# Economic Impacts of Energy Infrastructure Investments

**Presented to:**

**New Jersey Natural Gas**

**Michael Lahr**
**Erin Coughlin**
**Frank Felder**

**Edward J. Bloustein School of Planning and Public Policy**
**Rutgers, The State University of New Jersey**

**July 2010**

RUTGERS
Edward J. Bloustein School
of Planning and Public Policy

# Table of Contents

## Executive Summary

This report presents the estimated economic impacts in New Jersey of two energy infrastructure investments: a $28.6 million representative infrastructure construction project by New Jersey Natural Gas and a $4.5 million Residential Solar Lease Program by New Jersey Resources. The economic impacts of a representative construction project are associated with the initial expenditure, not any ongoing operation and maintenance needs or potential benefits of an extended distribution system. The economic impacts of the Solar Lease Program are related to the initial expenditures and 20 year estimated operation and maintenance needs. Based on the analysis, the economic impacts in New Jersey include:

### Typical New Jersey Natural Gas (NJNG) Infrastructure Construction Project

- 183 direct and 110 indirect and induced one-time job-years;[1]
- $11.2 million direct and $5.2 million indirect and induced income;
- $21.6 million direct and $16.1 million indirect and induced output;
- $14.2 million direct and $7.8 million indirect and induced gross state product;
- $964 thousand in business and household local taxes; and
- $794 thousand in business and household state taxes.

### New Jersey Resources (NJR) Residential Solar Lease Program

- 13 direct and 9 indirect and induced job-years--less than 1/3 of a job-year is ongoing over the 20 year operation and maintenance period;
- $1 million direct and $433 thousand indirect and induced income;
- $1.7 million direct and $1.3 million indirect and induced output;
- $1.2 million direct and $645 thousand indirect and induced gross state product;
- $75 thousand in business and household local taxes; and
- $67 thousand in business and household state taxes.

[1] A job-year is the equivalent of one job in a single year.

## 1. Introduction

This report presents the economic impact analysis of two energy infrastructure investments projects, a representative infrastructure construction project and the Residential Solar Lease Program.

Infrastructure investments are part of New Jersey Natural Gas' (NJNG) and New Jersey Resources' (NJR) continuous plan to replace, reinforce, and expand its infrastructure to maintain the reliability, safety, and integrity of its natural gas distribution system and the conservation and preservation of the environment. The construction and residential solar investments will generate new economic activity and create jobs within New Jersey. These investments are consistent with state goals to increase reliability and promote employment through enhanced energy infrastructure projects.

Input-output models show how sectors of an economy interact. For a given industry, these models show the production "recipe" for the goods and services it sells and the shares of its revenues that are used as inputs by other industries in the same economy. The special advantage input-output models hold over other economic models is their extreme sectoral detail—they can articulate on the order of 500 industries. This detail enables refined accuracy in the estimates of the multiplier effects that they derive. The economic impacts of the two projects evaluated in this study are estimated using the R/ECON™ Input-Output model developed and maintained by the Center for Urban Policy Research at Rutgers University's Edward J. Bloustein School of Planning and Public Policy. The model estimates a battery of measures of regional economic impacts, including jobs, labor income, gross domestic product, and tax revenues.

The report is organized as follows: Section 2 provides a literature review of multipliers. Section 3 provides the methodology, assumptions and results of the economic analyses. Section 4 provides a brief summary of the findings. Appendix A provides a detailed comparison of available input-output models.

## 2. Multiplier Literature Review

Multiplier effects result from the system of economic transactions that follow a change (a new project, program, or event) in an economy. The affect of an economic change is comparable to the affect of a drop of water on a still pond. The drop of water creates a large primary "ripple:" in an economy this would be a direct change in the purchasing patterns of affected firms and institutions. Suppliers of the affected firms and institutions change their purchasing patterns to meet the demands of the firms directly affected by the economic disturbance, thereby creating a smaller, secondary "ripple." In turn, those who meet the needs of the suppliers must change their purchasing patterns to meet the new demands, and so on; thus, a number of subsequent "ripples" are created by that one drop of water.[2]

[2] CUPR (b).

The multiplier effect can be categorized into three components--direct, indirect, and induced effects.[3]

- A *direct effect* is the immediate economic impact resulting from a change in economic activity.
- An *indirect effect* is the economic activity of suppliers generated from the direct economic activity. For example, the additional materials and labor demanded for an energy infrastructure expansion project.
- An *induced effect* is the change in consumer spending that is generated by changes in labor income within the region as a result of the direct and indirect effects of the economic activity.

The following brief literature review identifies multiplier effects associated with renewable energy and energy infrastructure investments across various geographies and reviews the methods used. The economic impacts of the investments provide some context for the NJNG/NJR economic impact estimates. Note that different economic geographies yield variations in multiplier effects as do the different emphases in the energy industries involved. Appendix A compares regional input-output models produced by major vendors in the United States.

In 2008, the Center for American Progress[4] analyzed the effect of a green economic recovery program on New Jersey's economy. Using the U.S. Bureau of Economic Analysis (BEA) Regional Input-Output Modeling System (RIMS II), the authors estimate that an investment of one million dollars in New Jersey energy efficiency, mass transit, smart grid, wind, solar and advanced biofuels creates 17.9 jobs within the state. RIMS II utilizes location quotient (i.e. does not account for the movement of goods or services across regions), thereby consistently overestimating the economic impacts of investments (see Appendix A). The Center for American Progress analyzed the economic effect of the combined 6 investments; therefore, the economic impacts are not directly comparable to the NJR project.

According to a 2001 Renewable Energy Policy Project[5] report based on surveys of the solar industry, via phone and written communication, the manufacture and installation of one megawatt (MW) of photovoltaics in the United States would require 35.5 direct, full-time jobs. Survey employment estimates are based on actual experience of projects of various sized in multiple geographical locations, as recalled by industry experts, while input-output models are based on investments and historic economic interactions. The report lacks the cost data associated with the job creates; therefore, a comparison to the NJR solar program is not possible.

In 2009, the Political Economy Research Institute (PERI)[6] evaluated the effect of public infrastructure improvements in the United States on employment using the IMPLAN

[3] CUPR (b); Pollin *et al.* (2008); Heintz *et al.* (2009).
[4] Pollin *et al* (2008).
[5] Singh & Fehrs (2001).
[6] Heintz *et al* (2009).

input-output model. Table 1 shows the number of jobs created for every one million dollars invested (2000 constant dollars).

**Table 1** PERI United States Infrastructure Employment per $1 Million Invested ($2000)

| | Direct & Indirect | Total* |
|---|---|---|
| Natural Gas Pipeline Construction | 16 | 21.9 |
| Solar | 11 | 15.8 |

* Direct, indirect and induced

The estimated jobs created per one million dollars invested in national natural gas and solar infrastructure projects is much higher than the estimated jobs created per one million dollars invested in the NJNG/NJR infrastructure projects analyzed in this report (see Section III). The PERI report analyzed the economic impacts on the entire United States whereas this analysis determines the economic impact of NJNG/NJR infrastructure investments on New Jersey. The economic impact on New Jersey will be smaller than the impact on the United States.

## 3. Economic Impact Analysis

### *Approach*

The economic impacts of a representative NJNG infrastructure construction and NJR Residential Solar Lease Program are estimated using the Rutgers Economic Advisory Service (R/ECON™) Input-Output Model. The R/ECON™ Input-Output Model, housed at the Center for Urban Policy Research at the Bloustein School of Planning and Public Policy, consists of over 500 individual sectors of the New Jersey economy and measures the direct and indirect effects of changes in expenditures in one industry on the economic activity in all other industries.

R/ECON™ uses various measures to indicate the effects of an economic activity on the total economy of the region. These measures include the changes in regional employment, output, income, gross state product and tax revenue that result from a change in economic activity.[7]

**Employment** is a measure of jobs at the place of business. The value of this measure depends on the prevailing mix between full- and part-time jobs for the regional industries affected by the economic change. All jobs generated at regional businesses are included, even though households in other regions may spend the wages of commuters.

**Output** is the value of industry production exchanged between firms and/or other organizations and the sector change in sales, except for construction and wholesale and retail trade. The wholesale and retail trade sector sales equal the change in sales plus the cost of goods sold. The construction sector change in output is equal to the change in sales of construction contractors plus the added cost of those materials and outside subcontractors.

[7] CUPR (a).

**Income** includes wages, salaries and proprietors' income. It does not include nonwage compensation (such as pensions, insurance and health benefits), transfer payments (such as welfare or social security benefits) or unearned income (such as dividends, interest or rent). Wages are paid to labor at their place of work and spent at their place of residence, which may be outside the region.

**Gross State Product** is the difference between the value of goods and services purchased as production inputs and the value of goods and services produced. The total wealth generated by the economic activity consists of wages, state and local taxes, federal taxes, changes in nonwage employee compensation, profit-type income, net interest and capital consumption allowances.

**State taxes** are revenues collected by state governments through personal and corporate income, state property, excise, sales and other state taxes generated by changes in output or wages or by purchases of visitors to the region.

**Local taxes** are revenues collected by substate governments, occurring mainly through property taxes on new worker households and businesses, but including income, sales and other major local taxes in selected areas, where applicable.

### a. Representative NJNG Infrastructure Construction Project

***Assumptions***

The representative NJNG infrastructure construction project undertaken in 2010 costs a total of $28.6 million.

- Contractor Costs (including labor, overhead, facility maintenance and operation): $14,887,962
- Traffic Control: $1,878,371
- Locating: $750,000
- Restoration: $3,029,661
- Rental Equipment: $885,125
- NJNG Labor and Overhead: $2,255,425
- Town/State Permitting: $74,554
- Construction Materials (99 percent are from outside New Jersey): $4,886,144

***Results***

The R/ECON$^{TM}$ Input-Output Model estimated economic impacts from a representative infrastructure construction project are shown in Table 2. The direct impacts in New Jersey include 183 jobs, $11 million in income, $22 million in output and $14 million in gross state product.

**Table 2** Economic Impacts of a Representative NJNG Construction Project

| | Direct | Indirect & Induced | Total |
|---|---|---|---|
| Employment (jobs) | 183 | 110 | 293 |
| Income ($ thousands) | $11,241 | $5,197 | $16,438 |
| Output ($ thousands) | $21,567 | $16,085 | $37,652 |
| Gross State Product ($ thousands) | $14,197 | $7,768 | $21,965 |

In 2008, the average earning per job in New Jersey was $59,910.[8] The average earnings for a job created directly from a representative NJNG construction project is $61,426, 3 percent higher than the statewide average.

Table 3 shows the components that make up the total gross state product.

**Table 3** A Representative NJNG Construction Project's Contributions to the Increase in Gross State Product

| | | Dollars ($ thousands) |
|---|---|---|
| **Wages (Net of Taxes)** | | $15,002 |
| **Business Taxes** | | $3,178 |
| | Local | $548 |
| | State | $440 |
| | Federal | $2,191 |
| | General | $1,667 |
| | Social Security | $523 |
| **Profits, Dividends, Rents & Other** | | $3,785 |
| **Total Gross State Product** | | **$21,965** |

Every million dollars spent on NJNG infrastructure construction projects results in:

- 10.2 jobs
- $573,807 income dollars
- $27,709 state tax revenues
- $33,635 local tax revenues
- $766,727 in gross state product

A total of 293 jobs are created, 183 directly, from the economic investment. Table 4 presents the direct and total employment generated by sector. The construction, manufacturing, retail trade and service sectors are estimated to experience the greatest increases in employment. Still, all major sectors of the economy are influenced by the representative project.

[8] United States Bureau of Economic Analysis.

**Table 4** Representative NJNG Construction Project's Direct and Total Employment Created by Sector

| | Direct | Total |
|---|---|---|
| Agriculture, Service, Forestry & Fishery | 0 | 1 |
| Mining | 1 | 1 |
| Construction | 105 | 106 |
| Manufacturing | 20 | 34 |
| Transportation & Public Utilities | 3 | 12 |
| Wholesale | 3 | 8 |
| Retail Trade | 2 | 40 |
| Finance, Insurance & Real Estate | 0 | 13 |
| Services | 50 | 77 |
| Government | 0 | 1 |
| **Total Effects** | **183** | **293** |

### b. NJR Residential Solar Lease Program

***Assumptions***

NJR's Residential Solar Lease Program is a market test implementation of 130 solar installations, slated to be installed over a four-month period beginning about May 1, 2010. Solar installers will purchase and install the solar systems and receive payment from NJR in three steps, 50 percent upon installation of the system, 40 percent upon interconnection and 10 percent after closeout. Residents will receive a five-year warranty from the installer, covering any repairs and maintenance, at no cost to NJR. NJR will maintain and repair the solar installations from years six through twenty.

The initial expenditure for the Solar Lease Program will total $4,520,060.

- NJR Labor Costs: $761,020
- NJR Consultant that Specializes in Developing Renewable Energy Programs: $44,980
- NJR Operation and Maintenance Costs (years 6-20): $17,940
- Labor: $866,710
- Materials: $2,793,700
- Trucking Costs (shipping the materials to New Jersey): $39,520
- Solar Installation Company Operation and Maintenance Costs (years 1-5): $523

***Results***

The R/ECON$^{TM}$ Input-Output Model estimated economic impacts of the NJR Solar Lease Program are shown in Table 5. The direct impacts in New Jersey are 13 jobs, $1 million dollars in income, $1.7 million in output and $1.2 million in gross domestic product.

**Table 5** Economic Impacts of the NJR Solar Lease Program

| | Direct | Indirect & Induced | Total |
|---|---|---|---|
| Employment (jobs) | 13 | 9 | 22 |
| Income ($ thousands) | $1,008 | $433 | $1,440 |
| Output ($ thousands) | $1,687 | $1,293 | $2,979 |
| Gross State Product ($ thousands) | $1,223 | $645 | $1,868 |

In 2008, the average earning per job in New Jersey was $59,910.[9] The average earnings for a job created directly from the NJR Residential Solar Lease Program are $77,538, 29 percent higher than the statewide average.

Table 6 shows the components that make up the total gross state product.

**Table 6** NJR Solar Lease Program's Contributions to the Increase in Gross State Product

| | | Dollars ($ thousands) |
|---|---|---|
| **Wages (Net of Taxes)** | | $1,330 |
| **Business Taxes** | | $257 |
| | Local | $39 |
| | State | $36 |
| | Federal | $182 |
| | General | $146 |
| | Social Security | $36 |
| **Profits, Dividends, Rents & Other** | | $282 |
| **Total Gross State Product** | | **$1,868** |

Every million dollars spent on the NJR Residential Solar Lease Program results in:

- 4.9 jobs;
- $318,666 income dollars;
- $14,666 state tax revenues;
- $16,563 local tax revenues; and
- $413,296 in gross state product.

A total of 22 jobs are created, 13 directly, from the economic investment. Table 7 presents the direct and total employment generated by sector.

[9] United States Bureau of Economic Analysis.

**Table 7** NJR Solar Lease Program's Direct and Total Employment Created by Sector

| | Direct | Total |
|---|---|---|
| Construction | 9 | 9 |
| Manufacturing | 0 | 1 |
| Transportation & Public Utilities | 0 | 1 |
| Retail Trade | 0 | 3 |
| Finance, Insurance & Real Estate | 0 | 1 |
| Services | 4 | 7 |
| **Total Effects** | **13** | **22** |

## 4. Summary and Conclusions

The economic impact analysis of NJNG's typical construction project and NJR's Solar Lease Program demonstrates that both investments have significant positive impacts on New Jersey's economy. The investments are fundamentally dissimilar; the Solar Lease Program invests in electricity production while the construction project invests in the transportation and distribution of natural gas, reducing potential natural gas leaks. Additional differences derive from two main sources: (1) the explicit assumption that compared to the pipeline equipment and materials, the solar photovoltaic arrays are largely produced out of state and (2) the likelihood that the pipeline has a longer lifetime than the solar photovoltaic array presumed lifetime of 20 years, determined from the operation and maintenance assumptions.

The positive economic impacts of infrastructure investments, along with other state economic policies, can begin to improve New Jersey's current economic crisis. A typical NJNG construction project is labor-intensive and produces an estimated $22 million in New Jersey gross state product. The NJR Residential Solar Lease Program generates an estimated 22 jobs, contributes almost $2 million to New Jersey's gross state product and works towards achieving the state's solar and environmental goals. To reiterate the major findings of the economic impact analysis:

A typical NJNG infrastructure construction project with an initial investment of $28.6 million is estimated to result in

- 293 one-time job-years in New Jersey;
- $16.4 million in New Jersey income; and
- $22 million in New Jersey gross state product.

The NJR Residential Solar Lease Program's estimated initial expenditure of $4.5 million is estimated to result in

- 22 job-years, primarily on-time, in New Jersey;
- $1.4 million in New Jersey income; and
- $1.9 million in New Jersey gross state product.

## Appendix A: Comparison of Input-Output Models[10]

In the United States, there are three major vendors of regional input-output (I-O) models to estimate economic impacts, the U.S. Bureau of Economic Analysis's (BEA) RIMS II multipliers, Minnesota IMPLAN Group Inc.'s (MIG) IMPLAN Pro model, and the Center for Urban Planning Research's (CUPR) R/ECON™ I–O model.[11] Although the three systems have important similarities, there are significant differences that should be considered before deciding which system to use in a particular study.[12]

### Model Accuracy

Regional models should retain maximum industrial detail as aggregating industry sectors is an important source of error in the calculation of impact multipliers. RIMS II, IMPLAN and R/ECON™ regionalize the U.S. national I–O technology coefficients table at the highest levels of disaggregation (more than 500 industries). Regional purchase coefficients (RPCs) are the proportion of the region's demand for a good/service that is fulfilled by the region's own producers rather than by imports from producers in other areas. It expresses the proportion of purchases of a good/service that do not leak out of the region but feed back to its economy, with corresponding multiplier effects. The accuracy of the RPC is crucial to the accuracy of a regional I–O model because a sector's regional multiplier effects vary directly with its RPC.

The CUPR and MIG techniques for estimated RPCs should provide better estimates of regional imports and exports than the location quotient (LQ) approach used by RIMS II because they allow for the cross-hauling of a good or service among regions while RIMS II does not.[13] Further, the CUPR RPC equation should be more accurate than MIG's. MIG estimates RPCs at a more aggregated level (two-digit SICs, or about 86 industries) and applies them at a desegregate level (over 500 industries) while CUPR estimates and applies the RPCs at the most detailed industry level. Applying aggregate RPCs can induce as much as 50 percent error in impact estimates (Lahr and Stevens 2002).

Although both R/ECON™ and IMPLAN use an RPC-estimating technique that is theoretically sound and update it using the most recent economic data, some practitioners question the accuracy for three reasons. First, the observations used to estimate the RPCs are based on 30-year old trade relationships—the Commodity Transportation Survey (CTS) from the 1977 Census of Transportation. Secondly, the CTS observations are at the state level; therefore, sub-state RPC's must be extrapolated and are potentially not as accurate as expected. Thirdly, CTS does not measure the interstate provision of service but only for shipments of goods. IMPLAN relies on relationships from the 1977 U.S. Multiregional Input-Output Model that are not clearly documented. R/ECON™ relies on the same econometric relationships that it does for manufacturing industries but employs expert judgment to construct weight/value ratios for the nonmanufacturing industries.

---

[10] CUPR (b).

[11] R/Econ™ builds from the PC I-O model produced by the Regional Science Research Corporation.

[12] See Brucker, Hastings and Latham. (Summer 1987). Regional input-output analysis: A comparison of five ready-made model systems. *The Review of Regional Studies*. CUPR and MIG have added new features since that date.

[13] Stevens, Treyz and Lahr (1989) confirm that LQ methods tend to overestimate RPCs.

The RIMS II multipliers have the advantage of being constructed from the full set of the most recent regional earnings data available because the BEA is the main federal government purveyor of employment and earnings data by detailed industry. It therefore has access to the fully disclosed and disaggregated versions of these data. The other two models rely on older data from *County Business Patterns* and Bureau of Labor Statistic's Quarterly Covered Employment and Wage data, which have been 'improved' by filling-in for any industries that have disclosure problems (when three or fewer firms exist in an industry or region).

**Model Flexibility**

For the typical user, the most apparent differences among the three modeling systems are the level of flexibility enabled and the type of results yielded. R/ECON™ allows changes in individual cells of the 515-by-515 technology matrix as well as in the 11 515-sector[14] vectors of region-specific data that produce the regionalized model. The model tends to be simple to use and its User's Guide is straightforward and concise, providing instruction about the proper model implementation and interpretation of the results.

IMPLAN, a Windows-based software program, is the most user-friendly of the three modeling systems. The Windows orientation enables MIG to provide many more options without increasing complexity. Like R/ECON™, IMPLAN's regional data on RPCs, output, labor compensation, industry average margins and employment can be revised. It does not have complete information on tax revenues other than those from indirect business taxes (excise and sales taxes), and those cannot be altered. Also like R/ECON™, IMPLAN allows users to modify the cells of the 538-by-538 technology matrix. It also permits the user to change and apply price deflators so that dollar figures can be updated from the default year. The plethora of options, which are advantageous to the advanced user, can be extremely confusing to the novice. Although default values are provided for most options, the accompanying documentation does not clearly point out which items should get the most attention. Further, the calculations needed to make any requisite changes can be more complex than those for R/ECON™. Much of the documentation dwells on technical issues regarding the guts of the model. For example, while one can aggregate the 538-sector impacts to the one- and two-digit SIC level, the current documentation does not discuss that possibility and advises users to produce an aggregate model, which is likely to be error ridden.

RIMS II typically delivers a set of 38-by-471 tables of multipliers for regional output, earnings and employment (supplement tax multipliers are available at an additional cost). Although the model's documentation is generally excellent, use of RIMS II alone will not provide proper estimates of a region's economic impacts because RPC estimates are <u>not</u> supplied with the model. For example, to estimate the impacts of rehabilitation, the engineering cost estimates must be converted into demands for labor, materials and services by industry and the percentage of the labor income, materials and services which will be provided by the region's households and industries must be estimated. These percentages are difficult to ascertain; however, R/ECON™ and IMPLAN provide them

[14] The 11 sectors include: output, demand, employment per unit output, labor income per unit output, total value added per unit of output, taxes per unit of output, nontax value added per unit output, administrative and auxiliary output per unit output, household consumption per unit of labor income, and the RPCs.

as an option. Further, it is impossible to change RIMS II's parameters if superior data are known. The model ought not be used to evaluate any project/event where superior data are available or to evaluate a change in regional demand (a construction project or an event) as opposed to a change in regional supply (the operation of a new establishment).

**Model Results**

Detailed total economic impacts for about 500 industries can be calculated for jobs, labor income and output from R/ECON™ and IMPLAN only. These two modeling systems can also provide total impacts as well as impacts at the one- and two-digit industry levels. RIMS II provides total impacts and impacts on only 38 industries for these same three measures. Only the R/ECON™ manual warns about the problems interpreting and comparing multipliers and any measures of output.

As an alternative to the conventional measures and their multipliers, R/ECON™ and IMPLAN provide results on 'value added,' the region's production of wealth. Value added is the region's contribution to the national gross domestic product, is the single best measure of the total economic impacts of a disturbance, and consists of labor income, nonmonetary labor compensation, proprietors' income, profit-type income, dividends, interest, rents, capital consumption allowances and taxes paid.

Additionally, IMPLAN provides information on personal income, proprietor income, other property-type income and indirect business tax impacts. R/ECON™ breaks out tax collection impacts into local, state and federal governments and provides jobs impacts in terms of either about 90 or 400 occupations. It also provides a return-on-investment-type multiplier measure, which compares the total impact on all main measures to the total original expenditure that caused the impacts.

Both R/ECON™ and IMPLAN both have flexible formatting of the results. On request, they print the results directly or into a file (Excel® 4.0, Lotus 123®, Word® 6.0, tab delimited, or ASCII text). They permit previewing the results on the computer's monitor and print the job impacts in either or both levels of occupational detail.

**R/ECON™ Equation**

The R/ECON™ model RPCs are estimated from the 1977 CTS by estimating the demands for an industry's production of goods/services that are fulfilled by local suppliers (*LS*) as

$$LS = D^{e(-1/x)}$$

and where for a given industry

$$x = k\, Z_1^{a1} Z_2^{a2}\, P_j\, Z_j^{aj}$$ and $D$ is its total local demand.

Since for a given industry RPC = $LS/D$ then

$$\ln\{-1/[\ln(\ln LS/\ln D)]\} = \ln k + a_1 \ln Z_1 + a_2 \ln Z_2 + S_j a_j \ln Z_j$$

which was the equation that was estimated for each industry.[15]

The odd nonlinear form yields high correlations between the estimated and actual RPC values and assures the value range between 0 and 1. The empirical implementation of this equation show that total local industry demand ($Z_1$), the supply/demand ratio ($Z_2$), the

[15] See Treyz and Stevens (1985).

weight/value ratio of the good ($Z_3$), the region's size in square miles ($Z_4$) and the region's average establishment size in terms of employees for the industry compared to the nation's ($Z_5$) are the variables that influence the value of the RPC across all regions and industries. The latter of these maintain the least leverage on RPC values.

It is important that local industry demand, the supply/demand ratio and the region's size in square miles are included to extrapolate the estimation of RPCs for smaller areas because the CTS data is at the state level. The CTS data only cover manufactured goods. Although the RPS estimates are calculated effectively, making them equal to unity via the above equation, the estimates for services drop on the weight/value ratios. A very high weight/value ratio forces the industry to meet the demand through local production. Consequently, a region's RPC for the service sector is often very high (0.89).

Similarly, hotels and motels tend to be used by visitors from outside the area and a weight/value ratio similar to the industry production would be expected. An RPC for this sector is often about 0.25. Ordinary location quotient approaches would show hotel and motel services serving local residents. Similarly, IMPLAN RPCs are built from data that combine this industry with eating and drinking establishments. The result of aggregating is that the RPC represents neither industry (a value of about 0.50) but is applied to both. In the end, not only is the CUPR's RPC-estimating approach the most sound, but it is also widely acknowledged by researchers in the field as being state of the art.

**Advantages and Limitations of Input-Output Analysis**

Input-output modeling is one of the most accepted means for estimating economic impacts because it provides concise and accurate means for articulating interrelationships among industries. The models can be quite detailed, more accurately assessing multiplier effects of changes in economic activity. Research has shown that aggregated models can produce results with as much as 50 percent error. The errors are generally attributed to poor estimation of regional trade flows resulting from the aggregation process.

Input-output models can be set up to capture the flows among economic regions. For example, the model could estimate the impacts for each region as well as the total state economy, if the data on employment and imports had been made available.

A limitation of input-output modeling is several key assumptions are made. First, the input-output model approach assumes there are no economies of scale to production (i.e. the proportion of inputs used in a production process does not change regardless of the level of production). This assumption will not work if the technology matrix depicts a recessional economy and the analyst is modeling activity in a peak economic year. In a recession year, the labor-to-output ratio tends to be excessive because firms are generally reluctant to lay off workers when they believe an economic turnaround is about to occur.

A less-restrictive assumption of the input-output approach is that technology is not permitted to change over time. It is less restrictive because the technology matrix in the United States is updated frequently and, in general, production technology does not radically change over short periods.

Finally, the technical coefficients used in most regional models are based on the assumption that production processes are spatially invariant and are well represented by the nation's average technology.

**References:**


Brucker, S., Hastings, S., & Latham, W. (1987). Regional input-output analysis: A comparison of five ready-made model systems. *Review of Regional Studies*, 17(2): 1-29.

Center for Urban Policy Research (CUPR) (a). A description of R/ECONTM I-O: A regional input-output model developed by Rutgers University's Center for Urban Policy Research. Rutgers, The State University of New Jersey.

--- (b). Appendix. Input-output analysis: Technical description and application. Rutgers, The State University of New Jersey.

Heintz, J., Pollin, R., & Garret-Peltier, H. (2009). How infrastructure investments support the U.S. economy: Employment, productivity and growth. *Political Economy Research Institute.*

Lahr, Michael L. & Stevens, Benjamin H. 2002. A study of the role of regionalization in the generation of error in regional input-output models, *Journal of Regional Science*, 42, 377-407.

Pollin, R., Garrett-Peltier, H., Heintz, J., & Scharber, H. (2008). Green recovery: A program to create good jobs and start building a low-carbon economy. *Center for American Progress*.

Singh, V., & Fehrs, J. (2001). The work that goes into renewable energy. *Renewable Energy Project.*

Stevens, B., Treyz, G. & Lahr M. (1989). On the Comparative Accuracy of RPC Estimating Techniques, in: R.E. Miller, K.R. Polenske and A.Z. Rose, eds., Frontiers in Input-Output Analysis (Oxford University Press, New York), 245-257.

Stoddard, L., Abiecunas, J., & O'Connell, R. (2006). Economic, energy, and environmental benefits of concentrating solar power in California. *National Renewable Energy Laboratory.*

Treyz, G. and Stevens, B.. 1985. The TFS Regional Modeling Methodology. *Regional Studies*, 19: 547-562.

United States Bureau of Economic Analysis. Local Area Personal Income. Accessed at <www.bea.gov/regional/reis/default.cfm?selTable=CA25N&series=NAICS>.