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Spent nuclear fuel and residential property values: the influence of proximity, visual cues and public information *

David E. Clark[1], **Tim Allison**[2]

[1] Department of Economics, Marquette University, P.O. Box 1881, Milwaukee, WI 53201-1881, USA (e-mail: clarkde@marquette.edu)
[2] Policy and Economic Analysis Group, Decision and Information Sciences Division, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439, USA (e-mail: tallison@anl.gov)

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Abstract. This article examines whether public knowledge of spent fuel storage at nuclear power plants, and any local adverse risk perceptions that may have occurred, affect the sale price of single-family residential properties. We present evidence from the Rancho Seco, California, plant on residential property values using an hedonic modeling framework. We include a large number of control variables, data with a high level of spatial detail and a number of public information variables in order to model property market effects within a fifteen mile radius of the plant. Our findings indicate that proximity and visual reminders of the plant have some influence on local property markets, and that there is a small media coverage effect on single-family home sale prices.

JEL classification: R14, R20

Key words: Nuclear fuel, property values, hedonic modeling

1 Introduction

In this study, we are interested in determining whether public knowledge about spent nuclear fuel storage activities at nuclear power plants, and any adverse risk perceptions and stigmatization that may occur in the surrounding area, lead to measurable effects on the sale price of single-family residential properties. Spent

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nuclear fuel is currently stored in water pools at most of the nation's 72 commercial nuclear power plant sites awaiting the opening of a permanent federal disposal facility at Yucca Mountain in southern Nevada The project has experienced massive opposition from the State of Nevada and from local citizens groups, however, much of it based on heightened perceptions of risk associated with the long-term presence of nuclear waste in southern Nevada, spent fuel transportation to the repository site, as well as the potential effects adverse perceptions could have on tourism and economic development in the area.

Along with political opposition to the project a large literature has also developed, much of it based on the findings of public opinion surveys illustrating negative imagery and public perceptions of risk related both to the repository and to nuclear waste transportation and nuclear facilities in general. Much of this literature suggests that public concern and political opposition is rooted in the intense negative imagery that the public attaches to facilities, activities and technologies associated with the words "nuclear" and "radioactive," and the exaggerated adverse economic response that may be generated by events that are associated with nuclear energy, facilities and transportation through a process referred to as "the social amplification of risk." (see Kunreuther et al. 1988, Slovic et al. 1991, Erikson 1994, Jenkins-Smith 1994, Metz 1994).

Public and political opposition to the civilian spent fuel management program has led to significant delay in the opening of a repository, and as a result spent fuel pools at many of the nations nuclear power plants are approaching storage capacity. In response, a number of utilities who are facing immediate spent fuel pool storage capacity problems have constructed or are planning to construct dry storage facilities. As there is significant doubt over whether a repository will be available for the disposal of commercial spent fuel in the near future, dry storage of spent fuel at reactor sites is likely at all 72 of the nations nuclear power plants.

In this article, we present evidence of the impact of the plan to construct and operate a dry storage nuclear waste facility at the Rancho Seco nuclear power plant on local residential property values. The article is part of a larger study which examines a sample set of properties which were sold within a 15-mile radius of several California nuclear power plant sites along with a control site (see Clark et al. 1997, Metz and Clark 1997, Metz et al. 1997). The Rancho Seco plant, located approximately 25 miles southeast of downtown Sacramento, California, began operation in April 1975 and has been idle since June, 1989 when a public referendum resulted in the end of electricity generation at the plant because it was no longer able to produce competitively priced power. Since that time the plant has remained open as spent fuel is still stored in the pool storage facility inside the reactor building. In October, 1991, the Sacramento Municipal Utility District (SMUD), which owns the plant, applied for a license to construct and operate a dry storage facility. SMUD officials have estimated that they can reduce annual operating costs at the plant by nearly $1 million if the waste is placed in dry storage at the site.

Our analysis is aimed at addressing the claim that adverse risk perceptions and stigmatization as a result of existing and planned nuclear waste facilities

necessarily leads to local economic impacts. A number of studies have found adverse risk perceptions and stigmatization result from spent fuel storage activities in the area immediately surrounding power plant sites (Pasqualetti 1994, Bassett and Jenkins-Smith 1996). An examination of residential property market impacts in the vicinity of a nuclear power plant over a period in which plans to dry store spent fuel on-site have been made public is likely to indicate whether local economic impacts result from adverse risk perceptions. Our analysis covers the five-year period 1990 through 1994. As the announcement by the utility to dry store fuel came in October 1991, we are able to measure property value impacts from the plant during both the pre-announcement and post-announcement periods.

While the placement of spent fuel in dry storage at Rancho Seco does not increase the amount of waste stored at the site, placing the fuel in dry storage facilities has the potential to adversely affect the local economy, and in particular the local property market, in a number of ways. First, the application process to the Nuclear Regulatory Commission draws public attention to the fact that spent fuel remains at the plant, even though the plant is not operational. Second, the increased media coverage may serve to inform the public about the risks associated with the existence of spent fuel, and about the risks of transferring the waste from wet storage. Furthermore, some residents may view dry storage to be more or less hazardous than wet storage in pools. Finally, critics of dry storage have argued that it will effectively create *de facto* permanent waste storage facilities at individual utility sites should the Federal Government fail to successfully site a permanent repository in Nevada.

There is no evidence in the literature of any impact on residential property prices resulting from adverse perceptions associated with the siting of power plant spent fuel storage facilities. In a review of the literature on residential price effects of nuclear power plants, Fox et al. (1985) conclude that the siting of a temporary nuclear waste storage facility in Tennessee is more likely to be capitalized into residential property values if there is an increase in the public's knowledge or understanding of the risks associated with facility. They further contend that "the willingness to pay for distance from the facility" is likely to have significant price effects only for properties within approximately one mile of the plant.

2 Theoretical model

2.1 Literature review

Since the path-breaking work of Lancaster (1966) and Rosen (1974), the hedonic model has been used to determine the willingness to pay to avoid proximity to noxious or hazardous activities. For example, Michaels and Smith (1990), McClelland et al. (1990), and Kohlhase (1991) investigated the influence of proximity to hazardous waste dumps; Blomquist (1974) studied coal-fired power plants, and Kiel and McClain (1995) considered how proximity to an incinerator affects

residential home prices. The hedonic model has also been used to determine whether environmental accidents or natural disasters influence residential home prices. For example, Gamble and Downing (1982, 1986) and Nelson (1981) investigated the property value impacts of the 1978 nuclear accident at Three Mile Island, and Bernknopf et al. (1990) examined how earthquake and volcano hazard notices affect the perceived market value of properties. The Bernknopf et al. study is particularly interesting since it not only estimates the property value impacts of hazardous events, but also investigates how knowledge about the risks associated with future earthquakes (as conveyed by public notices of earthquake risks which are required at the time of sale) affect the property market.

2.2 A brief development of hedonic theory

The theory which underlies the hedonic model has been developed extensively elsewhere (see Hageman (1981) with specific regard to nuclear power plants) and thus, it is not reproduced in its complete form in this article. The hedonic model views housing as a differentiated bundle of attributes $z = (z_1, z_2, \ldots, z_n)$ where the vector z represents structural housing characteristics and features of the neighborhood. Assuming (a) perfect information about the bundle of attributes embodied in all properties in the market; (b) zero transactions costs in market trades of the packaged bundle; and (c) a continuous offering of attributes in the real estate market, the interaction between utility-maximizing consumers and cost-minimizing producers will generate an equilibrium price for housing which implicitly prices each attribute in the bundle, $p(z)$. The price function, $p(z)$ is generally assumed to be nonlinear, since the costs of repackaging a bundle of attributes is prohibitive once a house is built. Under these conditions, the implicit price of an attribute can be derived as the partial derivative of the equilibrium price function with respect to that attribute, $p_{zi}(z) = \partial p / \partial z_i$. Given the aforementioned assumptions, $p_{zi}(z)$, which is sometimes called the implicit price function, is equal to the marginal willingness to pay for a marginal increment in attribute z_i.

2.3 The role of information

Recall that the hedonic model assumes that sellers and buyers have perfect information about the quantities of all characteristics, z, in the housing bundle. In the absence of perfect information, however, the price function is dependent on the perceived level of the attribute vector, z_*. Thus, the equilibrium price function is also a function of the perceived level of attributes (i.e., $p(z_*)$). While the perceived level of knowledge about attributes is capitalized in the equilibrium price function, unknown attributes cannot be capitalized. Suppose the perceived level of an attribute (z_{*i}), is a function of an index of public knowledge (α) about the attribute (where $0 \leq \alpha \leq 1$), and the actual level of z_i (i.e., $z_{*i} = f(z_i, \alpha)$. The index is assumed to vary between no information, ($\alpha = 0$) and complete

information ($\alpha = 1$). Thus, if $\alpha = 0$ then $z_{*i} = f(z_i, 0) = 0$. In contrast, if $\alpha = 1$ then $z_{*i} = f(z_i, 1) = z_i$. The implicit price for attribute z_i thus depends not only on the attribute level, but also on the level of public information. Using this as a background, we can evaluate the influence of new public information in the hedonic model.

Given that the equilibrium price function is $p(z_*)$, suppose that new information becomes available concerning a particular attribute, z_i. Press coverage that informs the public about the decision to build a nuclear waste dry storage facility has the potential to effect the level of the equilibrium price function since $p(z_{*i}(z_i, \alpha))$. That is, $\partial p(z_*)/\partial\alpha = \partial p/\partial z_{*i} \times \partial z_{*i}/\partial\alpha$ is nonzero if the attribute matters to local residents (i.e., $\partial p/\partial z_{*i} \neq 0$), and as long as information affects the perceived level of the attribute (i.e., $\partial z_{*i}/\partial\alpha \neq 0$). If news coverage raises public safety concerns, then $\partial p(z_*)/\partial\alpha < 0$ since $\partial p/\partial z_{*i} < 0$ and $\partial z_{*i}/\partial\alpha > 0$. Note that as the actual information tends towards complete information (i.e., $\alpha \to 1$), then $p(z_*) \to p(z)$. Second, additional information can also have an effect on the implicit price function, since anything that shifts the equilibrium price function (p_{zi}) is likely to influence the implicit prices that are derived from that function (i.e., $\partial p_{*i}/\partial\alpha$). For example, Kiel and McClain (1995) show that the effect of an incinerator plant on residential home prices varies with the phase of the project. In this model, as the project goes from the pre-rumor to the rumor stage, the value of α increases from zero to some positive value. Kiel and McClain found that the equilibrium price surface shifts, and also the implicit value of distance from the plant changes, with the phase of the project.

3 Empirical model

3.1 Model specification

Applications of the hedonic model have been criticized for focusing extensively on one phenomenon to the exclusion of other salient locational factors. The issue of specification is an important one. For example, a recent article by Smith and Huang (1993) found that the number of demographic and neighborhood characteristics affected the likelihood of identifying a statistically significant linkage between air quality (specifically particulate matter) and sale prices. If one is to avoid the bias from excluded variables in estimates of the implicit valuation of characteristics of nuclear plants, then other attributes which vary spatially, and which may be correlated with proximity to the plant, need to be included in the model.

The empirical model is broadly specified as follows:

$$\ln \text{RPRICE} = f\ (\text{STRUCTURE, NEIGHBORHOOD, CITY, TIME, NUCLEAR})$$

where the real sale price of housing (measured in logarithmic form) is a function of five vectors of determinants: STRUCTURE, NEIGHBORHOOD, CITY, TIME and NUCLEAR. Individual categories will be described shortly.

Property sales data were obtained from TRW REDI-Property and represent individual single-family residential home sales which took place between 1990

and 1994 within 15 miles of the Rancho Seco plant. Since we are interested in the role played by public information about the plant, we have chosen a period over which there was active media coverage about the plant in general, and nuclear waste in particular. One advantage of focusing on Rancho Seco is that since the plant is shut down and only a small workforce remains at the plant, employment effects, which can increase the value of properties for workers living close to the plant, are likely to be minimal. Several screens were applied to the data. First, we screened out properties which sold for less than $10,000 (in real terms) based on the possibility that these were not arms-length transactions. In addition, several observations had variables which appeared to be miscoded (e.g., one property reported a price in excess of $100 million) and were subsequently dropped from the sample. Finally, data were dropped when the latitude or longitude was missing, since this would prevent matching to the locational attributes. This resulted in a sample of 758 properties.

3.2 Use of GIS tools

An important empirical task is to match proximity of the phenomenon affecting property sales prices to individual properties. To accomplish this, we used Geographic Information System (GIS) software.[1] Since all property sales data are geocoded, distance to the closest hazard or annoyance factor can be readily computed provided the location of the activity can also be geocoded. If hazard data could not be accurately assigned a latitude/longitude coordinate, then the characteristics were matched according to other criterion (e.g., by census tract, or zip code).

3.3 Independent variables

Complete variable definitions, data sources, and descriptive statistics are reported in Table A.1. The vector STRUCTURE contains characteristics of the home, including the age of the house, the number of bedrooms, the number of full and half baths, the presence of central air conditioning, the number of stories in the structure, the number of fireplaces, the interior square footage of the building, and the size of the lot on which the house is located.

We included numerous attributes of neighborhoods in the NEIGHBORHOOD category to account for the influence of locational phenomenon on housing markets. These factors include demographic features such as racial and ethnic mix, as well as median income and poverty levels. Other measures include the occupancy rates of housing units in the neighborhood, the percent of neighborhood properties that are owner occupied and the average travel time to work in the neighborhood. School quality is proxied by the student-teacher ratio in local public schools. Although other public services are not included, the effective property

[1] PC-based GIS software packages from MapInfo and Scan/US were used in this project.

tax rate on the home is available, which can be used to proxy not only the local property tax burden, but also the level of public services within the community. Noxious activity in the community is proxied by several measures, including proximity to interstate highways, airports and railroads. Although controls for proximity to Superfund sites, hazardous waste disposal sites, and correctional facilities were contained in the database, no such facilities were within 5 miles of the closest property, and hence they were not included in the analysis.

3.4 Modeling public information

The goal of this study is to determine the extent to which $\partial p/\partial\alpha \neq 0$ and $\partial p_{*i}/\partial\alpha \neq 0$ (i.e., public information affects the equilibrium price, and implicit price functions respectively). To do so requires that public information, α, be measured. Accordingly, we examine articles about Rancho Seco appearing in the local newspaper, the Sacramento Bee, between 45 and 120 days of the sale of the property. Articles published within 45 days of the sale are assumed to have appeared after the offer to buy has been accepted, while press coverage appearing more than 4 months prior to the sale is assumed to be too early in the process to influence the sale price. Over the 5 year period, there were 62 articles or editorials written about the plant.

Although other media outlets (e.g., television, radio, national newspapers) exist, we chose to focus on press coverage in the dominant local newspaper for several reasons. First, any public information on the Rancho Seco plant which appears in national media outlets is also likely to be reported in the local media. Thus, local coverage actually proxies national coverage as well. The converse is obviously not true, with issues that are reported in the local media, in most cases not finding their way into national media outlets. Second, it is a relatively easy task to determine readership of local newspapers. The same cannot be said for the audiences of local television and radio stations. Third, even if estimates of audience size and geographic range could be obtained for television and radio markets, individual stations do not typically keep the transcripts of news reports in a readily accessible format. Thus, assembling data for all media outlets was not possible, and we use local newspaper coverage as a proxy for the level of public information from all sources (i.e., local and national newspaper, radio, television) about the activities at the plant.

3.5 Research questions

The model specifications explored in this article are designed to answer the following four questions:

1. Is there a relationship between housing prices and distance from the Rancho Seco plant and is that relationship stable over time?
2. Do visual cues about the Rancho Seco plant influence the relationship between the real sales price and distance from the plant?

3. Have announcements about spent nuclear fuel affected the price-distance relationship?
4. Has newspaper coverage in the period between 45 and 120 days prior to the sale affected the sale price of the property either inside or outside the visual range?

To investigate these questions, the elements of the NUCLEAR vector are measured using several different specifications. To address the first question, we include variables measuring distance from the plant, as well as a dummy variable for the time period after the newspaper announcement of plans to build a spent fuel dry storage facility at the plant. To address the second question, a dummy variable for the visual range[2] of the plant is also included, and that dummy variable is interacted with distance from the plant. The third question is tested by including a dummy variable for properties that sold after the announcement was made regarding dry storage of spent fuel at Rancho Seco. That dummy variable is also interacted with distance from the plant. To address the fourth research question, the influence of newspaper coverage about the plant is measured in four ways. Total volume of press coverage is measured by the number of paragraphs in the articles which appeared in the relevant time period prior to the sale. The content of the articles is proxied by whether those articles dealt with general nuclear issues, spent nuclear fuel, or transportation of nuclear waste. The press coverage variable is interacted with distance from the plant and the visual range dummy variable.

4 Empirical findings

Complete variable definitions and descriptive statistics for each variable are provided in Table A.1. The model is estimated using a semi-log functional form. Although some authors have suggested using flexible functional forms (Rassmussen and Zuehlke 1990), others have expressed concern about the accuracy of implicit prices derived using flexible form specifications (Cassel and Mendelsohn 1985). Furthermore, when there is the possibility of an omitted variables bias, Cropper et al. (1988) have shown that the semi-log model outperforms other functional forms. The White test reveals no significant problem with heteroskedasticity in any of the models estimated. All of the models explained approximately 83% of the variation in the log of the real sales price.

Before evaluating the findings for individual models, the coefficients on the control variables are discussed. Since the signs and statistical significance of levels of coefficients on the control variables are insensitive to the specification of the nuclear variables, we discuss the findings on the control variables for the first specification only (Table 1).

[2] A survey of the area surrounding the plant was undertaken by the authors, consisting of photographs of the plant taken at locations where residential development is present. These photographs reveal that the plant is located on relatively flat terrain, with few natural or man-made surface features or vegetation interrupting views of the facility. Under normal weather conditions, the cooling towers at Rancho Seco are visible from a distance of up to approximately 10 miles in all directions.

Table 1. Evaluation of price gradient, announcement effects and visual cue effects. Dependent variable: log of real housing price

Variable	Coefficient	t-score	Variable	Coefficient	t-score
Intercept	9.753199	5.058			
	Structural characteristics			*City dummy variables*	
BEDROOM	−0.008132	−0.682	ACAMPO	−0.057327	−0.245
FULLBATH	0.025188	1.333	ELKGROVE	0.135675[a]	2.934
HALFBATH	0.017775	0.986	GALT	−0.173894	−0.442
CNTRLAIR	0.007453	0.391	HERALD	−0.195765	−0.499
FIREPLCE	0.038423	2.811	LOCKEFRD	−0.621811	−1.605
NUMSTORY	−0.073537[a]	−3.920	SLGHHOUS	−0.259757	−0.918
AGEHOUSE	−0.001679[a]	−2.898	WILTON	−0.449223	−1.036
LOTAREA	5.96E-07[a]	6.321			
BLDGAREA	0.000421[a]	21.346			
	Neighborhood characteristics			*Nuclear and date variables*	
%ASIAN	−3.196974	−0.916	DATE	9.36E-05	1.140
%BLACK	1.709588	0.609	DISTANCE	0.042521[a]	2.598
%HISPANIC	2.371015	1.111	VISUAL	0.208866[a]	2.464
%PUBASST	−0.642847	−0.311	ANNOUNCE	0.006125	0.245
MEDHHINC	−2.00E-05	−0.952	DIST*DATE	−1.86E-05[a]	−2.923
%OCCUPIED	−2.165146[a]	−2.905	DIST*VISUAL*ANNC	−0.011330	−1.633
%OWNEROC	2.295343[b]	1.831			
TRAVTIME	0.059638	1.239			
OZONE	−0.665362[a]	−2.362			
INTRSTAT	−0.008446	−0.296			
RAILROAD	−0.038185[a]	−2.424			
AIRPORT	−6.96E-08	−0.128			
TOXRELINV	−0.009127	−0.434			
WATER	0.015092	1.033			
TSRATIO	21.27992[b]	1.879			
TAXRATE	−8.197497[a]	−2.042			
POPDENSITY	−3.50E-06	-0.241			

Adjusted R^2: 0.833731 Log-likelihood: 362.4889 F-statistic: 98.32961 Number Obs: 758

Joint F-tests:

Structural characteristics:	$F_{9,748} = 159.920^c$	Distance variables:	$F_{3,754} = 3.580^c$
Neighborhood characteristics:	$F_{17,740} = 6.826^c$	Date variables:	$F_{2,755} = 26.678^c$
City dummy variables:	$F_{7,750} = 2.678^c$	Visual variables:	$F_{2,755} = 3.147^c$
		Announce variables:	$F_{2,755} = 1.038$

[a] Statistically significant at the 5% level of significance in a two-tailed test.
[b] Statistically significant at the 10% level of significance in a two-tailed test.
[c] Statistically significant at the 5% level of significance.

4.1 Findings on the control variables

Chow tests were conducted on each category of control variable, and all groups were found to be statistically important. Individual coefficients in the STRUCTURAL characteristics category were typically of the predicted sign and frequently significant. For example, the number of fireplaces and the square footage of the lot and the building increased the sale price, whereas multistory homes and homes that were older had lower sales prices *ceteris paribus*. Likewise,

NEIGHBORHOOD characteristics were often correctly signed and significant, although there were some exceptions. Whereas higher owner occupancy rates (among all occupied units) increased the sale price as expected, higher overall occupancy rates (across all units) had a negative and significant coefficient. The latter finding may reflect newer neighborhoods experiencing high levels of construction and hence lower occupancy rates. Noxious activity, measured by close proximity to railroads and high ozone levels, reduced housing prices, as did exposure to relatively high property tax rates. Finally, high teacher-student ratios in the local school system significantly increased housing prices. Variables in the CITY dummy variable category are expressed relative to Sacramento, the omitted dummy variable. We assume that these dummy variables capture amenities and disamenities not adequately captured in the NEIGHBORHOOD characteristics category. In addition, fiscal expenditures are also proxied by these variables. Compared to Sacramento, for example, housing prices are significantly higher in Elk Grove, whereas they are lower (although not quite significant at the 10% level in a two-tailed test) in Lockeford.

4.2 Findings on nuclear and date variables

To investigate the first two research questions, we estimate a model with six different variables. Temporal changes in the hedonic function and the price-distance gradient are captured by including a continuous measures of time (DATE)[3] and DISTANCE[4] separately, and then interacted. To test for the importance of visual cues of the plant, we include a dummy variable for the visual range (VISUAL) which takes on a value of one if the property is within the 10 mile visual range of the plant, and zero otherwise.[5] Finally, a dummy variable for the announcement of dry storage at Rancho Seco (ANNOUNCE = 1 for properties selling after the announcement) is also included. The variable DISTANCE is interacted with ANNOUNCE and VISUAL to permit the gradient within the visual range to change in the post-announcement period.

Question #1: Is there a stable price-distance relationship? Turning to the variables related to distance and time, there is support for the hypothesis that housing prices vary significantly with distance from the plant. The partial derivative of the hedonic function with respect to DISTANCE includes three separate terms: $\partial \ln P / \partial \text{DISTANCE} = 0.043 – 1.86E\text{-}5 * \text{DATE} - 0.011 * \text{VISUAL} * \text{ANNOUNCE}$ (Table 1). The first term indicates that real housing prices rise by about 4.3% per mile (i.e., $7476 in 1998 dollars evaluated at the mean housing price) at the

[3] Dummy variables for the year in which the property sold were also investigated, with no changes in the signs on the coefficients, and only minor changes in significance levels.

[4] An investigation of higher order terms reveals no support for quadratic or cubic distance specifications.

[5] Since visual cues for properties closer to the plant may be expected to be stronger, we experimented with different values for the visual range, ranging from within 3 miles, to within 10 miles. The highest significance levels on visual variables are found when VISUAL is defined as being within 10 miles of Rancho Seco.

beginning of the period. However, the second term implies that over the 1990–1994 period, the distance gradient has been significantly flattening approximately 0.7% per year (i.e., $1208 per year in 1998 dollars). Interestingly, Gamble and Downing (1982) initially find evidence of a rising gradient from Three Mile Island of $163 per mile which is approximately 0.5% of the average sale price of homes within 5 miles of the plant in 1978. Taking into account housing inflation since 1978, the real price would increase by $419/mile in 1998 dollars. However, Gamble and Downing conclude that the evidence of a positive gradient is an anomaly resulting from a misspecified model.

Viewed collectively, these two coefficients indicate a positive but flattening gradient for the five years of the sample. Thus, we can conclude that a price-distance relationship does exist but that it is not static. Rather, aversion to the plant, as reflected in a rising housing price with greater distance has been declining over the five years of the sample. The importance of the third term is discussed below.

Question #2: Do visual cues about the Rancho Seco plant influence the relationship between the real sales price and distance from the plant? We hypothesize that visual reminders of the plant can influence housing prices and also influence the price-distance gradient. The change in the housing price function resulting from being within the visual range is: $\partial \ln P / \partial \text{VISUAL} = 0.209 – 0.011 * \text{DISTANCE} * \text{ANNOUNCE}$. The first term shows housing prices significantly higher inside compared to outside the visual range (i.e., 20.9% or $37,201 higher for the mean valued home in 1998 dollars). This finding is somewhat surprising, since one would expect that if anything, visual cues would tend to stigmatize a property. Gamble and Downing (1982) also find positive impacts from a visibility dummy variable although they conclude that this is due to multicollinearity with site-specific amenities in the model. The second term suggests a flattening of the price-distance gradient within the visual range following the announcement of the dry storage facility at Rancho Seco, although the coefficient is not quite significant at the 10% level of confidence. While it could be argued that being within the visual range of the plant might actually proxy an "openness" amenity, this is not the case in this sample since the entire geographic area is relatively flat. Hence all properties would have access to this amenity.

Question #3: Have announcements about spent nuclear fuel affected the price-distance relationship? Collectively, as indicated by the Chow test, the two variables capturing the influence of the announcement of high level waste on property values are statistically insignificant. The individual coefficients are also insignificant, although the variable which evaluates the interaction between distance, the visual range and the announcement has a t-score of more than 1.6. Overall, these findings suggest that there is no evidence to support a significant detrimental influence of the announcement of a dry storage facility on sale prices, either directly or through its influence on the slope of the gradient.

Question #4: Has newspaper coverage in the period between 45 and 120 days prior to the sale affected the sale price of the property either inside or outside

Table 2. Evaluation of public information[1]

	Dependent variable = log of real sales price							
	Specification #2 Total paragraphs		Specification #3 Nuclear general		Specification #4 Nuclear transportation		Specification #5 Nuclear waste	
Variable	Coefficient	*t*-score	Coefficient	*t*-score	Coefficient	*t*-score	Coefficient	*t*-score
Intercept	9.750665	5.064	9.736714	5.049	9.676857	5.021	9.687632	5.024
Structural characteristics								
BEDROOM	−0.00857	−0.72	−0.00893	−0.75	−0.00922	−0.774	−0.00929	−0.78
FULLBATH	0.025999	1.379	0.026431	1.4	0.025106	1.329	0.026151	1.386
HALFBATH	0.018415	1.023	0.018692	1.037	0.01814	1.007	0.01879	1.043
CNTRLAIR	0.013572	0.715	0.011976	0.626	0.013914	0.728	0.014275	0.737
FIREPLCE	0.038143	2.795	0.037791	2.766	0.037291	2.732	0.037424	2.74
NUMSTORY	−0.07309	−3.916	−0.07313	−3.91	−0.07294	−3.905	−0.07311	−3.912
AGEHOUSE	−0.00163	−2.817	−0.00166	−2.86	−0.00164	−2.834	−0.00163	−2.81
LOTAREA	5.83E-07	6.193	5.92E-07	6.292	5.80E-07	6.141	5.87E-07	6.233
BLDGAREA	0.000423	21.49	0.000422	21.42	0.000424	21.474	0.000423	21.447
Neighborhood characteristics								
%ASIAN	−0.0272	−0.783	−0.029	−0.83	−0.029	−0.835	−0.03018	−0.869
%BLACK	0.014344	0.512	0.015265	0.544	0.014282	0.509	0.015143	0.54
%HISPANIC	0.022469	1.055	0.022892	1.073	0.023325	1.095	0.023477	1.101
%PUBASST	−0.00618	−0.299	−0.00641	−0.31	−0.00671	−0.325	−0.00665	−0.322
MEDHHINC	−1.88E-05	−0.896	−1.93E-05	−0.92	−1.97E- 05	−0.937	−1.99E-05	−0.948
%OCCUPIED	−0.02042	−2.751	−0.02078	−2.8	−0.02049	−2.759	−0.02082	−2.803
%OWNEROCC	0.021966	1.758	0.022314	1.783	0.022522	1.801	0.022699	1.814
TRAVTIME	0.057073	1.188	0.058273	1.211	0.059214	1.232	0.059473	1.237
OZONE	−0.60715	−2.166	−0.61406	−2.19	−0.60913	−2.172	−0.61899	−2.208
INTRSTAT	−0.01242	−0.436	−0.01015	−0.36	−0.01018	−0.358	−0.01001	−0.351
RAILROAD	−0.03589	−2.291	−0.03624	−2.31	−0.03637	−2.32	−0.03652	−2.329
AIRPORT	−1.02E-07	−0.188	−7.32E-08	−0.14	−1.14E-07	−0.211	−9.24E-08	−0.17
TOXRELINV	−0.01	−0.476	−0.00982	−0.47	−0.01037	−0.494	−0.00952	−0.453
WATER	0.014484	0.995	0.015518	1.063	0.014644	1.005	0.015188	1.042
TSRATIO	22.7768	2.029	23.39602	2.082	23.36644	2.082	23.84656	2.123
TAXRATE	−7.73156	−1.932	−7.62489	−1.9	−7.55787	−1.886	−7.61883	−1.9
POPDENSITY	−2.88E-06	−0.199	−2.49E-06	−0.17	−3.19E- 06	−0.221	−3.41E-06	−0.236

Table 2. (continued)[1]

	Dependent variable = log of real sales price							
	Specification #2 Total paragraphs		Specification #3 Nuclear general		Specification #4 Nuclear transportation		Specification #5 Nuclear waste	
Variable	Coefficient	*t*-score	Coefficient	*t*-score	Coefficient	*t*-score	Coefficient	*t*-score
City dummy variables								
ACAMPO	−0.0249	−0.107	−0.04027	−0.17	−0.03493	−0.15	−0.04208	−0.181
ELKGROVE	0.135592	2.938	0.13276	2.874	0.135029	2.925	0.132146	2.861
GALT	−0.09988	−0.255	−0.10774	−0.28	−0.11067	−0.283	−0.11366	−0.29
HERALD	−0.10216	−0.263	−0.11156	−0.29	−0.11107	−0.285	−0.11551	−0.297
LOCKEFRD	−0.56816	−1.472	−0.59008	−1.53	−0.58712	−1.521	−0.6033	−1.563
SLGHHOUS	−0.22505	−0.798	−0.24014	−0.85	−0.24012	−0.852	−0.25023	−0.888
WILTON	−0.39938	−0.924	−0.41472	−0.96	−0.41866	−0.969	−0.42714	−0.988
Nuclear and date variables								
DATE	1.18E-06	0.019	9.45E-07	0.016	−1.25E-08	0	3.05E-07	0.005
DISTANCE	0.03128	2.06	0.031844	2.094	0.031934	2.103	0.032199	2.12
VISUAL	0.131465	1.884	0.129646	1.855	0.130693	1.872	0.128811	1.844
DISTANCE*DATE	−1.18E-05	−2.494	−1.17E-05	−2.48	−1.15E-05	−2.431	−1.17E-05	−2.491
DISTANCE*NEWS	2.00E-05	1.865	0.000268	1.176	0.000986	1.653	0.000385	1.407
Adjusted R^2	0.834136		0.833654		0.833965		0.833792	
Lik.	362.8863		361.7861		362.4947		362.1006	
F-statistic	101.1837		100.8355		101.0596		100.9349	
Number Obs.	758		758		758		758	

[1] Full regression results available on request from authors.

the visual range? To measure the volume of press coverage about the plant, we determine the total number of paragraphs that were written about the plant during the period between 45 and 120 days prior to the sale. Each article written was then characterized three ways, according to whether it dealt with general nuclear issues (e.g., routine inspections by the NRC, emergency drills, etc.); issues related to nuclear waste (e.g., the building of the independent spent fuel storage installation); and/or issues related to the transportation of nuclear waste (e.g., discussions of transporting spent fuel to interim storage elsewhere in the country). Any one article may contain one or more of these characteristics.[6] Given the findings regarding the importance of visual cues, we experimented with several different specifications. We report our findings, including those for the media variable (NEWS) and the media variable interacted with distance (DIST*NEWS) in Table 2.[7] Given the insignificance of the announcement effects in the first specification, we drop ANNOUNCE from the models reported in Table 2.

In all models, the coefficient on distance is positive and significant at the 90% level of confidence or higher. As with the earlier specification, there is a significant and positive price gradient (i.e., prices rise approximately 3.1% per mile) that has been diminishing about 0.4% per year over the 1990-1994 period. Likewise, housing prices are significantly higher in the visual range. Turning to the influence of articles concerning nuclear waste, the volume of coverage does appear to steepen the distance gradient, although the impact is small. The mean number of total paragraphs (44.08 paragraphs) increases the slope of the distance gradient by just 0.08%, or $156/mile in 1998 dollars on the mean housing price. With regard to the content of the articles, neither the number of articles on nuclear power in general, or nuclear waste specifically has a significant influence on the slope of the housing price function. Articles on transportation of waste do have a significant influence at the 10% level of significance. However, the marginal influence on the housing price of the mean number of articles is even smaller 0.01% (or $16/mile). Furthermore, we note that these results on media coverage do not appear to be robust with variations in the model specification. Specifically, when the DISTANCE*NEWS is interacted with the visual range variable, the significance levels drop dramatically.

[6] Each article was classified using a modification of the Delphi method, where each article was classified independently with a view to eventually reaching a consensus classification. Three individuals (the two authors and a third colleague) independently ranked each article on each of the three criteria. When at least two individuals agreed on the classification, a consensus was assumed to have been reached. If there was no consensus, each individual was given the assessments of the other two individuals (with the identity of that person revealed) and asked to re-evaluate their classification decision. On the rare occasion where this did not lead to a consensus, the three individuals met to arrive at a consensus.

[7] Since other media coverage is not controlled, we remind the reader that newspaper coverage variables actually proxy all news sources, not just print media.

5 Conclusions and policy implications

In many regards, the Rancho Seco plant provides ideal circumstances to investigate the influence of spent fuel storage on property markets. The plant is no longer operating, so employment effects are insignificant. The plant has been located in the community for a considerable time, and hence the long-run adjustments in the residential mix, identified by Galster (1986), are likely to have already occurred. In addition, low activity levels at the plant have also meant that there have not been any protests outside the plant in recent years. Such protests may tend to accentuate property value impacts in the short run.

Our findings reveal that the Rancho Seco nuclear power plant does appear to exert some influence on the local real estate market, as housing prices rise significantly with distance from the plant, although the slope has been flattening over time. In addition, the magnitude of the slope is somewhat sensitive to the specification of visual and media control variables. There is also evidence that visual cues influence the hedonic function, although they do not appear to be detrimental. The reason for a positive coefficient on the visual variable is somewhat unclear. Finally, there is little evidence to support the contention that media attention on the plant has a strong detrimental influence on housing in the community. Although news coverage does appear to increase the aversion to the plant as indicated by a more positive price gradient, the magnitude of the impact is low.

With an increasing number of nuclear plants approaching spent fuel storage pool capacity, and significant doubt over a repository becoming available in the near future, dry storage of spent fuel at reactor sites is becoming highly likely at all 72 of the nations nuclear power plants. Using evidence from the Rancho Seco plant, this article has attempted to show that distance, visual reminders and media based public knowledge about spent fuel storage activities at power plant sites, may lead to measurable effects on the sale price of single-family residential properties.

Current opposition to the Yucca Mountain project in southern Nevada, spent fuel transportation and nuclear facilities in general is in large part based on the claim that significant adverse economic impacts will occur in proximity to the particular activity. Many opponents of the Federal repository and transportation program suggest that the solution to the spent fuel disposal problem will only become apparent with a fundamental restructuring of the Federal spent fuel management program. Unfortunately, the amount of time that will be needed in order to develop a fundamentally new program will require that spent fuel generated by nuclear power plants remains at the reactor sites. As the evidence presented in this article indicates, there are just as likely to be adverse economic impacts, albeit minor, of risk perceptions at the power plant sites as have been claimed for the repository in southern Nevada.

Table A.1. Data characteristics

Dependent Variable and Independent Variables in the STRUCTURAL Category			
Variable Name	Definition [mean, standard deviation]	Source	Predicted Sign
RPRICE	Real sale price of the property (1990 dollars) levels: [$\mu = 153,340.0$, $\sigma = 67,347.30$] logs: [$\mu = 11.864, \sigma = 0.328$]	TRW nominal price divided by the national CPI for housing	lnRPRICE is the dependent variable
BEDROOM	Number of bedrooms in house [$\mu = 3.292, \sigma = 0.654$]	TRW	+
HALFBATH	Number of half bathrooms in the house [$\mu = 0.185, \sigma = 0.389$]	TRW	+
FULLBATH	Number of full bathrooms in the house [$\mu = 2.061, \sigma = 0.486$]	TRW	+
FIREPLACE	Number of fireplaces in the house [$\mu = 0.869, \sigma = 0.484$]	TRW	+
CNTRLAIR	1=presence of central air conditioning, 0=otherwise. [$\mu = 0.800, \sigma = 0.400$]	TRW	+
NUMSTORY	Number of stories in the structure [$\mu = 1.172, \sigma = 0.378$]	TRW	?
LOTAREA	Lot size in square feet [$\mu = 37,903.39, \sigma = 85,926.24$]	TRW	+
BLDGAREA	Structure size in square feet [$\mu = 1,743.834, \sigma = 564.590$]	TRW	+
AGEHOUSE	Age of the house in years [$\mu = 12.047, \sigma = 12.625$]	TRW	?

Variables in the NEIGHBORHOOD and CITY Categories			
Variable Name	Definition [mean, standard deviation]	Source	Predicted Sign
OZONE	Distance weighted value of the nearest ozone monitor, computed as ozone concentration/ distance of monitor to property [$\mu = 0.459, \sigma = 0.170$]	EPA-AIRS AQS database	-
AIRPORT	Distance weighted value of nearest airport, computed as number of airport operations/distance of airport to property in miles [$\mu = 13,761.50, \sigma = 16,528.87$]	TRW	-
INTRSTAT	1=interstate highway within 0.25 miles of property, 0 otherwise [$\mu = 0.067, \sigma = 0.250$]	MapInfo computed	-
RAILROAD	1=railroad tracks within 0.25 miles of property, 0 otherwise [$\mu = 0.232, \sigma = 0.422$]	MapInfo computed	-
TOXRELINV	1= at least 1 manufacturing facility which are on the Toxic Release Inventory within 1 mile of the property, 0=otherwise [$\mu = 0.154, \sigma = 0.361$]	Landview II	-

Table A.1. (continued)

Variables in the NEIGHBORHOOD and CITY Categories			
Variable Name	Definition [mean, standard deviation]	Source	Predicted Sign
%ASIAN	Percent of census tract population that is Asian or Pacific Islander [$\mu = 0.03370, \sigma = 0.0165$]	Census STF-3A	?
%BLACK	Percent of census tract population that is Black [$\mu = 0.01807, \sigma = 0.0120$]	Census STF-3A	?
%HISPANIC	Percent of census tract population that is Hispanic [$\mu = 0.12121, \sigma = 0.0618$]	Census STF-3A	?
%PUBASST	Percent of census tract population that is receiving public assistance [$\mu = 0.0803, \sigma = 0.0371$]	Census STF-3A	-
%OCCUPIED	Percent of census tract housing units that are occupied [$\mu = 0.9512, \sigma = 0.0362$]	Census STF-3A	+
%OWNEROC	Percent of census tract housing units that are owner occupied [$\mu = 0.7772, \sigma = 0.0907$]	Census STF-3A	+
WATER	1=stream, river or lake within 0.25 miles of the property, 0=otherwise [$\mu = 0.290, \sigma = 0.454$]	MapInfo computed	-
TRAVTIME	Average household travel time to work in the census tract [$\mu = 27.042, \sigma = 2.560$]	Census STF-3A	-
TAXRATE	1994 tax payment /1994 assessed value [$\mu = 0.012, \sigma = 0.001$]	TRW	-
TSRATIO	Average teacher-student ratio for the public school district in which the property is located. [$\mu = 0.037, \sigma = 0.007$]	California Department of Education	+
POPDENSITY	Population density of the census tract, measured as persons per square mile [$\mu = 966.604, \sigma = 1,363.380$]	Census STF-3A	?
MEDHHINC	Median household income of the census tract [$\mu = 42,892.76, \sigma = 7,377.279$]	Census STF-3A	+
ACAMPO, ELKGROVE, GALT, HERALD, LOCKEFRD, SLGHHOUS, WILTON	City dummy variables for Acampo, Elk Grove, Galt, Herald, Lockeford, Sloughhouse, or Wilton. Dummy variable=1 if dwelling lies within the city political boundaries, 0=otherwise [$\mu_{ACAMPO} = 0.008, \sigma_{ACAMPO} = 0.089$] [$\mu_{ELKGROVE} = 0.523$, $\sigma_{ELKGROVE} = 0.500$] [$\mu_{GALT} = 0.269, \sigma_{GALT} = 0.443$] [$\mu_{HERALD} = 0.010, \sigma_{HERALD} = 0.102$] [$\mu_{LOCKEFRD} = 0.030$, $\sigma_{LOCKEFRD} = 0.171$] [$\mu_{SLGHHOUS} = 0.058$, $\sigma_{SLGHHOUS} = 0.234$] [$\mu_{WILTON} = 0.062, \sigma_{WILTON} = 0.241$]	TRW	?

Table A.1. (continued)

Variables in the NUCLEAR and DATE Categories			
Variable Name	Definition [mean, standard deviation]	Source	Predicted Sign
DATE	Time trend variable for date of sale. 1=January 1, 1990. [μ = 1007.758, σ = 535.]	TRW	?
DISTANCE	Distance (in miles) of property from Rancho Seco plant. [μ = 12.554, σ = 2.412]	Computed using MapInfo	?
ANNOUNCE	1=property sold 45 days after announcement of intention to construct dry storage waste facility in October, 1991. 0=otherwise. [μ = 0.702, σ = 0.457]	Computed.	?
VISUAL	1=property within 10 mile visual range. 0=otherwise. [μ = 0.117, σ = 0.321]	Computed using MapInfo.	?
NEWS	News variables defined for period between 120 and 45 days prior to sale. News measures include total number of paragraphs, number of articles covering general nuclear issues, number of articles covering nuclear waste issues, and number of articles covering nuclear transportation issues. [$\mu_{\text{PARAGRAPH}}$ = 44.089, $\sigma_{\text{PARAGRAPH}}$ = 43.988] [μ_{NUCGEN} = 1.396, σ_{NUCGEN} = 2.142] [μ_{WASTE} = 1.066, σ_{WASTE} = 1.832] [$\mu_{\text{TRANSPORT}}$ = 0.353, $\sigma_{\text{TRANSPORT}}$ = 0.798]	Computed using modified Delphi method from inventory of articles received from Sacramento Bee.	?

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