Economic Modeling of Residual Generation for the Lingayen Gulf Watershed

Douglas H. McGlone and **Herminia R. Caringal**
Marine Science Institute, College of Science, University of the Philippines
Velasquez St., U.P. Campus, Diliman, Quezon City 1101 Philippines
Tel. No. (632) 922-3921; TelFax: (632) 924-7678

ABSTRACT

The Philippines is one of four countries involved in the Southeast Asian core project of LOICZ (Land Ocean Interactions in the Coastal Zone) which has among its general goals the determination of how changes in human activities affect the fluxes of materials between land, sea, and atmosphere through the coastal zone. The economic component of the Philippine project addresses the question: "How does a change in economic activity affect coastal waters?" Of particular concern is the introduction of anthropogenically-derived residuals (N, P, C, SS) into coastal waters.

A regional input-output (IO) model for Region 1 of the Philippines has been developed to estimate how projected changes in economic activity may affect residual flows into Lingayen Gulf. A residual coefficient matrix, derived from information obtained with a rapid assessment model (RA) of residual generation in the Lingayen Gulf watershed, has been incorporated into the IO model. Such a model allows for analysis of various economic scenarios for the region, with projections of residual generation as the output. The resulting changes in residual flows may then serve as inputs to biogeochemical models of Lingayen Gulf. From this process, the impact of various economic scenarios on the water quality of Lingayen Gulf may be ascertained.

This paper discusses and compares the RA and IO models of residual generation for the Lingayen Gulf watershed and provides examples of the scenario analysis process.

Keywords: economic modeling, Lingayen Gulf, rapid assessment watershed, residual generation

INTRODUCTION

Changes in land use, climate, sea level, and human activities alter the fluxes and retention of nutrients in the coastal zone. How these changes can be quantified or determined is a general goal of the LOICZ (Land-Ocean Interactions in the Coastal Zone). This project has devised a methodology for creating simple biogeochemical budget models for coastal waters (Gordon and others 1996), with the ten-year objective of obtaining enough of these budgets throughout the world to estimate the net flux of carbon from coastal waters to the deep ocean waters.

A complicating factor in the biogeochemical modeling of residual fluxes in coastal waters is that a substantial portion of the residuals entering these waters are generated by economic activity within the relevant watershed. As economic activity changes, so will the amount of residuals entering the coastal waters. Thus, changing economic activity has the potential of altering the overall flux of carbon from coastal to deep ocean waters. This paper describes the basic economic sub-model for the Philippines.

Residual generation models

How will a change in economic activity affect the flow of residuals (C, N, P, SS) into coastal waters? A methodology is needed that is generally applicable and available across a wide variety of sites. For many of these sites, data is scarce in a number of areas. With these factors in mind, we begin with rather simple models. For site-specific purposes, these models may be expanded as data allows.

A regional economic activity model may be used to estimate the generation of residuals (James 1985). In its simplest form, residual discharges are given as:

$$r = CX \qquad (1)$$

where

r = a matrix of residual discharges (residual type by economic activity)
C = a matrix of residual discharge coefficients with c_{kj} = the quantity of residual k per unit of sectoral activity j
X = a diagonal matrix of sectoral activity levels.

Total discharges of each residual type are then given by:

$$R = rS = CX \qquad (2)$$

where

R = a vector of residuals by type (summed across all activities)

S = a summation vector.

So, each element of the column vector R represents the sum of the corresponding row in the r matrix. That is, the total discharge of residual type k is the sum of each activity's discharge of residual k.

In the above formulation, X is simply an exogenous estimation of output for each activity in the region. The model may be expanded by allowing economic activity to be represented by a regional input-output model. In such a model, production (X), or supply, is equated to the sum of intermediate (inter-industry) demand (AX) and final demand (Y):

$$X = AX + Y \qquad (3)$$

with

A = $[a_{ij}]$ where a_{ij} is the Leontif IO technical coefficient and

$a_{ij} = z_{ij}/X_j$, where z_{ij} is the monetary value of the input flow from sector i to sector j (3a)

Manipulation of equation 3 yields

$$X = (I - A)^{-1} Y \qquad (4)$$

where

$(I - A)^{-1}$ represents the Leontif inverse matrix.

Substituting equation 4 into equation 2 gives

$$R = C (I - A)^{-1} Y \qquad (5)$$

The total change in residual generation brought about by a change in one or more components of final demand are determined by

$$\Delta R = C (I - A)^{-1} \Delta Y \qquad (6)$$

In equations 5 - 6, matrix R represents the amount of residuals generated during both direct activities and the indirect "support" activities. For example, if fish aquaculture is the direct activity being addressed, agricultural activity may be considered an indirect or support activity, since aquaculture feeds are often derived from agricultural output. Thus, an increase in aquaculture may increase nitrogen loading into coastal waters not only from the application of feeds, but also by increased use of fertilizers in the agricultural sector.

Equations 2 and 5 - 6 represent two alternative but related approaches to addressing the question of how economic activity affects the generation of residuals. Equations 5-6 represent the input-output (IO) modeling approach, which has often been employed by economists in the past 30 years to describe residual flows (Forsund and Strom 1976, Mendoza 1994, Orbeta and others 1996, Miller and Blair 1985). Equation 2 represents the rapid assessment (RA) method utilized by WHO (Economopoulos 1993), which may readily be incorporated into a geographical information systems (GIS) modeling approach such as that discussed in Turner et al. (1997).

Each approach has its strengths and weaknesses. A favorable aspect of the IO approach is that it captures the interrelationships between sectors of the economy. A change in activity of one sector typically requires changes in activity in other sectors. These interrelations are not captured in the RA modeling approach, and thus, may lead to an underestimation of residual discharges. On the other hand, data constraints typically require a considerable degree of aggregation of economic sectors in regional IO models. An RA/GIS model allows for a considerable degree of disaggregation, and allowance for consideration of spatial relationships. These relationships may be of particular importance when taking account of environmental assimilation of residuals.

Input-output model

A 12-sector (with the household sector endogenized) regional IO model was created for Region I of the Philippines. This regional model was based on the 229-sector 1994 national model, adjusted using the simple location quotient method of reduction (Secretario 1999).

Highlights of the input-output model components
This section gives a brief description of the development and the components of the regional IO model. Table 1 identifies the 11 production sectors and the household sector as used in the model. Table 2, the 1994 regional 12 x 12 sector IO table for Region 1 of the Philippines, (rows 1-12 and columns 1-12, collectively referred to as the production sector), shows the inter-industry flow of goods (including an endogenized household sector).

Table 1. Sectoral description (Ilocos region I/O table)

Code	Description
1	Agriculture
2	Fishery
3	Forestry
4	Mining and quarrying
5	Manufacturing I
6	Manufacturing II
7	Electricity, gas and water
8	Waterworks and supply
9	Construction
10	Transportation, communication and storage

Such an inter-industry transactions table is derived from a larger set of income and production accounts for a region (Secretario 1999).

Each element of the transactions table (the z_{ij} terms of equation 3a, expressed in monetary units) represents the sale (supply) of sector i's outputs to sector j for use as inputs to j's production process. Thus, by reading row 1 it is seen that sector 1 supplies an amount of 2,399,734 to sector 1 (itself), 200 to sector 2, 20 to sector 3, etc.

The columns show the amount each sector purchases (demands) from all other sectors. Thus, sector 2 demands (or buys) an amount 200 from sector 1; 149,876 from itself; 0 from sector 3; etc. Such demand of one production sector for the output of other producing sectors for use as inputs is termed intermediate demand, and is represented by the "AX" vector in equation 3.

Table 2 is an account of the amounts that each sector demands from other sectors in order to satisfy their own production processes. That is, the inter-industry transactions table (in particular, the columns) represents intermediate demands. The values for the AX vector are determined by the summation of each row sector. Thus, the right-most column, labeled "Total Intermediate Demand," is the AX column vector of equation 3. The column sum of each production sector is termed "Total Intermediate Inputs." Table 2 can be expanded in a variety of ways. First, there are inputs to the production process that must be paid for, other than those produced by other industries. The primary example of these value-added items is employee compensation. For the

Table 2. Sector Transaction Table, 1994 (Ilocos Region, in thousand pesos)

Code	1	2	3	4	5	6	7	8	9	10	11	12	TID
1	2399734	200	20	0	321644	29426	0	0	0	0	98986	2390321	2850010
2	355	149876	0	2	24348	58	0	0	0	0	49333	1753267	223972
3	0	0	198	3434	11515	3655	578	2	1300	1	1	0	20684
4	424	26	0	0	298	250847	1719	0	225440	19	1591	0	480364
5	1012232	178397	15	18169	580905	250994	746	262	357665	6455	719863	19751759	3125703
6	1590268	252689	1964	189395	307513	1675043	132909	5289	3373165	730750	1126510	5347774	9385495
7	141534	26811	47	4900	81811	303896	10479	4745	101783	38259	621418	1329913	1335683
8	4365	0	0	43	11752	181	0	0	11383	7522	85954	238703	121200
9	6431	11332	24	12449	24846	64531	4788	1579	309322	59068	955612	75468	1449982
10	354229	57705	1028	12837	86840	132922	0	478	592956	60972	776879	4708613	2076846
11	743945	62340	677	49014	302584	397675	40736	2932	995823	449427	2545190	19915057	5590343
12	9280960	1006353	15163	242978	463976	472364	83561	12366	1304463	889417	12091316	0	25862917
TII	15534477	1745729	19136	533221	2218032	3581592	275516	27653	7273300	2241890	18924333	55510875	52523199
NHOA	8187868	1151556	16	407850	848347	1665256	187065	16110	2412551	806845	19189624	0	25278276
TPI	8187868	1151556	16	407850	848347	1665256	187065	16110	2412551	806845	19189624	0	25278276
TI	23722345	2897285	19152	941071	3066379	5246848	462581	43763	9685851	3048735	57335230	55510875	77801475

Note:

TII: Total Intermediate Inputs; NHOA: Non-Household Operating Activities; TPI: Total Primary Inputs; TI: Total Inputs; TPI = NHOA; TID = Total Intermediate Demand; TI = TII + TPI

Table 3. 12 sector transaction table (Ilocos Region 1994, in thousand pesos)

Code	PCE	GCE	GFCF	CS	E - M	TFD	TO
1	2390321	0	1983520	177951	16320543	20872335	23722345
2	1753267	0	0	0	920046	2673313	2897285
3	0	0	0	0	-1532	-1532	19152
4	0	0	0	11790	448917	460707	941071
5	19751759	0	0	166076	-19977159	-59324	3066379
6	5347774	0	1235028	21615	-10743064	-4138647	5246848
7	1329913	0	0	0	-2203015	-873102	462581
8	238703	0	0	0	-316140	-77437	43763
9	75468	0	5809729	0	2350672	8235869	9685851
10	4708613	0	229882	0	-3966606	971889	3048735
11	19915057	6704644	536392	0	-4078971	23077122	28667465
12	0	0	0	0	0	0	25862917
TII	55510875	6704644	9794551	377432	-21246309	51141193	103664392
NHOA	0	0	0	0	0	0	25278276
TPI	0	0	0	0	0	0	25278276
TI	55510875	6704644	9794551	377432	-21246309	51141193	

Note: PCE: Private Consumption Expenditures; GCE: Government Consumption Expenditures; GFCF: Gross Fixed Capital Formation; CS: Change in Stocks; E-M: Net Export; TFD: Total Final Demand; TO: Total Output

The column sums X_j are represented in Table 2 by the Total Input (TI) row. It should be noted that the column sum X_j is the sum of all inputs – those of both – the production and payment sectors.

The technical coefficient a_{ij} may be interpreted as the (currency unit's) worth of sector i input per (currency unit)'s worth of output of sector j. The technical coefficients are viewed as representing a fixed relationship between a sector's outputs and its inputs. If technology changes, then the values for the technical coefficients will change.

purposes of this model, other categories are lumped together under operating surpluses. This collection of inputs is known as the payments, or value-added sector.

A second point of expansion for Table 2 is to include the final demand sectors (Table 3). Final demands are demands derived from sources outside the production sector of the region. Final demand sectors include personal consumption expenditures of households (PCE), government consumption expenditures (GCE), business investment (gross fixed capital formation, GFCF), and net exports (E-M) to other regions (both domestic and international). An adjustment for changes in stock inventory (CS) is also included. Final demands are summed up across rows to give the Total Final Demand column vector (TFD in Table 3), denoted as 'Y' in equation 3. Adding the intermediate and final demand column vectors gives the total output (TO) column vector (the right-most column of Table 3, for sectors 1-12), denoted as 'X' in equation 3.

Table 4 is the technical coefficient matrix, represented by the matrix 'A' in equation 3. To derive this matrix, each of the z_{ij} elements of Table 2 is divided by the appropriate column sum X_j, as shown in equation 3a.

An alternative definition of the technical coefficient is that it indicates the portion of a column sector j's input demand that is provided for by row sector i. Thus, sector 1 (agriculture) provides 10% of it's own input demand.

The vector and matrix requirements of equation 3 are now provided for. To gain the form of equation 3, the Leontif inverse matrix $(I – A)^{-1}$ is created (Table 5). The elements of the Leontif inverse are known as output multipliers. Each element indicates the value of the change of a row sector's output due to a unit change in final demand for the column sector's output. This may be seen by rearranging equation 4 to give

$$dX / dY = (I – A)^{-1} \tag{7}$$

A low column sum reveals a weak sectoral inter-linkage; otherwise, it shows a sector's strong dependence on the other sectors' output to meet a unit increase in final demand for its output. The sector with the largest multiplier provides the largest total impact on the economy.

Table 4. 12 sector technical coefficient table (Ilocos region 1994, in thousand pesos)

Code	Description	1	2	3	4	5	6	7	8	9	10	11	12
1	Agriculture	0.101159	0.000069	0.001044	0.000000	0.104894	0.005608	0.000000	0.000000	0.000000	0.000000	0.001726	0.043060
2	Fishery	0.000015	0.051730	0.000000	0.000002	0.007940	0.000011	0.000000	0.000000	0.000000	0.000000	0.000860	0.031584
3	Forestry	0.000000	0.000000	0.010338	0.003649	0.003755	0.000697	0.001250	0.000046	0.000134	0.000000	0.000000	0.000000
4	Mining and quarrying	0.000018	0.000009	0.000000	0.000000	0.000097	0.047809	0.003716	0.000000	0.023275	0.000006	0.000028	0.000000
5	Manufacturing I	0.042670	0.061574	0.000783	0.019307	0.189443	0.047837	0.001613	0.005987	0.036927	0.002117	0.012555	0.355818
6	Manufacturing II	0.067037	0.087216	0.102548	0.201255	0.100285	0.319247	0.287320	0.120856	0.348257	0.239690	0.019648	0.096337
7	Ekectricity, gas & water	0.005966	0.009254	0.002454	0.005207	0.026680	0.057920	0.022653	0.108425	0.010508	0.012549	0.010838	0.023958
8	Waterworks & supply	0.000184	0.000000	0.000000	0.000046	0.003833	0.000034	0.000000	0.000000	0.001175	0.002467	0.001499	0.004300
9	Construction	0.000271	0.003911	0.001253	0.013229	0.008103	0.012299	0.010351	0.036081	0.031935	0.019375	0.016667	0.001360
10	Transpo., comm & storage	0.014932	0.019917	0.053676	0.013641	0.028320	0.025334	0.000000	0.010922	0.061219	0.019999	0.013550	0.084823
11	Other services	0.031361	0.021517	0.035349	0.052083	0.098678	0.075793	0.088062	0.066997	0.102812	0.147414	0.044391	0.358760
12	Household sector	0.391233	0.347343	0.791719	0.258193	0.151311	0.090028	0.180641	0.282567	0.134677	0.291733	0.210888	0.000000

Table 5. 12 X 12 leontief inverse matrix (Total Output Multiplier)

Code	Description	1	2	3	4	5	6	7	8	9	10	11	12
1	Agriculture	1.197679	0.079294	0.138001	0.061491	0.203582	0.062275	0.052399	0.064370	0.063039	0.070612	0.043342	0.155672
2	Fishery	0.027619	1.079175	0.047625	0.019489	0.029987	0.015293	0.016401	0.021293	0.018029	0.023074	0.014769	0.055182
3	Forestry	0.001974	0.001923	1.013439	0.005313	0.006210	0.002741	0.002831	0.001788	0.002187	0.001862	0.000948	0.003196
4	Mining and quarrying	0.018857	0.019369	0.030140	1.025410	0.021768	0.083158	0.034385	0.023938	0.062102	0.030718	0.009353	0.024153
5	Manufacturing I	0.409252	0.393299	0.612923	0.287339	1.505037	0.281044	0.236337	0.292850	0.305950	0.318165	0.193308	0.696315
6	Manufacturing II	0.378036	0.387541	0.604542	0.510188	0.430460	1.711726	0.619669	0.459028	0.776373	0.613780	0.177894	0.480346
7	Ekectricity, gas & water	0.065546	0.066143	0.098984	0.062159	0.088148	0.125171	1.082861	0.166997	0.084734	0.081576	0.040390	0.096521
8	Waterworks & supply	0.005779	0.005077	0.009378	0.004106	0.008953	0.003570	0.003487	1.004405	0.005375	0.007360	0.004344	0.010531
9	Construction	0.020056	0.022988	0.033802	0.032147	0.029976	0.035140	0.030099	0.057150	1.058057	0.043700	0.027670	0.031680
10	Transpo., comm & storage	0.109571	0.105949	0.212686	0.087720	0.110908	0.094690	0.068007	0.090296	0.142282	1.109046	0.061434	0.174973
11	Other services	0.407030	0.361304	0.674161	0.340652	0.418986	0.344071	0.350271	0.384853	0.413080	0.494831	1.234874	0.706772
12	Household sector	0.714532	0.630372	1.257144	0.503344	0.510287	0.378482	0.423220	0.554991	0.452823	0.599046	0.361110	1.462215
TOM	Total Output Multiplier	3.356	3.152	4.733	2.940	3.364	3.137	2.920	3.122	3.384	3.394	2.170	3.898

Residual coefficient matrix. The basic components of the IO model are now provided for. The next step in modeling residual generation with the IO model is to create the residual coefficient matrix 'C' of equation 1. This first required the quantification of residual generation in the study site, and then applying the information to equation 3a.

A rapid assessment (RA) approach was used to estimate residual generation in the Lingayen Gulf watershed. The first step in building RA model is to identify the relevant economic sectors for each residual type. The level of activity for each sector is determined, and then matched with the appropriate residual discharge coefficient, as in equation 2. Residual discharge coefficients may be obtained from a variety of general sources, notably the World Health Organization (Economopoulos 1993), or from specific studies of particular sites (e.g. Hinga and others 1991, Valiela and others 1997). When possible, however, discharge coefficients were obtained from local studies. Padilla et al. (1997) proved to be a valuable starting point in obtaining discharge coefficients that could be applied to the Lingayen Gulf watershed.

With appropriate data, a spatial dimension may be attached to each activity sector to allow a better account for assimilation of residuals as they pass from their point of origin, through the natural environment, and into the coastal waters. Some studies (e.g. Valiela and others 1997, Hinga and others 1991, Jaworski and others 1992) have accounted for assimilation by simply attaching fixed assimilation coefficients to each step of a residual's movement through the environment. In this case the coefficient represents assimilation for an 'average' distance to the coastal waters. Assimilation estimates may be incorporated directly into the residual coefficient (as in this study) or placed in their own distinct matrix.

A detailed description of the creation of the residual coefficients may be found in the SWOL Philippine Core Research Site 1998 Annual Report. The resulting residual coefficient matrix is given in Table 6. The set of total residual generation entering coastal waters is given in Table 7.

While the estimates of residual generation from the rapid assessment exercise are at best 'guesstimates', the quality of the estimates may be ascertained to some degree by comparing the values obtained with the results from biogeochemical modeling. The results shown in Table 8 indicate the ambient concentrations of N, P, C, and SS in the water column, and the percentage of the ambient concentration that may be attributed to economic activity. The numbers appear reasonable.

Analogous to the concept of the output multiplier is that of the residual multiplier. The residual multiplier matrix M is given as:

$$M = C\ (I-A)^{-1} \qquad (8)$$

The elements of $M = [m_{kj}]$ show the amount of residual k generated for a one unit change in final demand in sector j. These residual multipliers are provided in Table 9. As an example, in order to service a one unit (in the tables presented, one unit is equivalent to P 1,000 which was equivalent to about US $40.) increase in agricultural final demand, approximately 0.00057 metric tons (or 0.57 kg) of nitrogen will be discharged into coastal waters.

The residual coefficient matrix is created from a pre-existing estimate of residual generation. This is then allocated among the sectors of the IO model. Thus, the estimates of residual generation for the given levels of economic activity represented by the IO model are as good as (in fact the same) the estimates provided by the RA exercise. It is hoped that, despite the high level of aggregation in the IO models, estimates of changes in residual flows brought about by changes in economic activity will be better than estimates given by RA model.

Scenario analysis

With the completion of the residual coefficient matrix, and using the model of equations 5 - 6, we are now prepared to perform some scenario analyses.

Scenario analysis may take the form of projecting changes in final demand (ΔY in equation 6). The result will be an estimate of the overall change in residual generation brought about by the change in economic activity necessary to service the change in final demand. Two scenarios are presented for the 12-sector model (Table 10) for the purpose of

Table 6. 12 X 12 residual coefficient matrix

Descriptiom	1	2	3	4	5	6	7	8	9	10	11	12
N	0.000413	0.000021	0.000000	0.000000	0.000023	0.000000	0.000000	0.000000	0.000000	0.000000	0.000012	0.000088
P	0.000234	0.000019	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000005	0.0001145
SS	0.1157700	0.000023	0.000000	0.022030	0.000208	0.000000	0.000000	0.000000	0.000000	0.000000	0.0023111	0.000000
C	0.000000	0.000003	0.000000	0.000000	0.000223	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0010139

Table 7. Effluents produced by economic activities in Lingayen Gulf (in metric tons per year)

Economic Activity	Carbon/BOD5	SS	Nitrogen	Phosphorus
Household activities				
- domestic sewage	56,284	-	4,912	6,176
- solid waste	19,536	-	4,467	2,680
- detergents	36,748	-	445	350
	-	-	-	3,146
Urban Runoff				
Non-point Agricul-	-	66,253	354	149
tural Runoff	-	2,743,592	9,706	1,553
- crop fertilization				
- cropland erosion	-	-	5,097	-
	-	2,743,592	4,609	1,553
Livestock				
- commercial piggery	-	-	83	69
- poultry	-	2,194	71	69
	-	493	12	-
Aquaculture				
Erosion	7,876	66	61.7	55
Mining	-	-	4,609	-
	-	20,732	-	-
Total				
	64,160	**2,830,643**	**19,725.7**	**8,002.0**

Table 8. Estimation of total material concentrations in Lingayen Gulf and those contributed by economic activities

Material	Ambient concentration	Concentration derived from economic activities (% constribution) 3
DIN	0.81[1] µmol/L	0.33 •mol/L (41)
DIP	0.12[1] µmol/L	0.04 •mol/L (33)
TSS	2.5± 4.5 mg/L	2.6 mg/L (37-100)
	6.3 mg/L[2]	

Table 9. Residual multiplier matrix for 12 sector I/O model

DESCRIPTION	1	2	3	4	5	6	7	8	9	10	11	12
N	0.000573	0.000125	0.000192	0.000081	0.000170	0.000070	0.000069	0.000088	0.000079	0.000096	0.000070	0.000220
P	0.000365	0.000113	0.000181	0.000074	0.000109	0.000060	0.000063	0.000081	0.000069	0.000088	0.000058	0.000209
SS	0.140097	0.010548	0.018327	0.030556	0.025330	0.009896	0.007683	0.008930	0.009685	0.010062	0.008118	0.020334
C	0.000816	0.000730	0.001411	0.000574	0.000853	0.000446	0.000482	0.000628	0.000527	0.000678	0.000409	0.001638

demonstrating the workings of the model, and making a comparison with results from a simpler rapid assessment (RA) approach.

1. 53% growth in the net export of agriculture, translates into a 20% growth in final demand for agriculture. Final demand for all other sectors is held constant. Table 11 shows that total output changes in all sectors.

2. 20% across-the-board growth in total final demands.

This is a clear indication of the interrelationships present in the economy. The resulting changes in residual generation is shown in Table 12. The rapid assessment model would estimate lower increases in each residual (the increase in agricultural output necessary to meet the increased final demand, multiplied by the residual coefficients for agriculture). The RA model would predict a 10% increase in N, a 7.1% increase in P, a 15.1% increase in SS, and no change in C. Thus, the rapid assessment model would seem to underestimate residual generation by 28 % for N, 36 % for P, 17.4% for SS, and would completely ignore any changes in C.

The second scenario again shows how the rapid assessment model may under-estimate residual generation (Table 12). The RA method essentially estimates a change in residuals equal to the change in sectoral output (set equal to the change in final demand) multiplied by the sector's share in residual generation (e.g., the 20% increase in final demand for agriculture would be equivalent to a 15.6% increase in agricultural output. This would be multiplied by the 64.4% share that agriculture has in the generation of

Table 10. Changes in the total final demand (ΔY) 12 sector regional model, 1994 (in thousand pesos)

Code	Description	Scenarios 1	Scenarios 2
1	Agriculture	3696402.80	3696402.80
2	Fishery	0.00	184009.20
3	Forestry	0.00	306.40
4	Mining and quarrying	0.00	92141.40
5	Manufacturing I	0.00	3962216.60
6	Manufacturing II	0.00	1897284.20
7	Electricity, gas and water	0.00	440603.00
8	Waterworks and supply	0.00	63228.00
9	Construction	0.00	1632080.20
10	Transportation, communication and storage	0.00	747344.80
11	Other services	0.00	632413.00
12	Households	0.00	0.00

Table 11. Incuded changes in total output (ΔX) (in thousand pesos)

Code	Initial X	Scenario 1 ΔX	Scenario 1 $\Delta\%$	Scenario 2 ΔX	Scenario 2 $\Delta\%$
1	23722345	4427104.603	18.66	5582417.598	23.53
2	2897285	102089.450	3.52	514890.217	17.77
3	19152	7297.831	38.10	45178.466	235.89
4	941071	69704.380	7.41	558673.958	59.37
5	3066379	1512760.299	49.33	9090308.156	296.45
6	5246848	1397374.316	26.63	8609449.000	164.09
7	462581	242285.253	52.38	1559430.644	337.12
8	43763	21363.099	48.82	146986.036	335.87
9	9685851	74134.871	0.77	2060646.255	21.27
10	3048735	405017.947	13.28	2187334.982	71.75
11	28667465	1504548.147	5.25	5919144.825	20.65
12	25862917	2641199.414	10.21	7180584.346	27.76

Table 12. Induced changes in residual generation, ΔR (in metric tons)

#	Initial R	IO Model Scenario 1 ΔX	IO Model Scenario 1 $\Delta\%$	IO Model Scenario 2 ΔX	IO Model Scenario 2 $\Delta\%$
N	15189	2116.829	13.90	3236.472	21.30
P	12117	1349.224	11.10	2170.397	17.90
SS	2833967	517855.724	18.30	674166.894	23.90
C	56976	3015.140	4.75	9306.558	16.30

#	Initial R	Rapid Assessment Method Scenario 1 ΔX	Rapid Assessment Method Scenario 1 $\Delta\%$	Rapid Assessment Method Scenario 2 ΔX	Rapid Assessment Method Scenario 2 $\Delta\%$
N	15189	1525	10.0	1630	10.7
P	12117	866	7.1	873	7.2
SS	2833967	427933	15.1	432253	15.3
C	56976	0	0.0	883	1.5

nitrogen, to give an estimated 10% increase in nitrogen generation). The RA method would underestimate nitrogen generation by 49%, phosphorus by 60%, suspended solids by 36%, and carbon by 90%.

The above scenarios serve to demonstrate how the rapid assessment methodology represented by Equations 1 and 2 may result in a significant underestimation of residual generation. The input-output model, by capturing intersectoral linkages, provides a more thorough assessment of the changes in activities that lead to residual generation. It should be noted that the economy of the study site is dominated by agriculture, with relatively little industrial development. In an economy with a more robust industrial sector, particularly in the agricultural product-based Manufacturing 1 sector, the inter-linkages among residual-generating sectors would be stronger, and the relative value of the input-output model would be that much greater.

One potential weakness of the specific IO model is that, because of time and data constraints, there is no distinction in the transaction table between commodities produced within the region and those imported from other regions, whether domestic or international in origin. This provides no great obstacle in using the IO model for estimating residual generation. One must simply assume that during conditions of changing demand, the mix of regionally and non-regionally sourced inputs does not change. This assumption is an extension of the typical IO assumption that the technological input mix is constant (that is, the coefficients of the A matrix are constant). Of course, over longer time horizons, these assumptions become less tenable. Typically, however, governments attempt to overcome this criticism by updating their IO tables every 5 or 10 years.

Use of the competitive type IO model becomes problematic for simple or total output multiplier analysis. In such cases, it becomes more important to make the distinction between inputs produced within the regional economy and those imported from outside. While analyzing the changes in multipliers and in the technological coefficient matrix over time could theoretically be of use, the practical fact is that the methods of constructing IO tables have changed over time, and typically, IO tables over time are not compatible for purposes of comparison. For example, the period between 1979 and 1985 saw the introduction of the distinction between commodities and industries, thus allowing an improved method of allocating secondary output of industries. The negative result of this is that pre- and post-1979 IO tables are no longer directly comparable.

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REFERENCES

Economopoulos AP. 1993. Rapid assessment of sources of air, water, and land pollution. Geneva, Switzerland: World Health Organization.

Forsund FR, Strom S. 1976. The generation of residual flows in Norway: an input-output approach. J Environ Econ Man 3: 129-141.

Hinga KR, Keller AA, Oviatt CA. 1991. Atmospheric deposition and nitrogen inputs to coastal waters. Ambio 20: 256-260.

Jaworski NA, Groffman PM, Keller AA, Prager JC. 1992. A watershed nitrogen and phosphorus balance: The upper Potomac River basin. Estuaries 15: 83-95.

Mendoza NF. 1994. Input-output modeling. The Philippine Environmental and Natural Resources

Accounting Project-Phase 2-Technical Appendices. Pasig City, Philippines.

Miller RE,Blair D. 1985. Input-output analysis: foundations and extensions. Engelewood Cliffs, N. J.: Prentice Hall.

Orbeta EM, Cortez AM, Calara AN. 1996. Region XI Policy Simulation Study: Application of ENRA Framework: Regional Study 4. Pasig City, Philippines: Philippine Environmental and Natural Resources Accounting Project:

Padilla J, Castro L, Morales A, Naz C. 1997. Evaluation of economy-environment interactions in the Lingayen Gulf Basin: A partial area – based environmental accounting approach. Philippines: DENR and USAID.

Secretario FT. 1999. Research project on the construction of input-output tables for the Ilocos Region.

Turner RK, Adger N. 1997. Towards integrated assessment in the coastal zone: a draft discussion document.

Valiela I, Collins G, Kremer J, Lajtha K, Seely B, Brawley J, Sham CH. 1997. Nitrogen loading from coastal watersheds to receiving estuaries: new method and application. Ecol Applic 7(2): 358-380.