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Input–Output and General Equilibrium Models for Hull and Humber Region in England

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Abstract This paper shows how one can construct an input output table for four Humber sub regions in England with information on levels and share of employment and output provided by the Humber Forum using coefficients from the national input–output table of UK. It then illustrates how these can be applied to construct multisectoral general equilibrium models specific to Hull, East Riding, North Lincolnshire and North East Lincolnshire regions situated in two sides of Humber estuary and a regional model that takes these four inter-dependent economies constituting the Humber economy. A dynamic model is constructed for Hull to assess the prospects in next hundred years based on micro consistent dataset in which households and firms are assumed to have perfect foresight in making their consumption and production decisions. These models are then applied to evaluate impacts of tax policies that can distort relative prices of commodities and factors of production and thus can distort the efficient allocation of scarce economic resources and on welfare of households in the Humber region. To my knowledge this is the first study of this type for this region.

Keywords Hull and Humber · Input output model · General equilibrium · Growth · Efficiency · Welfare · Tax policy · Regional model

JEL Classification C67 · C68 · O15 · R13

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Introduction

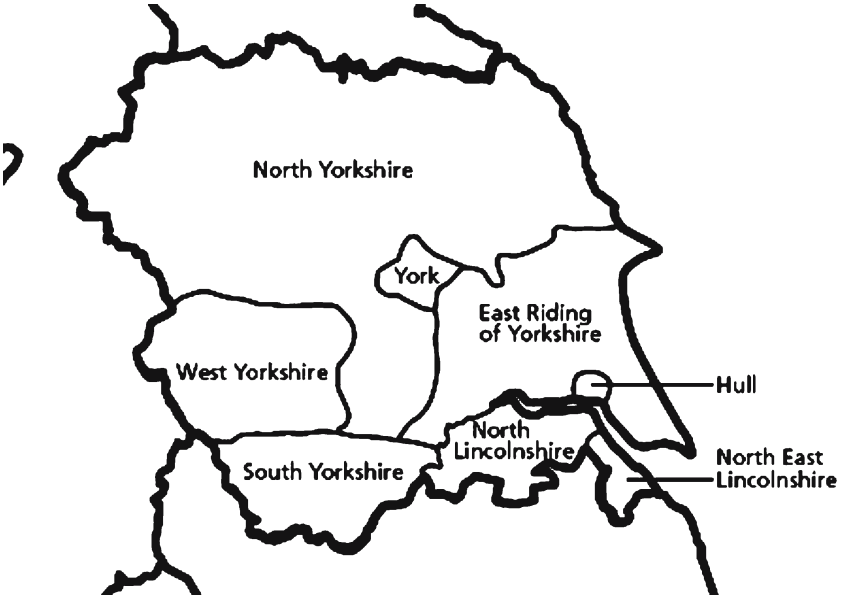
Humber region, consisting of Hull, East Riding, North Lincolnshire and North East Lincolnshire counties in the North and South sides of Humber estuary as shown in the map below, is one of the dynamic sub-regions in the North Eastern part of England. This estuary has been an active route for international trade via the North Sea in the Northern England for Ireland-Liverpool-Manchester-Leeds-Hull-Rotterdam or the Zeebrugge segment of EU trade[1] for a long time. With well developed railways, roads, canal systems and air transports from the Humberside International Airport, it is well integrated to the Yorkshire and Lincolnshire and the other parts of UK, EU and the Global economy. The regional authority of Humberside, the Humber Forum (HF 2003) has recently announced a plan for transforming Humber to a self reliant, confident, creative, world- class, prosperous and sustainable economy. It has published some information on the structure of business and employment for this region that includes Hull, East Riding, North East Lincolnshire and North-Lincolnshire with its vision for an advanced Humber economy http://www.humberforum.com).

Based on estimates of sectoral shares and aggregate levels of employment and output, the HF has set sectoral growth targets for nine sectors – agriculture, energy and water, manufacturing, construction, distribution, transport and communication, public administration, and other services – for up to 2012.[2] I argue that the sectoral growth rates chosen by the HF can be only tentative, based on intuitive judgments of professionals and politicians involved in regional planning but these growth rates need to be determined scientifically after realistic evaluation of full knock on effects of economic events to be more accurate in economic planning and projections. Household and government spending or business investments or trade activities have more than first round effects that accumulate over time until the regional economy settles down to a new steady state because of such initial push. The HF can improve its growth projections using more integrated input–output or general equilibrium models which account for price based income and substitution effects on decisions of households and firms aiming for efficient allocations of scarce economic resources under their disposal.

[1] Ports of Humberside and Immingham also have direct connections to commercial ports of Oslo in Norway, Gothenburg in Sweden, Esbjerg in Denmark, and Hamburg and Bremerhaven in Germany.

[2] See Humberside feasibility study from the Central Unit for Environment Planning in 1969 for earlier plans and Manners et al. (1972) and Leahy and Williams (1996) for comparative regional analyses of Humber with the Rest of UK from regional planning perspective, Hull City and County Council (1970); Wood D. M. (1998) about the regeneration; Macmohan (1961) for related Acts of the parliament.

Map 1: Yorkshire and Humber Region in the United Kingdom
http://www.20millionvotes.org.uk/images/content/map_yh.gif



Map 2: Composition of Yorkshire and Humber Region
http://www.ice-yorkshireandhumber.org.uk/yorkshirehumber/images/yorks.gif

The major objective of this paper is to develop a consistent and coherent micro-founded macroeconomic general equilibrium model for each of the four sub-regions and to build a regional and a dynamic general equilibrium model for Hull and Humber. In the process of research, I will construct an input–output table for all four sub-regions separately and apply the micro-consistent data set contained in those input output tables to build a general equilibrium model for each sub region as well as for the entire Humber region based on dynamic choices for a set of preferences of households and the technology of production of firms operating in the region. The price based income and substitution effects are important for allocation of scarce economic resources, for investment and for capital accumulation in such models. These aspects are vital for smooth and speedier rates of growth according to the aspirations expressed in advanced economy policy foresights for sustainable development of Humber (HF 2003). Sections II and III provide details on the underlying Leontief model for the input–output table of Hull, which then is applied to derive input–output tables for East Riding, North Lincolnshire and North East Lincolnshire. Uses of these input–output tables for impact analyses and manpower projection and planning are briefly explained in section IV. A brief discussion of applied general equilibrium models for each sub-region and Humber region with those benchmark data is in Sections V followed by a brief note on results of a dynamic general equilibrium model in section VI. Conclusions and references are given in sections VII and VIII.

Main Elements of the Input–Output Model of the Hull Economy

On the supply side the gross output by sectors, reflect the cost of production that is divided into intermediate inputs, value added, tax and import components. On the demand side, each sector sells its product for intermediate use by itself and by other sectors and for final demand. Consistency requires equality between supply and demand for each sector. The sum of labour income, capital income, and production taxes should equal final demand of households for consumption, of producers for investment, of government for public spending and of the Rest of the World Sector (ROW) for net exports. A nine sector input output model can be constructed with a standard Leontief (1949) model for each of four Humber regions as following:

$$\begin{aligned} X_1 &= a_{1,1}X_1 + a_{1,2}X_2 + \ldots . + a_{1,9}X_9 + F_1 \\ X_2 &= a_{2,1}X_1 + a_{2,2}X_2 + \ldots . + a_{2,9}X_9 + F_2 \\ X_9 &= a_{9,1}X_9 + a_{9,2}X_9 + \ldots . + a_{9,9}X_9 + F_9 \end{aligned} \tag{1}$$

where X_i represents gross output of sector i, the intermediate inputs are linked by a Leontief technology coefficient such as $a_{i,j} = \frac{X_{i,j}}{X_j}$, where $a_{i,j}$ shows how much sector $i$commodity is required to produce one unit of sector j commodity with $X_{I,j}$ being the intermediate input from sector i to sector j.

This essentially is a simultaneous equation model with nine equations which gives the solutions for gross output of all nine sectors, X_1 to X_9 and can be applied to assess the impact of changes in the final demand on gross output, employment,

investment or for manpower required by these industries for smooth functioning of these economies.

$$\begin{aligned} &(1-a_{1,1})X_1 - a_{1,2}X_2 - a_{1,3}X_3 - \ldots .. - a_{1,9}X_9 = F_1 \\ &-a_{2,1}X_1 + (1-a_{2,2})X_2 - a_{2,j}X_j - \ldots - a_{2,9}X_9 = F_2 \\ &-a_{9,1}X_1 - a_{9,2}X_2 - a_{9,j}X_j - \ldots (1-a_{9,9})X_9 = F_9 \end{aligned} \tag{2}$$

It is better represented by a matrix system as:

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \\ X_8 \\ X_9 \end{bmatrix} = \begin{bmatrix} (1-a_{1,1}) & -a_{1,2} & -a_{1,3} & -a_{1,4} & -a_{1,5} & -a_{1,6} & -a_{1,7} & -a_{1,8} & -a_{1,9} \\ -a_{2,1} & (1-a_{2,1}) & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & (1-a_{i,j}) & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & (1-a_{8,8}) & . \\ -a_{9,1} & -a_{9,1} & . & . & -a_{9,j} & . & . & . & (1-a_{9,9}) \end{bmatrix}^{-1} \cdot \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \\ F_7 \\ F_8 \\ F_9 \end{bmatrix} \tag{3}$$

In a standard matrix notation, the input output model is given by $X = (I - A)^{-1}F$. Solution for this model exists when the determinant of (*I-A*) is nonzero, or when this matrix is non-singular, i.e. $|I - A| \neq 0$ and it can easily be checked using matrix routine in Excel.

Construction of an Input–Output Table for Hull Economy

A balanced and consistent input–output table provides the basis for assessment of economic policies taking account of entire structure of Hull economy. It also provides benchmark data for a general equilibrium model. This section shows a procedure to construct such an input–output table for Hull based on existing data on per capita GDP, level of employment and output and their sectoral compositions from the HF with some production and demand side coefficients taken from the national input–output table for UK until such information becomes available for the Hull and Humber region. It is expected that a detailed survey could be conducted to gather necessary information on the cost of production of firms and the patterns of expenditure of households, investment structure of firms, net exports from the Rest of the World sector and the spending of the government sector. For the time being it is assumed that the production technology and preferences of economic agents in Hull are not significantly different than those of the national economy, which might not be too unrealistic given the freedom of choices and movement of goods, factors and assets based on market signals. With proper consideration of above points, one can construct a nine sector Hull economy input output table completing six steps as following.

1. Take the total employment and output and sectoral composition of these employments and output from the existing data from the HF (Table 1).
2. Split the total output in labour and capital income using employment and income per capita information. Sectoral employment is obtained by multiplying the sectoral share by total employment. Then sectoral labour income is obtained

Table 1 Hull economy: composition of employment and output by sectors

	Employers	Employment	Output 2002 (ml £)	Output 2012
Agriculture and Fishing	0.3%	0.01%	0.10%	0.10%
Energy and Water	0.1%	0.60%	1.30%	1.30%
Manufacturing	11.7%	20.70%	28.20%	28.20%
Construction	7.3%	4.10%	4.30%	4.30%
Distribution, hotels and restaurants	35.3%	24.30%	17.00%	17.00%
Transport and communication	5.4%	5.40%	9.70%	9.70%
Banking, Finance and insurance	19.6%	12.60%	12.40%	12.40%
Public administration, education and health	11.8%	27.40%	23.50%	23.50%
Other services	8.6%	4.90%	3.40%	3.40%
Total	7,562	120,856	312,5881	3,125,881,000

Source: http://www.humberforum.com

by multiplying the sectoral employment by the gross value added per worker. Sectoral output is obtained by multiplying the sectoral share of output by total output. Capital income is the difference between total output and the labour income. All these numbers are presented in Table 2.

3. Analyses of inter-sectoral linkages require information on input–output coefficients which do not exist for the Hull and Humber. If the structure of production for each sector is not very different in Hull than in the national economy the Hull economy input–output coefficients can be approximated by the national input–output coefficients. Some adjustment is necessary for education and public services sector, and the mining and utility sector from the existing nine sector IO table for the national economy as given in Table 3. This needs to be refined when better data becomes available. It may not be too unrealistic if the regional coefficients do not vary significantly from the national coefficients.

Table 2 Hull economy: capital and labour income by sectors

	Capital Income	Employees	Labour Income	Total Income
Agriculture and Fishing	2,967,039.9592	12.09	158,841.04	3,125,881.00
Energy and Water	31,105,990.5520	725.14	9,530,462.45	40,636,453.00
Manufacturing	552,697,487.5440	25,017.19	328,800,954.46	881,498,442.00
Construction	69,288,056.2720	4,955.10	65,124,826.73	134,412,883.00
Distribution, hotels and restaurants	145,416,040.8560	29,368.01	385,983,729.14	531,399,770.00
Transport and communication	217,436,294.9680	6,526.22	85,774,162.03	303,210,457.00
Banking, Finance and insurance	187,469,532.5920	15,227.86	200,139,711.41	387,609,244.00
Public administration, education and health	299,357,583.2080	33,114.54	435,224,451.79	734,582,035.00
Other services	28,447,844.0080	5,921.94	77,832,109.99	106,279,954.00
Total	1,534,185,869.96	120,868.09	1,588,569,249.04	3,122,755,119.00

Derivation capital and labour income obtained following steps mentioned above. See excel file for details.

Table 3 Input–output coefficients for Hull

	Agric	Enrwtr	Manu	Const	Distb	Trans	Busi	Edupub	OthSect
Agric	0.086583	0.000604	0.035177	4.74E-05	0.003639	0.000487	5.68E-05	0	0.000832
Enrwtr	0.000826	0.120376	0.016645	0.004751	0.000677	0.000173	3.03E-05	0.13229	0.000321
Manu	0.203363	0.068337	0.202288	0.152745	0.102854	0.083622	0.043803	0.040461	0.056192
const	0.007105	0.00526	0.000636	0.249816	0.003891	0.001532	0.022375	0	0.000821
Distb	0.041515	0.017505	0.037544	0.016244	0.026867	0.025066	0.008611	0.008509	0.004443
Trans	0.010121	0.044796	0.027601	0.010509	0.09595	0.158739	0.065376	0.004386	0.017857
Busi	0.080511	0.049237	0.073745	0.124203	0.14469	0.125707	0.249916	0.045159	0.075562
Edupub	0.011525	0.006898	0.019606	0.003223	0.007749	0.008697	0.004566	0.294183	0.003965
OthSect	0.015615	0.001811	0.012468	0.002867	0.006459	0.013893	0.015504	0.004291	0.043622

Source: Input Output Table, ONS (1995); Aggregation as in Bhattarai (2005).

4. Derive the gross output of Hull using the above Leontief coefficients assuming that final demand to be equal to total value added as in Table 4. Then decompose this final demand into consumption, investment, government consumption and export components again based on approximations from the national input–output table as in Table 5 until such information is obtained from the primary survey in Hull.
5. Derive tax or imports components as residuals in the supply side – gross output minus intermediate, labour and capitals costs altogether.
6. For consistency of demand should equal supply for each sector as shown in constructed input output tables for Hull, East Riding, North Lincolnshire and North East Lincolnshire in Tables 6, 7, 8 and 9.

The gross output taking account of all intermediate transactions can be obtained using an input output model[3] as $X = (I - A)^{-1}F$. For Humber region the technology coefficient matrix A is taken from the national input–output table as in Table 3. Leontief inverse times the final demand equals the gross output of the economy in Table 4.

The input–output table for Hull emerging from above six-step derivations appears in Table 6. This is a very preliminary table and in my knowledge first such table for Hull. It should be taken very cautiously as a lot of information is taken from the national input–output table with only primary information on employment and output from the Humber Forum. For instance this estimation suggests gross output of Hull region to be equal to 5.5 billion in 2003. More work is required for splitting the residual costs between taxes and imports. Treating them as difference between the gross output and sum of labour, capital and intermediate costs is not very satisfactory. This requires company level data on taxes and imports. Similarly more work is required in determining the input–output coefficients and coefficients of final demand. Nevertheless, it gives some indication on how the different bits of

[3] Pyatt and Round (1979); Robinson (1991); Jackson (1998); Dietzenbacher and Stage (2006) have more on input_output model

Table 4 Gross output to Hull by production sectors

Agric	Ener	Manu	const	Distb	Trans	BusiFin	Edupub	OthSect	Total
62,648,983	242,181,122	1,452,733,597	218,010,053	647,427,906	587,275,170	1,025,074,800	1,107,405,717	166,690,690	5,509,448,037

Hull economy fit together and how the inter-sectoral relations should look like for a comprehensive understanding of the Hull economy. This can be important in a comprehensive, consistent and realistic assessment of economic policies in Hull. Similar methods are employed to construct the input–output tables for East Riding, North Lincolnshire and North East Lincolnshire as presented in Tables 7, 8 and 9, Excel files include these details.

The next sections will present how the input output model can be applied to assess the impacts of changes in the composition of demand or for manpower projections with the information on skill-industry matrices. That will be followed by some discussions on regional and dynamic general equilibrium models that can be applied based on the micro-consistent data set constructed above that reflect on economic behaviours based on the real price system for goods and factor markets of these four economies.

Impact Analyses and Manpower Projections with an Input–Output Model

The input output tables estimated in Tables 6, 7, 8 and 9 can provide a comprehensive framework to think about the much complicated economic relations among producers, consumers, investors and the public sector and the Rest of the World sectors and for the distribution of resources between workers and the owners of capital among production sectors in Humber. These can also be applied to estimate negative or positive impacts of public policy measures such as taxes and transfers that affect on output, employment and investment. The short run impacts of

Table 5 Structure of final demand for Hull IO table

	Consumption	Investment	Public spending	Exports	Total
Agric	0.772232	0.000115	0.004819	0.222834	1
Enrwtr	0.040784	0.00012	0.005654	0.953441	1
Manu	0.219586	0.097767	0.04372	0.638926	1
Const	0.921867	5.64E-05	0.074581	0.003495	1
Distb	0.062893	0.858263	0.078844	0	1
Trans	0.863897	0.020094	0.00955	0.106459	1
BusiFin	0.558103	0.022052	0.07465	0.345195	1
Edupub	0.727305	0.078453	0.078222	0.11602	1
OthSect	0.27582	6.32E-06	0.695715	0.028458	1

Table 6 Input–output table of Hull (preliminary version September 2006)

	Agric	Ener	Manu	const	Distb	Trans	BusiFin	Edupub	OthSect	Total IntD	Cons	Inv	Gov	Exp	FinDem	Gross Output
Agric	5,424,334	146,182	51,103,260	10,332	2,356,000	286,072	58,173	0	138,751	59,523,102	2,413,905	359	15,064	696,553	3,125,881	62,648,983
Ener	51,759	29,152,785	24,181,417	1,035,782	438,617	101,317	31,026	146,498,529	53,438	201,544,669	1,657,334	4,889	229,778	38,744,453	40,636,453	242,181,122
Manu	12,740,455	16,549,844	293,870,093	33,299,988	66,590,412	49,108,956	44,901,826	44,806,943	9,366,636	571,235,155	193,565,032	86,181,836	38,539,146	563,212,427	881,498,442	1,452,733,597
const	445,127	1,273,868	924,286	54,462,477	2,518,915	899,934	22,935,688	0	136,876	83,597,170	123,910,811	7,577	10,024,705	469,790	134,412,883	218,010,053
Distb	2,600,885	4,239,266	54,540,953	3,541,288	17,394,296	14,720,767	8,826,788	9,423,261	740,631	116,028,136	33,421,309	456,080,801	41,897,660	0	531,399,770	647,427,906
Trans	634,047	10,848,762	40,096,965	2,291,118	62,120,697	93,223,579	67,015,336	4,857,625	2,976,586	284,064,713	261,942,717	6,092,623	2,895,527	32,279,591	303,210,457	587,275,170
BusiFin	5,043,906	11,924,241	107,131,988	27,077,550	93,676,055	73,824,349	256,182,410	50,009,645	12,595,412	637,465,556	216,326,008	8,547,703	28,934,907	133,800,626	387,609,244	1,025,074,800
Edupub	722,037	1,670,647	28,482,588	702,575	5,016,943	5,107,570	4,680,990	325,779,390	660,943	372,823,682	534,264,949	57,630,395	57,460,555	85,226,136	734,582,035	1,107,405,717
OthSect	978,243	438,545	18,112,753	625,085	4,181,482	8,159,000	15,892,873	4,751,447	7,271,307	60,410,736	29,314,185	672	73,940,538	3,024,559	106,279,954	166,690,690
Total IntDem	28,640,792	76,244,139	618,444,303	123,046,194	254,293,417	245,431,543	420,525,111	586,126,840	33,940,580							2,386,692,918
Labour	158,841	9,530,462	328,800,954	65,124,827	385,983,729	85,774,162	200,139,711	435,224,452	77,832,110							1,588,569,249
Capital	2,967,040	31,105,991	552,697,488	69,288,056	145,416,041	217,436,295	187,469,533	299,357,583	28,447,844							1,534,185,870
Taxes	31,265,941	118,511,672	−46,141,443	−28,339,275	−134,049,400	30,906,536	157,066,037	−109,267,613	18,187,479							38,139,935
Imports	−383,631	6,788,858	−1,067,705	−11,109,749	−4,215,881	7,726,634	59,874,408	−104,035,545	8,282,676							−38,139,935
Gross output	62,648,983	242,181,122	1,452,733,597	218,010,053	647,427,906	587,275,170	1,025,074,800	1,107,405,717	166,690,690	2,386,692,918	1,396,816,251	614,546,854	253,937,879	857,454,135	3,122,755,119	

Table 7 Input–output table of East Riding (preliminary version September 2006)

	Agric	Ener	Manu	const	Distb	Trans	BusiFin	Edupub	OthSect	Cons	Inv	Gov	Exp	FinDem	Gross Output
Agric	25,267,934	123,704	42,455,598	14,280	2,277,232	245,991	50,538	0	110,998	170,886,181	25,392	1,066,452	49,310,693	221,288,717	291,834,991
Ener	241,106	24,670,047	20,089,453	1,431,577	423,953	87,122	26,954	104,707,348	42,749	2,170,601	6,403	300,939	50,743,395	53,221,337	204,941,645
Manu	59,348,301	14,005,023	244,141,580	46,024,656	64,364,117	42,228,370	39,008,879	32,025,005	7,493,089	144,545,774	64,356,770	28,779,323	420,582,039	658,263,905	1,206,902,925
const	2,073,514	1,077,989	767,878	75,273,803	2,434,701	773,845	19,925,592	0	109,498	183,340,677	11,211	14,832,735	695,109	198,879,733	301,316,553
Distb	12,115,589	3,587,407	45,311,567	4,894,493	16,812,759	12,658,261	7,668,354	6,735,117	592,487	32,415,454	442,354,481	40,636,698	0	515,406,632	625,782,665
Trans	2,953,551	9,180,580	33,311,782	3,166,605	60,043,836	80,162,155	58,220,196	3,471,905	2,381,199	217,789,452	5,065,645	2,407,455	26,838,518	252,101,070	504,992,879
BusiFin	23,495,803	10,090,685	89,003,180	37,424,486	90,544,215	63,480,924	222,560,848	35,743,548	10,076,034	171,964,767	6,794,854	23,001,323	106,362,585	308,123,530	890,543,254
Edupub	3,363,432	1,413,756	23,662,782	971,045	4,849,213	4,391,955	4,066,654	232,845,313	528,739	374,857,653	40,435,359	40,316,193	59,797,427	515,406,632	791,499,521
OthSect	4,556,908	371,111	15,047,724	863,944	4,041,684	7,015,854	13,807,081	3,396,017	5,816,875	21,632,997	496	54,565,917	2,232,035	78,431,444	133,348,642
Labour	9,647,823	9,647,823	184,380,610	48,239,113	249,771,407	55,742,975	100,766,147	377,337,062	35,375,350						1,070,908,309
Capital	211,640,894	43,573,514	473,883,295	150,640,620	265,635,225	196,358,095	207,357,383	138,069,570	43,056,094						1,730,214,691
imports	−63,650,855	82,475,457	34,059,348	−48,582,454	−131,286,684	33,477,865	157,170,426	−73,167,422	19,077,523						9,573,205
taxes	780,992	4,724,549	788,127	−19,045,613	−4,128,993	8,369,466	59,914,201	−69,663,942	8,688,007						−9,573,205
Gross output	291834991.5	204941645	1206902925	301316553.2	625782665.5	504992878.8	890543254.2	791499521.1	133348642	1,319,603,554	559,050,611	205,907,034	716,561,801	2,801,123,000	

changes in consumption, government spending, investment or the net exports in output, employment, capital stock and distribution of resources in the economy are captured by a multiplier matrix, $\Delta X = (I - A)^{-1} \Delta F$. For instance, a 10 percent change in the consumption demand of manufacturing products will impact the gross output, employment and capital accumulation by $\Delta X = (I - A)^{-1} \Delta C_{man}(0.1)$ or in employment by $\Delta L = \sum l_i (I - A)^{-1} \Delta C_{man}(0.1)$ or in capital stock by $\Delta K = \sum_i k_i (I - A)^{-1} \Delta C_{man}(0.1^i)$ with l_i and k_i as labour and capital coefficients for production in sector *i*.

One can ask similar questions about the impacts of changes in other components of final demand. These can include increase or decrease in net exports, investment or the public spending for all sectors or for some combination of them or for one of them on the partial basis as required by policy makers. Similarly when ideal occupation industry matrix is known from technical relations in production, the above input–output tables can also be applied to estimate the gap in various categories of manpower in these economies. If $M_{i,s}$ denotes the manpower of *s* skill category required form *ith* industry where *s* denotes such as engineers, scientists, economists, teachers, professionals and managers, skilled non-manual workers, skilled and semiskilled workers and unskilled workers, $M_{i,s}=IOM_{i,s}X_i$ can give a required projection of manpower to produce X_i goods with the industry occupation matrix $IOM_{i,s}$ which shows how many s skill category workers are required for industry i to produce X_i amount of goods. Comparing such estimate with the existing number of those workers gives an estimate of the manpower gap by skill categories. These projections can be important for indicating planning by schools, colleges and universities and training institutions. All of these analyses however are for short run because of constant relative price assumptions behind the input–output table.

Input–Output Table as a Micro-Consistent Dataset for Each Sub-Region

More important use of the IO table remains as a micro consistent data set to calibrate the general equilibrium model of an economy allowing income and substitution impacts to occur across sectors of any changes in relative prices and to illustrate how various components of the economy are coordinated by the market mechanism for allocation of scarce economic resources. The essence of such an economy is often reflected by a circular flow diagram in which demand for and the supply of goods and services respond to relative prices, income and expenditure balance for households and the public sector; saving equals investment; and net factor inflows from the Rest of the World sector equals the balance in the current account. More elaborately when one considers inter-dependence among regions, flows of trade in goods and services and factors of production among them can have significant influence in each of them. Such interactions have local as well as global consequences. Various scenarios behind the vision for a sustainable self-dependant, creative and productive advanced economy of Hull and Humber can be analysed more realistically in this framework. The consistency and coherency of an economic plan in this manner can spur innovative efforts required higher rates of economic growth.

Table 8 Input–output table of North East Lincolnshire (preliminary version September 2006)

	Agric	Ener	Manu	const	Distb	Trans	BusiFin	Edupub
Agric	3,662,300	80,906	28,077,835	7,676	1,399,997	178,139	31,282	0
Ener	34,946	16,134,984	13,286,077	769,476	260,638	63,091	16,684	78,823,409
Manu	8,601,863	9,159,724	161,462,031	24,738,378	39,569,776	30,580,468	24,145,357	24,108,337
const	300,532	705,039	507,833	40,459,874	1,496,805	560,394	12,333,360	0
Distb	1,756,017	2,346,276	29,966,619	2,630,803	10,336,149	9,166,718	4,746,488	5,070,178
Trans	428,084	6,004,387	22,030,610	1,702,059	36,913,753	58,050,932	36,036,602	2,613,641
BusiFin	3,405,450	6,599,625	58,861,888	20,115,763	55,664,777	45,970,905	137,758,670	26,907,647
Edupub	487,491	924,641	15,649,284	521,939	2,981,199	3,180,517	2,517,140	175,285,322
OthSect	660,472	242,718	9,951,751	464,372	2,484,747	5,080,663	8,546,180	2,556,512
Total IntDem	19,337,155	42,198,301	339,793,928	91,410,341	151,107,840	152,831,826	226,131,763	315,365,045
Labour	4,416,096	4,416,096	153,680,145	43,277,742	242,885,287	68,007,880	107,752,745	230,520,217
Capital	4,378,039	20,207,482	317,685,491	62,251,878	75,462,400	132,498,398	82,200,571	163,457,031
imp	14,342,866	63,574,560	−12,685,724	−25,129,902	−82,153,096	9,889,587	97,838,609	−58,143,850
tax	−175,986	3,641,824	−293,545	−9,851,590	−2,583,732	2,472,397	37,296,597	−55,359,744
Gross output	42298170.28	134038262.9	798180294.6	161958468.5	384718700.2	365700087.2	551220284.7	595838699.5

Static Regional General Equilibrium Model for Humber Region

I have developed specific models for Hull, East Riding, North Lincolnshire and North East Lincolnshire sub regions with the input–output tables constructed above.[4] Each model includes a representative household that demands goods and services from all nine sectors according to its preferences and budget constraints and pays taxes to the government and provides its labour and capital endowment to the producers. Each firm produces the optimal level of output to maximise its profit hiring workers and capital on marginal productivity principle. Each economy imports goods and services to provide for internal demand and it also exports to the Rest of the World based on the ratio of prices of imported and exported commodities.

The local government also uses its revenue to provide for public consumption. The equilibrium is attained by the Walrasian process in which relative prices adjust until the demand equals supply in each market. Each of these models is solved with GAMS/MPSGE software (Rutherford 1998). Likely impacts of labour and capital income taxes in the level of employment, output and capital stock by sectors are shown in Table 10. The results show size and proportions in terms of labour, capital, regional output and aggregate supply for each of these four regions. These are results of optimal choices made by producers given their technology and by consumers given their budget constraints with the market clearing prices assuring the general equilibrium in the regional economic system.

The first column lists sectors by regions; the next four columns represent labour, capital, domestic output and aggregate supply for each sector and region; the last four columns compare sizes of domestic output, aggregate supply, employment and

[4] See Scarf (1986); Kehoe (1985), Shoven and Whalley (1992), Zou (1996), Miller and Spencer (1977); Whalley (1985); Elbers (1992); Rutherford (1998); Bhattarai (2001); Bhattarai and Whalley (2000, 2006) for some developments in national and regional applied general equilibrium models.

Table 8 (continued)

OthSect	Total IntD	Cons	Inv	Gov	Exp	FinDem	Gross Output
65,900	33,504,035	6,791,111	1,009	42,381	1,959,634	8,794,135	42,298,170
25,381	109,414,685	1,004,258	2,962	139,233	23,477,124	24,623,578	134,038,263
4,448,724	326,814,659	103,505,463	46,084,206	20,608,124	301,167,843	471,365,636	798,180,295
65,010	56,428,849	97,284,282	5,949	7,870,550	368,839	105,529,620	161,958,469
351,766	66,371,013	20,021,831	273,226,065	25,099,791	0	318,347,687	384,718,700
1,413,742	165,193,809	173,216,847	4,028,915	1,914,747	21,345,770	200,506,278	365,700,087
5,982,245	361,266,969	106,013,577	4,188,921	14,179,955	65,570,863	189,953,316	551,220,285
313,918	201,861,451	286,541,495	30,908,821	30,817,731	45,709,202	393,977,248	595,838,699
3,453,538	33,440,953	12,613,132	289	31,814,692	1,301,389	45,729,502	79,170,455
16,120,224	1,354,296,423	806,991,996	358,447,137	132,487,203	460,900,664	1,758,827,000	3,113,123,423
27,379,796	882,336,005						882,336,005
18,349,706	876,490,995						876,490,995
11,900,966	19,434,015						19,434,015
5,419,764	−19,434,015						−19,434,015
79170455.36	3,132,557,438	806,991,996	358,447,137	132,487,203	460,900,664	1,758,827,000	

capital stock across regions relative to the Hull sub-region. Comparisons can be made across regions and sectors based on these equilibrium results. For instance, the Hull is larger than all other regions in business and finance, in education and public services, in transport and communications, and in other sectors. All other regions are bigger than Hull in agricultural sector. The North East Lincolnshire is smaller than Hull in all except the agriculture sector. Knowing levels of variables in this manner can itself become an important factor for policy making in both pubic and private sectors.

Input–Output Table and Dynamic General Equilibrium Model of Hull Economy

A dynamic general equilibrium model is developed for the Hull economy based on input–output table constructed above in which consumers and producers look far out in the future, up to 100 years. The consumption and production decisions are consistent to preferences of households and technology of firms and constraints they face in the process of optimisation. In the balanced steady state investment plans are consistent to the underlying growth process as well as the sectoral rates of depreciation of capital stocks.

There can be an adjustment towards this steady state once the economy deviates from this bringing disequilibrium into the system though all economic relations are fully consistent in equilibrium in the steady state. Ultimately capital accumulation and the natural rate of population growth are the driving forces of the model economy.[5]

[5] See Pyatt (1963); Becker (1980); Chamley (1985); King and Robson (1993); Judd et al. (2000) for theoretical dynamic equilibrium models, Rutherford (1998) and Bhattarai (2005) for applied dynamic multisectoral general equilibrium models.

Table 9 Input–output table of North Lincolnshire (preliminary version September 2006)

	Agric	Ener	Manu	const	Distb	Trans	BusiFin	Edupub
Agric	7,271,493	87,967	40,772,323	11,184	1,700,571	226,136	43,015	0
Ener	69,384	17,543,091	19,292,948	1,121,233	316,596	80,090	22,941	68,976,307
Manu	17,078,989	9,959,097	234,461,881	36,047,206	48,065,243	38,820,014	33,201,980	21,096,576
const	596,706	766,568	737,434	58,955,581	1,818,163	711,386	16,959,450	0
Distb	3,486,570	2,551,037	43,515,059	3,833,441	12,555,277	11,636,582	6,526,836	4,436,780
Trans	849,960	6,528,393	31,991,040	2,480,133	44,838,983	73,692,070	49,553,483	2,287,129
BusiFin	6,761,517	7,175,577	85,474,392	29,311,423	67,615,776	58,357,222	189,430,231	23,546,179
Edupub	967,913	1,005,335	22,724,603	760,537	3,621,251	4,037,470	3,461,288	153,387,609
OthSect	1,311,367	263,900	14,451,114	676,654	3,018,211	6,449,587	11,751,746	2,237,137
Total IntDem	38,393,900	45,880,965	493,420,793	133,197,392	183,550,072	194,010,558	310,950,971	275,967,717
Labour	2,708,849	7,223,598	196,843,045	76,750,728	211,290,241	82,168,427	97,518,573	197,745,995
Capital	31,063,771	31,052,038	516,884,991	78,603,324	166,963,103	167,748,961	183,919,927	133,225,681
Taxes	11,963,238	58,242,838	−47,009,274	−37,754,856	−91,606,162	16,244,571	119,885,636	−43,817,306
Imports	−146,788	3,336,400	−1,087,786	−14,800,907	−2,881,032	4,061,143	45,701,041	−41,719,199
Gross output	83,982,970	145,735,839	1,159,051,768	235,995,681	467,316,222	464,233,660	757,976,149	521,402,888

Tax distortions harm such economy and reduce the amount of capital accumulation and welfare level of households. For space regions the results of this dynamic model are presented in terms of growth rates of investment, capital stocks and output up to year 2100 in Figs. 1, 2 and 3. If the base year patterns continue, the growth rates of investment fall steadily in agriculture, construction, manufacturing, education and public sectors from around two percent in 2000 to about below 1.5 percent in year 2100, rise to about 2 percent rate for energy and water sector but fall continuously up to 2050 in business finance sector to pick up continuously by the second half of the century. Similar pattern is observed also in other sectors.

The growth rate of capital stock is shown in Fig. 2, which tends to converge to the steady state growth rate of 2 percent except in the agriculture sector where it continues to decline until the end of the model horizon. The growth rates of output declines, like that of investment, in agriculture, manufacturing, construction, distribution and education and public services sectors, but rises continuously in the utility (energy and water) and business finance sectors and turns upward towards the steady state in the transportation and communication sectors.

Similar projection can be made about the employment by sectors, relative prices of goods and factors of production, exports, imports, public revenue and expenditure and the level of welfare for households over the model horizon. It is not possible to discuss all of these results in one paper.

Conclusion

This paper shows how one can construct an input output table for four Humber sub regions with information on levels and share of employment and output provided by the Humber Forum using additional coefficients from the national input output table. It then illustrates how these can be applied to construct a multisectoral general equilibrium models specific for Hull, East Riding, North Lincolnshire and

Table 9 (continued)

OthSect	Total IntD	Cons	Inv	Gov	Exp	FinDem	Gross Output
97,661	50,210,350	26,080,291	3,875	162,760	7,525,695	33,772,620	83,982,970
37,612	107,460,203	1,561,049	4,605	216,429	36,493,553	38,275,636	145,735,839
6,592,745	445,323,732	156,724,940	69,779,355	31,204,217	456,019,524	713,728,036	1,159,051,768
96,341	80,641,629	143,215,785	8,758	11,586,527	542,982	155,354,052	235,995,681
521,296	89,062,878	23,789,476	324,640,878	29,822,990	0	378,253,344	467,316,222
2,095,082	214,316,272	215,902,975	5,021,767	2,386,602	26,606,045	249,917,388	464,233,660
8,865,331	476,537,649	157,071,763	6,206,386	21,009,294	97,151,056	281,438,500	757,976,149
465,207	190,431,212	240,717,248	25,965,825	25,889,302	38,399,302	330,971,676	521,402,888
5,117,939	45,277,655	19,872,383	455	50,125,039	2,050,379	72,048,256	117,325,911
23,889,214	1,699,261,580	984,935,909	431,631,905	172,403,159	664,788,535	2,253,759,508	3,953,021,088
31,603,241	903,852,697						903,852,697
40,445,015	1,349,906,811						1,349,906,811
14,695,865	844,552						844,552
6,692,576	−844,552						−844,552
117,325,911	3,953,021,088	984,935,909	431,631,905	172,403,159	664,788,535	2,253,759,508	3,953,021,088

Table 10 Sectoral and regional comparison of labour, capital, domestic output and supply: results from the regional general equilibrium model of Humber regions

	Labour	Capital	Domout	Supply	Domoutr	Supplyr	Labourr	Capitalr
AGRIC .HULL	158,841	2,967,040	62,336,060	61,952,430	1.000	1.000	1.000	1.000
AGRIC .ER	9,647,823	211,640,900	306,175,200	242,524,300	4.912	3.915	60.739	71.331
AGRIC .NL	2,708,849	31,063,770	76,604,060	76,457,270	1.229	1.234	17.054	10.470
AGRIC .NEL	4,416,096	4,378,039	25,995,670	40,338,540	0.417	0.651	27.802	1.476
ENER .HULL	9,530,462	31,105,990	196,647,800	203,436,700	1.000	1.000	1.000	1.000
ENER .ER	9,647,823	43,573,510	71,722,790	154,198,200	0.365	0.758	1.012	1.401
ENER .NL	7,223,598	31,052,040	105,905,900	109,242,300	0.539	0.537	0.758	0.998
ENER .NEL	4,416,096	20,207,480	46,986,580	110,561,100	0.239	0.543	0.463	0.650
MANU .HULL	328,801,000	552,697,500	890,588,900	889,521,200	1.000	1.000	1.000	1.000
MANU .ER	184,380,600	473,883,300	752,261,500	786,320,900	0.845	0.884	0.561	0.857
MANU .NL	196,843,000	516,885,000	704,120,000	703,032,200	0.791	0.790	0.599	0.935
MANU .NEL	153,680,100	317,685,500	509,698,200	497,012,500	0.572	0.559	0.467	0.575
CONST .HULL	65,124,830	69,288,060	228,650,000	217,540,300	1.000	1.000	1.000	1.000
CONST .ER	48,239,110	150,640,600	349,203,900	300,621,400	1.527	1.382	0.741	2.174
CONST .NL	76,750,730	78,603,320	250,253,600	235,452,700	1.094	1.082	1.179	1.134
CONST .NEL	43,277,740	62,251,880	186,719,500	161,589,600	0.817	0.743	0.665	0.898
DISTB .HULL	385,983,700	145,416,000	651,643,800	647,427,900	1.000	1.000	1.000	1.000
DISTB .ER	249,771,400	265,635,200	757,069,300	625,782,700	1.162	0.967	0.647	1.827
DISTB .NL	211,290,200	166,963,100	470,197,300	467,316,200	0.722	0.722	0.547	1.148
DISTB .NEL	242,885,300	75,462,400	466,871,800	384,718,700	0.716	0.594	0.629	0.519
TRANS .HULL	85,774,160	217,436,300	547,268,900	554,995,600	1.000	1.000	1.000	1.000
TRANS .ER	55,742,970	196,358,100	444,676,500	478,154,400	0.813	0.862	0.650	0.903
TRANS .NL	82,168,430	167,749,000	433,566,500	437,627,600	0.792	0.789	0.958	0.771
TRANS .NEL	68,007,880	132,498,400	334,464,700	344,354,300	0.611	0.620	0.793	0.609
BUSIFIN.HULL	200,139,700	187,469,500	831,399,800	891,274,200	1.000	1.000	1.000	1.000
BUSIFIN.ER	100,766,100	207,357,400	627,010,200	784,180,700	0.754	0.880	0.503	1.106
BUSIFIN.NL	97,518,570	183,919,900	615,124,100	660,825,100	0.740	0.741	0.487	0.981
BUSIFIN.NEL	107,752,700	82,200,570	387,810,800	485,649,400	0.466	0.545	0.538	0.438
EDUPUB .HULL	435,224,500	299,357,600	1,126,215,000	1,022,180,000	1.000	1.000	1.000	1.000
EDUPUB .ER	377,337,100	138,069,600	804,869,500	731,702,100	0.715	0.716	0.867	0.461
EDUPUB .NL	197,746,000	133,225,700	524,722,800	483,003,600	0.466	0.473	0.454	0.445
EDUPUB .NEL	230,520,200	163,457,000	608,273,300	550,129,500	0.540	0.538	0.530	0.546
OTHSECT.HULL	77,832,110	28,447,840	155,383,500	163,666,100	1.000	1.000	1.000	1.000
OTHSECT.ER	35,375,350	43,056,090	112,039,100	131,116,600	0.721	0.801	0.455	1.514
OTHSECT.NL	31,603,240	40,445,010	108,583,000	115,275,500	0.699	0.704	0.406	1.422
OTHSECT.NEL	27,379,800	18,349,710	65,968,100	77,869,070	0.425	0.476	0.352	0.645

ER = East Riding, NL = North Lincolnshire, NEL = North East Lincolnshire

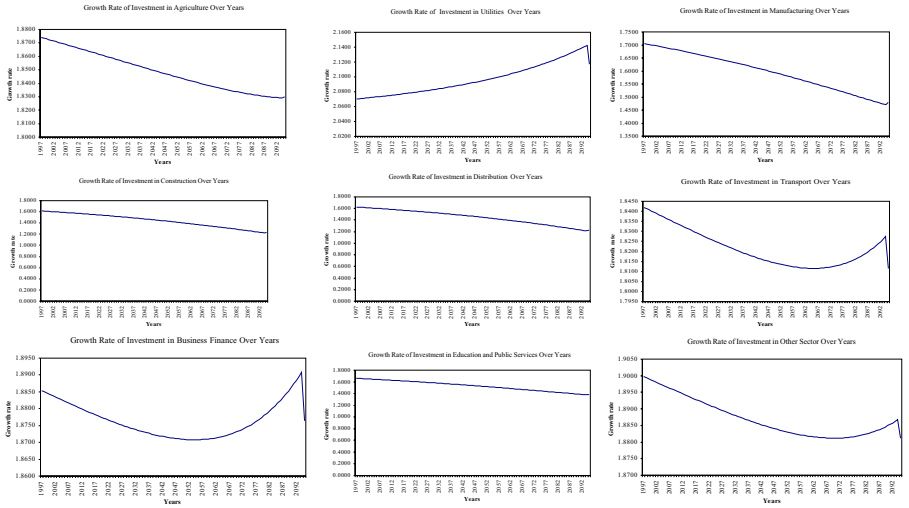


Fig. 1 Growth rates of investment by sectors in Humber region GE model over 21st century

North East Lincolnshire regions situated in two sides of the Humber estuary in England. The regional model of Humber is made of these four inter-dependent economies. A dynamic model is constructed for Hull to assess the prospects in the next 100 years based on micro consistent dataset in which households and firms are assumed to have perfect foresight in their consumption and production decisions. These models are then applied to evaluate impacts of tax policies that distort relative prices of commodities and factors of production and thus are harmful for efficient

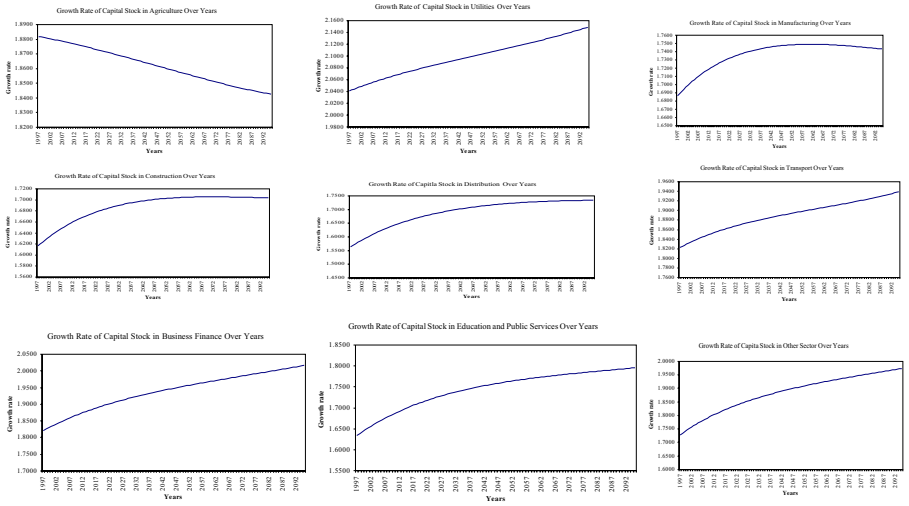


Fig. 2 Growth rates of capital stock by sectors in Humber region GE model over 21st century

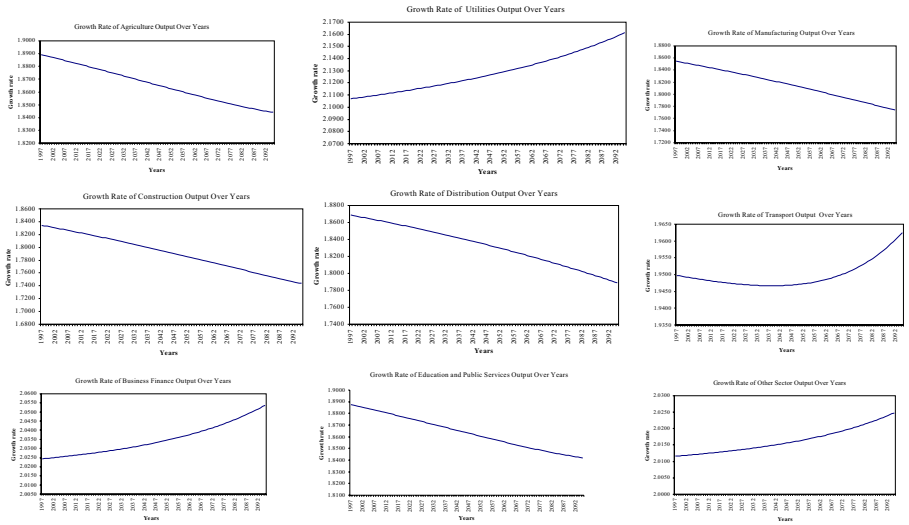


Fig. 3 Growth rates of output by sectors in Humber region GE model over 21st century

allocation of scarce economic resources and on the welfare of households in the Humber economy over next 100 years. To my knowledge this is the first study of this type for this region.

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