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Estimating the Economic Impact of Natural and Social Disasters, with an Application to Hurricane Katrina

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Summary. This paper examines taxable sales in the Los Angeles and Miami metropolitan areas to find evidence of the short- and long-run effects of the Rodney King riots and Hurricane Andrew on their respective economies. The comparison of these two events shows that the King riots had a long-term negative effect on Los Angeles' economy while Hurricane Andrew had a short-term positive effect on the Miami economy. The paper also applies the contrasting experiences of Los Angeles and Miami to New Orleans following Hurricane Katrina. In some ways, Katrina is a hybrid of these two events since it combines elements of both a natural disaster and a social disaster. The paper examines how Katrina is similar to each of the previous incidents and how these similarities might affect the recovery of New Orleans following the storm.

Introduction

Hurricane Katrina, which swept into New Orleans and the Gulf Coast on 29 August 2005, caused far and away the largest damages in real dollar terms of any hurricane in US history, with estimates of property losses ranging from $70 to $125 billion (Wildasin, 2006). Its final death toll of over 1400 also places it among the worst natural disasters ever suffered by the United States. New Orleans was particularly hard hit by the storm, as flood waters remained for weeks after Katrina while levies were repaired. Many wonder how long, if ever, it will take the economy of New Orleans to recover from this cataclysmic event. This paper examines the prospects of post-Katrina New Orleans through the lens of two disasters that struck major American cities 14 years ago: Hurricane Andrew, which hit Miami in August 1992, and the Rodney King riots, which took place in Los Angeles in late April and early May 1992. In addition, we use the contrasting experiences of Los Angeles and Miami to identify the types of policies that are likely to be successful in rebuilding the New Orleans economy.

Both Hurricane Andrew and the Rodney King riots represent a highly significant event in each city's economic history. Until Katrina, Hurricane Andrew was the most expensive natural disaster in US history with insured losses topping $15.5 billion in nominal terms and total property losses exceeding $26 billion (National Weather Service, 2005). Similarly, the Rodney King riots, which resulted in 53 deaths, 10 000 arrests, 2300 injuries, more than 1000 destroyed buildings and an estimated cost to the city of $1 billion in damages, were the

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worst civil disturbances the US has seen in modern years (Matheson and Baade, 2004).

The two cities, however, took markedly different paths to recovery following the disasters and that is of particular importance to this paper. The initial devastation wrought by Hurricane Andrew was followed by a surge in economic activity in the south Florida area as residents and businesses returned flush with private and public insurance payments earmarked for rebuilding. Los Angeles, on the other hand, despite the anticipation that 500 private corporations would invest more than $1 billion in the riot-torn areas of south central Los Angeles, failed to restore its economy in the short run. In fact, the private group launched to encourage private redevelopment funding only brought in $400 million in corporate investment from 1992 to 1999, with much of that money going to areas that were among the least affected by the riots (Matheson and Baade, 2004). Economic activity in Los Angeles following the riots took at least 10 years to return to its previous levels, if indeed full recovery ever occurred.

The next section of the paper reviews existing literature on the economic impact of natural disasters on local economies. This is followed by empirical analyses of the economic aftermaths of Hurricane Andrew and the Rodney King riots that demonstrate the contrasting paths after these two events. This is followed by a discussion of the Hurricane Katrina rebuilding effort in light of the previous results.

Review of Natural Disaster Impact Studies

Scholars have devoted modest attention to assessing the economic impact on local, regional and national economies that have experienced natural disasters. Given the substantial economic disruption that these catastrophes can create, it is surprising that there is a paucity of literature on the subject. Pelling *et al.* offered this explanation for the scarcity of studies on the economic consequences of natural disasters

> Given the far-reaching consequences of disaster shocks with a natural trigger it is perhaps surprising that disaster studies have held a relatively marginal place in development theory and practice until very recently. Disaster shocks have consistently been interpreted as exceptional events operating outside 'normal' development theory and practice. As a result disaster vulnerability has not been integrated into development planning (Pelling *et al.*, 2002, p. 301).

As further noted by Hirschleifer

> Sociologists, psychologists, historians, and policy planners have all devoted considerable attention to the nature, sources, and consequences of disaster and recovery, but the professional economic literature is distressingly sparse. ... Yet disasters are natural economic experiments; they parallel the tests to destruction from which engineers and physicist learn about the strength of material and machines. Much light would be thrown upon the normal everyday economy if we understood behaviour under conditions of great stress (Hirschleifer, 1993).

There are important reasons to accelerate the study of the economic impact of natural disasters, in particular hurricanes, on the US. First, hurricanes appear to be increasing in frequency and severity. In addition, population and income growth along the Atlantic and Gulf coasts have put an increasing number of people and properties at risk. Unfortunately, these two trends suggest that economic disruptions from storms will increase in the coming years. Further research on the aftermath of hurricanes can aid in current and future economic recovery efforts by applying lessons learned from the past.

The social and economic devastation wrought by Katrina has clear implications for government policy. Costs associated with this storm have exceeded anything previously experienced and a more precise rendering of those costs is essential to sound economic decision-making. In addition to the deaths,

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displacement and property losses, significant social costs in terms of race and class relations have been incurred. Katrina sent the unmistakable message that storms of this intensity stretch social institutions and infrastructure beyond their ability to cope and new strategies must be developed to minimise the direct physical damage and loss of life as well as the indirect social damage, which may dwarf the direct costs inflicted by these severe storms. Storms of unprecedented ferocity and frequency necessitate modification and reinforcement of social institutions to prevent the breach of not only physical levées but social structures as well. This paper does not identify what a breach in social structures means for the economic recovery period. Rather, it is the contention of this report that the revival from storms, such as Katrina, may well be protracted and impaired not only as a result of the extensive physical damage, but through rupturing those social institutions that serve an essential function in the recovery after a natural catastrophe.

Current literature on the economic impact of hurricanes does not reach a consensus on whether the net effect of a catastrophe is positive or negative in the long run, or whether any such economic effects are transitory or permanent. Most studies suggest that major storms cause temporary disruptions in economic activity followed by a short-term boom period as the region engages in rebuilding efforts (West and Lenze, 1994). For example, in summarising the impact of Hurricane Hugo, Gillespie concludes

> There was a loss of 6,800 jobs in tourism and trade immediately following the storm. Most of the negative impact on employment directly attributable to Hugo was short-lived. Although many businesses were closed by the storm, most of them were back in business by early spring. The positive impact on the construction industry of Hugo building was enormous, adding over 8,000 jobs by the spring, which more than offset the brief loss of jobs in the tourism and trade sectors (Gillespie, 1991, p. 2).

Burrus *et al.* observe that the literature supports the proposition that the short-term substantial destruction wrought by a hurricane the size of Andrew is reduced by rebuilding efforts financed by external sources.

> Long-run migration effects aside, these studies indicated that the short- to medium-run impact of high-intensity of storm damage on regional economic activity is ameliorated by reconstruction-related local spending (financed largely from extraregional sources, such as insurance claim payments and federal disaster funds (Burrus *et al.*, 2002, p. 118).

However, Guimraes *et al.*, who use a multisector regional econometric model, finds different results

> We found that the income gains were neutral overall, despite a major surge in construction, retail, and other sectors. In one of the most affected sectors of South Carolina, agriculture and forestry, the income gain remained below the unreimbursed wealth loss. Thus, we maintain that catastrophe was not a positive economic force (Guimraes *et al.*, 1993, p. 103).

Using evidence from three case studies on the recovery of countries after natural disasters, Benson and Clay (2004) find that natural disasters often hinder long-run development. Because governments face pressure to satisfy immediate needs after a disaster, this often draws investment away from development of physical and human capital stocks. In addition, Benson and Clay also detail the relationship between disaster preparedness and the level of development. While least-developed countries typically have the smallest losses in magnitude, the impact of natural disasters on living standard is typically the most severe (a similar argument appears in Toya and Skidmore, 2005). In addition, Kahn (2005) notes that death tolls from natural disasters in developing nations are much higher than in the industrialised world. One reason for these findings is that the large majority of property in least-developed countries is ill-equipped to

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withstand natural disasters. Further, some least-developed countries have large numbers of citizens living in isolated areas, which complicates relief efforts.

Countries with higher levels of development tend to have larger losses because of higher property values, but the impact of the disaster is lower because of higher insurance rates and better preparedness, such as building construction and advanced weather and seismic monitoring devices. Development, however, can also increase the risk of a natural disaster. For example, urban development that encourages migration to coastal areas can put more people in the path of a tropical storm. Furthermore, just as poorer countries are likely to suffer disproportionately from natural disasters, poorer segments of the population within industrialised countries are also more vulnerable to natural disasters than the affluent (Zedlewski, 2006). The plight of those without the means to leave New Orleans in the face of Hurricane Katrina is one obvious example of this.

West and Lenze (1994) note the difficulties associated with regional econometric modelling when applied to natural disasters. The economic multipliers used in models such as the US Bureau of Economic Analysis Regional Industrial Multiplier System (RIMS II) (and other multiplier models) are based upon interindustry relationships within regions during normal production patterns. Following major disasters, however, the economy within a region may be anything but normal and these same interindustry relationships may not hold. Since there is no reason to believe that the usual economic multipliers are the same following disasters, any economic analyses based upon these multipliers may be highly inaccurate (Matheson, 2004).

Previous studies also conclude that the paths to recovery differ according to the size of the storm. This is not unexpected considering that the level of destruction varies directly with the hurricane's strength. It is worth noting, however, that frequent 'low-intensity' hurricanes can still generate substantial damage. Burrus *et al.* observe that

> Low-intensity hurricane strikes have substantial impacts on local economies. We find that the impact of a low-intensity hurricane is, on average, between 0.80 and 1.23% of annual regional output. If a region's average annual rate of growth is 4%, these potential impacts amount to approximately one-fifth to one-third of an average year's growth (Burrus *et al.*, 2002, p. 124).

Business interruptions, particularly in the tourist industry, typically occur with each storm, regardless of the storm's strength when it hits land. Thus, the impact on tourism of high- and low-intensity storms may be comparable in some situations. Burrus *et al.* (2002) also suggest that the frequency of hurricanes is important in determining their economic impact. Parts of the country that experience a greater incidence of low-intensity storms, for example, may be more economically vulnerable than areas that suffer from high-intensity, but infrequent, storms.

Finally, there is some support for the view that the cumulative effect of storms within a relatively short period of time is not additive. In studying the employment effects of hurricanes that affected Wilmington, North Carolina, Ewing and Kruse conclude that the economic impact of hurricanes is transitory and further observe that

> There may be a limit to the gains and losses associated with hurricanes that is based on the number of hurricanes that hit an area as well as the timing of the hurricanes. For instance, Bertha had a significant impact on the Wilmington economy whereas Bonnie that was similar in strength did not. Wilmington had not been hit by a hurricane for several years prior to Bertha and then experienced a total of five hurricanes in less than five years.
>
> In many respects, Hurricane Bertha was unremarkable when compared with the other four hurricanes that followed her. However, as the first, Bertha triggered a flurry of activity that appears to have reduced the adverse impact of the larger

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storms that followed (Ewing and Kruse, 2005, pp. 9–10).

Horwich's (2000) examination of the Kobe, Japan, earthquake of 1995, arrives at similar findings. While property damage was severe, the loss of life, although large, was a fraction of that experienced by developing nations that suffered through similarly damaging earthquakes. As appears to be the case in most studies of hurricanes, the economic disruption caused by the disaster was largely temporary. Manufacturing in the city, for example, returned to 98 per cent of its pre-earthquake trend within 15 months. It is important to keep these general observations in mind in assessing the economic damage of the Rodney King riots or Hurricane Katrina.

An Empirical Examination of Hurricane Andrew and the Rodney King Riots

The first step in determining an economic impact of a major event is to identify variables vital to making such an assessment. In order to isolate the economic effects of a natural or manmade disaster—i.e. to minimise statistical 'noise'—it is crucial to find data as specific to the area and as high-frequency as possible. California provides quarterly data on taxable sales for individual cities and counties, while Florida provides monthly taxable sales data for individual counties. Taxable sales data are collected at the point of sale, which reflects economic activity at a specific location. Other data, such as personal income, may reflect economic conditions in geographical areas outside that in which the individual lives. Taxable sales are a good indicator of economic wellbeing as they are strongly correlated with many measures of economic activity such as personal income or gross domestic (city) product. In addition, both datasets provide a sufficient number of observations before and after their respective incidents to permit meaningful statistical analysis. The California data are available from the first quarter of 1987 through the third quarter of 2004, providing 5 years of data before and 12 years of data following the riots. The Florida data are available from the first month of 1980 through the middle of 2005.

Because we use county-level taxable sales as our data source, we are unable to distinguish between 'direct' losses, or losses occurring at the time of the disaster, and 'indirect' losses, or the value of goods and services not produced after the disaster. In a 2003 publication, the Economic Commission for Latin America and the Caribbean outlines a method to estimate separately these direct and indirect losses. In comparison, we examine only the sum of these types of losses that are traceable with taxable sales data.

In addition, we are unable to quantify the effects on informal economic activity, social capital, the environment or specific segments of the population. It should at least be noted that it is generally accepted that the magnitude of the informal economy versus the formal economy is smaller in an industrialised nation such as the US as compared with the relatively poorer countries in Latin America. In the poorest Los Angeles neighbourhoods struck by the Rodney King riots (and the poverty-stricken areas hit by Hurricane Katrina in New Orleans), however, the informal sector may be comparatively large. Furthermore, the racial undercurrents present in both of these catastrophes highlight the need to consider the role of social capital in the economy. At the very least, losses in taxable sales should be seen as a lower bound for the total economic losses suffered by an economy due to a natural or social disaster.

Since the gross personal income of Los Angeles County in 1992 exceeded $200 billion in nominal terms and that of Miami/Fort Lauderdale/West Palm Beach metropolitan statistical (MSA) area in 1992 was nearly $100 billion, even the effects of a major economic event such as Hurricane Andrew or the Rodney King riots can be obscured by the normal economic fluctuations of these large, diverse economies. Many factors including the local, regional and national business cycle, state and federal government policies, monetary policy and inflation, international factors, consumer and business

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confidence, wealth effects and a host of other ingredients influence taxable sales. The next step is to separate the impact of Hurricane Andrew and the Rodney King riots from these other factors.

One method for filtering much of the 'noise' is to analyse the change in taxable sales in an area affected by an event compared with that of an otherwise similar area that did not feel the effects of the event. To this end, the taxable sales in the City of Los Angeles are calculated as a percentage of the taxable sales in the rest of the County of Los Angeles. Since it is reasonable to assume that many economic, seasonal, political and demographic factors will affect the economies of the County and the City of Los Angeles in a similar way, this method serves to account for the economic impact of all the variables that the city and county have in common. The city/county ratio, therefore, is influenced only by economic events that are unique to one area or the other. While some rioting occurred in areas peripheral to the City of Los Angeles (most notably in the City of Inglewood), the vast majority of the destruction occurred within the Los Angeles city limits. Thus, the riots, if significant, should affect the city/county taxable sales ratio. Figure 1 plots this ratio over the period of the sample and the data exhibit an acceleration of the decline of the City of Los Angeles' taxable sales as a percentage of those of the county.

Similarly, the taxable sales ratio for the Miami MSA, which includes Miami-Dade, Broward and Palm Beach counties, is calculated as a percentage of the taxable sales for the rest of the state. In Florida, county data are used in lieu of city data because Hurricane Andrew caused damage throughout the Miami MSA, rather than the relatively localised damage of the Rodney King riots. Figure 2 plots the south Florida taxable sales ratio (adjusted for seasonality) over the period of the sample. Even a cursory glance at Figure 2 reveals a reduction in taxable sales around the time of Hurricane Andrew followed by a substantial spike in taxable sales immediately afterwards.

Figure 1. Taxable sales ratio for Los Angeles City versus Los Angeles County. Ratio of taxable sales in the City of Los Angeles to the remainder of the County of Los Angeles. Note that while significant downturns in the ratio are common, they are generally accompanied by immediate reversals. This is reflected by the negative coefficients on the one- and two-period lagged dependent variables in the regression results. The exception is the 1992 period of the Rodney King riots.

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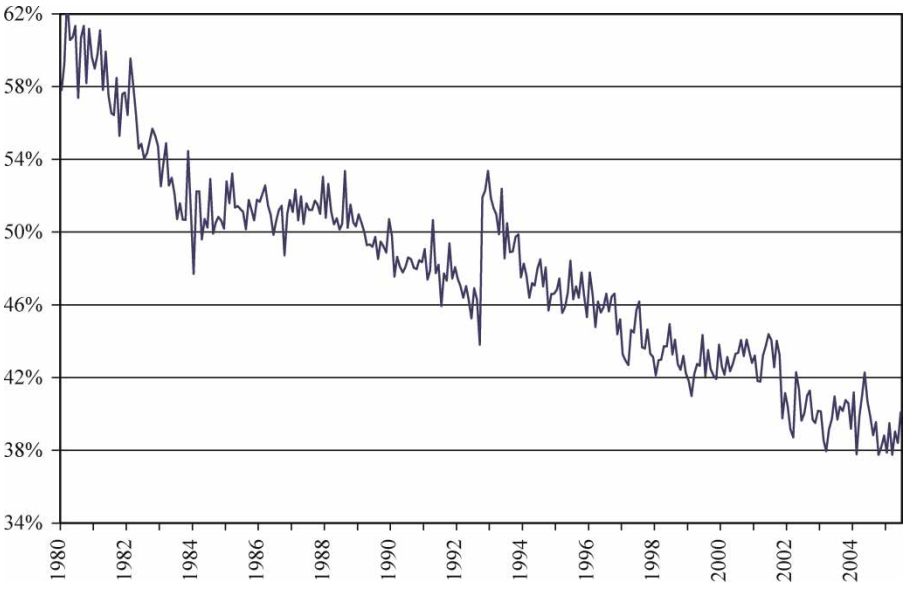

Figure 2. Taxable sales ratio for Miami MSA versus state of Florida. Ratio of taxable sales in the three counties of the Miami MSA (Broward, Dade and Palm Beach) to the remainder of the state of Florida.

In order to examine the impact of the Rodney King riots and Hurricane Andrew on taxable sales in their respective cities, we use intervention analysis on an ARIMA model as outlined in Box and Tiao (1975). In addition to its previous use in analysing the impact of the Rodney King riots (Matheson and Baade, 2004), others have employed similar techniques to analyse a wide array of economic problems ranging from the impact of the US bombing of Libya in 1986 on terrorist activity (Enders *et al.*, 1990) to the effects of Federal Emergency Management Agency (FEMA) policies on employment in hurricane-stricken cities (Ewing and Kruse, 2005). Intervention analysis provides a formal test for the change in the mean of a series as a result of an exogenous shock at a specific point in time.

The general intervention ARIMA(P,D,Q) model for the taxable sales ratio is

$$y_t^* = \beta_0 + \sum_{p=1}^{P} \Phi_p y_{t-p}^* + \sum_{q=0}^{Q} \Theta_q \varepsilon_{t-q} + \beta_1 z_t \quad (1)$$

where, y_t^* is the taxable sales ratio in time-period t; P is the number of lagged values of y_t^* in the model known as the autoregressive (AR) dimension of the model; ε_t is an error term, Q is the number of lagged values of the error term representing the moving average (MA) dimension of the model; and z_t is an independent variable representing the effect of the Rodney King riots. D is the number of times y_t (as well as any independent intervention variables) is differenced to create y_t^* .

The model can be modified to include a quarterly or monthly seasonal component. These seasonal variables are statistically insignificant at any reasonable confidence level and therefore are dropped from the Los Angeles data. Seasonal variables, however, are statistically significant in the south Florida model. These variables are included in the estimation, but they are removed from the results for brevity.

It is clear from Figures 1 and 2 that neither of the taxable sales datasets is stationary and augmented Dickey–Fuller tests confirm this suspicion. However, augmented Dickey–Fuller tests on first-differenced taxable sales with a trend term and no lagged differences reject the null hypothesis of a unit root in both datasets at any reasonable significance level. Based on these results, we set D equal

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to one in both ARIMA models. Next, we determine the autoregressive and moving average dimensions through estimation and diagnostic testing. Trial and error reveal that the Los Angeles data are best described by a model with two lagged dependent variables and no moving average term, so that P is equal to 2, and Q is equal to 0. The maximum likelihood estimation (MLE) results for this model are shown as equation (1) in Table 1. The one result of note is that the constant term is negative and significant, indicating that taxable sales in the City of Los Angeles have been falling in comparison with those in the County of Los Angeles over the sample frame.

To determine the effect of the riots, a dummy variable, z, is entered for the model. The specification of this variable depends on whether the effects of the riots on taxable sales are temporary or permanent as well as the nature of any recovery from the riots. Since the original time-series does not follow a stationary path, one should not necessarily expect that the taxable sales ratio would return to its previous level following a shock to the economy. In addition, non-stationarity does not preclude instances where a shift in one direction is countered by a later movement in the opposite direction. Since private and government agencies committed themselves to repairing the damage, one would expect a rapid recovery in the ratio to its previous levels, or, to borrow a term from development models, a recovery to the steady state. If recovery did occur, realised growth rates in the ratio should, therefore, be higher than predicted by the model over subsequent periods.

Box and Tiao (1975) suggest multiple intervention and response possibilities. The MLE results shown in Table 1, equation (2), demonstrate one extreme where the riots can be seen as a pure pulse function with the riots causing only a single-period decline with a complete recovery in the following period, as in Figure 3b. In a first differenced model, $z = 1$ in 1992.2, $z = -1$ in 1992.3 and $z = 0$ elsewhere. On the other extreme, the event can be seen as pure step event causing a one-period decrease to a permanently lower level as shown in Figure 3a. In this model, where the taxable sales are first differenced, the intervention variable, z, takes a value of 1 in

Table 1. Intervention analysis of the Rodney King riots, sample period 1987.1–2004.3 (dependent variable: $y_t^* = \Delta$(taxable sales ratio))

Equation	Constant	AR (1)	AR (2)	z (Intervention)	Diagnostics
(1)	−0.00136***	−0.393***	−0.280**	—	log L = 267.862
	(−3.58)	(−2.91)	(−2.22)		SSE = 0.001938
(2)	−0.00137***	−0.358***	−0.240**	−0.0063	log L = 268.859
	(−3.49)	(−3.02)	(−2.00)	(−1.43)	SSE = 0.001885
(3)	−0.00118***	−0.403***	−0.276**	−0.0129***	log L = 271.680
	(−3.23)	(−3.47)	(−2.38)	(−2.82)	SSE = 0.001737
(4)	−0.00136***	−0.358***	−0.235**	−0.0089	log L = 269.402
	(−3.50)	(−3.02)	(−1.96)	(−1.77)	SSE = 0.001856
(5)	−0.00136***	−0.389***	−0.265**	−0.0113***	log L = 270.921
	(−3.71)	(−3.32)	(−2.24)	(−2.49)	SSE = 0.001776
(6)	−0.00136***	−0.405***	−0.278**	−0.0127***	log L = 271.728
	(−3.81)	(−3.48)	(−2.40)	(−2.84)	SSE = 0.001735

Notes: All taxable sales ratios have been first-differenced. The coefficients are reported with their associated t-statistic for the null hypothesis that the estimated value is equal to zero. *** and ** represent statistical significance at the 1 per cent and 5 per cent significance levels respectively.

Equation (1): no riot variable. Equation (2): riot variable in 1992.2 only. Equation (3): riot variable from 1992.2 to end of sample frame. Equation (4): riot variable with convex recovery $(1/t)$ from 1992.2 to end of sample. Equation (5): riot variable with 5-year linear recovery from 1992.2 to 1997.1 inclusive. Equation (6): riot variable with linear recovery from 1992.2 to end of sample frame.

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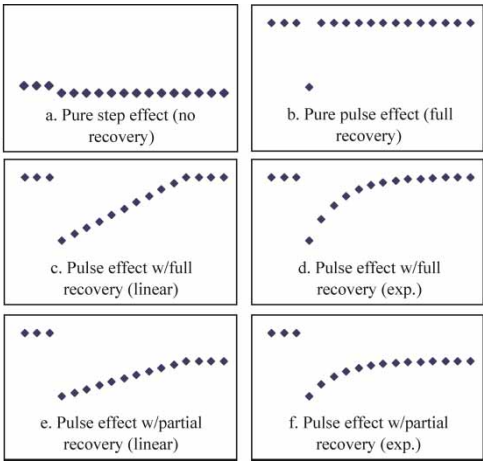

Figure 3. Various impulse-response possibilities.

the second quarter of 1992 and a value of 0 in all other periods. The MLE results for this model, as seen in Table 1, equation (3), clearly show that this pure step model displays a much better fit than a pure pulse model shown in equation (2), suggesting that the effects of the riots have persisted beyond the quarter in which they occurred. The dummy variable for the pure pulse model is negative but not statistically significant while the dummy variable for the pure step model is not only negative but also highly statistically significant. This indicates that something during the second quarter of 1992, most probbaly the riots, had a long-lasting negative impact on the economy of the City of Los Angeles while leaving the economy of the rest of the County of Los Angeles relatively unscathed. The coefficient on the z variable in equation (3) shows that the taxable sales ratio in the city fell by 1.29 percentage points. Based on taxable sales in the city and the rest of the county of $5.94 billion and $12.96 billion respectively, a 1.29 percentage point drop in the city–county ratio corresponds to a $166 million drop in taxable sales in the City of Los Angeles during the quarter of the Rodney King riots with losses continuing into the future.

Another possible response to the riots would include an immediate negative impact followed by a gradual return to the original level over a number of periods that so that $z = 1$ in 1992.2, $z = -1/n$ in the subsequent n periods, and $z = 0$ elsewhere (corresponding to Figure 3c in the undifferenced data), or $z = 0$ prior to 1992.2, $z = 1$ in 1992.2, $z = -(1/\alpha)^n$ for all periods subsequent to 1992.2 (corresponding to Figure 3d in the undifferenced data). Alternatively, the response could be an immediate negative impact followed by a return to a level that is either higher or lower than that existing before the riots, as in Figures 3e and 3f.

Without a detailed *a priori* expectation of the effects of the riots on economic activity, one is simply left to the task of examining multiple models for fit. Models similar to Figures 3d and 3f showed poor model fit under nearly all values of α. This is not surprising as there is little indication from media reports of a rapid reconstruction and recovery. For comparison, the MLE results for a model with $\alpha = 2$ and full recovery is shown in Table 1, equation (4).

The linear recovery models as in Figures 3c and 3e provide more interesting results. The MLE results for the linear, full recovery models are shown in Table 1 as equations (5) and (6) for post-riot periods of 5 years and the entire sample (12.5 years) respectively. The relatively poor fit of the 5-year model (compared with the pure step model) suggests that recovery did not come quickly. This confirms the general impression of people in riot-struck areas. A *Los Angeles Times* poll taken 5 years after the riots revealed that 35 per cent of respondents in areas affected by the violence reported that some businesses in their neighbourhoods had still not reopened 5 years after the fact (*Los Angeles Times*, 1997).

In comparison, the model in equation (6), which assumes full recovery over the entire sample, displays a slightly better fit than the pure step model. This indicates that after 12 and a half years, the city's economy may have finally returned to its previous levels. This recovery model also slightly outperforms any of the linear models that provide for only partial recovery and any models that provide for full recovery over a shorter time-period.

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Overall, the results indicate that, at best, the City of Los Angeles has only just recovered from the riots that occurred over 12 years ago and the model fits between equation (3) (no recovery) and equation (6) (12.5-year linear full recovery) are also close enough to permit one conceivably to take an even more pessimistic view and suggest that the economy has yet to recover entirely. The results in Table 1, equation (6) point to $5.56 billion in lost taxable sales over the entire 12-year post-riot history of Los Angeles City. The results in Table 1, equation (3), which assume that recovery from the riots has never occurred, produce $14.34 billion and counting in lost taxable sales.

Of course, while some of the consumer spending that occurred in the city may have moved out of the region entirely due to the riots, much of this consumer spending is likely simply to have shifted from the City of Los Angeles to suburbs within the rest of the Los Angeles metropolitan area. Thus, the $5.56 and $14.34 billion figures should be treated with care for two reasons. First, from a region-wide standpoint, the City of Los Angeles' loss may be another city's gain so that county-wide taxable sales losses are likely to be much lower than the figures quoted for the city. This, however, is little comfort to tax officials in the City of Los Angeles. Secondly, as spending shifts from the City to the County, the numerator in the City/Rest of County ratio falls while the denominator rises, biasing the loss figures upwards. Thus, the losses quoted should be seen as an upper bound to the total taxable sales losses in the City. Even considering these two factors, however, the evidence suggests the Rodney King riots had a profoundly negative effect on the economy of the City of Los Angeles for a prolonged period of time.

Miami, on the other hand, presents an entirely different story. The Miami data are best described by a model with two lagged dependent variables and a moving average term lagged for 1 year, so that P is equal to 2, and Q is equal to 12, but Q does not include MA terms for lagged periods 1–11. The maximum likelihood estimation (MLE) results for this model are shown as equation (1) in Table 2. Monthly dummy variables are included in the model to account for seasonal variations in Miami's taxable sales versus the rest of the state but the resulting coefficients are omitted from the table. Since seasonal dummy variables have been included, the sign on the constant term cannot be interpreted in the same manner as in the Los Angeles model.

To determine the effect of the hurricane, a dummy variable for August 1992, z(HA), is entered into the model. A cursory examination of taxable sales following August 1992, however, clearly shows a recovery in taxable sales in the month immediately following Hurricane Andrew so a second intervention dummy variable, z(RCV2), is entered for September 1992. The MLE results for a model with a single month of heightened taxable sales following the hurricane are recorded in Table 2 as equation (2). The dummy variable for z(HA) is negative and significant in indicating that something, most probably Hurricane Andrew, had a large negative impact on the south Florida economy in August 1992, while leaving the rest of Florida's economy relatively unscathed. The coefficient on the z(HA) variable shows that the taxable sales ratio in the MSA fell by 5.32 percentage points. Based on taxable sales in the MSA and the rest of the state of $3.08 billion and $7.67 billion respectively, a 5.32 percentage point drop in the ratio corresponds to a drop in taxable sales in the city of $408 million in the month of August. The sign and magnitude of the coefficient for the z(RCV2) recovery variable, however, show that taxable sales recovered in the month immediately following the hurricane. Specifically, taxable sales in the month after the hurricane are 1.49 percentage points above pre-hurricane levels, which means after one month Miami recovered about $114 million, or nearly 30 per cent, of the loss caused by Hurricane Andrew.

The next step is to determine how long the bump in taxable sales persisted after Hurricane Andrew and in what manner did this 'recovery effect' wear off. As is the case

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Table 2. Intervention analysis of Hurricane Andrew, sample period 1980.01–2005.06 (dependent variable: $y_t^* = \Delta$ (taxable sales ratio))

Equation	Constant	AR(1)	AR(2)	MA(12)	*z*(HA)	*z*(R2)	*z*(R1)	Diagnostics
(1)	0.00853**	−0.582***	−0.278***	0.174***				log L = 895.538
	(−2.45)	(−10.43)	(−4.97)	(3.07)				SE = .05035
(2)	0.00854***	−0.594***	−0.272***	−0.164***	−0.0532***		0.0149	log L = 909.851
	(−2.58)	(−10.45)	(−4.83)	(2.90)	(−4.94)		(1.37)	SSE = 0.045972
(3)	0.00864***	−0.616***	−0.296***	0.150***	−0.0449***		0.0388***	log L = 914.163
	(−2.64)	(−10.87)	(−5.26)	(2.70)	(−4.06)		(3.28)	SSE = 0.044713
(4)	0.00866***	−0.650***	−0.331***	0.163***	−0.0299***		.0553***	log L = 922.643
	(−2.64)	(−11.72)	(−5.98)	(2.97)	(−2.67)		(5.45)	SSE = 0.042351
(5)	0.00906***	−0.656***	−0.334***	0.179***	−0.0258**	0.0662***	0.0527***	log L = 924.521
	(2.72)	(−11.87)	(−6.03)	(3.25)	(−2.29)	(4.31)	(4.31)	SSE = 0.041849

Notes: All taxable sales ratios have been first-differenced. Dummy variables for seasonal components are omitted from results. The coefficients are reported with their associated t-statistic for the null hypothesis that the estimated value is equal to zero. *** and ** represent statistical significance at the 1 per cent and 5 per cent significance levels respectively.
Equation (1): no Andrew variable. Equation (2): Andrew variable in 9/1992, recovery variable in 10/1992. Equation (3): Andrew variable in 9/1992, convex recovery decline (1/t) from 10/1992 to end of sample frame. Equation (4): Andrew variable in 9/1992, linear recovery decline from 10/1992 to 4/1994. Equation (5): Andrew variable in 9/1992, convex ramp over three months and linear recovery decline variable from 1/1993 to 4/1994.

with the Rodney King riots, the taxable sales ratio following the initial drop and subsequent recovery could take several paths. Taxable sales could remain permanently high following a hurricane, which is an unlikely scenario. Alternatively, taxable sales could gradually return to their previous levels following a concave function where $z = 0$ prior to 1992.08, $z = 1$ in 1992.09, $z = -(1/\alpha)^n$ for all months after September 1992 (corresponding to the inverse of Figure 3d in the undifferenced data) or a linear function where $z = 1$ in 1992.08, $z = -1/n$ in the subsequent n periods, and $z = 0$ elsewhere (corresponding to the inverse of Figure 3c in the undifferenced data).

Again, without a detailed *a priori* expectation of the effects of the hurricane on economic activity, one is simply left to the task of examining multiple models for fit. As in the case of Los Angeles, models similar to Figures 3d and 3f showed poor model fit under nearly all values of α. For comparison, the MLE results for a model with $\alpha = 2$ and full recovery is shown in Table 2, equation (3).

The linear return models as in Figures 3c and 3e provide more interesting results. The MLE results for a linear, full return model over an 18-month period, the return period which showed the best model fit, are shown in Table 2, equation (4). The coefficients on z(HA) and z(RCV2) show that taxable sales in south Florida fell by 2.99 percentage points in the immediate aftermath of Andrew, but quickly rebounded to a level 5.53 percentage points above the usual level by the following month, after which they returned to their previous levels over the succeeding 18 months.

An even more detailed examination of taxable sales following Hurricane Andrew suggests that it may have taken several months following the hurricane for recovery spending to hit its peak. Table 2, equation (5), shows the regression results for a final model including a third intervention variable, z(RCV1), which takes an undifferenced value of 0.7 in the month immediately after Andrew, 0.85 two months after the hurricane and 1 a full three months after the event; z(RCV2) assumes a linear decline in taxable sales down to previous levels over the following 15 months for an 18-month total period in elevated taxable sales as in equation (4).

The results in Table 2, equation (5), provide the best model fit and point to an immediate drop in taxable sales of $198 million during the month of Hurricane Andrew. In the following months, however, south Florida residents, flush with cash from insurance settlements and subsidised government loans and grants, returned to the area and began to purchase goods to replace those destroyed by the storm and to rebuild homes and businesses. Spending reached its post-Andrew peak within 3 months and the bump in economic activity persisted for fully 18 months. In total, south Florida enjoyed an increase in spending over the subsequent year and a half that totalled $3.81 billion.

The $3.81 billion figure should be viewed with caution for two reasons. First, as in the case of Los Angeles, while some of the consumer spending that occurred in the south Florida area may have moved out of the region entirely due to the hurricane, some of this consumer spending may have simply shifted to other parts of the state as people temporarily relocated after the disaster. This fact would overestimate the early negative impact of the hurricane on the state overall even though observed impact on the south Florida region was quite large. Secondly, Hurricane Andrew also affected other areas of the state besides the Miami metropolitan area (although not to nearly the same magnitude as the damage to Miami). If other counties in Florida also had a similar pattern of taxable sales as those studied, the denominator in the City/Rest of County ratio should also fall and rise along with the numerator leading to an underestimation of the total effect of the hurricane on both the south Florida and overall state economies.

It should also be noted that there is no reason to believe that the composition of taxable sales in Los Angeles or Miami is the same before and after the incidents, nor can intervention analysis shed light on what makes up taxable sales in either region. For

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example, building supply stores may have benefited at the expense of the tourism industry. The fact remains, however, that total taxable sales after their respective disasters, regardless of composition, followed distinctly different paths in Miami and Los Angeles.

An Application to Hurricane Katrina

In light of the two contrasting results in the previous section, it is time to turn attention to the aftermath of Hurricane Katrina and the path to recovery in New Orleans. Obviously, since both events dealt with devastating hurricanes, it is natural to compare the aftermath of Hurricane Katrina with the aftermath of Hurricane Andrew and therefore anticipate a spending boom in New Orleans once the city is back on its feet. In many ways, however, Hurricane Katrina appears to be a hybrid of the Hurricane Andrew and the Rodney King riots events combining the damaging physical effects of a natural disaster like Hurricane Andrew with the devastating social disruption of the Rodney King riots. Much like the King riots a decade earlier, Hurricane Katrina highlighted the racial divisions present in the country and had repercussions far beyond the physical damage done to the city. A crucial policy question is what private citizens and government can do to ensure that New Orleans follows the positive path to recovery taken by Miami and not the dead end that occurred in Los Angeles. In order to predict how such factors might influence the recovery of New Orleans, it is important to identify the differences between the events in Miami and Los Angeles that affected their recovery or lack thereof.

The first primary difference between Hurricane Andrew and the Rodney King riots is the economic and racial demography of the areas affected by each event. The areas affected by the Rodney King riots were concentrated in the poorest areas of Los Angeles while Hurricane Andrew was much more of an 'equal opportunity' disaster. For example, in the nine census tracts surrounding the intersection of Florence and Normandie, the infamous epicentre of the riots where White truck driver Reginald Denny was beaten by a mob during the first few hours of the riots, the average poverty rate was just over 30 per cent in 1990. In comparison, the poverty rates for the entire County of Los Angeles MSA and the Miami MSA are around 18 per cent. Assuming that there are lower investment returns in poorer neighbourhoods, then private businesses will be slower to rebuild in these areas. Similarly, residents have less reason to return to damaged or destroyed homes in poor areas due to poor economic and employment prospects.

In this aspect, New Orleans may be likely to follow the path of Los Angeles as New Orleans is among the poorest large metropolitan areas in the country. The lower Ninth Ward area of New Orleans, which is one of the neighbourhoods with the most severe flood damage, was over 98 per cent Black and had poverty rates over 36 per cent in 2000. While wealthier areas of the city such as the French Quarter will undoubtedly undergo an economic resurgence, the experience of Los Angeles suggests that, without specific attention to rebuilding and reconstruction in the poorest neighbourhoods of New Orleans, economic activity in these areas is unlikely to rebound.

While it is likely that most economists would be in favour of allowing redevelopment money to flow to where it will be most productive, it is important to note that the devastation of middle- and lower-class neighbourhoods in New Orleans has a profound impact on the ability of the richer areas of the city to recover as well. These classes provided workers for the vital tourist industry and their abandonment of New Orleans has impaired the ability of the city to meet adequately the needs of service establishments in the French Quarter and central business district that cater to tourists (Baade and Matheson, 2007).

The labour and housing shortages make it doubtful that the city could host a major event at this juncture. For example, each large event at the Superdome (the large

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multipurpose sports arena in the city) requires approximately 2500 part-time workers. Unfortunately, the lack of housing in New Orleans means that no such pool of potential part-time workers is available in the city. Indeed, following Katrina, many of the workers who maintain the hotels and provide labour to the restaurant and bar business are housed in the hotels (Baade and Matheson, 2007). A Superdome and convention centre that is up and running tomorrow would bring in guests who would displace the very workers that provide guest services. While the poor and middle classes cannot survive without the jobs that the rich tourist areas provide, neither can the tourist industry survive without the labour supplied by the poor and middle classes and, at the very least, policy-makers need to consider carefully both the efficiency and equity aspects of redevelopment spending.

Important racial aspects also differentiate the post-disaster experiences of Los Angeles and Miami. The areas suffering the most damage in the Rodney King riots were predominantly in Black neighbourhoods. Only 43 per cent of White respondents in a *Los Angeles Times* poll reported that the riots directly affected their neighbourhoods compared with 83 per cent of African Americans. In this way, New Orleans imitates Los Angeles. The vast majority of residents trapped within the city as floodwaters rose following Katrina were poor Blacks from neighbourhoods like the Ninth Ward, who did not have access to transport that would have allowed them to escape the storm.

Recovery from the Rodney King riots was even more racially skewed. Five years after the riots, 37 per cent of Black respondents reported living in neighbourhoods where businesses had been damaged in the riots and had not yet reopened compared with less than 10 per cent of Whites. While the recovery efforts from Katrina are only just beginning, there are already racial differences in evaluating the effectiveness of the initial response. In a Gallup poll taken immediately after Katrina, roughly 60 per cent of Blacks thought that the federal government was slow in responding to the crisis because the victims were poor and Black, compared with roughly 20 per cent of Whites (CNN, 2005). Such underlying racial disharmony may make rebuilding in New Orleans as politically difficult as it proved to be in Los Angeles.

Another primary difference between the riots and Hurricane Andrew is the extent of human casualties. While Hurricane Andrew caused massive physical damage, the human toll was relatively light with only 26 deaths directly attributable to the storm. The Rodney King riots, on the other hand, caused far less property damage but resulted in 53 deaths and 2300 injuries. It is reasonable to presume that neighbourhood safety will be a factor as people decide whether to invest in a rebuilding effort. In Miami, many may believe that technological fixes are available that can minimise future damages even though the area cannot avoid being in the path of future storms. For example, Stark (2002) argues that stricter building standards enacted in the wake of Hurricane Andrew may reduce property damage by up to one-third.

Hurricane Katrina caused nearly 1500 deaths in the Gulf Coast region, including over 1100 fatalities in Louisiana, making it the deadliest natural disaster in the US in over 75 years (Louisiana Department of Health and Hospitals, 2006). Unless authorities can convince former residents that future hurricanes no longer pose such a danger to human life, many residents are unlikely to take the risk by returning to the region.

A final difference is the government response to each event. Since natural disasters comprise the overwhelming majority of officially declared federal disasters, there is little ability to analyse any systematic bias on the part of the Federal Emergency Management Agency (FEMA) against human-induced problems. However, a cursory examination of FEMA's response to the Rodney King riots versus other major catastrophes suggests that the agency seems to be far more willing to

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expend large sums of money on major natural disasters than on major social disruptions. The FEMA allocated just $148 million to rebuilding efforts in Los Angeles while dedicating $1.70 billion to Miami just four months later. It should be noted that, despite the large gap in gross payments, as a percentage of reported damages, FEMA's assistance to Los Angeles (roughly 15 per cent) is roughly equal to that provided to Miami (roughly 11 per cent). This was not the case following the 1994 Northridge earthquake, however. After this natural disaster, the Los Angeles area received $7.24 billion in FEMA payments covering nearly 50 per cent of total damages (Garrett and Sobel, 2003). It comes as no surprise, therefore, that taxable sales in California registered no measurable dip as a result of this damaging earthquake. It is reasonable to presume that the minimal federal response to the Rodney King riots, especially when compared with the lavish aid packages received by some cities in other circumstances, was at least in part responsible for the affected areas' slow or non-existent recovery from the turmoil.

Conclusions

Hurricane Katrina was a storm of unprecedented ferocity. By virtually any measure, the damage wrought dwarfs that caused by any past storms or the Rodney King riots. While a final damage assessment from Katrina may take years to compile, early estimates for total losses caused by Katrina are over $100 billion, or approximately five times that of Hurricane Andrew, and insured losses are estimated at up to $60 billion, which far exceeds Andrew's inflation-adjusted insured losses of $20.8 billion (Wildasin, 2006). For this reason, it cannot be assumed that the transition back to normalcy will be as quick as it was with previous disasters. Indeed, the particular details of the Katrina disaster, ranging from the city's geography to the intense local and national political pressures involved, make it unique in many ways.

There are lessons to be learned, however, from recovery efforts in past disasters. While everyone is hopeful that New Orleans will follow the path towards rapid revitalisation taken by Miami in the wake of Hurricane Andrew, the failure of Los Angeles' economy to recover following the Rodney King riots suggests that there is potential for an uneven recovery biased against racial minorities and the economically disadvantaged. Our concern is that the rebuilding effort will be modest at best and slow to develop in poorer areas, with the prospect of long-lasting negative effects on income. In wealthier areas, the pecuniary incentive for private business and citizens to rebuild is stronger and in some cases the rebuilding effort can cause net income *gains* in response to a natural disaster as was the case with Hurricane Andrew in Miami.

Based on the past events in Miami and Los Angeles, we make two specific recommendations to promote economic recovery in New Orleans. First, citizens must be convinced that the natural and man-made barriers against future hurricanes are sufficient to allow the city to weather future storms. Without such guarantees, displaced residents, both rich and poor, have little incentive to return to the city. Secondly, while private investment dollars and insurance settlements are likely to result in the reconstruction of the wealthier and economically vibrant areas of the city such as the French Quarter, it is clear that public money will be necessary to rebuild significant portions of the city, especially those areas where private money is slow to return. To this end, we recommend targeting a disproportionate amount of federal transfers towards poorer areas and areas with significant minority populations in order to stimulate growth. Effort, in addition, must be directed to rebuilding and strengthening social institutions. The clear undercurrents of social and economic unrest revealed in the aftermath of Hurricane Katrina suggest that the damage exceeded that which can be estimated through simple economic measures such as taxable sales or personal income. Rebuilding efforts, therefore, will be far more difficult than simply repairing damaged physical infrastructure.

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