

## **Natural Disasters and U.S. Economic Growth: 1952-2009**

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### **Abstract**

*Over the second half of the twentieth century, the United States has been hit by a number of major natural disasters. The impact of these disasters on U.S. economic growth is evaluated within a growth accounting framework controlling for national economic and financial conditions using an error correction model. The results of the analysis indicate that natural disasters have a small but statistically significant impact on the growth of gdp. Based upon the error correction analysis, it takes approximately 2.3 months for the national economy to return to normal trend growth following a natural disaster.*

**Key terms:** natural disasters, economic growth.

### ***1. Introduction***

Economic development is not simply a straight path of continual growth, but as Simmi and Martin (2010) point out, one that is repeatedly buffeted by all manner of disturbances large and small. Over the course of the twentieth century, the United States has been repeatedly affected by a variety of natural disasters of varying size and impact, such as Hurricane Betsy in 1965, the Loma Prieta earthquake in 1989, and Hurricane Andrew in 1992 to more recent events such as the Hurricane Katrina in 2005 and even more recently flooding along the Mississippi River this past year. While all disaster events do cause some level of economic impact, these impacts are generally most keenly felt within the affected region. Whether a disaster's economic impact is more widely distributed across the entire economy and how it may affect the national economy and long run economic growth is of ongoing concern. Over the last sixty years, the costs and vulnerability arising from natural disasters in the U.S. have increased dramatically. From 1950 to 2010, the costs associated with natural disasters have averaged approximately \$11 billion annually. Each year, the nation is struck by an average of 12.5 natural disaster events. These events include a wide range of natural hazard events such as droughts, earthquakes, hurricanes and tropical storms, to floods and wildfires.

Rising populations and economic development throughout the Southeastern, Southwestern, and Western U.S. have led to ever larger numbers of people, capital investments (housing and plant and equipment), and physical infrastructure vulnerable to a wide range of natural hazards. Analysts such as Bagstad, Stapleton and D'Agostino (2007), suggest that tax and subsidy programs and general development policies implemented by federal, state and local governments have contributed to this rising vulnerability by creating perverse sets of incentives that increase and encourage development within these hazard zones. Both Stehr (2006), and Sadowski and Sutter (2005) have noted that urban areas are facing greater vulnerability to catastrophic events, and face rising damage costs from hurricanes and storm damages while simultaneously experiencing reductions in death and injuries due to these events. Nordhaus (2006) finds that increases in hurricane damages are readily attributable to increased coastal development and possibly to global warming as well.

Studies such as Worthington and Valadkhani (2004) and Yang (2006) find that natural hazard events can and do have significant impact upon financial market returns. These impacts though are predominantly short run in nature. Few if any recent studies look directly at the impact on overall national economic activity and growth. Most studies tend to focus upon directly impacted regions or specific market sectors. In general, disasters tend to cause regional short term economic disruptions that may manifest themselves through both positive and negative changes in regional and sectoral employment, affect regional housing markets, and also impact regional price levels (Michel-Kerjan 2010; MacDonald, Murdoch and White 1987; Kask and Maani 1992). The focus of this paper is how natural disasters impact U.S. growth overall, and how transitory the shock from these events may be.

### ***2. Assessing the impact of natural disaster***

The impact of natural hazards on the economy can be evaluated through a number of different econometric and simulation methodologies (e.g. computable general equilibrium modeling [(CGE), input-output and dynamic input-output models).

Simulations methods, while capable of highlighting a wide range of effects across many sectors, also tend to have extensive data requirements that can be difficult to apply to the disaster scenario. Econometric modeling on the other hand, while reducing some of the level of detail that can be assessed generally does not require the same level of disaggregated data and can be more readily applied to the disaster scenario. Studies such as those by Baade, Baumann and Matheson (2005), and Vogel and Veeramacheni (2003; 2004) successfully use econometric methods to evaluate the impacts of disaster events on economic activity. These studies use both ARIMA and autoregressive techniques to assess the impact on regional and localized economic activity. In this study, the impacts of natural disaster on the U.S. are assessed through a growth accounting framework following Romer (1989), Mankiw et al. (1990, 1992), Coulumbe and Tremblay (2001), and Vinod and Kaushik (2007). At the core of this analysis is the production function, in which output (Y) is a function of capital (K), labor (L), and human capital (H), with technology entering the model as an exogenous variable (A). Additionally, a disaster damages variable is introduced into the final estimating equation to account for the impact of disaster on economic activity.

In the analysis, gross domestic product (GDP) is represented by a production function of the form:

1.  $Y(t) = A(t)K(t)^\alpha H(t)^\eta L(t)^{1-\alpha-\eta}$ ,  
where A represents a measure of technology or productivity, K is capital, H is human capital, L is labor, t is time, and  $\alpha$  and  $\eta$  are scale factors. Dividing both sides through by population, Equation 1 can be recast in per capita terms:
2.  $y(t) = ak(t)^\alpha h(t)^\eta l(t)^{1-\alpha-\eta}$ ,  
Taking logs on Equation 2 yields:
3.  $\log(y) = \log(a) + \alpha \log(k) + \eta \log(h) + (1 - \alpha - \eta) \log(l)$ ,  
where lower case y, a, k, h, and l represent per capita output, technology, capital, human capital, and labor respectively. Differentiating Equation 3 with respect to time and dividing by y yields the per capita growth equation:
4.  $g_y = g_a + \alpha g_k + \eta g_h + (1-\alpha-\eta)g_l$ ,  
where the subscripted g represents the respective growth rates of output, technology, capital, human capital and labor respectively. Since it is impractical to measure 'a' directly, it is set to a constant plus an error term yielding equations 5 and 6:
5.  $\log(y) = c + \alpha \log(k) + \eta \log(h) + (1 - \alpha - \eta) \log(l) + \mu_1$ , and
6.  $g_y = c + \alpha g_k + \eta g_h + (1-\alpha-\eta)g_l + \mu_2$ .  
Modifying equation 5 by the addition of a disaster damages variable, results in the following:
7.  $\log(y) = c + \alpha \log(h) + \beta \log(L) + \gamma \log(k) + \delta \log(\text{Disaster Damages}) + \mu_1$ .

Equation 7 is estimated to evaluate the impact natural hazards on overall U.S. economic activity using the Engle Granger two step error correction methodology. Time series such as GDP, capital investment, and other national data tend to be nonstationary and thus present some issues in terms of standard regression analysis. The two-step error correction approach consists of the following steps. Data series for the analysis are first evaluated to evaluate if they are stationery in level form, I(0), or in other words, that a unit root exists. If the series are not stationery in levels but instead integrated in first difference form I(1), Equation 7 can then be estimated in level form with the inclusion of a time trend. The resulting residual from this equation is then examined and if it is found to be stationery I(0), then the variables are said to be cointegrated. The equation can then be re-estimated in first difference form including a new variable, the residual which is now lagged one period and represents an error correction term. Since the evaluation is conducted in log form, estimating this new equation is tantamount to estimating the growth equation (Equation 6) with the inclusion of both the error-correction term and a disaster damages variable (which since it enters as a logged first difference is now a growth rate). This error-correction term represents the adjustment factor for the relationship that brings it back to the long run.

### 3. Data and analysis

Data for the analysis was collected from a number of sources. Information on the frequency and overall level of damages from natural disasters is from the EM-DAT (EM-DAT: OFDA/CRED International Disaster Database) database. The database includes natural disasters dating back as far as 1900 and through 2010. U.S. national economic data was not as extensive however, and thus the analysis was restricted to the period of 1950 to 2010. Real U.S. gross domestic product, real private gross domestic investment and the personal consumption expenditures index (PCE) were collected from both the Bureau of Economic Analysis and NIPA tables.

The PCE index was used to convert nominal disaster damage costs from the EM-DAT database into real costs through the period under analysis. Population estimates used in the analysis to convert the data into per capita terms was collected from the U.S. Census bureau. Data on labor force and labor force participation rates were collected from the Bureau of Labor Statistics website. Education data was collected from the National Center for Education Statistics, and is used as a proxy for human capital. It is measured as the percentage of the population with a four year college degree.

The actual equations that are estimated are:

$$8. \log(y) = c + \alpha \log(h) + \beta \log(l) + \gamma \log(k) + \delta \log(\text{Disaster Damages}) + \lambda \text{Trend} + \mu_1, \text{ and}$$

$$9. \text{dlog}(y) = c + \alpha \text{dlog}(h) + \beta \text{dlog}(l) + \gamma \text{dlog}(k) + \delta \text{dlog}(\text{Disaster Damages}) + \tau (\text{Error Correction})_{-1} + \mu_2.$$

Equation 8 includes a time trend variable that starts at 1950. In Equation 9, the error correction term is the residual from estimating Equation 8, lagged one period. Variables for the analysis are listed in table 1. Summary statistics of the data are shown in Table 2.

Analysis of the variables indicates that they are non-stationery in levels, but are stationery in first differences. Following the procedure outlined above, equation 8 is estimated first and the residual examined to see if it is stationery I(0). If it is found to be stationery, then the variables are cointegrated and the analysis in the second stage can proceed. A priori, theory suggests that the signs on the coefficients for labor force and capital should be positive, or in other words that increases in both labor force and capital investment would lead to increases in output. While theory would also suggest that the coefficient on human capital should also be positive, in practice, it tends to be sensitive to the data that is used as a proxy for this variable. Human capital is acquired in a myriad of ways from formal education that may come about by attendance in primary, secondary, and post-secondary institutions, as well as by learning by doing. Additionally, attendance in formal education, especially post-secondary may be impacted by general economic conditions. It is possible that during periods of high growth, students may leave college when employment opportunities arise prior to being awarded their college degree and people may return to college during downturns. Thus, a priori, it is difficult to hypothesize the sign of this coefficient. The same thing is true when hypothesizing the sign on the disaster damages variable. Disaster events may cause extensive damage at the regional level, and lead to losses in human and physical capital.

However, there are a number of possible outcomes from the disaster scenario including situations where the disaster leads to increases in employment and output as a result of recovery and reconstruction activities. Additionally, since disaster events tend to be localized, there is the possibility that trade and production activities are shifted to other parts of the country. That being said, even with the potential silver-lining effects arising from reconstruction activities, there are liable to be uncompensated losses, suggesting that the coefficient should be negative. Initial analysis of the all of the individual variables,  $y$ ,  $h$ ,  $l$ ,  $k$ , and  $DD$ , indicate that they are not stationery in levels, I(0), but are all stationery in first difference form, I(1). The residual from estimating the first equation was found to be stationery, and thus it was possible to apply the two step procedure. Estimates for both the first equation in level form with the inclusion of a trend variable and the error correction equation are shown in Table 3. Coefficient estimates for all of the variables are consistent with 'a priori' hypotheses, with changes in capital and labor force accounting for the predominant amount of change in output and output growth.

In the level equation, human capital was found to have a negative and significant relationship with output. As previously explained, this may be attributable to the fact that the proxy for human capital is the percentage of the population with a four year college degree, and thus reflects movement of individuals between the labor force and college to gain additional human capital skills. In the error correction equation, while still estimated as negative, the percentage of the population with college degrees was not statistically significant. The coefficient on disaster damages was estimated to be negative in both equations. In the level regression, though it was not found to be significant, suggesting that disasters had very limited impact on overall U.S. gdp. This outcome is consistent with the disaster literature (see for example Albala-Bertrand 1993; 2000). While disasters may have a very large localized or regional impact, this impact does not necessarily translate into gdp losses in the national economy. Estimates for the error correction equation, or what is essentially the growth equation show a slightly different result. Here, the coefficient on the disaster damages coefficient is found to be negative and statistically significant. The overall effect though is very low, impacting short term growth by just under two tenths of a percent. The error correction term in the second regression captures the adjustment process from short run to long run trend. A negative and statistically significant coefficient indicates that the economy will eventually return back to trend growth following disruptions such as those arising from natural disaster.

In this case, the estimated coefficient of  $-0.19$ , suggests that it will take approximately 2.3 months for U.S. gdp to return to trend growth rates following a major natural disaster.

#### 4. Conclusions

Natural hazards are a continual source of short term disruption to the economy as current events continue to demonstrate. During the late spring and summer of 2011 the Midwestern U.S. and areas along the Mississippi delta faced the threat of flooding. Parts of the west and southwest continue to face problems from drought conditions to wildfire. The Southeast and Gulf Coast are now in the middle of hurricane season. While it is true that regionally, natural hazard events can cause serious and sometimes long term impacts upon local and regional economies, these impacts do not necessarily affect overall national output. The analysis presented above, indicates that to a large degree, this is the case for the U.S. Natural disasters have a limited but perceptible impact on the growth of U.S. gdp. This impact though is almost completely eliminated within a few months as growth rates revert back to trend. Economic agents from firms to households will make decisions regarding reconstruction, the location of plant and equipment, and the whole host of other economic considerations. While the impacted community may continue to feel the effects of the hazard's impacts, domestic trade patterns, relationships and economic activities within and between the region and the national economy adjust.

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**Table 1: Variables used in the analysis**

Variable	Series title	Source	Period
y	Per capita real U.S. GDP	BEA	1950-2010, Annual
h	Percentage of population with 4 year college degree	NCES, U.S. Census Bureau	1952 – 2009, Annual
l	Labor force participation rate	BLS	1950-2010
k	Real gross private domestic investment per capita	NIPA, U.S. Census Bureau	1950-2010
DD	Disaster damages per capita	EM-DAT	1950-2010

**Table 2: Summary Statistics**

Variable	y	h	l	k	DD
Mean	28781.31	0.586892	63.56600	3969.312	49.62014
Median	27014.14	0.592508	64.20000	3592.941	30.26549
Maximum	43818.38	0.645094	67.10000	7461.279	537.1573
Minimum	14247.62	0.527846	58.70000	1458.478	0.184265
Std. Dev.	8874.601	0.043096	3.018961	1770.251	84.13492
Observations	50	50	50	50	50

**Table 3: Two Step Estimation**

Variable (dep. var.: log y)	Coefficient Estimate	Variable (dep. var.: Dlog y)	Coefficient Estimate
C <sub>1</sub>	3.666668*** (1.0061)	C <sub>2</sub>	0.015036*** (0.001813)
Log k	0.164097*** (0.02717)	Dlog k	0.169693*** (0.011637)
Log l	0.879605*** (0.25005)	Dlog l	0.715547*** (0.255953)
Log h	-0.476518** (0.15458)	Dlog h	-0.311745 (0.225023)
Log DD	-0.002392 (0.00146)	Dlog DD	-0.001641** (0.000536)
Trend	0.015654*** (0.000851)	Error Correction(-1)	-.191836** (0.065518)
Adj R2	0.997		0.849
F	3309.664***		49.72***
1952-2009	50 observations	1960-2009	44 observations

\* 0.10 level of significance.      \*\* 0.05 level of significance.      \*\*\* 0.01 level of significance