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EFFECTS OF NUCLEAR POWER PLANTS ON RESIDENTIAL PROPERTY VALUES*

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1. INTRODUCTION

Over the past several decades there has been growing opposition to nuclear power plants, intensified by the March, 1979, accident at the Three Mile Island (TMI) plant near Harrisburg, PA. If many people are genuinely concerned over the health and safety aspects of nuclear power, logic suggests that when confronted with a choice for residential location, they would not choose to live (purchase property) near a nuclear power plant unless they expect some form of compensation. Compensation could arise when long-term locational or site disamenities, such as those arising because of proximity to a nuclear power plant, are capitalized negatively into property values, or when there are expectations of payments for possible property damages.[1]

This paper presents the results of two studies: the first examines the effects on residential property values of four nuclear power plants in the Northeastern United States before the March, 1979, TMI accident; the second examines the effects on property values in the vicinity of the TMI plant following that accident.

Valuing locational disamenities by examining their negatively capitalized effects on property values has been widely applied in recent years to environmental intrusions such as air and noise pollutants.[2] These studies are based on the hedonic price model developed by Freeman (1974), Griliches (1971), and Rosen (1974), whereby sale prices are regressed on a set of explanatory variables.[3] Specifically,

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[1]The expectation of future damage awards from federal, state, and/or private insurance sources should be positively capitalized into property values, thus partially or fully offsetting negative effects. In the absence of any historical precedence for awards for property value effects, including (as of this date) the TMI accident, it would seem that such expectations would be very low. Moreover, if awards are tied to a property and not an owner, new purchasers after an accident would not be eligible and no positive capitalization would occur. For a more detailed discussion of these points, including the transitional gains trap elaborated by Tullock, see Nelson (1981).

[2]For a review of the rather extensive literature on this subject see Freeman (1979a, 1979b).

[3]Nelson (1975) provides a good summary of the conceptual economic framework and the development of the basic theoretical model of housing markets.

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the various attributes or characteristics of a house serve as surrogates for the flow of services provided by that house (and its location) when attempts are made to relate housing price to service flows. This follows from the belief that people, in choosing their house and its location, reveal their preferences by their willingness to pay for certain housing and locational characteristics. If people value quiet, nearness to employment, or relief from a potential hazard, the real estate market should reveal these preferences.

An economic relationship must therefore exist between market price and the quality and quantity of housing service that any given dwelling provides the occupant. Location is one attribute that can provide a number of such services: nearness (accessibility) to employment, schools, and shopping; as well as distance or remoteness from undesirable environmental variables such as noise, congestion, odors, or perceived hazards from a nuclear power plant. This relationship implies that for consumer equilibrium in the housing market, price differentials must arise among various locations which compensate consumers for the differences in housing services associated with specific locations. Otherwise, consumers would not remain at particular locations and locational choice for new entrants would be restricted. Because of mobility and the ability to buy and sell in the housing market, consumer equilibrium requires that for identical housing in all respects at two different locations, except that location 1 is near a nuclear plant and location 2 is well removed, the price of housing at location 1 must be less than that at location 2 by an amount which will just compensate buyers for the additional hazards they perceive at location 1. Otherwise, the consumer would be better off at location 2. Hedonic prices represent compensating price differentials, since individuals are assumed to choose locations such that price differences among different housing and site characteristics are equalized at the margin (equilibrium willingness to pay).[4]

We used hedonic price equations to test the hypothesis that residential property values are directly related to distance from nuclear power plants (the closer to a plant the lower the values, ceteris paribus). Multivariate regression analyses were used to obtain estimates of the implicit or hedonic prices of housing characteristics. A simplified linear economic relationship would take the form

$$V_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + \cdots + b_n X_{ni} + u_i \qquad (i = 1, \ldots, N) \tag{1}$$

where V is selling price of the ith house in dollars; $X_1, \ldots, X_n$ are the variable amounts of the housing characteristics, including distance from the nuclear plant or other plant related variables; $b_1, \ldots, b_n$ are the implicit prices to be estimated; b_0 is a constant term; and u is a stochastic error term reflecting possible omitted variables, measurement errors, and market variations.

In order to show the effect, if any, of proximity to a nuclear plant on the value of housing, it is important to include in the analysis as many variables as possible among those that a priori are known to affect housing prices. The method depends on a causal relationship, not merely one of association. Potentially, a large number

[4]There is some controversy over the basic assumptions underlying the hedonic price model, which we will not discuss here. For elaboration see Freeman (1979a) and Pearce (1978).

of variables contribute to housing price differences within any market area. These variables include characteristics of the house and lot, such as floor area and size of lot; indicators of accessibility such as distance to employment centers and major highways; locational variables such as land use mix and neighborhood characteristics; and public sector descriptors such as availability of utilities, tax ratios, and land use controls.[5]

The authors are aware of only one study which statistically examines the effect of nuclear power plants on property values.[6] Two studies examined the effects of fossil-fueled power plants on property values, both of which reported positive results.[7] Webb (1980) surveyed 26 residents within five miles of a nuclear plant in the Midwest following the TMI accident. Fifteen *thought* their property has sustained a loss in value. Using equalized assessed real property values as a proxy for growth, Gamble (1980) studied 64 communities near four nuclear power plants in the Northeast. There was no adverse impact on growth; after the plants became operational the rates of growth in the communities nearest the plants exceeded the rates for the more distant communities, a reversal of the growth rate trends before the plants were constructed.

Section 2 of this article discusses the method used to determine property value effects. Section 3 reports on a study completed prior to the TMI accident of March, 1979, which examined property value effects of four nuclear power plants in the Northeastern U.S. Section 4 presents the findings of a second study that was carried out to determine the effects of the TMI accident on residential property values. Section 5 presents the conclusions and a discussion of the results.

2. METHOD

The linear and log-log functional forms of the multiple regression model were used to explain variation in the selling price of housing, expressed as follows:

$$V_i = b_0 + \sum_{j-1}^{n} b_j X_{ij} + \mu \tag{2}$$

$$\ln V_i = \ln b_0 + \sum_{j-1}^{n} b_j \ln X_{ij} + \mu \tag{3}$$

where

V_i = the deflated selling price of the ith residential property,
b_0 = constant term,
X_{ij} = independent variables from 1 to n associated with the ith property, and
μ = an error term, assumed to be randomly distributed, reflecting all other unexplained variations.

[5]Characteristics of the occupants, such as income, should not be used in hedonic price equations.

[6]Nelson (1981) examines the effects of the TMI accident on housing prices in two small residential communities.

[7]Blomquist (1974) studied a plant in Chicago and Jack Faucett Associates (1976) studied a plant in a rural section of Maryland.

The dependent variable is the actual market selling price of houses corrected for inflation.[8] The California Statistical Procedures Computer Programming Package (1977), using the Breaux (1968) modification of the Effroymson (1960) algorithm and developed specifically for property value analysis, was used to screen and select the independent variables. Data were gathered on all those variables which the literature and property value effects studies have shown as having likely important causal effects on property values. We could have specified some or all of these variables in a regression equation, but for some variables there was either not enough variation or enough observations for the coefficient estimate to be reliable based on the degrees of freedom for each variable. We specified a minimum of six observations for each variable. Multicollinearity is another specification problem that is reduced by use of the algorithm. Further, using the algorithm avoids specifying an equation which may contain bias by including variables that the researcher feels are important in explaining property value effects.

In this algorithm each variable, as entered, is tested against all variables. The test is the reduction in the standard error of the estimate, variables with the greatest reduction being entered first. All variables are tested to assure that the t-value for that variable exceeds 2, a value that was chosen so as to obtain a significance level of at least 5 percent for all variables in the final regression equation. A variable is removed by the algorithm if it fails this test. The search continues for new variables from among all variables, including those previously removed. Thus, the final equation resulting from the algorithm is one in which all variables are significant. The significant variables were then used in the Statistical Analysis System (SAS) regression package (GLM) for the remainder of the analysis to test the hypothesis that property values are directly related to distance from the plant; i.e., properties close to a nuclear plant have lower values than more distant properties, all other factors being equal. When nuclear plant related variables were not selected by the algorithm as being significant in explaining property value differences, we forced them into an equation using the SAS package to see what their levels of significance were and to see what effects their introduction had on the other independent variables.

3. PROPERTY VALUE EFFECTS OF FOUR NUCLEAR PLANTS

The four plants are: Pilgrim, near Plymouth, MA; Millstone, near Waterford, CN, on Long Island Sound; Oyster Creek in Lacey Township, NJ, along the

[8]Because sales do not occur at the same time, a deflation index was computed to correct for inflationary effects over the sampling period. An initial deflation index, reflecting the average monthly price changes, was used to correct actual sales prices. The month of sale was entered in the regression equation as an independent variable, and the initial deflation index adjusted until the month of sale was no longer significant. The final deflation indexes selected were monthly rates of 0.5 and 0.7 for the two studies, respectively. We feel that this approach provides a more accurate measure of inflationary effects in specific real estate markets than does the use of national average data. In addition, the month of sale variable was entered in all equations as an independent variable.

Atlantic coast; and R. E. Ginna near Rochester, NY on Lake Ontario.[9] Regression analyses are applied to a sample of 540 observations for the four plants. The dependent variable is the actual market selling price of houses that sold between 1975 and 1977 within selected housing developments, corrected by a deflation factor of 0.5 percent per month (see footnote 8). Housing developments that reflected a high degree of homogeneity of lot and house characteristics over the 20-mile distance from each plant were selected; therefore, not all sales during the time period were included.[10]

Sales and property characteristics data were obtained from county or township tax assessment offices or from multiple listing services. Each property in the sample was site inspected and the property descriptors recorded. In total, 76 property, sale, and community characteristics were a priori identified as possibly affecting the sale prices of houses.[11] These characteristics were then used to structure the independent variables for use in the regression equations. The California statistical procedures package selected the significant variables (at a 5 percent or better level).

We used two variables to indicate possible effects of the nuclear plants on property values: variable 33, nuclear plant visible (a binary variable to account for any price discrimination that might have arisen when the nuclear plant was directly visible from the property), and variable 34, distance to plant in miles. These two variables should be negatively and positively significant, respectively, to uphold our hypothesis that nearness to the plant is negatively capitalized into property values.

The results of the separate linear regressions for each plant are shown in Table 1, where all variables significant at the 5 percent or better level are included.[12] The signs of the coefficients are as predicted, except for variable 4, corner lot, in the Oyster Creek equation. Corner lots were common in only two developments in this study area, both of which were older developments containing lower priced homes. This variable probably reflects the lower values associated with these two developments rather than the usually higher values associated with corner lots. The magnitudes of all the remaining coefficients are close to what one would expect.

[9]These plants were not randomly selected, but were selected from those plants in the Northeast around which we felt property value effects would most likely be evident and around which residential development was quite homogeneous. The results, therefore, cannot be used for predictive purposes.

[10]All plants were fully operational by mid-1972, so any market adjustments to the presence of the plants should have occurred.

[11]For a thorough discussion of the variables including their method of construction, data source, means, and ranges, as well as a more detailed presentation of the data analyses and results see Gamble et al. (1979).

[12]A few of the variables may need further explanation. Variable 5, outstanding view, is 1 if there is a particularly striking unobstructed view of natural features from the lot; 0 if otherwise. Variable 6, view from house, is 1 if there is any view of natural features from the lot; 0 if the lot is surrounded by housing or other developments. House grade refers to the relative quality of materials and design of the house at the time of construction. House condition refers to the level of maintenance given the house over the years. The remaining variables are commonly used in property value regression models and should need no further elaboration.

TABLE 1: Regression Results: Separate Analyses of Four Nuclear Plant Sites in the Northeast

Variable	Predicted Sign	Regression Coefficients (F Value)			
		Pilgrim	Millstone	Oyster Creek	R. E. Ginna
Constant		9,013	14,903	8,863	31,162
2. Built 1969–1977 (b)[a]	+	2,856*** (11.52)		2,435** (9.26)	
3. Lot Depth (ft)	+			55.88*** (11.16)	
4. Corner Lot (b)	+			-1,602** (-6.09)	
5. Outstanding View (b)	+		3,796** (5.08)		10,198*** (20.00)
6. View from House (b)	+			2,176*** (16.71)	
7. House Grade good (b) × Area of Second Floor (ft²)	+		11.701*** (10.03)		
8. House Grade Good (b) × Area of First Floor (ft²)	+	8.230*** (32.33)	4.801** (5.23)		
9. House Condition Poor (b)	−		-4,589** (6.55)	2,650*** (-7.82)	
10. House Condition Good (b)	+			3,446*** 15.86)	
14. Distance to Major Employer (miles)				244.43*** (−42.24)	956.46*** (−64.37)
17. Month of Sale (Month)	+			103.43*** (17.35)	
18. Area of First Floor (ft²)	+	11.128*** (20.88)	15.217*** (47.84)	9.714*** (95.15)	8.702*** (14.14)
19. Area of Second Floor (ft²)	+	5.126*** (15.40)	13.523*** (46.32)	12.872*** (26.92)	6.240*** (8.76)
20. Area of Finished Basement (ft²)	+			5.346*** (8.05)	
21. House on Slab (b)			-2.558** (-6.00)		-5,627*** (-6.09)
22. Attach Garage (Number of Cars)	+	3,960*** (28.92)		1,164*** (4.32)	
23. Detached Garage (Number of Cars)	+	2,024** (4.61)		2,951*** (9.07)	
24. Internal Garage (b)	+	3,009*** (7.12)			
25. Fireplaces (Number)	+	3,015*** (17.56)	4,111*** (19.32)	2,764*** (18.03)	7,128*** (18.14)
27. Stone exterior (b)	+			2,211** (4.71)	
28. Bedrooms (Number)	+	1,543*** (7.40)			
29. Lot Area (ft²)	+		0.1718*** (10.18)		
30. Water Frontage (b)	+		10,162*** (20.52)	7,927*** (182.36)	
R^2		.809	.761	.874	.706
F		54.131***	55.858***	64.004***	22.778***
SEE		4,311	6,633	2,999	5,075
Residual Degrees of Freedom		115	175	148	57

Notes:
**Significant at the 1–5 percent level.
***Significant at the 1 percent or better level.
[a](b) refers to a binary variable.

Differences in the magnitudes of a coefficient among study areas reflect the housing and community characteristics associated with each area plus the fact that the same variables are not important in each equation.

All the equations are significant at the 1 percent or better level, and they explain between 70 and 87 percent of the variation in housing prices. As is to be expected, the same variables do not explain variations in housing prices in all four areas (only if the housing and community characteristics in all four areas were almost exactly alike would the equations be similar). There are several reasons for this variation. First, there are study area differences in the basic housing stock. For example, there are very few seasonal homes near the R. E. Ginna plant as compared to the three other plants. Second, there may not be enough observations for a particular variable within a study area for that variable to become significant. For example, in the Pilgrim, Millstone, and Ginna study areas there were only three, five, and two houses, respectively, with stone exteriors (variable 27), whereas in Oyster Creek there were 15 such houses. Third, there may not be enough variation in the measurement of a given variable within a study area for that variable to influence price. For example, in the Pilgrim, Oyster Creek, and Ginna study areas, lot sizes (variable 29) were apparently too uniform to explain differences in housing prices.

The two most important variables to the study, 33 (plant visible) and 34 (distance to plant), are not significant in any of the four study area equations. Based on these results, there is no evidence to indicate that the nuclear plants have any measureable effects, positive or negative, on single family housing prices. The fact that there were different significant variables in the four separate equations does not detract from these findings.

Table 2 presents the regression results when the data from all four study areas are combined,[13] all equations being linear.[14] All variables except numbers 33 and 34 that are significant at the 5 percent or better level (those originally selected by the California statistical procedures program) are included.[15]

The two variables indicating nuclear plant effects on property values (number 33, plant visible, and number 34, distance to plant) are not significant in the regular equation (the first column of data in Table 2). In separate subsequent regressions we forced in these two variables to see: (1) their level of significance, (2) the sign and value of their coefficients, and (3) the effects they had on other coefficients.

When variable 33, plant visible, is forced in it has a positive coefficient of 1,189, a sign that is opposite to that predicted to support the hypothesis and is significant at the 5–10 percent level. The coefficients of only two other variables are

[13]Some researchers have questioned the combining of two or more distinct housing market areas into a common data set to analyze hedonic price relationships. A recent study by Butler (1980) points out that the hedonic relationships of different metropolitan areas are considerably more alike than has generally been thought. We assume this to be true for our areas as well.

[14]The log-log form of the equation for the pooled data was specified, but the results did not improve the explanatory ability of the variables over the linear form. Both the R^2 and F values for the log-log form were slightly lower than those for the linear form.

[15]Variables 31 and 32 refer to subjective evaluations of the quality of community beach associations which have made certain kinds of improvements, membership in which is contingent upon owning property within a certain development.

TABLE 2: Regression Results: Combined Analyses of Four Northeastern Nuclear Plants

Variable	Predicted Sign	Regression Coefficients (F values)		
		Regular	Variable 33 Forced In	Variable 34 Forced In
Constant		19,509	19,363	19,588
1. Built Before 1914 (b)[a]	−	−3,462***	−3.604***	−3.498***
		(−7.95)	(−8.63)	(−8.06)
2. Built 1969–1977 (b)	+	2,233***	2,236***	2,229***
		(14.72)	(14.83)	(14.63)
6. View from House (b)	+	1,346***	1,151*	1,324**
		(4.86)	(3.47)	(4.65)
7. House Grade Good (b) × Area of Second Floor (ft^2)	+	7,797***	7,706***	7,756***
		(11.58)	(11.36)	(11.42)
8. House Grade Good (b) × Area of First Floor (ft^2)	+	6,139***	6,256***	6,220***
		(22.51)	(23.43)	(22.43)
9. House Condition Poor (b)	−	−2,368***	−2,216**	−2,320**
		(−6.85)	(−5.98)	(−6.43)
11. On Unpaved Road (b)	−	−1,437**	−1,392**	−1,427**
		(−5.18)	(−4.87)	(−5.09)
12. On Major Highway (b)	−	−2,118**	−2,093**	−2,111**
		(−5.68)	(−5.57)	(−5.64)
13. Distance to Swim Area (Miles)	−	−241.00**	−253.15***	−240.29***
		(−20.13)	(−22.00)	(−19.95)
14. Distance to Major Employer (Miles)	−	−195.96***	−188.02***	−191.54***
		(−38.49)	(−34.96)	(−32.16)
15. Distance to Limited Access Highway (Miles)	−	−532.41***	−534.54***	−527.46***
		(−59.81)	(−60.56)	(−56.50)
16. Distance to State Park (Miles)	−	−350.37***	−357.90***	−362..74***
		(−18.04)	(−18.87)	(−16.61)
18. Area of First Floor (ft^2)	+	11.436***	11.409***	11.396***
		(151.72)	(151.719)	(148.448)
19. Area of Second Floor (ft^2)	+	10.333***	10.236***	10.318***
		(110.59)	(108.72)	(109.89)
20. Area of Finished Basement (ft^2)	+	3.574***	3.671***	3.589***
		(9.86)	(10.433)	(9.915)
21. House on Slab (b)	−	−1,466**	−1,508**	−1,448*
		(−5.18)	(−5.50)	(−5.01)
22. Attached Garage (Number of Cars)	+	2,257***	2,279***	2,283***
		(29.37)	(30.07)	(29.16)
23. Detached Garage (Number of Cars)	+	2,230***	2,201***	2,224***
		(17.92)	(17.52)	(17.77)
24. Internal Garage (b)	+	2,107***	2,147***	2,113***
		(10.34)	(10.78)	(10.38)
25. Fireplaces (Number)	+	2,509***	2,495***	2,500***
		(26.31)	(26.16)	(26.03)
26. Central Heating (b)	+	1,688**	1,849**	1,704**
		(4.58)	(5.46)	(4.65)
29. Lot Area (ft^2)	+	0.0571***	0.0551***	0.0571***
		(7.51)	(7.01)	(7.49)
30. Water Frontage (b)	+	8,104***	7,950***	8,104***
		(114.43)	(109.37)	(114.26)

TABLE 2: Continued

Variable	Predicted Sign	Regression Coefficients (*F* values)		
		Regular	Variable 33 Forced In	Variable 34 Forced In
31. Average Beach Association (b)	+	2,577*** (7.31)	1,917* (3.57)	2,517*** (6.77)
32. Good Beach Association (b)	+	3,696*** (8.40)	3,642*** (8.19)	3,682*** (8.31)
33. Plant Visible (b)	–		1,189* (3.48)	
34. Distance to Plant (Miles)	+			−20.296 (−0.14)
R^2		.8055	.8068	.8056
F		85.166***	82.419***	81.759***
SEE		5,295	5,282	5,299
Residual Degrees of Freedom		514	513	513

Notes:
*Significant at the 5–10 percent level.
**Significant at the 1–5 percent level.
***Significant at the 1 percent or better level.
[a](b) refers to a binary variable.

simultaneously affected to a significant degree: view from house (Number 6) decreases in value about $200 and in significance from the 1–5 percent to 5–10 percent level, and average beach association (Number 31) decreases $660 in value and in significance from the 1 percent or better level to the 5–10 percent level. It is quite obvious that variable 33 is strongly related to variables 6 and 31, because of the change in sign from that hypothesized for variable 33 and the simultaneous decrease in values of the coefficients for variables 6 and 31.

The third column shows the results when variable 34, distance to plant, is forced in. Its coefficient is not significant and is also negative, a sign opposite to that expected. None of the other coefficients in the equation are strongly affected.

The hypothesized negative effects of the plants on property values were not revealed by variables 33 and 34. The conclusion of the regression analysis, based on sales data for 540 single family homes near the four nuclear power plants, is that no evidence exists to support the hypothesis that these nuclear power plants had an adverse effect on residential property values.

4. EFFECTS OF THE TMI ACCIDENT

Following the March 28, 1979, accident at the TMI nuclear plant near Harrisburg, PA, a concern frequently mentioned was a decrease in real property values in the vicinity of the plant. Our purpose now is to measure this effect. Here we use a sampling approach different from that used in Section 3. Sales of 583 single family homes within 25 miles of the plant, and of 112 homes in a control area

TABLE 3: Effects of TMI Accidents on Property Values

Variable	Expected Sign	Regression Coefficients (*t* value)			
		Before Accident (Linear)	After Accident (Linear)	Before and After Accident (Linear)	Before and After Accident (Log-Log)
Constant		−435	8,964	2,053	3.3937
1. House Built Before		6,135***	−5,012*	−6,295***	−0.0720***
1915 (b)[a]		(−4.43)	(−1.89)	(−5.18)	(3.84)
2. House Built 1915–	−	4,603***	—	−4,610***	−0.0402**
1933 (b)		(−3.36)		(−3.77)	(−2.15)
3. House Built 1934–	−	3,426*	−6,573**	−4,191***	−0.0705***
1946 (b)		(−1.86)	(−2.00)	(−2.65)	(−2.93)
4. House Built After	+	2,564***		1,761*	—
1968 (b)		(2.14)		(1.69)	
5. Lot Frontage (ft)	+	48.54***	—	36.99***	0.1394***
		(5.78)		(5.28)	(5.82)
6. Lot on Paved Road	+	—	—	3,865**	0.0493*
(b)				(2.16)	(1.82)
7. House Grade Poor (b)		6,833***	10,075***	−7,475***	−0.2683***
		(−3.60)	(3.75)	(4.32)	(−11.35)
8. Public Sewer (b)	+	3,493***	—	2,863***	0.0407***
		(3.42)		(3.35)	(3.04)
9. House Grade Good (b)	+	9,380***	6,891*	8,563***	0.0684**
		(4.19)	(1.89)	(4.62)	(2.46)
10. Airport Noise (b)		2,571*	—	—	—
		(−1.80)			
11. Trees on Lot (b)	+		3,598**	—	—
			(2.31)		
12. Two Family House (b)	+	6,330**	−5,726*	—	.0585*
		(2.51)	(1.71)		(1.92)
13. Flood Plain (b)			−8.257***	−3,202*	−0.0447*
			(2.68)	(1.84)	(−1.68)
14. House Condition Poor	−	−3.646***	−4,033*	−3,691***	0.1249***
(b)		(−3.01)	(−1.89)	(−3.52)	(−7.84)
15. House Condition	+	3,815***	4,782**	3,349***	—
Good (b)		(2.78)	(2.09)	(2.88)	
16. Floors (Number)	+	4,169**	—	3,254**	—
		(2.31)		(2.25)	
17. Bathrooms (Number)	+	2,330***	−	2,210***	0.1854***
		(3.00)		(3.28)	(3.19)
18. Area of First Floor	+	11.26***	10.02***	10.34***	0.2914**
(ft^2)		(5.92)	(3.45)	(6.66)	(6.33)
19. Area of Second Floor	+	—	—	—	0.0211*
(ft^2)					(1.99)
20. Attached garage	+	2,298***	3,361**	2,845***	0.0894**
(Number of Spaces)		(3.20)	(2.35)	(4.52)	(2.34)
21. Detached Garage	+	—	3,290**	1,289**	0.0631*
(Number of Spaces)			(2.62)	(2.10)	(1.66)
22. Internal Garage (b)	+	—	5,433***	2,341***	—
			(2.91)	(2.66)	
23. Fireplaces (Number)	+	3,571***	4,447***	4,044***	0.0166***
		(3.87)	(2.84)	(5.14)	(3.04)
24. Central Air Condi-	+	5,684***	—	5,146***	0.0406*
tioning (b)		(3.02)		(3.28)	(1.66)
25. Modern Kitchen (b)	+	2,739***	—	2,142**	0.0423***
		(2.69)		(2.45)	(3.21)
26. Stone Front Exterior	+	—	2,864**	—	0.0218**
(b)			(2.15)		(2.04)
27. Tax Rate (per $1,000)	−	−168***	204*	−196***	−0.2317***
		(−2.84)	(−1.93)	(−3.83)	(−4.56)
28. Bedrooms (number)	+	—	—	1,007**	0.0137**
				(2.19)	(1.97)
29. Distance to TMI	+	163***	105†	163***	0.0385**
(Miles)		(2.84)	(1.07)	(3.02)	(2.27)
30. After Accident (b)				924†	(−0.0081†
				(0.78)	(−0.24)

TABLE 3: Continued

Variable	Expected Sign	Regression Coefficients (t value)			
		Before Accident (Linear)	After Accident (Linear)	Before and After Accident (Linear)	Before and After Accident (Log-Log)
31. (Var. 29) × (Var. 30)	–			−74† (−0.76)	0.0102† (0.30)
R^2		.767	.833	.766	.787
F		46.42	19.50	58.14	65.83
Standard Deviation		7,360	6,590	7,276	.1107
Residual Degrees of Freedom		410	113	551	551

Notes:
†Not significant.
*Significant at the 5–10 percent level.
**Significant at the 1–5 percent level.
***Signifcant at the 1 percent or better level.
— Variables entered but have t values less than 1.00.
ᵃ(b) denotes a binary variable.

around Williamsport, PA, about 75 miles north of TMI, form the data base.[16] Two time periods were specified from which valid sales were selected: (1) before the accident, from January, 1977, through March, 1979; and (2) after the accident, the last nine months of 1979. Several distance zones around the TMI plant were also specified.[17] Sales were recorded by months, but the actual values were converted to real values (corrected for inflation) by a deflation factor of 0.7 percent per month as determined by an earlier regression (see footnote 8).

The sampling of house sales in the TMI study differed from the method used in the previous four-plant study because of basic spatial differences in growth patterns. The four nuclear plants studied earlier were all located along or very near the coasts of major water bodies (the Atlantic Ocean and Lake Ontario). Growth primarily occurred in a strip fashion along the coasts, with only minor development inland from the plants. In the case of TMI, growth in the Harrisburg SMSA area spread out in all directions from the central city. A time sampling difference in the two studies (one time period in the four-plant study, 1975–1977, and two time periods in the TMI study) was necessary in order to isolate correctly the effects due solely to the accident. We did not assume, just because of the findings from our earlier four-plant study, that the TMI plant before the accident had no effects, positive or negative, on housing prices. To measure properly the accident-induced effects, we would have to take into account the pre-accident effects on prices. Thus

[16]The Williamsport, PA area was selected because of its remoteness from any nuclear power plant and because of its similarity to the TMI area in terms of population growth and density, per capita income, land use mix, and location along the Susquehanna River.

[17]All valid sales in both time periods within three miles of the plant were used. Because of the large volume of sales in the more distant zones, sampling was done. Within 3–5 miles of the plant a random sample of 20 percent of all valid sales was used; from 6–25 miles a random sample of 1 percent was used; and a 5 percent sample was used in the control area. Before the accident sales totaled 505; after the accident sales totaled 190. There were 272 sales within five miles of the plant, of which 70 occurred after the accident.

house sales data were gathered from two time periods, one before and one after the March, 1979, accident.

The analytic procedures used in this study are the same as those used in the earlier study. From the initial list of independent variables, the California statistical procedures package identified those that were significant in explaining variations in house prices either before or after the accident and over the entire time period.

The regression results are shown in Table 3. Before interpreting the results, three variables need further explanation. Airport noise (Number 10), a binary variable, was inserted to account for any price effects by nearness to one of two airports serving the Harrisburg area, one of which, Harrisburg International, almost abuts the TMI plant. All property sales that fall within the NEF 30 noise contour interval for each airport were assigned 1, otherwise 0. There were 41 such sales before the accident, 10 after.

Property sales located on the flood plain (variable 13) were identified from flood plain maps, and were assigned 1, otherwise 0. There were 15 such properties before the accident, seven after. A troublesome fact is that much of the flood plain and the area within the NEF 30 noise contour coincide; also, they are in close proximity to TMI.

Variable 12, two family house, refers to a house which has rooms for rent. There were 17 such observations in the study area assigned a value of 1, otherwise 0.

The variables important for the purpose of this study, those related to the TMI plant and the accident, are numbers 29, 30, and 31. The first column shows the regression results for all property sales occurring before the accident. The variables in this equation all have the anticipated signs, and the magnitudes of the coefficients are reasonable. The important variable in this equation, distance to TMI (Number 29), is highly significant, which means that property values are expected to increase by $163 for each mile that a property is located from the plant; i.e., property values near the plant are lower than values for more distant properties. Whether this is TMI related or not is an important question that will be discussed shortly.

Column 2 gives the results of the regression on property sales that occurred during the nine months following the accident. For all variables except Number 12 (two family house) the signs are as predicted and, in general, the magnitudes of the coefficients are reasonable. The reasons why this variable became negative after the accident may be that: (1) rapidly rising mortgage interest rates during this period may have made people reluctant to invest in such properties for fear that rental income would not cover their costs, and (2) of the six sales of such properties after the accident, the majority may have been in poor condition, thus commanding lower prices. Whatever the reason, it is not accident related, nor are the other differences in the first 28 variables between these two equations explained by the accident.

Variable 29, distance to TMI, is not significant in the after accident data set, leading us to conclude that the accident itself had no apparent effects on housing prices.

Columns 3 and 4 contain results for the linear and log-log functional forms,

TABLE 4: Mean Annual Residential Prices and Number of Sales by Areas, Selected Years 1966–1979

Areas	1966	1970	1973	1975	1976	1977	1978	1979
0–5 miles								
Mean price	10,399	11,298	20,564	25,644	28,588	31,375	34,224	36,473
Number of Sales	296	374	388	351	561	597	415	406
5–25 Miles								
Mean price	13,030	15,970	25,087	28,041	31,420	34,143	37,424	41,463
Number of Sales	11,673	11,267	13,243	8,489	11,529	12,831	12,400	11,111
Control								
Mean price	13,233	17,981	22,832	29,537	30,956	33,111	37,933	40,247
Number of Sales	705	514	715	525	546	749	779	576

respectively, of the regressions run on the complete data set (property sales both before and after the accident). These regressions were run to substantiate further the effects, if any, on house prices. The signs of all the significant variables are in the direction anticipated and magnitudes are reasonable. The log-log form explains somewhat more the variation in selling prices than does the linear form.

Variable 29, distance to TMI, is significant and positive in both equations. Variable 30, after accident (a binary variable), is not significant in either equation, meaning that there were no significant differences in real housing prices in the two time periods. When variable 30 is interacted with variable 29 (after accident × distance to TMI) to produce variable 31, its coefficient is not significant in either equation.[18]

Based on the significance of the distance to TMI variable in several of the previous equations, it appears that our hypothesis is supported and that the presence of the plant did have an adverse effect on the price of single family homes. Regression coefficients, however, only depict relationships; they do not explain cause and effect. Is the relationship between property values and distance from TMI due to the plant, or is it due to some other phenomenon?

Because of our familiarity with the area, we know that the housing market in the area within a few miles of the plant contains old industrial communities in which older homes on small lots predominate. Mean annual residential sales data from 1966 (the first year in which State Tax Equalization Board data are available) through 1979 show that residential prices within five miles of TMI have traditionally been lower than those in the greater Harrisburg and control areas. These data are given in Table 4 and shown in Figure 1, where the number of sales are all valid sales of single family homes in the respective areas for the indicated year. There appears to be no noticeable effect resulting from the plant opening or from the accident on any of the curves.

Our sample sales data reflect the somewhat lower quality housing in communities near the plant as compared to the more distant communities. Table 5 shows

[18]See McClave and Benson (1979) for an excellent discussion of the use and interpretation of interacting two or more variables in multiple regression.

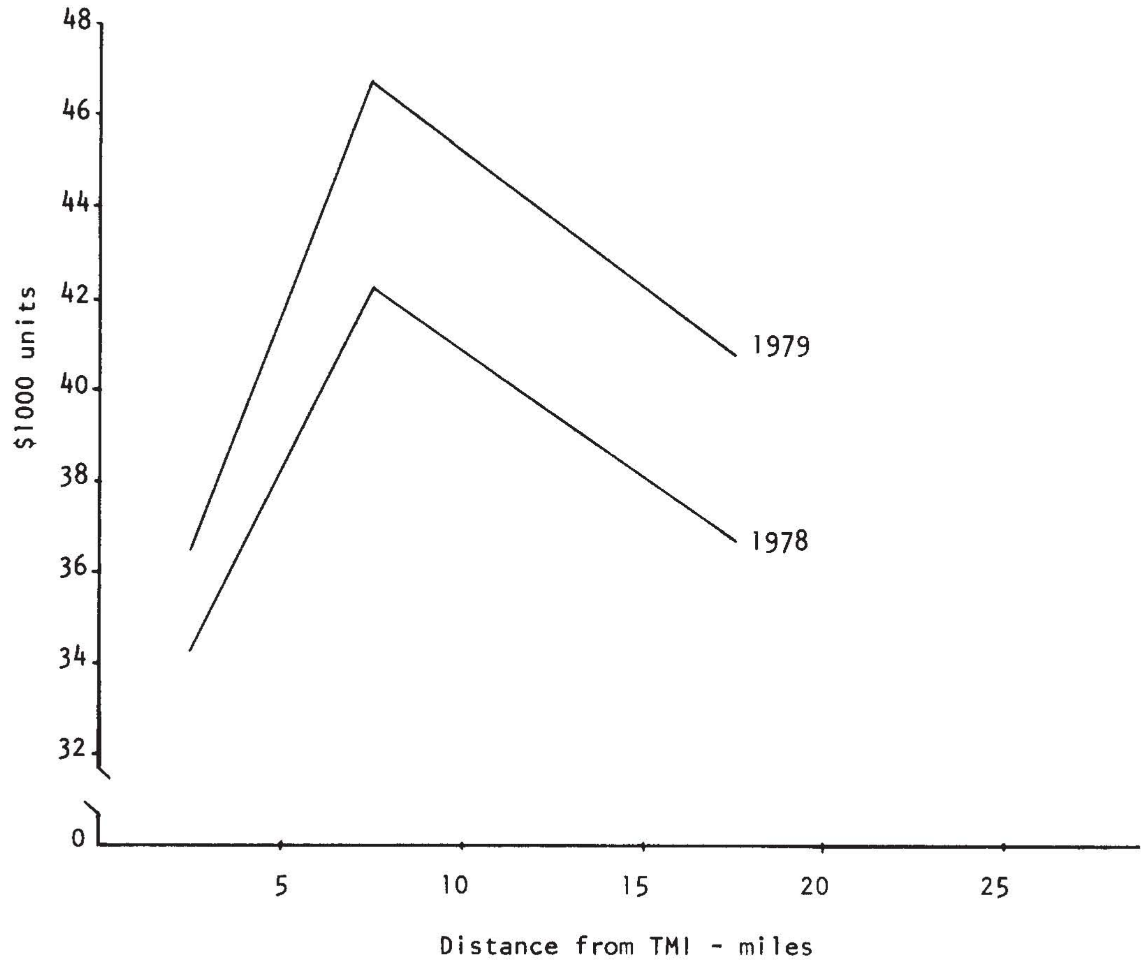

FIGURE 1: Mean Residential Prices, Selected Years, 1966–1979, By Areas.

the proportion of housing in our samples in poor condition and of lower grade by distance zones from TMI, and the average year built.

If community quality characteristics are reflected in the positive and significant distance to plant coefficient, might there be some objective measure of these which could resolve this problem? Data on two variables, available from the 1970 census, might reflect quality: the proportion of houses constructed on or before

TABLE 5: Proportion of Poor Condition and Low Grade Housing in Sample Data by Distance Zones from TMI, and Average Year Built

	Poor Condition (Percent)			Low Grade (Percent)			Average Year Built		
	Before	After	Before & After	Before	After	Before & After	Before	After	Before & After
0–5 miles	19.3	21.4	19.9	6.9	8.6	7.4	1932	1933	1933
5–10 miles	15.7	7.1	13.9	3.9	0.0	3.1	1951	1959	1953
10–25 miles	11.8	17.0	13.0	2.7	6.8	3.7	1937	1940	1938

1939 and the proportion of houses lacking all or some plumbing. When introduced into the regression equations, however, neither affected the magnitude or significance of the distance to plant variable, due to the fact that they were too closely related to existing variables that already depicted these housing characteristics.

Another possibility is that the distance to plant variable is not a linear or logarithmic function and is therefore misspecified in our equations. Computing and plotting the annual sales means for 1978 and 1979 for three distance zones around TMI using the complete STEB data set, we get Figure 2. These curves show that the distance to plant variable may be misspecified, and thus no interpretation of the meaning of the coefficient is possible. Further evidence of misspecification of

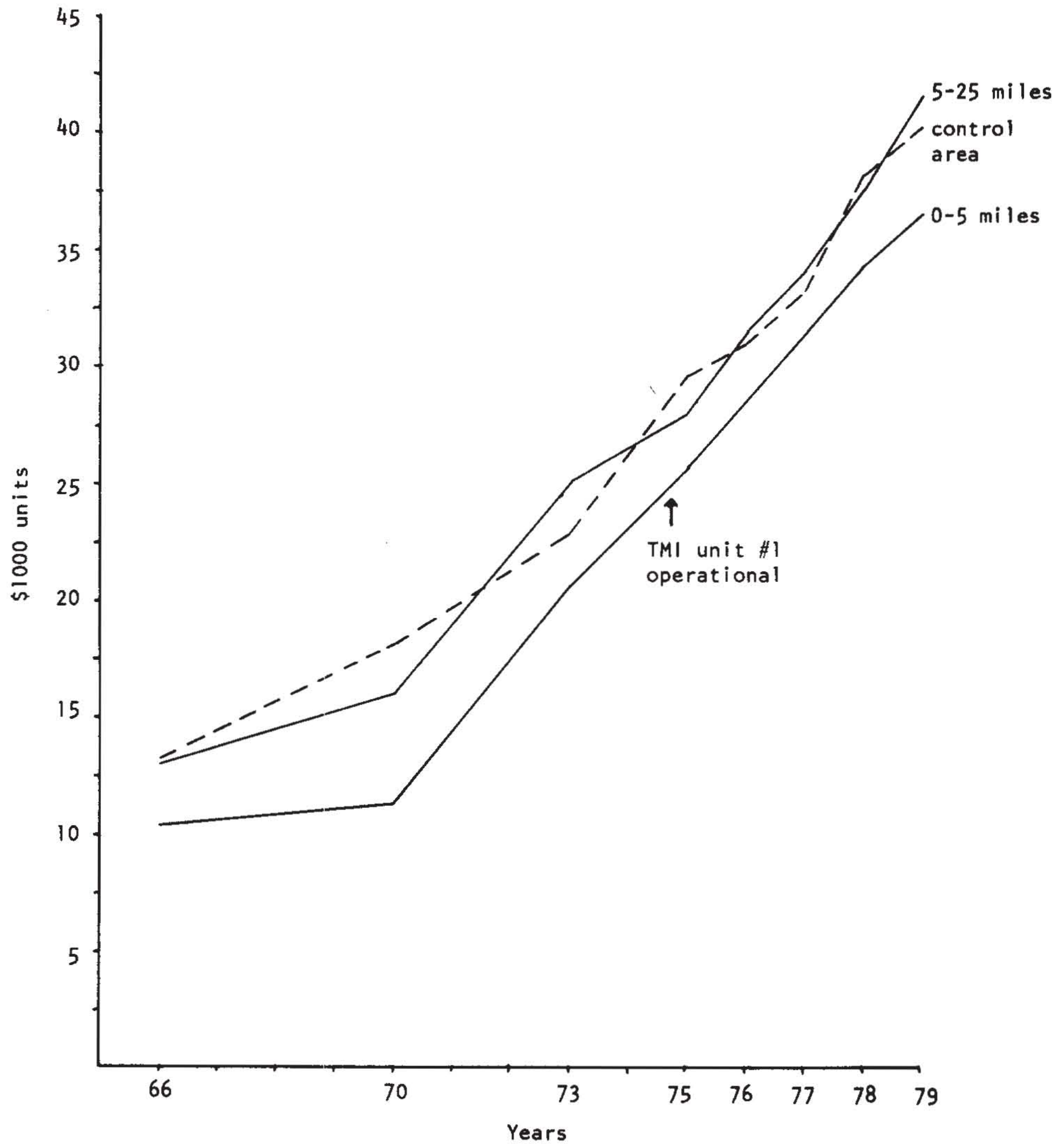

FIGURE 2: Annual Mean Sales Values By Distance Zones Around TMI, 1978 and 1979.

this variable was revealed when the coefficient for distance to TMI variable using the complete data set (including the control 80 miles away) was much smaller than the value shown in Table 3.

We next substituted the binary variable, close to TMI, for the distance to TMI variable in the before, after, and before and after accident data sets that included the entire study and control areas. In these runs, close to TMI was defined in two ways: 0–5 miles and then 0–2 miles. The results are shown in Table 6, omitting the nonplant related variables that changed little in magnitude and none in sign from those shown in Table 3. Within five miles of TMI, the price of housing is significantly lower (at the 1-3 percent level of significance) in the full data set (column 3), with no evidence that the accident had an effect on prices. However, there was no significant difference in the price of housing within two miles of TMI (column 4), indicating that whatever factors are influencing price close to TMI, they must exist beyond two miles from the plant. We have not been able to identify these factors. Logic suggests, however, that TMI is not one of them, for one would certainly expect that if the plant was adversely affecting housing prices, this effect would be felt most strongly on housing nearest the plant, a situation not supported by the regression results just discussed.

In summary, the results of our first TMI regression equations, which tested the hypothesis that housing prices were directly related to distance from TMI, indicated that the plant had a significant adverse affect on prices, but we presented

TABLE 6: Regression Results, TMI Related Variables, Substituting "Close to TMI" for "Distance to TMI" Variable in Full Data Set[a]

Variable	Before	After	Before & After	Before & After
	1	2	3	4
30. After Accident (b)			−323†	331†
			(−0.42)	(0.51)
36. Close to TMI (b)	−1,559*	−1,534†	−1,915**	
0–5 miles	(−1.89)	(−1.28)	(−2.50)	
37. After × Close (30 × 36)			1,167†	
			(0.92)	
39. Close to TMI (b)				−1,556†
0–2 Miles				(−1.44)
40. After × Close (30 × 39)				−2,730†
				(−1.15)
R^2	.772	.819	.770	.768
F	57.52	26.60	65.29	70.95
Standard Deviation	7,210	6,339	7,068	7,089
Residual Degrees of Freedom	474	161	662	662

Notes:
†Not significant.
*Significant at the 5–10 percent level.
**Significant at the 1–5 percent level.
[a]The significant variables describing house and lost characteristics are not included.

evidence that the distance variable was misspecified. The historical trends in mean annual residential prices by distance zones reveal that housing prices within five miles of TMI have been consistently below those farther away, going back eight years before the plant became operational. Further regression analysis indicates that housing prices in a zone within two miles of the plant are not significantly different from the total sample, but within a 0–5 mile zone they are significantly lower. Our inclination is to suspect that some factor, not identifiable, is responsible for this variation in housing prices.

In subsequent regressions we analyzed the data to see if there might be distributional effects in terms of (1) direction from the TMI plant, and (2) value classes of residential property. Four quadrants, North, East, South, and West, were delineated and entered as binary variables. Close to TMI (0–5 miles) was also entered as a binary variable and, as before, the data were structured into three time periods: before, after, and before and after the accident.

The results, shown in Table 7, report only those variables that contribute to an understanding of the quadrant effects, omitting the other variables that were very similar in most respects to those shown in Table 3. In the after accident data set, one coefficient is weakly significant, that for the south quadrant for variable 33 in which close to plant is interacted with the quadrant variable. There were only eight observations after the accident in this 0–5 mile area south of the plant, concentrated in a community lacking sewers and containing low value properties, many of which are converted small vacation homes. We do not believe this coefficient reflects the accident, particularly since the coefficient for the interactive variable 34 (close to TMI × quadrant × after) has a t value of only 0.04 for the south quadrant in the before and after accident data set.

In the before and after accident data set, two coefficients are significant for the quadrant binary variable (32); the north quadrant with a negative coefficient of −$3,026 and the south quadrant with a positive coefficient of $2,321. The positive coefficient is opposite to that which we would predict from the accident. The negative coefficient for the north quadrant, we suspect, reflects the unidentifiable factors discussed previously. None of the coefficients in this data set for variable 33 (close to plant × quadrant) and variable 34 (close to plant × quadrant × after accident) are significant. We conclude that there is not sufficient evidence to indicate that the accident had significant adverse effects on residential property values when examined in terms of their direction from the plant. Apparently prospective buyers did not discriminate against properties located downwind of the TMI plant.

We also used regression analyses to determine if the accident had any effects among three value classes of residential properties: low, medium, and high. The parameters for the value classes were selected by use of a histogram for the 1977 sales, and then deflators were applied to subsequent sales values through 1979. Significant independent variables for each value class were ascertained by using the California statistical procedures program. Three regression equations were specified for each value class (before, after, and before and after accident) and three binary variables relating to the accident were entered into the regressions

TABLE 7: Relevant Regression Results to Determine Quadrant Effects

Variables	North Quadrant		East Quadrant		South Quadrant		West Quadrant	
	Regression Coefficients (*t* values)							
	After	Before & After	After	Before & After	After	Before & After	After	Before & After
32. Quadrant	1,794†	-3,026***	572†	520†	1,758†	2,321**	257†	742†
	(-0.88)	(-3.15)	(0.29)	(0.53)	(0.84)	2.11	(0.10)	(0.66)
33. Close[a] × quadrant	3,888†	1,267†	-663†	1,918†	6,682*	-4,231†	766†	1,592†
	(1.40)	(0.77)	(0.21)	(1.12)	(1.88)	(-1.17)	(0.22)	(-0.87)
34. Close × quadrant × after		-34†		751†		174†		505†
		(0.02)		(0.29)		(0.04)		(0.20)
R^2	.84	.77	.84	.77	.84	.77	.84	.77
F	18.79	53.77	18.41	53.01	19.10	53.04	18.40	52.48
Standard Deviation	6,519	7,241	6,575	7,281	6,474	7,279	6,576	7,309
Degrees of Freedom	111	548	111	548	111	548	111	548

Notes:
†Not significant.
*Significant at the 5–10 percent level.
**Significant at the 1–5 percent level.
***Significant at the 1 percent or better level.
[a]Within 0–5 miles of TMI plant.

TABLE 8: Regression Results, TMI and Accident Related Variables, Comparing Control Area to TMI Area[a]

Variable	Regression Coefficients (*t* values)			
	0–5 Mile Area			10–25 Mile Area
	Before	After	Before & After	Before & After
30. After Accident (b)			−368† (−0.33)	−374† (−0.32)
35. Lycoming Control (b)	1,592* (1.77)	276† (0.20)		−1,649† (−1.26)
36. Close to TMI (b)			−1,804** (−2.03)	
37. After × Close (30 × 36)			1,177† (0.86)	
38. After × Lycoming (30 × 35)				492† (0.25)
R^2	.818	.816	.801	.773
F	45.26	16.97	55.10	34.89
Standard Deviation	5,511	5,649	5,608	7,883
Residual Degrees of Freedom	242	92	357	349

Notes:
†Not significant.
*Significant at the 5–10 percent level.
**Significant at the 1–5 percent level.
[a]The significant independent variables describing house and lot characteristics are not shown.

(close to TMI, after accident, and close × after). The results of the regressions, not reproduced here, show that the accident had no effects on the prices of residential properties when considered in terms of low, medium, or high value classes.

A final step was to compare the TMI area to the control area, in Lycoming County, PA. If property value effects were rather evenly dispersed over more than a 25-mile radius around the plant, then our previous analyses would not uncover them. The same three time periods (before, after, and before and after accident) were specified and separate regression equations were constructed for the 0–5 mile and 10–25 mile areas surrounding TMI.[19] The independent variables relevant to this analysis (all binary) were, after accident (30), Lycoming Control (35), and close to TMI (36).[20] Variables 35 and 36 were interacted with variable 30 in separate regression runs in the before and after data set.

Table 8 presents the results of several regression equations, showing the coefficients for the independent variables relevant to the accident and areas involved. The signs and magnitudes of the coefficients for the house and property

[19]It was felt that if no significant differences existed in the 0–5 or 10–25 mile zones, there would not likely be any differences in the 5–10 mile zone around TMI.

[20]Close to TMI is the same as the 0–5 mile zone around the plant.

selected variables followed the same general pattern as shown in the regression results in Table 3, and thus are not repeated here.

Before the accident, housing prices were somewhat higher in the Lycoming control area than prices in the 0–5 miles zone around the plant. After the accident, however, there was no significant difference in the price of housing in the two areas. In the before and after data set (column 3) housing prices were lower in the 0–5 mile zone, which follows the earlier findings and supports the positive but weakly significant coefficient for variable 35 in the first equation. The significance of the lower values for housing in the 0–5 mile zone disappears after the accident (variable 37). In the 10–25 mile area (Column 4), neither the Lycoming control area nor the 10–25 mile zone show significant differences in explaining variations in the selling price of houses. We conclude that after the accident there were no significant housing price differences between the control and TMI areas.

5. CONCLUSIONS AND DISCUSSION

Regression analyses using actual sales values for 540 single family properties in the vicinity of four nuclear power plants in the Northeast before the March, 1979, accident at the Three Mile Island plant found no significant positive or negative effects on property values. The same analytic approach, with 695 observations of property sales around the TMI plant, uncovered no evidence that the accident had adverse effects on property values through 1979. As part of the TMI investigation, differential effects were sought for three value classes of residential property, distance zones from the TMI plant, and direction from the plant, but no effects attributable to the accident could be identified.

Records of residential sales show that immediately following the accident there was a sharp decline in the number of sales within about ten miles of the plant. Some of the realtors we talked to characterized this period as a virtual collapse of the market. However, within 4–8 weeks of the accident the real estate market returned to near normal conditions, considering the coincidental effects of high interest rates and scarcity of mortgage funds at that time. This does not imply that, even today, there may not be an occasional buyer who will refuse to purchase a particular property because of its proximity to TMI. Apparently there were too few such people in the market during 1979 to affect measurably the demand for and consequently the price of housing in the area. However, this means that some properties may remain on the market for a longer time before being sold, thus increasing the holding costs for some sellers. This situation was not investigated.

Shortly after the accident the utility employed a large number of clean-up workers and nuclear technicians. These people should have little aversion to living near a nuclear plant, and they may have had a positive effect on the real estate market, counteracting an actual negative effect and thus resulting in a near zero net effect. It is the net effect of course, that our data measure. In terms of the concern of current property owners over the effects of the accident on property values, it is the net effects that are relevant, not the individual effects. We are inclined to believe that neither positive nor negative individual effects exist. Our rationale for this view is based on our conviction that very few, if any, clean-up workers would locate west of the plant, across the Susquehanna River, where the only access to the plant requires driving northward to the bridge crossings at Harrisburg. If this is the case, then no positive effect from the clean-up workers would occur here to balance any negative effects, and the results of our analyses for areas to the west of TMI must reflect, therefore, the singular negative effect of the accident. The results for this area showed no effects on prices. To accept the existence of counteracting effects, all negative effects must have been concentrated to the north or east of the plant (most of the area to the south of the plant is also across the Susquehanna River with even more difficult access to TMI). We find it difficult to believe that potential buyers would discriminate against properties close to TMI only when they were located north or east of the plant. However, if the influx of clean-up workers did have a positive influence on the housing market east of the plant, then the possibility exists that after clean-up operations are complete their exodus from the area might have a depressing effect—a long delayed reaction to the accident.

There is also a possibility that shortly after the accident most people realized that the nuclear contaminants were contained and that there was no imminent danger of massive spill or release of radioactive materials; therefore, no capitalization effect occurred once the market returned to normal within a few weeks. However, as the immense difficulties associated with the clean-up have become known, and the longer the plant remains closed with the contaminants contained therein, there may appear long-term capitalization effects. In addition, sharply rising electric power costs for the utility's customers, due to clean-up costs and to the cost of purchasing replacement power, may over time inhibit growth and development in the utility's service area, thus indirectly affecting property values.

Another possible explanation for the lack of capitalization effects in the nine months following the accident is that buyers anticipate federal or state compensation for any possible losses that may be identified, and that the expected value of such compensation is positively capitalized into property values. If it turns out that the seller receives the compensation (assistance tied to the property and not the owner) then the seller receives a windfall gain.[21] If the buyer receives the compensation, then he or she is no better off, since the compensation will be equal to the premium paid for the property. In such a case there remains the very difficult task of estimating from market sales data only the negative effects of the accident.

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[21]If the buyer knows in advance that compensation would be paid to the seller, no capitalization of the TMI accident would occur. There could be capitalization of anticipated future accidents.

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