Hedonic property value models have been frequently used to value environmental amenities (or dis-amenities) since markets for these goods (bads) do not usually exist. Typically, researchers cite Rosen’s (1974) seminal work that allows one to interpret functions of the hedonic regression coefficients as the marginal willingness to pay (MWTP) for the environmental good. A key assumption needed for the Rosen result to hold is market equilibrium. Recent years have witnessed extreme circumstances, such as wild swings in housing prices, high levels of mortgage default, and most significantly, high levels of foreclosure when this assumption is unlikely to hold. In this paper, we address the following question "How can we interpret the coefficient estimates for environmental goods in hedonic property value models where markets are dominated by foreclosures?" We then focus on housing market conditions when interpreting the hedonic literature on (airport) noise, Superfund sites, air quality, and flood risk.

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I. Introduction

Hedonic property value models have been frequently used to value environmental amenities (or dis-amenities) since markets for these goods (bads) do not usually exist. Typically, researchers cite Rosen’s (1974) seminal work that allows one to interpret functions of the hedonic regression coefficients as the marginal willingness to pay (MWTP) for the environmental good. This allows the results from the hedonic models to be used to evaluate the net benefits from environmental policies and actions such as cleaning up Superfund sites and improving air and water quality.

A key assumption needed for the Rosen result to hold is market equilibrium. However, under extreme circumstances in the housing market, this assumption is unlikely to be realistic. Recent years have witnessed such extreme circumstances, such as wild swings in housing prices, high levels of mortgage default, and most significantly, high levels of foreclosure. Figure 1 displays the percent of consumers with new foreclosures between the first quarter of 2003 and the first quarter of 2012 for select states and for the U.S. For the U.S., the rate was steady until the middle of 2006, then if rose steadily and peaked in the second quarter of 2009 at which point it was triple the value in early 2006. There is considerable heterogeneity across states.

Given this turmoil, we address the following question "How can we interpret the coefficient estimates for environmental goods in hedonic property value models when housing markets are dominated by foreclosures?"

Even when the market is in equilibrium, there are problems with the standard hedonic model that can result in coefficient estimates that are biased estimates of MWTP. In particular, endogeneity and omitted variables bias plague early studies that attempt to estimate MWTP for environmental goods. Recent studies rely on more modern methodologies to mitigate these
biases. These include random experiments, instrumental variables, regression discontinuity, and the difference-in-difference framework (e.g. Chay and Greenstone (2005) and Bajari et al. (2012)).

The typical application of one of these approaches in environmental economics uses observational data that varies both spatially and temporally. In these cases, it is a common assumption that the parameters (other than the intercept) are constant over time. However, Bartik (1988), among others, have pointed out that when there is a large-scale change in an environmental good, say, through the imposition of air quality standards, this assumption is unlikely to hold since general equilibrium effects due to residential re-sorting will shift the hedonic function. The impacts of larger-scale changes in environmental quality are probably better measured using recently-developed sorting models that capture the general equilibrium effects that these changes can engender (see Kuminoff et al. (2010) for an excellent review of these models). For example, Smith et al. (2004) show that the general equilibrium effects can be quite different than the partial equilibrium effects from a market-wide change in air quality in Los Angeles.

National and urban business cycles can affect the supply and demand for housing which will then affect the housing market outcomes that are the basis for the hedonic equation. In particular, housing demand is affected by household income whose changes are tied to the business cycle. Estimates of MWTP will be smaller (larger) in absolute value when demand is depressed (expanded) due to poor (good) economic conditions. Hence, it is important to consider the underlying market conditions when estimating hedonic price functions. In their meta-analysis of hedonic implicit prices for reductions in total suspended particulates, Smith and Huang (1995) find a wide variation in estimates that depend on the city, year of analysis, and
vacancy rates. Their results are a clear indication that location and time considerations are crucially important.

These issues aside, hedonic coefficient estimates are unlikely to be accurate measures of MWTP when the housing market is not in equilibrium as is likely to be the case during the recent downturn. DiPasquale and Wheaton (1994) find evidence that the housing market takes years to clear. Riddel (2004) also finds evidence that housing market exhibits long periods of disequilibrium. Guren and McQuade (2012) show that foreclosures have increased the downturn and slowed the recovery in the housing market, so that disequilibrium in markets with foreclosure can be quite persistent. Other authors have noted that a key to prolonged market disequilibrium, particularly in a down market, is the downward stickiness of house prices. There are numerous reasons for this downward stickiness. Leamer (2007) offers one: sellers’ valuations of their houses are based on recent comparable transactions whereas buyers’ valuations are based on their predictions of future values. So when the market is hot and prices are rising, buyers value units more than sellers and sales volume is high. But when the market is cold, the opposite occurs. Sales only occur when sellers get “lucky” and are matched with a buyer with a relatively high valuation. As Leamer (2007) points out, what are observed in a cold market are sellers’ prices, not market prices.

Another explanation is given by Genevose and Mayer (2001); owners are not (psychologically) willing to sell their houses for less than they paid for them; so called “loss aversion”. Kiel and Zabel (1999) offer a similar psychological mechanism to explain why new owners tend to over-value their homes more than owners who have been in their homes for longer periods of time; self-serving bias (Lowenstein, Issacharoff, Camerer, and Babcock 1993)
that arises because the value that new owners place on their house reflects their perceived abilities in bargaining in the housing market.

In Section II, we discuss the Rosen framework for hedonic models. The key point is that the ability to interpret the coefficients in this model as MWTP relies on an equilibrium assumption that is questionable in today’s housing market that is dominated by foreclosures.

One sign that the market is not in equilibrium is a large number of vacancies. Vacancy rates above the “natural rate” (that arises from housing search) are an indication of excess housing supply. The recent downturn in the housing market has led to an unprecedented number of foreclosures at the national level that has pushed the vacancy rate in many housing markets above the natural rate. This has resulted in a state of housing market disequilibrium which violates one of the key assumptions underlying the Rosen framework. The analysis of how the housing cycle affects the hedonic function is the goal of this study. In Section III, we discuss the role that vacancies play in the housing market and pay particular attention and how they are affected by foreclosures. A related issue is that of hot and cold markets and how this can affect the composition of buyers and ultimately the coefficient estimates for environmental amenities.

Given that foreclosures can affect the level of prices and potentially the hedonic coefficients, it is important to control for them in the hedonic regression. In Section IV, we specify the different ways in which foreclosures have been added to the hedonic and discuss the related literature.

The results of this analysis will have important implications for the evaluation of the benefits of environmental goods and hence the economic efficiency of policies that affect the provision of environmental goods. For example, there is a large literature that uses hedonic models to estimate the benefits from cleaning up Superfund sites (e.g. Kiel and Williams (2007),
Greenstone and Gallagher (2008), and Gamper-Rabindran and Timmons (2011)). Given our findings, we will provide a re-interpretation of these results in Section 5. We also survey the literatures on hedonic estimates of implicit prices for airport noise, air quality, and flood risk and provide a critical interpretation of these results in this section. Finally, we sum up our findings in Section VI.

II. The Rosen Framework of Hedonic Prices in Spatial Equilibrium

The basis of the Rosen model is the pricing of a heterogeneous good with multiple characteristics. The problem is cast in characteristic space where consumers and producers of the good decide where to locate based on their optimal outcomes from utility and profit maximization. Hence we can think of each point in the characteristic space as a specific good; that is the heterogeneous good with a specific set of characteristics.

This framework lends itself quite naturally to the residential location decision whereby individuals choose over a set of housing units located across a housing market. The choice of a particular spatial location results in housing services that emanate from the structural characteristics that comprise the housing unit and from the local public goods and other spatial amenities that are associated from this location. Further, producers or housing developers (assumed to be owners of undeveloped land) are also making decisions about when to build and what specific structure to construct in this housing market. The outcome of these optimizing decisions, under a set of assumptions, will result in an equilibrium hedonic price function. This function can be used to determine the implicit prices of the structural and neighborhood characteristics. The interest in environmental economics is the pricing of local environmental (dis)amenities such as hazardous waste sites and air, water, and noise quality.
Based on the solutions to the consumer and producer maximization problems, the equilibrium hedonic price schedule $p(z)$ represents a set of tangencies between consumer bid functions and producer offer functions. Rosen shows that under these equilibrium conditions the coefficients corresponding to the housing characteristics in the hedonic equation can be interpreted as consumers’ MWTP for these characteristics.

Hedonic valuation of environmental commodities is based on this model. If the function were known, we could take the derivative of $p(z)$ with respect to environmental characteristic $z_i$ and claim that this derivative represents the MTWP for $z_i$, and on that basis cost-benefit analysis of some environmental improvement can be undertaken. Of course $p(z)$ is not known and must be estimated from data. There are two sets of issues which then arise: first the hedonic function is based on both the bid and offer functions and the points on the hedonic are due to factors that affect both consumers and producers. This introduces a classic simultaneous equations problem in the estimation of $p(z)$. But, as Palmquist (1991) points out, for many environmental issues the useful information is contained in the demand side of the market. Ignoring the supply side is not problematic because housing supply is dominated by an existing stock which is fixed in place by historical circumstances. On this account, the above model of builder/supplier decisions can be replaced by one in which consumers are matched with a given distribution of $z$ (Epple 1987). Environmental goods in this model are simply one more element of $z$ which consumers take as given. Even on this assumption of fixed supply, a second issue arises, which is that absent full information on both the distribution of $z$ and consumer taste and income, the functional form of $p(z)$ cannot be determined from the model. As Epple (1987) points out $p(z)$ can be either
concave or convex at some value $z^*$, depending on the densities of $y$, $\alpha$, and $z$ in the neighborhood of $z^*$ (where $\alpha$ is consumer preferences)\(^1\).

Estimates of $p(z)$ therefore must be estimated from regression analysis, where the dependent variable is the price of the house and the independent variables are the $z$’s which are given some nonlinear functional form. This functional form is generally taken to be one that fits the data well, since (to repeat) the theory gives no guidance. In any case, with the parameters of $p(z)$ estimated, derivatives can be calculated and cost-benefit analysis undertaken. To take a common example, it is often assumed (again, because the fit of the regression is good) that the hedonic function takes the form:

$$\ln p_{it} = \beta_{0t} + X_{it} \beta_t + u_{it}$$  \hspace{1cm} (1)

where $p_{it}$ is the price of the $i^{th}$ unit at time $t$ and $X_{ijt}$ is the value of characteristic $j$ for unit $i$ at time $t$. In this case, the hedonic price of the $j^{th}$ characteristic in period $t$ is $\beta_{jt} \bar{p}_t$ where $\bar{p}_t$ is the average price at time $t$. This particular functional form highlights two ways in which the hedonic price can vary over time: (1) the overall price of housing can vary; (2) the parameter associated with the environmental characteristic can vary over time. While other functional forms will require different calculations of hedonic prices, these basic principles generally still apply.

Now consider the price of this characteristic as time passes, particularly in light of the events of 2007 and beyond. The housing market of this era can be characterized by three phenomena:

1. A fall in the general price of housing
2. A fall in the frequency of trading — the so-called “cold housing market”

\(^1\) Of course, this only identifies a local approximation to willingness to pay. Undertaking a cost-benefit analysis based on non-marginal changes in environmental goods requires estimates of household bid functions (e.g. Zabel and Kiel (2000) and Coulson and Bond (1990).
3. An increase in the number of foreclosures and vacancies in general and in particularly so in certain neighborhoods.

The question then is “do these phenomena have an effect on either $\beta_{jt}$ or $\bar{p}_t$?” Clearly the first has an effect on (average) price. We discuss the role of the latter two phenomena in determining $\beta_{jt}$ and/or $\bar{p}_t$ in the next section.

III. Foreclosures, Vacancy Rates, and the Housing Market

The housing crisis of 2007 and going forward has led, as noted, to a large increase in foreclosed properties. This has generated real effects in the housing market, among which is a notable increase in housing vacancy rates. Figure 2 displays historical trends in what the Census calls ownership vacancy rates for the period 1986-2009 for the US as a whole and for four selected states: Florida, Nevada, Ohio, and Pennsylvania. Note first that the U.S. rate was more or less constant between 1 and 2 percent until the time of the crisis, whereupon it basically doubled to nearly 2 percent between 2005 and 2009. However the changes in this rate were quite heterogenous across states. The first two, Florida and Nevada, were widely regarded as centers of the housing bubble and its deflation in the key years. The vacancy rates displayed in Figure 2 reflect this. These states’ vacancy rates were, though above the national average, quite stable until 2005, whereupon they rose dramatically, to above 5 percent in 2008. This is widely viewed as being the result of homeowners leaving their property in the wake of default and foreclosure events. This interpretation is reinforced by examining the vacancy trend for Ohio, whose residents were also severely hit by foreclosures. Ohio had a lower than average vacancy rate for

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2 This is the vacancy rate for single family and condominium units, and is distinguished from the rental vacancy rates derived from apartment buildings and is traditionally several percentage points greater than the owner rate. The source is http://www.census.gov/hhes/www/housing/hvs/rates/index.html.

3 See Malloy and Shan (2013)
much of the pre-crisis period but beginning even in 2004 had a strong upsurge in vacancies which left it well above average at the end of the period. By contrast, Pennsylvania which had a rather less severe foreclosure crisis, did not experience a rise in vacancies during the crisis period. One last point to note is that all of the states, and the US generally, experienced a downturn in the vacancy rate in 2009.

It is interesting to compare the figure for vacancy rates with Figure 1 for foreclosures. These two figures display a similar pattern between 2003 and 2009. This is an indication of the strong relationship between foreclosures and vacancies. Yet, they are not exactly the same. For example, Ohio had a lower than average vacancy rate but a higher foreclosure rate than the U.S. prior to the housing crisis but a higher than average vacancy rate and a lower than average foreclosure rate since the crisis began.

Figures 3 and 4 display FHFA house price indices, vacancy rates, and foreclosure rates for Los Angeles and Las Vegas for 1985-2010 (foreclosure rates are only available starting is 1999). Vacancy rates and house prices show an inverse relationship in Los Angeles though there was not a significant upswing in vacancy rates during the recent downturn in house prices. On the other hand, foreclosures did show a dramatic increase starting in 2007. In Las Vegas, both vacancy rates and foreclosures experienced significant increases during the recent housing crisis. It is unlikely that coefficients estimates from hedonics using recent transaction data from Los Angeles or Las Vegas will provide accurate estimates of MWTP.

This discussion of vacancy rates motivates the development of a structural model of the housing market that allows for disequilibrium where the vacancy rate falls out naturally as an error correction mechanism (Coulson and Zabel 2012). This builds on models developed by DiPasquale and Wheaton (1994), Follain and Velez (1995), and, in particular, Hwang and
Quigley (2006). This model highlights the dynamic nature of the housing market and it includes a mechanism by which markets in disequilibrium can “correct” back towards an equilibrium outcome. Further, vacancy rates are modeled as a function of foreclosures. Estimating this model will give some idea of how long this correction process can be expected to take and how foreclosures can lengthen the time to recovery. It also provides a natural measure of market disequilibrium; the vacancy rate (and implicitly foreclosures). We will use the characteristics of this disequilibrium model of the housing market when interpreting the implicit prices in hedonic models.

III.3 Hot and Cold Markets

Now consider again the housing and foreclosure crisis as a shock to both prices and vacancies. There is not only a house price decline, but also an increase in vacancies due to the default and foreclosure process. What models like Hwang and Quigley’s empirically demonstrate is that the interconnectedness of these variables exacerbates the effects of these shocks, but that nevertheless the effects on price are only temporary.

Another strand of literature takes a slightly different approach. Krainer (2001) notes that whether a market is “hot” or “cold” can have profound effects on the price and vacancy rates in a market. To summarize his model, in a hot market, sellers are able to (and want to) sell houses quickly, thus vacancy rates are low and prices are high. Since these quantities depend on the “state of nature” there is nothing that drives vacancy rates back to their “natural” values. These ideas are amplified in Novy-Marx (2009) who notes that additional entry by buyers is induced when markets are hot, because the value of entry increases. This raises prices, and reduces vacancy, even more, exacerbating the values of these fundamentals.
The opposite of course is true in these models during cold markets, when buyer entry is low, prices fall, and illiquidity and vacancies increase. Thus to the extent that hedonic prices depend on housing prices, the recent crisis will cause a fall in hedonic prices, and it is possible that this is a more permanent state of nature for that housing market. In the current housing market, it is likely that household’s perceptions of the “expected” level of foreclosures fundamentally changed in many housing markets. One can imagine a foreclosure expectations augmented housing market akin to the expectations augmented Phillip’s curve.

Chernobai and Chernobai (2013) note that buyer heterogeneity exists in these markets. They categorize buyers into long- and short-term buyers, and note that short-term buyers are more likely to buy low quality units than long-term buyers (because the costs of attaching themselves to the low quality unit are lower). The authors do not distinguish between hot and cold markets, nor apply the quality heterogeneity of housing to environmental goods in particular, one can nevertheless assume that people who buy houses in areas with negative environmental attributes are more likely to be short term buyers. Transaction rates will therefore be higher in these areas and the hedonic price of environmental attributes is likely to be higher than it would be if this buyer selection did not exist (i.e. in a market where buyers and sellers are randomly matched). A cold market is cold, therefore, because these short term buyers are the ones who have left the market. The price of housing falls in all markets, but the price in low-quality (i.e. with negative environmental attributes) areas will fall farther—that is, the hedonic price of environmental commodities falls. Long-term buyers, who now dominate the market, have less desire to live near a superfund site. Thus not only $P$ falls in a cold market, but $\beta$ does as well.
IV. Adding Foreclosures to the Hedonic Model

The composition of transactions that are used to estimate the hedonic can affect the estimates of the hedonic parameters. This composition bias is known to be an issue when generating house price indices but it may also affect the estimates of MWTP for environmental goods as well. This is particularly relevant in the context of the recent housing downturn, as the sale of foreclosed properties has significantly impacted the composition bias of transacted units.

Foreclosed houses are likely to sell at lower prices than non-foreclosed units both because financial institutions have an incentive to sell them quickly because they do not collect rents while vacant units and because these units are subject to vandalism and because foreclosed properties are likely to not have received proper maintenance during the foreclosure process. This might indicate that foreclosed properties that sell can be included with just the addition of a dummy for foreclosures or with some other characteristics such as time vacant

\[
\ln p_{it} = \beta_{0t} + z_{it} \beta_t + f_{it} \gamma_t + u_{it}
\]

(2)

where \( f_{it} \) is a binary indicator that the property is foreclosed.

A recent paper that looks at how foreclosed properties affect house prices is Campbell, Giglio, and Pathak (2011, henceforth CGP). They estimate a hedonic equation using transaction data for Massachusetts for 1987 to 2009. CGP’s estimate of \( \gamma_t \) is -0.260, -0.344, and -0.308 for single-family, multi-family, and condos. On the other hand Harding, Rosenblatt and Yao (2012) find that the yields obtained by purchasers of foreclosed properties are similar to those obtained by buyers of similar though non-distressed units, suggesting that the observed foreclosure discount is due to self-selection.

It could also be the case that the coefficients are different for foreclosed units

\[
\ln p_{it} = \beta_{0t} + z_{it} \beta_t + f_{it} \gamma_t + z_{it} \cdot f_{it} \delta_t + u_{it}
\]

(3)
in this case allowing for separate coefficients for foreclosures is the same as dropping them from
the sample (or estimating a separate equation for foreclosed properties). CGP find that there is a
larger discount for foreclosed properties that are found in low quality census tracts and larger
when the structure is worth less. They claim that this result may be due to greater vandalism in
lower quality neighborhoods and “fixed costs of protection that justify larger proportional
discounts on cheaper houses.”

Foreclosed properties can also affect the prices of nearby properties. So at the least, we
need to modify the model for non-foreclosed properties to account for this affect

\[ \ln p_{it} = \beta_{0t} + z_{it} \beta_{1t} + f_{i}(d_{it}) + \gamma_{i} + f_{it} (\delta_{i}) + u_{it} \]  \hspace{1cm} (4)

where \( f_{i}(d_{i}) \) is the number of foreclosures within distance \( d_{i} \) of unit \( i \) at time \( t \). CGP find that an
additional foreclosure that is 0.05 miles away causes prices to fall by about 1 percent. Using
similar data, Gerardi, Rosenblatt, Willen, and Yao (2012) find that properties within 1/16 of a
mile of (1) a seriously delinquent property, (2) a bank-owned property, (3) a property sold by the
bank in the last year, and (4) a property sold by the bank more than a year ago sell at 2.8%, 3.3%,
2.4% and -0.2% discounts, respectively. The authors claim that the best explanation for the
discount is the reduced investment by owners of distressed properties. Immergluck and Smith
(2005) also finds substantial impacts of foreclosed properties on nearby values. Every
foreclosure within 1/8-mile lowers property values by about 1% and like CGP, found that the
discount is greater in low to moderate income neighborhoods. A companion paper (Immergluck
and Smith (2006)) perhaps contrary to the claim of CGP, does not find an increase in property
crime in neighborhoods with larger numbers of foreclosures (though violent crime does increase
in these neighborhoods).
The above literature suggests that the effect of foreclosures on neighborhoods is the result of (a) external effects of vacancies and abandonment of foreclosed properties; (b) contagion effects. The hedonic literature itself suggests further links. Structural hedonic models (e.g. Epple, 1987) suggest that hedonic prices arise from the matching of units to buyers. The distribution of characteristics is matched to the distribution of buyers. In a market with nontrivial amounts of foreclosure, there can be in effect two submarkets, one with foreclosed properties, and the other without. The matching process then not only allocates units to buyers, but also allocates buyers across the two submarkets. The separation of buyers across the two markets would presumably be based on buyer tolerance for risk and for higher transactions costs, particularly in the form of higher time costs. These conditions suggest that the hedonic price function will be far different across the two submarkets.

This research has implications for the main subject of this paper. First, foreclosures do have an immediate impact on the price of property. As noted above, this has direct implications for the hedonic evaluation of environmental goods. Lower property prices more or less immediately imply lower characteristic prices. As the analysis above shows, this may be only true in disequilibrium.

V. An Analysis of Empirical Studies that Estimate Hedonic Prices for Environmental Goods

Of interest to environmental economists are the costs of residing near hazardous waste sites, landfills, incinerators, nuclear power plants, industrial facilities and commercial sites such as gas stations and water and air quality. Other environmental goods are actually amenities such as open space in the form of parks or wetlands. But these can also have negative impacts on house prices as the existence of open space can impose restrictions on development. A classic example
is the imposition of critical habitat designation for endangered species. The point to remember is that hedonic prices are equilibrium outcomes based on the supply and demand for housing. Hence it is not possible to determine whether the impacts of specific characteristics are supply or demand driven.

In this section, we survey the literature on implicit prices of four environmental goods; noise, Superfund sites, air quality, and flood risk. Our goal is to conduct a kind of informal meta-analysis, to ascertain whether the hedonic prices of these environmental disamenities varies with the business cycle, and or the housing cycle. The above discussion suggests that they do, and we find in our survey below that this is indeed the case.

V.1 Noise Pollution

Consistent data of the type that is recommended to get “best” estimates of hedonic prices for environmental goods is quite difficult to assemble. We can obtain some intuition from meta-studies of the hedonic prices of environmental goods. This evidence has more cross-sectional variation than time variation, but the evidence contained there can still be quite informative. In the case of aircraft noise pollution we can take advantage of explicitly an explicitly meta-analytical survey of this topic undertaken by Take, for example, the studies of aircraft noise gathered for the meta-analysis of Nelson (2004). Nelson reports, for each of these studies in his survey, both the average property price and the hedonic price of one decibel of aircraft noise, expressed as a percentage of property value- he calls this the NDI%. In the case of the semilog hedonic function this would be simply the hedonic parameter \( \beta \), and for the linear functional form it would be the parameter value divided by the average property price\(^4\). We convert this hedonic valuation to price levels by converting back to marginal prices (i.e. multiplying NDI%\(^4\)).

\(^4\) We exclude a few Canadian studies and those which use rent rather than sales price as the variable of interest.
by the average property value in the sample). As it happens, the studies used by Nelson encompass two distinct periods of analysis. The first set uses property data from the period 1969 through 1971 and the second draws from 1980 to 1993. Because of the differences between these two periods it is prudent to analyze them separately, so Figures 6 and 7 provide scatter plots of the relationship between the hedonic price of aircraft noise and the average housing price, for each of the two periods. Within each period there is a clear positive relationship between the two. It may be thought that this is a product of including the price itself in the calculation of the hedonic price, but this is not the case. In a more rigorous (meta)-regression analysis, Nelson finds that that the NDI% itself is positively related to sales price.

Would this positive relationship between housing prices and hedonic prices apply to time series variation within a given market? There is no reason to think not otherwise. Willingness to pay for everything, including environmental amenities, will be higher when the economy is in a boom phase, and lower during recessions; environmental commodities are presumably normal goods. In addition, the above analyses suggest that this will be the case simply because of the types of buyers who enter and exit at different phases of the cycle.

Pope (2008) estimates the impact of a disclosure of publically available airport noise on housing prices in the residential housing market surrounding the Raleigh-Durham International Airport (RDU). The motivation behind such disclosure laws is to level the information playing field between buyers and sellers. The disclosure program began on April 1, 1997. Pope estimates a house price hedonic that includes airport noise contours using data from Wake County North Carolina (where RDU is located) for the 1992 to 2000 period. The results indicate that the airport noise disclosure led to at most a 3% decrease in the price of houses. This is almost a 40% increase in the impact of airport noise on house prices (the impact was 8% prior to
the disclosure program). The impact of the disclosure policy is likely to be causal since there is little evidence that residents knew about this prior to its inception and because RDU hired a “noise officer” to make sure that there was full compliance. The Raleigh-Durham area experienced sustained house price increases over the 1992 to 2000 period so this change probably reflects both the impact of the disclosure and an increase in absolute value of the MWTP for noise due to the income effect.

V.2 Superfund Sites

One environmental good whose benefits have frequently been estimated using hedonics is the cleanup of Superfund sites. Most studies have found that Superfund sites have a significantly negative impact on house prices. A recent paper that has received a lot of attention is Greenstone and Gallagher (2008; GG hereafter). GG recognize the problem that omitted variables bias can cause in estimating the benefits from cleanup; in particular areas surrounding superfund sites are likely to be different from areas without superfund sites and unless these differences are controlled for, estimates of cleanup benefits will be biased. GG use the regression discontinuity (RD) approach in their study to address this problem. The initial listing of hazardous waste sites as Superfund sites was based on a score of 28.5 or higher on the Hazardous Ranking System (HRS). GG compare changes in house prices between 1980 and 2000 for census tracts that are near hazardous waste sites with HRS scores that are just above and below the 28.5 cutoff. The main model is a regression of house prices measured at the census tract level on an indicator for census tracts that contain, or are near, Superfund sites, along with house prices in 1980, and other controls. GG’s RD results show little or no capitalization based on NPL listing. This contrasts
with the OLS results using the full sample that find statistically significant positive impacts on prices due to NPL listing.

What can we take away from these results given the analysis in this paper? First, GG assume a national housing market; while they do include state fixed effects, GG estimate a single parameter for the NPL listing effect. The result is some kind of average that masks the heterogeneity across housing markets (typically MSAs are considered to be single housing markets). Second, the individual markets are likely to be at different points in their housing cycles and this will affect the estimates. Third, GG assume that the hedonic is stable across 20 years which is a tenuous assumption. At the national level, the beginning of 1980 was a recessionary period as nominal house prices actually fell by 5.0% in 1980 and real house prices fell by 18.5%! Conversely, the housing market was at the beginning of a boom cycle in 2000 as nominal house prices grew by 6% that year. All else equal, the MWTP for risk reduction associated with Superfund sites was probably lower in 1980 versus 2000. GG assume a constant value for the coefficient on TSP and this is likely to bias (the magnitude of) their estimate away from zero.

In a response to GG, Gamper-Rabindran and Timmins (2011; G-RT hereafter) provide alternative estimates of Superfund site cleanup. First, GG estimate the impact of listing only whereas G-RT estimate the impact of deletion and listing separately. Second, G-RT use data from census blocks whereas GG use data from census tracts. Third, the unit of observation in GG is the site whereas it is the census block in G-RT. Fourth, the samples of hazardous waste sites used are different across the two analyses. Fifth, G-RT compare sites within 3km and 5km whereas GG use buffers of 3-5 miles that are likely to include units unaffected by the NPL sites.

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5 House price data are from Bob Shiller’s website: http://www.econ.yale.edu/~shiller/data.htm
and hence bias downward the impact (though this means that when calculating the total benefits from cleanup, more houses are used, so there is a tradeoff.)

G-RT find that median house values increase by 19% for blocks within 1km and by 5.8% for blocks within 3km of a site that is cleaned up compared to similar blocks where the site is not cleaned up. Using tract-level data, G-RT show that the impact is 20.9% at the 10th percentile of housing values, 16.3% at the median, and is insignificant beyond the 60th percentile. As they note, this reflects the fact that the cheaper houses are closer to the NPL sites. These results are in contrast to GG who find that placement on the NPL has little discernible impact on house prices. These results are subject to the same three caveats that correspond to the GG results (listed above).

Kiel and Williams (2007) analysis of the benefits from Superfund cleanup differ from the above studies in that they estimate separate regressions for each housing market. Their data set consists of house sales and characteristics for 20 U.S. counties from 1970 to 1996. These counties were chosen to provide geographic variation though they are not necessarily a random sample of all Superfund sites. There are a total of 57 Superfund sites in the sample; each of these counties includes at least one NPL listing.

Kiel and Williams note that previously published studies that focus on at most a few Superfund sites do find that their presence does have a negative impact on house prices. But they point out that these studies may suffer from publication bias and that the sites chosen are likely to be more publicized and hence more hazardous. The authors’ use of a large number of counties helps to overcome these biases. Further, the explanatory variables in each of the 57 regressions are as similar as possible so that the results are comparable across sites.
For Each Superfund site, Kiel and Williams estimate five regressions defined by the discovery and EPA’s proposal, listing and cleanup of the site. The main variable that measures the impact of the site on house prices is the natural log of the distance (LNDISTANCE) to the site. In only 18 of the 57 cases is the estimated coefficient for this variable positive and significant when the site is placed on the NPL though in 33 of the 57 cases, this variable is positive (and significant?) in at least one of the regressions. For the 18 sites with a positive and significant coefficient estimate for LNDISTANCE, the low/mean/high coefficient estimate is 1%/16%/92%. So there is a very large range of estimates. Kiel and Williams run a regression of the indicator of whether the estimated coefficient for this variable positive and significant when the site is placed on the NPL. The only observable characteristics that have significant explanatory power are site size and the percent of blue collar workers. There were no variables in this regression that captured the housing market cycle. It is quite likely that adding these variables would help explain the disparities in the results across sites.

V.3 Air Quality

Measuring the value of air quality improvements is another application of the hedonic house price model. For example, it is interesting to know what the benefits are from achieving the EPA’s National Ambient Air Quality Standards for non-attainment areas. These studies go back to Ridker and Henning’s (1967) analysis using 1960 Census data for Saint Louis.

Smith and Huang (1995) carry out a meta-analysis of 86 estimates of the MWTP for reductions in total suspended particulates (TSP) from studies that were published or circulated in 1988 or earlier. The mean/median value for a 1 unit decrease in TSP is $109.90/$22.40 (in $1982-1984). They found a wide variation in estimates that depended on the city and year of
analysis. They point out that this is a clear sign that local conditions matter. This is consistent with our belief that the point of the housing cycle to which these estimates of MWTP apply will significantly affect their value.

Smith and Huang regress the MWTP estimates on a number of city characteristics, hedonic model characteristics, data characteristics, and data year using both OLS and MAD estimators. They include as city indicators, TSP level, real income, and vacancy rates. Real income has a positive effect on MWTP, reflecting the positive income effect. As we show, vacancy rates are a measure of the housing disequilibrium; higher rates occur in a down market. As expected, then, the associated coefficient estimate is negative. Finally the TSP level has a negative coefficient estimate. While one would expect that the MWTP to reduce TSP would be higher at higher levels of TSP (lower levels of air quality), the negative coefficient like signifies that higher TSP levels are proxying for other city-wide factors that affect the demand for air quality (other than real income). As a caveat, these estimates are measured with a varying degree of precision depending on the estimator and the set of variables included as regressors. As Smith and Huang suggest, the meta-analysis approach can be a useful way to adjust the MWTP estimates for local (i.e. income levels) and market conditions to come up with estimates that are more comparable across geographic regions and economic conditions.

Sieg et al. (2004) develop and estimate a general equilibrium urban model in order to calculate the benefits from increases in air quality in the Los Angeles metropolitan area between 1990 and 1995. One of the steps of this procedure is to estimate house prices that are based on the school district fixed effect in a hedonic house price regression that includes structural characteristics and locational attributes (other than local public goods). This regression uses data on actual house transactions between 1989 and 1991.
The results from the general equilibrium urban model are used to estimate the benefits from significant improvement in ozone concentrations between 1990 and 1995. These “improvements” actually range from an increase of 2.7% to a decline of 33%. MTWP is estimated for each school district’s price and air quality conditions in 1990. Then the WTP for the change in ozone between 1990 and 1995 is estimated. Partial equilibrium results do not allow for moving and for the house prices to change. These can be quite different from the general equilibrium results that relax these restrictions. In particular the average partial equilibrium estimate of WTP across all 93 school districts is $1210 ($1990) whereas the general equilibrium estimate is $1371. There is substantial heterogeneity around these means and the difference between partial and general equilibrium estimates of WTP can vary substantially across school districts.

Again, a key assumption of the general equilibrium urban model is that the market is in equilibrium. Hence, similar issues that we have discussed in the context of the hedonic model apply here as well. Figure 3 shows a house price index of Los Angeles for 1985 to 2010. The period between 1989 and 1991 was a peak in the housing market in Los Angeles which was followed by a 25% decline in prices by 1995 and a 100% increase in the vacancy rate. This decline in the market is a sign that there was also a decline in MWTP over this period that is not accounted for in the analysis in Sieg et al (2004).

Chay and Greenstone (2005; CG hereafter) use the hedonic property value approach to estimate the MWTP to reduce the ambient level of TSP. They use decennial census data from 1970 and 1980 to estimate a first-differenced county-level national model of log house prices that includes the difference in TSP levels between 1970 and 1980. While this reduces some of the omitted variables bias that is inherent in a cross-section model, they point out that changes in
house prices and changes in TSP between 1970 and 1980 are likely both corrected with economic shocks such as changes in industrial activity. To mitigate this bias, CG instrument for changes in TSP using an indicator of county nonattainment status in 1975 and 1976. This is correlated with changes in TSP since nonattainment status requires local governments to implement plans for pollution reduction. They also show that the nonattainment indicator is likely to be exogenous as it is not related to a large number of economic, socio-demographic and housing stock variables. CG’s estimate of the elasticity of house values with respect to TSP levels ranges from -0.20 to -0.35.

One drawback of this study is that it specifies a national market. Thus the impact that CG estimate is an average that can mask any heterogeneity across all U.S. markets. The U.S. was in a recession in 1970 as the unemployment rate rose continuously from 3.9% in January to 7.1% in December. The beginning of 1980 was a recessionary period as the unemployment rate increased from 6.3% in January to 7.8% in July and after that it declined slightly to 7.2% in December. House prices rose in 1970 by 1.9% but actually fell by 3.8% when adjusted for inflation (CPI). Nominal house prices actually fell by 5.0% in 1980 and real house prices fell by 18.5%!\(^6\) Hence the MWTP for TSP reduction was probably lower in 1980 versus 1970 since the housing market was at the bottom of its cycle. CG assume a constant value for the coefficient on TSP and this is likely to bias their estimate towards zero.

Kim et al (2003) estimate the MWTP for improvements in sulfur dioxide (SO2) and nitrogen dioxide (NOx) concentrations in the Seoul metropolitan area using data on transactions of 609 for owner-occupied units in 1993. They use standard hedonic specifications and a model that includes a spatially lagged dependent variable. Both models produce similar results: the MWTP for a 4% improvement in mean SO2 concentrations is about $2,400 or 1.4% of mean

\(^6\) House price data are from Bob Shiller’s website: http://www.econ.yale.edu/~shiller/data.htm
housing price. The MTWP for NOx improvements is not significantly different from zero. The Korean housing market was in a downturn during 1993 as annual real prices declined more than 10%.\(^7\) The estimate of MWTP would likely be higher if data from a few years earlier was used when annual real house prices rose by close to 10%.

Neill et al (2007) estimate the impact of carbon monoxide (CO) and particulate matter less than ten microns (PM10) on house prices in Las Vegas, NV in 1999. Their data set includes 15,718 single-family transactions. The CO and PM10 variables are monthly averages for the nearest monitoring station (there were 18 and 16 monitoring stations for CO and PM10, respectively). Using bootstrapping methods, they estimate a mean elasticity for CO of -0.02 and a mean elasticity for PM10 in the range of -0.02 and -0.04. Both estimates are consistently statistically significant. These results indicate that while the impact is statistically significant, the practical impact of CO and PM10 on house prices in Las Vegas in 1999 is small. The housing market in Las Vegas was fairly stable in 1999 with an annual growth rate of around 1-2% though the vacancy rate actually increased by 1 percentage point that year (see Figure 4). Thus (the absolute value of) these estimates are likely to reflect MTWP for air quality.

Bajari et al. (2012) propose a new method for estimating hedonic coefficients in the presence of time-varying correlated unobservables. This procedure requires that a house sell at least twice (first in period \(t\) and the in period \(t'\)). Buyers are assumed to be uncertain about the dynamics of the omitted attribute. The uncertainty arises because the omitted attribute and its price can change over time. The authors assume that this omitted attribute follows a first-order Markov process. Further, it is assumed that the expected value of the error term from this first-order Markov process is zero conditional on information available to the buyer at time \(t\).

\(^7\) http://www.globalpropertyguide.com/Asia/South-Korea/Price-History
The data are all transactions from the Bay Area for 1990-2006. The authors also include information on ambient air quality for PM10, SO2, and O3. They estimate a series of cross-sectional and fixed effects models and their “efficient housing market model.” In order to identify the MWTP for the three pollutants using the latter model, they assume that the corresponding coefficients are constant over time. The results show that failing to control for time-varying omitted attributes leads to estimates that are substantially upward biased and are even the wrong sign for PM10. The estimated elasticities are approximately -0.08, -0.2, and -0.6 for PM10, SO2, and O3, respectively. The estimated MWTP are approximately -$100, -$160, and -$175 for a 1 \( \mu g/m^3 \) increase in PM10, a 1 ppb increase in SO2, and a 1 ppb increase in O3, respectively.

The estimated elasticity for PM10 is much lower in magnitude than what was found by CG (-0.20 to -0.35). The mean MWTP in Smith and Huang’s meta-analysis is $109.90 in $1982-1984. This translates to around $200 in $1992-1993 which is twice as high as the estimate in Bajari et al.\(^8\) Seig et al. (2004) obtain an estimate of MTWP for ozone of $67 (in $1990) and they state that the values in the literature at that time ranged from $8 to $181. Hence the value of $160 obtained by Bajari et al. is at the high end of these estimates. Baraji et al. use data for the 1990-2006 period. This corresponds to periods of price decline, then moderate and then significantly high price growth in the Bay Area. Vacancy and foreclosure rates were generally low over this period. The estimates of MWTP that the authors obtain is likely to be reasonable given that it corresponds to this long time period over which the market is in both low and high points of the housing cycle.

\(^8\) It is not clear what year the MWTP estimates in Bajari et al (2012) are measured in. They use a median house price of $417,800 to calculate MWTP. Figure 1 plots median house prices by year and the value is around $417,800 in 1993.
V.4 Water Proximity and Flood Risk

In the wake of attention paid to the possibility of climate change leading to rising water levels, increased attention has been paid to the hedonic price of flood risk. Several property value studies have included, and focused on, location within areas that are at risk for such events. This has taken on added urgency in light of severe weather events, particularly Hurricanes Katrina and Sandy.

Early papers simply focused on whether houses were located in a flood plain or not. Shilling et al (1985), MacDonald et al (1990), Speyrer and Ragas (1991), Harrison et al. (2001) and Bin and Polasky (2004) all found that location in a flood plain decreased property values between roughly 1% and 8% of property values, although there is some disagreement about whether this price drop is related to the actual expected losses from flooding events or from the cost of flood insurance. The two should be roughly the same but turn out to sometimes be quite different. Also, salience appears to be key issue. Discounts are higher in the years immediately following an extreme weather event although this can be due to reduced income and economic activity following the event, (Carbone, et al (2006)). Finally, as pointed out by McKenzie and Levendis (2010) most of these studies used quite gross measures of location—that is, a simple binary for location in the flood plain. These latter authors use building elevation as a measure of flood risk, and with this more nuanced characteristic, find premiums on the order of 1.4% of house value per foot of elevation in New Orleans. This rises to 4.6% of house value after Hurricane Katrina—again demonstrating the importance of a salient event. Whether before or after Katrina the parameter estimates are seemingly quite dramatic results, but perhaps this is due to the scarcity of elevated property in the area.
A recent paper by Turnbull, Zahirovic-Herbert and Mothorpe (2012) speaks directly to the issues raised by the recent crisis. In this paper the authors, as in the above research, estimate the decline in property values that result from being in a flood plain, this time in Baton Rouge, Louisiana. Interestingly, they also estimate differences in time on the market, i.e. liquidity of houses in and out of the floodplain at different points in the housing cycle. Since their data consists of sales before Hurricane Katrina they do not grapple with issues concerning the effect of a severe weather event nor those concerned with the current housing market, but are able to separate their data period into times of rising and falling real estate markets. Moreover, they are able to separately control for flood risk and view, by identifying the latter with contiguity with a body of water.

The results coincide with expectations. As before, being in the highest risk flood plain entails a discount. More importantly, the discount is greater during times of relatively hot markets (about 3% of house value) versus relatively cold markets (about 1% of house value). This suggests (as before) that people are willing to pay more for environmental amenities (such as not being in a flood plain). The time on the market differential is of interest as well. Houses in flood plains entail greater risk, and this risk adds to the time on the market, even if the property is discounted (e.g. Hilber 2005). But this risk evidently matters more during cold markets. Being in the highest risk areas adds over four days to time on the market when the market is falling, but only 1.5 days during better times. This of course has lessons for current cold markets, when real estate liquidity—never high to begin with—became quite low. As suggested above, the value of environmental amenities can vary quite a lot over the housing cycle.
VI. Conclusion

Hedonic property value models have been frequently used to value environmental amenities (or dis-amenities) since markets for these goods (bads) do not usually exist. These estimates are often used to evaluate environmental policies based on the assumption that the estimates can be interpreted as MWTP for environmental amenities. So it is important to understand the validity of this assumption. To this end, this paper has addressed the question “what can we learn from hedonic models where markets are dominated by foreclosures?” or more generally, “what can we learn from hedonic models when markets are not in equilibrium?” Our answer is that hedonic estimates are unlikely to provide accurate estimates of MWTP when the housing market is not in equilibrium. As a means for determining when the housing market is likely to be in equilibrium, we develop a disequilibrium model of the housing market where vacancies fall out naturally as the error correction mechanism and where vacancies are specified as a function of foreclosures. Results from estimating similar models show that housing market disequilibrium can last for long periods of time because of downward sticky prices.

Further, foreclosures can prolong the time of market recovery and hence the periods of disequilibrium (Guren and McQuade 2012). This can lead to permanent changes in market fundamentals such as the expected level of foreclosures. Hot and cold markets can affect the types of buyers in the market and this can impact the overall price level and the implicit hedonic prices for local public goods such as environmental amenities.

Even when in equilibrium, estimates of MWTP are likely to vary over the housing cycle. Hence, it is important to consider the state of the housing market when interpreting hedonic estimates for environmental goods. Averaging over estimates of hedonic prices from different
points of the housing cycle is recommended. More formerly, the meta-analysis approach can be a useful way to adjust the MWTP estimates for local (i.e. income levels) and market conditions to come up with estimates that are more comparable across geographic regions and economic conditions (Smith and Huang 1995).

The composition of transactions that are used to estimate the hedonic can affect the estimates of the hedonic parameters. Recent studies have shown that foreclosures do sell for a discount though none have investigated if the implicit prices are different for foreclosed properties. So at a minimum, a dummy for foreclosed sales should be included in the regression model. There is also evidence of spillover effects and these need to be accounted for in hedonic models that use data from areas with large numbers of foreclosures.

With these conclusions in mind, we evaluate the recent literature that uses hedonic models to estimate impacts of airport noise pollution, Superfund sites, air pollution, and flood risk. We interpret the results by considering the state of the housing market cycle, vacancy rates and foreclosures.
References


Figure 1

Percent of Consumers with New Foreclosures by State

Source: FRBNY Consumer Credit Panel/Equifax
Note: Based on the population with a credit report
Figure 2


year

United States  Ohio  Pennsylvania  Nevada  Florida
Figure 3

Los Angeles House Price Index, Vacancy and Foreclosure Rates

- House Price Index
- Vacancy Rate
- Foreclosure Rates
Figure 4

Las Vegas
House Price Index, Vacancy and Foreclosure Rates

Year

Vacancy Rate
Foreclosure

House Price Index

Rate
0 5 10 15 20

Index
Vacancy Rate
Foreclosure

Las Vegas House Price Index, Vacancy and Foreclosure Rates