Re-Configuring RECONS Regional IO Models as Multi-Regional IO Models

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ABSTRACT
The US Army Corps of Engineers (USACE) is one of the world’s largest public engineering, design, construction and management agencies, and its civil works mission areas include navigation, flood risk management, hydropower, water supply, recreation, and environment with an annual budget of $5 billion (US). To estimate total regional economic impacts of USACE’s programs, a Regional Economic System (RECONS) was developed for both direct federal spending and related economic activities associated with USACE’s infrastructure and programs. The RECONS database currently contains more than fifteen hundred single-regional input-output (S-RIO) models of individual counties, multi-county areas, states, multi-state regions and the US. This collection of S-RIO models includes geographic redundancies, as a state-wide model may implicitly include a county contained in another local area model. As a result, estimated impacts cannot be reliably aggregated over the geographic hierarchy of models: county-level impacts may not sum to state impacts and state-level impacts may not sum to nation-wide impacts. To overcome these shortcomings, RECONS S-RIO models are being re-formulated as multi-regional (MRIO) models. Three alternative formulations of MRIO models are being considered. Alternative A formulates a suite of 3-region MRIO models each with 3 endogenous regions (Local, Rest-of-State, and Rest-of-US). Alternative B1 formulates a single MRIO with 50 State-level endogenous regions but includes no “local” regions. Alternative B2 formulates a single MRIO with 3,142 County-level endogenous regions. These alternative formulations are evaluated considering how well they support aggregating results both vertically and laterally. Impacts on users due to increased complexity of using MRIO models was also examined. Finally, computer storage and the practicality of computational requirements of the alternative MRIO models for implementation as an online model for use across the nation were also evaluated.
RECONS and Single-Region I-O Models (S-RIo)
The US Army Corps of Engineers (USACE) is one of the world’s largest public engineering, design, construction and management agencies, and its civil works mission areas include navigation, flood risk management, hydropower, water supply, recreation, and environment with an annual budget of $5 billion (US). To estimate total regional economic impacts of USACE’s programs, a Regional Economic System (RECONS) was developed to examine the economic impacts of both direct federal spending and related economic activities associated with USACE’s infrastructure and programs (Chang, et. al., 2019).

The RECONS database currently contains more than fifteen hundred single-region input-output (S-RIo) models of three types: Local S-RIos of individual counties or multi-county areas, State S-RIos for individual States or multi-State regions, and a US S-RIo of the entire US national economy. The characteristics of S-RIo models are also shown in Table 1. All RECONS S-RIo models were built by extracting economic multipliers and ratios from IMPLAN economic modeling system (IMPLAN, 2018).

Technically, the endogenous region of Local and State S-RIo models consists of a single region (county, multi-county, or State), with two exogenous trade regions: domestic (Rest-of-US) and foreign (Rest-of-World). The US S-RIo model consists of one endogenous domestic region and exogenous foreign (Rest-of-World) trade region.

Table 1. RECONS S-RIo Model Types

<table>
<thead>
<tr>
<th>Types of RECONS Single-Region IO Models (S-RIo)</th>
<th>Geographic Extent of the S-RIo Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local S-RIo Models</td>
<td>County/Multi-County</td>
</tr>
<tr>
<td>State S-RIo Models</td>
<td>State</td>
</tr>
<tr>
<td>US IO Model</td>
<td>US</td>
</tr>
</tbody>
</table>

USACE program impacts are typically described for three geographic contexts: Local impacts (using a Local S-RIo model), impacts on the State economy (using a State S-RIo), and nation-wide impacts (using a US S-RIo). Attempting to aggregate impacts across the geographic hierarchy from the results of three separate S-RIo models can produce inconsistencies. For example, as a State model may implicitly include a county contained in Local area model. As a result, impacts cannot be reliably aggregated “vertically” in the geographic hierarchy of Local-State-US S-RIo models. That is, Local impacts may not sum to State impacts and State impacts may not sum to US-wide impacts. Similarly, impacts cannot be reliably aggregated “laterally” across the same geographic strata, such as summing all Local or all State impacts. These characteristics are shown in Tables 2 and 3.

Table 2. Analysis Scope of S-RIo Models

<table>
<thead>
<tr>
<th>Type of S-RIo</th>
<th>Local Scope</th>
<th>State Scope</th>
<th>US Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local S-RIo Models</td>
<td>County/Multi-County ONLY</td>
<td>NONE</td>
<td>NONE</td>
</tr>
<tr>
<td>State S-RIo Models</td>
<td>NONE</td>
<td>State Only</td>
<td>NONE</td>
</tr>
<tr>
<td>US IO Model</td>
<td>NONE</td>
<td>NONE</td>
<td>US Only</td>
</tr>
</tbody>
</table>
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Table 3. Aggregation of S-RIO Impacts

<table>
<thead>
<tr>
<th>Type of S-RIO</th>
<th>Vertical Aggregation of Model Results</th>
<th>Lateral Aggregation of Results Between Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local S-RIO Models</td>
<td>UNRELIABLE</td>
<td>UNRELIABLE</td>
</tr>
<tr>
<td>State S-RIO Models</td>
<td>UNRELIABLE</td>
<td>UNRELIABLE</td>
</tr>
<tr>
<td>US IO Model</td>
<td>UNRELIABLE</td>
<td>UNRELIABLE</td>
</tr>
</tbody>
</table>

Alternative MRIO Model Formulations

To resolve the inconsistencies that can arise when aggregating impact results from separate S-RIO models both vertically and laterally across geographic hierarchies, two alternative formulations of multi-regional input-output models (MRIO) are being considered. The first type of MRIO, referred to as “Alternative A” has 3 endogenous regions, Local and Rest-of-State (RoS), Rest-of-US (RoUS), and 1 exogenous Rest-of-World (RoW) region. The second type of MRIO, “Alternative B”, has two variants. Alternative B1 has 50 endogenous regions, one for each State, and one exogenous RoW region. Alternative B2 has 3,142 endogenous regions, one for each County, and one exogenous RoW region. Re-populating the RECONS database with Alternative A-type MRIO models would require one MRIO for each Local reporting area. While there are currently about 1,200 Local S-RIO, the collection of Alternative A type MRIO-type models could potentially have as many as one for each county and each multi-county area. In the cases of Alternative B1 and Alternative B2, the RECONS database would contain a single MRIO model respectively, as shown in Table 4.

Table 4. Number and Geographic Scope of MRIO Models

<table>
<thead>
<tr>
<th>MRIO Model</th>
<th># of Models in RECONS Collection</th>
<th>Geographic Extent of the MRIO Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt A 3-Region MRIO Models</td>
<td>As many as 3,142 or more</td>
<td>Local &gt; RoS &gt; RoUS</td>
</tr>
<tr>
<td>Alt B1 States-Only MRIO Model</td>
<td>1</td>
<td>State &gt; US</td>
</tr>
<tr>
<td>Alt B2 All- Counties MRIO Model</td>
<td>1</td>
<td>Local &gt; State &gt; US</td>
</tr>
</tbody>
</table>

RECONS with a Collection of Alternative A-type MRIO Models

Each RECONS MRIO model following the Alternative A formulation has 3 endogenous regions in a geographical hierarchy of Local > RoS > RoUS. This means that each Alternative A MRIO models covers the entire geographic hierarchy, as shown in Table 4. For each Alternative A MRIO, vertical aggregations would be consistent. This is a huge benefit compared to the current RECONS collection of S-RIO models. However, lateral aggregations between Alternative A MRIO models are not possible since each MRIO model defines Local or RoS differently. Table 5 summarizes Alternative A MRIO models with respect to vertical and lateral aggregation.
Table 5. Vertical and Horizontal Aggregation of MRIO Models

<table>
<thead>
<tr>
<th></th>
<th>Vertical Aggregation</th>
<th>Lateral Aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt A 3-Region MRIO Models</td>
<td>YES</td>
<td>UNRELIABLE</td>
</tr>
<tr>
<td>Alt B1 States-Only MRIO Model</td>
<td>YES (No Local)</td>
<td>YES (No Local)</td>
</tr>
<tr>
<td>Alt B2 All-Counties MRIO Model</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

**RECONS with a Single Alternative B1-type MRIO Model**

A single RECONS MRIO model following the Alternative B1 formulation has 50 endogenous regions representing a geographic hierarchy of State > US. That is, the economic impacts on each State or group of States could be identified and all 50 represent the US economy in sum. Of course, limiting the spatial granularity to 50 States means that the Alternative B1 MRIO model do not have a Local component in the geographic hierarchy, as shown in Table 4. Both vertical aggregations from State to US and lateral aggregations among States can reliably be made using the Alternative B1 MRIO (see Table 5). This is a significant improvement over both the current S-RIIO and Alternative A MRIO, albeit without a Local component.

**RECONS with a Single Alternative B2-type MRIO Model**

A single RECONS MRIO model following the Alternative B2 MRIO configuration has 3,142 endogenous regions encompassing a geographic hierarchy of Local > State > US. Local economic impacts can be readily aggregated into any multi-County, State or multi-State groupings including the entire US economy in sum. In other words, the Alternative B2 MRIO spans the entire Local > State > US geographic hierarchy and can reliably be aggregated in both the vertical and lateral dimensions as shown in Table 5.

**Computation and Storage Considerations**

MRIO models with high geographic granularity with respect to endogenous regions have a clear advantage for supporting the reporting requirements of USACE program analysis. However, the computational and computer media storage costs increase exponentially with respect to the number of endogenous regions. Tables 6 describes the computer storage requirements of individual S-RIIO and MRIO models. Table 7 shows the computer storage requirements of each collection of models. Of course, for Alternatives B1 and B2 there are only one MRIO model in the collection.

To estimate the computer storage requirements, it was assumed that there are 536 industries in each region. The number of bytes of computer storage is estimated as the number of matrix cell values a model has multiplied by 4 since each cell value requires 4 bytes of computer storage. The number of multiplier matrix cells a model has is the square of the number of industries multiplied by the number of endogenous regions.

Apart from the Alternative B2 MRIO, storage requirements are modest ranging from 3 to 30 Gigabytes (GB). However, Alternative B2 consumes nearly 11,000 GB or about 11 Terabytes (TB). A model this size is not a deterrent, but rather is an indicator of substantial time and costs. And it is likely that applying sparse-matrix methods could reduce the storage requirements substantially.
Table 6. Computer Storage Requirements of Individual Models

<table>
<thead>
<tr>
<th>Type of Model</th>
<th>Individual Model # of Industries</th>
<th>Individual Model # of IxI Matrix Cells</th>
<th>GB per Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-rio</td>
<td>536</td>
<td>287,296</td>
<td>.001</td>
</tr>
<tr>
<td>Alt A 3-Region MRIO Models</td>
<td>1,608</td>
<td>2,585,664</td>
<td>0.010</td>
</tr>
<tr>
<td>Alt B1 States-Only MRIO Model</td>
<td>26,800</td>
<td>718,240,000</td>
<td>2.675</td>
</tr>
<tr>
<td>Alt B2 All-Counties MRIO Model</td>
<td>1,684,112</td>
<td>2,836,233,228,544</td>
<td>10,565.792</td>
</tr>
</tbody>
</table>

Table 7. Computer Storage Requirements of Alternative Model Collections

<table>
<thead>
<tr>
<th>Type of Collection</th>
<th># of Models in Collection</th>
<th>GB per Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-rio</td>
<td>3,193</td>
<td>3.4</td>
</tr>
<tr>
<td>Alt A 3-Region MRIO Models</td>
<td>3,142</td>
<td>30.2</td>
</tr>
<tr>
<td>Alt B1 States-Only MRIO Model</td>
<td>1</td>
<td>2.7</td>
</tr>
<tr>
<td>Alt B2 All-Counties MRIO Model</td>
<td>1</td>
<td>10,565.8</td>
</tr>
</tbody>
</table>

**Analyst Usage Considerations**

While not especially onerous, MRIO models increase the amount of information that must be provided by the user/analyst when assessing policy scenarios. Current established procedures using RECONS S-RIO models require that the user/analyst essentially make a binary choice regarding each of a scenario’s direct effects. The choice is whether the procurement is made from a supplier located within the single endogenous S-RIO region or not. For example, if a project requires wood pilings, the choice must be made of whether the pilings are purchased from a supplier located in the Local endogenous region or not. If the supplier is Local, then the direct effect is applied to the Local S-RIO model; if the supplier is in the exogenous region, none of the direct effect is applied to the Local S-RIO model. As shown in Table 8, the choices for locating direct effects get more complex with MRIO models. With an Alternative A MRIO model, the analyst must explicitly allocate the direct effect among the 3 endogenous regions (Local, RoS, and RoUS) and 1 exogenous RoW region. With an Alternative B1 MRIO model, the analyst must explicitly allocate scenario direct effects among 50 endogenous State regions and 1 exogenous RoW region. With an Alternative B2 MRIO model, the analyst must explicitly allocate scenario direct effects among 3,142 Local endogenous regions and 1 exogenous RoW region.

Table 8. Burden on Analysts

<table>
<thead>
<tr>
<th>Type of Model</th>
<th>Number of Choices for Locating Direct Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Region</td>
<td>1</td>
</tr>
<tr>
<td>3-Region MRIO</td>
<td>3</td>
</tr>
<tr>
<td>All-States MRIO</td>
<td>50</td>
</tr>
<tr>
<td>All-Counties MRIO</td>
<td>3,142</td>
</tr>
</tbody>
</table>
Building RECONS MRIO Models

All S-RIO models currently in the RECONS database were constructed using off-the-shelf IMPLAN’s data (both control total data and trade flow data) along with IMPLAN’s Pro desktop software (IMPLAN, 2017). Alternative A, B1 and B2 MRIO models also use off-the-shelf IMPLAN control total data, however revised trade flow data are derived using a USACE custom trade model developed specifically for RECONS MRIO models. Further, the MRIO models are assembled using custom software procedures developed for RECONS. The USACE in-house custom MRIO model-building and trade model were developed because IMPLAN’s Pro desktop software does not support building these types MRIO models or modifying the IMPLAN trade flow estimates. Using IMPLAN’s data to build RECONS MRIO models is permitted under a license agreement granted by IMPLAN Group LLC to USACE.

Conclusions and Recommendations

As one of the major engineering and construction agencies in the US, RECONS provides provide consistent and defensible estimates of jobs, incomes and other economic impacts associated with USACE infrastructure and programs. Since RECONS incorporates impact area data, as well as multipliers, direct ratios (jobs to sales, income to sales, etc), and geographic capture rates that were extracted from the IMPLAN models, it’s essential to develop enhanced procedures to build economic impact models for the purpose of updating and enhancing the RECONS economic impact analysis system.

The paper provides a foundation for a managerial evaluation and alternatives for improving RECONS by moving from S-RIO to MRIO modeling. The evaluation criteria, including computer storage requirements, and the efficacy of vertical and lateral aggregation of impact results, are all practical challenges and are important to how USACE move RECONS forward in anticipating of the high computing power and larger capacity in both storage and bandwidth.

For future recommendations and implementations, this administrative review could be part of consideration for future development of the methods to extract IMPLAN data set and build “physical” models in RECONS. Instead of a pre-determined set of “regions” with multipliers and economic ratios, MRIO, regardless which alternative discussed in this paper, will allow a finite number of models in RECONS with virtually infinite combinations of regions to be analyzed in RECONS. As Corps analysts not only have used the tool to track progress and justify the continued operation, maintenance and construction work, they also constantly in need of evaluating new projects or infrastructures in various proposed locations. These MRIO alternatives will provide not only a reliable aggregation/disaggregation with spatial granularity, but will also serve as a powerful tool for the Corps’ planning process.
References
