DCG Regional Accounting Engine

Technical Guide

Decision Commerce Group, LLC

Contents

Introduction

Our regional economic accounting engine is an input/output based mathematical model similar to other regional impact models. The difference is that we designed our model specifically to support economic development management and governance functions, while other models - such as IMPLAN and REMI - are designed for technical specialists to perform research studies of potential policy and economic development impacts.

All of these regional impact models are based on the input/output structure of the economy, but each has its particular method for modeling local purchasing patterns. For IMPLAN, REMI, and RIMS 2[1], the intention is to devise a local purchasing method that closely estimates actual local purchasing patterns, assuming that purchasing patterns continue to resemble past behavior. The differences between models are well documented in the literature and unless benchmarked, can provide widely varying estimates of impacts and associated multipliers. The research literature does suggest, from both a theoretical and empirical standpoint, that using the simple location quotient method overstates local purchasing. For the other methods, such as regional pooling and econometric analysis, the literature is less conclusive regarding estimated versus empirical results.

We designed our model differently due to our view that multipliers are not an input to the economic development process, but an outcome of your efforts. Regional impact estimates are not static, reported numbers, but like a budget developed for a business, represent an active performance target that guides efforts to improve economic performance of the regional system. That is, when estimating impacts, you create a budgeted impact that you will manage to, and then through your management efforts, you work to hit that goal. We designed our app to produce these pro forma impact budgets – a series of projected or assumed impacts that flow from a mathematical model, the actual results of which are a function of the economic development effort. Since you are constantly working project by project to improve your regional economy over its current state, we specifically designed the model to incorporate this improvement potential.

With this design in mind, we built our app and regional life cycle accounting engine differently than other regional impact models. We focused on local purchasing targets, tracing connections round-by-round, and supporting measurement of public benefits to provide balanced reporting of public benefits and costs in response to the Government Accounting Standards Board Statement No. 77 (GASB77).

---

[1] *RIMS II, An essential tool for regional developers and planners*, Bureau of Economic Analysis, U.S. Department of Commerce, December 2013, *https://www.bea.gov/regional/pdf/rims/rimsii_user_guide.pdf*

- *Local purchasing targets*: We designed our model to use a choice of two different local purchasing patterns: one based on local capacity constraints, which represent an upper limit of local purchasing potential, and another based on simple location quotients, which represent a target for increasing local purchasing over past patterns. We provide these two choices since, as economic development professionals, your work influences multipliers.

- *Round-by-round accounting*: Our life cycle accounting engine uses a round-by-round algorithm to compute pro forma impacts. A regional economy is a system of connections, and by tracing each of the resulting demand/supply connections back through the supply chain and forward through the spending of income, we give you information on where local connections weaken and on the largest connections by value that create priorities for improving, measuring, and auditing performance.

- *Public benefits reporting*: GASB77 opens the door to providing citizens with a balanced reporting of public costs and benefits associated with economic development abatements. We designed our budgeting workbook specifically to support the management, measurement, and auditing of public benefits associated with these economic development abatements. We support workforce, income, economic production, and natural resource criteria for public benefits, recognizing that different projects and economies have different potential public benefits. Our workbook includes worksheets that link life cycle industry production with these specific benefits.

In the remainder of this document, we present a discussion of key elements of our regional economic accounting engine, namely the local purchase assumptions and the benefits of the round-by-round approach. We then use several examples from the RIMS II documentation to show a comparison between the RIMS II results and the DCG model values.

Local purchase assumptions in regional input output models

A key issue in determining the level of economic impacts is the amount of local purchases undertaken by local industries. The fewer local purchases (i.e. more imports), the more leakage out of the local economy and hence a smaller amount of funds to recirculate though the inter-industry interactions. Impact modeling has used a variety of methodologies to estimate the percentage of local purchases made by resident firms. The early modelers actually conducted surveys of local firms to get estimates of their purchase behavior. But this was and still is a costly approach. In the 1970's considerable research went into developing "synthetic" coefficients to reflect local purchases.[2] Because of the low cost and ease of developments,

[2] "Nonsurvey techniques for constructing regional interindustry models", William A. Schaffer, Kong Chu, Papers of

these synthetic methods became commonplace and the method of choice. The simplest non-survey or synthetic method was the use of a location quotient of an industry as measure of the current basic import patterns of the region that is assumed to hold for any new growth in local demand. The location quotient (LQ) is the percentage the industry's activity of the region it is in compared to the national ratio. If an industry is relatively more important in the region than in the nation it will have a location quotient greater than one. If less important then the location quotient will be less than one. In modeling it is assumed that if an industry has a location quotient greater than one then it will be the supplier to the region's industry and there will be no imports. If the location quotient is less than one, then the share of local purchases from that industry will be equal to the LQ.

Other approaches that have been used to represent current local purchase coefficients are the use of interregional trade flows matrices (IMPLAN[3]), supply demand pooling (IMPLAN) and econometrically estimated "regional purchase coefficients" (REMI[4], IMPLAN). All three of these approaches assume that the new activity generated by the direct impact will behave as the "average" of current activities. In addition new expansion will be generated to meet the needs of increased final demand. This is an often criticized assumption of static input output models, in that growth is unconstrained either by supply limitations and/or price impacts. Recent discussion of the various approaches to developing regional coefficients is presented by Szabo.[5]

Round-by-Round (RBR) Simulation Approach

The demand for final goods sets off a chain of activities in the producing industries. The initial purchase of final goods generates demand for intermediate goods and raw material. The input output model provides a useful way to represent this chain of events. The chain of events can be computed by a heuristic round-by-round approach[6] or by a formal solution to the input-output model. The two methods can be shown to yield the same results.

The modeling solution is derived from the basic input output relationship as represented by the following equation: (X= aX+Y) that indicates that total output (X) is the sum of inter-industry demands (aX) and final demand (Y). This also can be represented as Y= (I-A)*X and then solving for X presents: $X=(I-A)^{-1}Y$. If one wishes to know what changes in output (dx) that are brought

---

the Regional Science Association, December 1969, Volume 23, Issue 1, pp 83-101

[3] IMPLAN PRO Overview
http://www.implan.com/index.php?option=com_content&view=article&id=278&Itemid=1691

[4] REMI, "Estimating Trade Flow Parameters (Industry Betas and Sigmas)", May 2010, Frederick Treyz, Ph.D. Nicolas Mata Sherri Lawrence.

[5] "Methods for regionalizing input-output tables," Norbert Szabo, REGIONAL STATISTICS, 2015, VOL 5, No1: 44–65; DOI: 10.15196/RS05103

[6] *Regional Impacts Models*, William A. Schaefer (Professor Emeritus) Georgia Institute of Technology, School of Economics, Revised (pdf) version, March 2010. http://www.rri.wvu.edu/WebBook/Schaffer/index.html

about by a change in final demand (dy) then one solves the equation: $dx=(I-A)^{-1} dy$. The term $(I-A)^{-1}$ often is referred to as the Leontief inverse and contains the information on the inter-industry transactions.

The Leontief Inverse Matrix can be solved by standard matrix inverse routines or as discussed in Miller and Blair[7] by a numerical methods iterative process (Equation 1).

Equation 1. Iterative solution of the Leontief Inverse
$(I-A)^{-1} = I + A + A^2 + \dots\dots\dots + A^n$

Consequently, the solution to the input output model can also be expressed as an iterative model (Equation 2).

Equation 2. Matrix solution to the Input Output model
$X = (I-A)^{-1} Y$ $X = I Y + AY + A^2 Y + \dots\dots\dots + A^n Y$

Consequently, the solution to the input output impact model (that is changes in the level of output (dx) required to support a change in demand (dy)) can be expressed as shown in Equation 3.[8]

Equation 3. Iterative solution of the Input Output Impact model
$dx = I\,dy + A dy + A^2 dy + \dots\dots\dots + A^n dy$

[7] Input-Output Analysis, Foundations and Extensions, Second Edition, Miller R and Blair. P, Cambridge University Press, New York, 2009, pp. 31-34

[8] Equation 15.4. in "A note on the usefulness, even in the computer age, of the round-by-round method of performing input-output impact calculations," Stevens, B. Regional Science Research Institute, RSRI discussion paper series, no 132, 1988

The iterative model shown in equation 3 can be rearranged to show how the result of first round drives the second round and that result driving the next and so on, thus generating the "round-by-round" approach (Equation 4).

Equation 4. The "round-by-round" implementation of the impact model

$$dx = I\,dy + Ady + A(A\,dy) + \ldots\ldots\ldots + A(AAA\ldots.A\,dy)$$

The round-by-round approach is easily implemented in a computer program such as shown in Figure 1.

Figure 1. Pseudo Code to Compute Change in Output (DX) from change in Final Demand (DFD) by iteration over 50 rounds with the incremental changes for each iteration shown by DY

```
R = 50
DX = 0
DY = DFD
For r=1 to n
  DY= A * DY
  DX=DX + DY
  RO(r)=DY
End For
```

Where:
R= number of rounds
DX = vector of Output Change by industry
DY = vector of demand changes by industry
RO Vector of Vectors containing changes in output by round

Early use of round-by-round to solve the inverse problem was discussed in Ben Steven's brief article in support of further use of the round-by-round approach. Steven's discussion of round-by-round has been reprinted.[9] Most analysts, however, have followed the development of local input output tables and computing the inverse in order to get the desired “impact multipliers.” Indeed much of the impact analysis tends to focus on the multipliers and not so much on the underlying changes occurring as a result of the impact.

Our use of the RBR approach[10]

The round-by-round approach allows us to investigate the sequence of events generating the final multipliers. The round-by-round approach is suggestive of a “flow of funds” simulation, in that each round indicates the transactions (and dollar flows) that occur in that round between buyers and sellers. It also mimics the common newspaper description of how impacts take place in a local economy.

This simulation method has been used in developing our capacity-constrained (CAPCON) and location quotient (LQ) models, and provides a much broader view of the changes that a region undergoes than focusing on just the multiplier. It is relatively easy to develop iterative routines that also provide considerable flexibility and ease of extensions.

Due to this flexibility, the RBR approach became the backbone of the Regional Studies Program at Oak Ridge National Laboratory (ORNL) led by Dr. David Vogt. Upon retirement, Dr. Vogt affiliated with Decision Commerce Group and led the design of our regional economic accounting engine. A few applications of the RBR simulation approach are discussed below.

Disaster loss and resilience: In the 1980’s Dr. Vogt designed and implemented a series of U.S. regional economic assessments systems for the Federal Emergency Management Agency to estimate the capacity loss from nuclear attack. These systems were also used to provide early estimates of the scale of damage from natural disasters. The Integrated Management and Economic Analysis System (IMEASY) provided the first computer based damage assessment used by FEMA in establishing the need for a federal response to Hurricane Hugo. The use of the computer assessment for Hurricane Hugo, rather than waiting for the traditional bottoms up assessments, expedited federal assistance for damage by two weeks. Information from the system was used by FEMA to direct priority visual damage assessment of critical defense manufacturing facilities following the Point Loma earthquake in California. The facility damage model was later incorporated into FEMA’s National Infrastructure information System. [11]

---

[9] “A Note on the usefulness of the ‘Round-by-Round’ method of performing Input-Output impact calculations”, Stevens, B., in *Dynamics and Conflict in Regional Structural Change: Essays in Honour of Walter Isard*, Volume 2, (ed) Chatterji, M., Kuene, R., New York University Press, Washington Square, New York, 1990.

[10] These studies were conducted while Dr. David Vogt was manager of the Regional Studies Program at Oak Ridge National Laboratory.

[11] "National Infrastructure Information System/Regional Impact Module", M93-66935, Vogt, D. P., and W. L. Jackson, Oak Ridge National Laboratory, Oak Ridge, Tenn., October, 1993.

In this early study for the Federal Emergency Management Agency, a national database of individual facilities (located by latitude and longitude) coupled with make and use data from the detailed national input output table was used to construct regional supply-demand balance tables for all of the commodities. The Facility Damage Assessment Model[12] investigated the impact of a national or regional disaster by an early spatial analysis model (i.e. a GIS). The locations of the potential adverse impacts were identified by "damage polygons" which were then computationally overlaid on the facility locations. The impacted facilities were then eliminated from a revised computation of the regional supply-demand balance tables. The differences in the pre-post disaster estimates of the supply-demand balances provided an estimate of the impact of the loss of key industries.

Freight analysis: The Freight Analysis Framework (FAF)[13] program of the Federal Highway Administration presents commodity flows and related freight transportation activity for all modes of transportation among states, sub- state regions, and major international gateways. ORNL transportation researchers developed a log-linear model to estimate the key commodities flows using basic commodity shipment data. However, a few locally shipped commodities were not covered by the standard data. For these "out-of-scope" commodities, the RBR method supported a supply/demand balance approach, augmented with a spatial potential model, to estimate local commodity shipments. [14]

Regional studies: The RBR approach was used in several small area energy related studies using social account matrices developed from local data. One study investigated the potential economic impact of locating the International Thermonuclear Experimental Impact (ITER) in the Oak Ridge Area.[15] The same Oak Ridge area social accounts model was then used to estimate the impact of the large-scale cleanup of the K25 gaseous diffusion plant.[16] A RBR model of the Minnesota River Valley was used to evaluate the potential economic benefit from using the soil-bank areas along the river as a location for growing poplar trees to be used as bio-fuels.[17]

---

[12] "Integrated Data Base Analysis and Modeling for Damage Assessment", (with D. Arnurius and A. Katzman), *Conference Proceedings: Advanced Computing for the Social Sciences*, ORNL and Department of the Commerce, Bureau of the Census, Williamsburg, Virginia, April 1990.

[13] *Freight Analysis Framework Home Page*, http://www.ops.fhwa.dot.gov/Freight/freight_analysis/faf/index.htm

[14] "Methodology for Regionalization of the Out-of-Scope Truck Commodity Flows (Freight Analysis Framework)", David Paul Vogt, Oak Ridge National Laboratory, Prepared for Freight Analysis Framework Project, Office of Operations, Freight Management and Operations, Federal Highway Administration, October 17, 200

[15] "Estimating Regional Economic Dividends from Locating the International Thermonuclear Experimental Reactor in Oak Ridge, Vogt, C.P. Yoder, T.N, July 6, 1994

[16] "Estimation of Indirect Local Economic Impacts of Alternative Clean-Up Options for K25, Draft, September 22, 1995 Vogt, D.P. Das, S.

[17] "Economic Impacts from Poplar Farming in Minnesota River Basin (MRB)" David Paul Vogt, Prepared for the McKnight Foundation, April 2000.

Industry studies: The RBR method was used to investigate the economic shifts that would take place in moving from traditional materials to either composite or aluminum intensive 3X generation vehicles. To accomplish this analysis, the make and use elements of the automobile industries were restructured to reflect production for aluminum and composite vehicles. The material requirements for the new vehicle were substituted in the use table of the current industry requirements. Thus, three scenarios models were implemented. The analysis showed "no major difficulties are likely to arise during the transition to either composite- or aluminum-intensive 3X vehicles. However, the transition would slightly increase labor requirements and require a less than 1% increase in intermediate materials, resulting in an expansionary boost to the economy."[18]

Multi-regional analysis: Dr. Vogt and Dr. Frank Southworth integrated the ORNL multi-modal network, ORNL spatial interaction model, and the ORNL RBR input-output model into a county-to-county multi-regional modeling framework. The first application of the framework was the Maritime Input-Output Model (MIO) [19] developed for the Army Corps of Engineers and used in an analysis of the economic benefits from improvements to the Saint Lawrence Seaway.[20,21,22] More recently, the social account model framework was imbedded into a multi-region micro simulation model to investigate local area economic post disaster development paths in a resilience study.[23, 24]

---

18 *Supporting Infrastructure and Acceptability Issues for Materials Used in New Generation Vehicles*, Sujit Das, Vogt, et.al., ONRL/TM-13731 (March 1999).

19 *The MIO Input-Output Model: Conceptual Overview.* Vogt, D.P, Southworth, F., Peterson, B.E. and Rizy, C. (2002a), Report prepared by Oak Ridge National Laboratory for the Ohio River Division, U.S. Army Corps of Engineers, Huntington, WV.

20 *Draft Reconnaissance Study - Great Lakes System Navigation Review*, ATTACHMENT 5 Maritime Input/Output Model, (Development of the Maritime Input-output Model, Phase 1, Application in the Great Lakes/St. Lawrence Seaway Navigation Reconnaissance Study, February 12, 2002, David Paul Vogt, Frank Southworth, Bruce Peterson, Colleen Rizy), Army Corps of Engineers, Detroit District, May 1, 2002.

21 "GLSLS BENEFITS & REGIONAL IMPACT MODELS: Maritime Input-Output Model", Vogt, D.P., presented at "The Great Lakes/St. Lawrence Seaway Study Modeling Workshop, U.S. Department of Transportation Headquarters, October 6 and 7, 2003, Washington, DC. , Prepared for the Army Corps of Engineers

22 "Application of the Maritime Input-Output Model", Presentation to Canadian Saint Lawrence Seaway commission and Transport Canada, January 17, 2002, Ottawa, Ontario. Prepared for the Army Corps of Engineers

23 *Socio-Economic Resilience And Dynamic Micro-Economic Analysis For A Large-Scale Disaster*, Richard G. Forgette,, Mark V. Van Boening, Gregory L. Easson, , Michael R. Hilliard, Todd E. Combs. David P. Vogt, June 2011 , Prepared for U.S. Department of Homeland Security under U.S. Department of Energy Interagency Agreement 43WT10301, Prepared by Oak Ridge National Laboratory Oak Ridge, Tennessee 37831-6283 managed by UT-Battelle, LLC, for the U.S. Department Of Energy under contract DE-AC05-00OR22725

24 "Socio-Economic Resilience and Dynamic Micro-Economic Analysis for a Large-Scale Catastrophe," Richard Forgette, Mark V. Van Boening and Greg Easson, (U.S. Department of Homeland Security Southeast Regional Research Initiative, Grant #80038, 2008).

The Capacity Constrained (CAPCON) Approach

Our use of the RBR approach allows us to enforce an "upper limit on new production potential." We assume that all industries could expand their current production by 20% without requiring major changes in current practices or price responses. We further assume the local producer will choose to use local producers up to the point of their capacity expansion. Consequently, the industry's "local purchase coefficient" will be determined dynamically during the model run. Thus using our CAPCON approach, we assume that new growth does not necessarily follow the past pattern, as it is indeed a new demand and change of past patterns. Moreover, we do have a constraint on the growth, and final output is not solely demand driven. This growth constraint is also on the labor factor, as we assume that local personal income growth could expand by 10%, before requiring a supply of in-commuting workers to meet the increase in labor demand.

Imposing a capacity constraint on local output addresses one of the key concerns in using demand driven input output models. While the LQ and other methods may limit local purchasing, these methods do not limit the scale of local production driven by the final demand change.

For the base CAPCON model used by our web apps, we have limited output growth to 20% of existing output potential for industries and 10% for local earnings. It is assumed that local producers will prefer to purchase input locally if possible. So if production takes place in a region, then the local supply chain can expand production by 20% without undue stress (i.e. rising prices). After that point then all additional local demand is met by regional imports. In the short term, the new production would likely come about from under-utilized capacity, but with a consistent level of demand the local firms would expand capacity to meet the new level.

Because of the wide variation in regional wages (and labor productivity), we adjust the "average national" jobs estimate based on the wage differential in the region. In high wage areas, we assume that this reflects more productive labor requiring fewer "jobs," while in low wage areas we adjust the number of "jobs" upward. We assume that the substitution is just within labor input and that the "wage bill" is constant, thus allowing other commodity prices to remain constant.

This treatment of labor is consistent with observations on regional wage and labor differences. High wages and productivity generally are thought to be associated with urbanization.

> "In 2010, in the journal *Nature,* a pair of physicists at the Santa Fe Institute showed that when the population of a city doubles, economic productivity goes up by an average of 130 percent.

Not only does total productivity increase with increased population, but so does per-capita productivity."[25]

This observation tends to hold across the board. Regional differences in high skill labor are mirrored by low skilled labor as well. [26] Enrico Moretti finds that the earnings of a high school graduate increase 7% for every 10% increase in the wages of college graduates.

In visualizing the round-by-round impacts, it becomes clear that the increased activity is dispersed across the many sectors of the economy. Indeed, in many instances the increased output is associated with fractional jobs numbers. Typically, in reporting the results of multiplier analysis the focus is on number of jobs. The lay public may interpret the "JOBS" number to mean the actual number of full persons employed. The more likely response is that firms will use overtime hours to meet the needs of the "fractional employees." The increased earnings number may be a more useful metric in defining the scale of an impact.

CAPCON multipliers for a large and a small region

The standard approaches in developing local purchase coefficients assume that the share of local purchases will remain the same at all levels of changes in final demand. With the CAPCON approach, since we intervene in the choice of local versus regional during the round-by-round cycle when the constraint is met, the resulting "multiplier" will be dependent on the current level of output in the impacted industries and may be different for different levels of final demand changes. That is, the multiplier is non-linear in scale and its size is dependent on the size of the final demand impact and the size of the local economy. It is emphasized that this is not true for the Location Quotient approach where the multiplier will be constant regardless of the size of the final demand impact. A practical consequence of this is that a single multiplier cannot be developed and distributed as is done by BEA using the RIMS 2, but rather the multiplier needs to be calculated for each situation.

To show this changing level attribute of the CAPCON multiplier we examine both a large and small region with various levels of final demand changes. Table 1 shows the differential impacts according to scale of impact for a large (Knoxville) and a small region (Anderson County, TN).

Table 1. CAPCON Output Multiplier Analysis

Impact Level	Knoxville, Tennessee		Anderson County, Tennessee	
	Type 1	Type 2	Type 1	Type 2
1,000,000	2.16	2.96	1.63	2.06

[25] "Why innovation thrives in cities", Larry Hardesty, MIT News Office, June 4, 2013, http://news.mit.edu/2013/why-innovation-thrives-in-cities-0604

[26] *The New Geography of Jobs*, Enrico Moretti, Mariner Books, Boston, USA, 2013 pp.97-99

10,000,000	2.16	2.96	1.60	2.02
100,000,000	1.88	2.55	1.47	1.81
1,000,000,000	1.61	2.12	1.18	1.32

As expected the large area multipliers are larger than small area multipliers. In both cases, the multipliers decline as the size of the impact increases reflecting the impact of meeting the constraint on various industries with the increasing demand. The large region (Knoxville) does not see the impact of this capacity constraint until the third level of increased final demand changes.

Comparison of the CAPCON and LQ approaches.

To provide a reference to the traditional model, we also generated the same exercises as done above for the LQ based analysis. The small, medium, and large impacts and differential between CAPCON and LQ for the large region versus the small region are presented in tables 2 and 3.

In our examples presented below, CAPCON has a larger impact than the LQ model, but this is not necessarily true. The difference between the two is based on the size of the impact and the level of local production. The LQ approach has an arbitrary constraint on production (local share of activity as compared to national). If the impacted sectors are relatively large in the region but absolutely small compared to the size of the impact then, when using the LQ approach, all the new demand may be met locally as the unconstrained "capacity" expands to meet a level of demand. This would result in a larger multiplier for the LQ multiplier than for the CAPCON.

Table 2. Type 2 Output Multiplier Analysis
Knoxville

Impact Level	Knoxville Impact metrics		
	CAPCON	LQ	Ratio of CAPCON to LQ
1,000,000	2.96	1.98	1.50
10,000,000	2.96	1.98	1.50
100,000,000	2.55	1.98	1.23
1,000,000,000	2.12	1.98	1.07

Table 3. Type 2 Output Multiplier Analysis
Anderson County

Impact Level	Anderson County Impact metrics

	CAPCON	LQ	Ratio of CAPCON to LQ
1,000,000	2.06	1.37	1.50
10,000,000	2.02	1.37	1.47
100,000,000	1.81	1.37	1.32
1,000,000,000	1.32	1.37	0.96

While the difference in the output multipliers seems relatively large in these cases, this does not necessarily translate into large difference in "JOB" estimates. The differences in employment for the above exercise are shown in tables 4 and 5. Large absolute differences in JOBS do not appear until large level of impacts. To allow the analyst to investigate these potential differences between the CAPCON and the LQ models, our web app provides both options.

Table 4. Jobs Generated by Type 2 Employment Multiplier			
Impact Level	Knoxville impact metrics		
	CAPCON	LQ	Ratio of CAPCON to LQ
1,000,000	16	11	1.45
10,000,000	165	106	1.56
100,000,000	1,398	1,064	1.31
1,000,000,000	11,481	10,638	1.08

Table 5. Jobs Generated by Type 2 Employment Multiplier			
Impact Level	Anderson County impact metrics		
	CAPCON	LQ	Ratio of CAPCON to LQ
1,000,000	12	6	2.00
10,000,000	113	64	1.76
100,000,000	1004	637	1.57
1,000,000,000	6,691	6374	1.05

The CAPCON model provides greater consistency in the results for a multi-level analysis. When using the LQ approach it is possible that an increase in an industry with a high location quotient in a sub-region will have an increase in production. However, when running the full region model the industry shows no growth. This is because in the larger region the industry has a low location quotient, and hence forces imports rather than local expansion. Thus, in this case there is an inconsistency in the independent runs. When using our capacity constraint model this inconsistency disappears as the larger region contains the capacity of the local region and will expand to the capacity limit. In the example in Table 6, a $100,000,000 expansion in the automotive transmission industry was assumed to take place in the local area (Anderson County). Analyses were then computed at both the sub-region level and the larger Metro Area of Knoxville level. The non-ferrous metals industry has a relatively larger presence in Anderson County than in the larger Knoxville area. For this case, it can be seen that for the LQ case the level of production estimated for the Metro area is smaller than the level of production in the sub-region, clearly a bit of an inconsistency.

Table 6. A comparison of type 2 models results for a sub-region of a larger area

$100,000,000 expansion in automobile transmission industry

	Industry Production of non-ferrous metal foundries	
	DCG CAPCON	DCG LQ
Sub Region Andersons County	$2,319,800	$6,233,264
Metro Area Knoxville	$2,319,800	$1,801,284

Using the DCG model result workbooks provided in Excel, it is easy to develop comparisons across model scenarios, using column cut-and-past technique. Table 7 shows the expanded local production of the industries in the above analysis that had greater production in the sub-region than the larger region. The current local production on non-ferrous materials in the sub-region is estimated to be $11,599,000, with an expanded capacity of 2,319,800, all of which is located in Anderson County for the CAPCON model. The LQ approach estimates considerable more expanded output in Anderson County than the CAPCON model (again not constrained) but with much less in the entire region.

Table 7. Industries with greater production in sub-region that containing Metro-area (combining results from two model runs – Anderson County and Knoxville SMSA)

Industry	**Current Local Output**	**Expanded Local Output In Anderson**	**Expanded Local Output in Knoxville**	**Difference**
Coal mining	$20,286,000	$326,660	$286,526	$40,134
Other support activities for mining	$26,419,800	$53,614	$8,834	$44,779

Plastics material and resin manufacturing	$82,965,000	$282,945	$213,835	$69,110
Nonferrous metal foundries	$11,599,000	$6,233,264	$1,801,284	$4,431,980
Metal can, box, and other metal container (light gauge) manufacturing	$12,341,000	$446,539	$230,948	$215,591
Turned product and screw, nut, and bolt manufacturing	$19,939,500	$2,984,657	$2,315,838	$668,819
Optical instrument and lens manufacturing	$5,112,000	$2,625	$2,381	$244
Industrial mold manufacturing	$546,000	$21,213	$16,886	$4,327
Material handling equipment manufacturing	$10,300,500	$53,130	$51,917	$1,213
Search, detection, and navigation instruments manufacturing	$15,885,000	$13,603	$4,569	$9,035
Nonupholstered wood household furniture manufacturing	$1,144,500	$6,896	$0	$6,896
All other miscellaneous manufacturing	$6,628,600	$168,288	$163,402	$4,886
Federal general government (nondefense)	$0	-$100,858	-$445,621	$344,763

Along with the estimates for the analysis region, the model also computes the state level and total expanded output requirements (Table 8). For the CAPCON model, we can assign the expanded production to the various regional levels. For the example, all of the $2,319,800 expansion in the Knoxville SMSA takes place in Anderson County, but an additional $4,188,461 takes place in the rest of the state outside of Knoxville. Thus, the CAPCON approach provides estimates of the extra-regional impacts that may be of interest in planning efforts.

Table 8. Regional Hierarchy Estimates for CAPCON Model

	Analysis Area Anderson County	Analysis Area Knoxville SMSA	State	Total
CAPCON	$2,319,800	$2,319,800	$6,508,261	$6,530,299
LQ	$6,232,492	$1,801,284	$6,471,407	$6,530,299

Visualization of impact sequence – identify when and where impacts occur

In addition to the multi-level analysis provided in the DCG modeling framework, we also provide considerable information on the sequences of activities generated in the round-by-round cycle of impacts. See the user guide for a full list of tables available for reviewing the sequence of events.

The majority of the expansion in local output generated by a new automobile transmission plant with capacity of $10 million dollars in the Knoxville SMSA is captured by the first ten rounds (Figure 2).

The manufacturing and service sectors are the major sectors most impacted by the expansion of an automobile transmission plant in Knoxville (Figure 3.).

Figure 2. Sequence of impacts for a new automobile plant in Knoxville SMSA

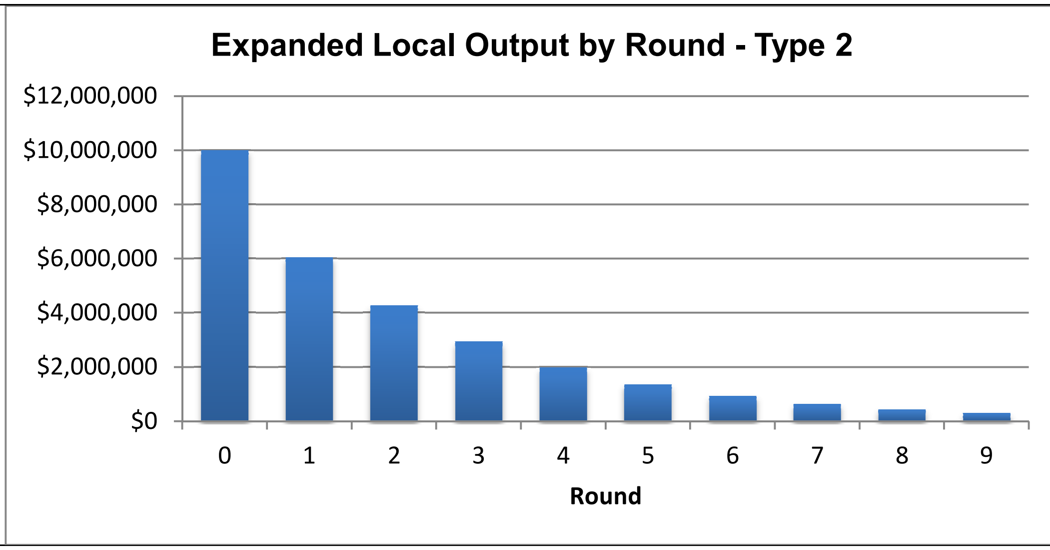
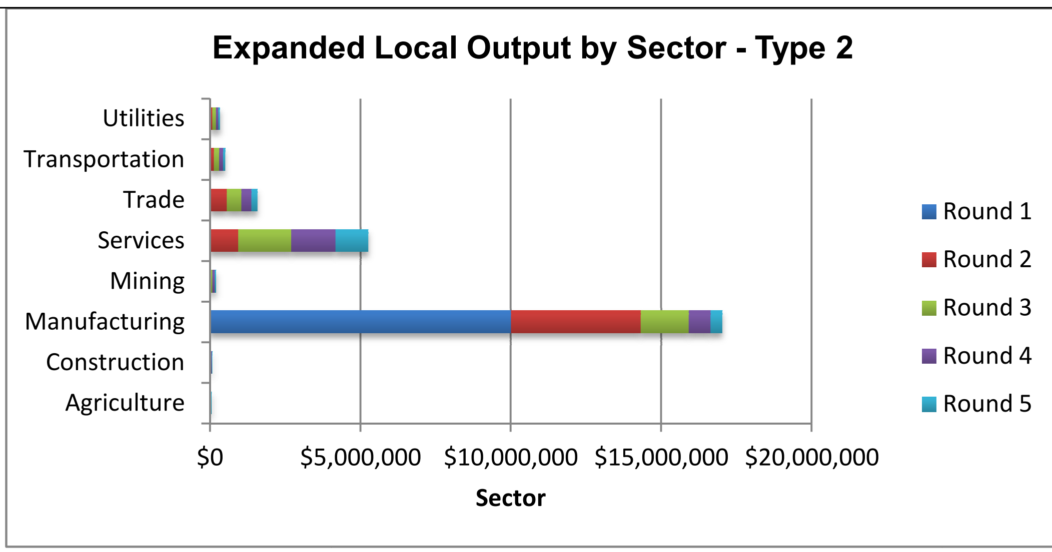


Figure 3. Sequence of impact by sector of a new automobile plant in Knoxville SMSA



CAPCON compared to RIMS 2

The Bureau of Economic Analysis Rims 2 Model provides both a representative LQ model and one that is highly utilized for basic quick impact analysis. The *RIMS 2 User Guide* provides several cases that can act as benchmark comparisons. Three of the examples, reflecting different economic sectors and level of impacts, have been selected for comparison to the DCG CAPCON and LQ estimates. A summary of the Type 2 (including household spending impacts) output multipliers is presented in Table 9. For these examples, the DCG LQ that is developed using similar assumptions as the RIMS 2 is a bit smaller than the RIMS 2. The CAPCON multiplier is a bit larger indicating for these examples the LQ model, while unconstrained, does not generate unduly large impacts.

Table 9. Comparison of BEA RIMS 2 and DCG Type 2 Output multipliers

Location	Sector	Activity	Expenditure	RIMS 2	DCG	
			$Million		LQ	CAPCON
Kokomo	Manufacturing	Auto Transmission	109.1	na	1.38	1.66
Austin	Service	University	10.1	2.19	1.91	2.83
Branson	Trade	Retail Sales	1.1	1.48	1.51	2.13

Multipliers for Manufacturing – Motor Vehicle Transmission Plant expansion in Kokomo, Indiana

The manufacturing sector example is the expansion of motor vehicle transmission plant in Kokomo, Indiana. There is expected to be a 109.1 million increase in final demand from 250 new jobs. [27] In this example, RIMS 2 did not provide the output multipliers, as it indirectly generated impacts from the employment multiplier. Tables 10 and 11 provide the type 1 and type 2 multipliers respectively.

The value added multipliers are similar for the RIMS 2 and DCG LQ multipliers. The CAPCON multipliers are a bit larger. The DCG employment multipliers are a bit larger than the Rims 2, likely because of the regional wage adjustment of the DCG approach.

Table 10. Type 1 Multipliers for deployment of a motor vehicle transmission plant in Kokomo, Indiana

Multiplier	Rims 2	DCG	
		LQ	CAPCON
Output	na	1.27	1.38

[27] RIMS II, p5-2 – 5-4

Value added	0.41	0.39	0.46
Employment	3.37	4.91	6.01
Employment multiplier is jobs per million			

Table 11. Type 2 Multipliers for deployment of a motor vehicle transmission plant in Kokomo, Indiana			
Multiplier	Rims 2	DCG	
		LQ	CAPCON
Output		1.38	1.66
Value added	0.47	0.46	0.66
Employment	4.41	6.01	8.23
Employment multiplier is jobs per million			

Multipliers for Service Sector – Increased University Spending in Austin Metro Area

The service sector example is the additional spending by a local university of $10 million in the Austin-Round Rock-San Marcos, Texas Metropolitan Statistical Area.[28] In this example, the DCG LQ Output and Value Added multipliers are slightly smaller than the RIMS2, while the CAPCON multipliers are a bit higher. In this case, the DCG employment multipliers are lower than the RIMS 2 because of the wage adjustment: a higher relative wage in the region reflecting more productive workers results in a lower number of jobs.

Table 14. Type 2 multipliers for additional University Spending in Austin Metro			
Multiplier	Rims 2	DCG	
		LQ	CAPCON
Output	2.19	1.91	2.83
Value added	1.30	1.16	1.63
Employment	24.01	17.68	23.74
Employment multiplier is jobs per million			

[28] RIMS II p. 3-7

Multipliers for Trade Sector – Expanded Tourism in Branson, Missouri

Rims 2 provided a trade sector example to illustrate the manner in which one can use trade margins to determine the scale of the impacts. In this case, it is expected that retail sales margins will be increased by $1.078 due to an increase in tourism.[29] For this case, the RIMS 2 and CAPCON LQ estimates for the Output and Value Added multipliers are similar, while the CAPCON multipliers are larger. The Employment multipliers for the CAPCON model are higher than the RIMS 2 reflecting the lower relative wages in Branson. In the CAPCON model, we adjust employment to reflect differential productivity, and in Branson's case, the lower wage/productivity means that firms will require more JOBS per dollar earnings than the national average.

Table 15. Type 2 multipliers for expansion in retail margins in Branson, Missouri

Multiplier	Rims 2	DCG	
		LQ	CAPCON
Output	1.48	1.51	2.13
Value added	0.97	0.93	1.29
Employment	19.41	21.63	27.21

Employment multiplier is jobs per million

Summary and extensions

The 1980's and 1990's were the golden age of regional economic modeling and analysis. Not only were regional input output models widely developed and utilized in impact analysis, but also more complicated regional and multi-regional econometric models were developed and used in policy analysis. John Kort, a major actor during this period, provides us with his "reflections on the history of regional science." [30] With tightening federal and state budgets at the change of the century, coupled with the high cost of these tools, a desire for off the shelf and cheaper alternatives arose. This need was primarily met by commercial tools, such as RIMS 2 for basic analysis, and REMI and IMPLAN for more complicated issues. Recently, Lahr has reviewed the history of input output analysis but importantly argues for the current relevance of the tools. As there always was a gap between academic acceptance and practitioners' use in

[29] RIMS II, p.6-3

[30] "Southern Regional Economics in the1990s: Back to Basics?", (Presidential Address, April 9, 1994), John Kort, Bureau of economic Analysis, U.S. Department of Commerce

the field of the basic input-output tools, he refreshingly provides some guidance for new academics and practitioners about useful areas to explore.[31]

Our goal in developing the CAPCON round-by-round approach and the web app was to help provide a base for continued use and expansion of the input-output analysis in the broader area of development planning. It is hoped that the easy to use app with extensive detail on the impact sequence will encourage policy analysts and planners to look beyond the “multiplier.”

The framework is very flexible allowing for a wide variety of enhancements and extensions. The capacity constraint can be set for individual industries, new industries can be incorporated into the regional tables, and local area information on existing industries can be can used instead of the secondary national databases on employment. A variety of interventions can be constructed to modify the impact sequences and the model could be extended to a time phased development planning process.

[31] Lahr, Michael L. (2016). *Regional Input-Output Analysis: An Appraisal of an Imperfect World*. Estudios Regionales. Un enfoque de Insumo-Producto University of Guadalajara. https://rucore.libraries.rutgers.edu/rutgers-lib/48325/story/]

