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Impact to New Jersey's Economy of the Loss of Electric Power in New Jersey's Urban Industrial Corridor

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CREATE REPORT

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Electricity Case:
Impact to New Jersey’s Economy of the Loss of Electric Power in New Jersey’s Urban Industrial Corridor

CREATE Report

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Abstract

The economic impacts of potential terrorist attacks on the New Jersey electric power system are examined using two regional economic models. The magnitude and duration of the effects vary by type of business and income measure. The shock is initiated in the summer 2005 quarter. The state economy quickly recovers within a year, if we assume that economic activity is restored in the next time period. However, if the attacks prompt an absolute of loss of activity because of migration or closing, then the economy does not fully recover by the year 2010. The policy implication is that the costs and benefits of making the system more resilient to plausible attacks should be weighed and that the restorative capacity of the system should be strengthened

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Introduction

The purpose of this report is to describe the results of using regional economic models to study the economic impact on New Jersey of a serious outage in electric power delivery. Although causes of such outages are numerous and the consequences are often similar regardless of the cause, the purpose here is to provide a tool to estimate the economic impacts of one particular cause – a potential terrorist attack. We view this analysis as an illustration of what it is possible to do for a larger region, for the entire United States, or for sub-regions. In essence, we look at the multi-faceted implications of no lights, no computers, no air conditioning or refrigeration, no manufacturing, and a dark world for specified lengths of time.

Key Literature

There is a large literature on electric reliability (U.S.-Canada Power System Outage Task Force, 2004a,b, Overdomain 2002, Wacker, Billinton 1989, Corwin, Miles, 1978, Shipley et al. 1972). With regard to this analysis, some key reports guided our work, and they are reviewed in this section. Zimmerman et al. (2005a,b) and Simonoff et al. (2005) conducted primary risk analysis research, and gathered important literature. A key contribution of this report was to categorize electric power system vulnerability to terrorism. Zimmerman et al. (2005a) identify some areas in the U.S. where an "extreme scenario" could occur. In those situations, transmission lines follow only one or two routes, and there are few substations and transformers. Moreover, there is effectively no in-region capacity to produce electric power independently, or such capacity is not resistant to regional failures. A "moderately extreme" case has the same grid limitations as the first scenario, but the impacted area has the capacity to produce energy independently. Even though in-region capacity may exist, it often has to be shut down in order to protect the equipment. The “moderate” scenario involves smaller areas that have independent sources of electricity, which is transmitted from a variety of directions. New Jersey, the study area for this project, falls between a moderately extreme and a moderate vulnerability.

Zimmerman et al. (2005a) identify transformers as particularly troublesome because they are configured in unique ways to specific locations. Damage to one can sometimes take a long time to repair. They add, on the basis of a statistical analysis of 400 events between 1990 and 2002 in the U.S., that the average number of outages a year has been increasing 9 percent a year, and the duration by 14 percent a year primarily because of the dominance of longer weather-caused events. Average event duration was 28.4 hours from 1990 through autumn of 2002, but has increased to 69 hours since then. The medians for these two points in time were 10.4 hours and 63.8 hours, respectively. Summer has 65 percent to 85 percent more outages than do the other seasons. The authors observe that winter events have expected durations that are 2.25 times summer events. That is, there are more summer events than winter events, but the winter events are longer than those in the summer. The frequency of spring and autumn events falls between these extremes.

Zimmerman et al. (2005a) point to mass transit as being highly vulnerable. Power outages to electrified rail or diesel electric motors could shut down train service, signaling systems, fare collection technology, and a variety of other electric-power based systems. Roadway traffic would be impacted because of its dependence on electronic signaling, and extreme congestion would be likely at bridges and tunnels. Gasoline pumping would also be a problem.

Zimmerman et al. (2005a,b) describe three types of losses that result from power outages: premature deaths, business losses, and public service disruption. They apply frameworks for each of these three types of losses to estimating the cost of an outage in the New York area. With regard to the first, the authors use $5.8 million (in 2005 year dollars), adapted from the U.S. EPA estimates, as an indicator of the value of a premature death. For illustrative purposes, this figure was applied to an assumed 150 deaths, which yielded a cost of $870 million.

Business losses are developed as a product of three components: gross domestic product (GDP) per capita, estimated number of people affected, and the estimated duration of an outage for the New York area. GDP per capita was obtained by dividing GDP by the U.S. population, yielding a cost of $112 per person per day. They checked this number by comparing the cost of the blackout of August 2003 that affected much of the eastern United States (using $112 per person per day) to the estimate of $6 to 10 billion from other sources (see ICF below). The estimated cost of the blackout was $112 per person per day for 50 million people or $5.64 billion, not including health-related costs, for a single-day power outage. This estimate was at the lower end of the estimates. The second component of business loss was number of customers affected. This was based on a statistical regression analysis of U.S. outage data from 1990 to 2004. The resulting coefficients were then used to construct scenarios based on expected duration of outages and number of customers affected. These estimates allow for calculations of business losses for outages in different seasons and geographical areas (Zimmerman et al., 2005a,b, Simonoff et al., 2005). For the New York area, this yielded 880,000 customers. Since the number of customers does not equal people affected, three people per customer was assumed for illustrative purposes. Realizing that realistically customers are a mix of industrial, commercial, and residential users, this assumed the average could substantially vary. Duration was similarly estimated from a statistical regression analysis, and the example for the New York area in winter was 19.6 hours. Total business loss using these estimates and assumptions came to $245 million.

Regarding public service disruption, Zimmerman et al. (2005b) used 50 percent of the hourly wage rate as the cost of congestion (presumably an opportunity cost of the employee’s time), commonly used in the literature (U.S. DOT 2003), and applied it to the number of workers in the New York area, the average wage rates nationally, and an assumed extra commuting time over a 24-hour period (estimated to be four hours per person per day). Using these estimates and assumptions, the total costs for a 20 hour outage was $1.2 billion. This estimate does not take into account many indirect effects, costs other than those related to the three factors of loss of life, business losses, and transportation congestion, nor does it include regional or national impacts that occur as a result of the impact on the New York area.

Sabotage or vandalism could greatly affect any estimates of electric power outages. The data base relating to sabotage or vandalism (which is the act most closely related to terrorism) in the United States is limited. Felder (2004a) studied 451 major disturbances in generation, transmission, and distribution reported to the U.S. Department of Energy between 1984 and 1999. Only three percent of the disturbances were attributed to sabotage or vandalism. Globally, where there have been many terrorist attacks against electricity, Zimmerman et al. (2005a) report that, regarding the form of a likely terrorist event, transmission lines and towers constituted 59 percent of incidents between 1994 and 2004 internationally. Nationally, the percentage is over 90 percent. Distribution lines, circuit breakers, transformers, substations, generation facilities, and switches and buses constitute the other terrorist targets. One reason transmission lines and towers account for such a high proportion of incidents is the large number of terrorist attacks against transmission lines and towers in the nation of Colombia in 2002. Disregarding terrorist events, within the U.S. natural hazards are far more likely to hit transmission and distribution lines and towers than other electrical equipment. While transmission lines are more frequently affected than are transformers and cables, longer outages are more likely to follow from damaged equipment that cannot be easily and quickly repaired, such as transformers and cables.

The economic consequences have been estimated for some major power outages. For example, ICF (2003) reported that the economic cost of the 1977 New York City blackout, which lasted 25 hours and initially lost more than 5000 MW, was $4.11 per kWh. The direct contribution of this loss, which includes loss of production, wages, and spoilage, was $0.66/kWh; the indirect contribution was $3.45/kWh. ICF notes that similar ratios of direct to indirect costs were observed during California’s electric power outages. They used similar ratios to estimate the cost of the August 14, 2003, blackout in the Northeast United States. That blackout lost 61,800 MW and affected more than 50 million people at its peak. The authors’ estimated a total economic cost to the nation of between $6.8 billion and $10.3 billion. ICF underscored that terrorist attacks could exact a larger toll because of the damage to equipment, time required to replace and/or repair it, and the psychological “hangover” that would hurt tourism, including substantial losses to airlines, hotels, and other service industries.

This sort of hangover was clearly demonstrated by a study of the impact of the 9/11 terrorist attack on New York’s Chinatown, which is near the site of the former World Trade Center. The Asian American Federation of New York (2002) found that businesses in the garment, restaurant, retail and tourism sectors suffered revenue loses ranging from 60 percent to 100 percent during the first two weeks. Three months after the 9/11 attack, garment factories continued to suffer (40 closed). The majority of businesses reported losses of 30 percent to 70 percent. The retail industry experienced a 55 percent drop in revenues, and jewelry sales declined by 50 percent. Six months after the attack, restaurant business and garment production were still below 2001 levels, and travel agencies reported operating at 20 percent to 60 percent of normal pre-attack levels

Studying the regional economic impact of power outage scenarios requires the researcher to make choices about the size, duration, and other elements of the disruptions. Eto et al. (2001) classified decision variables. The “magnitude” of an event is the extent to which it deviates from normal operation. Prior notification and estimation of downtime can substantially reduce equipment damage and cost. Large deviations often damage equipment and interrupt service, while small deviations may not even be noticed by the consumer. “Duration” is the length of the event. While even a short outage leads to high direct costs, an outage of a week or month can exacerbate indirect costs. “Frequency” is how often an outage occurs. Frequent outages can damage equipment. “Timing” specifies when the event occurs: time of day, day of the week, and season of the year. Each variation changes the cost burden borne by business, consumers, and government. Eto notes that day and work week outages are most likely to damage business; weekend and evening outages have more impact on residences. Winter outages are a threat to residences that can lose their heat, particularly if the event is prolonged. For example, residential customers may have to leave their homes if they are without heat, staying in hotels or doubling up with family or friends. In the summer, they may lose stored food and be forced to eat out, and purchase flashlight and candles. Also, asthmatics, elderly, and other vulnerable individuals, who depend upon air conditioning and other electrical devices, could suffer severe health-related conditions. An important observation made by Eto is that residential users tend to suffer more economic costs from a single long event than from a series of short events that add up to the same time span. That is, a single 8-hour outage is more costly than eight separate one hour events. In strong contrast, industrial and commercial customers are typically more heavily affected by frequent outages than by a single event. “Advance notice” was Eto’s fifth variable. But early warnings of terrorist attacks are rare.

Eto et al. (2001) also classify commercial and industrial costs of power outages. *Production losses* can occur. Some losses can be covered by increasing production at a later time, but they are likely to require higher costs through overtime payments and re-start costs. *Equipment damage* is a serious problem, as is *damage to perishable and hazardous raw materials.* Generating capacity can be extended with back-up systems, but back-up systems impose high costs for equipment, fuel, and personnel. Re-start costs can be substantial, especially for manufacturing industries that operate nonstop. Businesses realize some savings because they are not using raw materials, fuel or electricity. Further, they may not have to pay labor costs during down times, and damaged materials may be salvageable. The Eto et al. (2001) also detail striking cases of indirect impacts for commercial activity. For example, a 15-minute power outage in Vancouver, British Columbia, shut down the Vancouver Stock Exchange for a day because data and data back-ups were corrupted.

Eto et al. (2001) rated industries classified by four-digit SIC code with regard to their vulnerability to electricity loss. Some of these are major economic nodes in the study area, such as the chemical industry (SIC 28), petroleum refining (SIC 29), and selected food industries (SIC 20). This list underscores the importance of the input-output model, which incorporates the interactions between electricity generation and manufacturing industries.

The Eto et al. report also includes a lengthy presentation about the electricity demands of clean-rooms used in manufacturing, medical operations, and scientific research, whereas computer chip manufacturing is the typical illustration (over half of the use), many other industries use clean-rooms, including the dairy, milk and yogurt industry, pharmaceuticals, in-vitro preparations, biological products, computer and office machines, and many others. The authors note that many businesses that need clean-rooms cannot afford to pay for back-up generation capacity. The study region has a presence of these industries.

Some of the cost from electric power outage may be passed along to insurance companies and their full client base, but few companies are covered for all forms of possible damage from an outage that can cause problems ranging from destruction of product, to destruction of records, to relocation of business, and to worker injury and illness. Insurance records suggest that the number of insurance claims involving electrical equipment tend to peak in June, July, and August. (Eto et al. 2001). The number of claims during the summer months is typically double that of the six month period from October to April. Furthermore, power failures and surges that cause data losses occur most frequently during the summer when electricity usage peaks due to the use of air conditioning.

While a summer attack would have serious ramifications, a case can be made for winter as the worst case. The North American ice storm of 1998 had a major impact, especially in eastern Canada and the northern United States. The total estimated cost was almost $8 billion (Eto et al. 2001). Some of the impacts (roof collapses of homes and businesses) that happened then would not occur as the result of a terrorist attack against the electrical system. But other effects from a winter power outage could be pertinent including destruction of perishable goods, inability to get to work, loss of life or injuries from the event and the recovery, additional living expenses for those who had to relocate, and livestock deaths and other agricultural losses.

CEIDS (2001) examined the costs of outages on three industrial sectors: (1) digital-telecommunications, data storage, and retrieval services, biotechnology, electronic manufacturing, and the financial industry; (2) continuous-process manufacturing – paper, chemicals, petroleum, rubber and plastics, stone, clay and glass, and primary metals; and (3) fabrication and essential services – all other manufacturing plus utilities and transportation. Whereas these three sectors account for 17 percent of all business establishments in the country, they account for 40 percent of GDP.

CEIDS surveyed almost 1,000 businesses. Costs included lost production and sales, material spoilage or loss, labor cost increases, equipment damage, backup generation capacity, restart costs, and overhead. The survey found a clear non-linear increase in costs. An average a one-second outage cost $1,477; a three-minute one cost $2,107, and a one hour outage cost $7,795. The authors emphasized the high cost of equipment damage. Continuous-process manufacturers were the hardest hit. Average annual per-establishment cost of outages for this sector was $61,828 compared to $49,328 for fabrication and essential services; and $10,598 for digital companies. For companies in the digital economy and continuous-process manufacturing sectors, the authors estimated that the annual cost from power outages was about one-third of the annual electric bill. For fabrication and essential services, the annual costs per establishment exceeded the annual electric bill. New Jersey was listed as the state with the ninth highest aggregate annual outage costs. Even the smallest businesses paid for power outages; for example, a small digital companies, such as telecommunications, data storage and retrieval, electronics and financial, incurred costs averaging $17,784.

The Digital Power Group (2003) described the increasing dependence of society on electrical power. Using graphs, they argue that businesses have tended not to provide back-up systems because the frequency of floods, hurricanes, and earthquakes were not well understood. They focused a great deal of attention on preventing spikes in power that caused short-term disruptions. Sabotage, however, is not well understood either and remains a major threat from a policy perspective because equipment is likely to be destroyed causing power outages to last many hours. The organization calls for major public policy attention to this threat.

Taking a step back from the terrorist threat, Felder (2001, 2004b) distinguishes between “adequacy” and “security” in electric power systems. He argues that security requirements are a prescriptive, that is, utilities must be required to provide backup systems. Yet he is concerned that the introduction of competitive electricity markets makes it less likely that existing regulatory approaches will be consistent with market generation needs. Felder calls for the application of probabilistic risk assessment to identify events that would trigger a loss of power.

With regard to methods of analysis, the vast majority of studies rely on extrapolating simple multipliers derived from survey data. An interesting exception was a study by Rose and Liao (2005). As part of a study of the impact of water service disruptions, they argue that input-output models are based on rigid relationships between sectors. They assert that, under stress, systems compensate; that is, if one commodity or service becomes less available, systems show a tendency to seek a substitute or to produce with less. In the case of water, this might mean water conservation by making elements of the production process more efficient in water use, bringing in water from other sources, and relying on back-up supplies. Such tendencies toward resilience clearly would take place in the event of an electric power outage.

Data and Methods

The study area for this pilot project is the State of New Jersey. New Jersey has a population of 8.7 million, and the highest population density of any U.S. state, about 1,200 people per square mile. That population is spread out over 566 municipal governments with no city having more than 280,000 residents. While the density of people and business is highest in the northeast part of the state that is adjacent to New York City, there is no single load center for electricity in New Jersey.

In 1960, New Jersey was one of seven states with over 36 percent of non-agricultural jobs in manufacturing (U.S. Bureau of the Census 1967). In 1969, manufacturing accounted for 31 percent of non-agricultural jobs in the state. But the state lost 58 percent of its manufacturing jobs between 1969 and 2004. Manufacturing now accounts for less than 9 percent of jobs in the state. Only New York State registered a larger relative decrease (Brim and Anderson, 2001).

Building a hypothetical scenario for a terrorist attack on New Jersey's electrical system is an exercise fraught with four immediate uncertainties. First, there are no existing data on terrorist attacks on the electrical system in the United States from which to build a scenario. No one really can know what would happen. Second, although we can construct a very detailed scenario or set of scenarios based on hypothetical kinds of attack, to put such information in a report is inappropriate. Third, small blackouts are frequent, and, frankly, using a sophisticated economic model to examine the impact of small events is the equivalent of hitting a tack with a sledge hammer.

A fourth major obstacle is the absence of very detailed data that would allow us to add nuances to our economic forecasting models. Business revenue losses by detailed industrial categories due strictly to the lack of productive operation during the postulated power outage will be estimated by assuming that national inter-industry relationships prevail in New Jersey. Losses due to the disruption of other life lines as a result of the loss of electric power were not possible to pin down because pertinent critical data do not exist for the study area. However, we do capture some of these losses indirectly. For example, the transportation industry buys electricity to run the trains. When the electric power goes out, the transaction is reduced and hence indirectly we capture loss of transport of people and goods. But, ideally, we would like to have had the time to do field interviews with experts who could provide detailed coefficients about loss of rail commuters and the impact of those losses on the economy. The potential number of work hours lost by auto commuters also requires a special data set. The same is true for business losses that will be incurred from disruptions in the delivery of freight, water service, and the ability to use communications services. In addition certain business will take on losses of perishable inventories of product inputs or of the product itself. All of these are captured implicitly in part in the models because impacts of a loss of electricity effect all the businesses. But an explicit capability to capture these transactions requires field investigations before they can be incorporated into models. Given the time and resources available, it was not feasible to conduct extensive field research, and even with time, some of the data may not be possible to collect because of security issues.

The combination of data uncertainties led us to develop a simple and transparent set of scenarios and to conduct a number of sensitivity tests on it. The numbers derived from the scenarios serve only to illustrate the potential severity of impacts, not to foretell what those impacts would be in the case of an actual attack. The goal was to span the range of probable outcomes, essentially upper and lower bounds. Then we modified one of the assumptions and produced a second set of three simulations based on the three scenarios. In all, six sets of results were prepared.

One set of assumptions concerns where the event would occur. With regard to electrical power, the state has four main energy providers: PSE&G (Public Service Electric and Gas); JCP&L (Jersey Central Power and Light, a subsidiary of FirstEnergy);

Conectiv (previously Atlantic Electric), and Rockland (a subsidiary of Orange & Rockland).

Figure 1 about here

Our assumption is that the event would occur in the PSE&G service area, a part of the PJM, or Pennsylvania, Jersey, Maryland system. Within New Jersey, Public Service Electric & Gas has over 1.7 million residential customers and over 290,000 non-residential customers. This amounts to 55 percent of residential and 60 percent of non-residential customers in New Jersey (Board of Public Utilities 2005). The PSE&G service area goes down the urban-industrial spine of the state from Bergen and Passaic counties in the north to Gloucester County in the south. It includes 13 counties or parts of counties: Bergen, Passaic, Essex, Hudson, Morris, Union, Somerset, Middlesex, Monmouth, Mercer, Burlington, Camden, and Gloucester counties. These 13 counties account for 79 percent of the state's population and 86 percent of its job base (Census 2004, NJDOL 2005).

While the scenarios are tested on the PSE&G area, the reality is that the rest of the state would be affected. State-level impacts focus the findings so that they can be more effectively linked to policy. To reiterate, the power outage is calculated for the PSE&G territory, but the impact is measured state-wide.

As noted earlier, a scenario needs to include magnitude, duration, frequency, timing and notice. The outcomes in terms of electrical supply reduction are highly unlikely under normal conditions, but plausible as indicated by the effects of natural events and terrorist attacks elsewhere. We chose to place our hypothetical terrorist attack in summer 2005. We assume that under the middle scenario the attack knocks out 90 percent of electrical delivery capacity of the service area for two days. By the end of the second day, 25 percent has been restored. By the end of a week, 50 percent has been restored, and all the electrical supply has been restored by the end of two weeks. Thus annual available electrical delivery is reduced by 2.48 percent (Table 1). However, the full impact is to occur in 1 quarter, so the reduction in electricity in the summer 2005 quarter is 9.75 percent of the quarterly years supply. But the reduction is only in the PSE&G territory (55 percent of the state total electrical load). Thus we assume a reduction in total state electrical delivery of 5.45 percent in the third quarter of 2005.

A more destructive version knocks out 95 of electricity delivery during the first day. By the end of the second day only 15 percent has been restored. By the end of the first week, 25 percent has been restored, and 90 percent has been restored by the end of a month. The remaining 10 percent is not restored until the end of the second month. This accumulates to a 7.46 percent loss over the year. However, this is reduced to 4.10 percent in the service area and 16.42 percent in the summer quarter in the PSE&G area.

A less destructive version of the three starts with an 80 percent reduction during the first day, but a 50 percent restoration by the end of the second day, 75 percent by the end of the week, and full restoration by the end of second week. This would result in a 1.60 percent decrease if over the entire state, but 3.53 percent in PSE&G territory in the summer quarter**.** We believe that the combination of events that would produce the outcomes described below is highly improbable, but plausible (See table 1 for calculations of power losses).

Table 1 about here

Operationally, the first three simulations reduced jobs in the third quarter (summer 2005). We then restored these losses in the fourth quarter. It is plausible that the job losses could linger because activity was not re-engaged in the state (see below for a discussion). To test this possibility, we ran another set of three simulations in which only half the jobs lost in the third quarter of 2005 were restored in the fourth quarter.

The result of these assumptions was an articulated set of six simulations. We used R/ECON's structural econometric time series model of the state (RECON) for estimating statewide economic impacts. An input-output model was used to estimate the energy usage of the various industries. Both models are resident at our school. We did this because of the different capabilities of the two models. Input-output (I-O) models are built around a matrix that describes how sectors of an economy interact with one another (Lahr and Stevens 2002). That is, for a given industry (e.g., steel production) it shows the "production recipe" for the goods and/or services that it sells as well as the shares of its revenues that are consumed by other industries in the economy. Our I-O model (R/ECON I-O) has 517 economic sectors. For example, this model has separate categories for bricks (SIC 3251), glass (SIC 3210), and gypsum board (SIC 3275). Different amounts of these materials and equipment are needed to construct and rebuild factories, highways, generating and other facilities. RECON I-O was used to develop Table 2 which shows KWh/employee for those 13 of the 517 sectors that require more than 200,000 KWh for each employee. These sectors are highly sensitive to electrical power outages, but they may not be important industries in New Jersey with regard to value added or employment.

Table 2 about here

The second model is RECON--an econometric time-series model built along the lines of that by Conway (2001). It is a system of 220 equations each of which is based on historical data for New Jersey and the nation. The model is tailor-made to be used in New Jersey. The historical data used in the equations are for the period 1970-2004. National forecasts of employment, wages, and prices drive the model's New Jersey forecasts.

The model has six key sectors: (1) the industry sector, including employment, gross state product, wage rates, and price deflators for major industries; (2) the personal income sector; (3) the population and labor force sector; (4) the construction and motor vehicles sector; (5) the state tax revenues and expenditures sector, and (6) the electric utility sector. The model also includes a labor-area module that distributes employment, population, and income growth in the state to the State’s ten labor areas. The key focus of the model is employment. In general, employment in an industry depends on demand for the output of the sector and on wages and prices relative to national wages and prices. Other major variables are industry wage rates, the components of personal income, the inflation rate, and population. Industry wage rates depend on national wage rates in the same industry, labor market conditions, and relative inflation rates. The New Jersey inflation rate depends on the national inflation rate, and the components of personal income are essentially New Jersey's shares of national income components. Population growth is driven by total employment and by state wages and prices relative to their national counterparts.

The strength of the RECON model is its sensitivity to historical trends in the state economy. The strength of its entrenchment in historical trends is also one of its weaknesses. That is, the past cannot always inform us about how major economic events or activities will affect an economy. The second limitation is that full historical data by industrial sectors for employment and gross product are available at the three-digit NAICS level or less, depending on the sector. Lastly, RECON does not estimate federal and local taxes, but it does forecast about 80 percent of state tax revenues. The econometric results for income, output, jobs, and tax revenues are presented in tables 4-8.

The weaknesses of these or any other systematic models are that relationships among sectors are fixed. We do not know precisely how relationships among sectors change when they decline rather than increase. Steps that can and would be taken to patch together the grid are not captured by our models. In other words, these kinds of models do not have resiliency elements built into them. A model that had resiliency built into it would shorten the recovery period and hence reduce the economic losses. It would also allow analysts to assess the economic costs and benefits of resiliency.

In producing results with the RECON model, our first step was to determine the proportion of New Jersey's employment and wage income produced in the PSE&G service territory. We looked at these proportions for the third quarter of 2004, on the assumption that the proportions would not change much between the third quarter of 2004 and the third quarter of 2005. Table 3 below shows the proportion of employment and wage income for New Jersey's major industries in the study area. Data at a more detailed industry level was used to adjust the model for the attack scenarios for all industries except agriculture which is not included in RECON. The average share of jobs and wages accounted for by the industries in the counties served by PSE&G were 75 and 76 percent, respectively. This is more than the share of customers served by PSE&G and the proportion of electricity delivered by PSE&G of all electricity delivered to customers in New Jersey (58 percent in 2004Q3), because the utility does not serve all parts of each of the 13 counties. Note that the proportion of information jobs in the PSE&G area was 92 percent whereas the proportion in manufacturing was only 67 percent. That is, there are differences in the concentration of industry in the region, and those differences are accounted for in running the simulations.

Table 3 about here

Before presenting the results, we summarize the capacity of the RECON model to capture shocks to an economic system. The model knows the past and relies on the most recent past more than the distant past. In a way, it functions like a meteorological model that predicts tomorrow's weather primarily on today's weather with only a minor influence from what happened last week. When the model sees a dip in third summer quarter of 2005, it typically predicts a lesser decline (perhaps even a full rebound) in the next quarter. Its equations typically force its forecasts to slowly return a series to its long-run trend. If we did nothing, the economic predictions would eventually catch up to the long-term trend. But we can speed up the recovery by "manually" restoring some of the lost economy. In short, it is important that the reader recognize that even sophisticated models cannot directly capture the immediate reactions to economic shocks of business and government leaders and consumers.

Results

Baseline

The baseline forecast covers the period from 2005 through 2010. Table 4 summarizes the model results for the State of New Jersey for key indicators. We show selected data to highlight key indicators and time periods.

The number of non-agricultural jobs was 4.0 million in 2004 and the baseline simulation forecasts that it will increase to 4.24 million by 2010, that is, an increase of 240,000 jobs during six years (about 40,000 a year). This increase is consistent with the historical record of New Jersey (Hughes and Seneca 2004). For example, the state gained 567,000 jobs during the record expansion between May 1992 and June 2001 (about 57,000 a year). In contrast, during the downturn that lasted from March 1989 to April 1992, the state lost 259,000 jobs (about 65,000 a year).

Table 4 about here

Table 4 provides employment data for four specific business sectors. Production of food, chemicals, computers and electronics, and the information industry were selected because electricity is critical to them and because they are important parts of the state economy. Each of the four has been declining in terms of jobs in New Jersey for years. For example, New Jersey lost 36 percent of its manufacturing job base between 1990 and 2004. Employment in three manufacturing industries— food, chemicals, and computer and electronic products declined by 20, 26, and 49 percent, respectively. Employment in the information industry declined by 22 percent between its peak level in 2000 and 2004.

Table 4 also provides baseline information for personal income, gross state product and total state tax revenues. Personal income is a measure of the wealth of the residents. For this report, we focus on wages and salaries because these should be much more sensitive to local economic shocks than inheritance, stocks, bonds and other sources of income. Gross state product represents the wealth accumulated from all the economic endeavors in the state during the time period. State tax revenue is important to local policy makers.

Table 5 shows the impacts of the low impact simulation – a 3.525 percent cut in power in the PSE&G area during the summer 2005 quarter. As anticipated, job losses are more substantial in the four specific energy sensitive sectors than in the state as a whole in 2005, and these losses carry over into 2006. But by 2010, there is little residual effect. The state actually is predicted to add 6,100 jobs as a result of the event (net difference between the baseline and the simulation). With regard to wages and salaries, gross state product and state taxes, the simulations predict a negative impact in 2005. Yet by 2006, we have added back the lost employment, and so there actually is a positive rebound in these economic measures.

Table 5 about here

The medium impact simulation is described in Table 6. A cut of 5.454 percent in power in the PSE&G study area in the third quarter of 2005 leads to reductions in all the major indicators of the state's economy during 2005. But we restore the lost jobs, and so in 2006, personal income, gross state product and tax revenues rebound. Overall state employment also rebounds, although the four specific power sensitive sectors fall below the baseline forecast. By 2010, the impact of the event is hardly noticeable.

Table 6 about here

Even a loss of 16.415 percent in the PSE&G study area under the worst case scenario does not change the overall outcome by 2010. The short-run impacts are quite substantial, including the estimated loss of 135,000 jobs in 2005 (4.0532-3.9185 million), and even relatively higher losses in the four specific business sectors. Yet, assuming that the jobs are restored, Table 7 shows that much of the loss is made up in 2006, and by

2010 there is a complete rebound.

Table 7 about here

The results of Tables 5-7 are counterintuitive in the sense that no one wants to believe that a terrible event is good for the economy. Yet, the natural hazards literature predicts this outcome. Skidmore and Toya (2002) studied the relationship between natural disasters, economic growth, factor productivity and capital accumulation. They show that the rate of return to physical capital is reduced, but that more emphasis is placed on human capital. Furthermore, disasters spur regions to update their capital stock and adopt newer technologies. This finding is confirmed by studies of tornadoes, hurricanes, earthquakes, and other natural events (Guimaraes, Hefner, Woodward 1993, Clark 1998, Todd 1998, Ewing, Kruse 2002, Rose, Lim 2002, Ewing, Kruse, Thompson 2003). Indeed, Ewing and Kruse (2002) argue that proactive efforts to get public and private sectors to work together to prevent disasters improves local market conditions.

If the economic shock is due to human activity, especially a terrorist attack, can we expect the same result? That is, may we assume that all the activity lost during the impact period will return? Since we do not have much of a history of such shocks in the U.S., some analogies can be used for intentional acts, for example, land contamination. Contaminated sites may be the best counter case to natural hazards. The Appraisal Institute (Roddweig 2002) published an anthology that shows measurable stigma near contaminated sites. Stigma typically disappears over time because of increased market value of the site, changeover of people living near the site, deliberate change of land uses to accommodate contamination, and attenuation of media attention. Yet stigma can last for many years. In the case of Superfund sites, stigma lasted for at least five years, and more in some instances (see also, Greenberg, Schneider 1996; Edelstein 1988; Dale, Murdoch 1999; Hurd 2002; Bible et al. 2005).

Does a place attacked by terrorists engender a response similar to an area hit by a tornado, hurricane, or earthquake, or is the response more like that to a contaminated site? That is, in the case of an attack, do businesses and residents try to make plans to find a place safe from the threat and stigma? Greenberg et al. (2003) used data from two Pew Research Center surveys after 9/11 to show that New York City residents had stronger behavioral responses, including distress, fear, and difficult time sleeping, than their counterparts in Washington, D.C. and elsewhere in the nation. Some no longer went to places where terrorist attacks would be likely to occur; some would not fly on airplanes; but few chose to leave the region. With regard to businesses, New Jersey actually benefited by business relocation from New York City (Heilmann 2002; Dolly 2001, 2002). There clearly was relocation.

Would there a complete rebound if the electricity supply was attacked by terrorists? Whereas many of those afraid to be in the region already would have relocated after 9/11, there could be further relocation of electric-power-sensitive industries. Second, a terrorist attack would hasten the movement of businesses that were not certain about staying in the region, that is, hemorrhaging of weakly tied industries would speed up. A third related possibility is that existing businesses would stay, but expansions would take place outside the study area (Hughes, Seneca 2005). Overall, in the short run, it is plausible to assume that some businesses and residents would relocate and that the impact would be greater than demonstrated by Tables 5, 6, and 7.

To recognize this possibility, we reran the three simulations, but this time we did not assume that all the jobs in place when the summer 2005 quarter began would be restored in the winter. Instead, only half of the jobs are restored. Table 8 captures the essence of the difference between the first and second set of simulations. We present the results for the “medium” event scenario.

Table 8 about here

Comparing the results of Tables 6 and 8, the impact is only slightly noticeable in 2005. Total non-agricultural employment for the fully restored simulation was 4,009,000 compared to 3,988,700 for the half restored version, a difference of 20,000. But the difference jumps substantially in 2006. The fully restored simulation projects 4,092,100 jobs and the half restored version only 4, 007,900, a difference of 84,000. By 2010, the difference has only closed slightly to 67,000: 4,244,400 compared to 4,176,700.

There is no rebound for wages and salaries or for gross state product in the half restored simulation. In 2006, personal income is $3.2 billion less, wages and salaries are $4.5 billion less, and gross state product is $11.8 billion less than forecasted by the medium impact-fully restored scenario. The difference closes only slightly by 2010. Simulations were also made for the low and high impact scenario versions of the half restored model. These decrease or increase the magnitude of the difference between the fully and half restored scenarios. But the message is the same. The fully restored assumption leads to a rebound and net growth, and half restored model implies a loss of in the region and migration of economic activity.

Discussion

Before describing the research and policy implications of the research, we re-iterate the key limitation of applying these models to an economic shock event. The models capture the key transactions in the New Jersey economy. However, no simulation modeling can perfectly forecast the implications of a shock. Whether there is a sudden increase in demand for a product or a sudden decrease, models cannot anticipate what will happen in response to the sudden change. Simulations are limited by the reality of the underpinning assumptions made by the analysts and in the reality of the equilibrium conditions assumed in the model's equations and coefficient structures. When a shock occurs, the equations embedded in the model do not change even though some of the transactions may change. Model users can change the results by changing the inputs, but the model equations themselves remain unchanged.

In this specific research, detailed information about a number of interactions would have helped. The literature indicated that medical care facilities have their own back-up power source. Using that information, we cut power loss to the health care sector of the model by only 50 percent rather than completely. But we had no access to similar information for many other industries. For example, it may be that chemical, food, and other highly impacted businesses in New Jersey have installed back up systems. If they have, then their impacts should be less than forecasted. We also do not know precisely how many commuters would be unable to get to work for how long. Nor do we know what the impact of the scenarios would be on the capacity of public potable water systems and sewerage treatment systems to function at full capacity. These specifics serve to illustrate the need for detailed field-work to better understand the capacity of the existing systems. Upon receipt of such information, model inputs can be modified to produce more sensitive results.

More information is also needed to attempt an analysis of multiple events, rather than of a single occurrence. The models we have can accommodate multiple events in multiple time periods. But we need more information about equipment destruction, backup capacity, and other key variables before such simulations can be credibly done. If for example, multiple events are more likely to damage equipment, we need detailed information to use in forecasting models to produce realistic results.

With regard to transferring this modeling approach to the national scale or to specific regions, these kinds of models can be constructed for a variety of regions. But few currently exist that provide the detailed complementary capacity of the two we used. This study focused on one state. Models could be built to study the impact on a set of states, urban regions, and non-contiguous areas that maintain substantial transactions. Before committing substantial resources to constructing multi-regional models, we urge their potential users to carefully consider the set of regions to be studied. Ideally, we would construct a single model that is multi-regional, which would allow the policy maker to understand the multi-regional impacts of an event in one place, and of multiple events on many places. In the case of electrical power delivery, it makes sense to construct the regions around the service areas.

The most important policy implication of this study is obvious. If the electrical power system is resilient, then a terrorist attack on the system is likely only to have short-term consequences. If, however, the system fails to respond quickly, and businesses decide that it is not reliable, then any location can be seen as risky place in which to conduct business and live. While this is a pilot project—and we re-iterate the results cannot be taken at face value—it follows from the size of the impacts that state and utility officials can use the results as a starting point from which to ponder how much it is worth to build resiliency into the system. This is a daunting challenge, but one we think is imperative to undertake.

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Table 1. Power Outage Scenarios, percent Loss

Scenario	Length, days	Amount of loss, percent	Number of days lost* State	PSE&G summer quarter***
Middle	2	90	0.493	1.085
	5	75	1.027	2.260
	7	50	0.959	2.109
	Total event		2.479	5.454
Worse	2	95	0.520	1.145
	5	85	1.164	2.561
	24	75	4.930	10.846
	31	10	0.849	1.868
	Total event		7.463	16.415
Less	2	80	0.438	0.964
	5	50	0.685	1.506
	7	25	0.479	1.055
	Total event		1.602	3.525

*Based on each day is .2739 percent of the total.

**PSE&G is 55 percent of total.

***Multiplied by 0.55 to get PSE&G proportion and then by 4 to get summer quarter for PSE&G.

Table 2. Electricity Use Per Employee for Selected Industries

Industries Use 200,000KWh or more per employee

Industry	KWh/emp
Primary aluminum	786,758
Wet corn milling	383,064
Cement, hydraulic	337,973
Pipelines, except natural gas	330,867
Electrometallurgical products, except steel	329,776
Petroleum refining	289,269
Platemaking and related services	258,405
Soybean oil mills	257,097
Carbon black	232,366
Primary smelting and refining of copper	223,801
Industrial inorganic and organic chemicals	205,279
Natural gas transportation	200,415
Plastics materials and resins	200,304

Source: RECON I-O model.

Table 3. Attributes of PSE&G Service Area

	PSE&G Territory as a Proportion of NJ 2004:Q3		
	Jobs	**Wages**	**Wage Rates**
Natural Resources	38%	34%	0.90
Utilities	62%	58%	0.93
Construction	79%	81%	1.02
Manufacturing	67%	59%	0.89
Wholesale Trade	88%	86%	0.98
Retail Trade	81%	82%	1.01
Transportation and Warehousing	65%	67%	1.02
Information	92%	92%	1.01
Financial Services	84%	88%	1.04
Professional and Business Services	87%	88%	1.01
Educational and Health Services	63%	63%	1.00
Leisure and Hospitality Services	65%	59%	0.91
Other Services	84%	86%	1.03
Public Administration	76%	78%	1.02
Total	75%	76%	1.01

Source: Bureau of Economic Analysis, Regional Economic Information System.

Table 4. Economic Baseline for New Jersey, 2004-2010

Economic category	Year 2004 (Growth rate, percent)	2005 (Growth rate, percent)	2006 (Growth rate, percent)	2010 (Growth rate, percent)
Non-agricultural employment (1000s)	4002.0 (0.6)	4053.2 (1.3)	4089.1 (0.9)	4239.1 (0.9)
Food	31.2 (-2.5)	30.7 (-1.5)	30.5 (-0.7)	30.7 (0.2)
Chemicals	73.1 (-1.8)	72.5 (-0.8)	71.2 (-1.8)	71.3 (0.1)
Computers/ Electronics	31.4 (-3.0)	31.0 (-1.1)	30.4 (-1.9)	28.4 (-1.7)
Information	98.6 (-3.4)	97.4 (-1.2)	96.6 (-0.8)	93.8 (-0.7)
Personal income ($billions)	359.5 (5.2)	380.5 (5.8)	399.9 (5.1)	496.4 (5.6)
Wages/salaries	193.1 (4.5)	202.8 (5.0)	212.6 (4.1)	257.6 (4.9)
Gross state product, ($billions)*	391.0 (3.6)	403.3 (3.1)	413.3 (2.5)	466.0 (3.0)
Total state tax revenues($billions)	20.175 (10.1)	21.621 (7.2)	22.934 (6.1)	28.578 (5.7)

*Year 2000 dollars.

Table 5. Economic Simulation, Low Impact, Full Return of Employment

Economic category	2005 (Comparison to baseline, percent)	2006 (Comparison to baseline, percent)	2010 (Comparison to baseline, percent)
Non-agricultural employment (1000s)	4025.5 (-0.7)	4093.4 (1.0)	4245.2 (0.1)
Food	30.5 (-0.7)	30.5 (-0.8)	30.7 (0.1)
Chemicals	71.8 (-0.9)	71.1 (-1.9)	71.4 (0.1)
Computers/ Electronics	30.6 (-1.2)	30.2 (-2.4)	28.3 (-0.2)
Information	95.9 (-1.5)	95.7 (-1.8)	94.3 (0.5)
Personal income ($billions)*	379.5 (-0.3)	400.0 (5.1)	496.8 (0.1)
Wages/salaries	201.4 (-0.7)	212.7 (4.9)	258.0 (0.1)
Gross state product, ($billions)*	400.3 (-0.7)	412.1 (2.2)	466.6 (0.1)
Total state tax revenues($billions)	21.567 (-0.2)	23.242 (7.5)	28.784 (0.7)

*Year 2000 dollars.

Table 6. Economic Simulation, Medium Impact, Full Return of Employment

Economic category	2005 (Comparison to baseline, percent)	2006 (Comparison to baseline, percent)	2010 (Comparison to baseline, percent)
Non-agricultural employment (1000s)	4009.0 (-1.1)	4092.1 (1.0)	4244.4 (0.1)
Food	30.4 (-1.1)	30.5 (-0.8)	30.7 (0.1)
Chemicals	71.3 (-1.6)	71.1 (-1.9)	71.5 (0.2)
Computers/ Electronics	30.6 (-1.3)	30.5 (-1.6)	28.4 (0.1)
Information	95.2 (-2.3)	95.3 (-2.1)	94.8 (1.0)
Personal income ($billions)*	378.8 (-0.4)	400.1 (5.1)	496.9 (0.1)
Wages/salaries	200.6 (-1.1)	212.6 (4.9)	257.9 (0.1)
Gross state product, ($billions)*	398.6 (-1.2)	411.6 (2.1)	467.2 (0.3)
Total state tax revenues($billions)	21.544 (-0.4)	23.221 (7.4)	28.788 (0.7)

*year 2000 dollars

Table 7. Economic Simulation, High Impact, Full Return of Employment

Economic category	2005 (Comparison to baseline, percent)	2006 (Comparison to baseline, percent)	2010 (Comparison to baseline, percent)
Non-agricultural employment (1000s)	3918.5 (-3.3)	4106.1 (1.3)	4266.5 (0.6)
Food	29.7 (-3.4)	30.5 (-0.8)	30.8 (0.5)
Chemicals	69.0 (-4.7)	71.2 (-1.7)	72.4 (1.5)
Computers/ Electronics	29.7 (-4.1)	30.5 (-1.7)	28.4 (0.1)
Information	90.9 (-6.6)	96.0 (-1.4)	100.8 (7.4)
Personal income ($billions)*	375.5 (-1.3)	400.8 (5.3)	498.4 (0.4)
Wages/salaries	196.0 (-3.4)	213.1 (5.1)	259.4 (0.7)
Gross state product, ($billions)*	389.4 (-3.4)	411.9 (2.1)	472.5 (1.4)
Total state tax revenues($billions)	21.417 (-0.9)	23.138 (7.0)	28.883 (1.1)

*year 2000 dollars

Table 8. Economic Simulation, Medium Impact, Half Return of Employment

Economic category	2005 (Comparison to baseline, percent)	2006 (Comparison to baseline, percent)	2010 (Comparison to baseline, percent)
Non-agricultural employment (1000s)	3988.7 (-1.6)	4007.9 (-2.0)	4176.7 (-1.5)
Food	30.2 (-1.7)	29.8 (-2.2)	30.1 (-2.0)
Chemicals	70.9 (-2.2)	68.9 (-3.2)	68.7 (-3.6)
Computers/ Electronics	30.3 (-2.2)	29.6 (-2.6)	28.2 (-0.9)
Information	94.5 (-3.0)	89.0 (-7.9)	87.5 (-6.8)
Personal income ($billions)*	378.0 (-0.6)	396.9 (-0.7)	493.8 (-0.5)
Wages/salaries	199.6 (-1.6)	208.1 (-2.1)	253.4 (-1.6)
Gross state product, ($billions)*	396.9 (-1.6)	399.8 (-3.3)	457.7 (-1.8)
Total state tax revenues($billions)	21.537 (-0.4)	23.062 (0.6)	28.571 (0.0)

*year 2000 dollars

NEW JERSEY STUDY AREA