

ECONOMIC IMPACTS OF THE VIRGINIA TECH CARILION HEALTH SCIENCES AND TECHNOLOGY CAMPUS

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INTRODUCTION

The Virginia Tech Carilion (VTC) School of Medicine and Research Institute were established in 2010 on the Carilion-owned Riverside Campus in South Roanoke as a new type of private-public collaboration to advance scientific research, improve area health care access and quality, promote medical and science education, and help alleviate a shortage of physicians. It involves a partnership of Virginia Tech, a state research intensive flagship institution of higher education and Carilion Clinic, a nationally known integrated health system headquartered in Roanoke and serving one million residents in central and western Virginia. VTC is also seen as an important tool for transforming a regional economy that has suffered from the loss of traditional industry. This study examines the economic impact of VTC and of expansion plans that will see a gradual growth in the physical footprint of the Riverside Campus and clinical research and education activities occurring in and around the campus. These activities include the operation of a major research intensive allopathic medical school with 168 medical students, a translational biology, medicine and health graduate training program with close to 100 students, and approximately 500 graduate medical students across specialties and in conjunction with subspecialties, the expanding operation of the Virginia Tech Research Institute which conducts groundbreaking research in neuroscience, cardiovascular science, cancer, immunity, and other areas, that has already won over \$100M in extramural (mostly federal) research funding, and the clinical operations of the Carilion Clinic that occur on and near the VTC Riverside Campus.

This study examines the economic contribution of VTC using an economic impact model called REMI PI+ (Regional Economic Models, Inc. Policy Insight Plus). REMI PI+ is a well-regarded, peer-reviewed economic model that is used by numerous federal, state, and local government agencies and private consultants to examine the economic impacts of higher education, health care systems, and industrial expansions. The Weldon Cooper Center for Public Service has used this model in the last several years to examine the economic impacts of Virginia public higher education (Rephann 2017) and the University of Virginia's Cancer Center (2011).

The study consists of three sections. The first section provides a brief description of the history, development, and important features of VTC. It also describes future expansion plans. It does not describe the full impact of VTC on the Carilion Clinic enterprise or the economic impact of Carilion Clinic as a whole, the latter of which is examined in another study by the Roanoke-Valley-Alleghany Regional Commission (2016). The second section describes various ways in which VTC affects the state and local economies. Some of these pathways can be easily measured and economic impacts determined. Others, while important, are less easily quantified. The third section describes the results of the economic impact analysis. The economic impact of the health sciences campus in the most recent completed fiscal year (FY2017) is shown as well as projected economic impacts associated with expansion plans from FY2018 to FY2026.

SECTION 1

VIRGINIA TECH CARILION OVERVIEW

The Virginia Tech Carilion (VTC) School of Medicine and Research Institute was established in Roanoke in 2010 as a unique public-private collaboration between Virginia Tech and the Carilion Clinic. The partnership joins a major research university with strengths in life sciences, engineering and veterinary medicine with Carilion Clinic's experience and expertise in health care delivery and graduate medical education.

Virginia Tech is the second largest public university in the state with an enrollment of 33,170 students in 2016-17 and offers 90 Bachelor's, 76 Master's, and 62 Doctoral Degree programs. It ranks 44th highest in the United States for research expenditures, which totaled \$504.3 million in fiscal year 2015. It also hosts nationally recognized programs at its main campus in Blacksburg that intersect with VTC specialties, including programs in the life sciences such as bioinformatics, bioengineering, and veterinary medicine.

Carilion Clinic is the third largest private health system in Virginia. It serves the public through seven hospital campuses, over 1,600 physicians and providers, a Level I Trauma Center, a Cancer Center, and numerous other ambulatory care facilities. It also operates the Jefferson College of Health Sciences, a private health sciences college in Roanoke that offers 25 healthcare programs to over 1,000 students. Carilion Clinic has strong connections to clinical research in order to improve the quality of patient care. It provides a variety of clinical trial options to patients and matches Carilion medical specialists with academic collaborators at VTC and elsewhere in the United States and internationally who conduct innovative research.

The Health Sciences and Technology Campus consists of three intersecting components: The Virginia Tech Carilion School of Medicine (VTCsOM), the Virginia Tech Carilion Research Institute (VTCRI), and clinical operations of the Carilion Clinic. The School of Medicine, which is currently organized as a non-profit corporation that

is managed by Carilion Clinic, will be formally transferred to Virginia Tech on July 1, 2018. The school offers a patient-centered curriculum coupled with a strong emphasis on student academic research. The Research Institute conducts basic, translational and applied research with commercialization potential that can be tested in clinical settings provided by the Carilion Clinic. The VTCRI's areas of focus include cognitive and computational neuroscience, cellular and molecular neurobiology, cardiovascular science and regenerative medicine, and cancer, immunity, and infection. The Carilion Clinic connects VTC operations to a healthcare system with a vast geographic footprint and strong clinical operations.

In addition to improving health care and quality of life for regional, national and global residents and medical and science education opportunities for students, VTC is viewed as an essential tool for regional economic development and transitioning the Roanoke and New River Valley region towards a New Economy. Translational research at the VTCRI has already led to the formation of several startup companies and partnership with established companies. These activities, along with commercialization from the clinical enterprise form the basis for an innovation corridor in the central Roanoke area that will feature an improved transit system and infrastructure, known as the Roanoke Innovation Corridor. The Corridor will incorporate the VTC campus, Carilion Medical Center with its flagship Carilion Roanoke Memorial Hospital, and Jefferson College of Health Sciences in Downtown Roanoke and future industrial development along Jefferson, Williamson and Franklin Roads.

The Virginia Tech Carilion Health Sciences and Technology Campus is located close to downtown Roanoke and the Carilion Medical Center, in an area between Jefferson Street, Reserve Avenue, Franklin Road, and the Norfolk Southern railroad tracks. It currently consists of three buildings and a parking garage (see **Figure 1**). They include Riverside 1 (Riverside Center), a 100,000 square foot office

Figure 1. VTC Campus Landscape



Clockwise from upper left: (a) Riverside 1, (b) Riverside 2, (c) Parking Garage, (d) Rendering of Future VTC Biomedical Research Addition, and (e) Riverside 3.

building that contains office space for VTC SOM and Carilion Clinic, clinical spaces for Carilion Clinic, housing of the Virginia Tech Translational Biology, Health and Medicine graduate program and additional research space for health behaviors, musculoskeletal research and brain research.

Riverside 2 is a 155,000 square foot VTC Health Sciences and Technology Campus Building that houses most of the medical education and research space for VTC SOM and VTCRI. A third 210,000 square foot building, Riverside 3, is dedicated

to Carilion Clinic outpatient clinical services. In addition, the campus includes a 1,000 space 7 level parking garage and a 127 room Cambria Hotel and Suites (not pictured).

A site adjacent to the parking garage is the planned location for the campus' newest building: a 139,000 square foot VTC Biomedical Research Addition that will include major research facilities that expand on the successful programs at the VTCRI and add new research programs as well as a Comparative Oncology Research Center from Virginia Tech's

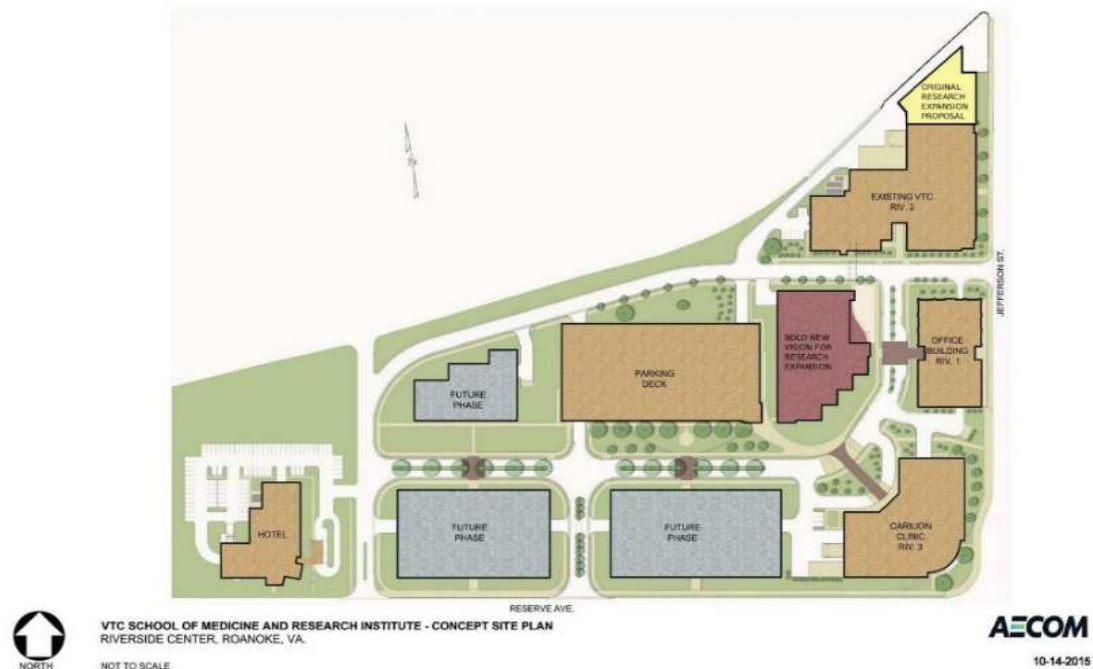
College of Veterinary Medicine and classroom spaces. The groundbreaking for the new Biomedical Research Addition was in October 2017. The \$90 million dollar construction project will alleviate cramped conditions for existing growing programs and accommodate programming for new research activities. The research activities will be in five major focus areas that represent the results of coordinated planning by Virginia Tech, VTCRI and Carilion Clinic (see below) and the new Comparative Oncology Research Center in collaboration with the Virginia-Maryland College of Veterinary Medicine. The new building will host expanded research programs on cardiovascular health, on brain health and disorders (neuroscience) and on infectious disease/ immunity already occurring at the institute as well as new research programs in metabolism and obesity and biomaterials-body device interfaces. The new research building will incorporate human, lab animal and companion animal health research together.

Most of the growth in the next 10 years will be tied to new Research Institute initiatives. Concurrently,

Carilion Clinic plans expansion and growth over the next 10 years to meet the needs of an aging population and a growing national profile in clinical services. VTCRI research teams are anticipated to expand by adding 25 to 30 faculty research teams in 5 research areas which are strategically aligned with Carilion Clinic's leading service lines. Additional teams will be added bringing the total up to 60 faculty research teams in 7 research areas by 2025. Each team typically consists of 5 to 15 research scientists, post-doctoral fellows, graduate and undergraduate students and other support employees.

Longer-term growth is anticipated as a result of new synergistic research, clinical, educational, and industrial collaboration activities. The campus master plan seeks to fill vacant space at the Riverside Campus as well as connect the research, clinical, and learning centers and foster open interaction and collaboration among the various units. The existing campus has four pad sites available for future development (see **Figure 2**). Some of this space may be developed to meet clinical needs and to accommodate industry partners. Since the student

Figure 2. VTC Site Plan



population is projected to increase rapidly from approximately 300 now to 800 students by 2025 and over 1,000 by 2035, adjacent housing for students as

well as visiting faculty and industry partners is also envisioned as part of any future expansion.

SECTION 2

VIRGINIA TECH CARILION OVERVIEW

The Virginia Tech Carilion partnership contributes to the Virginia economy through a variety of channels. This study takes into account only the following two sources of economic impact:

- **Operational expenditures.** VTC spending on supplies and services with Virginia based businesses and payroll for Virginia workers are sources of ongoing and growing economic stimulus to the Virginia economy.
- **Capital spending.** The construction of a Biomedical Research Addition building that will include biomedical research facilities, classroom facilities and a comparative oncology research center that also provides clinical services for treating companion animals based on clinical referrals and will generate spending on construction and furniture/equipment and provide a further temporary stimulus to the state economy during the time it is being built.

The model and manner in which these inputs are used in the economic impact model are described further in Appendix A (“Methodology and Data”). In brief, the analysis uses REMI PI+ (Policy Insight Plus), a dynamic, multi-sector regional economic simulation model customized for the state of Virginia. Model input data consists of VTC expenditures, including current and projected employee compensation, outlays on goods and services, and capital expenditures. The items cover VTCRI spending, VTC SOM spending, and Carilion Clinic spending at the Riverside Campus and close proximity.

The impact analysis does not incorporate all possible operational expenditure and capital increases that may occur during the FY2018-FY2026 period. For example, the research expenditure estimates show only the expected investments (e.g., recruitment costs, startup packages, endowments, ongoing support) for the new FTEs and their research groups who will be recruited into the new research building. It does not show expected research expenditures

that will be derived from the extramural grants of these teams that primarily represent funds that come into the Commonwealth from outside. Furthermore, the analysis does not utilize capital expenditure information for building projects that might occur after the construction of the Health Science and Technology Research Building is complete.

Moreover, VTC can be expected to have effects beyond operational and capital spending. The economic impacts of the first item on this list, graduate earnings and productivity, are alone likely greater in magnitude over time than the operational and capital expenditure economic impacts (Rephann 2017).

- **Graduate earnings and productivity.**

VTC graduates and post-docs that enter the Virginia workforce are more productive and command higher earnings than would otherwise be the case. Clinical workers also receive higher wages than the regional median. These effects expand the capacity of Virginia’s economy.

- **Visitor spending.** VTC research, educational, and clinical activities can be expected to attract three different types of visitors from out-of-state that spend in the local economy. They include friends and family of faculty, staff, and students; attendees for VTC hosted academic and research conferences and seminars, and patients (both human and companion animal) from out-of-state who are receiving clinical treatments and other types of patient care at VTC facilities.

- **Resident patient expenditures on clinical treatments.** The strategic alignment of the aforementioned VTCRI research and focus areas with the clinical expertise of Carilion in those same focus areas provides enhanced clinical care options to thousands of patients at Carilion Clinic facilities on the VTC Riverside Campus and other Carilion Clinic facilities throughout central and western Virginia. Additionally, Carilion Clinic’s planned

expansion of facilities and service lines will increase patient care capacity. The absence of these clinical care options would mean that many patients would need to travel elsewhere, including out-of-state to receive such care. Thus, VTC's presence helps to attract and retain patient revenues and supports spending in the Virginia economy. Furthermore, the smaller distances travelled by patients result in patient cost savings and improved quality of life for resident patients.

- **Labor supply and labor productivity.** Improvements in the health of Virginia residents that result from prevention practices, medical treatments, delivery models and therapies developed by VTC faculty and staff in areas such as cancer, cardiovascular disease, infections, and other health areas may improve the health of workers, which results in improved labor productivity. Productivity may improve because of decreased absenteeism. Also, businesses may realize direct cost savings from lower worker compensation rates, reduced personnel costs for overtime for replacement employees, and lower costs for employee turnover. Lower mortality and morbidity rates may also increase the labor supply by allowing workers to be productive members of the labor force for a longer period of time.

- **Startups.** University start-ups are entrepreneurial business ventures created as a result of licensing university intellectual property. New scientific discoveries from VTC research stimulate the creation of these new Virginia businesses. Carilion Clinic also cultivates entrepreneurial startups both independently and in collaboration with VTC. The employment and spending of these new firms, which grow over time provides additional stimulus to the state economy.

- **Commercialization and other outside income.** The University, Carilion Clinic, and faculty/staff earn licensure and royalty income from firms using that licensure which is then spent in the Virginia economy. Moreover, they may earn additional income from serving on company boards and as consultants.

- **Technological change.** Research and development undertaken at VTC can yield technological advances that are applied in a variety of fields, including biotechnology, chemistry, and medicine to improve medical treatments, industrial processes, products, and services. These investments may improve national and state productivity. These productivity improvements may be highly localized because of the importance of face-to-face contact in transmitting tacit or unpublished knowledge generated by VTC researchers. Moreover, Virginia firms that purchase or utilize VTC technologies may grow faster as a result.

- **Health Sciences and Technology District.** VTC will anchor the District, a designated geographic area within the Roanoke Innovation Corridor, where dozens of university spinoffs such as medical device, pharmaceutical, and biotechnology startups are expected to cluster in the next few decades. Experience elsewhere has shown that innovation districts attract other firms from similar industries and generate new startups. Economic research suggests regional productivity increases from geographically clustering similar firms because of knowledge sharing and the greater ability to attract and retain highly skilled workers and other specialized inputs (Porter 2000).

- **Recruitment of Health Care Professionals.** The presence of VTC and its associated research and clinical activities makes it easier for the Carilion Clinic to recruit and retain skilled specialists. The availability of the professional amenity offers opportunities for specialists to advance their skills and professional credentials and opens new possibilities for career mobility and intellectual challenges. This can result in productivity and quality of health care service improvements, lower costs for consumers in the region, and less travel outside of the region for access.

- **Amenities and quality of life.** VTC expands and improves health services available for Virginia citizens. Health system quality is an important regional amenity

(Bartik and Erickcek 2007). VTC faculty, staff, and students also participate in a wide variety of community engagement activities, devoting thousands of hours to health promotion and service activities in local public schools, free public health clinics and other area non-profits such as Habitat for Humanity. Moreover, VTC offers several programs that provide youth mentoring and service

learning opportunities such as Camp Carilion and Kids' Tech University that introduces middle school and high school students to career possibilities in health care. Migrants (i.e., retirees, transient talent and knowledge workers) choose places to live partly based on amenity values and are, therefore, more likely to choose Virginia as a place of residence because of such improvements.

SECTION 3 VTC ECONOMIC IMPACTS

In FY2017, VTC accounted for approximately \$132 million in spending and 766 employees. Of this amount, the VTCRI generated \$26.1 million in expenditures and employed 308 faculty, researchers, staff and students (see **Table 1**); VTC SOM (which is currently operated in association with Carilion Clinic but will be transitioned to Virginia Tech on July 1, 2018) had approximately \$16.1 million in spending and 64 employees; and Carilion Clinic spent \$90 million and employed 394 physicians and staff working in clinical areas within the Corridor, including a nearby clinical facility at Jefferson Plaza.

Table 1. VTC Related Employment and Expenditures

Year	Carilion Clinic Employment	Carilion Clinic Expenditures (Millions)	VTC Employment	VTC Expenditures (Millions)	VTC Capital Expenditures (Millions)
FY2017	394	\$89.8	372	\$42.1	\$1
FY2018	446	\$94.3	372	\$43.4	\$25
FY2019	446	\$97.9	618	\$110.8	\$55
FY2020	446	\$101.6	703	\$120.2	\$23
FY2021	446	\$105.4	788	\$129.5	**
FY2022	446	\$109.7	873	\$138.9	**
FY2023	446	\$113.9	958	\$155.5	**
FY2024	446	\$118.2	1,043	\$167.1	**
FY2025	446	\$122.6	1,128	\$178.7	**
FY2026	446	\$126.9	1,192	\$190.3	**

Source: VTC, Carilion Clinic and Weldon Cooper Center for Public Service

**Outyear (FY2021-FY2026) Capital Improvement Program is currently under development

The VTC Biomedical Research Addition will increase VTC's economic footprint through increased payroll, other operational expenditures, and capital spending. With this expansion total VTCRI and VTC SOM employment is projected to grow from 372 today to nearly 1,200 employees, including graduate and undergraduate student employees. Associated expenditures will increase from \$42.1 million in FY2017 to more than double that amount in FY2019. In FY2026, all activities at VTC are anticipated to generate approximately \$190.3 million in expenditures. The total also

reflects a conservative assumption that Carilion Clinic employment and expenditures stay roughly constant over the forecast horizon.

Table 2 shows the results of an economic impact analysis of VTC current and projected employment and expenditures using the REMI PI+ model. These results reflect the multiplier effects of VTC spending and employment on the state economy and other model dynamic economic feedback effects. The results are presented in total as well as for constituent components. Economic activity is represented by three variables including: (1) employment, (2) gross

domestic product, and (3) industrial output. Employment includes full-time and part-time workers and the self-employed whose employment is tied to VTC activities and is measured by place-of-work rather than place-of-residence. Industrial output reflects the total value of industry production during a period, including the value of intermediate input purchases. Gross domestic product reflects only

the value of production for final demand. All dollar denominated figures are nominal values.

To simplify the presentation, Virginia Tech economic impacts include both the Research Institute and School of Medicine, even though the latter unit will not be formally transferred to the university until FY2019. VTCRI is projected to generate most of the additional employment growth over the projection period (FY2018-FY2026). Carilion Clinic operations within the Riverside campus are shown separately. Finally, the table shows the economic activity of the VTC Biomedical Research Addition. Since

Table 2. VTC Economic Impacts, Actual (FY2017) and Projected (FY2018-FY2026) by Source

VTC (VTC-RI and VTC-SOM) Operations											
Category	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	
Total Employment	722	728	1,448	1,595	1,717	1,813	1,945	2,044	2,139	2,211	
Gross Domestic Product (Millions)	\$40.6	\$41.6	\$90.8	\$102.8	\$113.2	\$122.2	\$134.7	\$144.8	\$154.7	\$163.8	
Output (Millions)	\$69.1	\$70.4	\$151.4	\$171.2	\$188.1	\$202.8	\$223.0	\$239.4	\$255.8	\$271.1	
Carilion Clinic Operations											
Category	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	
Total Employment	971	1,108	1,125	1,107	1,077	1,043	1,013	990	970	955	
Gross Domestic Product (Millions)	\$81.2	\$95.5	\$100.2	\$102.5	\$103.7	\$104.9	\$106.2	\$108.1	\$110.2	\$112.9	
Output (Millions)	\$144.2	\$169.2	\$176.8	\$180.5	\$182.2	\$184.2	\$186.3	\$189.4	\$193.4	\$198.3	
Capital Expenditures											
Category	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	
Total Employment	6	278	612	251	12	-8	-20	-24	-23	-19	
Gross Domestic Product (Millions)	\$0.6	\$23.6	\$53.3	\$22.6	\$0.8	-\$1.2	-\$2.4	-\$2.8	-\$2.8	-\$2.5	
Output (Millions)	\$1.0	\$40.5	\$91.3	\$38.4	\$1.1	-\$2.2	-\$4.2	-\$4.9	-\$4.8	-\$4.2	
Total											
Category	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	
Total Employment	1,699	2,114	3,185	2,954	2,805	2,848	2,938	3,011	3,086	3,147	
Gross Domestic Product (Millions)	\$122.5	\$160.7	\$244.4	\$227.9	\$217.6	\$225.9	\$238.5	\$250.0	\$262.1	\$274.2	
Output (Millions)	\$214.3	\$280.1	\$419.5	\$390.2	\$371.5	\$384.8	\$405.1	\$423.9	\$444.4	\$465.2	

Note: In FY2017, VTC-SOM was operated by Carilion Clinic. However, employment and spending are counted here as part of Virginia Tech

the construction is scheduled to be completed by the end of calendar year 2019, the positive economic impacts dissipate quickly thereafter. Results indicate that VTC makes a combined economic

contribution to the state that grows from 1,699 in employment for FY2017 to 3,147 in FY2026. The effect on economic output of the state is projected to grow from \$214 million in FY2017 to \$465 million in FY2026. Over the same period, the effect on state gross domestic product is projected to grow from \$123 million to \$274 million. During the height of building activity in FY2019, capital spending is estimated to generate 612 in total employment for the state (including direct employment on the construction site as well as spin-off jobs elsewhere in Virginia), \$91 million in output, and \$55 million in GDP.

This economic impact analysis does not incorporate economic activity connected to university startup activity. A larger VTC and increased research expenditures are expected to stimulate additional innovation and research commercialization activities. Six companies have been started by VTCRI faculty to date. Two startups resulted from research and commercialization work by VTCRI faculty before they arrived in Roanoke. Four additional companies have been created by

Table 3. VTC Related Startups Located in Virginia, 2010-2016

Firm	Year	Product	Location	Estimated Employment
BEAM Diagnostics, Inc.	2011	Diagnostic Kit	Roanoke	3
Acomhal Research	2012	Pharmaceuticals	Roanoke	1
C9/3D Therapeutics	2016	Pharmaceuticals	Roanoke	1
Computational Psychiatry, Inc.	2015	Pharmaceuticals	Roanoke	1

Source: VTC

faculty since 2010, including BEAM Diagnostics, Inc., Acomhal Research, C9/3D Therapeutics, and Computational Psychiatry, Inc. that are based in the city of Roanoke. (See **Table 3**) University startups are projected to expand in tandem with the increased size and scope of research activities to 10 startups in 2025, and 25 startups in 2035 based on estimates provided by VTC leadership.

The economic impact analysis also does not measure the impact of business-industry collaboration on the growth of other private state businesses. VTC collaboration with business and industry helps to expand the knowledge base and translational research capabilities of university staff and also results in technology transfer to private industry. VTC faculty have established partnerships with over a dozen firms including several firms with Virginia operations such as Luna Innovations (Roanoke City), Insightec (Haifa, Israel), Indivior, Inc. (Richmond City), Altria (Richmond City), Teva Pharmaceuticals (Bedford County), and ImmuneArray (Richmond City).

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APPENDIX A. METHODOLOGY AND DATA

The Regional Economic Models, Inc. Policy Insight Plus (REMI PI+) model is a dynamic, multi-sector regional economic simulation model used for economic forecasting and measuring the impact of public policy changes on economic activity, area demographics, and government fiscal conditions. REMI PI+ is a conjoined model that utilizes different economic modeling approaches, including input-output analysis, econometric forecasting, and computable general equilibrium (Treyz, Rickman, and Shao 1991). The model used in this analysis includes 70 industry sectors and was customized for the state of Virginia. REMI PI+ and earlier versions of the software have been used in thousands of national and regional economic studies, including studies of university health centers (McMillen and Shaw 2007).

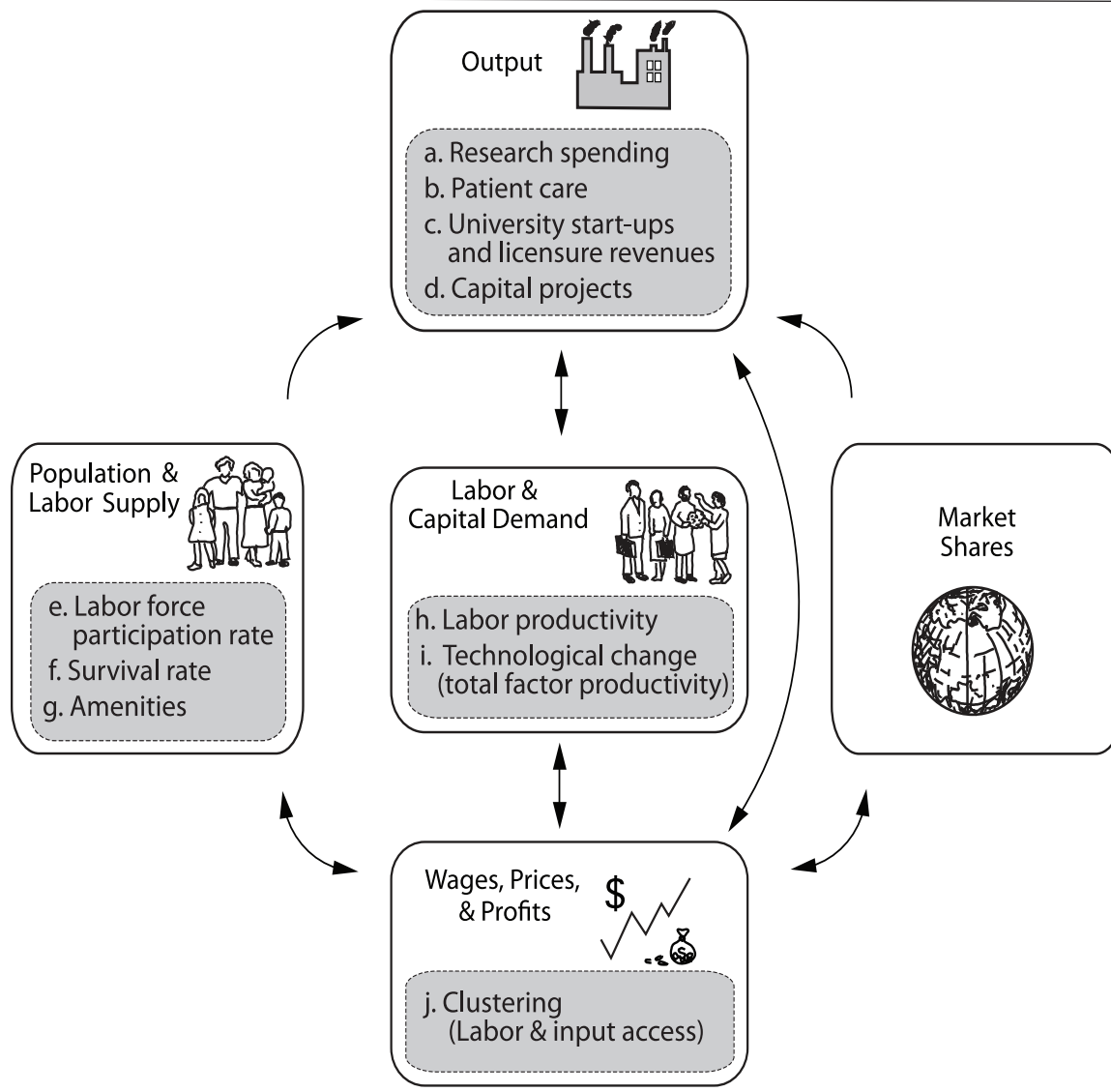
The REMI model is made up of five major modules or blocks (see Figure A.1), which interact simultaneously. The Output Block determines expenditures for final demand, including consumption, investment, government and imports as well as demand for intermediate inputs. Final demand responds to changes in other model blocks. This module contains a key engine in the model, an input-output model based on the Bureau of Economic Analysis (BEA) benchmark transactions table that measures flows of goods and services among industries. The Labor and Capital Demand Block determines employment, capital and fuel demand as well as labor productivity. The Population and Labor Force Block models the population characteristics of the region, including age, race and sex composition. Labor force participation adjusts in response to changes in wages and employment opportunities. A key driver of population changes is migration, which is influenced by relative wage levels as well as amenities. The Wage, Price and Costs Block determines factor and product price. The Market Shares Block helps to measure exports from and imports to the region. Changes in market share are driven by production costs, demand characteristics, distance to markets and output.

Figure A.1 shows how the mechanisms of economic impact described in the previous section relate to the modules in the REMI model. This study will consider only those selected linkages that affect the Output block and, in some instance, only selected expenditures within those linkages. These items are more readily quantifiable than many of the others and include expenditures resulting from the (a) attraction of research funds, (b) outpatient clinical patient care, and the (c) employment of Virginia workers by university startups.

Because of the absence of many expenditure estimates, the economic contribution estimates provided in this study should be regarded as conservative. For example, the research expenditure estimates shows only the expected investments (e.g., recruitment costs, startup packages, endowments, ongoing support) for the new FTEs and their research groups who will be recruited into the new research building. It does not show expected research expenditures that will be derived from the extramural grants of these teams. Furthermore, the analysis does not utilize capital expenditure information for the years FY21-FY26, which is still in the process of being developed.

More importantly, the analysis also leaves out several other sources of economic stimuli. For example, it does not measure the improved productivity and earnings of graduates who choose to remain in Virginia. It does not measure the economic effects of university startups, startup equity and licensing revenues that accrue to the university and faculty researchers. It also does not examine economic benefits or impacts of improved patient health and longevity or productivity increases attributable to technological breakthroughs.

Figure A.1 Modular Structure of the REMI PI+ Model with VTC Economic Impact Mechanisms



Input data for the REMI model was derived from VTC records and used as describe below:

*** Employment, Compensation, and Intermediate Purchases.** Virginia Tech and Carilion Clinic provided current tabulations of physicians, faculty and staff, post-docs, and students employed at the Riverside Campus and employee compensation. Projections of employment and compensation for future expansion years were also provided. University employment was assigned to the educational services industry employment (exogenous production) policy variable in REMI PI+ while Carilion Clinic employment was assigned to the private hospitals employment policy variable. Since the employee compensation for VTC activities (educational services and hospitals) were substantially above the state industry averages assumed in the REMI model, the REMI PI+ policy variable compensation variable was adjusted (compensation with exogenous

employment) to increase the compensation for the economic impact simulation. The university compensation increment over the expected value based on the educational services industry average was assigned to the REMI PI+ compensation policy variable. The same adjustment was done for Carilion Clinic compensation for the hospitals compensation policy variable. Intermediate inputs and investment were nullified within the employment simulation for VTC. Instead, procurement of goods and services based on actual expense data were entered as industry sales for the relevant industries (e.g., utilities, wholesale trade, telecommunications). Only the wholesale margin portions (assumed to be 18.3%) of goods purchases were entered as sales.

*** Capital Expenditures.** Estimated capital expenditures for the new building at the Riverside campus were obtained from Virginia Tech. Construction expenditure was subdivided into construction and furniture and equipment. Construction expenditures were entered as “industry sales” in REMI for the health care structures construction sector. Spending on furniture and equipment were also entered into the model, but only after accounting for wholesale margins. That is to say, it was assumed that the furniture and equipment were purchased through state-based wholesale vendors but that the actual capital items were manufactured and shipped from outside the state. These wholesale margins were assumed to be 31.6 percent of the sales total based on wholesale margins obtained from the U.S. Census Bureau wholesale trade report for furniture in 2015. The computed wholesale margins were assigned as wholesale trade industry sales in REMI PI+.