Title: Key sector analysis for a subnational region with leakages

Abstract

Key sector analyses have a long and rich history. However, almost all the previous analyses were conducted only within an input-output (IO) framework for a national economy. The present study (i) performs the analysis for a subnational (or regional) economy suffering severe leakages of industries' revenues due to a large amount of imports and a large fraction of factor income earned by non-residents, and (ii) extends the previous IO-based analyses to an analysis within a social accounting matrix (SAM) model, and further, to a multi-regional SAM (MRSAM) model. Comparing the results from the three alternative models show that the key sectors identified with the alternative models are considerably different. This finding points to the necessity of using SAM-based models for an accurate key sector analysis, and offers valuable implications for regional policymakers whose main interest is identifying the industries that they target for the economic development of their regions.

Key Words: Linkage measures; Social Accounting Matrix model; Alaska

1. Introduction

In the input-output (IO) economics literature, key sector analysis has often been conducted to evaluate the importance, or role, of an industry within an economic system (typically a national economy) comprising a large number of industries, via measuring the linkage (or relationship) among the industries. The analysis have been used to identify those industries which policymakers target for economic development of a country. Policymakers often ask which industries have the potential to make the largest contribution to the generation of output, employment, and income within the economy of interest. If several industries are identified as key sectors, they can implement policies (e.g., expansion of government expenditures and tax cuts) to stimulate the industries.

A plethora of key sector analyses have been performed using national-level IO models. However, the IO models have the weakness that they are unable to capture the distributional effects of policies on non-industry sectors such as households and subnational governments. Although Cardenete and Sancho (2006) used a social accounting matrix (SAM) model to overcome the weakness of the IO model, and to account for the role of non-industry sectors (households) in gauging the linkages, the study is focused on a national economy (Spanish economy). While national-level analyses are useful for national policymaking, regional policymakers will benefit more from regional-level analyses. To overcome the limitations of the previous studies, the present study uses three alternative regional economic models [IO, SAM, and multi-regional SAM (MRSAM) models] for a *regional* economy (Alaska economy), and compare the results to demonstrate the weaknesses of the previous approaches. The reason why this study used an MRSAM model is to take into account the effects on the linkage measures of the flows of commodities and factors of production among regions.

The economies of regions within a country are interconnected, and the United States (US) is not an exception, as an enormous amount of goods and services is traded and factors of production (labor and capital) flow among the states. Alaska is unique among states in the sense that the state imports a large quantity of commodities from other states for production and consumption in the state, and that a large fraction of labor and capital used in Alaska is from the rest of country. For example, base year data used in the present study indicates that Alaska's imports of the non-seafood food commodity (i.e., "Other Food Manufacturing" commodity) from the rest of the country is over five times larger than the quantity produced in Alaska. Overall, the imports of commodities from the rest of US to Alaska is about 31% of total production within Alaska (Seung 2014a). In addition, the quantity of the primary factors production imported from the rest of US for use in Alaska industries is also substantial. In 2016, the share of non-Alaska resident workers in Alaska industries is about 22% of total number of workers in the state and their wages accounts for about 16% of total wages earned by all workers in Alaska industries (Alaska Department of Labor and Workforce Development (ADOL) 2018). Therefore, key sector analysis using a single-region model, which does not consider these inter-regional flows of commodities and factors of production, will provide misleading results to policymakers, especially in import-dependent regional economies such as Alaska.

2. A Brief Overview of Key Sector Analysis

There are two different types of linkage that economists have analyzed to perform the key sector analysis – backward linkage and forward linkage. Backward linkage refers to the interconnectedness between an industry (call it industry *i*) and the supporting industries from which industry *i* buys the intermediate inputs needed to produce its output. An expansion in an industry *i*'s output will generate both direct and indirect effects. The direct effect is the initial increase in the output of the industry. Indirect effects are the effects that transpire due to the industry's purchase of intermediate inputs from the other industries. Each of the industries that sells inputs to the first industry will, in turn, need to buy intermediate inputs from the other industries in order to meet the increased production in the industry. This process will continue, and create round-by-round effects throughout the economy. Forward linkage is the relationship between an industry (industry *i*) and the industries to which this industry sells the outputs which are used as intermediate inputs in the purchasing industries. As in backward linkage, there will be direct and indirect effects that will be engendered. The importance or role of an industry is evaluated by considering these two types of linkages.

Key sector analysis has a long and rich history in IO literature. However, previous key sector analyses have at least three limitations. First, almost all key sector analyses have been executed based solely on inter-industry relationships represented by IO tables. The only exception is Cardenete and Sancho (2006) that utilized a SAM model where non-industry sectors such as factors of production and households are included as endogenous sectors to account for the distributional effects occurring through these non-industry sectors. The study found a substantial difference in the results for the key sectors detected from the IO and SAM models. As shown in the base year data used in the present study, the overall percentage of the aggregate sales revenue from all industries in the study region (here, Alaska) accounted for by the aggregate value added income generated from the industries is about 60%. A share of this value added income is distributed to households in the region and is spent on goods and services. Ignoring the connection between production activities and household income and expenditure, as in an IO model, will result in a tremendous underestimation of the linkage measures. The present study, by using a SAM model, address this limitation by capturing this connection. Second, all the previous key sector analyses were performed for national economies using national IO models. While national-level analyses are useful to national-level policymakers, these analyses will not provide valuable policy insights to policymakers at the regional level. Third, none of the previous studies conducting key sector analyses adopted a multi-regional framework such as multi-regional IO (MRIO)[1] or multi-regional SAM (MRSAM) models.

The earliest studies of key sector analysis (or linkage analysis) are Rasmussen (1956), Chenery and Watanabe (1958), and Hirschman (1958). A myriad of approaches are proposed for key sector analysis. There are three approaches most extensively adopted to quantify backward linkage and forward linkage in the literature. The first approach is by Chenery and Watanabe (1958) that quantifies the direct backward linkage (DBL) and direct forward linkage (DFL) based on the direct IO coefficients. In this approach, the DBL and DFL are obtained by calculating the column sums and the row sums, respectively, in the direct IO coefficient matrix. The second approach is by Rasmussen (1956) that relies on the elements in the Leontief inverse matrix for measuring total backward linkage (TBL) and total forward linkage (TFL). This approach quantifies TBL and TFL by computing the column sums and row sums, respectively, of the Leontief inverse matrix. There are also variants on this approach, with some studies (e.g., Beyers 1976; Jones 1976) using the output matrix (distribution matrix) from a Ghosh model (1958) to calculate DFL and the Ghosh inverse matrix to calculate TFL. The third approach is hypothetical extraction method (HEM, Schultz 1977). In this approach, the importance of an industry is gauged by comparing the actual level of total output in the economy with that resulting from hypothetically eliminating the industry from the economy, within a Leontief

[1] Shao and Miller (1990) examined spatial linkages within an MRIO model for US, but did not identified key sectors.

demand-driven model (to measure TBL) and within a Ghosh supply-driven model (to measure TFL).

The present study does not attempt to compare and discuss different linkage measures proposed in the literature. For a good comparative review and assessment of the linkage measures, see, for example, Sanchez-Choliz and Duarte (2003) and Cai and Leung (2004). The focus of the present study is on comparing the different key sectors identified by using several alternative underlying models, including IO, SAM, and MRSAM models, and thereby on offering both model choice implications and policy implications. In doing so, this study adopts a TBL measure proposed by Rasmussen (1956) because this measure includes both direct and indirect effects and a TFL measure by Beyers (1976) and Jones (1976) because of dissatisfaction with a TFL measure based on Leontief inverse.

3. Methods for Key Sector Analysis

This section describes the linkage measures used in the present study. Suppose the IO model can be represented compactly as:

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

where X is a vector of industry output; I is an identity matrix; A is Leontief IO coefficient matrix; Y is a vector of final demand; and $(I-A)^{-1}$ is the Leontief inverse. The industry-sectoring scheme used in the present study is presented in Table A.1 in Appendix A. Given the IO model in Equation 1 above, the TBLs from the IO model are computed by:

$$TBL = \frac{ne'(I-A)^{-1}}{e'(I-A)^{-1}e} \quad , \qquad (2)$$

where n is the number of industries; e is a column vector of ones; and e′ is a row vector of ones. TFLs from the IO model are quantified by:

$$TFL = \frac{n(I-B)^{-1}e}{e\prime(I-B)^{-1}e} \quad , \qquad (3)$$

where B is the output coefficient matrix from Ghosh's (1958) supply-driven model; and $(I\text{-}B)^{-1}$ is the Ghosh inverse.[2] The TBL in Equation 2 is a row vector where each element measures the total backward linkage of an industry, whereas the TFL in Equation 3 is a column vector where each element measures the total forward linkage of an industry.

Summing the measures in each of the two equations (Equations 2 and 3) across all industries yields *n*, which is the number of industries. Therefore, the average of each of the TBL and TFL measures is equal to unity and the TBL and TFL above represent the relative linkage indicator for an industry, that is, relative to the average. Once the linkage measures are computed using Equations 2 and 3 above for all the industries, the industries are typically classified into four categories, depending on the values of the TBL and TFL. The industries whose backward and forward linkage measures are both smaller than unity (i.e., the average) are classified as weak linkage sectors (WL). The industries whose backward linkage measure is larger than unity but whose forward linkage measure is smaller than unity are categorized as strong backward linkage sectors (SB). The industries whose backward linkage measure is smaller than unity but whose forward linkage is larger than unity are categorized into strong forward linkage category (SF). Finally, the industries whose backward and forward linkage measures are both larger than unity are classified as key sectors (KS). When applying the formulas in Equations 2 and 3 above to SAM and MRSAM models below, the matrices A and B

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[2] TBL and TFL, respectively, are based on two different IO models – Leontief demand-driven model and Ghosh supply-driven models. The use of Ghosh-driven model as *an impact analysis* where the forward linkage effects of a policy change are calculated could be problematic. Dietzenbacher (1997) suggested that the Ghosh model be interpreted as a price model when it is used to describe causal interpretation of the model (for impact analysis). However, the Ghosh-driven model is acceptable if the model is used, as in the present study, to gauge, *ex post*, the role of an industry as supplier of inputs to its forward-linked industries (Miller and Temurshoev 2017).

are replaced by the corresponding matrices estimated from the two different models, as discussed below.

4. SAM Models

4.1 Single-region SAM Model

An IO model is helpful because it accounts for major linkages in an economy, recording the inter-industry transactions of goods and services. However, IO models have the weakness that they cannot capture the flows from industries to value added sectors (factors of production), to other non-industry sectors such as households and government, and finally back to industries via purchases by these other non-industry sectors of goods and services produced by the industries. SAM models are an extension of IO models, take into account these flows, and therefore, can assess the distributional effects of various policies. Below, I discuss the structure of the SAM model adopted in the present study, relying on Holland and Wyeth (1993) and Seung and Waters (2013). For more details on SAM models, see Adelman and Robinson (1986), Holland and Wyeth (1993), and Seung and Waters (2013).

For the present study, several non-industry accounts are added to the IO accounts to construct a single-region SAM for Alaska. The additional accounts include value added (labor, capital, and indirect business tax), three different types of households (distinguished by income levels), and a combined state and local government. The structure of the single-region SAM is shown in Table A.2 in Appendix A. The SAM model is represented as:

$$T = (I - S)^{-1}K \quad , \qquad (4)$$

where T is a vector of endogenous sectors (accounts), S is SAM coefficient matrix, and K is a vector of exogenous sectors. Here $(I-S)^{-1}$ is called the SAM multiplier matrix or matrix of SAM inverse coefficients. For details on the structure of the SAM model, see Appendix B.

The linkage measures are calculated using Equations 2 and 3 for the three different models, one with only industry sectors (IO model) and the other two with both industry and non-industry sectors (SAM and MRSAM models). While the linkage measure for an industry obtained from the IO model includes only the inter-industry effects, the linkage measure for an industry computed with the two SAM models includes both the effects from the other industries and those from all the non-industry sectors.

The Leontief inverse, $(I-A)^{-1}$, in Equation 2 above includes the elements for only industries while the SAM multiplier matrix, $(I-S)^{-1}$, in Equation 4 above includes the elements for non-industry sectors as well as industry sectors. Therefore, when applying Equation 2 to the SAM multiplier matrix to calculate the TBLs from the SAM model, this study considers only the industry-by-industry portion in the SAM multiplier matrix so that the TBLs thus obtained can be compared in a meaningful way to those from the IO model. Similarly, only the industry-by-industry portion of the Ghosh inverse in Equation 3 is used to assess the TFLs from the SAM model.

4.2 Multi-regional SAM (MRSAM) model

Most of the model descriptions in this section are from Seung (2014b) and Seung (2017). Extending the single-region SAM above, an MRSAM model was constructed for three regions in the US – Alaska, West Coast (WC), and the rest of US (RUS). The structure of the MRSAM is similar to those in Round (1985) and Roberts (2000). A simplified diagram of the MRSAM used in the study is displayed in Table A.3 in Appendix A. A more detailed schematic of the MRSAM is found in Seung (2014b) and Seung (2017).

The MRSAM model can be also represented by Equation 4 above although the elements in the matrices in the equation are different. Specifically, T is now a vector of endogenous sectors for all the regions (three regions in this case), S is the MRSAM coefficient matrix that contains the coefficients for all the regions, and K is a vector of exogenous sectors for the regions. In addition, $(I-S)^{-1}$ is now the MRSAM multiplier matrix. For details on the structure of the MRSAM model, see Appendix B.

As mentioned, when calculating TBL measures for the SAM model, this study considered only the industry portion of the SAM multiplier matrix that has elements for Alaska industries and other Alaska endogenous sectors. In contrast, MRSAM multiplier matrix has elements for non-Alaska industries and other non-Alaska endogenous sectors as well as those for Alaska. This study compared the linkage measures from the three models for Alaska industries only. Therefore, in order to make a meaningful comparison of the TBL measures from MRSAM model to those from IO and SAM models, this study computed the TBL measures from the MRSAM model for Alaska industries only.

Specifically, for each Alaska industry (column) in the MRSAM multiplier matrix, $(I-S)^{-1}$, this study added up the elements in the rows for all the industries in the three regions where the number of elements in the column totaling 105 (3 regions x 35 industries). Multiplying the resulting number by the number of Alaska's industries yielded the numerator in Equation 2 above. The denominator was calculated by summing all the elements for the three regions' industries across all the Alaska industries (columns), where the number of elements here is equal to 3,675 (3 regions x 35 industries x 35 industries). By doing this, this study quantified the backward linkage of an Alaska industry to all the industries in the other two regions as well as to all the Alaska industries. Similarly, in calculating the TFL for an Alaska industry using Equation 3, this study summed up the elements for all the industries in all the three regions in the row for the Alaska industry in the MRSAM Ghosh inverse matrix.

5. Data

Using 2004 IMPLAN (IMpact analysis for PLANning, Minnesota IMPLAN Group, Inc. 2004) data[3], this study first constructed social accounting matrix (SAM) for Alaska. Since the seafood industry data from IMPLAN was not reliable, this study had to replace the seafood industry data from IMPLAN with data estimated based on various sources (Seung and Waters 2009).[4] After replacing the seafood data with the estimated data, this study aggregated all the seafood industry data into two data components, Fish Harvesting and Fish Processing.

There are a total of 80 accounts or sectors in the SAM. 77 of these accounts are endogenous accounts and the other three accounts are exogenous. The 77 endogenous accounts include 35 industries, 35 commodities, three value added accounts (labor income, capital income, and indirect business tax), three household accounts (distinguished by income levels), and one combined state and local government account. The three exogenous accounts include federal government, savings-investment account, and the rest of the world (ROW). The sector

[3] Admittedly, the data is somewhat old. Seafood industry data in IMPLAN is not reliable, which means that analysts should estimate the data based on information obtained from surveys or other available data. In addition, analysts should develop a SAM for seafood industry using the data thus obtained. Estimating seafood industry data and constructing a SAM requires a significant amount of time. Because the most recent year for which the seafood industry data was estimated is 2004, this study uses the IMPLAN data (only the non-seafood industry portion) for the same year (2004) for consistency, although the most recent IMPLAN data is available for year 2017.

[4] Sources used to estimate seafood industry data include the Commercial Fisheries Entry Commission (CFEC), Alaska Fisheries Information Network (AKFIN), Pacific Fisheries Information Network (PacFIN), and NMFS. The Research Group (2007) and Seung and Waters (2009) provide more detailed descriptions of the procedures followed to construct the Alaska seafood industry dataset.

aggregation scheme and the structure of the SAM are shown in Table A.1 and Table A.2 in Appendix A, respectively. To develop the IO model for Alaska, this study simply eliminated the non-industry, non-commodity accounts from the SAM, leaving only the 70 endogenous accounts in the resulting IO model.

Developing the MRSAM required constructing two additional SAMs, one for the WC, the other for RUS. To develop the WC SAM, this study utilized data from the IO model developed by Northwest Fisheries Science Center (NWFSC) for Pacific Coast fisheries (called IO-PAC model). The IO-PAC model was built out of 2006 IMPLAN data with seafood industry information estimated with survey data (Leonard and Watson 2011). The SAM for RUS was constructed using 2008 IMPLAN data and 2008 NMFS fish landings data. Since the three SAMs are based on different base years (2004 for Alaska, 2006 for WC, and 2008 for RUS), the GDP price deflator series was applied to adjust the Alaska and WC SAMs to 2008 levels.

To combine the three SAMs into an MRSAM, trade flows among the three regions had to be estimated. This study utilized IMPLAN version 3 to compute the multi-regional trade flows on the basis of 2008 IMPLAN data. To balance the MRSAM thus estimated, this study adjusted the exogenous accounts until the row and column sums are equalized for all the accounts in the MRSAM[5]. The final MRSAM has a total of 234 accounts. 231 of these are endogenous accounts (i.e., 77 endogenous accounts in each region). The three exogenous accounts are the same as above (federal government, savings-investment, and ROW).

[5] This study chose this method of balancing the MRSAM to preserve the original economic structures shown in elements in the endogenous sectors with the elements in the exogenous sectors adjusted to make the row and column sums equal.

6. Results and discussion

6.1 Backward linkages

This study first compares the results for backward linkage measures from IO and SAM models (Table 1). Notable result is that the rankings for Other Food Manufacturing industry[6] are strikingly different between the two models. The industry is ranked 8th (with TBL of 1.092) with the IO model while it is ranked much lower, 25th (with TBL of 0.947), with the SAM model (Table 1). This industry is characterized by a very low ratio of value added income to its total industry sales revenue. The base-year SAM indicates that only 19% of total revenue in the industry is paid to value added sectors. Including the value added sectors as endogenous sectors in the SAM model makes the backward linkage measure of the industry relatively weak compared to some of the other industries whose ratios of value added income to revenue are much higher. This makes the ranking of this industry drop dramatically with the SAM model. This result demonstrates that backward linkage analysis using an IO model, which ignores the link between the industry sectors and the non-industry sectors (value-added sectors and household sectors), can produce misleading results. By accounting for this link, the SAM model produces a much smaller backward linkage measure for the industry.

In contrast, the rankings of some industries (such as Wholesale Trade, Food Stores, and Other Retail Trade) rise in dramatically when the SAM model is used, as compared to the IO model. For example, Other Retail Trade is ranked 27th with IO model while it is 10th with the SAM model. This result shows again the significance of using a SAM model because of its

[6] Other Food Manufacturing includes all the food manufacturing activities, but excludes Fish processing. Baseline data indicates that Other Food Manufacturing does not use any raw fish but use a very small amount of processed fish as intermediate input.

ability to capture the distributional effects in the SAM. Other Retail Trade may not be crucial when considering its role only as purchasers of inputs from other industries. But a large share – approximately 65% -- of the industry's revenue is paid to value added sectors. The SAM model traces the distribution of this value added income to households and their consumption of goods and services. This makes the contribution of this industry larger, if measured with a SAM model, than some of the other industries, making the ranking rise with the SAM model.

Results reveal that the rankings of other industries do not change significantly, compared to these industries. As an example, there is no change in the ranking of Fish Processing which ranks very high in both of the models. The Fish Processing industry uses a large amount of input from other industries, especially, from Fish Harvesting (raw fish), and is one of the most vital industries driving the Alaska economy. The industry's dependence on the backward-linked industries is so strong that the rankings are very high and stable regardless of whether the link between industries and household expenditures is considered (SAM model) or not (IO model).

Comparing the results from SAM and MRSAM models (Table 1), some industries (Agriculture, Oil and Gas, and Utilities) are ranked much lower with the MRSAM model. For instance, Utilities is ranked 7th (with TBL of 1.061) with the SAM model while ranked 28th (with TBL of 0.946) with the MRSAM model. One likely reason is that, compared to other industries, these industries' dependence on the imported intermediate inputs is smaller than their dependence on Alaska-produced inputs. If a large share of the intermediate inputs used in this industry is supplied by Alaska industries, its relative importance (i.e., compared to other industries) as purchaser of Alaska-produced commodities will be higher within the SAM model, where only the linkages to Alaska industries are considered, than within the MRSAM model, where the linkages to both the industries in Alaska and non-Alaska states are taken into account.

On the other hand, the significance of industries such as Other Food Manufacturing and Eating and Drinking increase substantially with MRSAM model that accounts for the contributions of these Alaska industries to the whole US economy. This result may have occurred for one or both of the following two reasons. First, the reliance of these industries on the imported intermediate inputs is high, which will make spillover effects of these industries occurring in the non-Alaska states stronger than other industries. Second, the factor income leakages from these industries to the non-Alaska states are relatively large, compared to other industries. The SAM model does not account for the effects of factor income leakages on the non-Alaska states, that is, the effects of non-Alaska households' purchases of the commodities produced in the non-Alaska states with the income that they earn in Alaska.

The increased importance of these industries shown when using MRSAM model has some policy implications. First, the policymakers in Alaska may want to implement policies that encourage investments in the industries in the state that supply inputs to these industries so that these industries do not need to rely on imports as much (import substitution policy). Second, the policymakers need to consider policies that are designed to expand hiring of Alaska residents and to promote ownership of firms by Alaska residents in order to retain the Alaska-generated factor income within the state, and to maximize these industries' contribution to the state's economy.

In all the three models, Refined Petroleum, Fish Processing, Air Transportation, and Water Transportation are among the top conducers to Alaska economy (IO and SAM) and the whole US economy (MRSAM), from the perspective of their backward linkage effects.

6.2 Forward linkages

Table 2 shows the forward linkage results. As shown in Table 2, Oil and Gas industry is ranked the first in its forward linkage in all three models (with TFL ranging from 1.428 to 1.788). This means that the industry has a critical role both within Alaska (IO and SAM) and outside of Alaska (MRSAM) because output from this industry is used as an essential intermediate input in other industries, in particular, Refined Petroleum. This is an expected result from the finding that Refined Petroleum is the industry that has the strongest backward linkage (Table 1) and from the fact that Oil and Gas is the top backward-linked industry of Refined Petroleum. The next most important industry as supplier to other industries is Management Services; the industry ranks second in IO and SAM models and third in MRSAM model.

Comparing the forward linkage results from IO and SAM models, there are many industries for which the rankings are considerably different between the two models. For example, Fish Harvesting is ranked very high (fourth with TFL of 1.351) in IO model while very row (24th with TFL of only 0.960) in SAM model. While this industry supplies most of its output to the Fish Processing industry, the supply of the products (i.e., raw fish) directly to non-industry sectors such as households and government is not very large, making the ranking much lower in the SAM model. Wood Products shows a similar result; the ranking falls sharply in the SAM model.

In stark contrast to Fish Harvesting, Educational Services is ranked very low (27th with a very low TFL of 0.783) with IO model whereas it is far higher (sixth with TFL of 1.219) with the SAM model. While the contribution of this industry, as an input supplier to other industries, may not be strong (IO model), the service from the industry is a key expenditure item for households in Alaska, and therefore, its significance increases sharply with the SAM model. Again, this finding points to the criticalness of using a SAM model when measuring the role of an industry. An industry that does not reveal its importance with an IO model, which does not account for the role of non-industry accounts (such as households or government expenditures), can be found to be a very crucial industry if a SAM model is used.

While the rankings of the some industries in their forward-linkage contributions are drastically different between IO and SAM models, the rankings of other industries are not very different. As an instance, in addition to Fish Processing, the ranking of Air Transportation is very similar between the two models; it is ranked 30th and 31st, respectively, with the two models. Similar results are observed for Water Transportation with rankings of 31 and 32 with IO and SAM, respectively.

One interesting result is that, while the significance of some industries decreases as one goes from IO to SAM models, the importance of these same industries increases as one switches from SAM to MRSAM models. An example is the Fish Harvesting industry. The industry is ranked very high (fourth with TFL of 1.351) with the IO model, is ranked very low (24th with TFL of 0.960) with the SAM model (Table 2). But the ranking rises again to 10th (with TFL of 1.150) with the MRSAM model. As mentioned above, the role of this industry is low in the SAM model because the non-industry sectors (households) in Alaska do not directly consume a large amount of raw fish without it going through a fish processor first.[7] But since some raw fish is exported to non-Alaska states for processing and the processed fish is consumed in the non-

[7] In fact, Alaskans do eat raw and unprocessed fish, especially those caught in subsistence fisheries. However, because there is no data on Alaskans' direct consumption of the raw and unprocessed fish, this study does not consider the role of their direct consumption of the fish. Since it is likely that their direct consumption is small compared to the total amount of commercially harvested fish from Alaska waters, omission of their direct fish consumption is not likely to change the main findings in a considerable way in this study.

Alaska households, the forward linkage of this Alaska industry becomes stronger with MRSAM model.

Similarly, the importance of Refined Petroleum with SAM model is relatively low (22nd) while it becomes higher with MRSAM model (7th), due to the fact that a large fraction of the refined petroleum produced in Alaska is exported to other states. Base-year (2008) data reveal that about 31% of refined petroleum is exported to non-Alaska states. The exported commodity is used as either intermediate inputs or as consumer goods in the non-Alaska states, elevating the significance of the commodity within the MRSAM model.

In contract, the ranking of Education Services is relatively high (6th) with SAM model for the reasons mentioned above. But the significance of this industry is reduced drastically with MRSAM model (23rd). It is not surprising that, with a negligible amount of Educational Services exported to the non-Alaska states for use as either intermediate inputs or for household consumption in the non-Alaska states, the forward linkage of this industry becomes weak with the MRSAM model.

6.3 Key sectors

Table 3 presents the industries classified into four different groups identified with IO, SAM, and MRSAM models, respectively. The table list the industries that have WL (TBL<1 and TFL<1), the industries that have SB (TBL>1 and TFL<1), the industries with SF (TBL<1 and TFL>1), and finally the industries under KS category (TBL>1 and TFL>1).

Results from IO model (column 2 in Table 3) reveal that some industries (WL) are independent industries in the sense that they do not play a critical role either as purchasers of inputs from other industries or as sellers of inputs to other industries (e.g., Mining Services).

Notably, many services industries (such as Educational Services, Health Services, Entertainment Services, Lodging, and Eating and Drinking) are included in this category. There are industries that have strong backward but weak forward linkages (SB). As an example, Fish Processing industry is a vital sector that generates enormous backward linkage effects because it purchases a large amount of raw fish from Fish Harvesting industry and non-fish inputs from other industries. But the role of the industry as an input provider to other industries is not as significant.

Some industries have strong forward but weak backward linkages (SF) using the IO model. These industries are crucial industries as suppliers of inputs to other industries. Fish Harvesting, for example, is an essential industry as supplier of raw fish to Fish Processing industry. As expected, many service industries (Finance and Insurance, Real Estate, Professional Services, Management Services, Support Services, and Repair Services) are found to be sectors with strong forward linkages. The services provided by these industries are used as major intermediate inputs in other industries. Yet these industries are not shown to have immense backward linkage effects within the IO model.

Key sectors (KS) detected from the IO model are also presented in Table 3. These sectors make vital contributions to the regional economy both through inducing economic activities in the backward-linked industries and through enabling the economic activities in the forward-linked industries. The key sectors identified with the IO model include Oil and Gas, Utilities, Construction, Wood Products, Other Food Manufacturing, Other Manufacturing, Refined Petroleum, and Information. Some of these industries (Oil and Gas, Utilities, Wood Products, Other Manufacturing, and Refined Petroleum) are also identified as key sectors with

SAM model while the other sectors (Construction, Other Food Manufacturing, and Information) are not identified as key sectors within the SAM model (Columns 2 and 3).

A notable finding is that some sectors (e.g., Food Stores and Other Retail Trade) are key sectors with the SAM model (Column 3) while the same sectors have both weak backward and forward linkages (WL) with the IO model (Column 2). On the backward linkage side of these sectors, relatively high ratio of total revenue is paid to value added sectors (especially labor income and indirect business tax) or equivalently, relatively low ratio of total revenue is used to buy intermediate inputs. Because these value added sectors and households are included as endogenous sectors in the SAM model and because the SAM model takes into account the effects of the consumption of the Alaska-produced commodities by households and the combined state and local government in Alaska, the backward linkage is much stronger with the SAM model than with IO model that exclude these non-industry sectors.

On the forward linkage side, very high percentages of total outputs from these two industries (69% and 56%, respectively, of total outputs from Food Stores and Other Retail Trade) are consumed by households in the state or equivalently, very low percentages of the total outputs are supplied to other industries as intermediate inputs in the state. Therefore, the SAM model that includes household sectors as endogenous sectors produces the result that the forward linkages for these industries are very strong while the IO model does not.

Most of the service industries (except Waste Management and Lodging) have strong forward but weak backward linkages (SF, TBL<1 and TFL>1) in the SAM model. The strong forward linkages of some of these industries (e.g., Educational Services, Health Services, and Entertainment Services) are detected in the SAM model, but not in the IO model. Because households in the state spend a large portion of their income on the services from these industries, it is not surprising that these industries are shown to have strong forward linkages in the SAM model while not in the IO model.

Several industries have strong backward but weak forward linkages (SB, TBL>1 and TFL<1) in both IO and SAM models. These industries include Fish Processing, Agriculture, Air Transportation, and Water Transportation. Whereas these industries induce strong economic activities in the other industries by purchasing inputs from them, a very low percentage of the commodities produced in these industries is supplied to other Alaska industries or to non-industry sectors for final consumption with a large percentage of the commodities exported outside of Alaska. For instance, only 5% of the output from Air Transportation industry is used as intermediate input within the state with 87% exported to non-Alaska states. In the most extreme case, almost all the output (99%) from Fish Processing is exported to outside of the state.[8] The percentages of final consumption within the state of the commodities from these industries (Fish Processing, Agriculture, Air Transportation, and Water Transportation) are very low, ranging from 0% (Fish Processing) to 11% (Agriculture). As a result, the additional forward linkage effects from these industries captured by including the two non-industry endogenous sectors (households and the state and local government) within the SAM model are negligible. This makes these industries remain weak forward linkage industries with the SAM model. In fact, the TFL measures for these industries decrease (and the rankings drop) slightly when one goes from IO to SAM models (Table 2).

A considerable share of labor income generated in Fish Processing leaks out of the state due to a high ratio of non-resident workers employed in the industry. In 2006, 76% of the workers in the industry are non-residents who earned 68% of the total wages in the industry

[8] Exports include the exports from Alaska to rest of US and foreign countries.

(ADOL 2008). This means that a very small portion of the labor income generated in the industry stays in Alaska, and is distributed to Alaska households who spend their income on goods and services supplied in Alaska. As indicated in the results, even with high leakage rate of the labor income from the industry, the industry has a very strong backward linkages in both IO and SAM models, due mainly to a significant purchase of its major intermediate input (raw fish) from Fish Harvesting; the industry is ranked 2nd in backward linkages in both the two models (Table 1).

Comparing the results from SAM and MRSAM models, moderately different results are obtained when one considers the contribution of Alaska industries to the whole US economy in the MRSAM model (Columns 3 and 4, Table 3). Most of the industries identified as key sectors in the SAM model (Wood products, Other Manufacturing, Refined Petroleum, Wholesale Trade, Food Stores, Other Retail, and Other Services) remain key sectors with MRSAM model. The only exceptions are Oil and Gas and Utilities.

A few industries that do not exhibit strong backward linkages (e.g., Other Food Manufacturing, Information, Management Services, Support Services, and Eating and Drinking) are now identified as the industries having strong backward linkages (and as key sectors) with the MRSAM model. These industries are generally those industries which rely in large measure on imports for major intermediate inputs they use. For example, Eating and Drinking industry's top three intermediate inputs, determined as percentages of the industry's total revenue spent on the inputs as shown the base year data, are Other Food Manufacturing commodity (17%), Other Manufacturing commodity (7%), and Wholesale Trade commodity (4%). A high proportion, 87%, 86%, and 55%, respectively, of these three commodities supplied in Alaska are imported from non-Alaska states. This implies that the five industries above (Other Food Manufacturing, Information, Management Services, Support Services, and Eating and Drinking) enable strong economic activities in the non-Alaska states via purchasing inputs from these states, leading to these industries having very high backward linkages measures within the MRSAM model. It is shown that the TBLs with the MRSAM model are 1.136, 1.036, 1.003, 1.000, and 1.055, respectively, for these five industries (Table 1).

The state policymakers may want to pay attention to the industries that exhibit strong backward linkages with the MRSAM model whether or not the industries have also strong forward linkages; that is, the industries denoted either SB or KS in the final column in Table 3. These industries are those which suffer seriously leakages of their sales revenues due to a heavy reliance on either the imports of commodities (intermediate inputs) used in their production or factors of production owned by non-Alaska residents, or both. The state government may want to execute a policy designed to expand the Alaska production of these commodities (import substitution) and a policy that increases Alaska residents-owned factors of production. These policies will curtail leakages of the industries' revenues, and maximize their contributions to the state's economy. The positive effects of substituting imports for regionally produced commodities will be much larger if the commodities are also major expenditure items purchased by Alaska households.

7. Conclusions

One of the major concerns that regional governments have is how to maximize the economic contributions of the industries located in their region by implementing various economic development policies. To do so, they often target specific industries that have the potential to conduce the most to their regional economies. Key sector analysis is a valuable tool to identify such industries. Hirshman (1958) is the first attempt to identify key sectors that are essential for national or regional economic development. However, most previous key sector analyses are performed within a single-region IO model and for a national economy. The studies relying on IO models have the limitation that the models are devoid of a critical link between value-added income and household expenditures. As shown in the present study, key sector analysis based on IO models can provide misleading results from a policy perspective because these models do not include the induced effects from spending by non-industry sectors such as households and regional government. Key sector analyses zeroing in on a national economy are useful to national-level policy-makers. However, the national-level analysis can hardly offer any valuable implications about regional policies.

This study measured the linkages among industries in a regional economy. In doing so, this study employed three different regional economic models, IO, SAM, and MRSAM models, and compared the results. One important finding is that the results from the key sector analysis from IO and SAM models are starkly different from each other. This finding is consistent with the empirical evidence in Cardenete and Sancho (2006) that the results from key sector analyses are different between IO and SAM models. Some industries detected in the IO model as those not having strong backward / forward linkages do in fact exhibit strong backward / forward linkages in the SAM model. This difference results from he SAM model considering the effects of spending by non-industry sectors in the SAM model (backward linkage) and/or including the effects of products from an industry being distributed to non-industry sectors (forward linkage).

Policymakers may be misled if they are given only the key sector analysis results from an IO model. A certain industry that is shown to play a crucial role (i.e., be a key sector) when analyzed within an IO model may not be a key sector if examined using a SAM model (e.g., Information industry in this study). On the contrary, an industry that is not identified as a key sector with IO model can be shown to be one if one uses a SAM model (e.g., Other Retail Trade). An accurate understanding of key sectors will help facilitate policymaking by a regional government which is concerned with determining the industries in which the regional government invests to boost their economy.

For the first time in the literature, this study also used the MRSAM framework for key sector analysis at a regional level. By comparing the results from SAM and MRSAM models, an attempt was made to discover those industries which do not exhibit strong backward linkages with the SAM model, but which are identified as the industries having strong backward linkages (and as key sectors) with the MRSAM model. These industries are generally those which depend in a great measure on the intermediate inputs from non-Alaska regions (backward linkage). A large share of their sales revenues leak to the non-Alaska regions. Results demonstrate that policymakers at a regional level may want to identify the major input items imported by the industries suffering severe leakage of their revenues, and execute a policy that enlarge their production within their region to reduce the revenue leakages, and maximize the effects of economic development policies for their regions.

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Table 1 Backward linkage results

	IO model		SAM model		MRSAM model		Difference in rankings	
Industry	TBL	ranking	TBL	ranking	TBL	ranking	IO vs SAM	SAM vs MRSAM
Fish Harvesting	0.992	15	0.961	23	0.963	24	-8	-1
Fish Processing	1.288	2	1.183	2	1.114	3	0	-1
Agriculture	1.143	6	1.025	13	0.958	25	-7	-12
Oil and Gas	1.037	11	1.027	12	0.948	26	-1	-14
Other Mining	1.003	14	0.977	21	0.965	23	-7	-2
Mining services	0.828	33	0.863	35	0.849	34	-2	1
Utilities	1.06	10	1.061	7	0.946	28	3	-21
Construction	0.92	26	0.918	31	0.948	27	-5	4
Wood products	1.227	3	1.069	4	1.027	13	-1	-9
Other Food Manufac.	1.092	8	0.947	25	1.136	2	-17	23
Other Manufacturing	1.129	7	1.031	8	1.065	7	-1	1
Refined Petroleum	1.526	1	1.372	1	1.194	1	0	0
Wholesale Trade	0.887	30	1.007	15	1.015	14	15	1
Air transportation	1.152	5	1.122	3	1.11	4	2	-1
Water transportation	1.164	4	1.065	5	1.1	5	-1	0
Other transportation	0.963	19	1.008	14	0.985	20	5	-6
Food Stores	0.928	25	1.03	9	1.054	9	16	0
Other Retail Trade	0.919	27	1.03	10	1.042	10	17	0
Information	1.02	12	0.993	17	1.036	11	-5	6
Finance and Insurance	0.957	21	0.925	30	0.999	17	-9	13
Real Estate	0.94	24	0.945	26	0.889	33	-2	-7
Professional services	0.97	17	0.961	24	0.982	21	-7	3
Management services	0.974	16	0.993	18	1.003	15	-2	3
Support Services	0.965	18	0.98	19	1	16	-1	3
Waste Mgt. Services	1.071	9	1.064	6	1.035	12	3	-6
Educational Services	0.952	23	0.978	20	0.999	18	3	2
Health Services	0.907	29	0.937	27	0.978	22	2	5
Entertainment Services	0.963	20	0.964	22	0.937	30	-2	-8
Lodging	0.954	22	0.995	16	0.994	19	6	-3
Eating and Drinking	0.916	28	0.934	28	1.055	8	0	20
Repair Services	0.873	31	0.88	34	0.912	32	-3	2
Other Services	1.005	13	1.03	11	1.069	6	2	5
Miscellaneous	0.859	32	0.884	33	0.823	35	-1	-2
State /local gov't Serv.	0.706	34	0.915	32	0.925	31	2	1
Federal gov't Serv.	0.706	35	0.927	29	0.946	29	6	0

Table 2 Forward linkage results

	IO model		SAM model		MRSAM model		Difference in rankings	
Industry	TFL	ranking	TFL	ranking	TFL	ranking	IO vs SAM	SAM vs MRSAM
Fish Harvesting	1.351	4	0.96	24	1.15	10	-20	14
Fish Processing	0.707	33	0.505	34	0.848	28	-1	6
Agriculture	0.986	17	0.856	26	0.672	32	-9	-6
Oil and Gas	1.788	1	1.428	1	1.493	1	0	0
Other Mining	0.93	18	0.709	29	0.847	29	-11	0
Mining services	0.754	29	0.538	33	0.368	34	-4	-1
Utilities	1.058	12	1.1	16	1.177	6	-4	10
Construction	0.784	26	0.65	30	0.527	33	-4	-3
Wood products	1.24	6	1.021	23	1.057	18	-17	5
Other Food Manufac.	1.015	15	1.314	3	1.116	13	12	-10
Other Manufacturing	1.117	11	1.161	10	1.032	20	1	-10
Refined Petroleum	1.236	7	1.031	22	1.176	7	-15	15
Wholesale Trade	1.007	16	1.04	21	1.016	25	-5	-4
Air transportation	0.749	30	0.607	31	0.877	26	-1	5
Water transportation	0.744	31	0.584	32	0.822	30	-1	2
Other transportation	1.032	14	0.879	25	1.174	8	-11	17
Food Stores	0.86	22	1.139	14	1.03	22	8	-8
Other Retail Trade	0.884	21	1.069	17	1.049	19	4	-2
Information	1.122	10	1.065	18	1.186	5	-8	13
Finance and Insurance	1.147	9	1.22	5	1.242	2	4	3
Real Estate	1.176	8	1.14	13	1.212	4	-5	9
Professional services	1.345	5	1.197	7	1.12	12	-2	-5
Management services	1.562	2	1.351	2	1.232	3	0	-1
Support Services	1.373	3	1.225	4	1.154	9	-1	-5
Waste Mgt. Services	0.896	20	0.787	28	0.68	31	-8	-3
Educational Services	0.783	27	1.219	6	1.022	23	21	-17
Health Services	0.711	32	1.107	15	1.021	24	17	-9
Entertainment Services	0.913	19	1.15	11	1.106	14	8	-3
Lodging	0.811	25	0.835	27	1.084	15	-2	12
Eating and Drinking	0.852	23	1.143	12	1.084	16	11	-4
Repair Services	1.033	13	1.054	19	1.145	11	-6	8
Other Services	0.849	24	1.188	9	1.081	17	15	-8
Miscellaneous	0.779	28	1.192	8	1.031	21	20	-13
State /local gov't Serv.	0.702	34	1.041	20	0.86	27	14	-7
Federal gov't Serv.	0.702	35	0.496	35	0.31	35	0	0

Table 3 Classification of Industries

Industry	IO	SAM	MRSAM
Fish Harvesting	SF	WL	SF
Fish Processing	SB	SB	SB
Agriculture	SB	SB	WL
Oil and Gas	KS	KS	SF
Other Mining	SB	WL	WL
Mining services	WL	WL	WL
Utilities	KS	KS	SF
Construction	WL	WL	WL
Wood products	KS	KS	KS
Other Food Manufacturing	KS	SF	KS
Other Manufacturing	KS	KS	KS
Refined Petroleum	KS	KS	KS
Wholesale Trade	SF	KS	KS
Air transportation	SB	SB	SB
Water transportation	SB	SB	SB
Other transportation	SF	SB	SF
Food Stores	WL	KS	KS
Other Retail Trade	WL	KS	KS
Information	KS	SF	KS
Finance and Insurance	SF	SF	SF
Real Estate	SF	SF	SF
Professional services	SF	SF	SF
Management services	SF	SF	KS
Support Services	SF	SF	KS
Waste Management Services	SB	SB	SB
Educational Services	WL	SF	SF
Health Services	WL	SF	SF
Entertainment Services	WL	SF	SF
Lodging	WL	WL	SF
Eating and Drinking	WL	SF	KS
Repair Services	SF	SF	SF
Other Services	SB	KS	KS
Miscellaneous	WL	SF	SF
State and local government services	WL	SF	WL
Federal government services	WL	WL	WL

Note: WL = Weak linkage sector (orange); SB = Strong backward linkage sector (yellow); SF = Strong forward linkage sector (green); KS = Key sector (blue)

APPENDIX A

Table A.1 Industry Aggregation Scheme for Alaska SAM Model

IMPLAN SECTORS	INDUSTRIES in SAM and MRSAM
Sector 16 (Replaced with estimated data)	Fish Harvesting
Sector 71 (Replaced with estimated data)	Fish Processing
Sectors 1-15, 17, and 18	Agriculture
Sector 19	Oil and Gas Extraction
Sectors 20-26	Other Mining
Sectors 27-29	Mining services
Sectors 30-32, 495, and 498	Utilities
Sectors 33-45	Construction
Sectors 112-123	Wood products
Sectors 46-70 and 72-84	Other Food Manufacturing
Sectors 85-111, 124-141, and 143-389	Other Manufacturing
Sectors 142 and 396	Refined Petroleum
Sector 390	Wholesale Trade
Sector 391	Air transportation
Sector 393	Water transportation
Sectors 392, 394, 395, and 397-400	Other transportation
Sector 405	Food and Beverage Stores
Sectors 401-404 and 406-412	Other Retail
Sectors 413-424	Information
Sectors 425-430	Finance and Insurance
Sectors 431-436	Real Estate, Renting, and Leasing
Sectors 437-450	Professional- scientific and technical serv.
Sector 451	Management of Companies
Sectors 452-459	Administrative Support Services
Sector 460	Waste Management and Remediation Serv.
Sectors 461-463	Educational Services
Sectors 464-470	Health Service and Social Assistance
Sectors 471-478	Arts, Entertainment, and Recreation
Sectors 479-480	Accommodations
Sector 481	Food Services and Drinking Places
Sectors 482-486	Repair and Maintenance
Sectors 487-494	Other Services
Sectors 496, 497, 499-502, and 507-509	Government and non-NAICS
Sectors 503 and 504	State and local government services
Sectors 505 and 506	Federal government services

Table A.2 Social Accounting Matrix for Alaska

	Activity	**Commodity**	**Value-added**	**Households**	**State & Local Govt**	**Federal Govt**	**Savings-Investment**	**Rest of the World**
Activity		Gross Output						
Commodity	Intermediate Inputs			Household Purchases	S&L Govt Purchases	Fed Govt Purchases	Investment Demand	Exports
Value-added	Value-added							
Households			Factor Income	Inter-HH Transfers	S&L Govt Transfers to HHs	Fed Govt Transfers to HHs	HH Investment Income	
State & Local Govt			S&L Govt Factor Taxes + Indirect Business Tax	Household Taxes	S&L Govt. Transfers	Fed Govt Transfer	S&L Govt Investment Income	
Federal Govt			Social Security Tax + Indirect Business Tax	Personal Income Tax			Fed Govt Investment Income	
Savings-Investment			Business Savings	Household Savings	S&L Govt Savings	Fed Govt Savings		+(External Savings)
Rest of the World		Imports	Factor Income Leakage	HH Income Leakage	S&L Govt Leakage	Fed Govt Leakage	-(External Savings)	

Source: Seung and Waters (2010).

Table A.3 Simplified schematic representation of a three-region MRSAM.

	Alaska (AK)	West Coast (WC)	Rest of U.S. (RUS)	Rest of the World (ROW)
Alaska (AK)	Alaska Economy	WC purchases from AK	RUS purchases from AK	AK Exports
West Coast (WC)	AK purchases from WC	West Coast Economy	RUS purchases from WC	WC Exports
Rest of U.S. (RUS)	AK purchases from RUS	WC purchases from RUS	RUS Economy	RUS Exports
Rest of the World (ROW)	AK Imports	WC Imports	RUS Imports	

Source: Waters et al. (2014).

Appendix B Detailed descriptions of the structures of SAM and MRSAM models

1. SAM model

The SAM model in Equation (4) can be expressed alternatively as:

$$\begin{bmatrix} Q \\ C \\ V \\ IBT \\ H \\ SG \end{bmatrix} = (I - S)^{-1} \begin{bmatrix} eq \\ ec \\ ev \\ et \\ eh \\ eg \end{bmatrix} , \quad \text{(B.1)}$$

where:

Q = vector of industry output (endogenous)

C = vector of commodity output (endogenous)

V = vector of total primary factor payments (endogenous)

IBT = indirect business tax payments (endogenous)

H = vector of total household income (endogenous)

SG = total state and local government revenue (endogenous)

eq = vector of exogenous demand for industry output

ec = vector of exogenous demand for commodity output

ev = vector of exogenous factor payments

et = exogenous indirect business tax payments

eh = vector of exogenous federal transfers to households

eg = federal transfers to state and local government.

In Equation (B.1) above, vectors *Q*, *C*, *V*, *IBT*, *H*, and *SG* contain elements that are endogenous variables. Vectors *eq*, *ec*, *ev*, *et*, *eh*, and *eg* have elements that are exogenous variables. Non-zero elements are included in the vectors *ec*, *eh*, and *eg*. Vector *ec* is the final demand vector whose elements are investment demand, federal government demand, and export demand. Elements of *eh* include federal government transfers to households and capital income inflow from outside of Alaska. The components of *eg* include (i) federal government transfers, (ii) revenue from, for example, investments, leases, and trusts, and (iii) non-Alaska residents' tax payments. The elements in vectors *ec*, *eh,* and *eg* constitute injections of income or revenue into the state's economy. Leakages of income transpire via payments to nonresident factor owners (non-resident factor income), tax payments to the federal government, savings, and imports of commodities.

2. MRSAM model

As mentioned, the MRSAM model can be also represented by Equation (4) above:

$$T = (I - S)^{-1}K \quad .$$

where $T = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix}$, S= $\begin{bmatrix} Z_{11} & z_{12} & z_{13} \\ z_{21} & Z_{22} & z_{23} \\ z_{31} & z_{32} & Z_{33} \end{bmatrix}$, and $K = \begin{bmatrix} k_1 \\ k_2 \\ k_3 \end{bmatrix}$.

Here, *S* is now the matrix of direct MRSAM coefficients and $(I - S)^{-1}$ is now called the MRSAM multiplier matrix or the matrix of MRSAM inverse coefficients. t_r and k_r denote the column vectors of endogenous and exogenous accounts, respectively, for region *r*; Z_{rr} is a submatrix containing coefficients representing the intra-regional transactions; and z_{rs} a submatrix containing coefficients representing inter-regional transactions. All the coefficients in Z_{rr} and z_{rs} are derived by dividing the elements in the columns in the MRSAM by the column totals.

t_r is a column vector for region *r* comprising the following endogenous sub-vectors:

Q_r = vector of regional industry output

C_r = vector of regional commodity output

V_r = vector of total primary factor payments

IBT_r = indirect business tax payments

H_r = vector of total household income

SG_r = total state and local government revenue

Z_{rr} for region r is:

$$Z_{rr} = \begin{bmatrix} 0 & M_r & 0 & 0 & 0 & 0 \\ U_r & 0 & 0 & 0 & CS_r & GD_r \\ V_r & 0 & 0 & 0 & 0 & 0 \\ IBT_r & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & F_r & 0 & 0 & STR_r \\ 0 & 0 & SF_r & BTS_r & HTX_r & IGT_r \end{bmatrix}, \qquad \text{(B.2)}$$

where:

U_r = matrix of coefficients showing the use of commodities by industries in production

V_r = matrix of primary factor payments coefficients

IBT_r = matrix of indirect business tax coefficients

M_r = market share matrix (i.e., elements in make matrix divided by total output)

F_r = matrix of factor payment to household coefficients

SF_r = matrix of state and local factor tax coefficients

BTS_r = matrix of state and local indirect business tax coefficients

CS_r = matrix of household consumption coefficients

HTX_r = matrix of state and local government direct household tax coefficients

GD_r = matrix of state and local government demand coefficients

STR_r = matrix of state and local government transfer coefficients

IGT_r = matrix of intergovernmental transfers.

z_{rs} is:

$$z_{rs} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & IM_{rs} & 0 & 0 & 0 & 0 \\ 0 & 0 & LK_{rs} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} , \qquad \text{(B.3)}$$

where IM_{rs} is a matrix of imports from region r to s and LK_{rs} is a matrix of leakage of factor income from region s to region r. k_r is a column vector consisting of the following exogenous sub-vectors:

eq_r = vector of exogenous demand for regional industry output

ec_r = vector of exogenous demand for regional commodity output

ev_r = vector of exogenous factor payments

et_r = exogenous indirect business tax payments

eh_r = vector of exogenous federal transfers to households

eg_r = federal transfers to state and local government.