CONTRIBUTION OF RUTGERS UNIVERSITY TO THE NEW JERSEY ECONOMY

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Executive Summary

This study provides an overview of Rutgers University's contribution to the New Jersey economy. The report estimates Rutgers' direct and indirect contribution to the state economy through its expenditures, profiles the University's research funding and outputs, and highlights the activities of Rutgers Biomedical and Health Sciences.

Rutgers University's operating and capital construction expenditures generate a significant contribution to the New Jersey economy. This contribution consists of the University's direct employment and expenditures in the state, as well as the multiplier, or "ripple," effects of those initial expenditures as they are spent and re-spent throughout the broader state economy.

The R/ECON™ Input-Output Model of the New Jersey economy, developed and housed at Rutgers' Edward J. Bloustein School of Planning and Public Policy, was used to estimate the magnitude of the University's contribution to the state economy. Based on employment and operating expenditure data for Fiscal Year 2016, it is estimated that, on an annual basis, Rutgers' ongoing operations directly and indirectly support or generate:

- Nearly 58,000 jobs statewide, including over 26,000 directly employed by the University;
- Over $610 million in direct payments to in-state businesses;
- $4.3 billion in compensation;
- $5.2 billion in gross domestic product (GDP) for the state;
- $403.9 million in state tax revenues; and
- $394.3 million in local tax revenues (statewide).

The University returns nearly $6.70 in economic activity (GDP) for each dollar of state appropriation it receives.

In addition, Rutgers' capital expenditures on new construction, major renovations and building additions have additional economic impacts over and above those generated by the University's annual operating expenditures. In aggregate, over the Fiscal Years 2012-2016, Rutgers' capital expenditures of $1.14 billion are estimated to have generated:

- Nearly 2,400 jobs supported for five years (11,794 job-years);
- $957.8 million in compensation;
- $1.2 billion in gross domestic product for the state;
- $82.2 million in state tax revenues; and
- $80.4 million in local tax revenues (statewide).

Introduction

This study, conducted on behalf of the Rutgers University President's Office, estimates the contribution of the University's operating and capital expenditures to the New Jersey economy. Rutgers' ongoing operations and capital construction are carried out in support of the three core elements of the University's mission: education, research and service. In fulfilling these core functions, each year Rutgers spends significant amounts on its ongoing operations, including salaries for faculty and staff, purchases of material, equipment and services, and investments in long-term capital assets such as academic buildings and other facilities. In aggregate, these expenditures and their multiplier effects comprise a significant contribution to the New Jersey economy. The main purpose of this report is to estimate the size of this contribution.

In addition to the immediate and ongoing contribution of Rutgers to the New Jersey economy via its operating and capital expenditures, the University generates significant longer-term and broader economic impacts associated with its research output and educational functions. For example, Rutgers' research output includes numerous patents, licensed technologies and other products that generate revenue for the University while contributing to economic growth in a number of industries, and Rutgers Biomedical and Health Sciences makes significant contributions to development and provision of medical treatments through clinical trials, provision of care through free clinics and other activities.

This study is divided into three sections. Section I estimates the contribution of Rutgers' operating and capital expenditures to the New Jersey economy. The section includes a breakdown of the University's expenditures, a description of the methodology and economic model used in the analysis, and estimates of the University's contribution to the state economy. Section II provides an overview of the University's research funding sources and outputs. Section III highlights the work of Rutgers Biomedical and Health Sciences.

Section I: Contribution of Rutgers University Expenditures to the New Jersey Economy

Expenditures on operations and capital projects at all of Rutgers' campuses and facilities support further employment and business expenditures throughout the state economy. Economic impact analysis provides a method to measure the size of this contribution.

Economic Impact Analysis and the R/ECON Input-Output Model

The R/ECON™ Input-Output Model developed and maintained at Rutgers University's Edward J. Bloustein School of Planning and Public Policy is used to estimate the economic impacts of various types of expenditures or investments, in terms of employment, gross domestic product, compensation (i.e., income) and tax revenues.[1] The model consists of 383 individual sectors of the New Jersey economy and measures the effect of changes in expenditures in one industry on economic activity in all other industries. Thus, the expenditures made on labor, materials, equipment, third-party services and other inputs for ongoing operations or one-time capital projects have both **direct economic effects** as those expenditures become incomes and revenues for workers and businesses, and subsequent **indirect effects** as those workers and businesses, in turn, spend those dollars on other goods and services.[2] These expenditures on consumer goods, business investment expenditures, and other items in turn become income for other workers and businesses. This income gets further spent, and so on.

The R/ECON™ Input-Output model estimates both the **direct** economic effects of the initial expenditures (in terms of jobs and income) and the **indirect** (also known as **multiplier or "ripple"**) effects (in additional jobs and income) of the subsequent economic activity that occurs following the initial expenditures. The model also estimates the gross domestic product for New Jersey and the tax revenues generated by the combined direct and indirect new economic activity caused by the initial business expenditures and the re-spending of those dollars through the economy.

In addition, embodied in the model are estimates – known as regional purchase coefficients, or RPCs – of the share of local (i.e., in-state) demand for labor and material that can be met by in-state supply. That is, based on historical inter-industry relationships, the

[1] A detailed description of input-output analysis and the R/ECON™ Input-Output Model is provided in Appendix A.

[2] Input-output models divide impacts into three categories – direct effects, indirect effects, and induced effects. A *direct effect* is the change in purchases due to a change in economic activity. An *indirect effect* is the change in the purchases of suppliers to those economic activities directly experiencing change. 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. For ease of presentation, this report includes both indirect and induced effects in the category of indirect effects.

model can estimate the portion of the project expenditures that are made on labor, material and services produced *in New Jersey*. Similarly, these inter-industry relationships also capture the portion of *indirect* expenditures (i.e., spending of the business revenues and personal incomes initially generated by the project expenditures) that remain in the state. Those initial expenditures and indirect impacts that spill out of the state are referred to as economic "leakage." Leakages include payments to social security, income taxes, personal savings, and payments for goods and services sourced outside of New Jersey. Estimates of "leakage" associated with project expenditures can be further refined based on specific project information regarding the expected sourcing of labor, materials or other services.

Capital expenditures on construction and renovation are *one-time* outlays that generate one-time economic impacts. That is, the economic multiplier that result from the initial construction expenditures occur only once, as or shortly after the initial outlays are made. These impacts, in terms of employment, income, output (GDP), and tax revenues, do not continue once the capital construction project expenditures cease.

In contrast, the impacts of ongoing operational spending are assumed to be recurring, as long as expenditure levels are maintained at the same or similar levels from year to year.

Contribution of Rutgers Annual Operating Expenditures

Distribution of Rutgers Annual Operating Expenditures

Rutgers' annual operating expenditures contribute both directly and indirectly to the state economy. In Fiscal Year 2016, these expenditures totaled just over $3.5 billion.[3] The distribution of these direct expenditures drives the modeling of Rutgers' contribution to the state economy.

In FY 2016, Rutgers employed 26,027 total full- and part-time faculty and staff, including teaching and graduate assistants, with a total of $1.8 billion in salaries and wages (Table I-1).[4] Expenditures also included payments of $838.1 million to outside vendors, including $83 million in payments for utilities, and $67.4 million in scholarship and fellowship payments. For comparison, Rutgers' total state appropriation for FY 2016 (including operating budget funds and fringe benefits paid directly by the state) was

[3] FY 2016 data on University payroll, payments for products and services from third-party vendors and other expenditures were obtained from the Rutgers University Financial Statements.

[4] Employment is as of November 1, 2015. Some forms of direct aid to student accounts (e.g., tuition remission and housing costs) are treated as fringe benefits, and together with depreciation expense, were excluded from the model analysis. Input-output analysis tracks the flow of dollars spent through the economy, but does not capture the value of non-cash flows such as depreciation and direct aid to student accounts for tuition, housing or other costs. See Technical Note at the end of this report for additional information.

approximately $776 million, with an additional $153.8 million in state and local research grants and contracts.

Table I-1 Rutgers Operating Expenditures FY 2016	
Sector	**Expenditures ($ millions)**
Salaries & Wages (26,027 employees)	$1,824.8
Fringe*	$632.6
Scholarships and Fellowships**	$67.4
Utilities	$83.0
Supplies and Services	$755.1
Depreciation***	$151.3
Total Operating Expenditures	**$3,514.2**

*Some fringe benefits are excluded from expenditures included in the modeling process. See Technical Note at the end of the report for more information.
**Payments to students treated as income in the R/ECON™ Model.
***Depreciation is allocated as an expense, but does not enter directly into the impact model as an expenditure.

With the exception of services related to RBHS patient care, non-utility payments to vendors were allocated into the R/ECON™ Model based on the distribution of expenditures by industry for colleges and universities shown in the national input-output accounts.[5] Non-personnel patient care expenditures were allocated according to the expenditure distribution for the hospital sector. Because detailed information on the location of third-party vendors was not available at the time of the analysis, the model's RPCs were used to allocate payments between in-state and out-of-state vendors.[6] In total, of $838.1 million in payments to third-party vendors, $610.2 million were allocated to New Jersey vendors.

[5] "Use Tables/After Redefinitions/Producer Value – Use of commodities by industry after reallocation of inputs associated with redefined secondary production," U.S. Bureau of Economic Analysis, 2007 Benchmark Input-Output Accounts Data (https://www.bea.gov/industry/io_annual.htm).
[6] The RPCs also account for outflow from the state of income earned by workers who work in New Jersey, but may reside out-of-state.

Contribution of Rutgers Operating Expenditures to the New Jersey Economy

The results of the economic contribution analysis of Rutgers annual operating expenditures are shown in Table I-2, followed by a description of the impacts. In total, Rutgers University's estimated annual contribution to the state economy includes:

- 57,893 jobs
- $4.3 billion in compensation
- $5.2 billion in gross domestic product
- $403.9 million in state tax revenues

These impacts continue from year to year as long as operating expenditures are maintained at a similar level and distribution.

Table I-2
Aggregate Economic Impacts in New Jersey of Rutgers Annual Operating Expenditures

	Direct	Indirect	Total
Employment	26,027	31,866	**57,893**
Gross Domestic Product ($ million)	$2,414.8	$2,782.6	**$5,197.4**
Compensation ($ million)[7]	$2,263.5	$2,024.1	**$4,287.6**
State Tax Revenues ($ million)			**$403.9**
Local Tax Revenues ($ million)			**$394.3**

Research and Development Expenditures

It is worth noting that a significant portion – $658.1 million – of the $3.5 billion in total FY 2016 operating expenditures were R&D expenditures, including $338.5 million funded from federal government sources (NSF, NIH, etc.). The economic contribution of University expenditures from federal and other out-of-state sources can be thought of as a "net" contribution to the state economy, as the expenditures are not funded by state tax revenues or tuition paid by student residents.

Source: National Science Foundation, Higher Education Research and Development (https://www.nsf.gov/statistics/herd/)

[7] Direct compensation includes salaries and wages, direct payments to students for scholarships and fellowships, and the portion of fringe benefits not allocated to direct student aid for tuition, housing and other costs.

For each dollar of state appropriation received by Rutgers University for FY 2016 ($775.7 million), the University returned the following to the state economy[8]:

- $6.70 in gross domestic product
- $5.53 in compensation
- $0.52 in state tax revenues

Each dollar in state appropriation returns $6.70 in economic activity in New Jersey

- **Employment**

An average of 57,893 jobs are estimated to have been supported by the University's total operating expenditures of $3.5 billion in FY 2016. Employment would be generated across a wide range of sectors, as the initial direct expenditures supporting University jobs and business revenues for vendors in related sectors such as professional and business services and financial activities, "ripple" through the broader economy, generating indirect employment in other industries such as retail, services, transportation, etc.[9] Table I-3 provides the estimated sector distribution (job categories are from the U.S. Bureau of Labor Statistics) of the total employment generated by the $3.5 billion of expenditures. These employment levels are maintained year-to-year as long as payroll and other University operating expenditures continue at the same level.

57,893 jobs in New Jersey

Table I-3
Distribution of Operating Expenditure Employment Impacts by Sector

Sector	Employment
Services*	43,962
Retail Trade	5,193
Financial Activities	4,441
Manufacturing	2,204
Transportation & Public Utilities	1,281
Wholesale Trade	447
Natural Resources & Mining	217
Construction	148
Total	**57,893**

* Includes all direct Rutgers employment.

[8] This state appropriation leverages an additional $2.7 billion in funding through tuition revenues, research grants and contracts, and other sources.

[9] The broadly defined service sector includes professional and business services (e.g., engineering, architecture, accounting, legal services, etc.), education and health services, leisure and hospitality services, the information sector, and other service industries.

- **<u>Compensation</u>**

  Labor compensation represents the total wages, salaries and wage supplements (i.e., employer contributions to government and private pension funds) paid for all direct *and* indirect jobs supported by the University's operations. Rutgers' operating expenditures of $3.5 billion are estimated to generate $4.3 billion in compensation.

$4.3 billion in compensation

- **<u>Gross Domestic Product</u>**

  Total gross domestic product (GDP), a measure of the value of the new economic output generated in the state as a result of the operating expenditures, is estimated at $5.2 billion.

$5.2 billion in GDP

- **<u>State Tax Revenues</u>**

  Estimated state tax revenues generated by Rutgers' operating expenditures comprise the income taxes associated with the salaries paid to the workers in the direct and indirect jobs generated by the expenditures, as well as the sales, corporate business and other taxes associated with the economic output generated by those expenditures. In total, Rutgers' in-state expenditures are estimated to generate approximately $403.9 million in state tax revenues.

$403.9 million in state revenues

- **<u>Local Tax Revenues</u>**

  The estimated local tax revenues for the state represent property tax revenues that accrue, over time, as a result of improvements to existing or construction of new property afforded by the personal and business incomes generated directly and indirectly by Rutgers' $3.5 billion in operating expenditures. These local tax revenues are estimated at $394.3 million. Unlike the other impacts, the increase in property tax revenues occurs over a considerably longer period (see Appendix B for additional detail).

$394.3 million in local tax revenues

Contribution of Operating Expenditures by Campus

Table I-4 provides estimates of the shares of the University's total contribution to the state economy that are attributable to each campus. These shares are based on an estimated distribution of the University's total expenditures across campuses, including assignment of indirect cost pool allocations.[10]

Table I-4
Economic Impacts in New Jersey of Rutgers Annual Operating Expenditures, FY 2016
Allocation by Campus

	Employment			Compensation ($ millions)			GDP ($millions)			Tax Revenues ($ millions)	
	Direct	In-direct	Total	Direct	In-direct	Total	Direct	In-direct	Total	State	Local
New Brunswick	12,023	13,451	**25,474**	867.1	859.6	**1,726.6**	942.9	1,185.7	**2,128.6**	**166.8**	**161.7**
Newark	2,123	2,461	**4,584**	199.8	156.3	**356.1**	211.9	215.1	**427.0**	**32.1**	**31.3**
Camden	1,412	1,213	**2,625**	107.6	77.4	**185.0**	114.3	106.7	**221.0**	**16.0**	**15.7**
RBHS (includes healthcare services)	10,311	14,383	**24,694**	1,072.3	907.3	**1,979.6**	1,125.7	1,242.3	**2,368.0**	**184.8**	**181.6**
Central Campus	158	358	**516**	16.8	23.5	**40.3**	20.0	32.8	**52.7**	**4.1**	**3.9**
Total	**26,027**	**31,866**	**57,893**	**2,263.6**	**2,024.1**	**4,287.6**	**2,414.8**	**2,782.6**	**5,197.3**	**403.8**	**394.2**

[10] Allocations by campus were based on FY 2016 campus budgets. Allocation by campus of actual expenditures was not available at the time of the analysis.

Contribution of Rutgers Capital Expenditures, FY 2012-2016

Rutgers Capital Projects, FY 2012-2016

The capital expenditures included in this analysis comprise a wide range of construction and renovation activities at all the University campuses over the last five fiscal years. These include significant new structures and improvements to student housing, classroom and laboratory facilities, administrative buildings, recreational and athletic facilities and other campus buildings and infrastructure, as well as smaller renovations such as roof and elevator replacements. The period analyzed includes all or part of the construction activity for major projects including the Chemistry and Chemical Biology Building on Busch Campus, the Residential Honors College, academic building and Lot 8 Housing facility on College Avenue, the Business School facility on Livingston Campus, the Life Sciences Building in Newark and the Nursing and Science Building in Camden. In all, capital spending over the five-year period totaled nearly $1.14 billion.

Capital expenditures on construction and renovation are distributed across expense categories such as labor, equipment, material such as girders, cement and masonry, design and engineering services and other cost items. The distribution of these project expenditures differs across project types (e.g., new construction versus renovation, housing versus classrooms, infrastructure projects, etc.). Projects were classified into a range of types, including multifamily residential structures (i.e., dormitories), educational and vocational structures, and nonresidential maintenance and repair.

Contribution of Rutgers Capital Expenditures to the New Jersey Economy

The aggregate economic impacts of Rutgers' capital expenditures over the five years FY 2012 – FY 2016 are presented in Table I-5, followed by an explanation of each of the impacts.

Table I-5
Aggregate Contribution to the New Jersey Economy of Rutgers University's Capital Expenditures
FY 2012 – FY 2016

	Direct	Indirect	Total
Employment (5-year average)*	1,041	1,318	**2,359**
Compensation ($ million)	544.3	413.5	**957.8**
Gross Domestic Product ($ million)	601.5	596.7	**1,198.2**
State Tax Revenues ($ million)			**82.2**
Local Tax Revenues ($ million)			**80.4**

*Employment impacts are reported in terms of average employment supported annually by the expenditures over the five fiscal-year period – i.e., each of the 2,359 jobs is supported over the five-year period of the expenditures. Because of the uneven nature of capital expenditures, associated employment impacts are often also reported in *job-years* – i.e., one job lasting one year. The equivalent job-year estimates for the five-year period would be 5,203 direct jobs, 6,591 indirect, and 11,794 total. (See sidebar on the next page.)

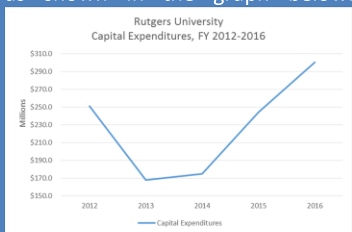
- **<u>Employment</u>**

An average of 2,359 jobs (or a total of 11,794 job-years) are estimated to have been supported annually by the total capital expenditures of $1.14 billion over the five-year period (see sidebar). Employment would be generated across a wide range of sectors, as the initial direct expenditures supporting jobs and business revenues in the construction, engineering, management and related sectors "ripple" through the broader economy, generating indirect employment in other industries such as retail, services, transportation, etc.[11] Table I-6 provides the estimated sector distribution (job categories are from

> *The equivalent of **<u>2,359 jobs in New Jersey,</u>** supported for 5 years*

[11] The broadly defined service sector includes professional and business services (e.g., engineering, architecture, accounting, legal services, etc.), education and health services, leisure and hospitality services, the information sector, and other service industries.

As with the operating expenditures described above, capital expenditures contribute to the New Jersey economy directly – in the form of employment and income in construction and related services such as design and engineering – and indirectly, as the initial income and business revenue are further spent through the economy. Unlike operating expenditures, however, capital expenditures tend to be "lumpy" – that is, they are not consistent on a year-to-year basis, as shown in the graph below.



Due to this inconsistency in expenditure levels and together with the non-recurring nature of the multiplier effects associated with capital expenditures, construction jobs and other employment temporarily supported directly or indirectly by capital expenditures in a given year are customarily reported in terms of "job-years" – equivalent to one job lasting one year. Since the expenditures are not expected to continue at the same level in subsequent years, the employment is not reported in terms of permanent jobs. Here, for purposes of analysis and ease of interpretation, the $1.14 billion in total capital expenditures are assumed to be spread evenly over the five-year period. Thus, rather than aggregate job-years, employment impacts in Table I-5 are reported in "jobs", each with an assumed duration of five years. [Compensation, gross domestic product (economic output), and tax revenues are reported in aggregate for the five years.]

the U.S. Bureau of Labor Statistics) of the total employment generated by the $1.14 billion of expenditures.

Table I-6
Distribution of Capital Investment Employment Impacts by Sector

Sector	Employment* (job-years)	Employment (5-year jobs)
Natural Resources & Mining	66	13
Construction	5,236	1,047
Manufacturing	934	187
Transportation & Public Utilities	552	110
Wholesale Trade	67	13
Retail Trade	1,153	231
Financial Activities	621	124
Services	3,165	633
Total	**11,794**	**2,359**

*Five-year averages may not precisely equal job-year totals times a factor of five due to rounding.

- **Compensation**

Labor compensation represents the total wages, salaries and wage supplements (i.e., employer contributions to government and private pension funds) paid for all direct *and* indirect jobs supported by the University's capital spending. Rutgers' capital expenditures of $1.14 billion are estimated to generate $957.8 million in compensation.

$957.8 million in compensation

- **Gross Domestic Product**

Total gross domestic product (GDP), a measure of the value of the new economic output generated in the state as a result of the capital expenditures, is estimated at $1.2 billion.

$1.2 billion in GDP

- **State Tax Revenues**

  Estimated state tax revenues generated by Rutgers' capital expenditures comprise the income taxes associated with the salaries paid to the workers in the direct and indirect jobs generated by the construction activity, as well as the sales, corporate business and other state taxes associated with the economic output generated by those expenditures. In total, the capital expenditures are estimated to generate approximately $82.2 million in state tax revenues.

$82.2 million in state tax revenues

- **Local Tax Revenues**

  The estimated local tax revenues for the state represent property tax revenues that accrue, over time, as a result of improvements to existing or construction of new property afforded by the personal and business incomes generated directly and indirectly by the construction expenditures. These local tax revenues are estimated at $80.4 million. Unlike the other impacts, the increase in property tax revenues occurs over a considerably longer period (see Appendix B for additional detail).

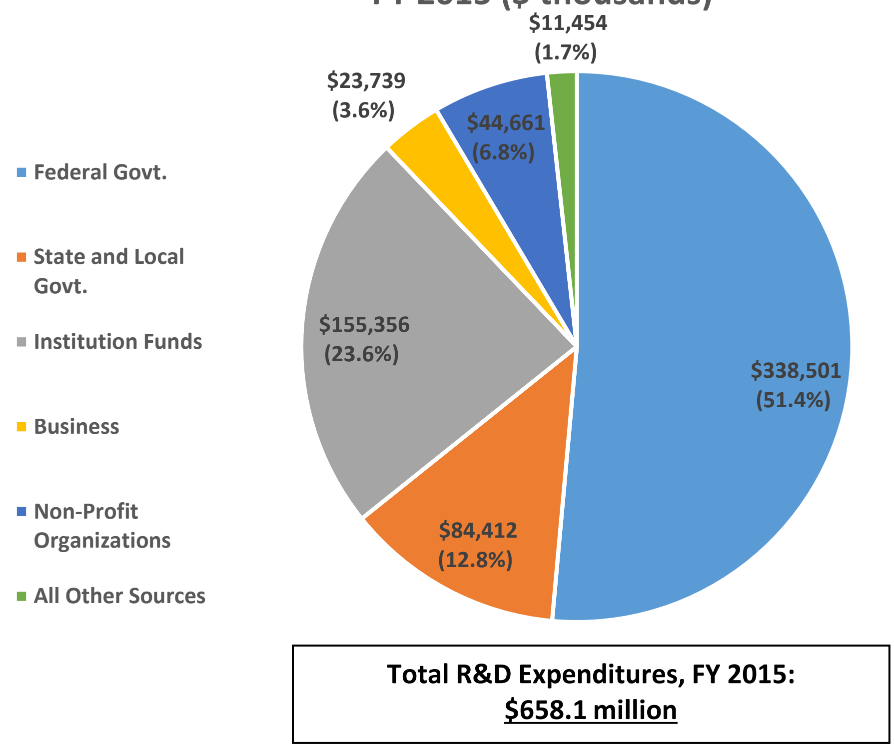
$80.4 million in local tax revenues

Section II: Research Expenditures and Output

Research Expenditures and Funding

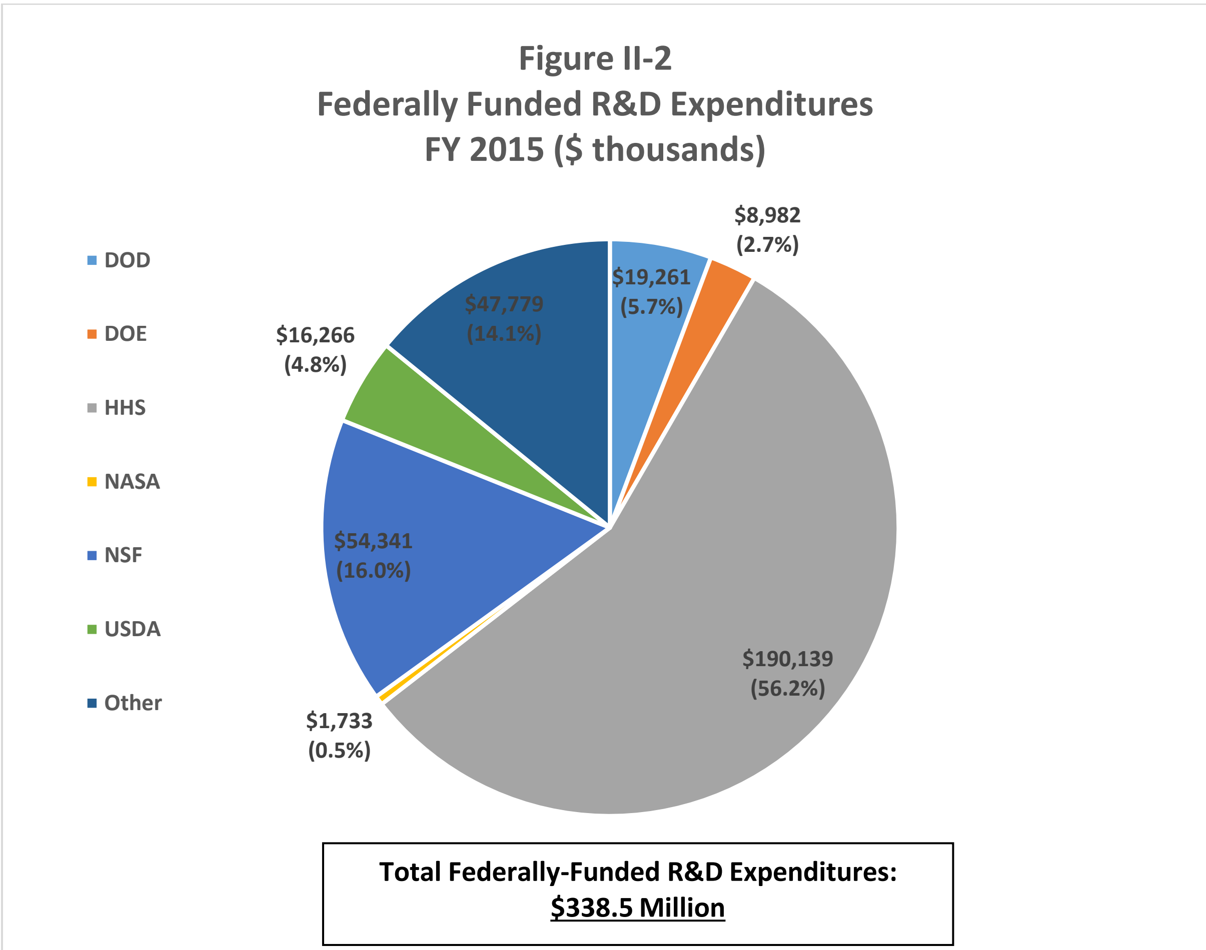
Each year, Rutgers implements a wide-ranging research agenda driven by significant external funding in the form of sponsored research grants and contracts. The economic contribution of these research expenditures is captured in the overall economic contribution of the University's annual operating expenditures provided in the preceding section. The chart below, based on data provided by Rutgers Office of Institutional Research, provides the amount and share of FY 2015 University research expenditures by funding source. Of a total of $658.1 million in research and development expenditures, $338.5 million (51%) were funded by federal agencies, with an additional $84.4 million (13%) funded by state and local government agencies.

Figure II-1
Rutgers University Research Expenditures by Funding Source FY 2015 ($ thousands)



Source: Rutgers University Office of Institutional Research and Academic Planning; Rutgers University Office of Research and Sponsored Programs. Note: Funding components may not sum to 100% due to rounding.

The federally funded portion of Rutgers' research expenditures comes from a broad array of federal agencies, including over 50% from the Department of Health and Human Services. These shares are shown in Figure II-2.



Source: Rutgers University Office of Institutional Research and Academic Planning; Rutgers University Office of Research and Sponsored Programs

Research Output

Each year, Rutgers research activity generates important outputs that benefit the University and the state economy through commercialization and licensing of new technologies and the creation of spinoff companies that create further jobs and economic activity in the state. Indicators of this activity include:

Patents, Disclosures and License Agreements

In FY 2015 and FY 2016, Rutgers researchers disclosed 352 inventions, the University entered into 182 license agreements, and Rutgers was granted 309 total patents for technologies developed at the University. :

- 82 U.S. patents in FY 2015
- 94 U.S. patents in FY 2016
- 65 foreign patents in FY 2015
- 68 foreign patents in FY 2016
- 184 disclosures in FY 2015
- 168 disclosures in FY 2016
- 25 exclusive license agreements in FY 2015
- 35 exclusive license agreements in FY 2016
- 50 non-exclusive license agreements in FY 2015
- 72 non-exclusive license agreements in FY 2016

License Revenue

Rutgers patents and licensing agreements generated a total of $31.5 million in royalty income for the University in FY 2015 and FY 2016 combined.

Spinoff Companies

Rutgers technologies have resulted in the creation of 119 startups to date, including 39 currently active companies in New Jersey. Thirteen startups have been created since FY 2015, with new technologies generating new opportunities for economic activity and growth in the state:

- Maverick Vascular Technologies, Inc. - 2015
- Elucid Bioimaging , Inc. - 2015
- Polymer Therapeutics, LLC -2015
- PolyCore Therapeutics, LLC. - 2016
- XPEED Turbine Technology, LLC. - 2016
- Virbio, Inc. - 2016
- Visikol, Inc. (restart of Phytosis, LLC) - 2016
- Z53 Therapeutics, LLC - 2016
- SubUAS, LLC - 2017
- OptoVibronex, LLC - 2017
- Aerial Technologies, Inc. - 2017
- CeraMaxx, LLC - 2017
- NewCo (Mega Hill option) - 2017

Section III: Rutgers Biomedical and Health Sciences

Rutgers Biomedical and Health Sciences brings together eight schools and five research and treatment centers and institutes, as well as affiliations with clinical partners throughout New Jersey. This broad instructional, research and clinical capacity presents significant opportunity for clinical trials, patient care, and other activities that generate economic and other benefits for the University and the state. In FY 2016, RBHS:

- Conducted 350 clinical trials
- Provided $12.6 million in low-cost and no-cost services to low-income patients through its clinics
- Employed more than 1,300 healthcare professionals
- Spent over $684 million in patient care-related expenditures

Conclusion

In implementing its core missions of education, research and service, Rutgers University also makes a significant contribution to the state economy through its operations and capital investments. The University's expenditures on the personnel, goods and services necessary to fulfill its core missions ripple through the state economy, generating additional economic activity in the form of employment, income, gross domestic product and tax revenues for state and local governments. This report has estimated the size of that contribution, including the effects of Rutgers' operating expenditures, which are estimated to support, on an ongoing annual basis:

- Nearly 58,000 jobs statewide, including over 26,000 directly employed by the University;
- Over $610 million in direct payments to in-state businesses;
- $4.3 billion in compensation;
- $5.2 billion in gross domestic product for the state;
- $403.9 million in state tax revenues; and
- $394.3 million in local tax revenues (statewide).

The report also estimated the contribution of Rutgers' capital expenditures for FY 2012 – FY 2016, which include:

- Nearly 2,400 jobs supported for five years (11,794 job-years);
- $957.8 million in compensation;
- $1.2 billion in gross domestic product for the state;
- $82.2 million in state tax revenues; and
- $80.4 million in local tax revenues (statewide).

A significant portion of Rutgers' operating expenditures are externally funded by sponsored research grants and contracts. Over half of the University's $638 million in externally sponsored research funding in FY 2016 was federally financed. This funding drives significant research output in the form of patents, invention disclosures, and licensed technologies that generate royalty income and lead to start-up companies which bring further economic activity to the state.

Rutgers Biomedical and Health Sciences brings important research and clinical capacity to the University. With its eight schools and multiple centers and institutes, RBHS educates future healthcare professionals, pursues innovative medical research that brings significant federal research funding to the state, conducts hundreds of clinical trials and provides clinical care to the community through its clinics and affiliated practices.

Appendix A: Input-Output Analysis and the R/ECON™ Model

This appendix discusses the history and application of input-output analysis and details the input-output model, called the R/ECON™ I-O model, developed by Rutgers University. This model offers significant advantages in detailing the total economic effects of an activity (such as historic rehabilitation and heritage tourism), including multiplier effects.

Estimating Multipliers

The fundamental issue determining the size of the multiplier effect is the "openness" of regional economies. Regions that are more "open" are those that import their required inputs from other regions. Imports can be thought of as substitutes for local production. Thus, the more a region depends on imported goods and services instead of its own production, the more economic activity leaks away from the local economy. Businessmen noted this phenomenon and formed local chambers of commerce with the explicit goal of stopping such leakage by instituting a "buy local" policy among their membership. In addition, during the 1970s, as an import invasion was under way, businessmen and union leaders announced a "buy American" policy in the hope of regaining ground lost to international economic competition. Therefore, one of the main goals of regional economic multiplier research has been to discover better ways to estimate the leakage of purchases out of a region or, relatedly, to determine the region's level of self-sufficiency.

The earliest attempts to systematize the procedure for estimating multiplier effects used the economic base model, still in use in many econometric models today. This approach assumes that all economic activities in a region can be divided into two categories: "basic" activities that produce exclusively for export, and region-serving or "local" activities that produce strictly for internal regional consumption. Since this approach is simpler but similar to the approach used by regional input-output analysis, let us explain briefly how multiplier effects are estimated using the economic base approach.

If we let $\mathbf{x}$ be export employment, $\mathbf{l}$ be local employment, and $\mathbf{t}$ be total employment, then

$$\mathbf{t} = \mathbf{x} + \mathbf{l}$$

For simplification, we create the ratio $\mathbf{a}$ as

$$\mathbf{a} = \mathbf{l}/\mathbf{t}$$

so that

$$\mathbf{l} = \mathbf{at}$$

then substituting into the first equation, we obtain

$$\mathbf{t} = \mathbf{x} + \mathbf{at}$$

By bringing all of the terms with t to one side of the equation, we get

$$\mathbf{t} - \mathbf{at} = \mathbf{x} \text{ or } \mathbf{t}\,(1\text{-}\mathbf{a}) = \mathbf{x}$$

Solving for **t,** we get

$$\mathbf{t} = \mathbf{x}/(1\text{-}\mathbf{a})$$

Thus, if we know the amount of export-oriented employment, **x,** and the ratio of local to total employment, **a**, we can readily calculate total employment by applying the economic base multiplier, 1/(1-**a**), which is embedded in the above formula. Thus, if 40 percent of all regional employment is used to produce exports, the regional multiplier would be 2.5. The assumption behind this multiplier is that all remaining regional employment is required to support the export employment. Thus, the 2.5 can be decomposed into two parts the direct effect of the exports, which is always 1.0, and the indirect and induced effects, which is the remainder—in this case 1.5. Hence, the multiplier can be read as telling us that for each export-oriented job another 1.5 jobs are needed to support it.

This notion of the multiplier has been extended so that **x** is understood to represent an economic change demanded by an organization or institution outside of an economy—so-called final demand. Such changes can be those effected by government, households, or even by an outside firm. Changes in the economy can therefore be calculated by a minor alteration in the multiplier formula:

$$\Delta \mathbf{t} = \Delta \mathbf{x}/(1-\mathbf{a})$$

The high level of industry aggregation and the rigidity of the economic assumptions that permit the application of the economic base multiplier have caused this approach to be subject to extensive criticism. Most of the discussion has focused on the estimation of the parameter **a**. Estimating this parameter requires that one be able to distinguish those parts of the economy that produce for local consumption from those that do not. Indeed, virtually all industries, even services, sell to customers both inside and outside the region. As a result, regional economists devised an approach by which to measure the *degree* to which each industry is involved in the nonbase activities of the region, better known as the industry's *regional purchase coefficient (r)*. Thus, they expanded the above formulations by calculating for each $\boldsymbol{i}$ industry

$$\mathbf{l}_i = \mathbf{r}_i \mathbf{d}_i$$

and

$$\mathbf{x}_i = \boldsymbol{t}_i - \mathbf{r}_i \mathbf{d}_i$$

given that $\mathbf{d}_i$ is the total regional demand for industry $\boldsymbol{i}$'s product. Given the above formulae and data on regional demands by industry, one can calculate an accurate traditional aggregate economic base parameter by the following:

$$\mathbf{a} = \mathbf{l}/\mathbf{t} = \Sigma \mathbf{l}_i/\Sigma \mathbf{t}_i$$

Although accurate, this approach only facilitates the calculation of an aggregate multiplier for the entire region. That is, we cannot determine from this approach what the effects are on the various sectors of an economy. This is despite the fact that one must painstakingly calculate the regional demand as well as the degree to which each industry is involved in nonbase activity in the region.

As a result, a different approach to multiplier estimation that takes advantage of detailed demand and trade data was developed. This approach is called input-output analysis.

Regional Input-Output Analysis: A Brief History

The basic framework for input-output analysis originated nearly 250 years ago when François Quesenay published *Tableau Economique* in 1758. Quesenay's "tableau" graphically and numerically portrayed the relationships between sales and purchases of the various industries of an economy. More than a century later, his description was adapted by Leon Walras, who advanced input-output modeling by providing a concise theoretical formulation of an economic system (including consumer purchases and the economic representation of "technology").

It was not until the twentieth century, however, that economists advanced and tested Walras's work. Wassily Leontief greatly simplified Walras's theoretical formulation by applying the Nobel prize–winning assumptions that both technology and trading patterns were fixed over time. These two assumptions meant that the pattern of flows among industries in an area could be considered stable. These assumptions permitted Walras's formulation to use data from a single time period, which generated a great reduction in data requirements.

Although Leontief won the Nobel Prize in 1973, he first used his approach in 1936 when he developed a model of the 1919 and 1929 U.S. economies to estimate the effects of the end of World War I on national employment. Recognition of his work in terms of its wider acceptance and use meant development of a standardized procedure for compiling the requisite data (today's national economic census of industries) and enhanced capability for calculations (i.e., the computer).

The federal government immediately recognized the importance of Leontief's development and has been publishing input-output tables of the U.S. economy since 1939. The most recently published tables are those for 2007. Other nations followed suit. Indeed, the United Nations maintains a bank of tables from most member nations with a uniform accounting scheme.

Framework

Input-output modeling focuses on the interrelationships of sales and purchases among sectors of the economy. Input-output is best understood through its most basic form, the *interindustry transactions table* or matrix. In this table (see table C-1 for an example), the column industries are consuming sectors (or markets) and the row industries are producing sectors. The content of a matrix cell is the value of shipments that the row industry delivers to the column industry. Conversely, it is the value of shipments that the column industry receives from the row industry. Hence, the interindustry transactions table is a detailed accounting of the disposition of the value of shipments in an economy. Indeed, the detailed accounting of the interindustry transactions at the national level is performed not so much to facilitate calculation of national economic impacts as it is to back out an estimate of the nation's gross domestic product.

Table A-1
Interindustry Transactions Matrix (Values)

	Agriculture	Manufact-uring	Services	Other	Final Demand	Total Output
Agriculture	10	65	10	5	10	$100
Manufacturing	40	25	35	75	25	$200
Services	15	5	5	5	90	$120
Other	15	10	50	50	100	$225
Value Added	20	95	20	90		
Total Input	100	200	120	225		

For example, in table A-1, agriculture, as a producing industry sector, is depicted as selling $65 million of goods to manufacturing. Conversely, the table depicts that the manufacturing industry purchased $65 million of agricultural production. The sum across columns of the interindustry transaction matrix is called the *intermediate outputs vector*. The sum across rows is called the *intermediate inputs vector*.

A single *final demand* column is also included in table A-1. Final demand, which is outside the square interindustry matrix, includes imports, exports, government purchases, changes in inventory, private investment, and sometimes household purchases.

The *value added* row, which is also outside the square interindustry matrix, includes wages and salaries, profit-type income, interest, dividends, rents, royalties, capital consumption allowances, and taxes. It is called value added because it is the difference between the total value of the industry's production and the value of the goods and nonlabor services that it requires to produce. Thus, it is the *value* that an industry *adds* to the goods and services it uses as inputs in order to produce output.

The value added row measures each industry's contribution to wealth accumulation. In a national model, therefore, its sum is better known as the gross domestic product (GDP). At the state level, this is known as the gross state product—a series produced by the U.S. Bureau of Economic Analysis and published in the Regional Economic Information System. Below the state level, it is known simply as the regional equivalent of the GDP—the gross regional product.

Input-output economic impact modelers now tend to include the household industry within the square interindustry matrix. In this case, the "consuming industry" is the household itself. Its spending is extracted from the final demand column and is appended as a separate column in the interindustry matrix. To maintain a balance, the income of households must be appended as a row. The main income of households is labor income, which is extracted from the value-added row. Modelers tend not to include other sources of household income in the household industry's row. This is not because such income is not attributed to households but rather because much of this other income derives from sources outside of the economy that is being modeled.

The next step in producing input-output multipliers is to calculate the *direct requirements matrix*, which is also called the technology matrix. The calculations are based entirely on data from table A-1. As shown in table A-2, the values of the cells in the direct requirements matrix are derived by dividing each cell in a column of table A-1, the interindustry transactions matrix, by its column total. For example, the cell for manufacturing's purchases from agriculture is 65/200 = .33. Each cell in a column of the direct requirements matrix shows how many cents of each producing industry's goods and/or services are required to produce one dollar of the consuming industry's production and are called *technical coefficients*. The use of the terms "technology" and "technical" derive from the fact that a column of this matrix represents a recipe for a unit of an industry's production. It, therefore, shows the needs of each industry's production process or "technology."

Table A-2
Direct Requirements Matrix

	Agriculture	Manufact-uring	Services	Other
Agriculture	.10	.33	.08	.02
Manufacturing	.40	.13	.29	.33
Services	.15	.03	.04	.02
Other	.15	.05	.42	.22

Next in the process of producing input-output multipliers, the *Leontief Inverse* is calculated. To explain what the Leontief Inverse is, let us temporarily turn to equations. Now, from table A-1 we know that the sum across both the columns of the square interindustry transactions matrix (**Z**) and the final demand vector (**y**) is equal to vector of production by industry (**x**). That is,

$$\mathbf{x} = \mathbf{Zi} + \mathbf{y}$$

where **i** is a summation vector of ones. Now, we calculate the direct requirements matrix (**A**) by dividing the interindustry transactions matrix by the production vector or

$$\mathbf{A} = \mathbf{Z}\mathbf{X}^{-1}$$

where $\mathbf{X}^{-1}$ is a square matrix with inverse of each element in the vector **x** on the diagonal and the rest of the elements equal to zero. Rearranging the above equation yields

$$\mathbf{Z} = \mathbf{A}\mathbf{X}$$

where **X** is a square matrix with the elements of the vector **x** on the diagonal and zeros elsewhere. Thus,

$$\mathbf{x} = (\mathbf{A}\mathbf{X})\mathbf{i} + \mathbf{y}$$

or, alternatively,

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y}$$

solving this equation for **x** yields

$\mathbf{x} =$	$(\mathbf{I}\text{-}\mathbf{A})^{-1}$		$\mathbf{y}$
Total =	Total	*	Final
Output	Requirements		Demand

The Leontief Inverse is the matrix $(\mathbf{I}\text{-}\mathbf{A})^{-1}$. It portrays the relationships between final demand and production. This set of relationships is exactly what is needed to identify the economic impacts of an event external to an economy.

Because it does translate the direct economic effects of an event into the total economic effects on the modeled economy, the Leontief Inverse is also called the *total requirements matrix*. The total requirements matrix resulting from the direct requirements matrix in the example is shown in table A-3.

Table A-3 Total Requirements Matrix				
	Agriculture	**Manufact-uring**	**Services**	**Other**
Agriculture	1.5	.6	.4	.3
Manufacturing	1.0	1.6	.9	.7
Services	.3	.1	1.2	.1
Other	.5	.3	.8	1.4
Industry Multipliers	.33	2.6	3.3	2.5

In the direct or technical requirements matrix in table A-2, the technical coefficient for the manufacturing sector's purchase from the agricultural sector was .33, indicating the 33 cents of agricultural products must be directly purchased to produce a dollar's worth of manufacturing products. The same "cell" in table A-3 has a value of .6. This indicates that for every dollar's worth of product that manufacturing ships out of the economy (i.e., to the government or for export), agriculture will end up increasing its production by 60 cents. The sum of each column in the total requirements matrix is the *output multiplier* for that industry.

Multipliers

A *multiplier* is defined as the system of economic transactions that follow a disturbance in an economy. Any economic disturbance affects an economy in the same way as does a drop of water in a still pond. It creates a large primary "ripple" by causing a *direct* change in the purchasing patterns of affected firms and institutions. The suppliers of the affected firms and institutions must change their purchasing patterns to meet the demands placed upon them by the firms originally 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 demands placed upon them by the suppliers of the original firms, and so on; thus, a number of subsequent "ripples" are created in the economy.

The multiplier effect has three components—direct, indirect, and induced effects. Because of the pond analogy, it is also sometimes referred to as the *ripple effect*.

- A *direct effect* (the initial drop causing the ripple effects) is the change in purchases due to a change in economic activity.

- An *indirect effect* is the change in the purchases of suppliers to those economic activities directly experiencing change.

- 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. Including households as a column and row in the interindustry matrix allows this effect to be captured.

Extending the Leontief Inverse to pertain not only to relationships between *total* production and final demand of the economy but also to *change*s in each permits its multipliers to be applied to many types of economic impacts. Indeed, in impact analysis the Leontief Inverse lends itself to the drop-in-a-pond analogy discussed earlier. This is because the Leontief Inverse multiplied by a change in final demand can be estimated by a power series. That is,

$$(\mathbf{I}\text{-}\mathbf{A})^{-1}\,\Delta\mathbf{y} = \Delta\mathbf{y} + \mathbf{A}\,\Delta\mathbf{y} + \mathbf{A}(\mathbf{A}\,\Delta\mathbf{y}) + \mathbf{A}(\mathbf{A}(\mathbf{A}\,\Delta\mathbf{y})) + \mathbf{A}(\mathbf{A}(\mathbf{A}(\mathbf{A}\,\Delta\mathbf{y}))) + \ldots$$

Assuming that **Δy**—the change in final demand—is the "drop in the pond," then succeeding terms are the ripples. Each "ripple" term is calculated as the previous "pond disturbance" multiplied by the direct requirements matrix. Thus, since each element in the direct requirements matrix is less than one, each ripple term is smaller than its predecessor. Indeed, it has been shown that after calculating about seven of these ripple terms that the power series approximation of impacts very closely estimates those produced by the Leontief Inverse directly.

In impacts analysis practice, **Δy** is a single column of expenditures with the same number of elements as there are rows or columns in the direct or technical requirements matrix. This set of elements is called an *impact vector*. This term is used because it is the *vector* of numbers that is used to estimate the *economic impacts* of the investment.

There are two types of changes in investments, and consequently economic impacts, generally associated with projects—*one-time impacts* and *recurring impacts*. One-time impacts are impacts that are attributable to an expenditure that occurs once over a limited period of time. For example, the impacts resulting from the construction of a project are one-time impacts. Recurring impacts are impacts that continue permanently as a result of new or expanded ongoing expenditures. The ongoing operation of a new train station, for example, generates recurring impacts to the economy. Examples of changes in economic activity are investments in the preservation of old homes, tourist expenditures, or the expenditures required to run a historical site. Such activities are considered changes in final demand and can be either positive or negative. When the activity is not made in an industry, it is generally not well represented by the input-output model. Nonetheless, the activity can be represented by a special set of elements that are similar to a column of the transactions matrix. This set of elements is called an economic disturbance or impact vector. The latter term is used because it is the vector of numbers that is used to estimate the impacts. In this study, the impact vector is estimated by multiplying one or more economic *translators* by a dollar figure that represents an investment in one or more projects. The term translator is derived from the fact that such a vector *translates* a dollar amount of an activity into its constituent purchases by industry.

One example of an industry multiplier is shown in table A-4. In this example, the activity is the preservation of a historic home. The *direct impact* component consists of purchases made specifically for the construction project from the producing industries. The *indirect impact* component consists of expenditures made by producing industries to support the purchases made for this project. Finally, the *induced impact* component focuses on the expenditures made by workers involved in the activity on-site and in the supplying industries.

Table A-4
Components of the Multiplier for the
Historic Rehabilitation of a Single-Family Residence

Direct Impact	Indirect Impact	Induced Impact
Excavation/Construction Labor	Production Labor	Expenditures by wage earners on-site and in the supplying industries for food, clothing, durable goods, entertainment
Concrete	Steel Fabrication	
Wood	Concrete Mixing	
Bricks	Factory and Office Expenses	
Equipment	Equipment Components	
Finance and Insurance		

Regional Input-Output Analysis

Because of data limitations, regional input-output analysis has some considerations beyond those for the nation. The main considerations concern the depiction of regional technology and the adjustment of the technology to account for interregional trade by industry.

In the regional setting, local technology matrices are not readily available. An accurate region-specific technology matrix requires a survey of a representative sample of organizations for each industry to be depicted in the model. Such surveys are extremely expensive.[12] Because of the expense, regional analysts have tended to use national technology

[12]The most recent statewide survey-based model was developed for the State of Kansas in 1986 and cost on the order of $60,000 (in 1990 dollars). The development of this model, however, leaned heavily on work done in 1965 for the same state. In addition the model was aggregated to the 35-sector level, making it inappropriate for many possible applications since the industries in the model do not represent the very detailed sectors that are generally analyzed.

as a surrogate for regional technology. This substitution does not affect the accuracy of the model as long as local industry technology does not vary widely from the nation's average.[13]

Even when local technology varies widely from the nation's average for one or more industries, model accuracy may not be affected much. This is because interregional trade may mitigate the error that would be induced by the technology. That is, in estimating economic impacts via a regional input-output model, national technology must be regionalized by a vector of regional purchase coefficients,[14] **r**, in the following manner:

$$(\mathbf{I}\text{-}\mathbf{rA})^{-1}\,\mathbf{r}\cdot\Delta\mathbf{y}$$

or

$$\mathbf{r}\cdot\Delta\mathbf{y} + \mathbf{rA}\,(\mathbf{r}\cdot\Delta\mathbf{y}) + \mathbf{rA}(\mathbf{rA}\,(\mathbf{r}\cdot\Delta\mathbf{y})) + \mathbf{rA}(\mathbf{rA}(\mathbf{rA}\,(\mathbf{r}\cdot\Delta\mathbf{y}))) + \ldots$$

where the vector-matrix product **rA** is an estimate of the region's direct requirements matrix. Thus, if national technology coefficients—which vary widely from their local equivalents—are multiplied by small RPCs, the error transferred to the direct requirements matrices will be relatively small. Indeed, since most manufacturing industries have small RPCs and since technology differences tend to arise due to substitution in the use of manufactured goods, technology differences have generally been found to be minor source error in economic impact measurement. Instead, RPCs and their measurement error due to industry aggregation have been the focus of research on regional input-output model accuracy.

[13]Only recently have researchers studied the validity of this assumption. They have found that large urban areas may have technology in some manufacturing industries that differs in a statistically significant way from the national average. As will be discussed in a subsequent paragraph, such differences may be unimportant after accounting for trade patterns.

[14]A regional purchase coefficient (RPC) for an industry is the proportion of the region's demand for a good or service that is fulfilled by local production. Thus, each industry's RPC varies between zero (0) and one (1), with one implying that all local demand is fulfilled by local suppliers. As a general rule, agriculture, mining, and manufacturing industries tend to have low RPCs, and both service and construction industries tend to have high RPCs.

A Comparison of Three Major Regional Economic Impact Models

In the United States there are three major vendors of regional input-output models. They are U.S. Bureau of Economic Analysis's (BEA) RIMS II multipliers, Minnesota IMPLAN Group Inc.'s (MIG) IMPLAN Pro model, and CUPR's own RECON™ I–O model. CUPR has had the privilege of using them all. (R/ECON™ I–O builds from the PC I–O model produced by the Regional Science Research Corporation (RSRC).)

Although the three systems have important similarities, there are also significant differences that should be considered before deciding which system to use in a particular study. This document compares the features of the three systems. Further discussion can be found in Brucker, Hastings, and Latham's article in the Summer 1987 issue of *The Review of Regional Studies* entitled "Regional Input-Output Analysis: A Comparison of Five Ready-Made Model Systems." Since that date, CUPR and MIG have added a significant number of new features to PC I–O (now, R/ECON™ I–O) and IMPLAN, respectively.

Model Accuracy

RIMS II, IMPLAN, and RECON™ I–O all employ input-output (I–O) models for estimating impacts. All three regionalize the U.S. national I–O technology coefficients table at the highest levels of disaggregation. Since aggregation of sectors has been shown to be an important source of error in the calculation of impact multipliers, the retention of maximum industrial detail in these regional systems is a positive feature that they share. The systems diverge in their regionalization approaches, however. The difference is in the manner that they estimate regional purchase coefficients (RPCs), which are used to regionalize the technology matrix. An RPC is the proportion of the region's demand for a good or service that is fulfilled by the region's own producers rather than by imports from producers in other areas. Thus, it expresses the proportion of the purchases of the good or service that do not leak out of the region, but rather feed back to its economy, with corresponding multiplier effects. Thus, the accuracy of the RPC is crucial to the accuracy of a regional I–O model, since the regional multiplier effects of a sector vary directly with its RPC.

The techniques for estimating the RPCs used by CUPR and MIG in their models are theoretically more appealing than the location quotient (LQ) approach used in RIMS II. This is because the former two allow for crosshauling of a good or service among regions and the latter does not. Since crosshauling of the same general class of goods or services among regions is quite common, the CUPR-MIG approach should provide better estimates of regional imports and exports. Statistical results reported in Stevens, Treyz, and Lahr (1989) confirm that LQ methods tend to overestimate RPCs. By extension, inaccurate RPCs may lead to inaccurately estimated impact estimates.

Further, the estimating equation used by CUPR to produce RPCs should be more accurate than that used by MIG. The difference between the two approaches is that MIG estimates RPCs at a more aggregated level (two-digit SICs, or about 86 industries) and applies them at a disaggregate level (over 500 industries). CUPR both estimates and applies the RPCs at the most detailed industry level. The application of aggregate RPCs can induce as much as 50 percent error in impact estimates (Lahr and Stevens, 2002).

Although both RECON™ I–O and IMPLAN use an RPC-estimating technique that is theoretically sound and update it using the most recent economic data, some practitioners question their accuracy. The reasons for doing so are three-fold. First, the observations currently used to estimate their implemented RPCs are based on 20-years old trade relationships—the Commodity Transportation Survey (CTS) from the 1977 Census of Transportation. Second, the CTS observations are at the state level. Therefore, RPC's estimated for substate areas are extrapolated. Hence, there is the potential that RPCs for counties and metropolitan areas are not as accurate as might be expected. Third, the observed CTS RPCs are only for shipments of goods. The interstate provision of services is unmeasured by the CTS. IMPLAN replies on relationships from the 1977 U.S. Multiregional Input-Output Model that are not clearly documented. RECON™ I–O relies on the same econometric relationships that it does for manufacturing industries but employs expert judgment to construct weight/value ratios (a critical variable in the RPC-estimating equation) for the nonmanufacturing industries.

The fact that BEA creates the RIMS II multipliers gives it the advantage of being constructed from the full set of the most recent regional earnings data available. 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 model systems rely on older data from *County Business Patterns* and Bureau of Labor Statistic's ES202 forms, which have been "improved" by filling-in for any industries that have disclosure problems (this occurs when three or fewer firms exist in an industry or a region).

Model Flexibility

For the typical user, the most apparent differences among the three modeling systems are the level of flexibility they enable and the type of results that they yield. R/ECON™ I–O allows the user to make changes in individual cells of the 383-by-383 technology matrix as well as in the 11 383-sector vectors of region-specific data that are used to produce the regionalized model. The 11 sectors are: output, demand, employment per unit output, labor income per unit output, total value added per unit of output, taxes per unit of output (state and local), nontax value added per unit output, administrative and auxiliary output per unit output, household consumption per unit of labor income, and the RPCs. The PC I–O model tends to be simple to use. Its User's Guide is straightforward and concise, providing instruction about the proper implementation of the model as well as the interpretation of the model's results.

The software for IMPLAN Pro is Windows-based, and its User's Guide is more formalized. Of the three modeling systems, it is the most user-friendly. The Windows orientation has enabled MIG to provide many more options in IMPLAN without increasing the complexity of use. Like R/ECON™ I–O, 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, which may be as many as four years prior to the current 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 of the 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 needed for the R/ECON™ I–O model. Much of the documentation for the model 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. Instead, the user is advised by the Users Guide to produce an aggregate model to achieve this end. Such a model, as was discussed earlier, is likely to be error ridden.

For a region, RIMS II typically delivers a set of 38-by-471 tables of multipliers for output, earnings, and employment; supplementary multipliers for taxes are available at 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 from a change in regional demand. This is because no RPC estimates are supplied with the model. For example, in order to estimate the impacts of rehabilitation, one not only needs to be able to convert the engineering cost estimates into demands for labor as well as for materials and services by industry, but must also be able to estimate the percentage of the labor income, materials, and services which will be provided by the region's households and industries (the RPCs for the demanded goods and services). In most cases, such percentages are difficult to ascertain; however, they are provided in the R/ECON™ I–O and IMPLAN models with simple triggering of an option. Further, it is impossible to change any of the model's parameters if superior data are known. This model ought not to be used for evaluating any project or event where superior data are available or where the evaluation is for 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 400 industries can be calculated for jobs, labor income, and output from R/ECON™ I–O 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 manual for R/ECON™ I–O warns about the problems of interpreting and comparing multipliers and any measures of output, also known as the value of shipments.

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

In addition to impacts in terms of jobs, employee compensation, output, and value added, IMPLAN provides information on impacts in terms of personal income, proprietor income, other property-type income, and indirect business taxes. R/ECON™ I–O breaks out impacts into taxes collected by the local, state, and federal governments. It also provides the jobs impacts in terms of either about 90 or 400 occupations at the users request. It goes a step further by also providing a return-on-investment-type multiplier measure, which compares the total impacts on all of the main measures to the total original expenditure that caused the impacts. Although these latter can be readily calculated by the user using results of the other two modeling systems, they are rarely used in impact analysis despite their obvious value.

In terms of the format of the results, both R/ECON™ I–O and IMPLAN are flexible. On request, they print the results directly or into a file (Excel® 4.0, Lotus 123®, Word® 6.0, tab delimited, or ASCII text). It can also permit previewing of the results on the computer's monitor. Both now offer the option of printing out the job impacts in either or both levels of occupational detail.

RSRC Equation

The equation currently used by RSRC in estimating RPCs is reported in Treyz and Stevens (1985). In this paper, the authors show that they estimated the RPC from the 1977 CTS data by estimating the demands for an industry's production of goods or 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.

This odd nonlinear form not only yielded high correlations between the estimated and actual values of the RPCs, it also assured that the RPC value ranges strictly between 0 and 1. The results of the empirical implementation of this equation are shown in Treyz and Stevens (1985, table 1). The table shows that total local industry demand (Z_1), the supply/demand ratio (Z_2), the 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.

Because the CTS data are at the state level only, it is important for the purposes of this study that the local industry demand, the supply/demand ratio, and the region's size in square miles are included in the equation. They allow the equation to extrapolate the estimation of RPCs for areas smaller than states. It should also be noted here that the CTS data only cover manufactured goods. Thus, although calculated effectively making them equal to unity via the above equation, RPC estimates for services drop on the weight/value ratios. A very high weight/value ratio like this forces the industry to meet this demand through local production. Hence, it is no surprise that a region's RPC for this sector is often very high (0.89). Similarly, hotels and motels tend to be used by visitors from outside the area. Thus, a weight/value ratio on the order of that for industry production would be expected. Hence, an RPC for this sector is often about 0.25.

The accuracy of CUPR's estimating approach is exemplified best by this last example. 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 (among others). The results of such aggregation process is an RPC that represents neither industry (a value of about 0.50) but which 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. This is because it provides a concise and accurate means for articulating the interrelationships among industries. The models can be quite detailed. For example, the current U.S. model currently has more than 500 industries representing many six-digit North American Industrial Classification System (NAICS) codes. The R/ECON™ model used in this study has 383 sectors. Further, the industry detail of input-output models provides not only a consistent and systematic approach but also more accurately assesses multiplier effects of changes in economic activity. Research has shown that results from more aggregated economic models can have as much as 50 percent error inherent in them. Such large errors are generally attributed to poor estimation of regional trade flows resulting from the aggregation process.

Input-output models also can be set up to capture the flows among economic regions. For example, the model used in this study can calculate impacts for a county, as well as a metropolitan area or a state economy.

The limitations of input-output modeling should also be recognized. The approach makes several key assumptions. First, the input-output model approach assumes that there are no economies of scale to production in an industry; that is, the proportion of inputs used in an industry's production process does not change regardless of the level of production. This assumption will not work if the technology matrix depicts an economy of a recessional economy (e.g., 1982) and the analyst is attempting to model activity in a peak economic year (e.g., 1989). 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. In a region as large and diverse as New Jersey, this assumption is likely to hold true.

Appendix B: Note on Local Tax Revenue Impacts

The estimated local tax revenues for the state estimated in this analysis represent property tax revenues that accrue, over time, as a result of improvements to existing or construction of new property. This activity is afforded by the personal and business incomes generated directly and indirectly by the construction expenditures.

Local tax revenues result from the expenditures generated from the income for workers and revenues for business.[15] The personal incomes and in business revenues are, in part, used to pay property taxes and to improve properties (both residential and commercial). Thus, households and businesses that benefit from the operating and capital expenditures acquire and/or improve residential and commercial properties or alternatively are able to pay rents that include associated property taxes.

Historical New Jersey fiscal and economic data are used to measure the relationship between business revenues and the amount of commercial property tax revenues collected, and between household incomes and the amount of residential property tax revenues collected.[16] Given both household income and business revenues associated with the construction expenditures, the R/ECON™ Input-Output Model invokes the known statistical relation of local property tax revenues to both household income and business revenues in order to estimate the addition to local tax revenues attributable to the expenditures.

[15] For businesses, the revenue increase is measured in terms of value-added, and it is the change in value added in the business sector that is the basis for the estimated change in property tax revenues.
[16] For the entire state, approximately 76% of total local property tax revenues are attributable to residential property; with approximately 21% derived primarily from commercial and industrial property.

Technical Note

Total University expenditures for FY 2016 were obtained from the FY 2016 Rutgers Financial Statements, Operating Expenses by Natural Classification.[17] The sum of the wages and salaries and fringe benefits reported therein totaled approximately $2.46 billion, compared to $2.0 billion in the Statements of Cash Flows.[18] Based on information in the Financial Statements $261.3 million of this discrepancy was assumed to be accounted for in the allocation of direct tuition and housing aid to student accounts in the form of fringe benefits, and was excluded from the economic model.[19] Depreciation expense of $151.3 million was also excluded from the model. Approximately $67.45 million in scholarship and fellowship funds paid out to students was treated as income (i.e., salaries and wages). Approximately $83 million was allocated to payments for utilities, as indicated in the Statement of Cash Flows, with the remainder of the $838.1 million in supplies and services expenses allocated across a range of industries based on the vector for colleges and universities in the national input-output accounts. Thus, with the exclusion of depreciation expense and direct aid to student accounts, a total of $3.1 billion of the $3.51 billion in total operating expenses reported in the FY 2016 Financial Statements were allocated into the model.

The $3.1 billion in expenditures were allocated across Rutgers campuses based on the FY 2016 budgets for individual campuses (allocation by campus of actual expenditures was not available).[20] Allocations were first based on the Direct Expenses for each campus, and the division of those expenses between personnel and non-personnel. To this initial allocation were added the campuses' shares of sponsored research and programs (assigned to personnel and non-personnel based on the Natural Expenses by Functional Classification in the FY 2016 Financial Statements[21]). Finally, based on allocations by Cost Center for Central Campus in the FY 2016 Budget Summaries, shares of the $547 million in indirect costs attributed to Central Campus were assigned to each campus. All shares were aggregated into personnel and non-personnel categories, then used to distribute FY 2016 total expenditures across campuses and across accounting classifications within each campus.

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[17] *Annual Financial Report of Rutgers, The State University of New Jersey*, *FY 2016*, p. 16.
[18] Ibid., p. 22.
[19] Ibid., p. 13.
[20] FY 2016 Operating Budget Summaries were used for Rutgers' New Brunswick, Newark and Camden campuses, as well as RBHS and the central administration (http://budgetfacts.rutgers.edu/).
[21] *Annual Financial Report*, p. 51.