breakdown.[13] In 1996, New Zealand's largest industries in terms of percent of total gross output were wholesale and retail trade (7.9 and 5.8 percent respectively) and ownership of owner-occupied dwellings (4.6 percent). In terms of value added, dairy cattle farming, and air transport, services to transport and storage contributed

11 This measure is calculated in (Gowdy 1991). See also (Adamou and Gowdy 1990) for more details.
12 These numbers, using basic prices, can be calculated from Table 1.
13 Shaded numbers in Table 2 (and other tables) are those referred to in the text.

the most to total, economy wide value added at 2.3 percent, followed by commercial property operators (2.2 percent) and central government administration (2 percent).

The contribution to value added was negative for investors in other property and virtually zero for services to mining, superannuation fund operation, owner builders, oil and gas exploration, petroleum and coal product manufacturing nec, health insurance, and prefabricated building manufacturing. The contribution of these industries to value added was low, in part because these industries are small. However, the value added for investors in other property, owner builders, and superannuation fund operation was also small as a proportion of their own gross output, at -0.6, 1.7 and 6.4 percent respectively. Operating surplus of investors in other property, services to mining, superannuation fund operation, oil and gas exploration, health insurance, and apple and pear growing contributed negatively to value added.

Value added as a share of industry output was largest for public order and safety services, at 80.3 percent, followed by 79.5 percent for primary and secondary education and 78.8 percent for commercial property operators. Value added is high in these industries, in part because of the large labour component.

New Zealand's two largest exporting industries are meat processing and dairy product manufacturing. In 1996, their share of total exports was about 11.4 and 11.3 percent respectively. Wholesale trade (9 percent) and air transport, services to transport and storage (7.8 percent) were also important exporters.

Exports made up about 60.9 percent of total gross output of the dairy product manufacturing industry and 65.1 percent of meat processing's total gross output. Only other leather product manufacturing, apple and pear growing, seafood processing, and kiwifruit growing exported a larger proportion of their gross output, with kiwifruit growing having the highest share (84.4 percent).

The largest providers of intermediate goods and services were wholesale trade and finance with 3.7 and 2.2 percent of total gross output, while superannuation fund operation and ownership of owner-occupied dwellings did not supply any intermediate products.

In 1996, ownership of owner-occupied dwellings, retail and wholesale trade were the largest suppliers of final consumption expenditure, with 14.6, 11.2 and 7.1 percent of total final consumption expenditure. Services to mining and water supply did not provide any final consumption expenditure, with water supply not producing any final demand output.

New Zealand industries produce a relatively small share of gross capital formation, 9.5 percent of total gross output in 1996, of which residential building construction supplied most of gross fixed capital (1.2 percent of total gross output), followed by non building construction (0.9 percent) and non residential building construction (0.8 percent). Gross capital formation, which is the sum of gross fixed capital formation and the change in inventories, was negative for some industries because of a decline in inventories.

Table 2: Some descriptive statistics

		Industry share of total gross output	Industry share of total value added	Value added as a share of industry output	Industry share of total exports	Exports as a share of industry output	Intermediate products as a share of total gross output	Industry share of consumption expenditure	Gross capital formation as a share of total gross output
1	Other horticulture	0.4	0.4	47.4	0.7	25.1	0.2	0.2	0.0
2	Apple and pear grow ing	0.1	0.2	46.0	0.8	75.0	0.0	0.0	0.0
3	Kiw ifruit grow ing	0.1	0.2	47.4	0.9	84.4	0.0	0.0	0.0
4	Other fruit grow ing	0.1	0.1	43.8	0.2	35.8	0.0	0.1	0.0
5	Mixed livestock and cropping	0.4	0.3	39.6	0.2	8.3	0.3	0.0	0.0
6	Sheep and beef cattle farming	1.6	1.3	36.9	1.0	8.8	1.5	0.0	-0.1
7	Dairy cattle farming	1.9	2.3	52.8	0.1	1.0	1.8	0.0	0.1
8	Other farming	0.4	0.3	41.7	0.2	9.3	0.3	0.1	0.0
9	Services to agriculture, hunting and trapping	0.5	0.5	45.3	0.1	3.1	0.4	0.0	0.0
10	Forestry	1.1	1.0	40.6	2.7	33.6	0.6	0.1	0.2
11	Services to forestry	0.1	0.1	57.9	0.1	11.1	0.1	0.0	0.0
12	Logging	0.2	0.2	62.8	0.1	5.2	0.2	0.0	0.0
13	Fishing	0.4	0.3	34.3	0.6	20.8	0.3	0.0	0.0
14	Coal mining	0.1	0.1	45.6	0.3	38.2	0.1	0.0	0.0
15	Services to mining	0.0	0.0	38.9	0.0	0.0	0.0	0.0	0.0
16	Other mining and quarrying	0.4	0.4	44.5	0.9	34.7	0.2	0.0	0.0
17	Oil and gas extraction	0.5	0.7	63.6	0.6	16.8	0.4	0.0	0.0
18	Oil and gas exploration	0.0	0.0	26.7	0.0	8.0	0.0	0.0	0.0
19	Meat processing	2.5	1.3	23.6	11.4	65.1	0.5	1.2	0.0
20	Poultry processing	0.2	0.1	24.8	0.0	2.4	0.1	0.4	0.0
21	Bacon, ham and small good manufacturing	0.1	0.1	26.3	0.0	4.6	0.0	0.3	0.0
22	Dairy product manufacturing	2.6	0.8	13.8	11.3	60.9	0.4	1.3	0.2
23	Fruit and vegetable, oil and fat, cereal and flour manufacturing	0.7	0.4	24.4	1.1	23.3	0.3	0.8	0.0
24	Bakery, sugar and confectionery manufacturing	0.6	0.4	25.0	0.6	13.0	0.2	1.1	0.0
25	Seafood processing	0.7	0.4	27.3	4.0	82.1	0.1	0.1	0.0
26	Other food manufacturing	0.6	0.4	29.2	0.9	21.8	0.3	0.6	0.0
27	Soft drink, cordial and syrup manufacturing	0.2	0.2	34.5	0.1	5.0	0.1	0.4	0.0
28	Beer, w ine, spirit and tobacco manufacturing	0.7	0.4	28.6	0.5	11.5	0.2	1.3	0.0
29	Textile manufacturing	0.7	0.5	30.5	1.5	29.3	0.4	0.4	0.0
30	Clothing manufacture	0.5	0.4	38.3	0.9	29.2	0.1	0.7	0.0
31	Footw ear manufacture	0.1	0.1	43.6	0.2	39.1	0.0	0.2	0.0
32	Other leather product manufacturing	0.2	0.1	25.8	1.2	69.7	0.1	0.0	0.0
33	Log saw milling and timber dressing	0.8	0.5	26.8	1.4	24.9	0.6	0.0	0.0
34	Other w ood product manufacturing	0.7	0.5	32.7	1.6	30.7	0.5	0.1	0.0
35	Paper and paper product manufacturing	1.5	1.3	38.1	3.8	34.5	0.8	0.5	0.0
36	Printing and services to printing	0.8	0.8	42.6	0.3	5.3	0.7	0.3	0.0
37	Publishing, recorded media manufacturing	0.8	0.9	47.6	0.2	2.6	0.7	0.5	0.0
38	Petroleum refining	0.7	0.1	7.3	0.4	8.3	0.4	0.7	0.0
39	Petroleum and coal product manufacturing nec	0.0	0.0	25.3	0.0	12.7	0.0	0.0	0.0
40	Fertiliser manufacturing	0.3	0.2	21.2	0.0	1.6	0.3	0.1	0.0
41	Other industrial chemical manufacturing	0.6	0.4	28.7	1.3	30.1	0.4	0.1	0.0
42	Medicinal, detergent and cosmetic manufacturing	0.5	0.3	29.5	1.0	27.8	0.2	0.6	0.0

Table 2: Some descriptive statistics (cont.)

	Industry share of total gross output	Industry share of total value added	Value added as a share of industry output	Industry share of total exports	Exports as a share of industry output	Intermediate products as a share of total gross output	Industry share of consumption expenditure	Gross capital formation as a share of total gross output
43 Other chemical product manufacturing	0.4	0.2	26.5	0.6	23.5	0.3	0.1	0.0
44 Rubber manufacturing	0.2	0.2	39.6	0.3	24.7	0.1	0.1	0.0
45 Plastic product manufacturing	0.8	0.7	37.7	1.1	19.6	0.5	0.2	0.0
46 Glass and glass product and ceramic manufacturing	0.2	0.2	43.4	0.2	12.0	0.1	0.0	0.0
47 Other non-metallic mineral product manufacturing	0.6	0.5	42.1	0.1	2.7	0.5	0.0	0.0
48 Basic metal manufacturing	1.0	0.6	30.4	2.4	36.2	0.6	0.0	0.0
49 Structural, sheet and fabricated metal product manufacturing	1.5	1.3	37.0	1.9	17.6	1.1	0.1	0.1
50 Motor vehicle and part manufacturing	0.9	0.4	18.5	0.4	6.8	0.2	0.6	0.4
51 Ship and boat building	0.2	0.2	40.4	0.3	21.8	0.0	0.2	0.1
52 Other transport equipment manufacturing	0.3	0.3	43.8	0.2	12.1	0.2	0.0	0.0
53 Photographic and scientific equipment manufacturing	0.1	0.1	40.6	0.3	36.5	0.0	0.0	0.0
54 Electronic equipment and appliance manufacturing	1.1	0.8	32.7	1.9	25.5	0.3	0.5	0.3
55 Agricultural machinery manufacturing	0.2	0.1	41.0	0.2	19.1	0.0	0.0	0.1
56 Other industrial machinery and equipment manufacturing	0.9	0.8	40.8	1.4	22.1	0.3	0.1	0.4
57 Prefabricated building manufacturing	0.1	0.0	25.2	0.1	14.4	0.0	0.0	0.0
58 Furniture manufacturing	0.5	0.4	33.4	0.4	9.7	0.1	0.5	0.2
59 Other manufacturing	0.2	0.2	40.1	0.5	33.4	0.1	0.1	0.0
60 Electricity generation	0.7	0.8	54.4	0.0	0.1	0.5	0.7	0.0
61 Electricity transmission	0.3	0.5	71.4	0.0	0.0	0.3	0.0	0.0
62 Electricity supply	1.5	1.0	30.2	0.0	0.0	1.0	1.4	0.0
63 Gas supply	0.3	0.2	39.0	0.3	16.4	0.1	0.2	0.0
64 Water supply	0.2	0.2	42.8	0.0	0.0	0.2	0.0	0.0
65 Residential building construction	1.4	0.7	21.4	0.0	0.3	0.2	0.1	1.2
66 Ow ner builders	0.4	0.0	1.7	0.0	0.0	0.0	0.0	0.4
67 Non residential building construction	1.1	0.4	15.8	0.1	1.2	0.3	0.0	0.8
68 Non building construction	1.3	1.0	33.5	0.0	0.3	0.5	0.0	0.9
69 Site preparation services	0.4	0.3	39.9	0.0	0.1	0.1	0.0	0.2
70 Building structure services	0.3	0.2	39.9	0.0	0.0	0.2	0.0	0.1
71 Plumbing services	0.3	0.3	37.4	0.0	0.2	0.2	0.0	0.2
72 Installation trade services	0.8	0.6	36.8	0.1	1.3	0.4	0.0	0.3
73 Building completion services	0.7	0.7	43.0	0.0	0.2	0.5	0.0	0.2
74 Other construction services	0.2	0.2	41.9	0.0	0.0	0.1	0.0	0.0
75 Wholesale trade	7.9	7.7	44.0	9.0	16.2	3.7	7.1	0.7
76 Retail trade	5.8	6.7	51.2	3.4	8.1	1.5	11.2	0.3
77 Accommodation	0.6	0.6	42.8	1.7	40.5	0.1	0.8	0.0
78 Bars, clubs, cafes and restaurants	1.1	0.8	32.9	1.9	24.3	0.1	2.4	0.0
79 Road freight transport	1.4	1.4	45.0	0.2	2.1	1.3	0.1	0.0
80 Road passenger transport	0.3	0.3	49.5	0.4	19.0	0.1	0.4	0.0
81 Water and rail transport	0.8	1.0	58.2	2.2	38.2	0.4	0.2	0.0
82 Air transport, services to transport and storage	2.6	2.3	38.8	7.8	41.6	1.0	1.5	0.0
83 Communication services	2.5	3.5	61.6	1.0	5.6	1.6	2.1	0.1
84 Finance	2.8	3.9	62.0	0.4	1.8	2.2	1.8	0.0

Table 2: Some descriptive statistics (cont.)

	Industry share of total gross output	Industry share of total value added	Value added as a share of industry output	Industry share of total exports	Exports as a share of industry output	Intermediate products as a share of total gross output	Industry share of consumption expenditure	Gross capital formation as a share of total gross output
85 Life insurance	0.4	0.3	31.7	0.0	0.1	0.0	1.1	0.0
86 Superannuation fund operation	0.1	0.0	6.4	0.0	0.0	0.0	0.3	0.0
87 Health insurance	0.0	0.0	32.9	0.0	0.0	0.0	0.1	0.0
88 General insurance	0.5	0.6	52.6	0.0	1.1	0.3	0.6	0.0
89 Services to finance and insurance	0.7	0.7	46.8	0.1	1.7	0.6	0.0	0.0
90 Residential property operators	1.3	1.7	61.7	0.0	0.4	0.0	3.9	0.0
91 Commercial property operators	1.3	2.2	78.8	0.0	0.5	1.3	0.0	0.0
92 Real estate agents	0.7	0.7	41.0	0.0	0.1	0.4	0.1	0.3
93 Ow nership of ow ner-occupied dw ellings	4.6	7.5	72.6	0.0	0.0	0.0	14.6	0.0
94 Investors in other property	0.2	0.0	-0.6	0.1	9.9	0.2	0.0	0.0
95 Vehicle and equipment hire	0.6	0.7	52.0	0.7	16.8	0.5	0.0	0.0
96 Scientific research	0.3	0.4	63.4	0.1	5.1	0.1	0.4	0.0
97 Technical services	0.9	1.1	55.8	0.2	3.8	0.6	0.0	0.2
98 Computer services	0.8	0.9	54.9	0.1	2.4	0.7	0.1	0.1
99 Legal services	0.6	0.9	69.4	0.1	3.1	0.5	0.2	0.1
100 Accounting services	0.5	0.8	69.9	0.1	2.6	0.5	0.0	0.0
101 Advertising and marketing services	0.9	0.8	37.7	0.2	2.7	0.9	0.0	0.0
102 Business administrative and management services	0.7	0.8	49.4	0.1	2.7	0.7	0.0	0.0
103 Employment, security and investigative services	0.4	0.5	60.2	0.0	1.0	0.4	0.0	0.0
104 Pest control and cleaning services	0.2	0.4	68.8	0.0	0.7	0.2	0.1	0.0
105 Other business services	0.7	0.6	39.5	0.3	6.4	0.6	0.1	0.0
106 Central government administration	2.0	2.0	46.2	0.2	1.2	0.2	5.4	0.0
107 Defence	0.5	0.7	62.7	0.0	0.6	0.0	1.5	0.0
108 Public order and safety services	0.5	0.9	80.3	0.0	0.2	0.0	1.6	0.0
109 Local government administration services and civil defence	1.5	1.5	45.0	0.1	0.9	0.1	4.1	0.0
110 Pre-school education	0.1	0.2	67.1	0.0	0.9	0.0	0.4	0.0
111 Primary and secondary education	1.4	2.4	79.5	0.3	3.0	0.1	4.0	0.0
112 Post school education	0.8	1.3	70.1	0.5	8.1	0.0	2.1	0.0
113 Other education	0.3	0.3	52.2	0.2	9.4	0.2	0.2	0.0
114 Hospitals and nursing homes	1.7	2.7	71.0	0.1	0.4	0.0	5.2	0.0
115 Medical, dental and other health services	1.0	1.5	63.6	0.1	1.0	0.1	2.7	0.0
116 Veterinary services	0.1	0.1	62.7	0.0	3.7	0.0	0.1	0.0
117 Child care services	0.1	0.1	63.6	0.0	0.0	0.0	0.1	0.0
118 Accommodation for the aged	0.3	0.4	61.4	0.0	0.6	0.0	0.8	0.0
119 Other community care services	0.2	0.3	53.9	0.0	1.6	0.0	0.6	0.0
120 Motion picture, radio and TV services	0.7	0.6	38.5	0.2	4.7	0.5	0.4	0.0
121 Libraries, museums and the arts	0.2	0.2	46.1	0.2	10.3	0.1	0.4	0.0
122 Horse and dog racing	0.1	0.1	33.5	0.2	28.2	0.1	0.1	0.0
123 Lotteries, casinos and other gambling	0.3	0.4	62.4	0.2	8.3	0.0	0.8	0.0
124 Other sport and recreational services	0.5	0.4	32.7	0.8	21.7	0.1	1.0	0.0
125 Personal and other community services	0.9	1.0	53.4	0.3	5.1	0.3	1.8	0.0
126 Waste disposal, sew erage and drainage services	0.1	0.2	48.7	0.0	1.1	0.1	0.0	0.0

4.2 Backward and forward linkages

The structure of production of the New Zealand economy can be assessed more formally with measures of backward and forward linkages. Backward and forward indices reported in this section are based on total requirement coefficients and hence take into account both direct and indirect linkages. Backward linkages measure the impact on the supplier industries of a dollar increase in the final demand for a particular industry's product. Forward linkages, on the other hand, measure the increase in the output of industry i needed to supply the inputs required to produce a unit of the final demand output in industry j.

Figures 1 and 2 plot the indices of backward and forward linkages for all 126 industries, using each sector's share in total final demand as a set of weights. Wholesale trade, ownership of owner-occupied dwellings, and retail trade have the largest backward linkage followed by dairy product manufacturing and meat processing. A high backward linkage means that an increase in the final demand of any of these industries' output will have a large impact on industries that supply inputs in the production of these industries' output.

Wholesale trade has also the largest forward linkage. This means that output in the wholesale trade sector must increase following an increase in final demand output in other industries in order to provide the required inputs for the production of an additional dollar's worth of final demand. Retail trade has the second largest forward linkage although substantially smaller than wholesale trade. Air transport, services to transport and storage, ownership of owner-occupied dwellings, communication services, meat processing, finance, and dairy product manufacturing also have relatively large forward linkages. These industries, apart from communication services, and finance, also have large backward linkages. At the bottom of the ranking for forward linkages is water supply as it does not produce any final output.

Alternatively, exports can be used as a weighting factor. Backward and forward linkages then show the effect on industries of a unit increase in export demand. The results of weighting backward and forward linkages by exports are reported in Figures 3 and 4. Backward linkages are highest for meat processing, dairy product manufacturing, wholesale trade and air transport, services to transport and storage. Other leather product manufacturing and seafood processing also have high backward linkages and an increase in export demand in these industries will affect the output of other industries.

When weighted by exports, wholesale trade, air transport, services to transport and storage, meat processing, and dairy product manufacturing have large backward as well as forward linkages. The forward linkages of retail trade, and paper and paper product manufacturing are also relatively high.

Backward and forward linkages are sensitive to extreme values and coefficient of variation indices are often calculated in addition. The backward and forward coefficient of variation indices weighted by final demand are plotted in Figures 5 and 6 and weighted by exports in Figures 7 and 8. The backward (forward) index measures the relative evenness with which an industry purchases from (sells to) other sectors. A relatively large value implies that a sector purchases (sells) inputs only from (to) a few industries in the economy.

Figure 1: Backward linkages (weighted by final demand)

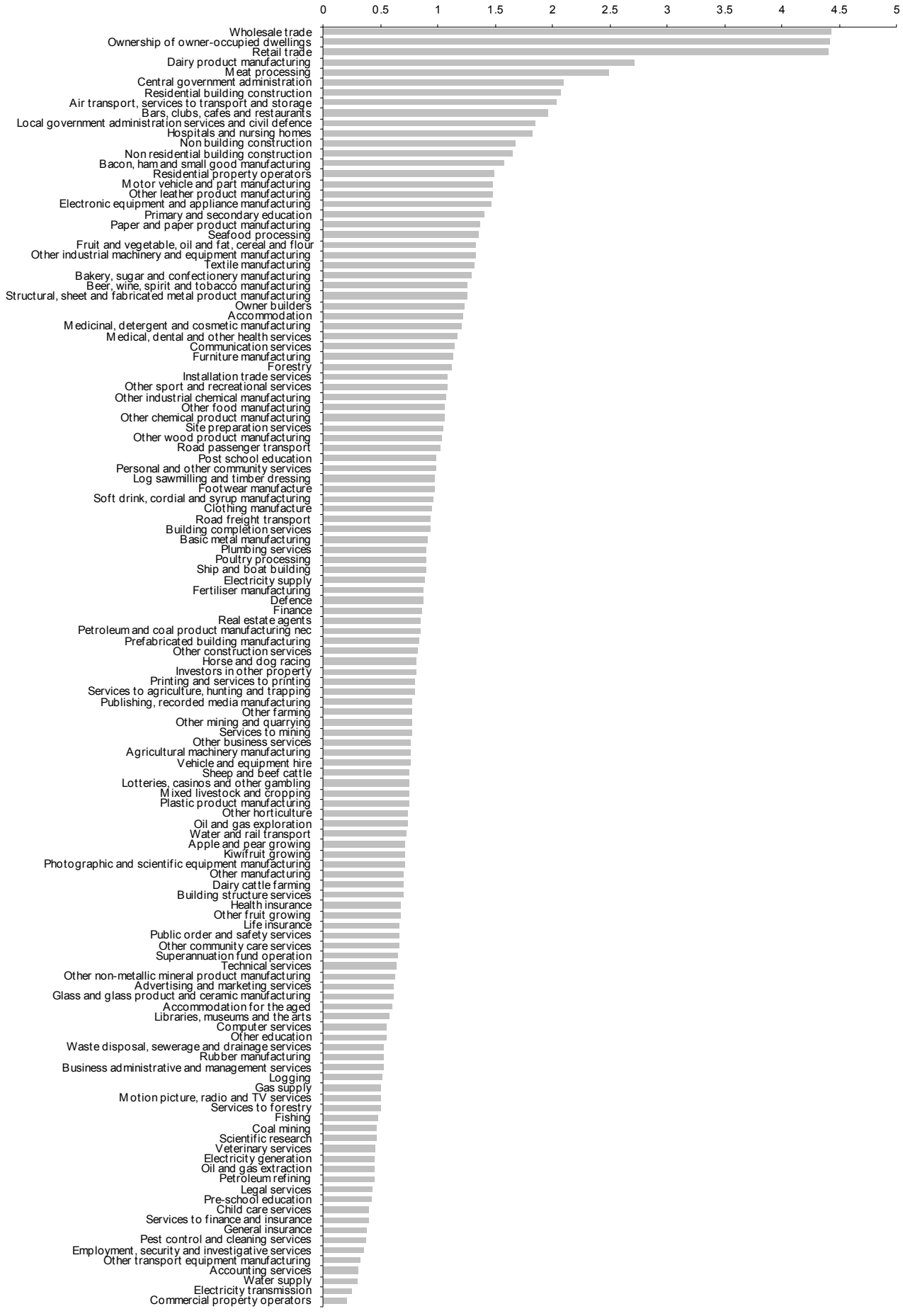


Figure 2: Forward linkages (weighted by final demand)

Figure 3: Backward linkages (weighted by exports)

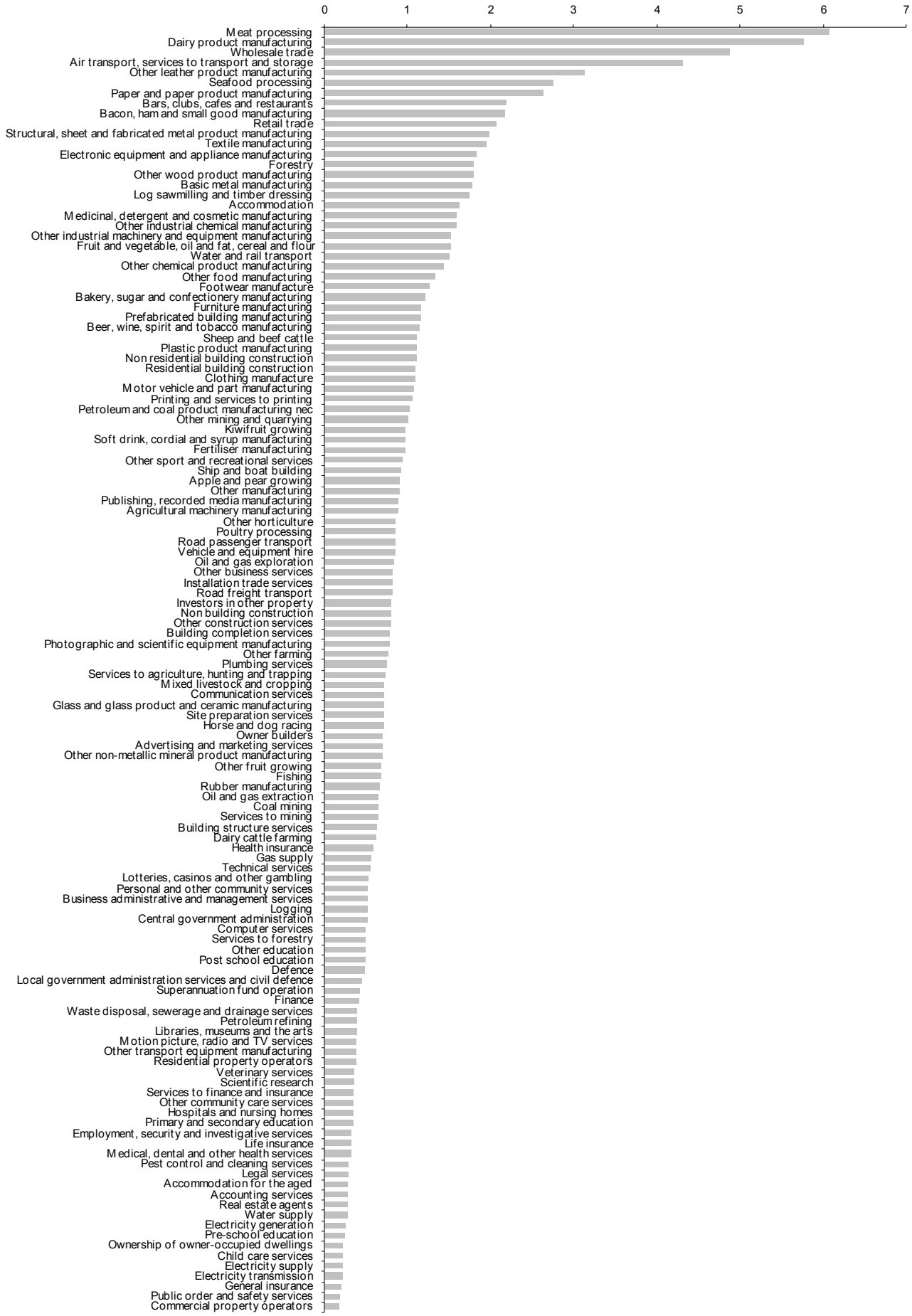


Figure 4: Forward linkages (weighted by exports)

Figure 5: Backward coefficient of variation index (weighted by final demand)

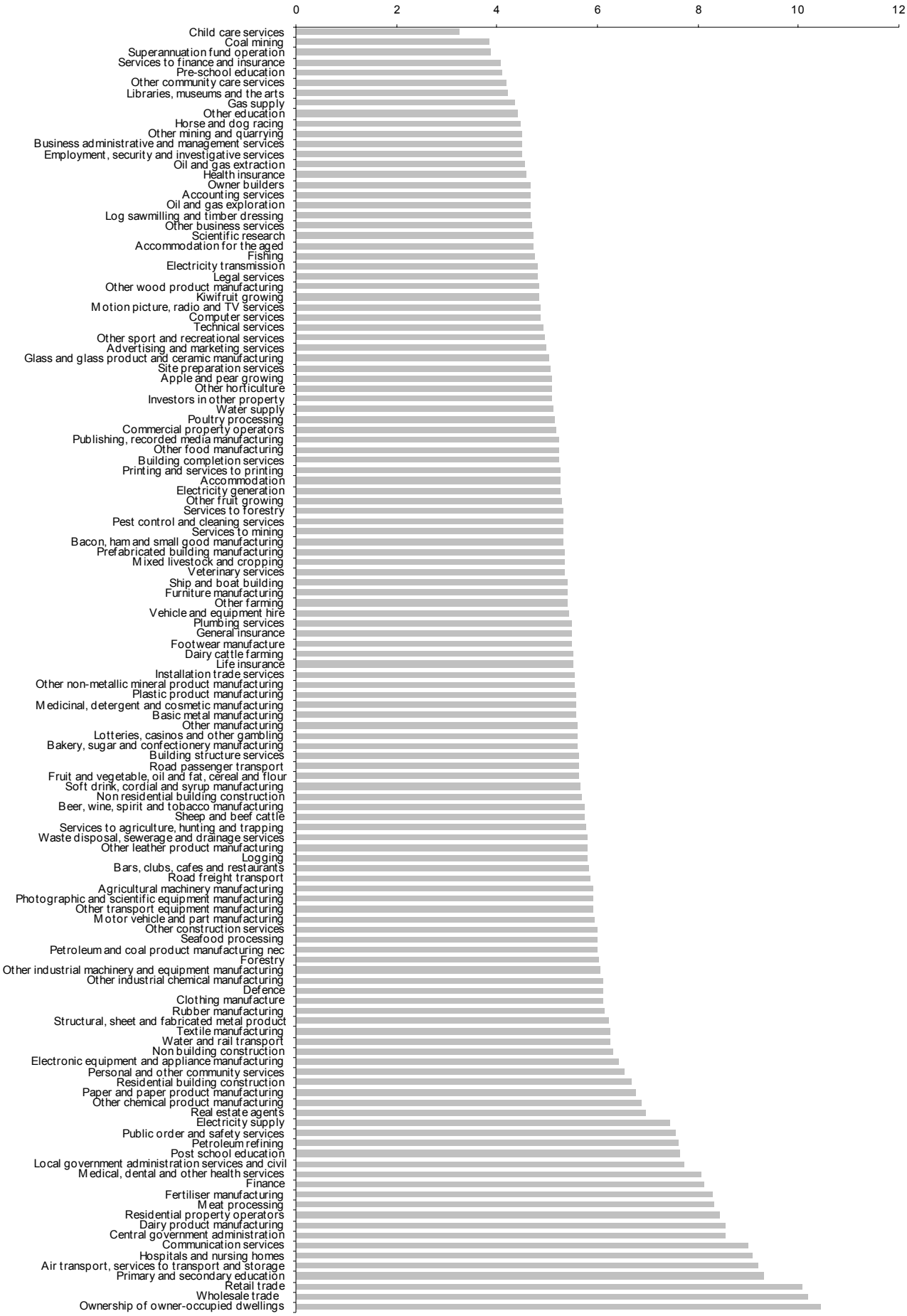


Figure 6: Forward coefficient of variation index (weighted by final demand)

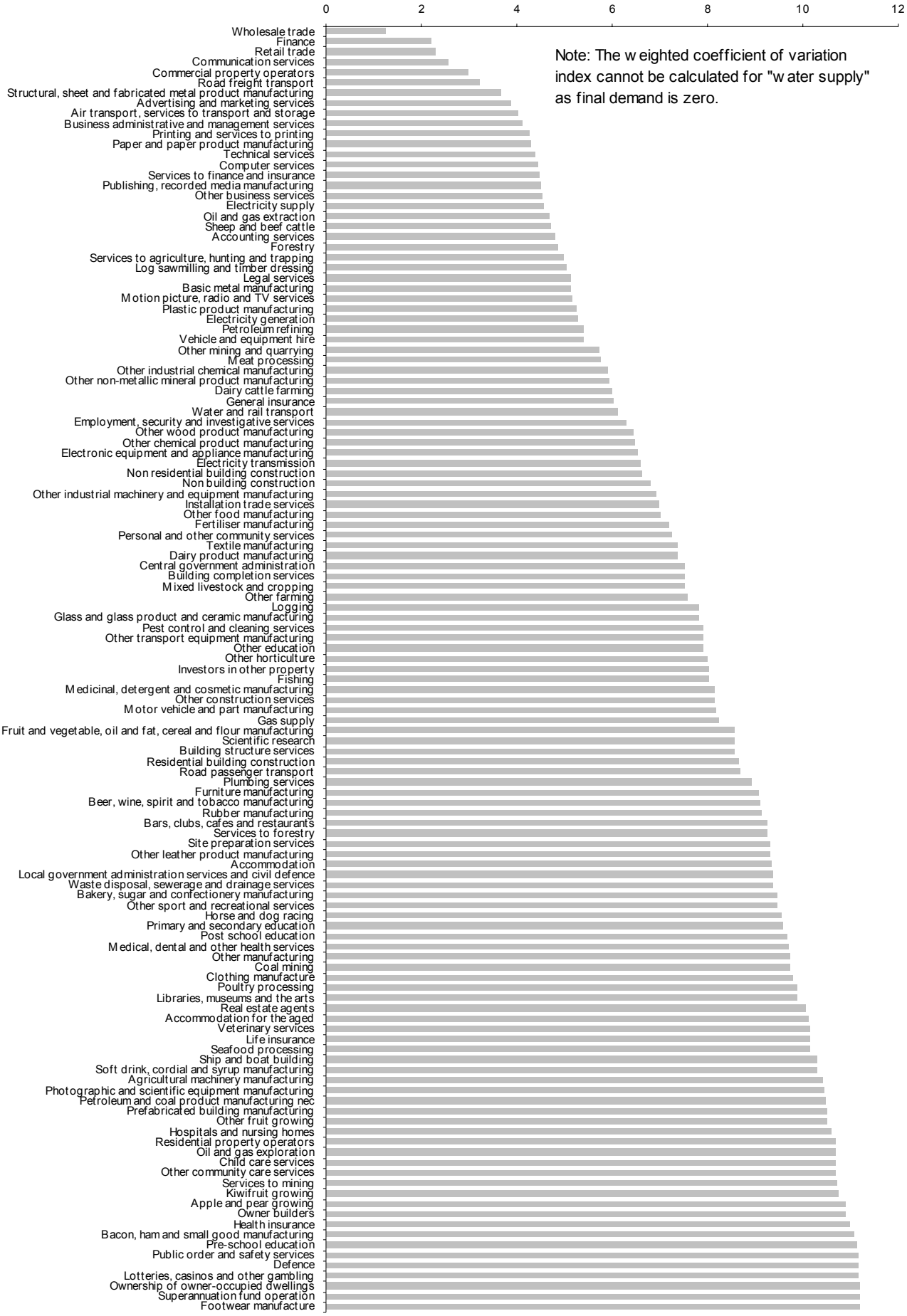


Figure 7: Backward coefficient of variation index (weighted by exports)

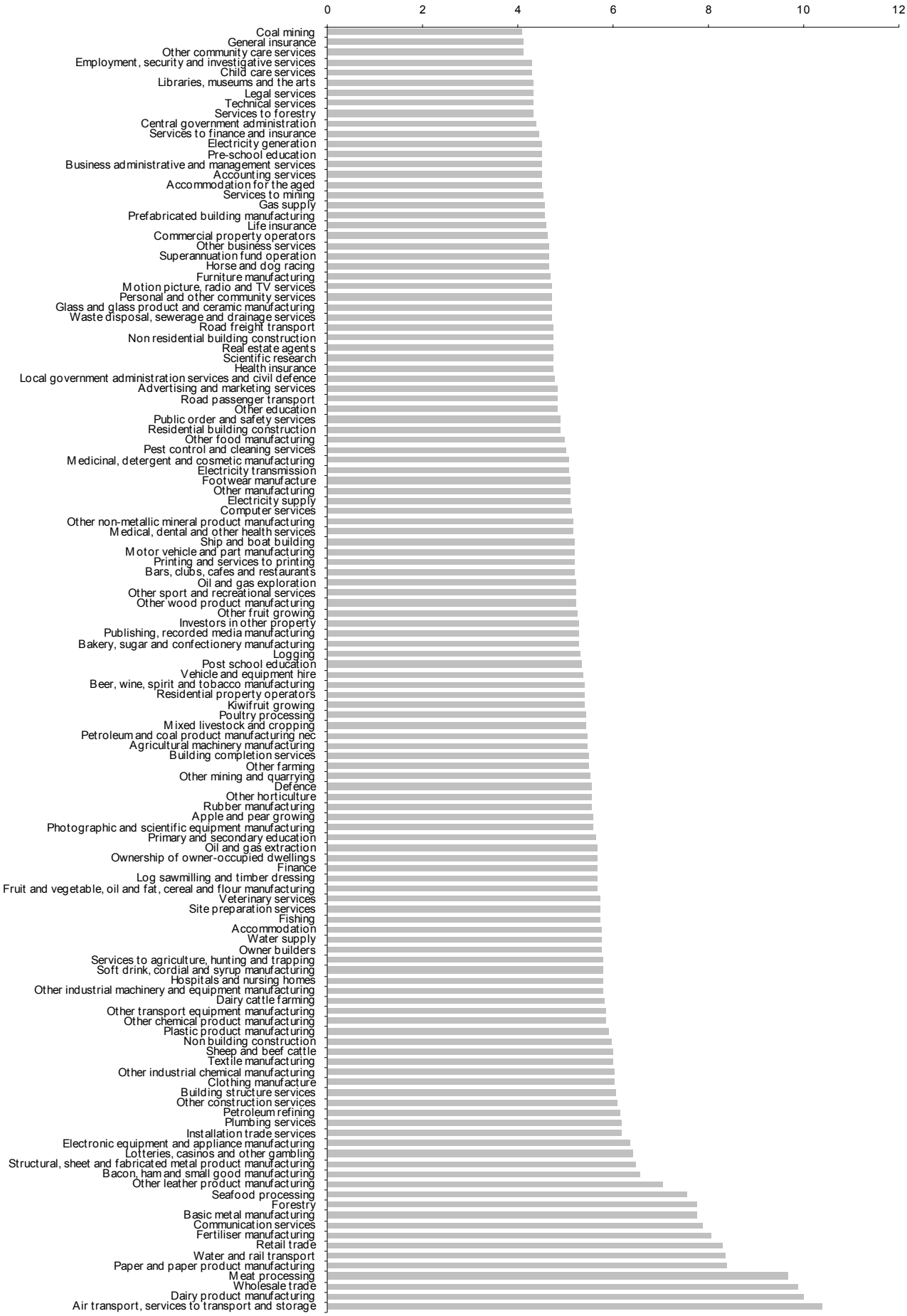
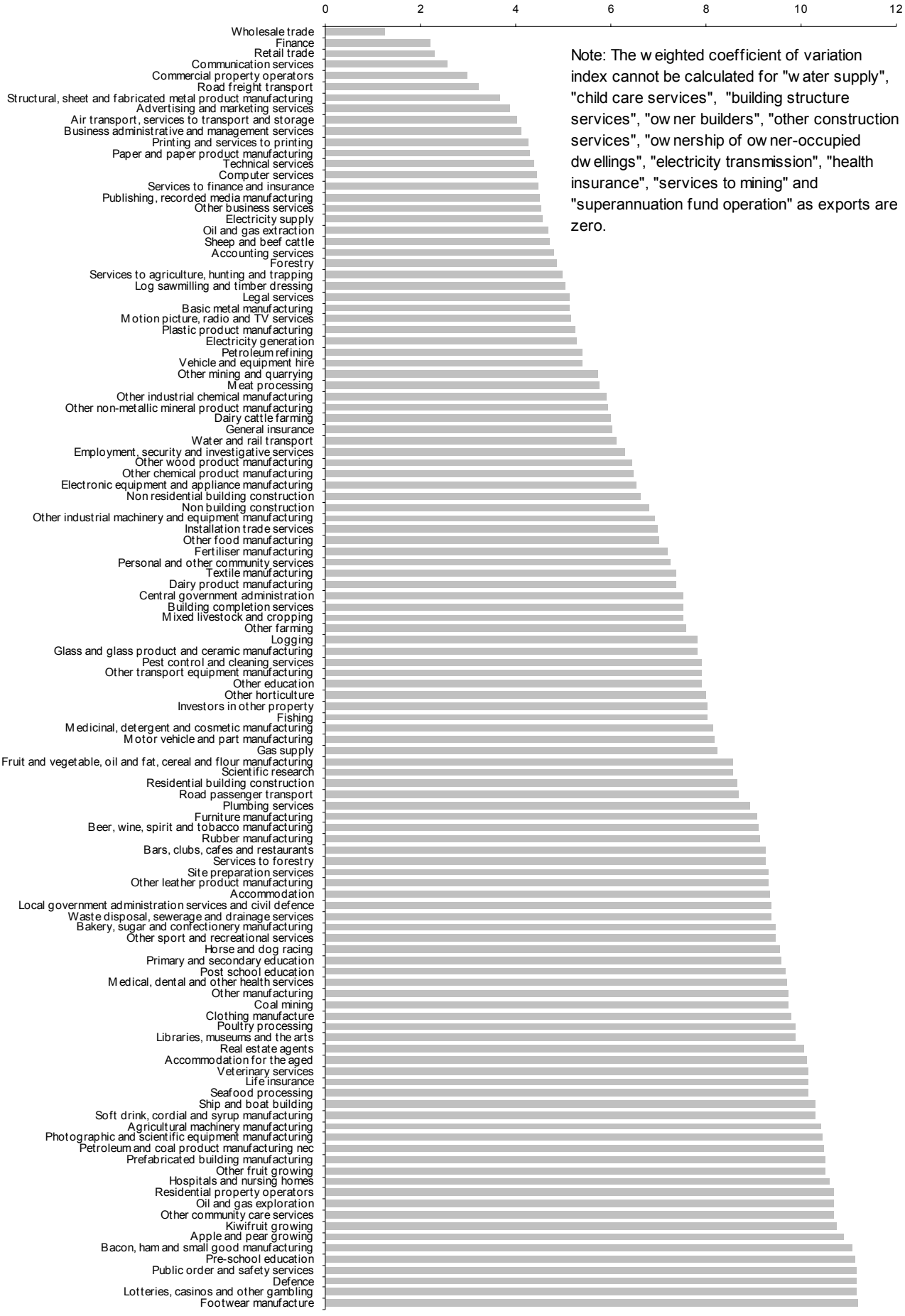


Figure 8: Forward coefficient of variation index (weighted by exports)



Note: The weighted coefficient of variation index cannot be calculated for "water supply", "child care services", "building structure services", "owner builders", "other construction services", "ownership of owner-occupied dwellings", "electricity transmission", "health insurance", "services to mining" and "superannuation fund operation" as exports are zero.

The backward coefficient of variation indices weighted by final demand and exports are high (i.e. the number of transactions with other industries is low) for some of the industries with large backward linkages, like ownership of owner-occupied dwellings, wholesale and retail trade, meat processing, dairy product manufacturing, and air transport, services to transport and storage. This indicates that the strong backward linkage of these industries is mainly the result of large inter industry transactions with only a few industries rather than widespread transactions with many different industries. The index is relatively stable for most sectors, varying between 3 and 6.5 for about 82 percent of the industries.

The rankings of industries by forward coefficients of variation are very similar for the indices weighted by final demand and exports. Measured in terms of evenness of transactions across industries, wholesale trade is the sector with most forward linkages. In fact, wholesale trade sells output to all industries except mining. Meat processing and dairy product manufacturing, on the other hand, move down in the ranking when industry linkages are measured in terms of evenness of transactions across industries, while finance and communication services move up.

4.3 Industry interconnectedness

Indices of concentration as a measure of industry interconnectedness focus on the number of sales or purchases (either direct or both direct and indirect) across industries (rather than the magnitude of transactions) and are hence related to coefficients of variation.

Figures 9 and 10 plot the backward and forward concentration indices for input coefficients, which measure direct transactions only. Figure 9 shows that the backward concentration index is very similar across industries, at around 11. This means that industries tend to buy from a large number of supplier industries. Among the industries with somewhat lower backward concentration are meat processing, fertiliser manufacturing, electricity transmission, commercial property operators, seafood processing, other leather product manufacturing, life insurance, real estate agents, general insurance, log sawmilling and timber dressing, water supply, and dairy product manufacturing. A low backward concentration index means that these industries do not require inputs from a lot of other industries directly to produce an additional unit of final output.

Some of these industries with low backward concentration have larger forward indices, i.e. they sell to more industries than they buy from, and hence move up in the ranking for forward concentration, like general insurance and commercial property operators, for example.

The forward concentration index is slightly more variable across industries than the backward index, in particular at the bottom end. Wholesale and retail trade have the largest forward concentration, while the index could not be calculated for industries that do not have forward linkages, namely ownership of owner-occupied dwellings and superannuation fund operation.

Figure 9: Backward concentration index for input coefficients

Figure 10: Forward concentration index for input coefficients

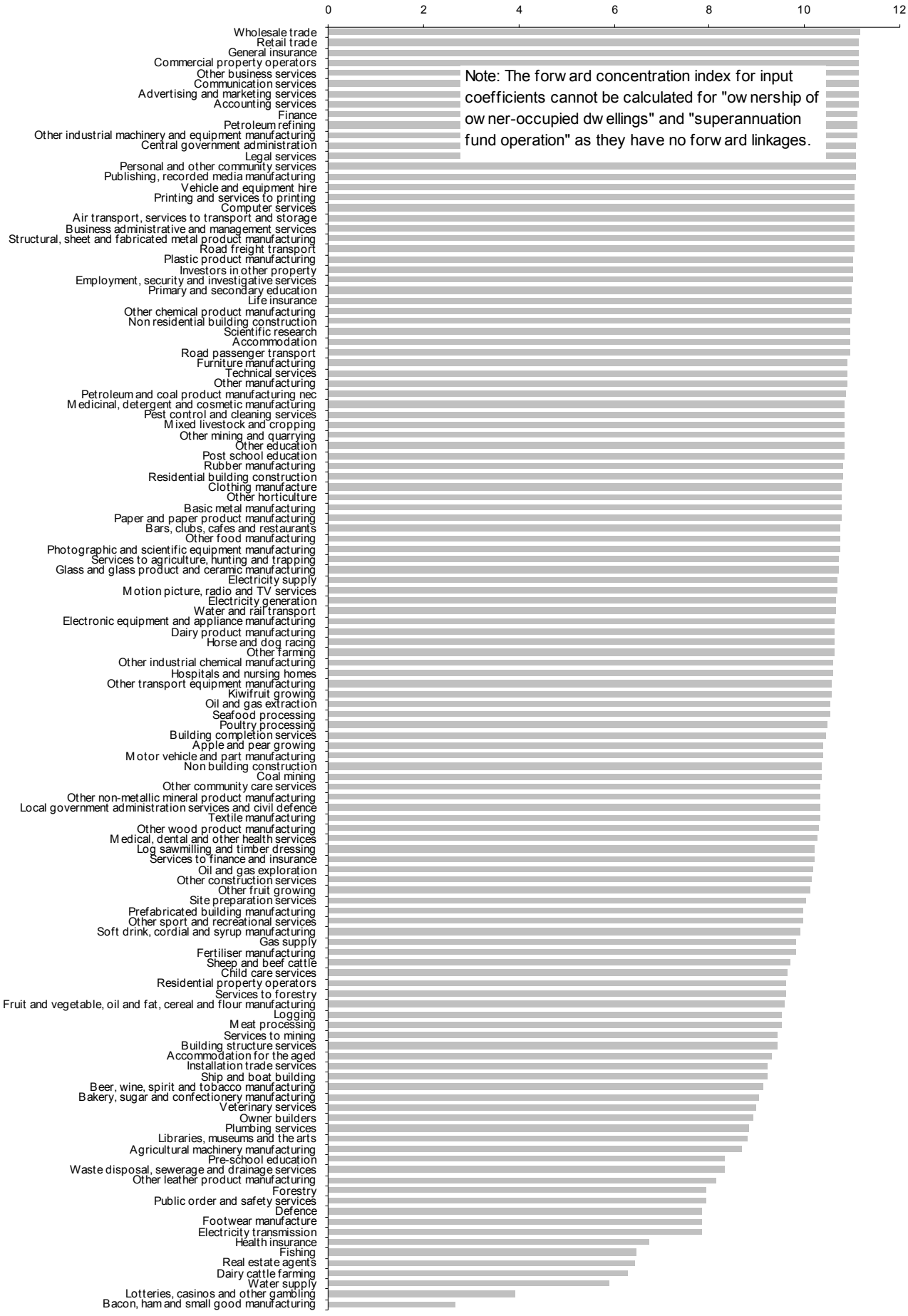


Figure 11: Backward concentration index for total requirement coefficients

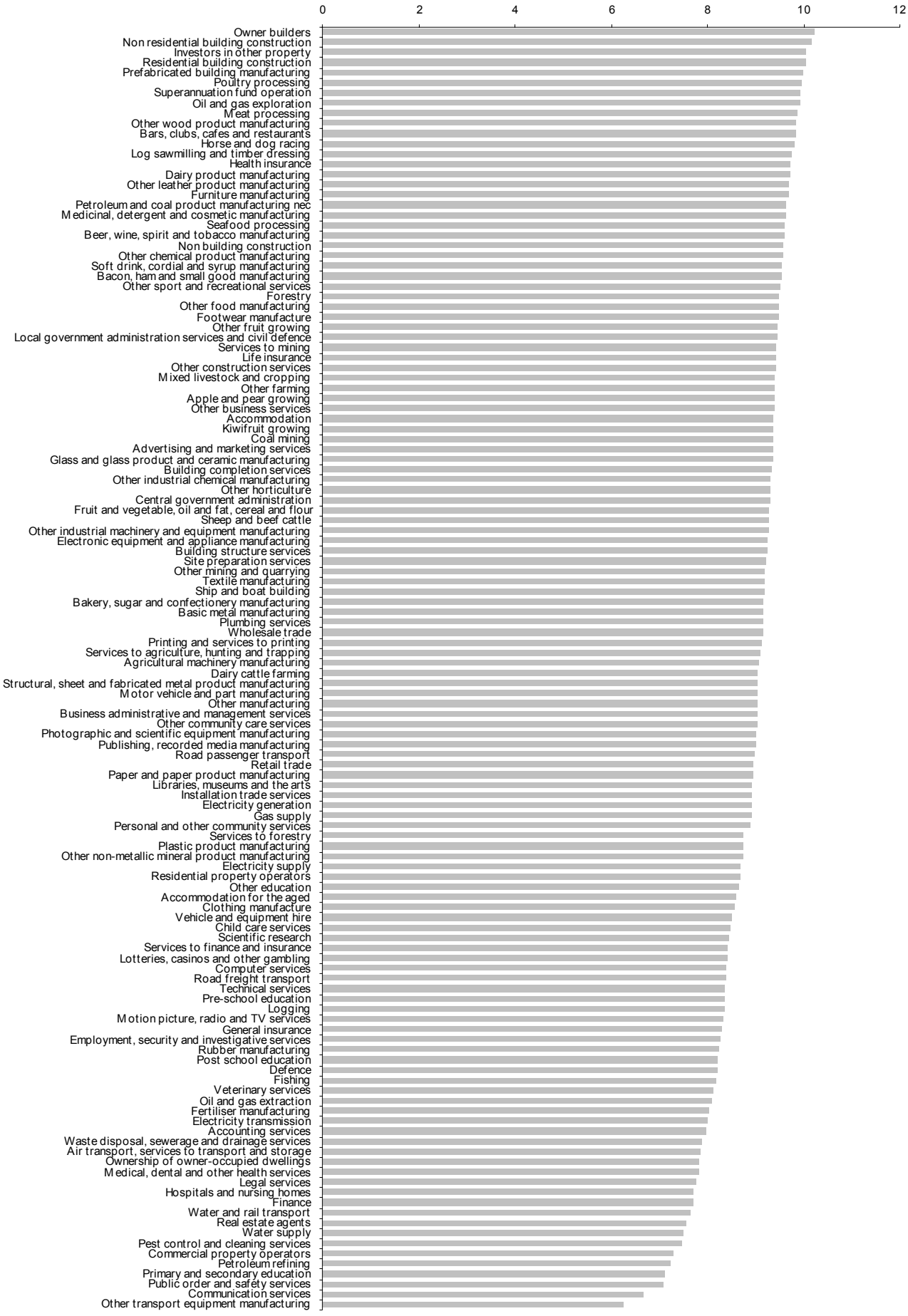
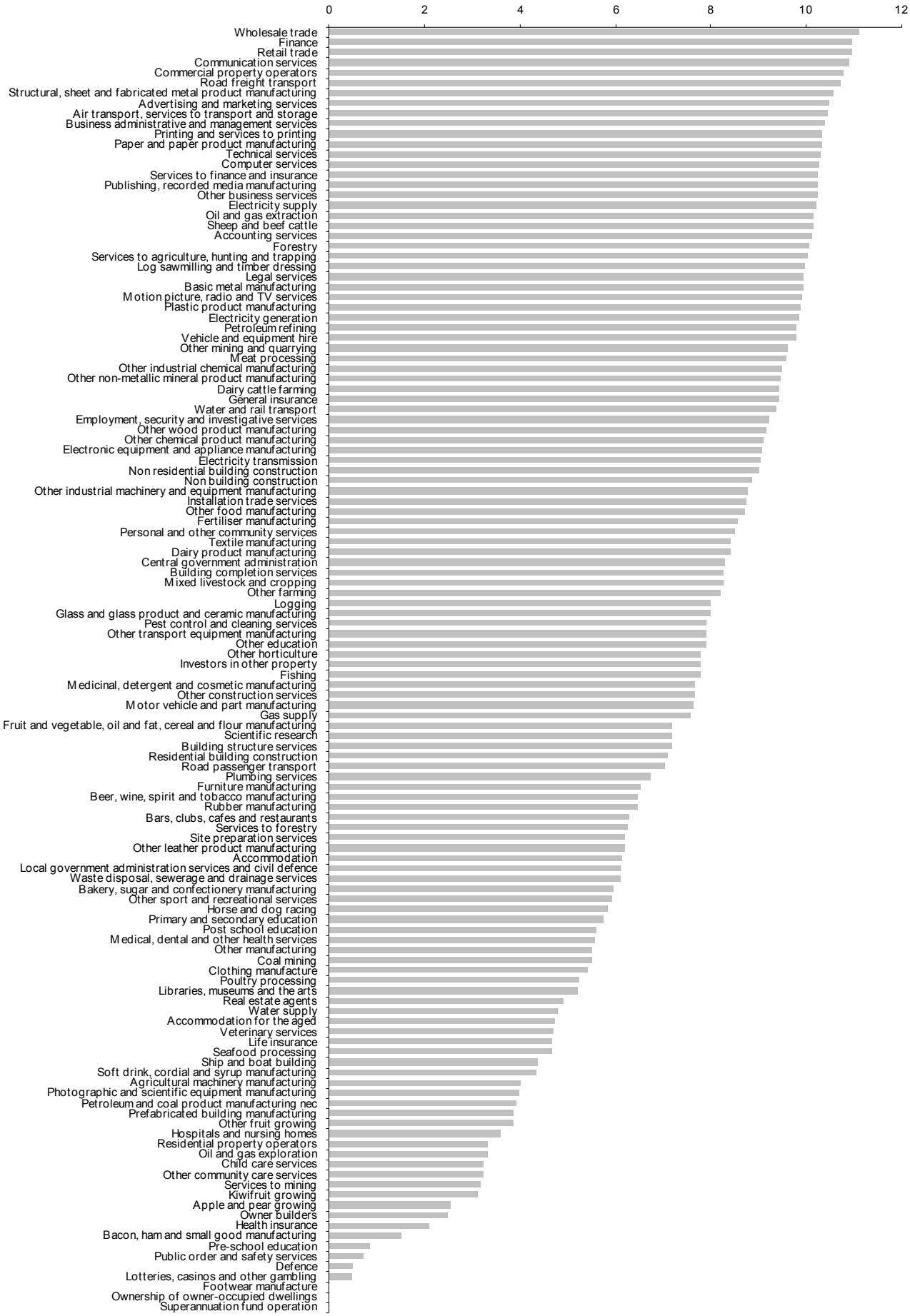


Figure 12: Forward concentration index for total requirement coefficients



Backward and forward concentration indices for total requirement coefficients, taking account of both direct and indirect transactions, are plotted in Figures 11 and 12. The backward concentration index for total requirement coefficients indicates how widespread across the economy the effects on supplier industries are from a dollar increase in final demand output by a particular industry. As in the case of the backward index for input coefficients (direct transactions), the effect on other industries is fairly even, i.e. the backward index is not very different across industries, and large. That is, industries purchase inputs from a large number of different industries to produce an additional dollar of final output.

However, a comparison of Figures 9 and 11 shows that the ranking of some industries changes dramatically when taking into account indirect linkages.[14] For example, dairy product manufacturing purchases the least from other industries directly, but moves up to 15th place when also accounting for indirect transactions. Another example is scientific research, which moves from most direct backward transactions to 90th place for direct and indirect purchases.

A comparison of the backward and forward concentration indices for total requirement coefficients (Figures 11 and 12) shows that the forward concentration index differs more widely across industries than the backward index. Some industries (those with a high forward index) sell output to a large number of industries, while those with a low index only sell to a few. The forward index is largest for wholesale trade, finance, retail trade, and communication services and small or zero for pre-school education, public order and safety services, defence, lotteries, casinos and other gambling, footwear manufacture, ownership of owner-occupied dwellings, and superannuation fund operation. A small or zero index means that these industries are generally unaffected by changes in final output in the rest of the economy. Footwear manufacture has a small forward index, in part because its transactions with other industries are too small to be reported in the inter industry transactions table. Footwear manufacture supplies inputs of $M 5 to other industries, but only those with wholesale and retail trade are reported ($M 1 each).

Taking into account indirect transactions does not change the industry ranking as much for the forward concentration index as for the backward index. This indicates that industries that indirectly sell to a lot of industries also have strong direct inter industries ties.

A second measure of industry interconnectedness is entropy. The row entropy is conceptually parallel to the backward concentration index and the column entropy to the forward index. A small row entropy means that following an increase in industry i's final output, industry i only sells additional output to a few industries. A small column entropy, on the other hand, implies that other industries only purchase additional output from a few industries following an increase in industry i's final output.

The row and column entropy for input coefficients are plotted in Figures 13 and 14. Two main points emerge from the comparison of the entropy measures and concentration indices for input coefficients. First, although the ranking of industries is different for the two measures, those industries that are in the top (bottom) half for the entropy measure are also in the top (bottom) half for the concentration index. Second, the column entropy shows larger variation than the row entropy, which is in line with the forward concentration index differing more across industries than the backward index.

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14 The ranking of industries also changes dramatically for backward linkages when taking account direct transactions only, but less for forward linkages.

Figure 13: Row entropy for input coefficients

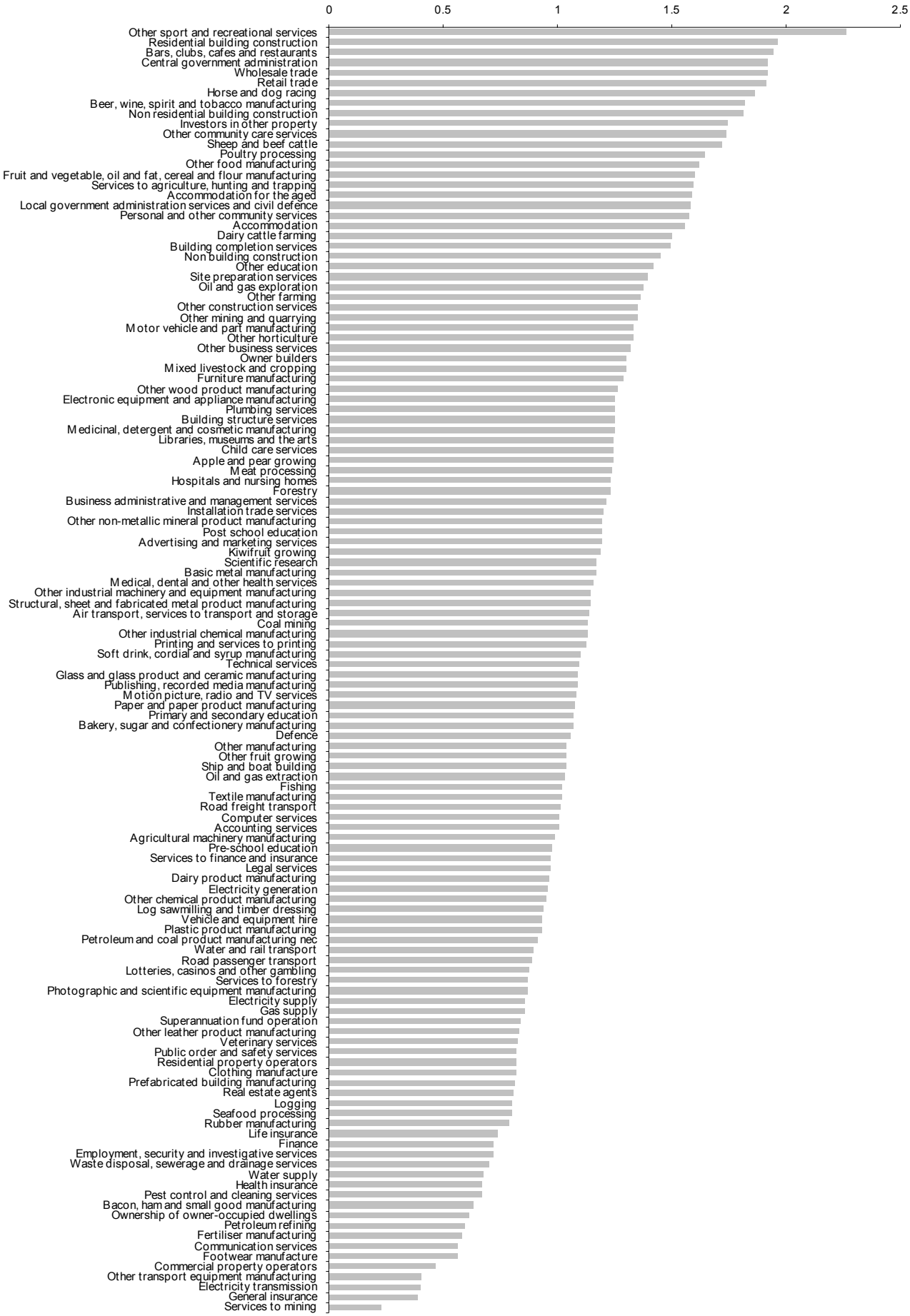


Figure 14: Column entropy for input coefficients

Figure 15: Row entropy for final demand weighted total requirement coefficients

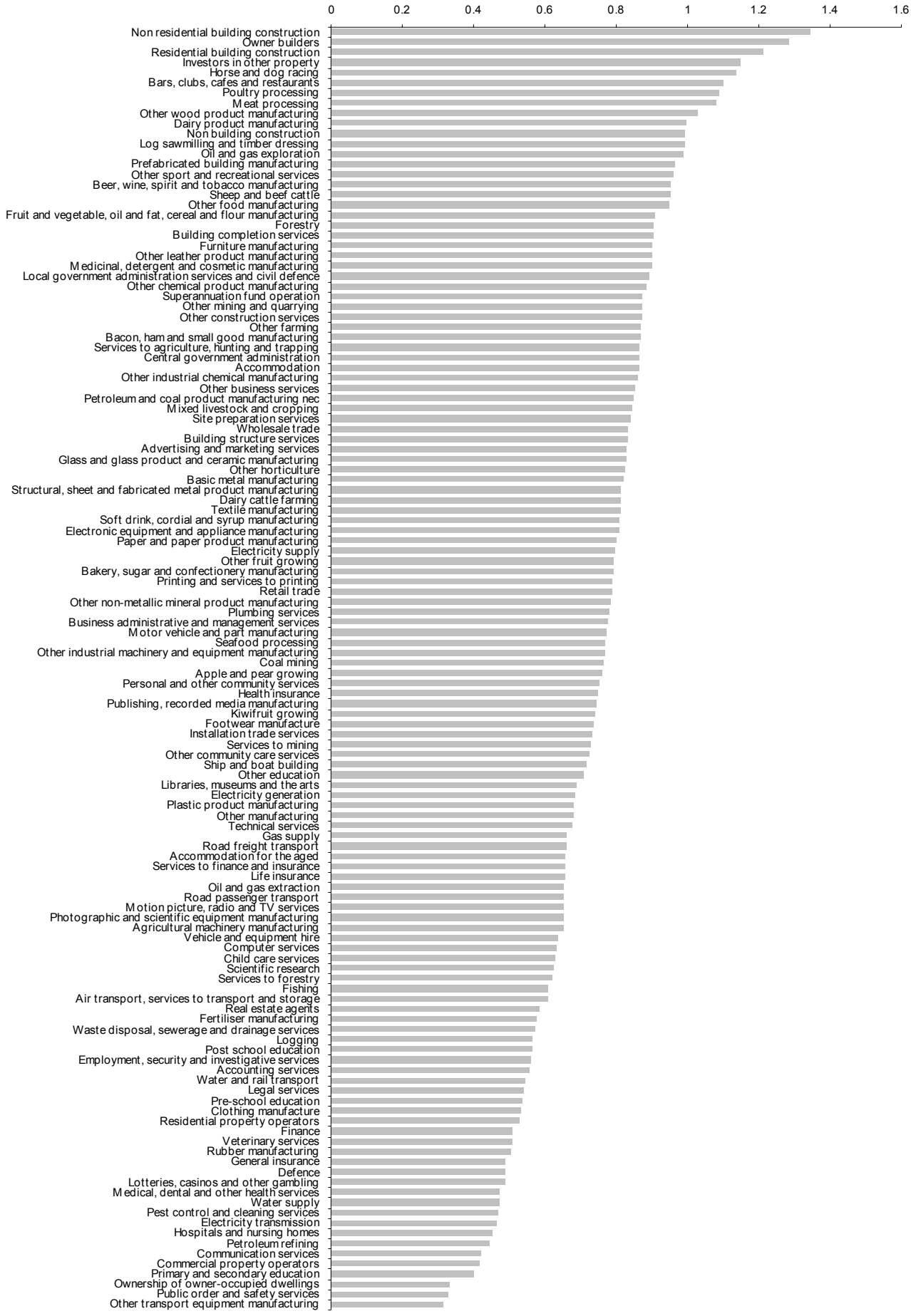


Figure 16: Column entropy for final demand weighted total requirement coefficients

Figure 17: Row entropy for export weighted total requirement coefficients

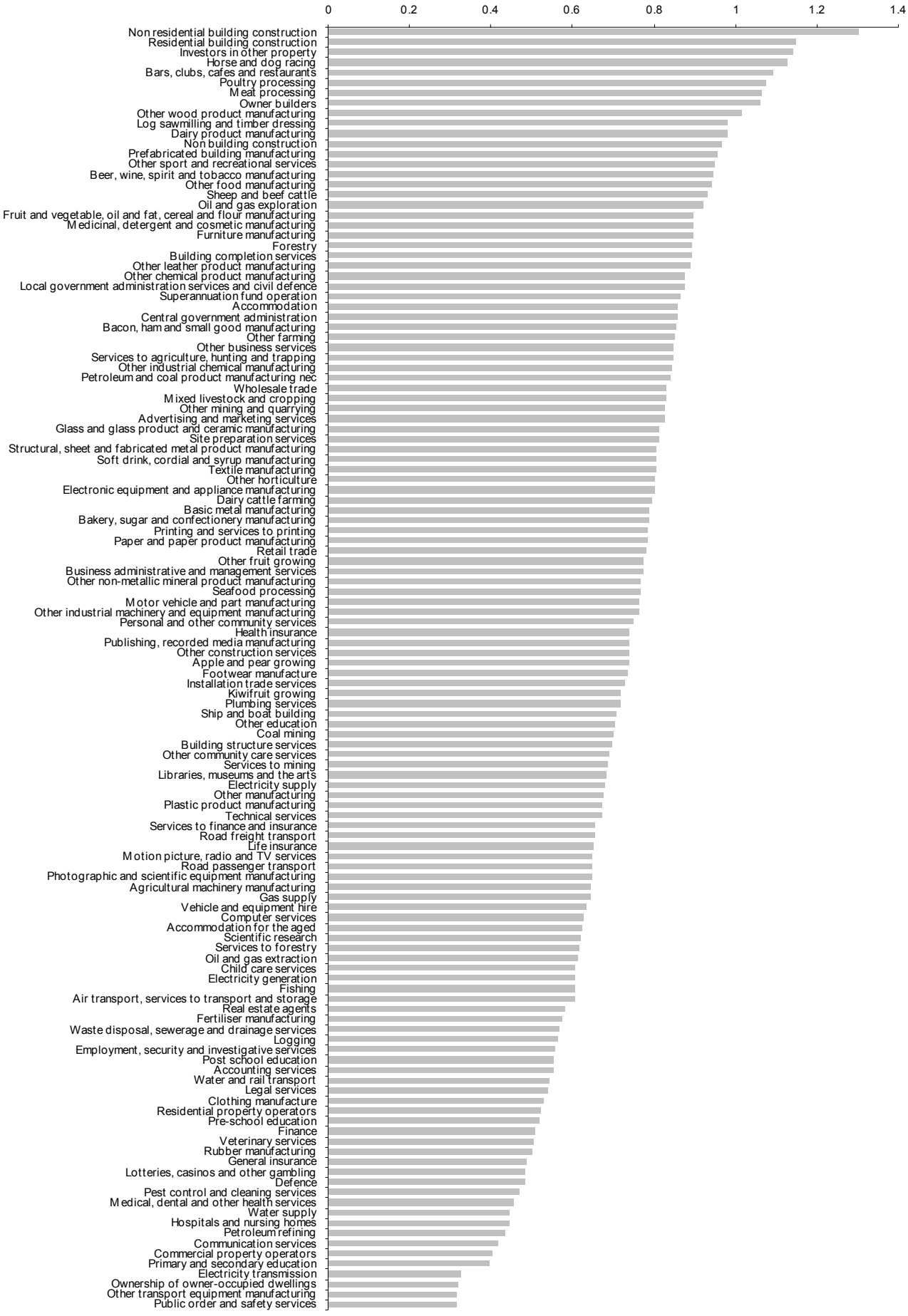


Figure 18: Column entropy for export weighted total requirement coefficients

The row and column entropies for total requirement coefficients weighted by final demand, i.e. taking into account both direct and indirect transactions, are plotted in Figures 15 and 16 and weighted by exports in Figures 17 and 18. The ranking of industries for total requirement coefficient entropies weighted by final demand and exports are similar, but different from the input coefficient entropies.

Industries with large row entropies for total requirement coefficients include non residential building construction, owner builders, residential building construction, and investors in other property. That is, a large number of industries will buy additional output from these industries following an increase in final demand. Industries with small row entropies include ownership of owner-occupied dwellings, other transport equipment manufacturing, and public order and safety services. An increase in the final output of these industries will largely leave other industries unaffected.

Column entropies weighted by final demand or exports are largest for wholesale trade. They are also high for a few other industries, including retail trade, air transport, services to transport and storage, communication services, paper and paper product manufacturing, meat processing, and dairy product manufacturing. A large column entropy means that following an increase in these industries final demand output will have a large stimulatory effect on the rest of the economy.

Finally, the (row) entropy, taking into account both inter industry sales and sales to final demand is plotted in Figure 19. When taking into account intermediate and final sales, accounting services, business administration and management services, other business services, and employment, security and investigative services have the largest entropy. That is, a large number of households and exporters, for example, will buy additional output from these industries following an increase in these industries' output. Moreover, other industries will also buy additional output from these industries in the form of intermediate products. The entropy is small for hospitals and nursing homes, residential property operators, pre-school education, footwear manufacture, public order and safety services and defence, and zero for ownership of owner-occupied dwellings, and superannuation fund operations.

4.4 Value added production multiplier

The value added production multiplier, which shows the direct and indirect contribution of a unit increase in final demand to value added in industry j relative to other industries, is plotted in Figure 20. It shows that the contribution to value added is largest for ownership of owner-occupied dwellings (6.6 percent) followed by retail sales (4.7 percent) and wholesale trade (4 percent). Value added is high for ownership of owner-occupied dwellings because of operating surplus. For retail and wholesale trade compensation of employees makes up the largest component of value added. The contribution to value added of hospitals and nursing homes (2.7 percent) and primary and secondary education (2.3 percent) is also high. Compensation of employees is the largest component of value added in these industries. Following an increase in final demand, the contribution to value added is virtually zero for superannuation fund operation, petroleum refining, owner builders, and investors in other property, largely because of a small labour component and operating surplus in these industries.

Figure 19: Row entropy for sales flows

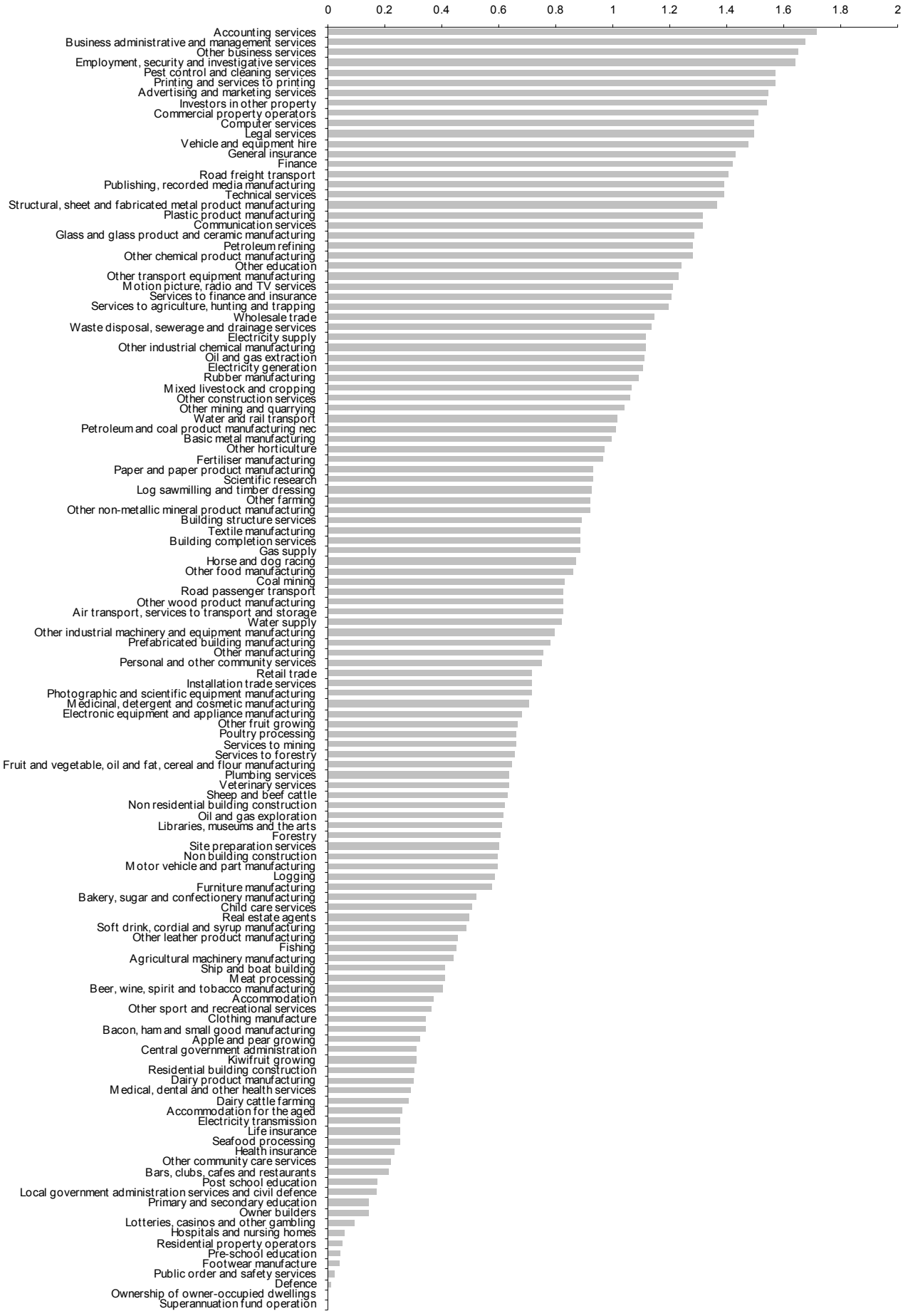
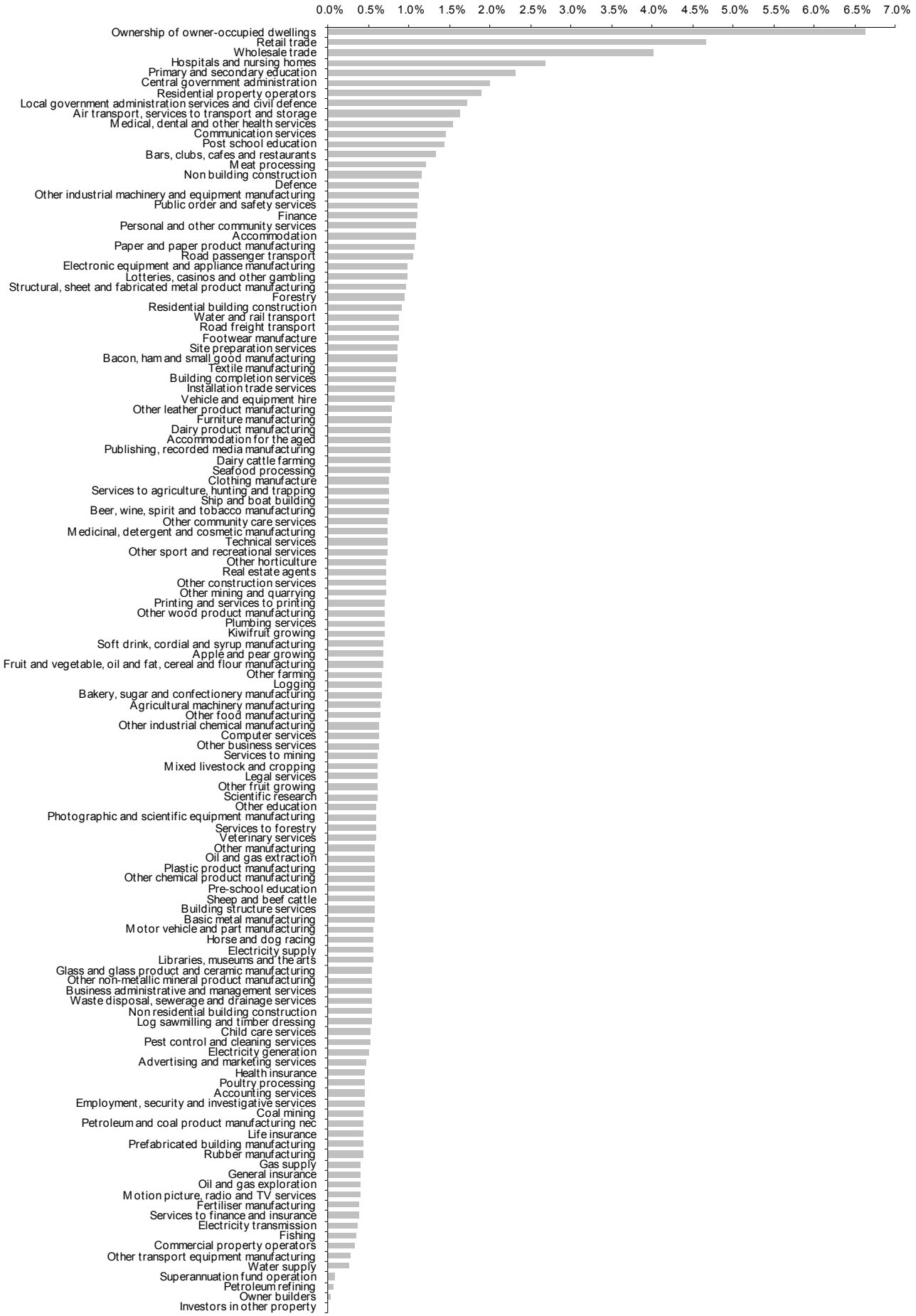


Figure 20: Value added production multiplier



5 Summarising the results

This section attempts to summarise the results from the different measures of inter industry connectedness discussed in the previous section and to draw some conclusions. The relationship between the different measures of connectedness is assessed using correlation coefficients and rank correlations, and a summary of key statistics is provided.

5.1 Correlation coefficients and rank correlations

Correlation measures the degree of association between two variables. The sample correlation coefficient, ρ_{XY}, between two measures of industry connectedness, X and Y, can be calculated as follows

$$\rho_{XY} = \frac{\sum_{i=1}^{N}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{N}(X_i - \bar{X})^2 \sum_{i=1}^{N}(Y_i - \bar{Y})^2}} \qquad (17)$$

where $\bar{X} = (1/N)\sum_{i=1}^{N} X_i$, $\bar{Y} = (1/N)\sum_{i=1}^{N} Y_i$, and X_i and Y_i denote the measures of connectedness X and Y for industry i.

Sample rank correlations, which measure the degree of association between the rankings of industries, are computed accordingly, by replacing X_i and Y_i in equation (17) with $r(X_i)$ and $r(Y_i)$, i.e.

$$\rho_{r(X)r(Y)} = \frac{\sum_{i=1}^{N}(r(X_i) - \bar{r}(X))(r(Y_i) - \bar{r}(Y))}{\sqrt{\sum_{i=1}^{N}(r(X_i) - \bar{r}(X))^2 \sum_{i=1}^{N}(r(Y_i) - \bar{r}(Y))^2}} \qquad (18)$$

where $\bar{r}(X) = (1/N)\sum_{i=1}^{N} r(X_i)$, $\bar{r}(Y) = (1/N)\sum_{i=1}^{N} r(Y_i)$, and $r(X_i)$ and $r(Y_i)$ are the rankings of industry i for linkage measures X and Y.[15] Correlation coefficients and rank correlations lie between the limits of –1 and +1 and are symmetrical, i.e. $\rho_{XY} = \rho_{YX}$ and $\rho_{r(X)r(Y)} = \rho_{r(Y)r(X)}$.

[15] Equation (18) reduces to $\rho_{r(X)r(Y)} = 1 - \frac{6\sum_{i=1}^{N}(r(X_i) - r(Y_i))^2}{N(N^2 - 1)}$.

Tables 3 and 4 report the correlation coefficients and rank correlations for all the measures of connectedness plotted in Figure 1 to 20. The following conclusions can be drawn from these statistics.

Coefficient of variation indices can probably be disregarded without substantial loss of information. This is because the coefficient of variation is a mixture of linkages measures and measures based on the number of transactions. It is derived from the magnitude of transactions between industries (like the linkages measures), but accounts for extreme values, which makes it similar to the measures based on the number of transactions. The coefficient of variation does not appear to be particularly strongly correlated with other measures (see, for example, row 5 in Table 3).

The backward and forward concentration index taking into account direct transactions only (i.e. using input coefficients) is also not highly correlated with other measures. Correlation coefficients are low and sometimes negative (see, for example, columns 9 and 10 in Table 3). Row and column entropy for input coefficients, which are conceptually similar to the backward and forward concentration index, are more highly correlated with other measures, in particular the column entropy (see, for example, columns 13 and 14 in Table 4). This is because the concentration index focuses on the intermediate sector, while entropy is descriptive of the characteristics of the economy as a whole. The row and column entropy for input coefficients is hence a better measure of direct transactions than the concentration index for input coefficients.

Correlation coefficients and rank correlations are similar for measures weighted by final demand and weighted by exports. This is probably because of the relatively large proportion of exports in final demand. For instance, the correlations between backward and forward linkages weighted by final demand and exports are high and positive (although somewhat lower for rank correlations).

The value added production multiplier is positively correlated with measures of backward and forward linkages, in particular weighted by final demand. This is likely because the measures are conceptually similar. Both the value added production multiplier and backward and forward linkages are based on the magnitude of transactions between industries. The value added production multiplier differs from other measures as it is the only measure that incorporates value added.

The row entropy for sales flows also differs from other measures as it explicitly takes into account final sales. As can be seen, for example, from column 19 in Table 3, its correlation with other measures varies substantially probably because of how it is constructed.

The forward and backward concentration index for total requirement coefficients is similarly correlated with other measures as the row and column entropy for total requirement coefficients weighted by final demand (see columns 11 and 15, and 12 and 16 in Tables 3 and 4). The correlation coefficient and rank correlation for the backward concentration index and row entropy for total requirement coefficients weighted by final demand are high (0.9). The rank correlation between the forward index and the column entropy is also high, at 0.7, but the correlation coefficient is somewhat smaller (0.3). The row and column entropy for total requirement coefficients weighted by final demand is also positively and quite highly correlated with backward and forward linkages.

Table 3: Correlation coefficients

	Backward linkages (weighted by final demand)	Forward linkages (weighted by final demand)	Backward linkages (weighted by exports)	Forward linkages (weighted by exports)	Backward coefficient of variation (weighted by final demand)	Forward coefficient of variation (weighted by final demand)	Backward coefficient of variation (weighted by exports)	Forward coefficient of variation (weighted by exports)	Backward concentration index for input coefficients	Forward concentration index for input coefficients	Backward concentration index for total requirement coefficients	Forward concentration index for total requirement coefficients	Row entropy for input coefficients	Column entropy for input coefficients	Row entropy for total requirement coefficients (weighted by final demand)	Column entropy for total requirement coefficients (weighted by final demand)	Row entropy for total requirement coefficients (weighted by exports)	Column entropy for total requirement coefficients (weighted by exports)	Row entropy for sales flows	Value added production multiplier
Backward linkages (weighted by final demand)	1.0	0.7	0.6	0.6	-0.6	0.4	-0.5	0.3	0.0	-0.1	0.2	0.0	0.3	0.3	0.2	0.7	0.3	0.6	-0.3	0.8
Forward linkages (weighted by final demand)		1.0	0.5	0.9	-0.4	0.7	-0.4	0.7	0.1	0.1	0.0	0.2	0.3	0.7	0.0	0.9	0.1	0.9	0.0	0.6
Backward linkages (weighted by exports)			1.0	0.7	-0.4	0.3	-0.7	0.3	-0.3	0.1	0.4	0.2	0.2	0.2	0.4	0.5	0.4	0.7	-0.1	0.2
Forward linkages (weighted by exports)				1.0	-0.3	0.7	-0.5	0.7	0.0	0.1	0.1	0.2	0.2	0.6	0.1	0.8	0.1	0.9	0.1	0.4
Backward coefficient of variation (weighted by final demand)					1.0	-0.3	0.6	-0.3	0.1	-0.1	0.2	-0.1	0.0	-0.3	0.1	-0.4	0.1	-0.4	0.2	-0.6
Forward coefficient of variation (weighted by final demand)						1.0	-0.3	1.0	0.0	0.3	-0.2	0.6	0.1	1.0	0.0	0.8	0.0	0.8	0.5	0.3
Backward coefficient of variation (weighted by exports)							1.0	-0.3	0.2	0.0	0.0	-0.2	0.0	-0.2	-0.1	-0.4	-0.1	-0.6	0.1	-0.3
Forward coefficient of variation (weighted by exports)								1.0	0.1	0.4	-0.2	0.7	0.1	0.9	0.0	0.8	0.0	0.8	0.5	0.3
Backward concentration index for input coefficients									1.0	0.2	0.1	0.0	0.5	0.0	0.1	0.1	0.1	0.0	0.0	0.1
Forward concentration index for input coefficients										1.0	0.0	0.6	0.3	0.4	0.1	0.2	0.2	0.2	0.5	-0.2
Backward concentration index for total requirement coefficients											1.0	-0.1	0.5	-0.2	0.9	-0.1	0.9	0.0	-0.2	-0.1
Forward concentration index for total requirement coefficients												1.0	0.1	0.7	0.1	0.3	0.1	0.4	0.7	-0.1
Row entropy for input coefficients													1.0	0.1	0.7	0.2	0.7	0.2	-0.1	0.2
Column entropy for input coefficients														1.0	-0.1	0.8	-0.1	0.7	0.6	0.3
Row entropy for total requirement coefficients (weighted by final demand)															1.0	0.0	1.0	0.1	-0.1	-0.2
Column entropy for total requirement coefficients (weighted by final demand)																1.0	0.1	0.9	0.1	0.6
Row entropy for total requirement coefficients (weighted by exports)																	1.0	0.1	0.0	-0.2
Column entropy for total requirement coefficients (weighted by exports)																		1.0	0.1	0.5
Row entropy for sales flows																			1.0	-0.3
Value added production multiplier																				1.0

Table 4: Rank correlation

	Backward linkages (weighted by final demand)	Forward linkages (weighted by final demand)	Backward linkages (weighted by exports)	Forward linkages (weighted by exports)	Backward coefficient of variation (weighted by final demand)	Forward coefficient of variation (weighted by final demand)	Backward coefficient of variation (weighted by exports)	Forward coefficient of variation (weighted by exports)	Backward concentration index for input coefficients	Forward concentration index for input coefficients	Backward concentration index for total requirement coefficients	Forward concentration index for total requirement coefficients	Row entropy for input coefficients	Column entropy for input coefficients	Row entropy for total requirement coefficients (weighted by final demand)	Column entropy for total requirement coefficients (weighted by final demand)	Row entropy for total requirement coefficients (weighted by exports)	Column entropy for total requirement coefficients (weighted by exports)	Row entropy for sales flows	Value added production multiplier
Backward linkages (weighted by final demand)	1.0	0.7	0.6	0.4	-0.6	-0.1	-0.5	-0.1	0.0	0.0	0.4	0.0	0.4	0.0	0.5	0.5	0.5	0.3	-0.4	0.7
Forward linkages (weighted by final demand)		1.0	0.3	0.5	-0.6	0.2	-0.4	0.1	0.0	0.2	0.0	0.3	0.3	0.3	0.1	0.8	0.1	0.5	-0.2	0.7
Backward linkages (weighted by exports)			1.0	0.7	-0.3	0.1	-0.6	0.0	-0.1	0.1	0.6	0.2	0.3	0.1	0.6	0.3	0.7	0.5	0.0	0.3
Forward linkages (weighted by exports)				1.0	-0.2	0.5	-0.4	0.2	0.0	0.4	0.1	0.5	0.2	0.5	0.2	0.6	0.3	1.0	0.3	0.3
Backward coefficient of variation (weighted by final demand)					1.0	-0.1	0.6	0.0	0.1	-0.1	0.2	-0.1	0.1	-0.1	0.1	-0.4	0.1	-0.2	0.2	-0.6
Forward coefficient of variation (weighted by final demand)						1.0	-0.2	0.7	-0.1	0.6	-0.2	1.0	0.1	0.9	0.0	0.6	0.0	0.7	0.7	0.0
Backward coefficient of variation (weighted by exports)							1.0	-0.1	0.1	0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.3	-0.1	-0.3	0.1	-0.4
Forward coefficient of variation (weighted by exports)								1.0	-0.2	0.3	-0.1	0.7	0.0	0.6	0.0	0.3	0.0	0.3	0.5	-0.1
Backward concentration index for input coefficients									1.0	0.2	0.0	-0.1	0.6	0.0	0.1	0.0	0.1	0.0	-0.1	0.3
Forward concentration index for input coefficients										1.0	-0.1	0.6	0.1	0.7	0.0	0.5	0.0	0.6	0.6	0.1
Backward concentration index for total requirement coefficients											1.0	-0.2	0.5	-0.2	0.9	0.0	0.9	0.0	-0.2	0.0
Forward concentration index for total requirement coefficients												1.0	0.1	0.9	0.1	0.7	0.1	0.7	0.7	0.0
Row entropy for input coefficients													1.0	0.1	0.7	0.3	0.6	0.2	-0.1	0.3
Column entropy for input coefficients														1.0	0.0	0.7	0.0	0.7	0.8	0.0
Row entropy for total requirement coefficients (weighted by final demand)															1.0	0.2	1.0	0.1	-0.1	0.0
Column entropy for total requirement coefficients (weighted by final demand)																1.0	0.2	0.7	0.2	0.5
Row entropy for total requirement coefficients (weighted by exports)																	1.0	0.2	-0.1	0.1
Column entropy for total requirement coefficients (weighted by exports)																		1.0	0.4	0.3
Row entropy for sales flows																			1.0	-0.4
Value added production multiplier																				1.0

The high correlation of the row and column entropy for total requirement coefficients weighted by final demand with other measures suggests that they are good overall summary statistics of the interconnectedness of the New Zealand economy. Backward and forward linkages, the row entropy for sales, and the value added production multiplier are also useful summary statistics as they are conceptually different from the other measures. The row and column entropy for input coefficients is also included in the summary of key statistics in the next section as it accounts for direct transactions only.

5.2 Summary of key statistics

Table 5 summarises the ranking of industries for backward and forward linkages, row and column entropy for input coefficients and total requirement coefficients weighted by final demand, the row entropy for sales, and the value added production multiplier. Shaded areas in the table indicate the top ten industries for each of the eight measures.[16]

The ranking of industries in Table 5 suggests that, in 1996, wholesale and retail trade had the strongest links with other industries, both ranking among the top ten industries for six out of the eight connectedness measures. Air transport, services to transport and storage, and central government administration (with five out of eight) and meat processing, and dairy product manufacturing (with four out of eight) also were highly connected.

A number of industries scored for three out of the eight connectedness measures. These industries include residential building construction, bars, clubs, cafes and restaurants, communication services, finance, ownership of owner-occupied dwellings, and investors in other property. Paper and paper product manufacturing, non residential building construction, commercial property operators, advertisement and marketing services, business administrative and management services, local government administration services and civil defence, and horse and dog racing all scored on two accounts.

Most of the industries that ranked among the top ten industries for one measure scored because of either the row entropy for sales flows or the value added production multiplier. These industries include printing and services to printing, residential property operators, computer services, accounting services, employment, security and investigative services, pest control and cleaning services, other business services, primary and secondary education, hospitals and nursing homes, and medical, dental and other health services.

Beer, wine, spirit and tobacco manufacturing, structural, sheet and fabricated metal product manufacturing, road freight transport, and other sport and recreational services had one measure rank among the top ten because of strong, direct links with other industries (entropy for input coefficients). Poultry processing, other wood product manufacturing, electricity supply, and owner builders had one of their measures rank among the top ten because of strong indirect links (entropy for total requirement coefficients).

16 The choice of top ten is arbitrary.

Table 5: Summary of rankings

		Backward linkages (weighted by final demand)	Forward linkages (weighted by final demand)	Row entropy for input coefficients	Column entropy for input coefficients	Row entropy for total requirement coefficients (weighted by final demand)	Column entropy for total requirement coefficients (weighted by	Row entropy for sales flows	Value added production multiplier
1	Other horticulture	78	70	31	60	44	66	42	53
2	Apple and pear growing	81	90	43	119	64	99	100	62
3	Kiwifruit growing	82	88	52	115	68	97	102	60
4	Other fruit growing	88	105	72	105	53	111	69	75
5	Mixed livestock and cropping	76	96	34	58	38	87	36	73
6	Sheep and beef cattle farming	74	86	12	45	17	73	76	86
7	Dairy cattle farming	85	66	21	77	47	56	106	43
8	Other farming	68	89	27	59	30	82	47	64
9	Services to agriculture, hunting and trapping	66	85	16	25	32	65	28	46
10	Forestry	34	17	46	61	20	12	80	27
11	Services to forestry	107	121	94	98	94	119	72	79
12	Logging	104	118	106	82	100	117	84	65
13	Fishing	108	81	75	95	95	80	91	119
14	Coal mining	109	104	59	96	63	100	55	107
15	Services to mining	70	125	126	117	71	125	71	72
16	Other mining and quarrying	69	61	29	31	28	45	38	56
17	Oil and gas extraction	113	64	74	28	85	39	33	82
18	Oil and gas exploration	79	117	26	110	13	118	78	114
19	Meat processing	5	6	44	56	8	8	94	14
20	Poultry processing	53	84	13	94	7	89	70	104
21	Bacon, ham and small good manufacturing	14	87	116	108	31	112	99	33
22	Dairy product manufacturing	4	8	84	66	10	9	104	40
23	Fruit and vegetable, oil and fat, cereal and flour manufacturing	22	32	15	63	19	50	73	63
24	Bakery, sugar and confectionery manufacturing	25	37	69	79	54	61	86	66
25	Seafood processing	21	30	107	101	61	67	110	44
26	Other food manufacturing	38	41	14	46	18	37	54	68
27	Soft drink, cordial and syrup manufacturing	47	82	62	103	49	96	89	61
28	Beer, wine, spirit and tobacco manufacturing	26	34	8	91	16	60	95	48
29	Textile manufacturing	24	35	76	44	48	33	50	34
30	Clothing manufacture	48	52	103	89	107	59	98	45
31	Footwear manufacture	46	102	121	124	69	113	122	31
32	Other leather product manufacturing	17	72	99	88	23	86	90	38
33	Log saw milling and timber dressing	45	45	87	42	12	36	46	98
34	Other wood product manufacturing	41	47	36	51	9	40	57	58
35	Paper and paper product manufacturing	20	10	67	23	51	6	44	22
36	Printing and services to printing	65	55	61	12	55	26	6	57
37	Publishing, recorded media manufacturing	67	50	65	16	67	23	16	42
38	Petroleum refining	114	31	118	19	120	20	22	124
39	Petroleum and coal product manufacturing nec	60	120	90	114	37	121	40	108
40	Fertiliser manufacturing	56	110	119	52	98	105	43	116
41	Other industrial chemical manufacturing	37	49	60	35	35	34	32	69
42	Medicinal, detergent and cosmetic manufacturing	30	44	40	49	24	44	67	50
43	Other chemical product manufacturing	39	76	86	37	26	57	23	84
44	Rubber manufacturing	102	100	108	76	111	91	35	111
45	Plastic product manufacturing	77	40	89	22	77	25	19	83
46	Glass and glass product and ceramic manufacturing	96	109	64	53	43	102	21	93
47	Other non-metallic mineral product manufacturing	94	97	49	43	57	81	48	94
48	Basic metal manufacturing	51	27	54	26	45	17	41	88
49	Structural, sheet and fabricated metal product manufacturing	27	18	57	7	46	11	18	26
50	Motor vehicle and part manufacturing	16	25	30	50	60	24	83	89
51	Ship and boat building	54	77	73	102	73	85	93	47
52	Other transport equipment manufacturing	122	98	123	47	126	77	25	121
53	Photographic and scientific equipment manufacturing	83	103	95	106	88	107	66	78
54	Electronic equipment and appliance manufacturing	18	21	37	41	50	15	68	24
55	Agricultural machinery manufacturing	72	91	80	111	89	94	92	67
56	Other industrial machinery and equipment manufacturing	23	24	56	34	62	18	60	17
57	Prefabricated building manufacturing	61	122	104	113	14	123	61	110
58	Furniture manufacturing	33	48	35	73	22	51	85	39
59	Other manufacturing	84	83	71	93	78	83	62	81
60	Electricity generation	112	51	85	30	76	27	34	101
61	Electricity transmission	125	124	124	99	118	124	108	118
62	Electricity supply	55	14	96	13	52	7	31	91
63	Gas supply	105	80	97	70	80	70	52	112

Table 5: Summary of rankings (cont.)

	Backward linkages (weighted by final demand)	Forward linkages (weighted by final demand)	Row entropy for input coefficients	Column entropy for input coefficients	Row entropy for total requirement coefficients (weighted by final demand)	Column entropy for total requirement coefficients (weighted by final demand)	Row entropy for sales flows	Value added production multiplier
64 Water supply	124	126	113	87	116	126	59	122
65 Residential building construction	7	13	2	57	3	22	103	28
66 Owner builders	28	54	33	118	2	88	117	125
67 Non residential building construction	13	19	9	32	1	13	77	97
68 Non building construction	12	15	23	48	11	14	82	15
69 Site preparation services	40	60	25	75	39	68	81	32
70 Building structure services	86	95	39	72	41	90	49	87
71 Plumbing services	52	65	38	86	58	74	74	59
72 Installation trade services	35	39	48	65	70	43	65	36
73 Building completion services	50	58	22	55	21	52	51	35
74 Other construction services	62	111	28	67	29	108	37	55
75 Wholesale trade	1	1	5	1	40	1	29	3
76 Retail trade	3	2	6	2	56	2	64	2
77 Accommodation	29	38	20	74	34	48	96	21
78 Bars, clubs, cafes and restaurants	9	22	3	71	6	31	113	13
79 Road freight transport	49	67	77	6	81	41	15	30
80 Road passenger transport	42	71	92	62	86	63	56	23
81 Water and rail transport	80	29	91	33	104	21	39	29
82 Air transport, services to transport and storage	8	3	58	8	96	4	58	9
83 Communication services	32	5	120	4	121	3	20	11
84 Finance	58	7	110	3	109	5	14	19
85 Life insurance	89	56	109	109	84	69	109	109
86 Superannuation fund operation	92	101	98	126	27	106	126	123
87 Health insurance	87	114	114	120	66	116	111	103
88 General insurance	119	57	125	21	112	35	13	113
89 Services to finance and insurance	118	99	82	29	83	72	27	117
90 Residential property operators	15	20	102	112	108	78	120	7
91 Commercial property operators	126	116	122	5	122	98	9	120
92 Real estate agents	59	33	105	84	97	71	88	54
93 Ownership of owner-occupied dwellings	2	4	117	125	124	122	125	1
94 Investors in other property	64	115	10	54	4	114	8	126
95 Vehicle and equipment hire	73	68	88	20	90	42	12	37
96 Scientific research	110	75	53	64	93	62	45	76
97 Technical services	93	36	63	17	79	16	17	51
98 Computer services	99	69	78	14	91	38	10	70
99 Legal services	115	59	83	18	105	30	11	74
100 Accounting services	123	106	79	15	103	79	1	105
101 Advertising and marketing services	95	92	51	9	42	55	7	102
102 Business administrative and management services	103	94	47	10	59	58	2	95
103 Employment, security and investigative services	121	119	111	27	102	115	4	106
104 Pest control and cleaning services	120	113	115	39	117	101	5	100
105 Other business services	71	74	32	11	36	47	3	71
106 Central government administration	6	9	4	40	33	10	101	6
107 Defence	57	46	70	123	113	93	124	16
108 Public order and safety services	90	43	101	122	125	103	123	18
109 Local government administration services and civil defence	10	12	18	78	25	29	115	8
110 Pre-school education	116	93	81	121	106	95	121	85
111 Primary and secondary education	19	16	68	83	123	32	116	5
112 Post school education	43	28	50	90	101	46	114	12
113 Other education	100	79	24	38	74	64	24	77
114 Hospitals and nursing homes	11	11	45	104	119	54	119	4
115 Medical, dental and other health services	31	23	55	69	115	49	105	10
116 Veterinary services	111	108	100	97	110	104	75	80
117 Child care services	117	112	42	100	92	109	87	99
118 Accommodation for the aged	97	63	17	92	82	75	107	41
119 Other community care services	91	73	11	107	72	84	112	49
120 Motion picture, radio and TV services	106	53	66	24	87	28	26	115
121 Libraries, museums and the arts	98	78	41	81	75	76	79	92
122 Horse and dog racing	63	107	7	85	5	110	53	90
123 Lotteries, casinos and other gambling	75	62	93	116	114	92	118	25
124 Other sport and recreational services	36	42	1	80	15	53	97	52
125 Personal and other community services	44	26	19	36	65	19	63	20
126 Waste disposal, sewerage and drainage services	101	123	112	68	99	120	30	96

6 Concluding remarks

This paper has investigated the production structure of the New Zealand business sector using the recently released 1996 input output tables. The analysis was undertaken at the most disaggregated level for which data are available, 126 industries. Indices of backward and forward linkages, measures of industry interconnectedness and a value added production multiplier were calculated.

Backward and forward linkages and measures of connectedness show how much each industry buys from and sells to other industries, directly and indirectly following a unit increase in final demand. In 1996, wholesale and retail trade, air transport, services to transport and storage, central government administration, meat processing, and dairy product manufacturing had the strongest backward and forward links with other industries. These industries were also important contributors to value added.

The paper provides a background for future work. At least two further studies are planned. The first study will examine structural change of the New Zealand economy over time, while the second will assess the degree of inter industry connectedness of the New Zealand economy compared to other OECD countries. A comparison of the 1996 tables to earlier data and to other OECD countries will provide further insights into the production structure of the New Zealand business sector.

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