2
The Input–Output Approach to Modelling the Regional Economy

In the previous chapter, we saw how models of the regional economy could be constructed in order to provide some insight into the major determinants of output and employment levels. Although these models were initially simplistic and focused attention only on the major regional aggregates (such as regional income and employment), there has recently been a proliferation of far more detailed models based upon time series data. A major requirement of these models, however, is a data set which spans several years, preferably at least a decade. An alternative approach to modelling regional economies is to construct a detailed snapshot of the input–output linkages that exist within a region. This can then be used for predicting the consequences of any planned or potential changes in the demand for the region's output. The technique was developed by Leontief during the 1930s and has since been used in a wide range of applications, including regional impact analysis.

The input–output method is based upon the simple, but fundamental, notion that the production of output requires inputs. These inputs may take the form of raw materials or semi-manufactured goods, or inputs of services supplied by households or the government. Households provide labour inputs whilst the government supplies a wide range of less visible services such as national security. Having purchased inputs either from other producing sectors, households or the government, an industry then produces output and sells this either to other producing sectors or to 'final demanders', such as households, the government, residents of other regions or to firms for investment purposes.

Exactly how input–output models are constructed, and the uses to which they can be put, is the subject matter of this chapter. The first part of the chapter deals with the construction of input–output models in general; the second part examines a number of interesting (and quite different) applications of regional input–output modelling.

2.1 The Input–Output Method

The Transactions Table

The input–output linkages that exist within an economy can be neatly formalised by constructing a transactions table (or flow matrix), which records all the production flows occurring within the regional economy during a specific year. Input–output models vary enormously in their degree of industrial disaggregation, ranging from the 7-industry model constructed for the Northern region (Northern Region Strategy Team 1976) to the gigantic 496-industry model of the Philadelphia economy (Isard and Langford 1971). In between these two extremes are models such as those for North Staffordshire (Pullen and Proops 1983) with its 27 industries and Scotland with its 76 industries. A condensed version of the 1979 Scottish transactions table (Henderson, 1984) is given in Table 2.1. Although only 9 producing sectors are identified in this table, it provides an excellent example of what an actual transactions table looks like.

The main elements of the transactions table can be understood by considering a simple illustrative example. Table 2.2 describes the input–output linkages in a three-industry economy. Consider first the upper left-hand quadrant, which is referred to as the processing sector. This sector lies at the heart of the input–output system. It describes the flow of output from one producing activity to another. Reading down the first column (and ignoring the numbers in brackets for the time being), we see that agriculture requires £20 worth of agricultural inputs and £20 worth of manufacturing inputs in order to produce £100 of agricultural output (shown in the gross output column on the extreme right of the table). Agriculture also needs inputs, however, from households (labour services=£40), the government (government services=£10) and from other regions (imports=£10). These are obtained from the payments sector in the lower left-hand quadrant. Finally, by reading along the first row, we see that agriculture sells its output not only to itself (£20) and to other producing sectors (manufacturing=£40) but also to 'final demanders' such as households (consumption=£20); and to residents of other regions (exports=£20).

Notice that the gross output of each industry is exactly equal to its gross inputs (i.e. the total outlay). This equality between gross output and gross inputs is a consequence of the fact that the transactions matrix is constructed on the principle of double-entry book-keeping. The entire output of each industry must be accounted for by the inputs used up during production. Any excess of the value of gross output over payments made for inputs is profit and is included in the payments made to the household sector. The transactions table therefore tells us exactly where the inputs of an industry *come from* and where its output *goes to*. In doing this, the table focuses attention on the interdependent nature of economic activities.

Before explaining how the information in the transactions table can

Table 2.1 *The Scottish Transactions Table 1979 (in £ Million)*

	Purchases by:													
	Agriculture, forestry, fishing	*Energy and water supply*	*Minerals, metals, chemicals*	*Metals and engineering*	*Other manufacturing*	*Construction*	*Distribution, hotels, catering*	*Transport and communications*	*Other services*	*Consumption*	*Government spending*	*Exports*	*Other*	*Total domestic output*
Sales by:														
Agriculture, forestry, fishing	256	0	7	0	747	1	23	1	1	108	7	156	10	1,315
Energy and water supply	46	272	251	62	110	14	155	124	17	585	93	426	71	2,226
Minerals, metals, chemicals	66	19	164	115	45	216	4	11	5	41	31	1,491	21	2,230
Metal goods and engineering	19	24	22	107	43	26	12	26	4	71	199	3,152	131	3,837
Other manufacturing	151	11	19	32	666	83	170	28	74	836	63	3,645	84	5,862
Construction	14	55	14	12	18	429	48	17	36	316	187	–	1,712	2,859
Distribution, hotels, catering	75	61	89	89	178	90	127	61	35	2,324	106	297	132	3,664
Transport and communications	14	61	81	60	197	58	165	116	81	508	118	583	59	2,098
Other services	35	55	111	283	356	42	311	72	178	1,229	2,433	254	58	5,416
Imports from rest of UK	123	564	531	1,005	1,054	285	286	197	131	1,744	214	3,822	1,020	10,977
Imports from rest of world	82	321	346	606	663	130	84	114	14	1,109	50	10	557	4,084
Income from employment	230	456	496	1,269	1,154	890	1,362	851	3,576	–	–	–	0	6,279
Other inputs	205	327	98	196	630	595	913	481	1,264	1,389	122	174	–122	10,283
Total input	1,315	2,226	2,230	3,837	5,862	2,859	3,664	2,098	5,416	10,259	3,624	14,007	3,733	61,131

Source: Henderson (1984), p. 13.

Table 2.2 *The Transactions Table*

	Inputs purchased by: Agriculture	Manufacturing	Services	*Final demand sectors:* Households	Government	Exports	Investment	*Gross output*
Output produced by:								
Agriculture	20(.2)	40(.2)	0(0)	20	0	20	0	100
Manufacturing	20(.2)	20(.1)	10(.1)	75	10	55	10	200
Services	0(0)	40(.2)	10(.1)	25	20	5	0	100
Payments for:								
Households services	40(.4)	45(.225)	70(.7)	5	0	0	0	160
Government services	10(.1)	15(.075)	5(.05)	0	0	0	0	30
Imports into region	10(.1)	40(.2)	5(.05)	0	0	0	5	60
Gross inputs	100	200	100	125	30	80	15	650

Note: ( )=technical coefficients. See text for details.
Source: Yan (1969), p. 20.

be used for forecasting the effects of changes in the final demand for the region's output, several additional features of this table should be noted. In particular, it provides valuable information about the underlying economic structure of the region. This is indicated not only by the pattern of inter-industry linkages (which are examined in more detail below), but also by the relationship between the final demand sector and the payments sector. Table 2.2 shows, for instance, that in this specific illustration the government expenditure of £30 in the region equals the payments to the government sector (viz. taxation). Exports can also be seen to exceed imports. Finally, the value added by the residents of the region during the production process is £160 (which is the total payment for household services). This is the region's GDP, as can be seen by subtracting payments to the government and to other regions from total final demand for the region's output:

		(£)
Household consumption	=	125
Government expenditure in region	=	30
Regional exports	=	80
Investment in region	=	15
Payments for government services (taxation)	=	−30
Imports into region	=	−60
Regional GDP	=	160

Fixed Coefficient Technology

The purpose of constructing a transactions table for a regional economy is not confined to describing input–output flows. Once the interdependencies between sectors have been quantified, it is possible to estimate the effect of any change in final demand on the entire system. But initially a few critical assumptions have to be made. Firstly, it is assumed that the production technology is one of fixed proportions (sometimes known as Leontief technology). In other words, industry j would have to double all its inputs in order to double its output. Furthermore, this relationship is assumed to remain constant over the period for which any forecast is being made:

$$x_{ij}=a_{ij}X_j \tag{1}$$

where:

x_{ij}=flow of output from industry i to industry j, reading i as a row and j as a column (e.g. $x_{12}=40$ in Table 2.2)
X_j=gross output of industry j (e.g. $X_2=200$)
a_{ij}=the technical coefficient relating inputs to output (e.g. $a_{12}=x_{12}/X_2=40/200=0.2$)

Equation 1 simply argues that the flow of output from industry i to industry j is a fixed proportion of industry j's gross output. If gross output increases by 1 unit in industry j, then a_{ij} extra inputs are required from industry i. The coefficient a_{ij} is obtained from the transactions table by simply dividing x_{ij} by X_j. The full set of these 'technical coefficients' are shown in parentheses in Table 2.2. (The next section utilises these coefficients for forecasting the impact of a given increase in final demand on the entire input–output system.)

A further assumption used in input–output models is that there are no constraints on productive capacity, which is assumed to be able to 'deliver the goods' if there is any increase in final demand.

Forecasting the Inter-Industry Effects of an Increase in Final Demand

To demonstrate the value of the input–output method in forecasting the consequences of an increase in final demand on each industry's inputs and output, it is helpful to take a specific numerical example. Suppose the final demand for agricultural output increases by £10. In this case, we assume that the increased demand originates entirely in the export sector. Suppose also that spare productive capacity exists in all sectors and that any increase in labour income will have no effect on household purchases from within the region (i.e. households are 'exogenous'). The assumption that households are 'exogenous' is obviously unrealistic, especially for applications of the input–output method to regional economies, and it will be relaxed below. An increase in agricultural output of £10 means that the agricultural sector requires:

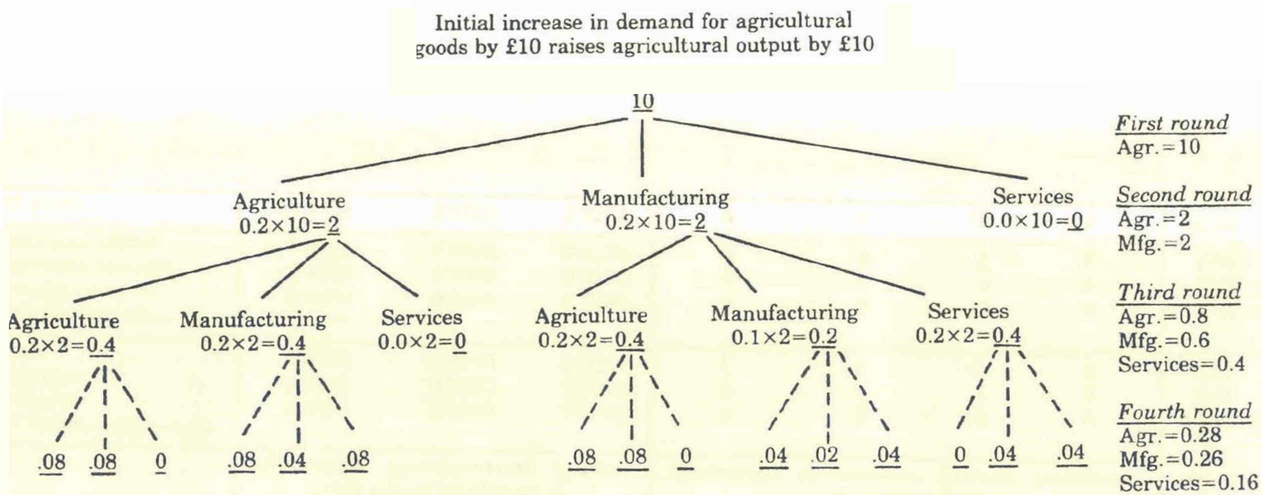
0.2×£10=£2 of additional agricultural output
0.2×£10=£2 of additional manufacturing output
0.4×£10=£4 of additional household services
0.1×£10=£1 of additional government services
0.1×£10=£1 of additional imports

This is only the second round, however, since extra output produced by any of the three industries will itself generate further output effects through inter-industry linkages. The inter-industry effects for the second, third and fourth rounds are shown in Figure 2.1.

With each round, it can be seen from Figure 2.1 that the net additions to output in each industry become smaller and smaller, eventually converging on zero. By adding the extra output produced in each round of expenditure, a cumulative total is obtained for each industry. In the present case, the cumulative effect on each industry of an increase in agricultural sales of £10 is as follows:

agriculture=10+2+0.8+0.28+ .... = £13.26
manufacturing=2+0.6+0.26+..... = £ 3.02
services=0.4+0.16+ .... = £ 0.67

The effects of an increase in the demand for agricultural exports of £10 are shown in the final column of Table 2.3. The effects on each



Cumulative effect on each industry of an increase in agricultural output of £10:

Agriculture	=	13.26
Manufacturing	=	3.02
Services	=	0.67
Total	=	16.95

Figure 2.1 *The Inter-Industry Effects of an Increase in the final Demand for Agricultural Goods*

Table 2.3 *The Effects of an Increase in the Final Demand for Agricultural Goods by £10*

	Extra inputs purchased by:			*Final demand sectors:*				*Gross*
	Agriculture	*Manufacturing*	*Services*	*Households*	*Government*	*Exports*	*Investment*	*output*
Extra output produced by:								
Agriculture	2.6520	0.6040	0.0000	0	0	10	0	13.26
Manufacturing	2.6520	0.3020	0.0670	0	0	0	0	3.02
Services	0.0000	0.6040	0.0670	0	0	0	0	0.67
Extra payments to:								
Household services	5.3040	0.6795	0.4690	0	0	0	0	6.45
Government services	1.3260	0.2265	0.0335	0	0	0	0	1.59
Imports into region	1.3260	0.6040	0.0335	0	0	0	0	1.96
Gross input	13.2600	3.0200	0.6700	0	0	10	0	26.95

individual input–output flow are obtained by simply applying the coefficients shown in brackets in Table 2.2 to the gross output column in Table 2.3.

It is particularly important to note that additional income earned by the household sector (i.e. £6.45) is not earned entirely by workers employed in the agricultural sector. Households supplying services to the manufacturing and service sectors also increase their income as a result of the indirect effects of the increase in output by these two sectors.

Output and Income Multipliers

Input–output models are constructed primarily because they provide a detailed breakdown of the effects of the predicted changes in output. It is sometimes useful, however, to provide a summary statement of these predictions. This can be done by constructing sectoral output multipliers and household income multipliers. We turn first to sectoral output multipliers.

These are obtained by first calculating the inverse matrix. The inverse matrix shows exactly how the output of each sector will be affected when the final demand for a region's output increases by £1. For very small input–output models (such as the 3×3 model being discussed here), it is possible to calculate the inverse matrix 'by hand'. But as the model increases in size, the task becomes more complex. Fortunately, the calculation of the inverse is made easy by the existence of computers and standard statistical packages.

In Table 2.3, for instance, we saw that an increase in final demand for agricultural goods by £10 would increase the gross output of each sector as follows:

Agriculture	£13.26
Manufacturing	£3.02
Services	£0.67

This implies that an increase in the final demand for agricultural goods by £1 would increase the gross output of each sector as follows:

Agriculture	£1.326
Manufacturing	£0.302
Services	£0.067

Summing these we obtain a total (direct+indirect) effect on gross output of £1.695. This is known as the sectoral output multiplier for the agricultural sector. A similar exercise can be undertaken for the other two sectors, the results for which are given in Table 2.4. The set of numbers given in Table 2.4 (excluding the column sums) are, in fact, the inverse matrix for the 3×3 model described in Table 2.2. Thus, a £1 increase in the demand for manufactured goods would raise gross output in agriculture, manufacturing and services by £0.302, £1.208

Table 2.4 *The Inverse Matrix and Sectoral Output Multipliers for Each Sector*

	Agriculture	*Manufacturing*	*Services*
Agriculture	1.326	0.302	0.034
Manufacturing	0.302	1.208	0.134
Services	0.067	0.269	1.141
Sectoral output multiplier	1.695	1.779	1.309

Note: The sectoral multiplier (k) is defined for the case where households are exogenous (see next section) as follows:

$$k = \frac{\textit{Direct effect} + \textit{Indirect effect}}{\textit{Direct effect}}$$

Source: Yan (1969) p. 37.

and £0.269 respectively; and similarly for a £1 increase in the demand for services.

To provide some idea of the size of these sectoral output multipliers in practice, Table 2.5 gives those recently estimated for the North Staffordshire economy by Pullen and Proops (1983). Also included in Table 2.5 is the corresponding set of employment multipliers. These are obtained by combining the sectoral output multipliers with each industry's output/employment relationship. The employment multiplier is simply the total employment generated as a result of the creation of one more job in one of the producing sectors. In general, both output and employment multipliers are seen to be small. Only 3 industries, for instance, have output multipliers greater than 1.3 whereas 8 industries have output multipliers less than 1.1. The smallness of these multipliers is a direct consequence of the substantial import leakages that occur as a result of the inter-industry linkages with other regions. This is reflected by the fact that 80% of the purchases of industrial goods and services in North Staffordshire are from outside the region. Such a high propensity to import inevitably results in low multipliers for the region's industries.

Output and employment multipliers are not the only types of multiplier that can be obtained from the input–output model. Income multipliers for households, for example, can also be calculated. These household income multipliers differ from sectoral output multipliers since the latter refer to the direct and indirect effects on the output of the processing sector whereas household income multipliers refer only to the effect of output changes on the income of the household sector. The simplest household income multiplier is obtained by first calculating the total increase in household income generated by an increase in the demand for any given sector's output by £1. The result is then divided by the increase in the household income of the sector experiencing the increase in demand. This is the household income multiplier.

It is easily obtained for each sector by utilising two pieces of information: (i) the inverse matrix (Table 2.4); and (ii) the purchase of household services per £1 of gross output (as given in Table 2.2). Suppose, for example, that the demand for agricultural output

Table 2.5 *Sectoral Output and Employment Multipliers for the North Staffordshire Economy*

Sector	*Output multiplier*	*Employment multiplier*	*Sector*	*Output multiplier*	*Employment multiplier*
Tiles	1.47	1.39	Mining, quarrying	1.12	1.11
Agriculture	1.40	1.23	Textiles, leather	1.11	1.10
Bricks, refactory goods	1.39	1.41	Metal manufacturing	1.10	1.08
Cement, building materials	1.29	1.66	Medical services	1.10	1.05
Tableware	1.26	1.13	Mechanical engineering	1.09	1.28
Paper, printing, publishing	1.26	1.21	Professional services	1.09	1.16
Vehicles	1.25	1.33	Clothing, footwear	1.08	1.08
Road transport	1.24	1.11	Distribution	1.07	1.21
Sanitary porcelain	1.20	1.14	Electrical engineering	1.07	1.10
Local government	1.18	1.11	Food, drink, tobacco	1.06	1.43
Timber, furniture	1.14	1.15	Instrument engineering	1.04	1.03
Coal, petroleum products	1.14	1.32	National government	1.01	1.01

Note: These multipliers were calculated on the assumption that households were exogenous (see next section).
Source: Pullen and Proops (1983), p. 192.

increases by £1. This will lead to an increase in the gross output of each sector by the amounts shown in column 1 of Table 2.4. Multiplying each number by the amount of household services needed to produce each unit of gross output (see the household row in Table 2.2), we obtain:

£1.326×0.4	= £0.530
£0.302×0.225	= £0.068
£0.067×0.7	= £0.047
Total effect on household income	=£0.645

Dividing this by the amount of household services required to increase gross output in agriculture by £1 we obtain:

$$\text{Household income multiplier for agriculture} = \frac{\textit{Direct effect}+\textit{Indirect effect}}{\textit{Direct effect}}$$

$$= \frac{£0.645}{£0.4} = 1.61$$

Performing similar calculations for the other two sectors, we obtain 2.58 for manufacturing, and 1.20 for services. The calculation of household income multipliers represents an additional valuable piece of information that can be obtained from input–output models.

Households: Exogenous or Endogenous?

In all the examples considered so far, no allowance has been made for the possibility that an increase in household income may lead to an increase in household consumption of locally-produced goods and services. This is clear from the column of zeros recorded for the household sector in Table 2.3. We may ask, however, whether it is reasonable to assume that household consumption is unresponsive to changes in household income. When household income increases, household consumption is likely to increase as well. There are two ways of taking this feedback effect into account. The first approach assumes that a proportional relationship exists between consumption and income. The second approach utilises estimated consumption functions which are non-proportional.

The assumption that a proportional relationship exists between consumption and income is the easiest of the two options since it only requires the 'conversion' of the household sector from a final demand sector into a producing sector. In short, households are treated as if their consumption were intermediate inputs which are purchased in order to produce an output labelled 'household services'. The process described in Figure 2.1 and Table 2.3 above would therefore be extended to cover the household sector as well as the three industries already included. Thus, a £10 increase in agricultural exports would