Informal and Formal Financial Resources and Small Business Resilience to Disasters

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Abstract

The following article examines the impact of Hurricane Katrina on small business success and adaptation. Small business success is characterized as increased revenues when compared to pre-disaster levels. Adaptation is characterized as post-Katrina changes to business infrastructure. A multivariate probit with sample selection allows the empirical analysis to account for the simultaneity of changes in revenue and adaptation and also sample selection bias introduced through business demise. The results suggest the importance of pre-disaster mitigation and adaptation activities as well as the effectiveness of formal financial resources in supporting adaptation. Informal financial resources are found to be largely ineffective.

Keywords: Resilience, adaptation, mitigation, small business, multivariate probit with selection

1. Introduction

Natural disasters are becoming more frequent as increased population density intersect increased incidence of extreme weather resulting from climate change (Rassmussen, 2004). This has fueled interest in the myriad of ways that countries, individuals, and businesses are affected by disasters. This article analyzes the impact of informal and formal financial resources on the ability of small businesses to reopen after a natural disaster (Hurricane Katrina) and adopt an adaptive strategy to lessen the impact of future natural disasters.

Small businesses are, in many ways, more vulnerable to disasters than large businesses. Limited access to capital and lack of geographic diversity can mean that small businesses are more likely to suffer long-term impacts; in fact, small businesses are more likely to close as a result of a disaster (Wasileski et al., 2011). For small business, the impact of a disaster can vary from closed and unlikely ever to reopen, to open and thriving. One approach to conceptualizing the varying impacts of a disaster is known as resilience. Resilient businesses are businesses that are open after disaster and return to or exceed pre-disaster levels of employment and profit (Wasileski et al., 2011; Stafford et al., 2010; Brewton et al., 2010; Marshall and Schrank, 2014). Resilience treats the disaster response as an adaptive process whereby entities can react and learn and prepare for a possible future event (Norris et al., 2008: Marshall and Schrank, 2014). By analyzing small businesses after a natural disaster we illuminate useful preparatory actions businesses may choose to adopt to increase their likelihood of being resilient.

Small business recovery is affected by available formal and informal financial resources. Formal resources can include loans from the Small Business Administration (SBA), write-downs or delayed payments to suppliers, and insurance payments. Informal financial resources, or often called bootstrapping financial tools (Winborg and Landstrom, 2001), include using household

resources to support the business. An additional form of informal financial assistance is called informal insurance and it involves borrowing money from friends or family members. Much emphasis in the small business financial literature has been given to start-up funds. In fact, studies have documented women's relative lack of access to formal start-up capital (Buttner and Rosen, 1989; Fay and Williams, 1993). This article expands the current literature by examining the extent to which informal and formal financial resources aid business resilience to disasters and further examines the extent to which these and other factors lead businesses to be considered survived, recovered or resilient using the *Small Business Disaster Recovery Framework* (Marshall and Schrank, 2014). The context by which this is examined is the medium-term, eight years after the Hurricane Katrina impacted small business in Southern Mississippi.

2. Background

On August 29, 2005, Hurricane Katrina made its third landfall on the border between Mississippi and Louisiana. Hurricane Katrina is known as the most severe hurricane to impact the United States with wind speeds that reached 140 miles per hour (MPH) over land, rainfall in the Gulf region that exceeded 1 inch per hour, and where large Mississippi cities such as Biloxi and Gulfport experienced storm surges in excess of 30 feet (Waple, 2005). The total insured damage from Hurricane Katrina is estimated to be $41.1 billion (Hartwig and Wilkinson, 2010).

2.1 Mitigation, Adaptation, and Resilience

The imminent preparations and immediate response to the disruption are known as mitigation activities. The Intergovernmental Panel on Climate Change (IPCC) defines mitigation and adaption as distinct processes. Mitigation refers to activities that temper and ease the

immediate impacts of a natural disaster (Smit et al., 1999). Because of this, mitigation is characterized as reactive, occurring directly before and immediately following the disaster.

Adaptation characterizes the mid-step between events, the reaction to the disruption when the disruption is not imminent. According to IPCC, adaptation refers to adjustments made when a disaster is expected but not impending. There are three categories of adaptation: 1) Anticipatory adaptation which refers to preparatory activities when the occurrence of a disaster is considered likely; 2) Autonomous adaptation which is less conscious and refers to spontaneous changes in ecological and human systems; and 3) Planned adaptation which refers to changes that take place after an event to return livelihoods to pre-disaster levels of welfare (Pachauri and Reisinger, 2007). This article will focus on both anticipatory and planned adaptation analyzing measures that were taken before the disaster to lessen the impacts and after to prepare for the next possible event.

Adaptation and mitigation culminate in the concept of resilience. Resilience is a term borrowed from ecology and applied to many fields including psychology, sociology, and economics. Ecology offers a basis for a workable definition of resilience. According to Holling (1978) resilience is "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variable" (14). The definition highlights the important components of resilience: change, reaction, and outcome. First, a disruption is imposed through some channel. Next is the reaction which is where adaptation occurs. Lastly, is the observable outcome and for resilient entities this means a return to an equilibrium state of being.

Three definitions of individual resilience are listed in Table 1, each highlight the importance of adaptation and mitigation, though the term mitigation does not appear explicitly. Another key to the definition of resilience is how successful resilience is measured. Some

definitions refer to a baseline level of activity (Butler, 2007) while others address the level of functioning (Egeland, 1993). The outcome of resilience is characterized by survival, persistence, or in some definitions, a return to an equilibrium level of activity (Norris et al., 2008). The nuances within these definitions have led to differing uses in the disaster literature.

Table 1. Definitions of individual resilience

Author, year	Definition
Masten, 1990	The process of, capacity for, or outcome of successful adaptation despite challenging of threatening circumstances
Egeland, 1993	The capacity for successful adaptation, positive functioning, or competence…despite high-risk status, chronic stress, or following prolonged or severe trauma
Butler, 2007	Good adaptation under extenuating circumstances; a recovery trajectory that returns to baseline functioning following a challenge

*Truncated version of a table appearing in Norris et al., 2008

2.2 Small Business Resilience

Some business literature refers to resilience as either survival, whether the business is open after a disruption, or how long a business is able to remain open after a disruption (Wasileski et al., 2011; Stafford et al., 2010). Other business studies look at recovery as a return to pre-disaster levels of activity, like the level of employment and profits prior to the disaster (Brewton et al., 2010). For this study we will use the model of business resilience developed by Marshall and Schrank (2014) which is diagramed in Figure 1. The business is characterized as either being closed or opened in the initial period following a disaster. In period two the business is considered demised if it cannot reopen. Businesses that are open can either be considered survived, recovered

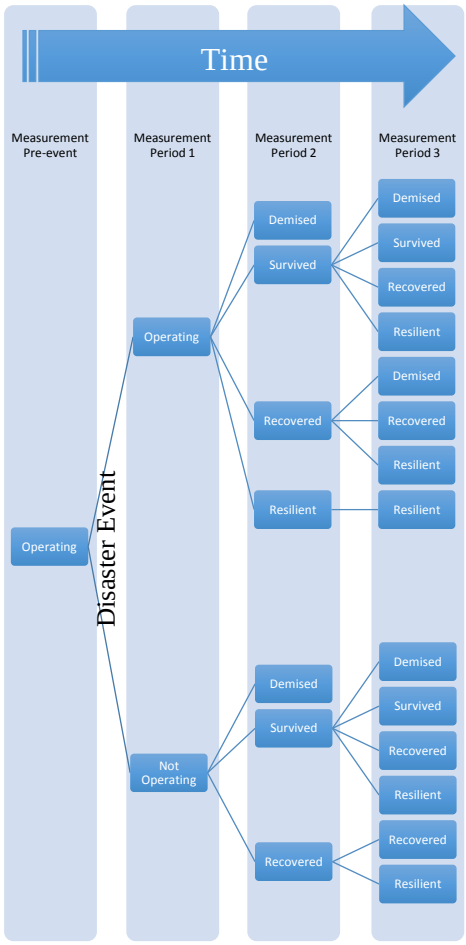
or resilient. A business is survived if it is operating below pre-disaster levels in terms of employment and profits. A recovered business is one that can cover its variable and fixed costs and is operating at pre-disaster levels. Resilience is an adaptive process. Either the business was adequately prepared to withstand the impact of the disaster with little impact or has made adjustments to their operation to prepare for a similar future shock. The first type of business is considered resilient. The second type of business may be considered resilient after they implement necessary changes, though this resilience is not tested until they experience a similar disaster.

Mitigation and adaptation will be experienced in different periods shown in Figure 1. In the pre-event stage, businesses may engage in adaptive activities, if the disaster is not imminent, or mitigation activities if the disaster is imminent. Immediately following the disaster, in period 1, businesses are mainly engaged in mitigation endeavors to minimize the immediate effects of the disaster. Measurement period 2 and 3 will be devoted to mostly adaptation.

There is a vast literature devoted to the a concept related to resilience known as vulnerability Those that study vulnerability contend that certain characteristics increase the likelihood that certain individuals and communities will experience more frequent disruptions with greater impact (Cutter, 1996; Cutter, 2003; Cutter, 2008). For small business vulnerability, it is helpful to focus on business and owner characteristics that may influence vulnerability and are, therefore, important to include as control variables. Also, certain community and geographic characteristics influence small business vulnerability. When a disaster happens some specific problems small business owners face are: a possible decline in the available workforce; a loss of inventory and equipment; no plan for disaster recovery (Runyan, 2006). With regard to Hurricane severity, proximity to the coast can indicate the likelihood of impact. Severity of damage is an important predictor of business recovery as is the size of the pre-disaster size of the business (Webb

et al., 2000). Additional predictors of business recovery include the age of the business, and the industry type (Dahlmamer and Tierney, 1996). Other important indicators of vulnerability were identified in a key study by Stafford et al., who found that smaller businesses, home-based businesses, and businesses with a female owner were less likely to survive a disaster (Stafford et al. 2010).

Figure 1. Small Business Disaster Recovery Framework



2.3 Family Resilience

Families are resilient in much the same way that individuals are resilient. Families, if they experience a harmful event, must adapt to minimize the impact by drawing upon various resources. Studies have looked into family adaptive capacities. Moen and Wethington (1992) provide a thorough review of these. They find consensus in that families adapt by decreasing expenditure, altering family needs, and finding new sources of income. There is an underlying economic tone to the adaptive process, but Moen and Wethington find that the ability to adapt to new economic goals can be constrained by cultural values. Another approach is to analyze family resilience from a psychological perspective. Family functioning is a term developed to capture family well-being. By establishing a pre-disaster level of family functioning, researchers have looked at how pre-disaster levels of human capital, social capital, and family functioning influence post-disaster family functioning (Brewton et al., 2010). Both economic and family functioning are important measures of family resilience.

2.4 Informal and formal financial resources

The adaptive capacity of a family business is influenced by the formal and informal financial resources at their disposal. Following a disaster, a small business may rely on household assets and savings, support from family members, and/or access more formal loans. When family businesses experience a disruption, families can use family savings for the business, but this has been associated with decreased business revenues (Olson et al., 2003). This also represents the resource exchange between household and business demonstrated by the Sustainable Family Business Model (Stafford et al., 1999).

Financing is a major hurdle for small business recovery. Small businesses, more than larger businesses, rely on day to day cash flows making them much more susceptible to cash flow disruptions (Runyan, 2006). Formal financial assistance, in the form of federal disaster assistance to the area, increases small business revenue (Haynes et al., 2011). In contrast, previous studies have found a negative association between the likelihood of recovery and receiving aid (Webb et al., 2000; Dahlhamer and Tierney (1996)), but this result is likely confounded by the severity of impact.

Studies have uncovered different business characteristics that lead business owners to access various financial resources. For instance sole proprietors are more likely to engage in household to business resource transfers (Haynes et al., 1999). Additionally, in times of crisis, business to household transfers positively impact small business survival (Haynes et al., 2011). Also, older businesses are less likely to use household resources because they have ample collateral established (Haynes et al., 1999). Additional differences exist in financial resources sought between less and more mature businesses. Older businesses are likely to access relationship-oriented sources, like borrowing from family members and minimize their investment in capital stock and minimize accounts receivable while younger businesses are likely to access owner financing like using personal credit cards (Winborg and Landstrom, 2001). Additionally, businesses in rural locations (especially farms) are likely to intermingle household and business resources like using a business vehicle for personal use (Haynes et al. 1999).

Studies have shown that men are likely to access different financial resources than women to start businesses. For example, men are likely to borrow capital where women are more likely to use household savings or loans from family (Aronson, 1991; Buttner and Rosen, 1989; Fay and

Williams, 1993). Though, once the business is established these differences seem to dissipate (U.S. Small Business Administration, 1989).

The literature has yet to examine the effect of formal and informal financial tools on adaptive capacity. This article analyzes the extent to which formal and informal financial resources aid small businesses in reopening after Hurricane Katrina and adapting for a future possible event to minimize the effect of a future hurricane. Using a simultaneous model we can assess the impact of adaptation on business success which is characterized by the change in business revenue. This model further allows us to fully integrate the mitigation and adaptation framework whereby we can assess the impact of pre- and post- Katrina mitigation and adaptation activities.

3. Methodology

The following section discusses the estimation employed to analyze small business resilience to Hurricane Katrina which integrates two estimation techniques: recursive bivariate probit and multivariate probit with selection. First the recursive bivariate probit is introduced and then this model is integrated into the selection model which becomes a multivariate probit.

The three dependent variables, whether the business is open, has adapted to Hurricane Katrina, and has experienced an increase in business revenues, are listed in Table 2. Because the status of the business as open or closed involves selection, let us first consider adaptation and changes in business revenue. For business owners to have adaptation post Hurricane Katrina, they must have engaged in any one of the following activities: made permanent changes to the building structure like retrofitting the building, elevated a utility box, or found a less vulnerable business location.

Table 2. Variables used in empirical analysis, with definitions

Category	Variable	Description
Dependent variables	Open	1 if business is open; 0 otherwise
	Adaptation Post H. Katrina	1 if permanent adjustments to the building structure were made after H. Katrina; 0 otherwise
	Change in Revenue	1 if business revenue is higher than pre H. Katrina levels; 0 otherwise
Financial resources	Informal Insurance	1 if business utilized household savings, a family asset, or borrowed from a family member since H. Katrina; 0 otherwise
	Insurance Money	1 if business received insurance indemnity; 0 otherwise
	SBA Loan ($ thousands)	Received loan from SBA (in thousands of dollars)
Mitigation and adaptation	Mitigation H. Katrina	1 if elevated inventory, equipment, supplies, or business records
	Mitigation H. Isaac	1 if elevated or removed inventory or important papers, boarded up windows, or shut off utilities
	Adaptation Pre H. Katrina	1 if permanent adjustments to the building structure were made before H. Katrina; 0 otherwise
Hurricane impact	Catastrophic damage	1 if damage to place of business was catastrophic, for instance, necessary to tear down or nothing was left.
	Distance to coast (km)	Euclidean distance to the Gulf Coast (in km)
Business and owner characteristics	Female	1 if Female; 0 otherwise
	Home based	1 if business is based out of the home; 0 otherwise
	Sole proprietor	1 if business is operated by a sole proprietor; 0 otherwise
	Number of employees Pre H. Katrina	Number of employees before H. Katrina
	Retail	1 if business is in retail industry; 0 otherwise
	Service	1 if business is in service industry; 0 otherwise
	Stress	Reported stress level regarding whether the business would survive[1]

3.1 Recursive bivariate probit

The relationship between adaptation after Hurricane Katrina and changes in business revenue are assumed to be determined simultaneously. Further we assume that there exists a causal relationship between adaptation and change in business revenue where adaptation following

[1] Likert scale: 1) No stress at all, 2) A slight amount of stress, 3) A moderate amount of stress, 4) A large amount of stress, 5) An extremely large amount of stress.

Hurricane Katrina is assumed to cause a change in business revenues. To accommodate these assumptions and the fact that each dependent variable is binary, a recursive bivariate probit is used. When a model has two binary dependent variables where one is endogenous and the specification is recursive, Maddala (1983) and Greene (2008) demonstrate that estimation by the recursive bivariate probit is impervious to endogeneity. (see Greene 2008 for a detailed explanation). This approach has been used in many studies including a study of university course offerings where Greene (1998) uses the recursive bivariate probit to address the endogenous relationship between gender economics courses in universities and the presence of a women's studies department which are considered to be simultaneously determined, though the establishment of a women's studies department having a causal effect on the presence of gender economics courses.

The bivariate probit (with its discrete dependent variables) is analogous to seemingly unrelated regressions (with its continuous dependent variables). The similarities are two-fold. First, both assume outcomes that are simultaneously determined. Second, both allow for the error terms to be correlated across equations (below this is given as ρ). The following model may be estimated where Y_1 takes on the value one if business revenues increased ($Y_1 = 1$) or zero if business revenues are the same or lower than pre-Katrina levels ($Y_1 = 0$). Y_2 takes on the value one if the business engaged in post-Katrina adaptation ($Y_2 = 1$) and zero if they did not ($Y_2 = 0$).

$$Y_1 = \beta_1 X_1 + \gamma Y_2 + \epsilon_1 \quad (1)$$

$$Y_2 = \beta_2 X_2 + \epsilon_2 \quad (2)$$

Where:

$$Y_1 = \begin{cases} 0 \; if \; Y_{1i}^* \leq 0 \\ 1 \; if \; 0 < Y_{1i}^* \end{cases}$$

$$Y_2 = \begin{Bmatrix} 0 \; if \; Y_{2i}^* \leq 0 \\ 1 \; if \; 0 < Y_{2i}^* \end{Bmatrix}$$

and:

$$\begin{pmatrix} \epsilon_1 \\ \epsilon_2 \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right].$$

Adaptation is a function of the exogenous variables contained in X_2. These include formal financial resources (or resources external to the family business), like insurance indemnities and small business loans and informal financial resources (or resources internal to the family business) such as the use of household savings, liquidating a family asset, or borrowing money from a family member. Also included in this equation are variables that control for the severity of Hurricane Katrina and business and owner characteristics. The severity of the storm's impact is captured in the business owners' evaluation of the damage to their business structure, whether it is considered catastrophic, and their proximity to the coast. Businesses located closest to the coast were impacted by the wind and storm surge, the latter responsible for considerable flooding.

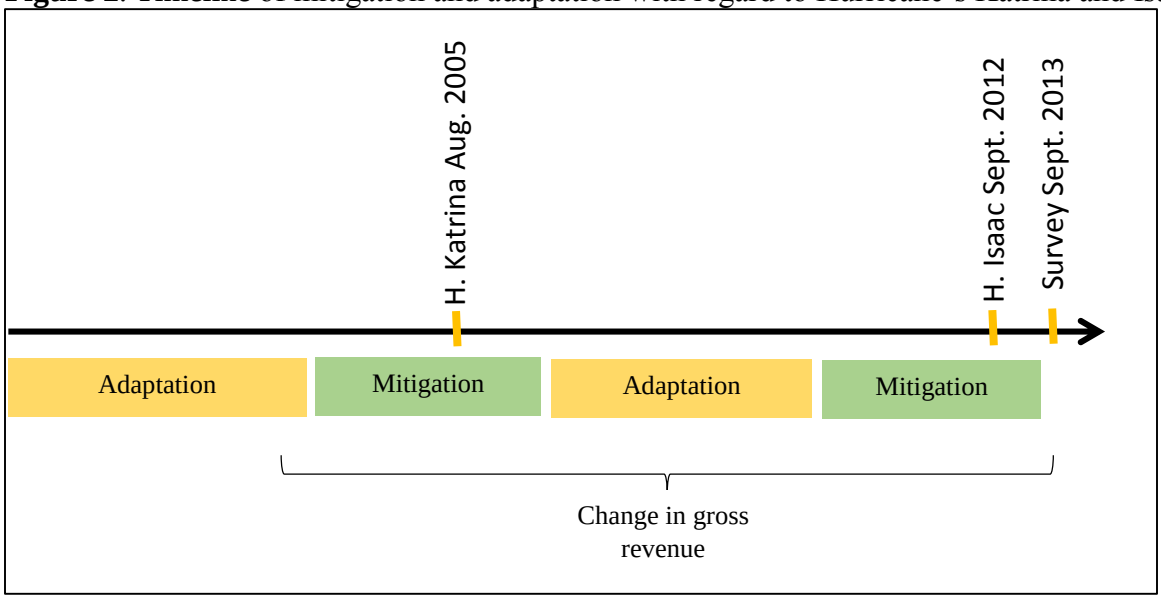
The change in business revenue (Y_1) is determined by variables that comprise X_1 and the impact from adaptation (Y_2). The presence of Y_2 in this equation is what makes it recursive and allows an examination of the causal effect of adaptation on the change in revenue and the indirect effect of various financial resources on revenue through adaptation.

Mitigation activities for both Hurricane Katrina and Hurricane Isaac are included in the specification of the change in revenue equation. Hurricane Isaac occurred in September of 2012 which is depicted in the timeline shown in Figure 3 and also shows the mitigation and adaptation windows for both events. Mitigation is characterized by activities that took place immediately before each hurricane and include elevating inventory or important papers, boarding up windows,

or shutting off utilities. Pre- Hurricane Katrina adaptation is similar to post- Katrina adaptation: making permanent changes to the building structure like retrofitting the building, elevating a utility box, or finding a less vulnerable business location. The same hurricane severity and business and owner characteristic controls are included in X_1 as appear in X_2.

Note that the financial resource variables appear in the specification of adaptation but not in the specification of the change in business revenue. Insurance payments, loans, and informal resources may influence a business's ability to open their doors after a disaster (we address the specification of this equation is the subsequent section) and the ability to finance adaptation, but does not directly impact changing revenue levels. The financial resource variables along with the stress variable satisfy the necessary exclusion restriction for identification of the bivariate recursive model. Exclusion restrictions allow for unbiased estimation of the endogenous variable without having to rely on normality assumptions (Monfardini and Radice, 2006)

Figure 2. Timeline of mitigation and adaptation with regard to Hurricane's Katrina and Isaac



3.2 Multivariate probit with selection

One limitation of the model described above is that Y_1 and Y_2 are only observed when the firms are open (Y_3=1). This results in non-random sample selection. With linear models, sample selection is corrected using Heckman's two stage model, where the first stage in a univariate probit (the selection equations) and calculate the inverse mills ratio and the second stage uses the inverse mills ratio in the linear regression as a control. This approach does not translate directly to non-linear regressions (Greene 2008). There have been advances in correcting for sample selection in non-linear, discrete models. Particularly, these have been approached in the bivariate setting, where one only observes (for example) the binary variable W_1 when variable $W_2 = 1$ (Poirer 1980; Abowd and Farber 1982; Meng and Schmidt 1985). The following regression analysis relies on recent developments made by Cappellari and Jenkins in the development of STATA multivariate probit programming (2003) and the multivariate probit model with selection (2006). Many studies have used the bivariate or multivariate probit selection framework: Jenkins et al. (2006) used this method to analyze bias introduced when individuals refuse to answer certain questions contained in household surveys; Montmarquette et al. (2001) use a bivariate selection model to estimate the determinants of university attrition; and Yen 2003 use a multivariate model with selection to analyze cigarette and alcohol consumption.

As the Cappellari and Jenkins article (2006) demonstrates, the bivariate case may be extended to the case at hand where only when Y_3=1 do we observe Y_1 and Y_2. The result is five corresponding unconditional probabilities:

$$Prob(Y_3 = 0|x_{i1}, x_{i2}, x_{i3}) = 1 - \Phi(x'_{i3}\beta_3)$$

$$Prob(Y_1 = 1, Y_2 = 1, Y_3 = 1|x_{i1}, x_{i2}, x_{i3}) = \Phi_3(x'_{i1}\beta_1 + \gamma, x'_{i2}\beta_2, x'_{i3}\beta_3, \rho)$$

$$Prob(Y_1 = 0, Y_2 = 1, Y_3 = 1|x_{i1}, x_{i2}, x_{i3}) = \Phi_3(-x'_{i1}\beta_1 + \gamma, x'_{i2}\beta_2, x'_{i2}\beta_2, \rho)$$

$$Prob(Y_1 = 1, Y_2 = 0, Y_3 = 1|x_{i1}, x_{i2}, x_{i3}) = \Phi_3(x'_{i1}\beta_1 + \gamma, -x'_{i2}\beta_2, x'_{i3}\beta_3, \rho)$$

$$Prob(Y_1 = 0, Y_2 = 0, Y_3 = 1|x_{i1}, x_{i2}, x_{i3}) = \Phi_3(-x'_{i1}\beta_1 + \gamma, -x'_{i2}\beta_2, x'_{i3}\beta_3, \rho)$$

Where:

Φ_3 is the trivariate normal distribution.

$$\rho = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{21} & 1 & \rho_{23} \\ \rho_{31} & \rho_{32} & 1 \end{bmatrix}$$

These probabilities can form a likelihood function and the function:

$$L = (1 - R)(x'_{i3}\beta_3) + R(x'_{i1}\beta_1 + \gamma, x'_{i2}\beta_2, x'_{i3}\beta_3, \rho) \quad (3)$$

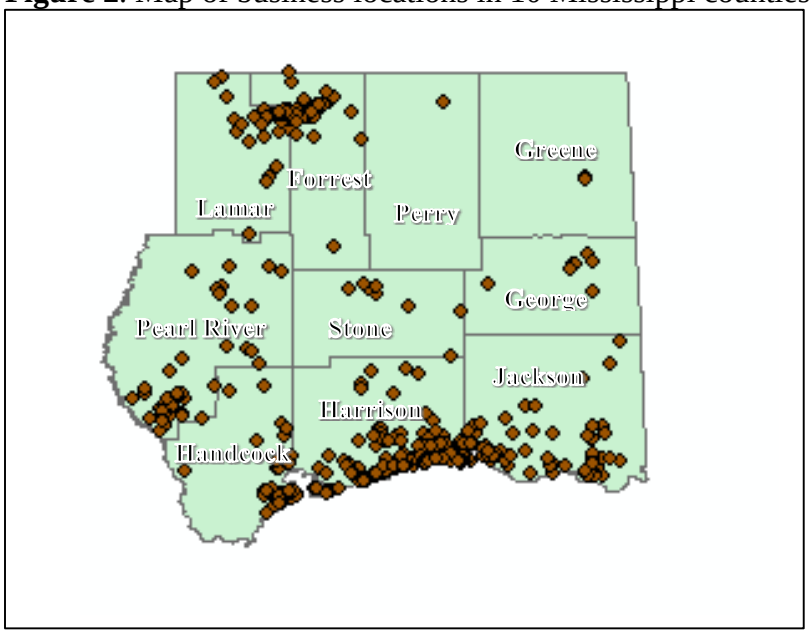
Where R is one if the business is open and zero otherwise. The Geweke–Hajivassiliou–Keane (GHK) smooth recursive conditioning simulator is used to calculate multivariate normal probabilities

The selection equation Y_3 is a function of exogenous variables X_3 which include formal financial resources, pre- Hurricane Katrina adaptation and mitigation. This specification assumes that these resources and actions will aid businesses owners in reopening their businesses following the disaster. For example, financial resources may assist in replacing lost inventory or repairing structural damage while pre- Hurricane Katrina adaptation and mitigation may have helped to lessen the impacts to inventory and the business structure.

3.3 Data

The *Small Business Disaster Resilience Survey*, a telephone survey of business owners residing in 10 Mississippi counties with a business operating before Hurricane Katrina, was conducted in August and September of 2013 and is the main source of data for the following analysis. The 10 counties are Forrest, George, Greene, Hancock, Harrison, Jackson, Lamar, Pearl River, Perry, and Stone and are located in southeastern Mississippi (Figure 2 shows a county map with business locations indicated). The dataset is unique because it includes businesses that are both open and closed after Hurricane Katrina. In order to include businesses that are no longer operating, a list of for-profit businesses was purchased from Dunn and Bradstreet and the sampling was done from this list (see Schrank et al. 2013 for a complete description of the sampling strategy). The original sample consisted of 499 complete observations. The sample was culled to remove responses of "I don't know" or non-responses. The sample used in the following analysis has 395 observations and includes both businesses that closed after Hurricane Katrina (N=84) and those that were open at the time of the survey (N=311).

Figure 2. Map of business locations in 10 Mississippi counties



4. Results

Descriptive statistics and the results of the empirical analysis are presented and discussed in this section.

4.1 Descriptive statistics

Descriptive statistics are displayed in Table 3, where the standard deviation is only shown for continuous variables. All other variable are binary. The sample of 395 businesses from southern Mississippi includes 311 that are operating and 84 businesses that were no longer operating. Of those that are open, 21 percent engaged in post-Hurricane Katrina adaptation and 50 percent reported an increase in business revenue.

The use of financial resources shows that for open businesses, 63 percent used informal financial resources or informal insurance. This survey question was not asked of the closed businesses thus limiting our ability to assess the impact of these resources on the likelihood of a

business being open. The impact of informal insurance on adaptation can be assessed as well as the indirect effects of informal insurance on revenue are through its impact on the ability to adapt. Information regarding two other sources of financial support, insurance indemnity and the amount of SBA loan, was solicited from open and closed business. Off all businesses, 51 percent received an insurance indemnity and the average SBA loan amount was approximately $14,000.

Mitigation increased between Hurricanes Katrina and Isaac with 43 percent of business mitigating for Hurricane Katrina and 50 percent mitigating for Hurricane Isaac. The rates of adaptation remained steady with 23 percent choosing to adapt before Hurricane Katrina and 21 percent choosing to adapt after Hurricane Katrina.

Vulnerability to the Hurricane is represented by proximity to the storm, level of hurricane impact, as well as other small business characteristics. In the sample, 19 percent reported catastrophic damage to their place of business. Thirty-two percent are female owned and 31 percent of businesses are operated out of the home. Almost half of the sample constitutes businesses that are operated by a sole proprietor.

Table 3. Descriptive statistics

Category	Variable	Observations	Mean	Std. Dev.	Min	Max
Dependent variables	Open	395	0.78		0	1
	Adaptation Post H. Katrina	311	0.21		0	1
	Change in Revenue	311	0.50		0	1
Financial resources	Informal Insurance	311	0.63		0	1
	Insurance indemnity	395	0.51		0	1
	SBA Loan ($ thousands)	395	14.33	73.21	0	960
Mitigation and Adaptation	Mitigation Pre H. Katrina	395	0.43		0	1
	Mitigation H. Isaac	311	0.50		0	1
	Adaptation Pre H. Katrina	395	0.23		0	1
Hurricane impact	Catastrophic damage	395	0.19		0	1
	Distance to coast (km)	395	31.08	39.44	0	119
	Female	395	0.32		0	1

Business and owner characteristics	Home based	395	0.33		0	1
	Sole proprietor	395	0.45		0	1
	Industry experience (yrs)	398	27.95	17.32	9	113
	Age of business (yrs)	395	29.05	12.55	2	74
	Number of employees Pre H. Katrina	395	6.32	13.60	0	175
	Retail	395	0.31		0	1
	Service	395	0.39		0	1
	Stress	395	2.84	1.43	1	5

4.1 Results

The results from the multivariate probit with selection are discussed in this section. Two specifications were estimated. The second specification includes interaction terms that are omitted from the first specification and the results of each specification will be discussed in sequence. The coefficients listed in Table 4 cannot be interpreted as marginal effects. An investigation of the marginal effects of specific variables is presented in the next section. The coefficients in each equation indicate the direction of the direct impact of each variable on the dependent variable. One additional caveat: with only 395 observations the estimation of the multivariate probit with selection may exhaust the statistical power of the model; therefore, the presence of statistical significance for any particular variable should not be overemphasized.

This initial specification is displayed in the first column. The first dependent variable (open) represents the selection equation. Variables that show an increase in the likelihood of being open are receiving an insurance indemnity, receiving an SBA loan and pre- Hurricane Katrina mitigation and adaptation activities. These are all intuitive, assuming financial resources help business owners repair physical damage to the building structure and inventory. Also, mitigation and adaptation are by their nature, meant to increase the likelihood of recovery, and the corresponding positive coefficients are consistent.

The results from the hurricane impact variables show that those who experienced catastrophic damage are less likely to be open. The distance to the coast shows a positive relationship, meaning that those further from the coast are more likely to be open. Among the business owner characteristics, female operators, and sole proprietors are less likely to be open and those with more industry experience are more likely to be open. Among business characteristics, older businesses and retail businesses (compared with all non-retail businesses) are more likely to be open. Service businesses (compared with all non-service businesses) and home-based businesses are less likely to be open.

Post- Hurricane Katrina adaptation is the next dependent variable. Those who received informal insurance or formal insurance are less likely to adapt. The former result may indicate the inadequacy of relying on informal insurance to meet financial needs. The later result is counter-intuitive and will be examined in greater detail in the second specification. As expected those who experienced catastrophic loss are more likely to adapt as are those who live closer to the coast. Female business owners and those with more industry experience are less likely to adapt while sole proprietors and those with older businesses are more likely to adapt. The last variable in this equation, stress, is an effective inducer of adaptation. Its positive coefficient indicates those with higher levels of stress regarding the possible failure of their business are likely to adapt.

The last remaining dependent variable in the analysis is the change in business revenues. There are direct and indirect effects present in this equation. In the next section we are able to assess both the indirect and direct effect through the calculation of marginal effects. For now we can interpret the direct effect of variables contained the change in revenue equation.

Those that adapted before Hurricane Katrina are more likely to have increased revenues than those that did not adapt. This is contrasted with those that adapted after Hurricane Katrina

who are less likely to have increased revenues. The difference between these results may indicate the value of preparedness. The results for mitigation are similar, though unexpected. Those who engaged in mitigation activities prior to Hurricane Katrina are more likely to have increased revenues while those who mitigated for Hurricane Isaac are less likely. The result corresponding to Hurricane Isaac is surprising; one would expect mitigation to be beneficial in preparation for each event. This result is examined in more detail in the second specification where the two mitigation variables are interacted to see the effect of mitigating for both events.

The hurricane impact variables are consistent with the results from the other equations. Those with catastrophic damage are less likely to have increased revenues while those who are farther from the coast are more likely to have increased revenues. Many of the business and owner characteristics have negative coefficients. Female business owners, sole proprietors, and home based businesses are less likely to have increased revenues. Businesses with more employees— an indication of the size of the business pre- Hurricane Katrina— are more likely to have increased revenues as are retail and service businesses. Older businesses and business owners with more industry experience are less likely to have increased revenues— a striking comparison to the earlier results that indicated these same businesses are more likely to be open. This is one additional level of information that is afforded by using a selection model.

The second specification addresses two unexpected results from the first specification. The first is the negative coefficient for insurance indemnity in the adaptation equation. One would expect that any form of financial resource would increase the likelihood of adaptation. Because businesses may have received an indemnity for any number of unknown reasons, the insurance dummy variable is interacted with the dummy variable for catastrophic damage. This interaction indicates the likelihood of adaptation for those with insurance and catastrophic damage, so that we

can filter out the effects of those who received indemnities for possibly irrelevant reasons. The coefficient on the interaction term is positive, indicating these individual were likely to adapt.

The second unexpected result occurred in the change in revenue equation where the coefficient for Hurricane Isaac mitigation is negative. The possibility that mitigating for Hurricane Isaac and not for Hurricane Katrina may be driving this result is further explored. An interaction term is introduced between the two mitigation variables, to compare those who mitigated for both Hurricanes with those who only mitigated Isaac. The results of this are not encouraging. The coefficient on the interaction term is negative, indicating those who mitigated for both Hurricanes are less likely to have increased revenue than those who did not mitigate. Because the mitigation activities associated with Hurricane Isaac are within the timeframe where the change in revenue is assessed, these counterintuitive results may be the product of endogeneity.

The ρ terms are displayed in Table 4 as well. These indicate correlation among the error terms in each equation. A test of the joint statistical significance of ρ21 and ρ31 indicates that selection bias cannot be ignored ($X^2 = 32.60, prob > X^2 = 0.000$).

Table 4. Regression results for multivariate probit with selection

Dependent variable	Variables	Specification (1)	Specification (2)
Open	Insurance indemnity	0.121	0.116
		(0.152)	(0.150)
	SBA Loan ($ thousands)	0.011***	0.011***
		(0.004)	(0.004)
	Adaptation Pre H. Katrina	0.097	0.086
		(0.181)	(0.177)
	Mitigation Pre H. Katrina	0.129	0.141
		(0.158)	(0.156)
	Catastrophic damage	-0.963***	-0.970***
		(0.187)	(0.187)
	Distance to coast (km)	0.003	0.003
		(0.002)	(0.002)
	Female	-0.174	-0.178
		(0.161)	(0.161)

	Home based	-0.066	-0.074
		(0.167)	(0.166)
	Sole proprietor	-0.253	-0.246
		(0.157)	(0.157)
	Industry experience (yrs)	0.004	0.004
		(0.007)	(0.007)
	Age of business (yrs)	0.012**	0.011*
		(0.006)	(0.006)
	Service	0.331*	0.307*
		(0.188)	(0.185)
	Retail	-0.217	-0.223
		(0.187)	(0.183)
	Constant	0.455	0.480*
		(0.278)	(0.277)
Adapt Post H. Katrina	Informal Insurance	-0.044	-0.019
		(0.249)	(0.226)
	SBA Loan ($ thousands)	0.002*	0.002*
		(0.001)	(0.001)
	Insurance indemnity	-0.238	-0.354**
		(0.176)	(0.178)
	Catastrophic damage	0.779***	0.334
		(0.222)	(0.315)
	Insurance ind. * Catastrophic dam.		0.772**
			(0.301)
	Distance to coast (km)	-0.002	-0.003
		(0.002)	(0.002)
	Female	-0.233	-0.215
		(0.192)	(0.188)
	Home based	-0.244	-0.225
		(0.194)	(0.191)
	Sole proprietor	0.033	0.024
		(0.175)	(0.172)
	Industry experience (yrs)	-0.015*	-0.015*
		(0.008)	(0.008)
	Age of business (yrs)	0.001	-0.000
		(0.005)	(0.005)
	Stress	0.166***	0.158***
		(0.060)	(0.057)
	Constant	-0.375	-0.247
		(0.357)	(0.344)
Change in Revenue	Adapt Post H. Katrina	-0.394	-0.326
		(0.724)	(0.608)
	Adapt Pre H. Katrina	0.162	0.166
		(0.183)	(0.183)
	Mitigate Pre H. Katrina	0.228	0.358
		(0.162)	(0.228)
	Mitigate H. Isaac	-0.326**	-0.228

	(0.153)	(0.191)
Mit. Pre H. Katrina * Mit. H. Isaac		-0.119
		(0.193)
Catastrophic damage	-0.222	-0.213
	(0.367)	(0.338)
Distance to coast (km)	0.003	0.003
	(0.002)	(0.002)
Female	-0.311*	-0.315*
	(0.166)	(0.166)
Home based	-0.128	-0.120
	(0.177)	(0.173)
Sole proprietor	-0.238	-0.235
	(0.158)	(0.157)
Industry experience (yrs)	-0.006	-0.006
	(0.008)	(0.007)
Age of business (yrs)	-0.007	-0.007
	(0.005)	(0.005)
Number of employees Pre H. Katrina	0.002	0.001
	(0.006)	(0.006)
Service	0.089	0.082
	(0.178)	(0.176)
Retail	0.511**	0.509**
	(0.205)	(0.201)
Constant	0.649	0.619
	(0.423)	(0.390)
ρ21	-0.512**	-0.551**
	(0.257)	(0.238)
ρ 32	0.473	0.467
	(0.426)	(0.363)
ρ 31	-0.745***	-0.792***
	(0.165)	(0.140)
N	395	395
Log-Likelihood	-504.47	-502.01
Wald Chi-squared	52.65***	53.59***

5. Effects of financial resources, behavior, and indicators of vulnerability

The following section explores the direct and indirect effects of key variables of interest on the probability of a business having increased revenues. To do this marginal effects are calculated from the conditional mean displayed in equation 4.[2]

$$\mathrm{E}_1 = \mathrm{E}[Y_1|Y_2 = 1, Y_3 = 1, x_1, x_2, x_3] = \frac{\Phi_3(\beta_1' x_1 + \gamma, \beta_2' x_2, \beta_3' x_3, \rho)}{\Phi(\beta_2' x_2)} \quad (4)$$

First we consider the varying effects of the formal and informal financial resources as well as adaptation and mitigation behavior. Second we consider the effects of small business vulnerability characteristics.

5.1 Financial resources and behavior

Different preparatory behaviors have a differing impact on the probability of a firm having increased revenues. To assess the total marginal effect on the probability of having increased revenue the marginal effect was calculated from the conditional probability, $Prob(Y_1 = 1|Y_2 = 1, Y_3 = 1, \bar{X})$. The variables listed in Table 5 are all discrete (except for SBA loan) so the calculation of the marginal effect is the evaluation of equation 4 when the discrete variable of interest is equal to 1 minus the evaluation of equation 4 when the same variable of interest is equal to 0, while holding all other variables at their means. For comparison, the marginal effect of SBA loans was calculated using the method for continuous variables described in the Appendix, and then evaluated at the mean SBA loan of $14,330.

[2] For a detailed exposition of the calculations of the marginal effects for both continuous and discrete variables please visit the appendix.

The total effect of pre-Hurricane Katrina adaptation translates into a 4.2 percent increased likelihood of having increased revenues. This is in contrast to the effects of post- Hurricane Katrina adaptation, which results in a business being 4.1 percent less likely to have increased revenue. The results of this are suggestive of the importance of adaptation before a severe event and the value of that adaptation. Pre- Katrina adaptation meant both an increased probability of being open (8.6 percent) and having increased revenue (4.1 percent). The pre- Katrina adaptation and the subsequent effect on business success is an example of resilience: businesses that have prepared (adapted), been tested (experienced Hurricane Katrina), and are successful (open with increased revenues). Those who adapted before Hurricane Isaac do not show increase revenues. It would be interesting to compare their pre- Isaac revenue levels with their post- Isaac revenue levels, as this might indicate the value of adapting for this event, but this data is not available.

Pre-Katrina mitigation resulted in a 9.5 percent increase in the probability of increased revenue. This is similar to the adaptation story. Those who mitigated prior to Hurricane Katrina were 14.1 percent more likely to be open and 9.5 percent more likely to have increased revenue. This result highlights the importance of mitigation activities in producing resilient businesses. These effects, compared with pre- Katrina adaptation, suggest mitigation is even more critical for resilience. Those who mitigated in preparation for Hurricane Isaac are 5.8 percent less likely to have increased revenues. Again, the comparison of pre- and post- Hurricane Isaac levels of revenue would provide a more accurate indication of the effect of these activities on resilience to this specific event.

Table 5. Marginal effects of select discrete variables on the conditional probability of increased revenues, $Prob(Y_1 = 1|Y_2 = 1, Y_3 = 1, \bar{X})$

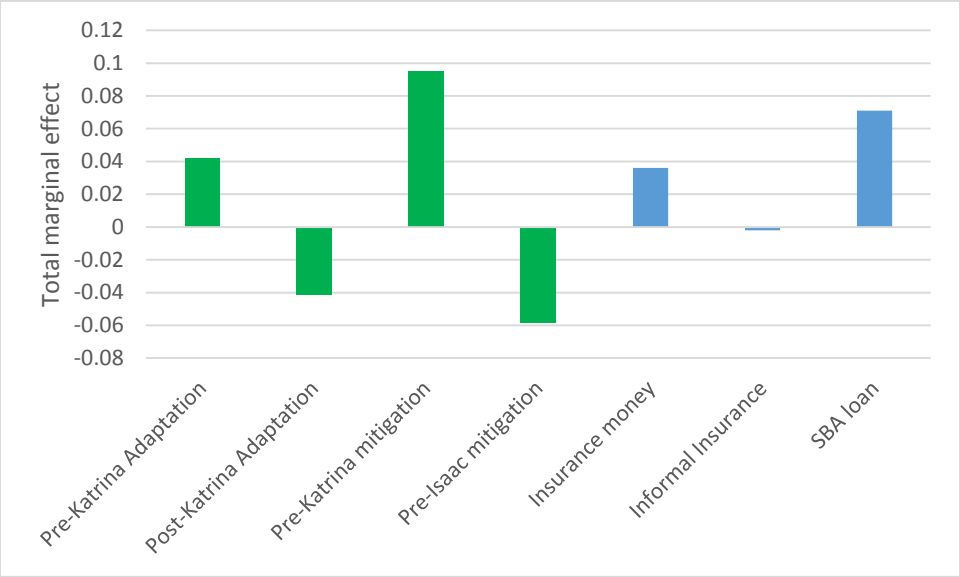
Variable	Total effect
Pre-Katrina Adaptation	0.042

Post-Katrina Adaptation	-0.041
Pre-Katrina mitigation	0.095
Pre-Isaac mitigation	-0.058
Insurance money	0.036
Informal insurance	-0.002
SBA loan	0.071

A comparison of financial resources shows the difference between their effectiveness at increasing the probability of having increased revenues. The results suggest that receiving the average SBA loan is the most effective. Receiving the average SBA loan ($14,330) results in the business having a 7.1 percent increased probability of increased revenues. Insurance money is the next most effective, where receiving an insurance indemnity makes it 3.6 percent more likely that the business will have increased revenues. It is important to remember that both of these variables appear in the open equation, so the total marginal effect incorporates both the indirect effect being open has on the probability of increased revenues.

Informal financial resources appear to be less effective than their formal counterparts. Businesses relying on informal insurance are 0.2 percent less likely to have increased revenues. This variable does not appear in the open equation so it is not known the effect it had on helping firms in this initial task. We do know that if a business is relying on informal insurance they are less likely to adapt, so the effectiveness and adequacy of this funding is questionable. Of the businesses in the sample 69 used only informal insurance, 17 used both informal insurance and received an SBA loan, 91 used informal insurance and received an insurance indemnity, and 18 accessed all three financial resources. Those 69 firms that only relied on informal financial resources are a cause for concern when trying to bolster business resilience. Why these businesses did not access formal financial resources is a research question with many policy implications and is a possible future research topic.

Figure 3. Total marginal effect of select variables on probability of having higher revenue levels than pre-Katrina levels, $Prob(Y_1 = 1|Y_2 = 1, Y_3 = 1, \bar{X})$



5.3 Vulnerability

Small business vulnerability to disasters is defined as those characteristics that make a business less likely to survive an extreme event. Important indicators of small business vulnerability include: severity of damage the size of the pre-disaster size of the business (Webb et al., 2000); number of employees, the age of the business, businesses operated by sole proprietors (Dahlmamer and Tierney, 1996), home based businesses, businesses owned by women (Stafford et al. 2010). Direct and indirect marginal effects for continuous variables that indicate vulnerability, like distance to the coast, business age and years of industry experience, are listed in Table 6.

Both increases in business age and years of experience have conflicting effects. They both decrease the probability of increased revenues directly and they also decrease the likelihood of increase revenue because of adapting. In contrast, increased business age and industry experience

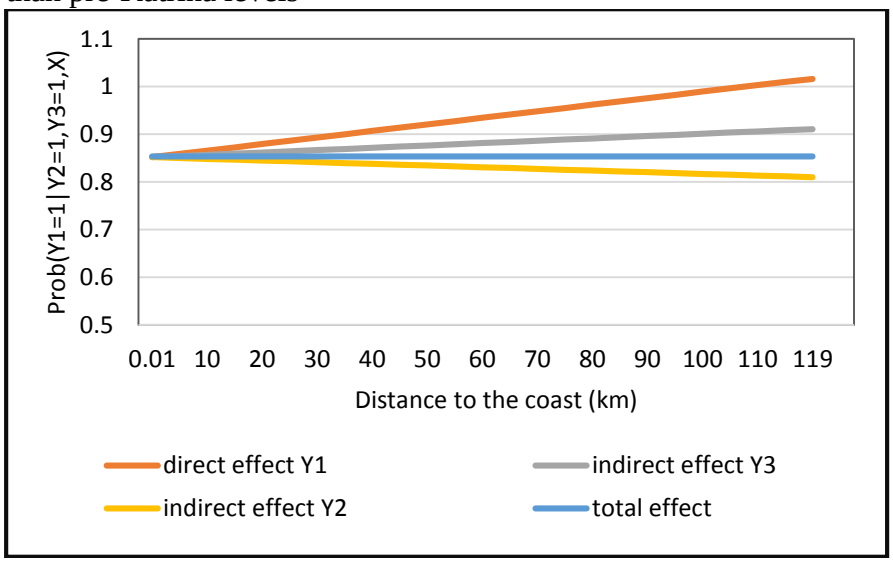
increases the probability of increased revenue because of being open. The total effect of these variables are negative, but are so small, they are negligible.

Table 6. Marginal effects of select continuous variables on the conditional probability: $Prob(Y_1 = 1|Y_2 = 1, Y_3 = 1, \bar{X})$

Variable	Direct effect: Y_1	Indirect effect: Y_2	Indirect effect: Y_3	Total effect $Y_1 + Y_2 + Y_3$
Distance to the coast (km)	0.0014	-0.0004	0.0005	0.0015
Business age	-0.0096	-0.0001	0.0020	-0.0077
Years of industry experience	-0.0003	-0.000044	0.0004	-0.000001

For each kilometer a business is from the coast, they are 0.14 percent more likely to have increased revenues (direct effect), they are 0.04 percent less likely to have increased revenues because they adapted, and they are 0.05 more likely to have increased revenues because they are open. Figure 4 shows each of these affects along with the total effect for the range of distances represented in the data (from 0 to 119 kilometers from the coast). The plot represents the probability at each distance, using the constant from the regression results and assuming all other variables are held constant at their means. We can see that the positive effect of distance on the probability of increased revenue, directly, through the revenue equation, and indirectly through the open equation. The total effect is weighed down by the negative effect on revenue for those who adapted. Within the dataset, it is unlikely that individuals living far from the coast adapted. In fact only 24 businesses reported adaptation activities that lived farther than 10 kilometers from the coast. Therefore we must consider the unlikeliness of adaptation for those far from the coast when assessing the effect of proximity to the coast.

Figure 4. Indirect and direct effect of distance to the coast on of having higher revenue levels than pre-Katrina levels



The other indicators of small business vulnerability to disaster considered in the empirical analysis are listed in Table 7 along with the total marginal effects which are consistent with previous literature (Webb et al., 2000; Dahlmamer and Tierney, 1996). Those businesses who experienced catastrophic damage to their businesses are 11.6 percent less likely to have increased revenues. Home based businesses are 9.5 percent less likely to have increased revenues. Sole proprietors are 12.68 percent less likely to have increased revenues and female business owners are 12.63 percent less likely to have increased business revenues. These finding are even more striking when the likelihood of adapting is considered. Both female business owners and owners of home-based businesses are less likely to adapt. As the coefficient on pre-Katrina adaptation indicated, this may be beneficial for the next serious event, so the fact that these individuals are less likely to adapt may have implications for their future business success. Therefore, these characteristics have policy implications for programs that are directed at increasing small business resilience to disasters.

Table 7. Total marginal effects of select continuous variables on the conditional probability: $Prob(Y_1 = 1|Y_2 = 1, Y_3 = 1, \bar{X})$

Variable	Total marginal effect
Catastrophic damage	-0.116
Home based	-0.095
Sole Proprietor	-12.68
Female	-12.63

6. Conclusions

The effects of natural disasters on small business resilience were studied in the context of 395 businesses who experienced Hurricane Katrina in Mississippi in August of 2005. Resilience was analyzed using the conceptual *Small Business Disaster Recovery Framework* developed by Marshall and Schrank (2014). Businesses are characterized as resilient based on their business operations and their ability to adapt to disasters. In this context an empirical analysis was conducted using a survey of small businesses in Mississippi. The effects of financial resources on adaptation behavior and changes in business revenue were analyzed in a multivariate probit with sample selection, which also accounts for sample selection bias resulting from businesses that are no longer open. To address changes in business revenue, revenue levels at the time of the survey (September 2013) were compared to revenue levels prior to Hurricane Katrina.

The empirical analysis shows the value of preparation. Firms that practiced mitigation and adaptation prior to Hurricane Katrina were more likely to be open and more likely to have increased revenues. In short they were more likely to be resilient.

Additionally, the empirical analysis shows the difference in effectiveness of formal and informal financial resources on the ability to reopen after the disaster and adapt their infrastructure

for a possible future even. Formal resources such as insurance payments and loans from the Small Business Administration increase the likelihood that a business will reopen after a disaster. Additionally, these resources increase the likelihood that a business will engage in adaptive activities like elevating their business structure or relocating to a less vulnerable area. In contract, those relying on informal insurance are less likely to do this. This may indicate that informal resources, like household savings and borrowing from friends and family, are insufficient to finance these projects. In our study, there were 69 firms who only relied on informal insurance. The reasons why these individuals did not choose to or were unable to access formal financial resources is a topic for future research.

Finally, the empirical analysis addressed some important sources of vulnerability, like proximity to the coast and type of business. Those with businesses close to the coast were 14 percent less likely to have increased revenues than businesses even 10 kilometers away from the coast. This shows the severe impact of living in a vulnerable area. In addition, certain business characteristics indicate vulnerability. For instance, businesses that are based out of the home are less likely to have increased revenues than those not based out of a home and the same is true for female business owners and businesses operated by a sole proprietor.

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8. Appendix: Marginal Effects

Marginal effects are calculated from the conditional mean displayed in equation 4.

$$\mathrm{E}_1 = \mathrm{E}[Y_1|Y_2 = 1, Y_3 = 1, x_1, x_2, x_3] = \frac{\Phi_3(\beta_1'x_1+\gamma,\beta_2'x_2,\beta_3'x_3,\rho)}{\Phi(\beta_2'x_2)} \quad (4)$$

For variables that appear in multiple equations (denoted with the subscript *i*) there will be both direct and indirect effects. The direct effect are given in the following:

$$\frac{d\mathrm{E}_1}{dx_{i1}} = \frac{1}{\Phi(\beta_2'x_2)} \cdot \frac{d\Phi_3(\beta_1'x_1+\gamma,\beta_2'x_2,\beta_3'x_3,\rho)}{dx_{i1}} \quad (5)$$

The indirect effects are the results of x_i appearing in equations 2 and 3.

$$\frac{d\mathrm{E}_1}{dx_{i2}} = \frac{1}{\Phi(\beta_2'x_2)} \cdot \frac{d\Phi_3(\beta_1'x_1+\gamma,\beta_2'x_2,\beta_3'x_3,\rho)}{dx_{i2}} - \mathrm{E}_1\left[\frac{1}{\Phi(\beta_2'x_{2,})} \cdot \frac{d\Phi(\beta_2'x_{2,})}{dx_{i2}}\right] \quad (6)$$

$$\frac{d\mathrm{E}_1}{dx_{i3}} = \frac{1}{\Phi(\beta_2'x_2)} \cdot \frac{d\Phi_3(\beta_1'x_1+\gamma,\beta_2'x_2,\beta_3'x_3,\rho)}{dx_{i3}} - \mathrm{E}_1\left[\frac{1}{\Phi(\beta_2'x_{2,})} \cdot \frac{d\Phi(\beta_2'x_2)}{dx_{i3}}\right] \quad (7)$$

Where:

$$\frac{d\Phi_2(\beta_2'x_2)}{dx_{i2}} = \varphi(\beta_2'x_2) \quad (8)$$

$$\frac{d\Phi_2(\beta_2'x_2)}{dx_{i3}} = 0 \quad (9)$$

and:

$$\frac{d\Phi_3(\beta_1'x_1+\gamma,\beta_2'x_2,\beta_3'x_3,\rho)}{dx_{mi}} = \varphi(\beta_m'x_m) \times \Phi_2\left(\beta_k'x_k, \beta_j'x_j \middle| \beta_m'x_m\right) \times \beta_{mi} \text{ for } m = 1..3 \quad (10)$$

According to Mullay (2011) equation 3 can be calculated as follows:

$$\frac{d\Phi_3(\beta_1'x_1+\gamma,\beta_2'x_2,\beta_3'x_3,\rho)}{dx_{mi}} = \varphi(\beta_m'x_m) \times \Phi_2(L_1) \times \beta_m, \quad (11)$$

Where:

$$L_m = H_m \Delta_{-1},$$

$$H_m = \begin{bmatrix} \left(\sqrt{1-\rho_{mk}^2}\right)^{-1} & 0 \\ 0 & \left(\sqrt{1-\rho_{mj}^2}\right)^{-1} \end{bmatrix},$$

and

$$\Delta_{-1} = \left[(\beta_k' x_k - (\beta_m' x_m)\rho_{km}),\ (\beta_j' x_j - (\beta_m' x_m)\rho_{jm})\right]^T.$$

L_1 forms the first two terms in the calculation of the bivariate normal CDF. The third term, the symmetric correlation matrix Σ, is given as:

$$\Sigma = \begin{bmatrix} 1 & \frac{(\rho_{kj}-\rho_{mk}\rho_{mj})}{\sqrt{(1-\rho_{mk}{}^2)(1-\rho_{mj}{}^2)}} \\ \frac{(\rho_{kj}-\rho_{mk}\rho_{mj})}{\sqrt{(1-\rho_{mk}{}^2)(1-\rho_{mj}{}^2)}} & 1 \end{bmatrix}$$

For dummy variables, the marginal effect is akin to the discrete change in the discrete variable. The conditional mean is evaluated at both $D_i = 1$ and $D_i = 0$ and the difference represents the marginal effect.

$$\left(\frac{\Phi_3(\beta_1' x_1+\gamma, \beta_2' x_2, \beta_3' x_3, \rho)}{\Phi(\beta_2' x_2)}\middle| D_i = 1\right) - \left(\frac{\Phi_3(\beta_1' x_1+\gamma, \beta_2' x_2, \beta_3' x_3, \rho)}{\Phi(\beta_2' x_2)}\middle| D_i = 0\right) \quad (11)$$