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Quantifying Macroeconomic Resilience Dividends in Cedar Rapids

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Abstract: Cedar Rapids, Iowa offers a unique case study in planning for increased resilience. In 2008, Cedar Rapids experienced severe flooding. Rather than simply rebuilding, the city of Cedar Rapids began to invest in a resilient flood control system and in the revitalization of its downtown neighborhood. This paper develops a Computable General Equilibrium (CGE) model for the regional economy of Cedar Rapids to quantify the net co-benefits of investing in increased resilience, or the "resilience dividend." The resilience dividend includes benefits to the community *even if another disaster does not occur*. The CGE approach to quantifying the resilience dividend can capture how co-benefits are distributed throughout the economy. Our CGE model combines a broad range of data sets, including firm-level employment and wages and property tax assessments, as well as the US Census' Public Use Microdata Sample (PUMS) and US Input-Output tables. We build a CGE model of Cedar Rapids at two different time periods: one in 2007, before the flooding, and one in 2015, after the flooding and initial investment in resilience. We show that a positive productivity shock to the economy results in larger co-benefits for employment and output growth in 2015 than in 2007. The two models demonstrate how economies that invest in increased resilience respond relative to those that do not.

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1. Introduction

Cedar Rapids, Iowa offers a unique case study in planning for increased resilience. In 2008, Cedar Rapids experienced severe flooding. Rather than simply rebuilding, the city of Cedar Rapids began to invest in both flood mitigation and in the revitalization of its downtown neighborhood. In addition to investments into a resilient flood-control system—a 20-year project that includes levees, removable walls, and new pump stations[1]—the city of Cedar Rapids has also invested in the revitalization of the downtown area in order to have a more dynamic local economy that can absorb shocks, such as extreme flooding, more easily. In addition to making Cedar Rapids more resilient to natural disasters, revitalization of the downtown area also provides benefits for the local economy and social systems in the absence of a natural disaster.

A natural question is whether these investments can produce "co-benefits," such as property value appreciation and business growth. Fung and Helgeson (2017) define the *resilience dividend* as the net co-benefits from investing in increased resilience in the absence of a natural disaster. The resilience dividend encompasses a broader set of potential benefits that can alter how decision makers view return on investment. A positive resilience dividend can help decision makers make a "business case" for resilience. Accounting for co-benefits of resilience planning allows long-term investments to be weighed against day-to-day benefits to the local economy.

This paper presents a Computable General Equilibrium (CGE) model approach to quantifying the resilience dividend. The CGE approach to quantifying the resilience dividend can show at a high level how co-benefits are distributed throughout an economy. The CGE approach is applied to modeling the regional economy of Cedar Rapids. To quantify the resilience dividend from investing in increased resilience, we build a CGE model of Cedar Rapids at two different time periods: one in 2007, before the flooding, and one in 2015, after the flooding and initial investment in resilience. After simulating an increase in productivity in each time period, we find that the increase in employment and output is an order of magnitude larger in 2015 than in 2007. The additional co-benefits in 2015, which are obtained *in the absence of a disaster*, comprise the resilience dividend.

In Section 2, we provide background on the resilience dividend and on our case study, Cedar Rapids. Section 3 provides an overview of the CGE approach to quantifying the resilience dividend, while Section 4 discusses the data we use to build our CGE model. Section 5 presents the CGE model of Cedar Rapids and Section 6 presents the simulation results. Finally, we discuss future directions in Section 7.

2. Background: The resilience dividend in Cedar Rapids

2.1. Background on the resilience dividend

The concept of the resilience dividend was popularized in Rodin (2014), which presents qualitative examples from the real world to illustrate the concept. A series of World Bank reports presented the resilience dividend as arising from a "Triple Dividend of Resilience" largely relevant to disaster risk management (DRM); see Tanner et al. (2016) and Mechler et al. (2016).[2] Bond et al. (2017) describe a

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[1] See http://www.cedar-rapids.org/local_government/departments_g_-_v/public_works/cedar_river_flood_control_system.php for an overview and progress report.

[2] The triple dividend consists of: 1. avoided or reduced losses, in the event of a disruptive event occurring; 2. increased economic resilience from reduced disaster risk; and 3. co-benefits for development.

Resilience Dividend Valuation Model (RDVM) and present six case studies in the developing-country context to illustrate.[3]

Fung and Helgeson (2017) note that much of the research to date on co-benefits focuses on climate change mitigation and adaptation. Moreover, co-benefits of resilience planning are typically considered in a developing-country context. Finally, quantification of co-benefits is very limited. This is understandable, as it is difficult to determine the full range of co-benefits *ex ante*, as in a Benefit-Cost Analysis (BCA), and to fully track co-benefits flowing throughout an economy *ex post*, as in a CGE model. Nevertheless, the CGE approach can provide a broad picture of how co-benefits are *distributed* throughout an economy.

2.2. The 2008 floods in Cedar Rapids

The Cedar River in Cedar Rapids, which runs roughly from the northwest of the city to its southeast, crested at 31.12 feet on June 12, 2008, exceeding the 500-year floodplain area (FEMA P-765). The city experienced a total of $5.4 billion in damages and economic losses (FEMA P-765). The flooding affected an estimated 10 square miles (2589 hectares, or 14% of the city), including 1126 city blocks, nearly 5400 homes, over 800 commercial and government buildings, and displaced an estimated 18,000 people.[4] The areas near the river experienced the worst impacts, including the downtown area on the east side of river and a largely residential area along the west side of the river.

In the aftermath of the 2008 flood, the city developed the *Framework for Reinvestment and Revitalization*, outlining a vision for Cedar Rapids as a "vibrant urban hometown – a beacon for people and businesses invested in building a greater community for the next generation."[5] At the core of the *Framework* was an extensive Flood Management System, envisioned to protect a stretch of 7.5 miles along the Cedar River[6] and projected to take 20 years to complete, at an estimated cost of $375 million. Nearly ten years after the flood, the cost was estimated to be $550 million.[7] The key components of the Flood Management System include levees, permanent and removable walls, gates, and pump stations. The city also engaged in a land acquisition program, funded by federal grants, to protect land prone to flooding, largely on the west side of the river (Tate, et al. 2016).

In addition, the Framework emphasized "the creation of Sustainable Neighborhoods," resulting in a Neighborhood Reinvestment Plan approved by the City Council on May 13, 2009. The Neighborhood Reinvestment Plan emphasized neighborhood revitalization as another key component in addition to the flood-control infrastructure.[8] The revitalization focused on ten neighborhoods, including Downtown Cedar Rapids, as well as the adjacent New Bohemia (NewBo) neighborhood and the historic Czech Village neighborhood across the river. Today, Downtown Cedar Rapids, NewBo, and Czech Village have become vibrant neighborhoods, attracting young professionals, entrepreneurs, and artists.

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[3] Note that Bond et al. (2017) define the resilience dividend as "the difference in net benefits from a project developed with a resilience lens versus one that is not," which is much broader than the definition used in this paper (Fung and Helgeson 2017).
[4] See the City of Cedar Rapids, Flood of 2008 Facts and Statistics: http://www.cedar-rapids.org/discover_cedar_rapids/flood_of_2008/2008_flood_facts.php.
[5] See City of Cedar Rapids, Flood Recover Planning: http://www.cedar-rapids.org/local_government/departments_a_-_f/community_development/flood_recovery_planning.php.
[6] See City of Cedar Rapids, Flood Management System: http://www.cedar-rapids.org/discover_cedar_rapids/flood_of_2008/flood_management_system.php.
[7] See The Gazette, July 5, 2018: https://www.thegazette.com/subject/news/government/cedar-rapids-flood-protection-funding-approved-army-corp-joni-ernst-iowa-2008-flood-20180706
[8] See City of Cedar Rapids, Neighborhood Reinvestment Action Plans: http://www.cedar-rapids.org/local_government/departments_a_-_f/community_development/neighborhood_reinvestment_action_plans.php.

Figure 1 presents a map of the city of Cedar Rapids, highlighting the three neighborhoods of Downtown Cedar Rapids, NewBo, and Czech Village, which have been particular targets for commercial and residential development to attract a younger, more dynamic work force. Due to their size relative to the whole economy, the CGE model combines Downtown Cedar Rapids, NewBo, and Czech Village into a single spatial unit. For simplicity, the combined spatial unit is called "Downtown."

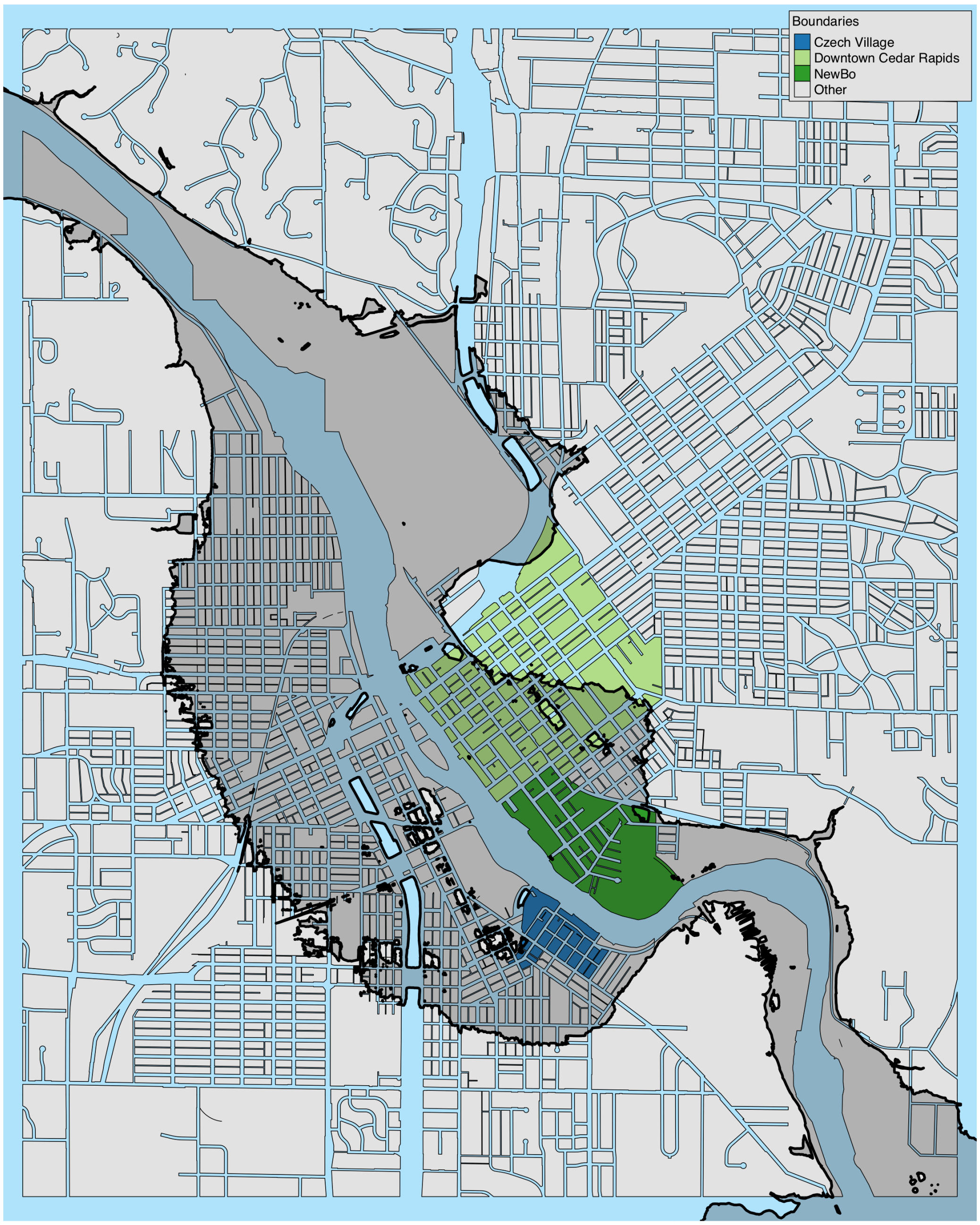

Figure 1. Detail of the "Downtown" area neighborhoods and extent of the 2008 flood (dark grey shading with black boundary). Map created using city of Cedar Rapids shapefiles.

It should be noted that 2008 ushered in another major catastrophe, one that affected the entire country. The Great Recession, which is officially recognized as beginning on December 2007 and ending on June 2009, saw large declines in Gross Domestic Product (GDP), home prices, and stock markets, while the national unemployment rate rose to 10 percent by October 2009.[9] Such added downward pressure on the local economy makes the path Cedar Rapids took seem even more impressive. While it is impossible to disentangle the effects of the recession from the effects of the flood, the impacts of reinvestment are expected to move in the opposite direction. Thus, they may be understated in our results.

3. The CGE approach to quantifying the resilience dividend

3.1. The CGE approach in this paper

This paper uses a comparative-static spatial CGE modeling approach. Comparative-static approaches compare two alternative equilibria in order to assess the impact of shocks to the economy.[10] The process of adjustment from the old (status quo) equilibrium to the new equilibrium is not explicitly represented in such a model, as the temporal element of a CGE model is not well defined.[11] Nevertheless, the difference between the status quo and the new equilibrium is attributed solely to the shock and thus, impacts of the shock are quantified through changes to prices and quantities.

Spatial CGE (SCGE) models allow for a geographic distribution of the impacts from shocks to an economy. Thus, SCGE models are a natural fit for exploring the distributive effects (in particular, the resilience dividend) of resilience planning associate with large-scale shocks across a community.

This paper uses annual economic data to build *two* SCGE models of Cedar Rapids: one based on the 2007 data and the other based on the 2015 data. Each model represents a status quo (pre-shock) equilibrium. In other words, the two models are "snapshots" of the pre-2008 economy and of the post-2008 economy, respectively. The snapshots may be thought of as alternative states of the world, providing plausible counterfactuals for quantifying the resilience dividend. In particular, if each snapshot responds to the same shock in different ways, the differences can be attributed to investments in resilience. In Sec. 6, we consider a shock that increases total factor productivity in each economy.

3.2. Limitations of the CGE approach to quantifying resilience dividend

The ultimate goal of the proposed SCGE modeling method is to quantify the resilience dividend. A CGE model provides distributional impacts of shocks, policy changes, and the current status of the region. Distributional impacts allow the analyst to understand not only the overarching net impacts, but to whom and where those impacts fall and are distributed. Large economic effects will be easily discerned, and the impacts can be selected to see how different scenarios may have played out in the region. Any effects of resilience actions that have co-benefits can be modeled to identify how those co-benefits manifest themselves throughout the economy. Thus, the resilience dividend can be quantified as a grand total, as well as determining who gets these benefits and where they go spatially. On the other hand, CGE models may not capture the entirety of the resilience dividend in many cases. Non-market benefits that never

[9] Federal Reserve History, The Great Recession: https://www.federalreservehistory.org/essays/great_recession_of_200709.

[10] In contrast, dynamic CGE models explicitly trace each model variable through time in order to capture the path to equilibrium (Pereira and Shoven 1988). Helgeson et al. (2017) discuss the potential difficulties with this approach.

[11] However, it is possible to distinguish between short-run and long-run equilibria (e.g., looking at whether capital stocks are allowed to adjust in a given run of the model).

actually materialize as real cash flows are not necessarily captured. Minor impacts may also be lost as the overall economic conditions may overwhelm them.

4. Data for the CGE approach

The primary objective of CGE data collection is to develop a social accounting matrix (SAM). A SAM quantifies all cash flows between pertinent actors within an economy (Hirway, Saluja and Yadav 2008). Once the SAM is constructed, it must be "balanced:" payments made by each component of the SAM should exactly equal payments received by each component of the SAM. A balanced SAM is the main input to the CGE model and represents the status quo for the economy.

The model is "calibrated" when the CGE model equations solve for an equilibrium (set of prices and quantities that clear markets) that exactly reproduces the status quo. Once the CGE model is calibrated, it is ready for simulated shocks. Shocks are applied to exogenous parameters of the CGE model (e.g., total factor productivity) and a new equilibrium is found. Comparative-static analysis compares the "status quo" equilibrium and the new equilibrium.

The following primary data sources are used to build the Cedar Rapids SAMs, based on the method for constructing a spatial SAM and CGE model developed in Cutler et al. (2017).

4.1. Quarterly Census of Employment and Wages (QCEW) data

We obtained establishment-level Quarterly Census of Employment and Wages (QCEW) data from 2006 to 2016 for Linn County, IA, of which Cedar Rapids is the county seat. The QCEW reports the quarterly count of employment and wages for establishments and includes the establishment's industry, defined by its North American Industry and Classification System (NAICS) code, and street address. This data is an excellent source to determine wage payments, employment, and number of firms by industry.[12] The advantage of establishment-level data is that we can customize how the data is aggregated into productive sectors, as discussed in Section 4.7. Moreover, since many of the records in the QCEW data contain street addresses for the establishments, we break sectors out spatially (e.g., "Downtown" versus "Other") as discussed in Section 4.6.

4.2. Public Use Microdata Sample (PUMS) data

Public Use Microdata Sample (PUMS) data allows us to determine the distribution of workers and wage payments by sector, household, and labor group, where households and labor groups are defined by household income and earnings, respectively. PUMS data is collected by the U.S. Census Bureau and reported at various intervals. PUMS relies on the use of American Community Survey (ACS) data. Unlike the decennial census, ACS surveys are conducted annually. Roughly one in thirty-eight households are invited to take the survey every year.[13] The data collected in the ACS is very similar to the data collected during the decennial census. The household income distribution can be obtained from this data set.

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[12] Because the data contains commercially identifiable information (CII) and, potentially, personally identifiable information (PII), such QCEW data is not publicly available. The QCEW data we obtained is collected by the Iowa Division of Labor for the BLS.

[13] See U.S. Census Bureau, "American Community Survey: how it works for your community." https://www.census.gov/content/dam/Census/programs-surveys/acs/about/2017%20How%20the%20ACS%20Works%20for%20Your%20Community_508.pdf.

We use PUMS data for the Linn County-Cedar Rapids Public Use Microdata Area (PUMA).[14] The Linn County-Cedar Rapids PUMA coincides with Linn County, and includes the city of Cedar Rapids as well as cities such as Hiawatha and Marion whose economies are intertwined with Cedar Rapids. Sectors are aggregated using NAICS codes. As noted below in Section 4.8, the NAICS codes for QCEW and PUMS data do not map one-to-one, so an intermediate step is necessary to map each NAICS code to one of our custom-defined sectors.

4.3. County and City Assessor data

We collected data from both the Linn County Assessor and the City of Cedar Rapids Assessor for 2006 to 2016. The tax assessment data includes parcel-level assessed values for land and improvements (i.e., the value of a building), which in turn are used to estimate land and capital values, respectively, in the SAM. In addition, by estimating household expenditures on housing services, such as rent and interest paid on mortgages,[15] we can estimate the value of housing services in the economy from assessments. Finally, the assessor data includes street addresses for each parcel. We can geocode the parcels in order to match capital and land values for non-residential buildings to the establishment-level QCEW data, as discussed further in Section 4.6.

4.4. City Budgets and the Comprehensive Annual Financial Report (CAFR)

A Comprehensive Annual Financial Report (CAFR) contains details of the financial state of a given governmental entity such as a state or municipality. CAFRs for the city of Cedar Rapids are publicly available online by fiscal year.[16] The CAFRs are useful resources for the determination of local government tax revenue, expenditures, and employment. The Cedar Rapids CAFR provides the information necessary to decompose employment and expenditures into constituent government "industries" (e.g., education, public health, and public safety). This information is critical to properly size and disaggregate the government sector within the CGE model.

4.5. Bureau of Economic Analysis (BEA) data

Bureau of Economic Analysis (BEA) data is vital in building the SAM. The BEA provides the Input-Output Accounts data needed to determine Input-Output (I-O) coefficients for the SAM and the values required to develop the relationship between investment and the stock of capital.[17]

The I-O data is generally taken at the national level and, in its raw form, gives the raw dollar amounts of input from each industry and the total output from each industry. These values can be used to determine I-O coefficients, which represent how much input each industry requires from every other industry in order to produce a dollar's worth of output. I-O coefficients define the flow of money between industries, and thus the linkages between industries necessary for the CGE model to determine how impacts on one industry flow to another.

The data for the investment capital linkage (CAPCOM) matrix comes from the BEA "Capital Flow" data. This data tracks the investment in new structures, equipment, and software by using industries. In essence, it measures how many commodities a specific industry purchases for investment from another

[14] PUMAs are "statistical geographic areas defined for the dissemination of Public Use Microdata Sample (PUMS) data" (https://www.census.gov/geo/reference/puma.html).
[15] We use the BLS Consumer Expenditure Survey category "Shelter" for these expenditures. See https://www.bls.gov/cex/csxgloss.htm#housing for more details.
[16] See http://www.cedar-rapids.org/local_government/departments_a_-_f/finance/cafr.php.
[17] See https://www.bea.gov/industry/input-output-accounts-data for more information.

industry. Like the I-O data, the CAPCOM tracks the interdependencies between industries; however, it focuses on new investments instead of required input. The raw data is taken from the I-O commodity categories (as opposed to the National Income and Product Account categories), which are in terms of producers' prices.

Other BEA data used for our model include estimates of employment and income, which are available at the county level. The BEA series "Personal Income and Employment by Major Component" provide estimates of income, population, and employment. Personal income is broken down by source (e.g., wages and salaries, contributions to government social insurance), while employment is broken down by wage earners and proprietors. The BEA series "Total Full-time and Part-time Employment by NAICS Industry" breaks employment down further by high-level (i.e., two-digit) NAICS code. These data sets offer a high-level, order of magnitude check on the PUMS and QCEW data on employment and wages.

4.6. Geographic data

We obtained parcel-level and boundary geographic information systems (GIS) data for the city of Cedar Rapids.[18] We use this data to visually assign parcels to the downtown neighborhoods of interest (Downtown Cedar Rapids, NewBo, and Czech Village). Any parcels outside of this area are assigned to the rest of the economy and we label them as "Other." Once we define the neighborhoods spatially, we can match the geocoded QCEW and assessor data to the neighborhoods in order determine which neighborhood an establishment or parcel belongs to.

4.7. Informal data from community leadership and agencies

The community itself proved to be an invaluable source of information. Conversations with the City Manager's Office, Cedar Rapids Economic Development, and Go Cedar Rapids (the tourism office) illuminated priorities with respect to both the immediate response to the 2008 floods, as well as short- and long-term recovery efforts and community goals. In particular, while we initially focused on the land acquisition program, conversations with local officials quickly revealed that revitalizing the downtown area was a key component of rebuilding after the 2008 floods.

Conversations with community officials also provided perspective on local economic trends and goals, both irrespective of the potential disaster and specific to the disaster occurrence. This informed how we defined the productive sectors for the model, by allowing us to focus on sectors the community itself identified as important. This was particularly helpful in identifying the sectors that are important in the Downtown area, as discussed in Section 5.1.

4.8. Combining the various data sets

The use of such varied sources of data can create challenges when combining them for the SAM (Helgeson, et al. 2017). One example of this complication is attempting to derive the I-O and CAPCOM data at the PUMS sector. The BEA and PUMS data sets are both based on NAICS codes; however, they aggregate those NAICS codes into larger industry categories that do not match one-to-one with each other. If industries are defined coarsely, this is not necessarily an issue. If the manufacturing industry data is disaggregated, as in our model, then there is no guarantee that each PUMS industry code will have a corresponding BEA code, or codes, that match in terms of NAICS codes covered. In this case, a fuzzy

[18] See City of Cedar Rapids GIS Division: http://www.cedar-rapids.org/local_government/departments_g_-_v/information_technology/available_gis_data.php.

match is required which will possibly lead to a NAICS code from a sector not in a specific PUMS industry code being in the I-O table for that PUMS industry code due to the inconsistency.

5. Modeling the Cedar Rapids economy

Cedar Rapids is the largest city in, and the county seat of, Linn County, Iowa. Cedar Rapids is an integral part of a regional economy that includes the neighboring cities of Marion, Hiawatha, Mount Vernon, and Robins, which together comprise the five most populous cities in Linn County. Given the close economic relationships between Cedar Rapids and the other cities in Linn County, this paper models the regional economy of Cedar Rapids as encompassing Linn County.

5.1. Important sectors

Figure 1 presents the largest employers in the city of Cedar Rapids in 2015, and their relative share of county employment for both 2007 and 2015. Note that two hospitals (St. Luke's and Mercy), the Cedar Rapids Community School District, and the city itself, are some of the largest employers in the city.

Employer	2007		2015	
	Employees	Percentage of Total County Employment	Employees	Percentage of Total County Employment
Rockwell Collins Inc.	9000	5.41%	8700	4.95%
Transmerica / Aegon	3500	2.10%	3800	2.16%
St. Luke's Hospital	2800	1.68%	2979	1.69%
Cedar Rapids Community School District	2900	1.74%	2879	1.64%
Nordstrom Direct	2862	1.79%	2150	1.22%
Mercy Medical Center	2498	1.50%	2140	1.22%
City of Cedar Rapids	1493	0.90%	1309	0.74%
Four Oaks			1100	0.63%
Quaker Foods and Snacks	1100	0.66%	1018	0.58%

Table 1. Principal employers in Cedar Rapids. Source: Cedar Rapids CAFRs, FY2015 and FY2007.

The city itself identified five "target industries" in developing a strategic economic development plan in 2014:[19]

- Life Sciences
- Logistics and Distribution
- Food Sciences and Processing
- Entrepreneurial Business Services, and
- Finance, Insurance, and Real Estate.

Based on the city's self-identified target industries, as well as on the industries that are important to the downtown area of Cedar Rapids, we defined the Cedar Rapids regional economy's productive sectors as shown in Table 1 and Table 2.[20] The corresponding two-digit NAICS codes and high-level NACIS industry names are also shown. The data used for the CGE model includes 6-digit NAICS codes, which

[19] See City of Cedar Rapids, Economic Development: http://www.cedar-rapids.org/local_government/departments_a_-_f/community_development/economic_development_services.phd
[20] Some of these industries were emphasized during conversations with City officials. See Sec. 4.8.

provide a much finer level of industry detail. As discussed in Section 4, we define these sectors by aggregating establishment-level employment and wage data.

Table 2. Sectors chosen for the Cedar Rapids CGE models that are not present in downtown Cedar Rapids.

Sector name	NAICS code	NAICS industry title
Electronics manufacturing	33	Manufacturing
Food processing	31	Manufacturing
Paper manufacturing	32	Manufacturing
All other manufacturing	31-33	Manufacturing
Construction	23	Construction
Transportation	48-49	Transportation and Warehousing
Online services	45 49	Retail Trade Transportation and Warehousing
Education	61	Educational Services
Health care	62	Health Care and Social Assistance
Wholesale trade	42	Wholesale Trade
Information	51	Information
Agriculture and mining	11 21	Agriculture, Forestry, Fishing and Hunting Mining
Utilities	22	Utilities

Note that manufacturing is broken down into four separate sectors: Electronics, Food, Paper, and All other manufacturing. Another key sector, Online services, includes retail and logistics, reflecting the importance of online retailers (e.g., Nordstrom Direct in Fig. 1). Non retail-oriented logistics are included in the Transportation sector. Moreover, Agriculture and mining are combined into a single sector due to their relatively small contribution to the local economy.

Table 3. Sectors chosen for the Cedar Rapids CGE models that are present within and outside downtown.

Sector name	NAICS code	NAICS industry title
Financial and insurance services	52	Finance and Insurance
Real estate services	53	Real Estate Rental and Leasing
Professional business services	54 55	Professional, Scientific, and Technical Services Management of Companies and Enterprises
Services	56 81	Administrative and Support and Waste Management and Remediation Services Other Services (except Public Administration)
Arts and entertainment	71	Arts, Entertainment, and Recreation
Accommodation	72	Accommodation and Food Services
Restaurants	72	Accommodation and Food Services
Retail	44-45	Retail Trade

The sectors in Table 2 represent the core sectors in found both within downtown Cedar Rapids and throughout the rest of the economy. In the CGE model, these sectors are identified spatially by the location of the firm (i.e., whether or not the firm is located in downtown Cedar Rapids). Professional business services (PBS) covers two distinct NAICS industries and reflects one of the city's self-identified target industries. Finally, Accommodation and Restaurants are separated out of NAICS code 72.

5.2. Summary Statistics: 2007 and 2015 Snapshots

This section presents select aggregate economic statistics that provide a snapshot of the Cedar Rapids regional economy in each of 2007 and 2015. Note that these are status quo outcomes in each model, rather than the results of a shock. In other words, these are "snapshots" of the pre-2008 economy and of the post-2008 economy.

Table 3 presents land and capital values, as well as total acres, for 2007 and 2015. Growth in the combined Downtown area was more pronounced: total capital values grew approximately 144% in the Downtown, while capital values in the rest of the economy grew 83%. Land values, on the other hand, only grew about 4.05% in the Downtown area. In contrast, growth in land values for the rest of the economy was about 37%.

Table 4. Land and capital values (in millions of dollars) and total acres for the Downtown area (Downtown Cedar Rapids, NewBo, and Czech Village) and the rest of the regional economy by year, based on County Assessor data for Linn County, IA.

District	Year	Land	Capital	Acres (Hectares)
Downtown	2007	42.74	384.58	197.67 (80.00)
Downtown	2015	44.78	824.64	477.27 (193.15)
Other	2007	2,739.99	10,345.41	370,559.25 (149,960.01)
Other	2015	3,755.79	18,948.89	498,265.87 (201,641.04)

During this period, the Downtown area grew in size by a factor of about 2.5, while the area of the rest of the economy only grew about 34%. Together with growth in capital, the growth in acreage reflects significant investment in developing Downtown relative to the rest of the economy.

Table 4 presents total employment and wages paid per worker for each year. While total employment in the Downtown area only grew by about 2.1% (compared to about 5.4% in the rest of the economy), wage per worker grew by 26.5% Downtown (compared to about 22.7% in the rest of the economy). Thus, while employment growth Downtown does not reflect the trend in capital and land area, wage per worker does appear to be growing slightly faster in Downtown.

Table 5. Employment (number of workers) and annual wage per worker (in dollars) for the Downtown area (Downtown Cedar Rapids, NewBo, and Czech Village) and the rest of the regional economy by year, based on the Quarterly Census of Employment and Wages (QCEW) for the state of Iowa.

District	Year	Employment	Wage per worker
Downtown	2007	5,801	11,244.89
Downtown	2015	5,924	14,230.58
Other	2007	115,080	10,556.87
Other	2015	121,296	12,951.05

6. Main results

6.1. Description of shocks

As a first step toward quantifying the resilience dividend, we compare how pre-2008 and post-2008 Cedar Rapids respond to a similar, non-disaster shock. A differential response to the same shock can be largely attributed to investing in resilience, including revitalization of downtown. We consider a positive shock to the economy: total factor productivity (TFP) increases by 2%. The intuition for the shock is that the economy uniformly becomes more productive (e.g., due to new advances in technology). In this scenario, which economy is better situated to reap the benefits of increased productivity?

6.2. Impacts of TFP shocks on output and employment

This section presents the impacts of the TFP shock on two important macroeconomic indicators: output and employment. The results show that post-2008 Cedar Rapids experienced greater benefits from the TFP shock than pre-2008 Cedar Rapids.

The columns in Table 6 present output, defined as domestic supply, in 2007 and 2015 Cedar Rapids. The rows present output before and after the TFP shock, as well as the change in output from the shock. As shown in Table 6, grew 5.1% in 2015 Cedar Rapids, compared with 1.7% growth in 2007 Cedar Rapids. This amounts to 3.4% greater output growth from the TFP shock in 2015 than in 2007. The additional growth in 2015 is a co-benefit of investing in increased resilience and is thus part of the resilience dividend. To put the impact on output in context, recall that the resilient flood-control system is estimated to cost $550 million over ten years, while the growth in domestic supply alone is $648 million, which does not include other co-benefits to the economy such as employment growth.

Table 6. Output (domestic supply) in 2007 and 2015, both before (pre-shock) and after (post-shock) a TFP increase of 2%. The TFP shock leads to proportionately larger output growth in 2015. Output values are in millions of dollars.

	2007	**2015**
Pre-shock	9783.05	12037.12
Post-shock	9956.99	12685.63
Difference	173.94	648.51
Percent change	1.7%	5.1%
Resilience dividend		**3.4%**

Table 7 presents a similar picture for employment. While TFP leads to 0.61% growth in 2007 employment, 2015 employment growth is about twice as large at 1.2%. This amounts to 0.59% greater employment growth from the TFP shock in 2015 than in 2007, another co-benefit of investing in increased resilience.

Table 7. Employment in 2007 and 2015, both before (pre-shock) and after (post-shock) a TFP increase of 2%. The TFP shock leads to proportionately larger employment growth in 2015. Employment values are in total number of workers.

	2007	**2015**
Pre-shock	93903	120843
Post-shock	94483	122348
Difference	580	1505
Percent change	0.61%	1.2%
Resilience dividend		**0.59%**

6.3. Intuition for results

Our CGE results indicate that sector output in Cedar Rapids had a greater response to the TFP shock in 2015 than in 2007. The explanation of the differences lies in the calculation of the sector level estimates for total factor productivity (TFP) *before* the shock. Consider the following general production function:

$$Y_i = \delta_i f(L_{ji}, K_i, LA_i),$$

where Y is output, *i* is the index across commercial sectors, δ_i is the estimate of sector level TFP, L is employment, the index *j* indexes labor groups and K is capital, and LA is land. In the construction of the SAM, sector level output, Y_i, is calculated and we have collected data for L, K and LA. Therefore, we can solve for δ_i as

$$\delta_i = Y_i / f(L_{ji}, K_i, LA_i).$$

The initial values for δ_i have important implications when TFP shocks are simulated. The larger initial value of δ_i implies that a given positive shock to δ_i will result in a larger impact on sector level output. The differential impacts from the same shock reflect the relative difference of the initial δ_i's across the two time periods. Table 6 presents the difference of 2015 and 2007 estimates of δ_i.

Table 8. Differences in the calculated initial values for δ_i (2015 – 2007) by sector.

Sector name	**Difference in δ_i**
Electronics manufacturing	0.310
Food processing	0.324
Paper manufacturing	0.052
Other manufacturing	0.009
Construction	0.433
Transportation	-0.390
Online	0.090
Finance and insurance	1.418
Finance and insurance (Downtown)	1.422
Real estate	-0.144
Real estate (Downtown)	-0.214
Professional business services	0.139
Professional business services (Downtown)	0.210
Education	-0.152
Health	-0.046
Services	-0.114
Services (Downtown)	-0.033
Arts and entertainment	-0.075
Arts and entertainment (Downtown)	-0.012
Accommodation	-0.022
Accommodation (Downtown)	0.075
Restaurants	0.494
Restaurants (Downtown)	0.347
Information	0.323
Wholesale trade	0.165

Retail	0.486
Retail (Downtown)	0.477
AGMIN	-0.074
Utilities	-0.011

The vast majority of sectors experienced an increase in the estimated δ_i from 2007 to 2015. Without a doubt the change in the downtown area was paramount to other changes in Cedar Rapids during this period. As Table 6 indicates, the expansion of the downtown area for finance/insurance, professional business services, restaurants, accommodation, and retail all experienced an increase in δ_i. This is consistent with a denser allocation of commercial sectors in the downtown area and the resulting higher values for δ_i. It is worth pointing out that most of the estimates for δ_i also increased for the sectors located outside of the downtown area. For the same shock to each economy, the higher values for δ_i in 2015 will result in a larger increase in sector level output and total output for the 2015 model.

7. Conclusion and future work

This paper presents a spatial CGE approach to quantifying the resilience dividend. In particular, we build two snapshots of Cedar Rapids (pre-2008 and post-2008) that serve as counterfactuals of an economy with and without investments in increased resilience. By simulating the same shock to each snapshot, we can quantify how impacts differ in Cedar Rapids pre-resilience versus Cedar Rapids post-resilience. In particular, we find that the same increase in total factor productivity leads to an order of magnitude larger increases in employment and output in post-2008 Cedar Rapids than in pre-2008 Cedar Rapids. This difference is the resilience dividend.

In future work, we will consider how pre-2008 and post-2008 Cedar Rapids respond to a wide range of positive and negative shocks to the economy. We also explore how each economy responds to a simulated natural disaster, which captures the *direct* impact of investing in increased resilience.

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