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Using Risk Assessment, Economic Assessment, and Risk Management to Improve Preparedness for Terrorist Attacks and Natural Disasters:
Assessment of the Regional Economic Impacts of Catastrophic Events:
CGE Analysis of Resource Loss and Behavioral Effects of an RDD Attack Scenario

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Abstract

We investigate the regional economic consequences of a catastrophic event – attack via radiological dispersal device (RDD) – centered on the downtown Los Angeles area. We distinguish two routes via which such an event might affect regional economic activity: (i) reduction in effective resource supply (the resource loss effect) and (ii) shifts in the perceptions of economic agents (the behavioral effect). The resource loss effect relates to the physical destructiveness of the event, while the behavioral effect relates to changes in fear and risk perception. Both affect the size of the regional economy. RDD detonation causes little capital damage and few casualties, but generates substantial short-run resource loss via business interruption. Changes in fear and risk perception increase the supply cost of resources to the affected region, while simultaneously reducing demand for goods produced in the region. We use results from a nationwide survey, tailored to our RDD scenario, to inform our model values for behavioral effects. Survey results, supplemented by literature review, suggest that in the region affected by the RDD, households may require higher wages, investors may require higher returns, and customers may require price discounts. We show that because behavioral effects may have lingering long-term deleterious impacts on both the supply-cost of resources to a region and willingness to pay for regional output, they can generate changes in regional GDP much greater than those generated by resource loss effects. Implications for policy that might mitigate these effects are discussed.

Key words: economic impact, terrorism, risk perception, radiological dispersal
1. ANALYTICAL FRAMEWORK FOR CONSEQUENCE ANALYSIS

The measurement of economic consequences of terrorism risk reduction is a critical input into policy decisions. The avoidance of various categories of direct and indirect economic impacts represents the benefits of risk reduction. Moreover, the implementation of these policies also has direct and indirect economic costs that should be considered.

A broad conceptual framework for estimating economic consequences of terrorist attacks and natural disasters has recently been formulated to take all of these factors into consideration (see Rose, 2009). This framework will serve as the basis for the methodology of this project. The detail and linkages of the methodology are valuable because they provide insight into how the various factors interact and indicate the breadth of economic consequence analysis.

The major categories of economic consequences in the analytical framework are presented below:

1. **Ordinary Direct Impacts.** This includes property damage (reductions in the capital stock) and direct business interruption (reduction in the flow of goods and services stemming from property damage and other causes).

2. **Casualties.** This refers to loss of life and injury.

3. **Direct costs of mitigation, emergency response, remediation, and recovery and reconstruction.**
4. Resilience, or the muting of impacts by increasing efficiency of resource allocation (static resilience) and speeding the time to recovery (dynamic resilience).

5. Extended Linkages. This includes “system linkages”, such as interdependent infrastructure that leads to cascading failures. It also includes “behavioral linkages” that magnify losses through risk amplification or other means.

6. Ordinary Indirect Effects. These represent general equilibrium or macroeconomic impacts of all of the factors 1 through 5.

7. Total Impacts. This is the sum of all of the above. Proper application will avoid double-counting of the various effects.

Until recently, economic consequence analysis focused almost entirely on standard target-specific effects, what we term Ordinary Direct Economic Impacts and Casualties. The major expansions of the framework are the addition of resilience and extended linkages, which greatly affect economic consequences. Resilience adjustments refer to actions that mute the initial shock and that hasten recovery. They have the effect of lowering direct business interruption, a major category of target-specific economic impacts. Extended Linkages refer to extreme behavioral reactions (such as fear of going to work or shopping in a high risk area) or cascading system failures (mainly through interdependent infrastructure). They have the effect of significantly increasing the impacts. Resilience can be quite effective in standard cases, potentially reducing losses by as much as 90% (Rose et al., 2007). However, in extreme cases, such as Hurricane Katrina, it can be substantially eroded. Extended Linkages can increase direct losses by more than an order of magnitude (Gordon et al., 2007). Direct Remediation costs should be inserted into the analysis at an early stage, in part, because they, along with the two more standard features, are subject to Indirect Effects (often referred to as multiplier, general equilibrium, or macroeconomic effects). The sum of all these positive and negative components yields a thorough bottom-line estimate of total economic consequences.

Actual estimation of the full slate of consequences is difficult. The problem is complicated by the fact that not only do a broad range of impacts need to be evaluated, but, in a full risk analysis, the consequence estimation should be done for a probability distribution of magnitudes and likelihood of success of a given threat, meaning that an extensive array of consequence analyses may need to be performed.

In the analysis below we focus on the newest area of consequence analysis—behavioral linkages. Specifically we examine how risk amplification gets translated into changes in economic behavior that substantially increases the business interruption losses from an RDD attack. These losses can be reduced by mitigation beforehand or by various actions during the emergency response, remediation, recovery and reconstruction phases. For example, government assurances of decontamination and of improved security to prevent future attacks can greatly reduce the fear and stigma that arise from a successful attack. All risk reduction strategies should be compared in a complete analysis.
2. BACKGROUND

Public officials, business leaders, and health care providers are now routinely advised to prepare for the impacts a major disaster or an epidemic might have on their community. Following the events of September 11, Hurricane Katrina, the London subway/bus bombings and most recently worry of a pandemic flu, individuals and organizations have become more aware of their vulnerability to catastrophic events. There is a clear need to provide researchers and practitioners with a better understanding of how a community should prepare for and respond to calamities of this kind (Lasker, 2004). Complicating the situation is the fact that perceptions of risk and risk-related behaviors may exacerbate the negative economic consequences of disasters. Early investigations showed that risk perceptions were largely driven by two factors: uncertainty and dread (Fischhoff et al., 1978; Fischhoff et al., 1981). Hazards whose dangers the public thought to be poorly understood, even by experts, were considered highly uncertain. Hazards whose dangers were thought to be potentially catastrophic and difficult to control were considered highly dreaded. Technologies such as nuclear power generated high perceptions of risk because they were both uncertain and dreaded. Natural disasters, such as hurricanes, were better understood, and protective actions more widely accepted; hence they caused less concern.

Researchers have also observed that some disasters lead to social, political or economic consequences that go far beyond the direct harm they caused. Slovic (1987) postulated that certain events lead to such ripple effects because they signal some increased future risk. This is referred as the social amplification of risk (Kasperson et al. 1988). The accident at Three Mile Island, for example, signaled to the public that nuclear power was unsafe and potentially catastrophic. Public reaction, together with the media and special interest groups, generates secondary social and economic consequences that eventually call for additional institutional responses and protective actions (Burns et al., 1993; Burns and Slovic, 2007).

Burns and Slovic (2010, forthcoming) investigated how event characteristics might play a role in the amplification of risk process. Using hypothetical scenarios they found vignettes involving terrorism, infectious diseases or managerial negligence greatly heightened perceived risk. They reasoned that events like terrorism generate feelings of uncertainty and lack of control. These feelings in turn markedly increase perceptions of risk because they signal increased future threat. The authors concluded that terrorism, especially as it involves infections disease or radiation, present a unique policy challenge for community leaders because these terrorist acts possess such high risk signal value.

We argue that there are two main routes via which catastrophic events affect regional economic activity: (i) reduction in effective resource supply (the resource loss effect) and (ii) shifts in the perceptions of economic agents (the behavioral effect). Broadly, the resource loss effect relates to the physical destructiveness of an event, while the behavioral effect relates to changes in fear and risk perception on the part of firms, households and government. Both affect the size of the regional economy. We apply this framework to investigation of the short-run and long-run regional economic consequences of an RDD scenario. An RDD attack may cause a small number of deaths
and injuries, and massive disruption from both the standpoints of ordinary business interruption and public perception reactions. These effects would represent a reduction in effective resource supply to the regional economy, directly reducing real regional GDP. Behavioral effects may generate regional economic damage additional to these resource loss effects. In the Burns and Slovic framework, an RDD event is likely to have characteristics of low perceived control and high uncertainty, thus generating high perceptions of risk and fear. Changes in fear and risk perception increase the supply cost of resources to the affected region, while simultaneously reducing demand for goods produced in the region. Community leaders may find it challenging to communicate about radiation and to persuade residents to return to work in the affected areas despite assurances from experts regarding safety. Consumption of goods originating near the blast site may for a time decline as consumers wrestle with worries of contamination. Investors may shy away due to concerns of long-run lingering contamination, a repeat attack, or concern for the stigma associated with the site. In brief, fear may prove pivotal in determining the short and long term effects from an RDD event. We show that because fear effects may have lingering long-term deleterious impacts on both the supply-cost of resources to a region and willingness to pay for regional output, they have the potential to generate changes in real regional GDP that are greater than those generated by the resource loss effect alone.

We use a large-scale regional computable general equilibrium (CGE) model to impose neoclassical economic formalism on our research problem. Our choice of CGE model as analysis tool is motivated by two features of such models. First, their marriage of detailed data and economic theory allows CGE models to be used to analyze economic shocks that are very rare by nature. The catastrophic event modeled in this paper is of this kind. As Dixon and Parmenter (1996; p. 7) note, use of econometrics in such circumstances may be frustrated by the absence of historically equivalent shocks within the relevant time series data. Second, CGE models emphasize detailed modeling of economic structure. As we show in Sections 4 and 5, their rich treatment of the structure of both supply and demand sides of the economy facilitate detailed modeling of the resource loss and behavioral impacts of catastrophic events.

Few studies to date have quantified the economic consequences of altered perceptions following a terrorist attack. Gordon et al. (2007) estimated the “fear factor” associated with a nearly two year decline in U.S. airline travel and related tourism following 9/11. Rose et al. (2009), examining the same event, adjusted for the fact that the air travel industry was already in decline due to a pre-9/11 recession. Gordon et al. used an input-output model with ad hoc adjustments for substitutes for air travel. Rose et al. used a CGE model with endogenous substitution and various general equilibrium adjustments. In contrast, the methodology presented below is the first to provide a comprehensive and systematic framework for analyzing the economic impacts of extreme behavioral responses to terrorism or any other disaster.

The remainder of this paper is structured as follows. In Section 2, we describe our RDD scenario. Section 3 provides an overview of our CGE model. Section 4 discusses how we translate the RDD scenario described in Section 2 into a set of model-compatible shocks.
Section 5 describes the short-run and long-run economic impact on the LA County economy of our RDD scenario. Section 6 concludes the paper.

3. DETONATION OF A RADIOLOGICAL DISPERAL DEVICE (RDD)

Our RDD scenario is based on DHS’ National Planning Scenario 11, “Radiological Attack – Radiological Dispersal Devices” (DHS 2005). In this scenario, the attacker uses a combination of explosives and radiological material (cesium-137) to create an RDD. The explosions cause 180 fatalities and 270 serious injuries. Radiological contamination covers approximately 36 city blocks. 20,000 potential radiological victims require some level of decontamination and medical treatment. Radiological material settling on streets, buildings and other outdoor and indoor surfaces cause authorities to close the area until they can complete enough decontamination and remediation to sufficiently reduce public health risks. Using the DHS scenario as a template, we choose a similarly-sized downtown Los Angeles region as the RDD attack site: zip code 90071 (Fig. 1).

Gordon et al. (2005) and Pan (2009) indicated that RDD attack scenarios could cause significant economic impact. Official decisions on when to reopen an area after radiological contamination may not be simply dictated by existing safety standards (Eraker 2004; Elcock, Klemic and Taboas 2004; Gordon et al., 2005). A variety of radiological decontamination and remediation techniques might be employed (Volchek et al., 2006), which could result in a range of public access closure times (see, for example, Gordon et al., 2005). Decisions on cleanup options may involve tradeoffs between public safety levels and the costs and economic impacts of decontamination. With business interruption a likely significant cost of RDD attack, we discussed our scenario with Los Angeles public officials, to understand their assessment of the range of cleanup options. Lengthy disruption times would arise if public health officials viewed the extent of contamination to be such that street and building surfaces, or even entire structures, required removal or replacement. Our discussions with Los Angeles public officials indicated that the decision of when to re-open an area would take into account both the desires of local businesses (who might press for rapid reopening, to minimize business impacts) and the concerns of the public (who desire not only access but also assurances of safety). To reflect a medium-cost cleanup effort, in Section 4 we model a 30 day shutdown of zip code 90071.

4. ORANI-LA: A LARGE-SCALE MODEL OF THE LA-COUNTY ECONOMY

4.1 Overview of the structure of ORANI-LA

ORANI-LA is a Los Angeles County implementation of the single U.S. region model ORANI-R, documented in Giesecke (2009). As detailed in that paper, ORANI-R is a single-region sub-national variant of the well-known single country models ORANI-G (Horridge 2003) and ORANI (Dixon et al., 1982). The model is implemented using IMPLAN data for LA-County (Minnesota IMPLAN Group 1997) and relevant parameter values from the large-scale CGE model of the U.S. economy, USAGE¹,².
ORANI-LA is a single-region comparative-static CGE model of the LA County economy. The model features detailed sectoral disaggregation, modeling both production and capital formation for 436 sectors, and commodity- and agent-specific demands for 19 margin commodities. Familiar neoclassical assumptions govern the behavior of the model’s economic agents. Decision-making by firms and households is governed by optimizing behavior. Each representative industry is assumed to minimize costs subject to constant returns to scale production technologies and given input prices. Household commodity demands are modeled via a representative utility-maximizing household. Units of new industry-specific capital are assumed to be cost minimizing combinations of commodities sourced from the local region, the rest of the U.S. and overseas. Imperfect substitutability between local, rest-of-U.S. and foreign varieties of each commodity are modeled via CRESH aggregation functions. Inter-regional and foreign export demands for local commodities are modeled via commodity- and destination-specific constant elasticity export demand schedules. The model recognizes the consumption of commodities by state and federal government. A variety of direct and indirect taxation instruments are identified. Commodity markets are assumed to clear and to be competitive. Purchasers’ prices differ from basic prices by the value of indirect taxes and margin services. The model is solved using the GEMPACK economic modeling software (Harrison and Pearson, 1996).

4.2 Short-run and long-run closures of the ORANI-LA model
In Section 5 we report short-run and long-run consequences of our RDD scenario. We discuss here our variable closure choices which, taken together, specify typical regional CGE model closures describing short-run and long-run timeframes.

The main defining characteristic of our short-run labor market closure is exogeneity of the regional population. This largely determines regional employment. However, we allow for small short-run movements in the regional participation rate, employment rate, and hours worked per worker, in response to movements in the regional real consumer wage. This allows the short-run employment response to differ from short-run settings for regional population. Under our short-run labor market setting, regional labor market pressures are mainly reflected in changes in the regional real wage, with no change in regional population, and only small changes in regional employment.

The main defining characteristic of our long-run labor market closure is endogeneity of regional population, which is modeled as a strong positive function of the regional real wage. In this context, regional labor market pressure is mainly reflected in changes in regional population (and thus employment) with little change in the regional real wage.

In both the short-run and long-run, household consumption spending is modeled as a fixed proportion of household income. This implicitly means the household savings rate is exogenous, and we have not modeled any rise in precautionary savings, which is likely to be minor.

In the short-run, industry-specific capital stocks are exogenous, with industry-specific rates of return on capital adjusting to clear industry-specific capital markets. In the long-run, rates of return on this capital are exogenous, with industry-specific capital stocks
endogenous. Long-run industry-specific investment is determined via an assumption of exogeneity in industry-specific gross capital growth rates.

In the short-run, regional and federal government real public consumption spending are exogenous. In the long-run, the ratio of regional and federal government real public consumption spending to real regional private consumption spending is exogenous.

5. SIMULATION DESIGN

5.1 Resource loss effects
We considered four potential resource loss effects arising from RDD attack: injuries, deaths, capital damage, and business interruption.

We based our estimate of lost labor input via death and injury upon detailed assumptions about the distribution of casualties, the proportion of the directly affected population that is employed, the occupational distribution of downtown employment, and average wage rates by occupation. We estimate that RDD-related casualties result in $7.5 million of lost labor input from deaths and $18.7 million of lost labor input from injuries. We model the direct impact of deaths as reduction in regional population sufficient to withdraw $7.5 million of labor from the LA County economy. We model lost labor input from injury as a decrease in regional labor productivity.

We assume that capital damage from the RDD attack will be negligible, so we set capital damage at zero for our RDD scenario. Capital in the contaminated area is simply “off-limits” during the disruption period. This is subsumed by our business interruption shocks.

We base our estimate of business interruption on an estimate of the value of gross output in the affected region, and an assumption of the number of days over which this output is disrupted. We estimate GDP of zip code 90071 at $9.8 billion. This represents about 2 per cent of LA County GDP, the region for which we estimate economy-wide impacts. We estimate the value of gross output in 90071 at $16.8 billion. We assume that decontamination of 90071 results in 30 days of foregone output via business interruption, which corresponds to $1.4 billion of lost output. We model business interruption as a decline in all-input-using technical efficiency calibrated to reduce output for a given level of inputs by $1.4 billion.

5.2 Behavioral effects
We evaluate the short-run and long-run regional economic consequences of three behavioral effects: a rise in regional required rate of return, a rise in regional wage premium, and fall in willingness to pay for regional goods. For the latter two effects, we base our shock values on results from a nationwide survey. For movements in required rates of return, we rely on the literature on stigmatised asset values.
Six hundred twenty five people nationwide, representing a diverse cross-section of the public, participated in an on-line survey. Panelists were recruited to participate and were asked to provide demographic information. If they met our targeted profile they were given one week to complete the questionnaire. By reading about and listening to an audio recording, all respondents reviewed a detailed description of an RDD attack, as well as a major earthquake occurring in the financial district of Los Angeles. The order in which these events were reviewed was randomly assigned. Prior to reviewing each scenario, respondents were asked questions about the likelihood and severity of either an RDD attack or a major earthquake in the U.S. during the next 12 months. They then read a news article of approximately 500 words and listened to a dramatization of the mayor of Los Angeles giving his next day account of the event and what was being done (see Table I). In his public address the mayor announces that the event is very serious and that the downtown area will be blocked off to the public until their investigation is completed. This was followed by questions about respondents’ initial reactions. Respondents then read and listened to a follow-up report from the mayor describing the findings and actions by city officials over the previous thirty days. The mayor now announces that he has received a reassuring report from safety experts and that it is safe to resume normal activities in the downtown area again. As a change of pace, participants answered some general shopping questions regarding their normal routine before moving on to review the second scenario.

Initial questions involved perceived risk, fear, attention to media coverage, worry and trust in first responders. These were followed by questions involving respondents’ willingness to buy products, use services or work near the Los Angeles financial district. We were primarily interested in how long people believed they would delay any activities connected with products, services or employment near the financial district (ranging from “would not delay” to “would never use again”). We focused on the use of professional services, buying food products, buying electronic products, taking a vacation or working near the financial district (see Table II). We also asked what compensation participants would require in product discounts or increased wages to resume or move forward right away with their intent to buy products or work within a mile of the financial district.

We decided not to survey the business community about required rate of return movements. We anticipated that public reaction would likely play a large role in business investment decisions. In part, it is this public reaction that our on-line survey elucidates. Now that our survey work has shown us how best to represent public response, in future work we plan to survey the business community. For this paper, we infer changes in required rates of return from estimates of the property price impacts of disease outbreaks and proximity to hazardous waste sites. Lucas (2004) found a short-run 15 per cent drop in home sale prices following an unanticipated outbreak of pediatric leukemia not linked to a specific source. Ihlanfeldt and Taylor (2004) examine the commercial property market, finding a 36 per cent drop in urban commercial property prices arising from proximity to small-scale hazardous waste sites. Greenstone and Gallagher (2008) report lower property price impacts of hazardous waste proximity. Their study of Superfund sites estimates 0.7 per cent to 4.7 per cent home price appreciation following site clean-up, although they are unable to reject that the actual price impact is zero. With estimates
of property price impacts ranging from 0 per cent to 36 per cent, we choose 15 per cent as a rough mid-point of this range to guide our estimate of the short-run rate of return consequences of the RDD event. We note that this number is close to that found by Lucas (2004). With the leukemia hazard studied in Lucas (2004) appearing suddenly, and the actual risk posed to people’s health ambiguous, this example has characteristics that most resemble our RDD scenario.

As discussed in Menzies et al. (2009) we can estimate the movements in required rates of return that are implicit in property price movements by using Tobin’s Q ratio, the ratio of an asset’s market value to its replacement cost. Typical values for Q are in the range 1.0 – 1.5. If we set the initial LA County level of Q at 1.25, then based on the approach outlined in Menzies et al. (2009), our RDD-induced 15 per cent reduction in asset values implies a change in gross rates of return of -2.4 percentage points. Assuming an initial gross rate of return of around 12 per cent, this implies a percentage fall in rates of return of 20 per cent. At any given level of investment, investors will require an increase in required rates of return to compensate for this anticipated decline. Hence, we implement perceived risk in investment as a 20 per cent increase in required gross rates of return in industries in the affected region. Ceteris paribus, such a shock will cause real investment to decline for any given level of actual gross rates of return. We draw the reader’s attention to the fact that, while our investor risk premia estimate is based on a literature survey, this 20 per cent movement in required rates of return is very close to our survey-based estimate of the short-run movement in compensating wage premia required by workers. Thus, in our simulations, we see the two suppliers of primary factors to the regional economy requiring near-identical percentage increases in their respective factor prices.

AORANI-LA models demands for commodities produced in LA County emanating from agents located in three regions: LA-County, the rest of the U.S., and the rest of the world. Demands for LA-County commodities by agents located in the latter two regions are modeled via constant elasticity demand schedules. We model declines in willingness to pay for LA-County commodities by these agents as vertical shifts in these demand schedules. Willingness to pay shifts by agents located within LA-County cannot be modeled so directly. ORANI-LA identifies three sources of commodity supply for LA-based economic agents: LA County, the rest of the U.S. and foreign. We view the shifts described in Table 8 as fear-induced wedges driven between willingness to pay for LA-sourced goods and willingness to pay for the competing imports from the rest of the U.S. and the rest of the world. Let \( T_{i,u} \) describe the rate of this fear-induced wedge between willingness to pay for domestic (LA County) and imported commodity \( i \) by user \( u \). We model \( T_{i,u} \) via:

\[
T_{i,u} = T^D_{i,u} - T^M_{i,u}
\]

where \( T^D_{i,u} \) is the power (one plus the rate) of a fear “tax” on the domestic (LA County) variety of good \( i \), and \( T^M_{i,u} \) is the power of the fear “tax” on the imported variety of good \( i \).
The initial (pre-event) values for $T^D_{i,u}$ and $T^M_{i,u}$ are 1. Hence the initial value for $T_{i,u}$ is 0. The change in $T_{i,u}$ is defined by:

$$100 \times \Delta T_{i,u} = T^D_{i,u} t^D_{i,u} - T^M_{i,u} t^M_{i,u}$$

where $\Delta T_{i,u}$ is the change in $T_{i,u}$, and $t^D_{i,u}$ and $t^M_{i,u}$ are the percentage changes in $T^D_{i,u}$ and $T^M_{i,u}$ respectively.

We interpret a fear-inducing event that creates a 10 per cent reduction in willingness to pay for domestic good $i$ as a movement in the value of $T_{i,u}$ from 0 to 0.10. That is, we exogenously set the value for $\Delta T_{i,u}$ at 0.10.

We allow the movement in $T_{i,u}$ to be expressed as revenue-neutral movements in $T^D_{i,u}$ and $T^M_{i,u}$. By driving wedges between supply prices and user prices, the movements in $T^D_{i,u}$ and $T^M_{i,u}$ create allocative efficiency losses, allowing the CGE model to calculate the direct economic cost of fear. At the same time, the movements in $T^D_{i,u}$ and $T^M_{i,u}$ are calibrated to collect no net “tax” revenue. Revenue-neutrality is achieved by calibrating the movements in $T^D_{i,u}$ and $T^M_{i,u}$ such that they leave the unit cost of commodity $i$ to user $u$ unchanged. The linearised unit cost function for commodity $i$ is given by:

$$p_{i,u} = S^D_{i,u} (p^D_{i,u} + t^D_{i,u}) + S^M_{i,u} (p^M_{i,u} + t^M_{i,u})$$

where

- $p_{i,u}$ is the percentage change in the unit cost of commodity $i$ purchased by user $u$,
- $S^D_{i,u}$ is the share of user $u$’s purchases of commodity $i$ represented by purchases from the domestic (LA County) source,
- $p^D_{i,u}$ is the percentage change in the price of domestic commodity $i$ purchased by user $u$,
- $S^M_{i,u}$ is the share of user $u$’s purchases of commodity $i$ represented by purchases of imported (rest of U.S. and foreign) commodity $i$,
- $p^M_{i,u}$ is the percentage change in the price of imported commodity $i$ purchased by user $u$.

Our aim is to find cost-neutral movements in $t^D_{i,u}$ and $t^M_{i,u}$ for a given $\Delta T_{i,u}$. Noting that $p^D_{i,u}$ and $p^M_{i,u}$ are determined independently of this aim, the movements in $t^D_{i,u}$ and $t^M_{i,u}$ are given by:
6. RESULTS

Tables IX and X present short-run and long-run results for regional macroeconomic variables. In our discussion of results, we focus on the event’s impact on the size of the regional economy. This is consistent with the interests of regional policy makers, who typically express their economic policy priorities in terms of summary measures like employment and real regional GDP. We will rely on a simple regional aggregate demand (AD) / aggregate supply (AS) framework to describe the results generated by our full-blown CGE model. Use of such stylized models to describe the workings of large-scale CGE models to a non-specialist audience has a long tradition.

In Fig. 2, the schedule AS, the short-run regional aggregate supply schedule, traces a positive relationship between the regional price level (as measured by the regional GDP deflator, $P_{GDP}$) and real regional GDP. Short-run AS is drawn with exogenous, industry-specific capital stocks ($K$), regional population ($P$), all-input-using technical efficiency ($A$), labor productivity ($LA$) and compensating wage premium ($WF$). With capital stocks, regional population, and productivity exogenous, the short-run AS schedule is highly inelastic. That the short-run AS schedule has any positive slope is due to our assumption that the regional employment rate, participation rate and hours worked per worker are all weakly positively related to the regional real wage (see Section 4.1.

The regional aggregate demand schedule (AD), traces a negative relationship between $P_{GDP}$, and real regional GDP. The AD schedule is negatively sloped because, ceteris paribus, a decrease in the price of goods produced in LA County ($P_{GDP}$) induces economic agents within and outside LA County to substitute towards LA County goods. The regional AD schedule is quite elastic for two reasons. First, international and inter-regional export demand schedules are price elastic. Second, inter-regional sourcing elasticities are quite high: local demanders can substitute towards alternative U.S. and foreign sources of goods when the LA County price level rises. In terms of the present application, the AD schedule is drawn for a given preference (or willingness to pay) for goods produced in LA County by economic agents both within and outside the region ($WTP^{LA}$ and $WTP^{RoW}$ respectively), given required rates of return on investment within the region (RROR), and given values for $A$, $LA$, $WF$.

6.1 Short-run consequences of RDD attack
As discussed in Section 4, we distinguish four short-run resource loss routes (business interruption, deaths, injuries and capital damage) and three behavioral routes (required

$$t^D_{i,u} = \left( \frac{100}{T^D_{i,u}} \right) \left( \frac{S^M_i / S^D_{i,u}}{T^M_i / T^D_{i,u} + S^M_i / S^D_{i,u}} \right) \times \Delta T_{i,u}$$

and

$$t^M_{i,u} = \left( \frac{100}{T^D_{i,u}} \right) \left( \frac{1}{T^M_i / T^D_{i,u} + S^M_i / S^D_{i,u}} \right) \times \Delta T_{i,u}$$
rates of return, willingness to pay, and compensating wage premiums) via which catastrophic events affect regional economic activity. The individual contributions of these factors to the total short-run impact of the RDD scenario are reported in Table IX.

6.1.1 Business interruption
Business interruption is the main route via which RDD attack affects the regional economy in the short run (column 1, Table IX). We model business interruption as a decline in all-input-using technical efficiency. In terms of Fig. 2, business interruption reduces input-using efficiency from $A_0$ to $A_1$. By increasing per unit production costs, this shifts the AS schedule from $AS_0$ to $AS_1$. Because the regional AD schedule is price elastic, the incidence of higher production costs is largely borne by capital returns, not output prices. In Table IX, this accounts for the sharp fall in average capital rentals (row 14, column 1). This causes regional investment to decline (row 4, column 1). It is this decline in investment that accounts for the movement of the AD schedule from $AD_0$ to $AD_1$. With business interruption moving both the AS and AD schedules in a “westerly” direction, the regional economy experiences a large decline in GDP (rows 1 and 16, column 1) with only a small change in the price level (row 13, column 1).

6.1.2 Deaths, injuries and capital damage
Our RDD scenario specifies no significant capital damage or destruction. This accounts for the absence of short-run capital damage effects in Table IX. Our RDD scenario also assumes few deaths and serious injuries. The scenario’s 180 deaths is modeled as a reduction in regional population sufficient to withdraw $7.5 million of labor from the LA County economy. In terms of Fig. 2, deaths cause the AS schedule to shift from $AS_1$ to $AS_2$. By generating a small rise in the regional price level (row 13, column 2) the value of employing labor rises. As such, demand for labor increases, generating a small increase in the regional wage (row 12, column 2). The increase in the wage induces small increases in regional participation rates, employment rates and hours worked per worker, all of which damp the direct employment consequences of the decrease in regional population (row 3, column 2). Hence, total regional employment falls by less than that given by the number of RDD-related deaths alone. This explains why the fall in GDP ($5 million) is less than the direct resource loss ($7.5 million).

Our RDD scenario specifies approximately $19 million in lost labor input via injuries. We model this as a decrease in regional labor productivity. Injuries cause real regional GDP to fall by $22 million (row 16, column 3). This is more than the direct value of lost labor inputs ($19 million) because a decline in labor productivity shifts both the AS and AD schedules (Fig. 2). By increasing per-unit production costs, lowering labor productivity shifts the AS schedule from $AS_2$ to $AS_3$. By decreasing effective labor input per unit of capital, lowering labor productivity reduces physical output per unit of capital, and thus also reduces the rate of return per unit of capital. This causes real investment to decline (row 4, column 3), shifting the AD schedule from $AD_1$ to $AD_2$.

6.1.3 Short-run behavioral effects
Survey results for respondents who evaluated the RDD attack are shown in Table III. Notice that willingness to use services, purchase goods, or work in downtown LA
immediately following the Mayor’s “all clear” signal is greatest for professional services and electronic products and least for food and vacation (first percentage in each cell). Using these responses we calculated the percentage of people who remain unwilling to use services, buy products or work near the financial district at different points in time (percentage in parentheses). We used the percentages within each column to approximate the decay in perceived risk over time for each product type or job. After six months, at least 41% of respondents indicated they still would not consider economic transactions in the financial district. The greatest reticence involved consuming food products with 17% saying they would never buy food products near the financial district in the future. We interpret the results in Table III as measuring short-run and long-run horizontal movements in demand schedules for commodities supplied by the downtown district. We chose the percentage of respondents still unwilling to purchase downtown commodities at six months and sixty months to represent, respectively, short-run (event year) and long-run horizontal demand schedule shifts (see Table IV)

We also asked respondents what percentage price reduction (or wage increase) they would require to consider using services, buying products or working in downtown LA immediately following the Mayor’s “all clear” (see Table V). Notice that almost half of the respondents said they would not buy food near the financial district right away for any level of incentive. Whereas less than a quarter indicated they would not accept any incentive to purchase electronic products right away. For those willing to accept some level of incentive the average percentage required is given in the bottom row of Table II and range from 15% to 23%. Incentive for jobs may have been a little higher because respondents had an opportunity to select a 100% wage increase. We used results from Table V to estimate vertical shifts in demand schedules for downtown products, and labor supply schedules to the downtown area (see Table VI). We recognized that the survey results in Table IV (describing horizontal demand schedule shifts) and the survey results in Table VI (describing vertical demand schedule shifts), while originating from different survey questions, may be measuring the same demand contraction. To reflect this, we first converted the Table IV horizontal demand shifts to equivalent vertical demand shifts, and took the average of these imputed vertical shifts and the survey values in Table VI (see Table VII) The values in Table VII relate to activities within the financial district and must be weighted by the share of each financial district activity in LA County activity (see Table VIII). It is these willingness to pay and wage compensation shocks that we apply to our CGE model.

We offer a caveat that projections much beyond six months should be regarded as an upper bound on people’s unwillingness to resume normal activities after a crisis like the one we describe. Research involving people’s forecasts of how well they will adapt to adverse circumstances suggests they consistently underestimate their ability to adjust (Gilbert et al., 1998, Gilbert et al., 2000). However, our results appear consistent with previous research by Hayes et al. (1995), Bostedt (2001), And Hulkrantz and Olsson (1997).

Columns (4) – (6) of Table IX report the short-run (event year) economic impacts of our three behavioral effects. As we shall see, relative to their long-run effects, the short-run consequences of the behavioral effects are small. This is because regional factor supplies
in the short-run are sticky, since capital stocks are exogenous, and regional employment is constrained by the short-run exogeneity of regional population. In terms of Fig. 2, these short-run features of the regional economy render the AS schedule inelastic. As such, the behavioral effects, which can be interpreted in terms of vertical movements of both the AD schedule (in the case of willingness-to-pay and required rate of return shifts) and the AS schedule (in the case of wage premium shifts) have limited scope to affect short-run real GDP.

In Section 4.2, we describe that investors, fearful of the implications of the RDD attack, require a 2.4 percentage point rate of return premium on investment in the directly affected area, which causes regional investment to fall (row 4, column 5). In terms of Fig. 2, this decrease in real investment shifts the regional AD schedule from AD\(_2\) to AD\(_3\). Given the inelastic short-run AS schedule, this movement in the AD schedule has only a small impact on regional GDP (rows 1 and 16, column 4).

As discussed in Section 4.2, we model willingness to pay declines on the part of economic agents located within LA-County as a rise in the perceived price of LA-County goods relative to their imported counterparts. In terms of Fig. 2, this is represented by a decline in willingness to pay for LA-County goods by LA-County-based agents from \(\text{WTP}_{0}^{LA}\) to \(\text{WTP}_{1}^{LA}\). This shifts the regional AD schedule from AD\(_3\) to AD\(_4\).\(^{10}\)

We implement stigma-related reductions in demand for LA-County exports via reductions in foreign and interstate willingness to pay. In terms of Fig. 2, willingness to pay for LA-County commodities by agents in the rest of the world falls from \(\text{WTP}_{0}^{ROW}\) to \(\text{WTP}_{1}^{ROW}\), shifting the regional AD schedule from AD\(_4\) to AD\(_5\).

Since the short-run AS schedule is inelastic, the impact of the AD movement from AD\(_3\) to AD\(_5\) is largely expressed as a fall in the regional price level (row 13, columns 5a and 5b) rather than a significant decline in regional activity (rows 1 and 16, columns 5a and 5b). Despite the small movement in regional GDP, the reductions in willingness to pay for LA County commodities nevertheless represents a real welfare loss to LA County. In Table IX, we see the decline in willingness to pay reduces the regional terms of trade (row 15, columns 5a and 5b). This explains why the fall in real private consumption (row 15, columns 5a and 5b) greatly exceeds the fall in real GDP (row 1, columns 5a and 5b).

In Section 4.2 we noted that workers will require a wage premium to induce them to work in the affected region. In terms of LA County as a whole, the short-run average increase in required wages is 0.49 per cent. In terms of Fig. 2, this represents a sizeable vertical shift in the regional AS schedule, from AS\(_3\) to AS\(_4\), as the regional wage premium rises from \(\text{W}_{0}^{W}\) to \(\text{W}_{1}^{W}\). Given the inelastic nature of the short run AS schedule, capital returns bear a large share of the incidence of this movement in aggregate supply (row 14, column 6). This causes investment to decline (row 4, column 6). In Fig. 2, this investment decline shifts AD from AD\(_5\) to AD\(_6\).
6.2 Long-run behavioral effects

Table X reports the regional macroeconomic consequences of the behavioral shocks for a typical year of the long-run. We use the survey results for year 5 to inform our long-run shocks. In aggregate, real regional GDP is projected to be lower by $2.6 billion in a typical year of the long-run period over which the adverse behavioral shifts persist (Table X, row 16, column 4). In the long-run, all behavioral effects have large adverse impacts on the size of the regional economy. Indeed, despite the absolute magnitude of the long-run behavioral shifts being only between one fifth and one third of their short-run values (compare columns 2 and 1, Table X), at $2.6 billion, the long-run annual impact of the behavioral shifts is almost three times larger than the event year behavioral impact of $890 million. Fig. 3 makes clear why behavioral shifts have large long-run consequences. Like the short-run, the long-run regional AD schedule is highly elastic. However unlike the short-run, the long-run regional AS schedule is also highly elastic. The elastic long-run AS schedule reflects our long-run regional factor supply closure (see Section 3.2). Under this closure, regional capital supplies are endogenous at going required rates of return, and regional population (and hence, regional employment) is endogenous subject only to a requirement for small movements in regional wage relativities to overcome household location preferences. As we shall see, with long-run AD and AS schedules highly elastic, small movements in either schedule generate large movements in regional economic activity.

6.2.1 Increase in required rates of return on capital

The increase in required rates of return represents an increase in the regional cost of capital. In the long-run, this flows into regional production costs. In Table X, this is expressed as a positive deviation in the regional GDP deflator (row 13, column 1). In terms of Fig. 3, this is represented by a shift in the AS schedule from AS\(_0\) to AS\(_1\). With regional production costs higher, demand for commodities produced in LA County falls. This accounts for the negative outcome for regional GDP (row 1, column 1).

6.2.2 Decrease in willingness to pay for commodities produced in Los Angeles County

Columns 2a and 2b of Table X report the macroeconomic consequences of the long-run reductions in local, interstate and foreign willingness to pay for LA County commodities discussed in Section 4.2. In terms of Fig. 3, declines in willingness to pay for LA County goods moves the regional AD schedule from AD\(_0\) to AD\(_2\). Given our long-run elastic regional factor supply assumptions, this generates a large contraction in regional economic activity (rows 1 and 16, columns 2a and 2b).

6.2.3 Increase in required wage in Los Angeles County

As discussed in Section 4.2, we assume that fear arising from perceptions of radiological contamination cause workers to require a 0.14 per cent wage premium to work in the LA County region. The actual increase in the long-run real regional wage is somewhat less than this, at +0.094 per cent (row 12, column 3). This reflects our assumption of location preference on the part of regional households. The increase in real regional wages causes regional production costs to rise (row 13, column 3), causing a decrease in demand for LA County goods (row 1, column 3). In terms of Fig. 3, this process is described by the
movement of the AS schedule from AS\textsubscript{1} to AS\textsubscript{2}. The resulting decrease in regional employment (row 3, column 3) places downward pressure on the real regional wage as households with some preference for residing in LA County accept lower long-run real wages to avoid emigrating.

6.3 Comparison of Effects
Approximately two-thirds of the RDD’s event-year GDP impact arises from business interruption. For a 30 day shut-down of the affected area, the impact of business interruption on GDP, via both direct and indirect routes, is $1.9 billion. The remaining resource loss effects contribute relatively little to short-run regional economic damage. At $27 million, casualties account for only 1.0 per cent of the short-run real GDP loss. With the exception of the compensating wage premium, short-run behavioral impacts on economic activity are also small. Behavioral effects tend to have limited scope to influence the regional economy’s short-run resource endowment or supply cost. An important exception is the compensating wage premium, movements in which directly affect short-run regional labor supply. The GDP impact of behavioral effects, at $890 million, constitutes approximately one-third of the RDD’s total short-run GDP impact.

While the impacts of behavioral effects are relatively small in the short-run, as the economy transitions to its long-run equilibrium, behavioral effects come to exert a significant damping effect on regional economic activity. In a typical long-run year, the behavioral effects cause LA County GDP to be $2.6 billion lower than otherwise. That is, the event’s adverse effects in a typical long-run year could be 50 per cent larger than the event’s total impact in the event year. The bulk of the long-run reduction in GDP (at $2.0 billion) arises from the higher compensation that investors and workers require to supply primary factors to the region.

Table XI provides a further comparison of results in terms of direct and indirect impacts and in terms of resource loss versus behavioral impacts. First, in terms of short-run business interruption effects, we distinguish between the direct (partial equilibrium) impacts from quarantine of the LA financial district, amounting to $1,400 million, and the total county-wide general equilibrium impacts of $1,870 million (presented in column 1, Table IX). The implicit LA county-wide multiplier here is 1.34. In contrast, a typical simple input-output Type II multiplier (including both indirect and induced effects) would be around 2.0. Regional CGE multipliers are smaller than their I-O counterparts, because CGE models contain resource constraints and price-responsive behavior.

In comparison to business interruption impacts, the short-run resource loss and behavioral effects are small. The former is due to the relatively small number of people killed and injured, and the latter to short-run stickiness in regional factor supplies.

We need also to place the long-run behavioral impacts in perspective. A full treatment in this regard requires a dynamic regional CGE model and an explicit time path describing the peak and decay of behavioral shocks. Nevertheless, results from our comparative-static model provide a basis for plausible conjectures about the path of long-run impacts.
In Table X, we presented results for a representative long-run year. For argument, we might view these results as representing impacts five years following the event year (Fig. 2). While stigma effects may be longer lasting, it is unlikely that the premia and discount adjustments to behavioral parameters will remain permanently. In Fig. 2, we portray these effects as having largely dissipated after ten years. As such, the event’s real GDP consequences have also dissipated by year ten. Assuming straight-line paths from the short-run behavioral GDP loss ($890m.) to the behavioral loss ($2628m.) in the long-run peak year (T1) to the behavioral loss ($0m.) in the year that fear effects have dissipated (T2) generates a total GDP loss of $890*(1+T1) + (-2628 − –890)*(1+T1)/2 − 2628*(T2–T1−1)/2. In Fig. 2 we describe T1 = 5 and T2 = 10, generating total behavioral losses to real GDP of $15,808 m. At a 5 per cent discount rate, the stream of real GDP losses described in Fig. 2 is $12,850 m.

Some important ratios are presented at the bottom of Table XI, including the implicit business interruption (BI) multiplier discussed above and a comparison of the long-run 1-year to short-run direct BI multiplier of 1.88. In contrast, the ratio of total long-run output impacts to short-run direct BI impacts is 11.3. This ratio helps make our point that omission of behavioral impacts could grossly underestimate the consequences of a terrorist attack involving a radiological device. The ratio of total behavioral impacts to total short-run ordinary impacts is 8.32.

Our analysis highlights the importance of finding ways to minimize the negative behavioral impacts of a terrorist attack. One strategy is a thorough clean-up of the site and reassurance that there is no lingering radiation. Of course, another is public confidence in preventing another attack. Our parameter estimates for risk premia are based on a combination of these contingencies. If we assume for illustrative purposes that half the increments are due to fear of lingering contamination, we could compare a NPV of $6,425 (=12850/2) of behavioral output losses with an increase in direct and indirect BI losses for additional quarantine time. One additional month would cost another $1.9 billion in BI (over and above any additional clean-up expenditures) and would only pass the benefit-cost test if it could reduce the behavioral losses by at least 30 percent.

Finally, we note that we have not considered major sources of economic resilience – strategies by individual businesses, households, and government agencies that may mute the impacts otherwise predicted by the CGE model (see, e.g., Rose, 2007). A prime candidate would be business relocation. For example, Rose et al. (2009) found that more than 95 percent of the businesses located in the World Trade Center area survived by finding alternative locations, the vast majority in adjacent areas. However, the actual time for most firms in the World Trade Center to fully relocate was 2-4 months. Hence, ordinary physical relocation may not be warranted for a 30-day quarantine period alone. Also, not all business “relocation” requires a physical move. Work in cyberspace, telecommuting, and shifts to branch offices have potential, especially in the financial industry, which dominates our target area. This could reduce the ordinary direct business interruption losses and reduce the pressure for a rapid cleanup. It would also likely reduce the long-run behavioral impacts, though to a much lesser extent.
7. CONCLUSIONS

In this paper we evaluate the regional economic consequences of an RDD attack centered on the Los Angeles downtown area. We base our estimates of the attack’s direct effects on an event of magnitude described in DHS’ National Planning Scenario 11, “Radiological Attack – Radiological Dispersal Devices” (DHS 2005). We base our estimates of long-run behavioral effects primarily on survey results from a nationwide survey.

We find that the economic damage wrought by such an event is dominated by the consequences of business interruption in the short-run and behavioral effects in the long-run. While we have not explored policy responses in this paper, the prominence of the business interruption and behavioral effects suggests a strong role for public policy intervention in mitigating both the short-run and long-run economic costs of an RDD event. An effective policy response might minimise the period of business interruption via efficient and expeditious site clean-up, judicious application of environment and planning regulations, and effective communication of the efficacy of radiological decontamination efforts. Conversations with Los Angeles emergency management personnel suggest resolving potential conflicts among key stakeholders, in advance of a crisis, could minimize delays and hence reduce business interruption. Similarly, mitigation of long-run behavioral effects, arising as they do from fear and uncertainty, provides significant scope for policy mediation, particularly in allaying community concerns about lingering contamination. A thoughtful and well-implemented communication program concerning the risks of radiation prior to an RDD attack would facilitate such trust. These considerations suggest the possibility of a trade-off between the speed (and thus perceived effectiveness) of site clean-up and the magnitude of long-run behavioral effects (if in haste the “all clear” is sounded prematurely). Our results also suggest a role for more traditional economic policy instruments. Since the long-run behavioral effects manifest as increases in long-run regional resource supply prices, and decreases in willingness to pay, these effects might be offset by countervailing federal government subsidies, aimed at directly addressing the cost and price handicaps imposed by misplaced fears of radiological contamination. In future work, we hope to explore the cost in federal government revenue of targeted subsidies addressing long-run behavioral effects from catastrophic events.
Usage is a detailed, dynamic CGE model of the U.S. It has been developed at the Centre of Policy Studies, Monash University, in collaboration with the U.S. International Trade Commission. Prominent applications of Usage include USITC (2004 and 2007).


3. “Constant ratios of elasticities of substitution, homothetic” (Hanoch 1971).

4. Abstracting from the occupational detail underlying our calculations, the $7.5 m. of lost labor input via deaths can be understood as 0.8 x 180 x $0.052m = $7.5 m., where 0.8 is the proportion of casualties that are employed, 180 is the number of deaths, and $0.052m. is the average downtown wage. Again, abstracting from detail, the $18.7 m. of lost labor input via injuries can be understood as 0.8 x (20,000 x 7 + 270 x 90) x $0.052 / 365, where 0.8 is the proportion of casualties that are employed, 20,000 is the number of minor injuries, 7 is the number of days convalescence associated with minor injuries, 270 is the number of serious injuries, and 90 is the number of days convalescence associated with serious injuries.

5. Our estimate of 90071’s GDP at factor cost is calculated as follows. From Bureau of Labour Statistics Quarterly Census of Employment and Wages we obtain VLAB, a vector of sectoral wagebills for zipcode 90071. Using LA County data on wages and capital payments from the ORANI-LA database, we calculate \( \Psi_s \) , the capital / labour ratio for sector \( s \). We calculate GDP for 90071 as \( \sum_s [VLAB_s + \Psi_s VLAB_s] \).

6. We calculate the value of output in zipcode 90071 as follows. Using LA County data on output and value added by sector from the ORANI-LA database, we calculate \( \Xi_s \), output / value-added ratios by sector. Using \( \Psi_s \), the capital / labour ratio for sector \( s \), and VLAB, the wagebill by sector in zipcode 90071 (see note 6 above), we calculate the total value of sales in zipcode 90071 as \( \sum_s \Xi_s [VLAB_s + \Psi_s VLAB_s] \).

7. Readers familiar with CGE modeling will recognize this approach is analogous to a cost-neutral twist, used in CGE modeling to generate autonomous movements in input ratios for given input prices (see Dixon and Rimmer 2002). Twist cost-neutrality is achieved via calibrated movements in input using efficiency. Unlike our “tax” approach, this does not generate changes in allocative efficiency, and as such, standard twists are not appropriate for modeling fear-induced changes in demand.

8. Early examples of explaining CGE results via stylised models can be found in Dixon et al. (1982 and 1984). A recent example is Dixon et al. (2010).

9. We convert survey results for horizontal demand shifts to vertical demand shifts using the formula \( f_{v_i} = \frac{f_q}{e_i} \), where \( f_q \) is the survey result for the percentage decrease in demand for commodity \( i \) at any given price (a horizontal demand schedule shift), \( e_i \) is the absolute value for the price elasticity of demand for commodity \( i \) (calculated from the ORANI-LA database) and \( f_{v_i} \) is the percentage change in willingness to pay for commodity \( i \) for any given level of demand for \( i \).

10. Our fear taxes also generate allocative efficiency losses (see Section 4.2). In terms of Fig. 2, this would be expressed as a “westerly” movement of the AS schedule. However this movement is small. To avoid clutter, it is suppressed in Fig. 2.
REFERENCES


Fig. 1. Section of Los Angeles central business district closed for radiological decontamination (zip code 90071)

(Map image © 2009 Google)
Fig. 2. Short-run resource loss and behavioral effects described in a regional aggregate demand / aggregate supply framework.
Fig. 3. Long-run behavioral effects described in a regional aggregate demand / aggregate supply framework.
Fig. 4. Stylised paths for stigma and real regional GDP impacts

Fear index
Real GDP loss

Fear index (Left axis)

-$890m.

-$2628m.

Event year, T
T1 say, T + 5
T2 say, T + 10
**Table I.** Survey excerpts relating to scenario description

<table>
<thead>
<tr>
<th>An Event as it is Occurring.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imagine now that you see the following news report in your newspaper or on the Internet or hear the report on television or the radio. Please read the following scenario carefully.</td>
</tr>
</tbody>
</table>

**Dirty Bomb Rocks Financial District of Los Angeles!**

180 Dead and Hundreds Potentially Exposed to Radiation as Mayor Requests Downtown to Seek Shelter for Hours

(An approximately 500 word scenario description followed together with an audio recording of the LA mayor.)

**The Aftermath of the Event: One Month Later**

Suppose you have been closely following the developments of this terrorist attack in Los Angeles and now see the following news report in your newspaper or on the Internet or hear the report on television or the radio.

**Radiation Levels Throughout Los Angeles Pose Little Threat says Panel of Health Officials!**

Today the Mayor Received a Reassuring Report from a Team of Radiation Experts Regarding Long-term Health Risks. The Downtown to Re-Open.

(An approximately 200 word scenario description followed together with an audio recording of the LA mayor.)
**Table II.** Survey excerpts relating to required compensation

**Delayed Involvement with the Financial District:**

*Questions asked following Mayor’s statement on Day 30 of scenario*

These two example questions pertain to professional services but the same format was used for vacation, food, electronic products and job. Not shown here is the paragraph description we provided for each just prior to the following questions.

Based on the Mayor’s announcement and actions taken by the city please answer the following two questions regarding your use of these professional services (for example, bankers, attorneys, stock brokers, architects, accountants, financial advisors, and real estate agents).

a. Would **never** use these professional services near the financial district again.

b. Would not use these professional services near the financial district for **at least five years** but would consider using these services there after that.

c. **d, e, f** - Same format but substitute 3 years, 1 year, 6 months, 1 month

da. Would **continue** to use these professional services near the financial district.

**Required Incentives to be Involved with Financial District Right Away**

What is the **absolute minimum** cost savings you would require to move forward with using these professional services **right away**, even if they are located within a mile of the financial district. Remember you had planned to spend **$3000** for these professional services.

Which of the following eight options **now** best describes your absolute minimum cost savings to continue to use these professional services in Los Angeles right away?

a. No incentive needed; I would use these professional services right away.

b. I would need at least 2% savings ($60) to use these professional services right away.

c. **d, e, f, g** - Same format but substitute 4%, 8%, 15%, 25%, 50%\(^1\)

h. Would not use these professional services right away for any cost savings.

\(^1\): *For required wage increases we used same format except with 100% included and we asked respondents to compare to their current or imagined wages if not working.*
Table III. Survey results depicting percentage wait times before doing business in the financial district.

<table>
<thead>
<tr>
<th>Wait Time (At least)</th>
<th>Professional Services</th>
<th>Vacation</th>
<th>Food</th>
<th>Electronic Products</th>
<th>Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right After “All Clear”</td>
<td>32%¹ (68%)²</td>
<td>12% (88%)</td>
<td>10% (90%)</td>
<td>28% (72%)</td>
<td>23% (77%)</td>
</tr>
<tr>
<td>One Month</td>
<td>15% (53%)³</td>
<td>13% (75%)</td>
<td>12% (78%)</td>
<td>10% (62%)</td>
<td>15% (63%)</td>
</tr>
<tr>
<td>Six Months</td>
<td>12% (41%)³</td>
<td>17% (58%)</td>
<td>24% (54%)</td>
<td>22% (41%)</td>
<td>14% (49%)</td>
</tr>
<tr>
<td>Twelve Months</td>
<td>22% (19%)</td>
<td>22% (36%)</td>
<td>16% (38%)</td>
<td>17% (24%)</td>
<td>16% (33%)</td>
</tr>
<tr>
<td>Thirty Six Months</td>
<td>7% (13%)</td>
<td>11% (25%)</td>
<td>10% (28%)</td>
<td>6% (18%)</td>
<td>12% (21%)</td>
</tr>
<tr>
<td>Sixty Months</td>
<td>4% (8%)⁴</td>
<td>12% (12%)</td>
<td>11% (17%)</td>
<td>10% (7%)</td>
<td>8% (13%)</td>
</tr>
<tr>
<td>Never in Future</td>
<td>8%</td>
<td>12%</td>
<td>17%</td>
<td>7%</td>
<td>13%</td>
</tr>
<tr>
<td>Sample Size (N)</td>
<td>331</td>
<td>331</td>
<td>331</td>
<td>331</td>
<td>332</td>
</tr>
</tbody>
</table>

1. Percentage indicating they would not wait to do business in the financial district.
2. Percentage who are still waiting.
3. Used in Table IV (short-run).
4. Used in Table IV (long-run).

Table IV. Size of horizontal shifts relating to financial district.

<table>
<thead>
<tr>
<th>Commodity/factor</th>
<th>Short-run</th>
<th>Long-run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Services</td>
<td>-41%</td>
<td>-8%</td>
</tr>
<tr>
<td>Vacation</td>
<td>-58%</td>
<td>-12%</td>
</tr>
<tr>
<td>Food</td>
<td>-54%</td>
<td>-17%</td>
</tr>
<tr>
<td>Electronic Products</td>
<td>-41%</td>
<td>-7%</td>
</tr>
</tbody>
</table>

Table V. Levels of required incentives to do business in the financial district right away.

<table>
<thead>
<tr>
<th>Required Incentive</th>
<th>Professional Services</th>
<th>Vacation</th>
<th>Food</th>
<th>Electronic Products</th>
<th>Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>26%</td>
<td>12%</td>
<td>14%</td>
<td>22%</td>
<td>13%</td>
</tr>
<tr>
<td>2%</td>
<td>2%</td>
<td>0%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>4%</td>
<td>3%</td>
<td>5%</td>
<td>8%</td>
<td>10%</td>
<td>9%</td>
</tr>
<tr>
<td>8%</td>
<td>12%</td>
<td>7%</td>
<td>4%</td>
<td>7%</td>
<td>9%</td>
</tr>
<tr>
<td>15%</td>
<td>12%</td>
<td>18%</td>
<td>10%</td>
<td>14%</td>
<td>11%</td>
</tr>
<tr>
<td>25%</td>
<td>10%</td>
<td>12%</td>
<td>8%</td>
<td>8%</td>
<td>17%</td>
</tr>
<tr>
<td>50%</td>
<td>12%</td>
<td>12%</td>
<td>8%</td>
<td>14%</td>
<td>7%</td>
</tr>
<tr>
<td>100%</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>7%</td>
</tr>
<tr>
<td>No Amount Is Enough</td>
<td>24%</td>
<td>34%</td>
<td>46%</td>
<td>23%</td>
<td>25%</td>
</tr>
<tr>
<td>Mean %</td>
<td>15%¹</td>
<td>19%</td>
<td>15%</td>
<td>16%</td>
<td>23%</td>
</tr>
</tbody>
</table>

¹: Used in Table VI.
**Table VI.** Size of vertical shifts relating to financial district.

<table>
<thead>
<tr>
<th>Commodity/factor</th>
<th>Short-run</th>
<th>Long-run¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional services demand</td>
<td>-15%</td>
<td>-3%</td>
</tr>
<tr>
<td>Vacation demand</td>
<td>-19%</td>
<td>-4%</td>
</tr>
<tr>
<td>Food demand</td>
<td>-15%</td>
<td>-5%</td>
</tr>
<tr>
<td>Electronic products demand</td>
<td>-16%</td>
<td>-3%</td>
</tr>
<tr>
<td>Labor supply</td>
<td>23%</td>
<td>6%</td>
</tr>
</tbody>
</table>

¹ Calculated by applying the rate of decay in horizontal shifts between the six month and sixty month marks (see Table III) to the values in the short-run column.

**Table VII.** Average of actual and imputed vertical shifts relating to product demands in the financial district

<table>
<thead>
<tr>
<th>Commodity/factor</th>
<th>Short-run</th>
<th>Long-run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional services demand</td>
<td>-22.6%</td>
<td>-4.5%</td>
</tr>
<tr>
<td>Vacation demand</td>
<td>-27.1%</td>
<td>-5.7%</td>
</tr>
<tr>
<td>Food demand</td>
<td>-19.2%</td>
<td>-5.9%</td>
</tr>
<tr>
<td>Electronic products demand</td>
<td>-14.5%</td>
<td>-2.7%</td>
</tr>
</tbody>
</table>

**Table VIII.** Average vertical product demand and labor supply shifts, LA-County

<table>
<thead>
<tr>
<th>Commodity / factor</th>
<th>Short-run</th>
<th>Long-run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional services demand</td>
<td>-0.84282%</td>
<td>-0.16856%</td>
</tr>
<tr>
<td>Vacation demand</td>
<td>-0.17924%</td>
<td>-0.03805%</td>
</tr>
<tr>
<td>Food demand</td>
<td>-0.00193%</td>
<td>-0.00060%</td>
</tr>
<tr>
<td>Electronic products demand</td>
<td>-0.00025%</td>
<td>-0.00005%</td>
</tr>
<tr>
<td>Labor supply</td>
<td>0.49295</td>
<td>0.13464</td>
</tr>
</tbody>
</table>

*Calculated by multiplying Table VII values by zip 90071’s share of each LA County activity.*
Table IX. Regional macroeconomic variables: RDD scenario, event year, percentage change relative to basecase (unless otherwise specified)

<table>
<thead>
<tr>
<th>Regional macro variable:</th>
<th>Resource loss effects</th>
<th>Behavioural effects</th>
<th>(4) Required rates of return</th>
<th>(5) Willingness-to-pay (WTP) movements</th>
<th>(6) Wage premium</th>
<th>(7) Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) Business interruption</td>
<td>(2) Deaths</td>
<td>(3) Injuries</td>
<td>(5a) LA based agents</td>
<td>(5b) Extra-LA based agents</td>
<td></td>
</tr>
<tr>
<td>1. Real GDP</td>
<td>-0.37</td>
<td>-0.001</td>
<td>-0.004</td>
<td>-0.004</td>
<td>-0.018</td>
<td>-0.014</td>
</tr>
<tr>
<td>2. Capital stock</td>
<td>0.00</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>3. Employment</td>
<td>-0.15</td>
<td>-0.002</td>
<td>-0.001</td>
<td>-0.006</td>
<td>-0.033</td>
<td>-0.014</td>
</tr>
<tr>
<td>4. Real investment</td>
<td>-0.20</td>
<td>-0.001</td>
<td>-0.004</td>
<td>-0.222</td>
<td>-0.188</td>
<td>-0.091</td>
</tr>
<tr>
<td>5. Real private consumption</td>
<td>-0.32</td>
<td>-0.001</td>
<td>-0.003</td>
<td>-0.013</td>
<td>-0.128</td>
<td>-0.055</td>
</tr>
<tr>
<td>6. Real public consumption</td>
<td>0.00</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>7. Real interregional exports</td>
<td>-0.20</td>
<td>-0.001</td>
<td>-0.003</td>
<td>0.017</td>
<td>-0.109</td>
<td>0.149</td>
</tr>
<tr>
<td>8. Real overseas exports</td>
<td>-0.18</td>
<td>-0.003</td>
<td>-0.005</td>
<td>0.050</td>
<td>0.254</td>
<td>0.236</td>
</tr>
<tr>
<td>9. Real interregional imports</td>
<td>0.07</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.026</td>
<td>-0.279</td>
<td>0.171</td>
</tr>
<tr>
<td>10. Real overseas imports</td>
<td>-0.11</td>
<td>-0.001</td>
<td>-0.002</td>
<td>-0.025</td>
<td>-0.060</td>
<td>-0.025</td>
</tr>
<tr>
<td>11. Real inventories</td>
<td>0.03</td>
<td>-0.002</td>
<td>-0.001</td>
<td>0.013</td>
<td>0.172</td>
<td>0.075</td>
</tr>
<tr>
<td>12. Real wage</td>
<td>-0.15</td>
<td>0.002</td>
<td>-0.001</td>
<td>-0.006</td>
<td>-0.033</td>
<td>-0.014</td>
</tr>
<tr>
<td>13. GDP deflator</td>
<td>0.02</td>
<td>0.001</td>
<td>0.001</td>
<td>-0.022</td>
<td>-0.255</td>
<td>-0.107</td>
</tr>
<tr>
<td>14. Average capital rental price</td>
<td>-0.41</td>
<td>-0.001</td>
<td>-0.006</td>
<td>-0.028</td>
<td>-0.392</td>
<td>-0.163</td>
</tr>
<tr>
<td>15. Regional terms of trade</td>
<td>0.08</td>
<td>0.001</td>
<td>0.001</td>
<td>-0.009</td>
<td>-0.200</td>
<td>-0.079</td>
</tr>
<tr>
<td>16. Real GDP ($m.)</td>
<td>-$1.873</td>
<td>$5</td>
<td>-$22</td>
<td>-$22</td>
<td>-$92</td>
<td>-$70</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations based on ORANI-LA simulations.
Table X. Regional macroeconomic variables: RDD scenario, long-run, percentage change relative to basecase (unless otherwise specified)

<table>
<thead>
<tr>
<th>Regional macro variable</th>
<th>(1) Required rates of return</th>
<th>(2a) LA based agents</th>
<th>(2b) Extra-LA based agents</th>
<th>(3) Wage premium</th>
<th>(4) Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>-0.17</td>
<td>-0.041</td>
<td>-0.088</td>
<td>-0.219</td>
<td>-0.52</td>
</tr>
<tr>
<td>Capital stock</td>
<td>-0.22</td>
<td>-0.048</td>
<td>-0.106</td>
<td>-0.191</td>
<td>-0.56</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.14</td>
<td>-0.035</td>
<td>-0.077</td>
<td>-0.241</td>
<td>-0.49</td>
</tr>
<tr>
<td>Real investment</td>
<td>-0.21</td>
<td>-0.055</td>
<td>-0.115</td>
<td>-0.184</td>
<td>-0.57</td>
</tr>
<tr>
<td>Real private consumption</td>
<td>-0.15</td>
<td>-0.044</td>
<td>-0.095</td>
<td>-0.167</td>
<td>-0.45</td>
</tr>
<tr>
<td>Real public consumption</td>
<td>-0.15</td>
<td>-0.044</td>
<td>-0.095</td>
<td>-0.167</td>
<td>-0.45</td>
</tr>
<tr>
<td>Real interregional exports</td>
<td>-0.10</td>
<td>0.008</td>
<td>-0.079</td>
<td>-0.156</td>
<td>-0.33</td>
</tr>
<tr>
<td>Real overseas exports</td>
<td>-0.15</td>
<td>0.023</td>
<td>-0.020</td>
<td>-0.439</td>
<td>-0.59</td>
</tr>
<tr>
<td>Real interregional imports</td>
<td>-0.05</td>
<td>0.024</td>
<td>-0.088</td>
<td>-0.083</td>
<td>-0.20</td>
</tr>
<tr>
<td>Real overseas imports</td>
<td>-0.11</td>
<td>-0.030</td>
<td>-0.065</td>
<td>-0.154</td>
<td>-0.36</td>
</tr>
<tr>
<td>Real inventories</td>
<td>-0.09</td>
<td>-0.001</td>
<td>0.005</td>
<td>-0.241</td>
<td>-0.32</td>
</tr>
<tr>
<td>Real wage</td>
<td>-0.02</td>
<td>-0.006</td>
<td>-0.013</td>
<td>0.094</td>
<td>0.05</td>
</tr>
<tr>
<td>GDP deflator</td>
<td>0.06</td>
<td>-0.006</td>
<td>-0.017</td>
<td>0.114</td>
<td>0.15</td>
</tr>
<tr>
<td>Average capital rental price</td>
<td>0.13</td>
<td>-0.003</td>
<td>-0.010</td>
<td>0.065</td>
<td>0.18</td>
</tr>
<tr>
<td>Regional terms of trade</td>
<td>0.05</td>
<td>-0.004</td>
<td>-0.012</td>
<td>0.085</td>
<td>0.12</td>
</tr>
<tr>
<td>Real GDP ($m.)</td>
<td>-$856</td>
<td>-$209</td>
<td>-$447</td>
<td>-$1,116</td>
<td>-$2,628</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations based on ORANI-LA simulations.
<table>
<thead>
<tr>
<th>Impact</th>
<th>Category</th>
<th>Real GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Short-run</td>
<td>Direct business interruption (BI)</td>
<td>-$1,400</td>
</tr>
<tr>
<td>(2) Short-run</td>
<td>Indirect business interruption (BI)</td>
<td>-$473</td>
</tr>
<tr>
<td>(3) Short-run</td>
<td>Other resource loss</td>
<td>-$27</td>
</tr>
<tr>
<td>(4) Short-run</td>
<td>Behavioral</td>
<td>-$890</td>
</tr>
<tr>
<td>(5) Short-run</td>
<td>Total short-run</td>
<td>-$2,789</td>
</tr>
<tr>
<td>(6) Long-run</td>
<td>One-Year Behavioral</td>
<td>-$2,628</td>
</tr>
<tr>
<td>(7) Long-run</td>
<td>Total Ten-Year Behavioral</td>
<td>-$15,808</td>
</tr>
<tr>
<td>(8) NPV</td>
<td>NPV (at 5%) of Total Ten-Year Behavioral</td>
<td>-$12,850</td>
</tr>
<tr>
<td>(9) Ratio = [(1)+(2)]/(1)</td>
<td>S-R total BI/S-R Direct BI</td>
<td>1.34</td>
</tr>
<tr>
<td>(10) Ratio = [(1)+(2)+(3)]/(1)</td>
<td>S-R Total/S-R Direct BI</td>
<td>1.36</td>
</tr>
<tr>
<td>(11) Ratio = (6)/(1)</td>
<td>L-R One-Year/S-R Direct BI</td>
<td>1.88</td>
</tr>
<tr>
<td>(12) Ratio = (7)/(1)</td>
<td>Total Ten-Year Behavioral/S-R Direct BI</td>
<td>11.3</td>
</tr>
<tr>
<td>(13) Ratio = (7)/[(1)+(2)+(3)]</td>
<td>Total Ten-Year Behavioral/Ordinary Loss</td>
<td>8.32</td>
</tr>
</tbody>
</table>

*Source: Authors' calculations based on ORANI-LA simulations.*