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Abstract

The measurement of inter-connectedness in an economy using input-output tables is not new, however much of the previous literature has not had any explicit dynamic dimension. Studies have tried to estimate the degree of inter-relatedness for an economy at a given point in time using one input-output table, some have compared different economies at a point in time but few have looked at the question of how inter-connectedness within an economy changes over time. The publication in 2009 of a consistent series of input-output tables for Scotland offers the researcher the opportunity to track changes in the degree of inter-connectedness over the seven year period 1998 to 2004.

The paper is in two parts. A simple measure of inter-connectedness is introduced in the first part of the paper and applied to the Scottish tables. It is shown that although the aggregate results might appear to indicate a degree of import substitution was taking place this result is not robust to industrial disaggregation. In the second part of the paper an extraction method is applied to an eleven sector disaggregation of the Scottish economy in order to estimate how interconnectedness has changed over time for each industrial sector. It is shown that for the majority of sectors the degree of interconnectedness with the rest of the Scottish economy has grown for others, in particular Financial Services and Energy and Water Supply it has not.

Keywords: Extraction method, Input-Output Analysis, Inter-connectedness, Scottish economy,

JEL Classification: R11, R12, R15

1. Introduction

The recent publication of consistent annual input-output tables relating to the Scottish economy for the seven year period 1998 to 2004[1] provides a data resource of a type that is rare in regional economics. As yet there appears to be little, if any, published work analysing the behaviour of the Scottish economy over the turn of the millennium as evidenced by these tables. This paper attempts to use the tables to investigate whether the Scottish economy was becoming more or less inter-connected (or more or less complex) over the period.

As a region develops it is subject to a great variety of economic, demographic and social forces which will affect its economic structure. Some forces act to increase the variety of the region's economic activity. For example, the existence and growth of one industry may encourage firms in industries that supply inputs to the first industry's production process to locate in the region. Equally growth of personal disposable income in a region might stimulate local consumer goods industries. In such cases there would be some reason to suppose that, ce*teris paribus*, a degree of import substitution might take place with intra-regionally provided goods and services displacing those previously externally provided. In such a situation the regional economy in question might be said to have become more inter-related or complex as both a greater magnitude and variety of transaction flows between agents in the regional economy would be evident. Such increased inter-connectedness would tend to reduce the dependency of the region on other areas and hence reduce the relative importance of inter-regional trade. The effect is likely to be moderated if the new activities which replace imports in their turn require inputs that are not provided locally.

In the particular case of the Scottish economy over the period 1998 to 2004 there is an additional factor that could have led to increasing inter-connectedness of the economy. Scottish devolution became a reality in 1999 with the commencement of the current Scottish Parliament. If this movement

[1] http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/Downloads

to devolution was accompanied with a growth in sympathy for sourcing supplies from Scotland it is likely that it would have reinforced any moves towards greater inter-connectedness.

On the other hand there are factors that would counteract this increasing complexity of intra-regional transactions. Comparative advantage arguments suggest that regions might, to some extent at least, become more specialised over time. If this were to be true one might expect, again *ceteris paribus*, inter-regional trade to increase. In addition productivity gains in transport and other trade related activities suggest that trade might be expected to increase over time both in diversity and magnitude suggesting an increasing complexity of inter-regional trade. Reductions in trade barriers might also lead to similar changes.

A further complication might arise from the recently observed phenomena of out-sourcing and off-shoring. Out-sourcing, a circumstance in which a firm buys in from other firms goods or services that it was hitherto providing for itself, might be expected to increase the inter-connectedness of the regional economy if the new provider of the input was locally based but not if it was a foreign firm. Essentially a new intermediate input would replace something that was previously accounted for in value added. Off-shoring on the other hand occurs when a company re-locates part of its production to a foreign location. Off-shoring of Scottish activities should have no first order effect on the extent of inter-connectedness for essentially a new import would be replacing previous value added.

The factors outlined above suggest that one should not search for an analytic answer to the question of whether regional economies become more or less complex over time. However the existence of a consistent series of input-output tables at least allows one to offer empirical evidence relating to the issue, albeit empirical evidence that is for only one region and for only one relatively short-run period. The consistent Scottish input-output tables are given at two levels of disaggregation. Detailed tables contain 126 sectors; summary tables report the data at an eleven sector aggregate level. In this

paper the aggregate tables are used. In further work it is hoped to extend the work to the 126 sector case as it is recognised that the results may be affected by the level of industrial disaggregation with which one works.

The rest of the paper is organised as follows. In the second section of the paper a simple summary measure of inter-connectedness is explained. The third section presents the results of applying this aggregate measure for the Scottish tables is given as are the results of applying the measure at an industrially disaggregated level. In section four of the paper an alternative measure, specifically designed to be applied at an individual sector level is introduced and then applied to the data in section five. The paper concludes with a brief commentary on the results.

2. A simple summary measure of Inter-connectedness

In this section attention is directed towards a measure of inter-connectedness that is a simple summary measure relating to the distribution of the input-output coefficients that can be derived from the original transactions tables. The basic relationships in the input-output framework are as follows

(a) The output of industry i is either used as an intermediate input in other industries $T_{i,j}$ j=1…n or is sold to final demand $F_{i,k}$ (where k represents Household consumption, Government consumption, Capital Formation or Exports etc.)

$$X_i = \sum_j T_{i.j} + \sum_k F_{i,k}$$

$$\text{or } X = T + F$$

(b) If we assume Leontiev technologies for each industry, the ratio of the intermediate input of i in industry j is a constant $a_{i,j}$

$$a_{i,j} = T_{i,j} / X_j$$

$$\text{thus } X_i = \sum_j a_{i.j} X_j + \sum_k F_{i,k}$$

$$\text{or } X = A.X + F$$

where A is the matrix of direct coefficients.

(c) Finally the system may be solved for output given a level of final demand

$$X = [I - A]^{-1}F = LF$$

where $L = [I - A]^{-1}$ is the Leontiev inverse matrix.

The measure of interconnectedness reported here, denoted by HJ, is the mean of the sums of the sector direct coefficients i.e. $HJ = (1/n)\sum_{i=1}^{n}\sum_{j=1}^{n} a_{i,j}$ a measure suggested by Hamilton and Jensen (1983). The larger are the intermediate coefficients the higher is the extent of internal transactions within the economy and the more interconnected or complex the economy is likely to be. Hamilton and Jensen find their measure to be among the more useful of the measures they consider and that seems to be confirmed by the recent findings of Wood and Lenzen (2009)

3. Results

The means of the sums of the sector direct coefficients of the seven industry by industry tables are given in Table 1 and pictured in Figure 1. The implication of these figures is that over the period and certainly between 2000 and 2004 the Scottish economy became more interconnected though the increase may not appear to be dramatic.

The typical distribution of the direct coefficients of an input-output table exhibits positive skewness. As an example the distribution of the direct coefficients of the Scottish Table for 2001, the mid-point of the period considered, is shown in Figure 2. Measures of connectedness, such as the one used in this paper, are clearly related to the mean of the direct coefficients. Writing $\overline{a_{ij}}$ as the mean of the direct coefficients, $HJ = n.\overline{a_{ij}}$. Thus, at the same time as considering the central tendency of the direct coefficients it may be wise to consider the behaviour of the skewness of their distribution. Bowley's robust measure of skewness, SK, which is not sensitive to outliers, is also reported in Table 1 and graphed in Figure 3. The correlation coefficient between SK and HJ is -0.653, whilst not being significant at traditional levels

for a sample of size 7, suggests that lower values of HJ are associated with higher values of SK, so increasing complexity as measured by HJ is associated with a general rise in the values of the $a_{i,j}$ coefficients together with a reduction in the skewness. It should be noted that changes in complexity or in skewness do not show any significant relationship with output growth in Scotland over the period.

If the input-output coefficients increase (at least on average) over the period then, because of the accounting identity implicit in the columns of the table, this increase must be at the expense of other inputs into the production of goods and services. Each column of an input-output table may be divided into a set of elements relating to intermediate inputs, a set relating to imported inputs and a set relating to value added components. These relate to the costs of purchasing the commodities and factors necessary to produce Scottish output. It is possible to compare the movements, in aggregate, of the three shares corresponding to the three sets of costs for the period 1998 to 2004. For Scottish output as a whole the shares are shown in Figure 4. It can be seen that as the Scottish economy became more complex as a result of the increase in the intermediate input coefficients this was associated with a fall in the share of gross output accounted for by imports of intermediate goods and services. Value added, as a proportion of Gross Output varied little over the period. As a result one might infer that the increased complexity was a result of a degree of import substitution.

However if relatively more of Scottish output was being used as intermediate inputs into Scottish production not only does that imply something about the relative importance of imports and value added in the cost structure, it must also imply something regarding the sales of Scottish output. If relatively more is purchased by other firms as intermediate goods and services, relatively less must be sold to satisfy domestic final demand or be exported. The shares of output divided according to those three categories are shown in Figure 5. It can be seen that over the period 1998-2004 not only did the relative importance of intermediate use of Scottish goods and services

increase in Scotland so did the relative share of Scottish output going to Scottish Domestic Final Demand (ie Consumers, Investment and Government). On the other hand relatively less of Scottish output was being exported at the end of the period (28.7%) than at the start (35.5%). It is worth stressing that the fall in the shares of imports and exports in Scottish Output over the period are not a result of actual falls in the value of Imports and Exports. Imports of intermediate goods and services rose by 8.0% and Exports of Scottish produced goods and services by 7.6%. However Scottish Gross Output grew by 29% over the same period.

Although the results above apply to the Scottish economy in general, it is interesting to examine whether qualitatively similar results exist for each industry in turn. The results of doing so are presented in Tables 2 and 3. Even allowing for the fact that the judgement of what constitutes a "most noticeable movement" is admittedly subjective, it is immediately clear that the results are not consistent across sectors; indeed in no case is the economy wide result replicated for any sector. In part this is due to the disparate sizes of the sectors and the relative importance of, on the one hand, costs and, on the other hand, markets to the various sectors. On the cost side it is important to recognise the crucial influence of the manufacturing sector. In 2001 the manufacturing sector accounted for 24% of the Gross Output of the Scottish economy but 32.3% of the intermediate imports into Scotland. It is also interesting to note the fairly consistent pattern in the service sectors where, broadly speaking Domestic inputs become relatively more important at the expense of value added. When considering where industries sell their output the two dominant features appear to be the importance of the Distribution and catering sector in Domestic Final demand, where in 2001 22.9% of all Domestic final demand was made up of expenditure on the output of Distribution and catering, and the marked change in the markets served by the Finance and business sector. The Intermediate input market accounted for 36% of the output of the sector in 1998 and 44% in 2004, whereas Domestic final demand

accounted for 34% of the total output of the sector in 1998 but only 27% in 2004.

4. Hypothetical Extraction

A second way of examining the interconnectedness of an input-output table is to calculate, for each sector in turn, the effect on the economy of that sector. This can be done by the hypothetical extraction method (Miller and Blair, 2009). Suppose, without loss of generality, that the first sector is to be extracted. The original system may be partitioned to show that sector separately.

$$A = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & A_{22} \end{pmatrix}$$

The extraction method then considers a revised version of this matrix in which the elements of the first row and column are changed

$$A^* = \begin{pmatrix} a^*_{11} & a^*_{12} \\ a^*_{21} & A_{22} \end{pmatrix}$$

Then the effect on the economy of the change is given as

$$\Delta X = \left[(I - A)^{-1} - (I - A^*)^{-1} \right] F$$

There are a number of minor variants of the method which differ in the treatment of the elements in the row and column pertaining to the extracted sector in the matrix of direct coefficients. Dietzenbacher and van der Linden (1997) set the column elements equal to zero. Cella (1984) sets the row and column elements equal to zero apart from the intra-sectoral element in the extracted row and column which is not changed. Finally Groenewold, Haggar and Madden (1993) set all row and column elements for the extracted sector equal to zero. It is this last approach, sometimes referred to as Industry shutdown, which is undertaken here. However it should be noted that the estimated effect on the rest of the economy of extracting any given sector is

identical whichever of the methods is chosen. (Appendix 12W.1, Miller and Blair, 2009[2])

5. Shutdown Results

Table 4 gives the flow-on effects of shutdowns in the eleven sectors for the seven input-output tables. It should be noted that the figures are relative figures in that the flow-on effects are expressed as the flow-on effects relative to the original size of the shutdown sector. That is to say that for Agriculture, forestry and fishing in 1998, the value of 0.554 given in the table implies that a shutdown of the sector which in that year had a gross output of £3,318m would have had a flow-on effect of 0.554 * £3,318m = £1,838m on the rest of the Scottish economy. The same data are shown in Figure 6.

It is clear from Figure 6 that the sectors dived themselves into three distinct groups. Three industrial sectors, Mining, Public administration and Education, health and social work exhibit relative large flow-on effects which rise, in the case of Mining quite considerably, over the period. A second group consisting of Agriculture, forestry and fishing, Manufacturing, Construction, Distribution and catering, Transport and communication and Other services have somewhat lower relative flow-on effects which also rise over the period. The last two sectors, Energy and water and Finance and business have relative low flow-on effects which remain fairly static over the period. In so far as the Finance sector was seen in that period as a key element of the Scottish economy it is perhaps disappointing that, along with its growth (gross output in the Finance and business sector grew by 86,5% over the period) it did not become more embedded in the regional economy.

6. Conclusion

The evidence supports the idea that the Scottish economy became more inter-related or complex over the turn of the millennium just as Scotland achieved a measure of devolution. However there is much variation in the

[2] http://www.cambridge.org/resources/0521739020/7512_Appendix%2012W.1%2027%20Jul%202009.pdf

experiences of the different industrial sectors within the Scottish economy. Although the aggregate results reported in the first half of this paper might appear to support the idea that the increasing inter-connectedness of the economy was accompanied by a shift from using imported inputs into the production process in favour of domestically produced inputs, this is not apparent in the sectoral results. The results of applying a variant of the extraction method indicate that inter-connectedness was increasing or remaining steady for each of the eleven industrial sectors analysed here. However the extent of the increase in inter-connectedness for the industrial sectors is negatively related to both the growth in industry gross output (r = -0.644) and industry value added (-0.699). Whether faster growing industries in a region are generally likely to increase their inter-relationships with the local economy at a slower than average rate, is something that requires a more extensive study than this.

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Table 1: Summary Statistics from the Direct Coefficients

Year	HJ[1]	SK[2]
1998	0.2828	0.5649
1999	0.2826	0.5744
2000	0.2838	0.5963
2001	0.3038	0.5749
2002	0.3050	0.5136
2003	0.3118	0.5492
2004	0.3293	0.5360

[1] $HJ = (1/n)\sum_{i=1}^{n}\sum_{j=1}^{n} a_{i,j}$

[2] $SK = (Q_3 + Q_1 - 2.Q_2)/(Q_3 - Q_1)$

Table 2: Most noticeable movements of Domestically produced inputs, Imported inputs and Value added by industrial sector, 1998 – 2004

Sector	Domestic Inputs	Imported Inputs	Value Added
Agriculture, Forestry, Fishing	Down then up	Little change	Up then down
Mining	Up	Up	Down
Manufacturing	Little change	Down	Up
Energy, Water	Up	Little change	Down
Construction	Little change	Little change	Little change
Distribution, Catering	Little change	Down	Up
Transport, Communication	Up	Little change	Down
Finance, Business	Up	Little change	Down
Public Administration	Up	Little change	Down
Education, Health, Social Work	Little change	Little change	Little change
Other Services	Up	Little change	Down
All Sectors	*Up*	*Down*	*Little change*

Table 3: Most noticeable movements of Domestic intermediate inputs, Domestic Final Demand Provision and Exports by industrial sector, 1998 – 2004

Sector	Inputs	Final Demand	Exports
Agriculture, Forestry, Fishing	Down	Up	Little Change
Mining	Up	Little Change	Down
Manufacturing	Little Change	Little Change	Little Change
Energy, Water	Up	Little Change	Down
Construction	Little Change	Little Change	Little Change
Distribution, Catering	Down	Up	Down
Transport, Communication	Little Change	Little Change	Little Change
Finance, Business	Up	Down	Little Change
Public Administration	Little Change	Little Change	Little Change
Education, Health, Social Work	Up	Down	Little Change
Other Services	Up	Down	Up
All Sectors	*Up*	*Up*	*Down*

Table 4: Shutdown Flow-on Effects by industry, 1998 – 2004

Industry Shutdown	1998	1999	2000	2001	2002	2003	2004
Agriculture, Forestry, Fishing	0.554	0.537	0.565	0.640	0.594	0.586	0.642
Mining	0.867	0.884	0.892	0.980	1.041	1.090	1.149
Manufacturing	0.462	0.483	0.506	0.563	0.589	0.612	0.636
Energy, Water	0.420	0.372	0.344	0.410	0.433	0.418	0.436
Construction	0.541	0.524	0.541	0.608	0.599	0.587	0.588
Distribution, Catering	0.525	0.502	0.547	0.656	0.638	0.641	0.628
Transport, Communication	0.483	0.500	0.533	0.605	0.610	0.599	0.612
Finance, Business	0.345	0.355	0.365	0.391	0.358	0.344	0.338
Public Administration	0.770	0.791	0.833	0.936	0.900	0.891	0.902
Education, Health, Social Work	0.728	0.732	0.754	0.854	0.819	0.815	0.809
Other Services	0.534	0.537	0.582	0.667	0.622	0.633	0.641

Figure 1: The mean of the sums of the sector direct coefficients

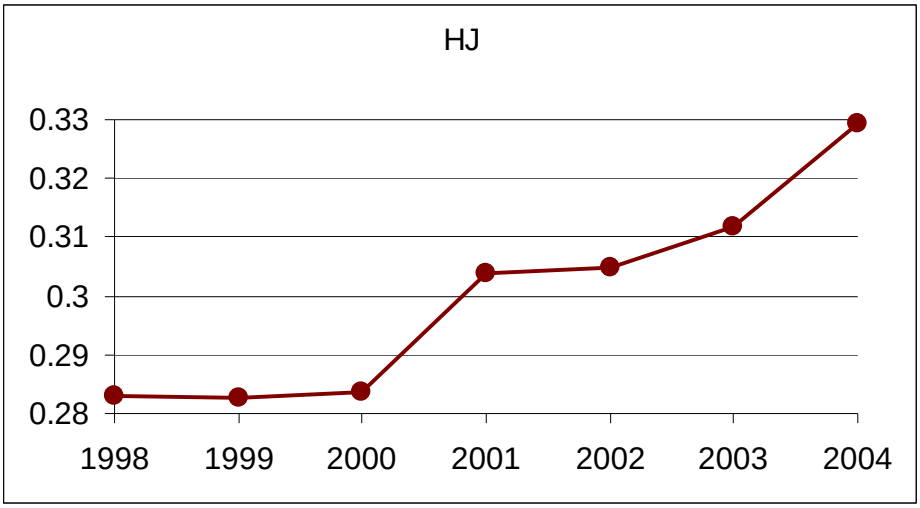


Figure 2: The distribution of direct coefficients (Scotland, 2001)

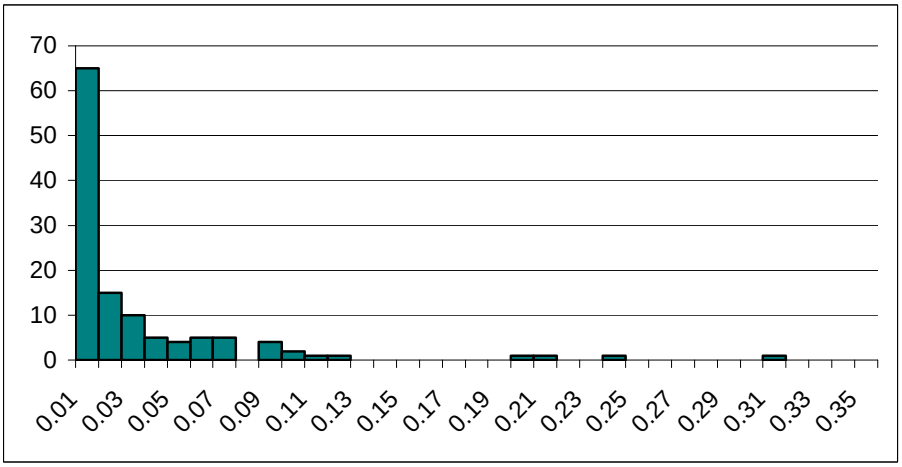


Figure 3: Skewness of Direct Coefficients, 1998 – 2004

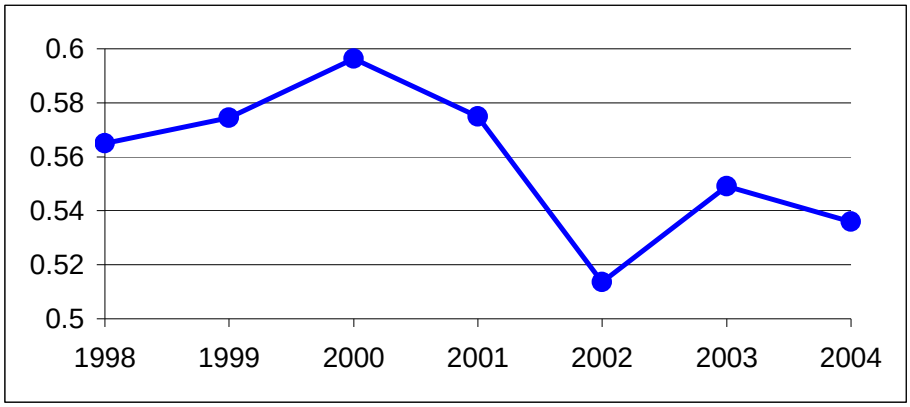
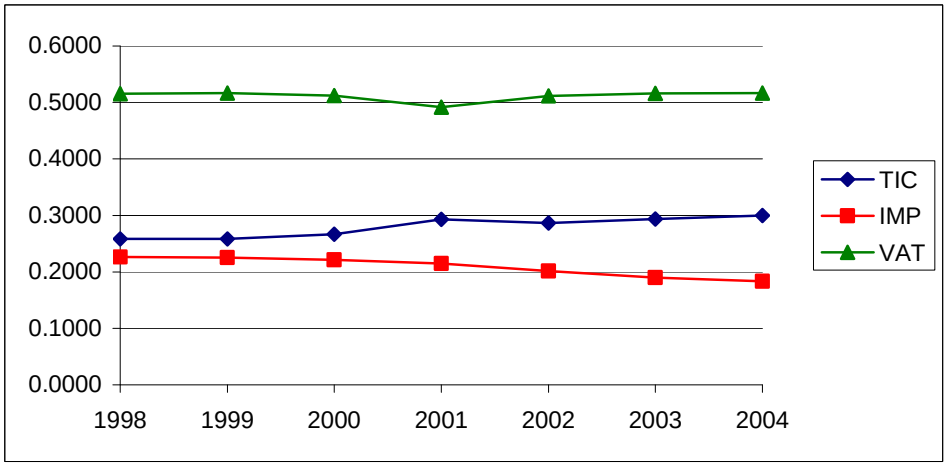


Figure 4: Gross Output Shares by cost (All industries) 1998 - 2004

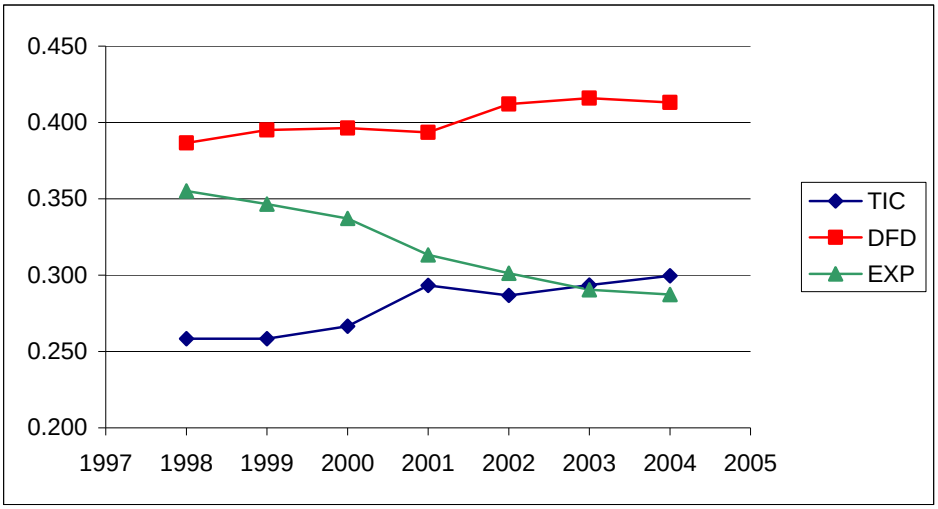


TIC: Total Intermediate Use

IMP: Imported Inputs

VAT: Value Added (plus Taxes less Subsidies)

Figure 5: Gross Output Shares by sales (All industries) 1998 – 2004



TIC: Total Intermediate Use

DFD: Domestic Final Demand

EXP: Exports

Figure 6: Shutdown Flow-on Effects by industry, 1998 – 2004