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ECONOMIC BEHAVIOR, MARKET SIGNALS, AND URBAN ECOLOGY

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ABSTRACT

Urban ecologists have extended the bounds of this field to incorporate both the effects of human activities on ecological processes (e.g., humans as generators of disturbances), and the ways in which the structures, functions, and processes of urban ecosystems, and human alterations to them, in turn alter people's behavior. This feedback loop from the perspective of urban ecologists offers a natural connection to economic models for human behavior. At their core, housing markets reveal price signals that communicate to developers the tradeoffs consumers are willing to make for the private characteristics of homes and the attributes of the neighborhoods where they are located. These signals together with local land use rules guide the location of development. The characteristics of this development in turn influence the functioning and evolution of urban ecosystems. This paper describes markets as coordination mechanisms and conveyors of information from a complex adaptive systems perspective. It also discusses the way in which physical and biological processes, infrastructural boundaries, and the institutional equivalent of "barbed wire" all simultaneously act to shape the transmission of ecosystem services over the landscape. These processes alter the spatial distribution of housing prices in ways that are both continuous and discrete.

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I. Introduction

Urban ecology embeds humans within the ecosystem [Pickett et al. 1997]. Over time urban ecologists have extended the bounds of the field to incorporate both the effects of human activities on ecological processes (e.g., humans as generators of disturbances), and the ways in which the structures, functions, and processes of urban ecosystems, and human alterations to them, in turn alter people's behavior. This feedback loop from the perspective of urban ecologists offers a natural connection to economic models for human behavior. This perspective is reflected in research programs of the urban LTER centers for the Central Arizona Project (CAP) and Baltimore Ecosystem Study (BES). As Grimm and Redman [2004] summarized the main question guiding the first six years of research for the CAP-LTER:

"How do the patterns and processes of urbanization alter the ecological conditions of the city and its surrounding environment, and *how do ecological consequences of these developments feed back to the social system to generate further changes?*" (p. 200, italics added).

Underscoring the need for additional research, in June 2014 Carl Zimmer of the New York Times profiled a study by Costanza et al. that placed a value of ecosystem "worth" at $142.7 trillion. While the size of these estimates certainly attract attention, on the whole they misrepresent the way economists typically measure tradeoffs. Nevertheless the sustained demand for these types of assessments from legislators and the public media suggests that policy makers and the general public are concerned about protecting ecosystems and their associated services.

Developing plausible measures of the tradeoffs people would make to protect ecosystem services requires an understanding of the decision making process of households and their perceptions of the surrounding ecosystem. Those decisions together with public and private efforts undertaken in response to changes in ecological and economic conditions contribute to the market and non-market outcomes that are used to recover measures of these tradeoffs. Hayek [1945] described the use of economic markets to answer resource allocation questions as “magical” given their ability to implicitly coordinate the actions of different people to realize a shared objective with minimal information. He recognized the key role of the prices arising as an outcome of market interactions in creating incentives that assure this coordination. In the intervening years, our understanding of markets and how to use them has grown. The development of innovative methodologies for using the information provided by markets to estimate economic measures of the importance of non-market services to people is a core area of ongoing economic research.

The expansion of urban ecology to incorporate the feedbacks from urban ecological stocks and flows to human behavior has created opportunities for economists to work with natural scientists to develop an integrated understanding of urban ecosystems. This chapter highlights the fact that economic behavior can take a number of forms. When that behavior involves transactions within markets external observers of the market outcomes can use them to provide the information needed to inform policy making associated with ecosystems. Residential housing markets are particularly useful as they function as conduits of information to coordinate the activities of heterogeneous buyers and sellers on urban and suburban landscapes.

At their core, housing markets reveal price signals that communicate to developers the tradeoffs consumers are willing to make for the private characteristics of homes and the attributes of the neighborhoods where they are located. These signals together with local land use rules guide the location of development. The characteristics of this development in turn influence the functioning and evolution of urban ecosystems. These processes lead to the uneven spatial sorting of individuals on the basis of income and tastes. This sorting process may then feedback through non-market institutions (e.g., home ownership associations, local land use ordinances) to further influence the character of development, with ensuing implications for housing markets, and so on. Given their role in shaping households' decisions of where to reside—with all the attendant consequences for related outcomes such as transportation patterns and air quality—understanding the role of markets is critical to understanding the human-driven dynamics of urban ecosystems.

The first section of this chapter provides additional background on the conception of markets as coordination mechanisms and conveyors of information from a complex adaptive systems perspective. The second section expands upon this background to consider the specific case of housing markets, where homes are not homogeneous "commodities" but spatially differentiated goods with "built-in" characteristics and location-specific services that are attached to them. They compete with a continuum of other properties that are also differentiated by construction related features and by those conveyed by their specific locations in the urban landscape. We describe how economists are able to combine spatially detailed information on housing and neighborhood characteristics to reveal how the transactions in markets can, in principle, reveal the nature of the tradeoffs that homebuyers would make for changes in the features of homes – including ecosystem services. We also discuss the complex manner in which physical and biological processes, infrastructural boundaries, and the institutional equivalent of "barbed wire" all simultaneously act to shape the transmission of ecosystem services over the landscape. These processes alter the spatial distribution of housing prices in ways that are both continuous and discrete.

The third section outlines the types of implementation decisions that must be made to represent these features in empirical analyses of market outcomes. This sections serves as background for the next that provides two examples from within the CAP-LTER that illustrate these general principles. The first example illustrates how housing markets can be used to estimate the effects of the urban heat island. The second describes how discrete development plans associated with configuring subdivisions around urban lakes can be treated as creating new ecosystems. The discrete nature of the differences in these services alters the strategy that must be used to learn about the tradeoffs people make for these services. Section five discusses an analysis that uses the PASS survey conducted thru the CAP-LTER to confirm the sorting behavior that underlies the logic of the hedonic framework.

Three lessons emerge from this summary of what can be learned from housing markets. The first is that ex post, market outcomes can document behaviors consistent with the feedback effects that Grimm and Redman hypothesized. The second is that fundamental tenants of economic decision making can be measured, even in the context of limited information on ecosystem services. Finally, we show that research coordination across disciplines can provide insights for both urban ecological research and economic models of people's choices of where to locate.

II. Markets, Information and Prices

Markets – particularly markets for housing – and the prices that are established in those settings are among the most important mechanisms for the feedbacks that Grimm and Redman emphasize for urban ecosystems. The challenge that markets address is the question of how to coordinate the production and allocation of goods and services across individuals with different tastes, skills, and endowments. Markets are a set of rules for exchanges between individuals. These exchanges are one form of the structured interactions we can observe between people as economic agents [Ostrom 2005]. However, they are far from universal; many resources are organized and allocated via non-market means such as firms [Coase 1960], social norms (e.g., the implicit rules for waiting in a line for service) and within families [Chiappori, 1992].

The defining feature of market institutions is that they primarily operate through the mechanism of arms-length monetary exchange between anonymous individuals or firms, with prices that are determined through the process of multiple exchanges where all parties can learn what others have paid (or received). These prices play a central role in the allocation of resources. This form of exchange lends itself most naturally to "private goods." These commodities or services can only be enjoyed (consumed) by the individuals possessing them—they are "rivalrous"—and other potential users can be excluded from their use—they are "excludable". Exchange in this context becomes a bilateral transaction that does not affect third parties. While some enthusiastic proponents of markets tend to characterize them as "self-organizing" in a sense that seems to suggest they emerge out of an institutional vacuum, this ignores how they co-evolve with and depend upon a number of supporting institutional features—many provided by governments—for their functioning. One such role is sometimes labeled the rule of law. That is, government assures that the conditions defining the exchange are enforced. In the absence of market institutions governing exchange, assuring contracts are enforced and that specific types of the information associated with each exchange are available to others, these interactions can become highly personalized, dependent on repeated interactions between the participants and reputations that these exchanges establish for their effectiveness.

In the absence of clear information on which to base transactions, considerable effort must be expended on the part of the buyer and the seller to verify what the buyer receives and what the seller gives correspond to what each party agreed to. The *transactions costs*, or the expenses associated with validating each part of the process, can be substantial, hampering mutually beneficial exchanges. Many features of well-organized markets serve to reduce these frictions. These include establishing weights and measures and product standards, enforcement of property rights, mechanisms to broadcast the reputations of good and bad participants, and the development of an established and reliable medium of exchange (e.g. money and institutions of credit).

A rigorous body of theory in economics has demonstrated how, under idealized conditions, prices can be found that yield an equilibrium in the market in the sense that all mutually-beneficial exchanges are exhausted [Kreps 2013]. The prices for all goods in this economy reflect the marginal benefits conveyed to the "incremental" buyer from the last unit purchased as well as the marginal costs of providing it by the seller. This marginal benefit is also described as the marginal willingness to pay for the last unit. Under these conditions, the ratios between the prices of any pair of private goods will reflect the relative (physical) tradeoffs, in equilibrium, that people make between the goods involved. Furthermore, under still more conditions, the equilibrium supported by these prices can be shown to be "efficient" in the sense that no individual can be made better off without making someone else worse off. The conditions when this "happy" outcome holds are quite stringent. Most notably, they rely on the ability to assume the goods involved in the exchange are all "private". It must be possible to assume that production or consumption behavior does not produce positive or negative spillovers to others in the economy as a result of the activities. Thus "externalities" and "public goods" undermine the ideal properties that are attributed to the exchanges because all the concerns associated with the choices involved in an exchange are not necessarily reflected – a critical result for understanding the nature of ecosystem service provision in an urban ecological system.

The understanding of markets in equilibrium is important, particularly, as we shall see below, for the process of developing measures for the economic values of ecosystem services using the information provided by the records of market transactions. Our description of the static nature of equilibrium analysis is deliberately simplified. Markets are rarely as "perfect" as the abstract theory assumes. Nonetheless, much of the essence of a market as a coordinating mechanism for economic activity under conditions with dispersed information is preserved when the assumptions are not fully satisfied. Moreover, in many situations economic models have been able to describe what to expect when some of the assumptions don't hold. Our description has also overlooked the connections in markets over time. While these details are important, they would detract from our basic point. Economies, like ecosystems, are dynamic, complex adaptive systems subject to frequent perturbations. Just as ecosystems can be viewed as complex systems for the conveyance of fluxes of energy, nutrients and water, so markets act to constantly redirect the production and consumption of goods and services. Markets achieve coordination of information and accomplish these re-allocations via prices. Prices convey information to producers about the costs of inputs and (potential) outputs. These signals, in turn, shape production behavior—driving corporations to produce more of goods with relatively high prices relative to their input costs. Consumers decide what to buy in relation to the constraints imposed by their current and anticipated future income and these market prices.[1] Prices are therefore an emergent property of the system that both coordinate the behavior of economic agents while also being affected by them.[2]

This ability of markets to transmit information through a diffuse network of agents in a way that alters their behavior "as if" they were coordinating is described by Hayek [1945] as a "marvel", who goes on to say:[3]

"Fundamentally, in a system where the knowledge of the relevant facts is disbursed among many people, prices can act to coordinate the separate actions of different people . . . The whole acts as one market, not because any of its members survey the whole field, but because their limited individual fields of vision sufficiently overlap so that through many intermediaries the relevant information is communicated to all. The mere fact that there is one price for any commodity—or rather that local prices are connected in a manner determined by the cost of transport, etc. —brings about the solution which . . . might have been arrived at by one single mind processing all the information which is in fact dispersed among all the people involved in the process." (p. 526)

So far, these descriptions of the operations of a market have operated at an idealized level, distant from applications to urban housing markets. Building a bridge to this application requires confronting two critical elements of real-world housing markets. The first is the

[1] In principle consumers should seek to equilibrate the extra satisfaction yielded per dollar of expenditure on all goods they consume. To do otherwise would suggest that they could reallocate their expenditures within their budget and be better off.

[2] The nature of the feedbacks in most economic models of markets—consistent with most (but not all) day-to-day experience with markets—is that they are stabilizing, tending toward equilibrium. Higher prices may lead to additional supply from producers, but this entry behavior will increase competition and reduce the price consumers are willing to pay to consume more, driving prices back down, etc.

[3] He characterized the economic challenges as one that involved extending "the span of our utilization of resources beyond the span of control of any one mind; and therefore, how to dispense with the need of conscious control and how to provide inducements which will make the individuals do the desirable things without anyone having to tell them what to do." (p. 527).

geographic extent of the market. Where does one market end and another begin? Instinctively when it comes to the degree of coupling in demand and supply factors within and across spatial domains, Tobler's first law of geography would seem to apply: "Everything is related to everything else, but near things are more related than distant things [Tobler 1970]." The differentials in prices for a given commodity (and their movements over time) should be closer than those sold far way – in large part due to the fact that the overlap in the set of potential consumers. Economists often find it convenient to impose some discreteness on this continuous intuition by defining the geographic extent of the market for a commodity as the area such that the "law of one price" holds. As Stigler [1966] observed:

"A market, according to the masters, is the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs." (p. 85)

Persistent differences in prices over space for a uniform commodity that are not explainable by differences in transportation costs indicate a setting where either the circumstances of supply or demand are spatially distinct – otherwise, arbitrage would tend to reduce the differential to the wedge in transportation costs.[4] In the case of housing markets, households tend to locate within a reasonable "commuter shed" of their places of employment, leading to a close coupling between the spatial extent of labor markets and housing markets. The law of one price assumes the prices relate to exactly the *same* commodity.

The second dimension considered in defining a market is the *commodity extent of the market*. This concept relates in important respects to the issue of defining what comprises the same commodity. As the diversity of goods and services has expanded, simple definitions for the commodity extent of the market have become harder to apply. The process of selecting a

[4] Internet technology has lowered the transaction costs of searching for lower prices and widened geographic market access for many commodities, perhaps strengthening the degree to which the law of one price holds.

definition for the commodity extent of the market seeks to answer the question of when goods (or services) should be considered as equivalent. Is Starbucks coffee “the same” as any other specialty coffee shop’s offering? The response to this question determines the extent to which a particular supplier has the ability to freely set a price without losing their customers to another seller. When there are three or more “similar” coffee shops within walking distance of each other, efforts to increase prices are more constrained than when there is no one. However, as the commodities (or services) appear distinctive to consumers based on their respective mixes of characteristics, then local competition may not be as effective. We would nevertheless expect the markets for such products to be closely connected due to the willingness of at least some customers to substitute from one brand to another if price differences become large enough. So in this sense the general insights of a modified law of one price still apply.

III. <u>Housing Markets and Non-market Valuation</u>

The possibilities for differentiation across housing are extensive; therefore, the economic model for the determination of housing and land prices must take account of the geographic scope that potential homeowners consider in searching for a home, while at the same time being sure to acknowledge the numerous ways homes can differ. One common approach to this challenge is to envision a geographic housing market populated by a continuum of customers with different preferences and income/wealth constraints[5]. Homebuyers’ preferences are defined over the *characteristics* of houses, where each home can be considered a differentiated “bundle” of these characteristics. These characteristics include both the features of the home and the spatially-specific characteristics attached to the neighborhood itself. The realization of each

[5] In defining this market, it need not be the case that all homebuyers consider the entire market (i.e. a metropolitan statistical area) when conducting their search. It is enough that there is sufficient mixing of customers across potential sub-markets that the “law of one price” holds approximately for observationally equivalent properties.

household's effort to select a "best" house subject to the constraints of income and wealth defines a family of "bid curves" for each characteristic. These are essentially inverse demand curves (i.e. the maximum price a homeowner would pay for an amount of the characteristic) for each characteristic as functions of the values of other characteristics and the household's income/wealth (see Palmquist [2005], Freeman, Herriges and Kling [2014]). At the same time, home suppliers (current home owners and developers) select offer prices based on their willingness to sell an existing home or (for developers) the cost of building a new one. This process is sometimes depicted as the joint tangency of the offer and bid curves with the housing price function at a level of the housing attribute being considered for analysis. Thus, the hedonic pricing logic replaces the law of one price definition for the market of a homogeneous good with the "law of one price function" that describes how houses with different measurable characteristics are priced in relationship to each other as part of the determination of an equilibrium.[6]

Economic theory places little structure on the shape of this function—it depends on the distribution of the housing stock across the vectors of characteristics that serve to define a "house" including its location versus the heterogeneity in household tastes for these same housing attributes. However, by examining the slope of the hedonic price function for any characteristic (the partial derivative) we can recover the implicit "price" that would be associated with a small increase (or decrease) in that characteristic in the current housing market. This price is the marginal willingness to pay for a little more of the characteristic for the "marginal" buyer. Simply put, it is a measure of the incremental value for a change in the characteristic for individuals that actually chose to live in the home at its base levels of distinguishable

[6] This equilibrium is not fixed over time. Changes in the quantity of housing demand or an influx of buyers with different preferences and incomes can both "shift" the hedonic price function (i.e. lead to proportional price appreciation or depreciation for *all* homes) or "twist" it by altering the relative prices of characteristics.

characteristics. There is no reason to think that this price should be constant at different levels of the housing attribute; increasing the number of bathrooms from 3 to 4 in a 2 bedroom house may, for instance, meet with a smaller increase in price than moving from 2 to 3. It is also possible that the prices for characteristics may be interrelated—a large backyard may contribute more to a home's price if there are clear views of the surrounding scenery.

In general, it is reasonable to expect the equilibrium hedonic price will be nonlinear in the continuous attributes (see Ekeland, Heckman and Nesheim [2004]). This non-linearity suggests that attempts to decompose *total* home prices into additive components (i.e. the part attributable to lot size versus the part attributable to good schools, etc.) aside from marginal changes would only be possible with strong assumptions on nature of preferences and housing supply that together contribute to the hedonic price function. The important takeaway message is that hedonic price functions allow for the estimation of incremental values for a small *change* in some characteristic or in a set of characteristics—not valuation of the total amount of any given characteristic.

The logic underlying the hedonic price function suggests that there is a great deal of information encoded in the price differentials across homes in a single housing market—adding yet another dimension to Hayek's appreciation of the informational role of prices. In principal, this encoded information allows an analyst to "unbundle" homes to find the implicit prices for small changes in their underlying characteristics. In most U.S. states and many foreign countries, analysts can readily access the records of millions of sales with transaction prices and attributes of the homes. It is now routine to use GIS software to combine these records with detailed information on the characteristics or services associated with the local "geography" that are conveyed by these houses' locations, such as data on the provision of local public goods, census demographics, surrounding land uses and land cover. This process permits estimation of price functions that approximate these hypothesized equilibrium relationships. However, extracting reliable signals from these data does assume that homebuyers recognize the differencesa and utilize a great deal of this information when they decide to purchase a home.

Fortunately, the process of buying a home does disclose a great deal of this information. Visiting homes physically (or virtually with increasingly sophisticated real estate support systems, such as Zillow) often reveals many of the visually apparent features of a home and its neighborhood, and real estate agents can provide additional detail on the neighborhood as well. Internet resources and smartphone apps offer access to homes on the market, recent sales prices, as well as the ability to predict what the home would sell for and so forth. It is easy to identify how the house is positioned in relation to positive and negative features of the area around it. Local schools, shopping, transportation access, weather, air quality, and a host of other features can be accessed. Many home buyers (and renters) can accomplish a great deal of the search and evaluation for a new location without ever visiting the areas they are considering. Thus, in many respects technology has reinforced the plausibility of the assumptions underlying the hedonic price function. Indeed, a number of studies have confirmed the quality of these statistical models as quite robust approximations, showing that price signals can be quite discriminating in their ability to isolate the effects of differences in site amenities or dis-amenities.[7]

IV. Non-market Valuation of Urban Ecosystem Services

Urban housing (and land) markets provide significant opportunities for estimating the tradeoffs people would be willing to make to protect and/or enhance urban ecosystem services.

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[7] The first such study was Cropper, Deck and McConnell [1988]. More recently Kuminoff, Parmeter and Pope [2010] repeated their analysis with updated methods and support the overall conclusion that hedonic models can offer reliable estimates of economic tradeoffs.

While few ecosystem services are directly transacted in markets, the fact that their consumption is often bundled with the purchase of spatially heterogeneous parcels of land allows the analyst to employ multivariate regression or related statistical techniques to uncover the implicit price signals embedded within residential housing market transactions.

However, it is important to understand that the hedonic price method is not equally well-suited to the valuation of all ecosystem services produced across the urban landscape. For hedonic pricing to be useful, the service in question must *capitalize* to the value of homes. Returning to the logic of the hedonic equilibrium, this requires the satisfaction of at least three important criteria. First, homebuyers must be aware of either the ecosystem service or a proxy variable that is closely correlated with the scientific measure used for these services in order to establish a relationship to the science-based measure for the tradeoffs people would make to enhance or maintain the services of interest. Second, potential homebuyers must "care enough" about the ecosystem service to be willing to pay to secure them with their housing.[8] This condition implies the homeowner recognizes how a privately valued service, related to the ecosystem service is conveyed through the purchase of a particular home, as opposed to another. Thus, the transactions in a housing market can be expected to reflect the willingness to pay for the privately appropriable portions of these services. The third criterion for an ecosystem service to capitalize is that it varies to a significant degree over the housing market being studied. For example, if a metropolitan area has one urban park it would be impossible to use data for that market to recover the implicit marginal value for the quality of the services of the park. Houses at different locations would have different conditions of access, but these would be unlikely to reflect changes in the quality of the park. Similarly, while variations in micro-climate may be

[8] Note that this criteria that the service be *valued* by individual homebuyers is not the same as asking whether the service is *valuable* in an overall, collective sense. Valuable ecosystem services can be provided with no hint of a trace of capitalization in home prices if the majority of individuals in the housing market are not mindful of them

reflected in housing prices within a single market (see our example below), valuation of significant shifts in climatic variables will typically not be possible within a single housing market. Efforts to estimate an incremental value for these services requires extending the dataset to multiple housing markets, which creates many problems of comparability. Michaels and Smith [1990] first raised issues associated with the spatial delineation of housing markets in considering the effects of landfills on property values[9].

The inability to use the hedonic price method within a single housing market to estimate an incremental value for changes in a service may not be because the value doesn't capitalize. Rather, it occurs because hedonic pricing works by exploiting *differences* in prices across houses within a housing market. While local climate may have an appreciable impact on the baseline *level* of housing prices, this effect is not detectable in price differences across properties.

Assuming that certain ecosystem services[10] capitalize into housing prices, the analyst is faced with a challenge of how to develop measures that represent their contributions to a hedonic price function. In making these judgments, the analyst inevitably translates the available physical measurements into indices for the services that are perceived and appropriated at the household scale. For example, in considering the valuation of microclimate, what measure (or measures) should one use? Mean daily temperatures? Daytime maximum temperatures? Or nighttime

[9] More recently, a number of authors have assumed a national housing market in order to exploit spatial differences in regulations at a national level of one or more features of environmental quality as a source for exogenous information to identify the effects of spatially delineated amenities. These studies have recognized the sorting can imply the site specific features cannot be treated as exogenous. They may be jointly determined with the equilibrium prices as households sort among the available neighborhoods to select the house that best matches their preferred home. This strategy assume the equilibrium assumption underlying the interpretation of the estimates is not affected. (see Chay and Greenstone [2005] for the case of air pollution and Greenstone and Gallagher [2008] for landfills with hazardous substances). Recent research by Kuminoff and Pope[forthcoming] and Klaiber and Smith [2013] suggests that there are clear tradeoffs. The identification strategy can compromise the ability to interpret the capitalized values of site specific amenities as incremental values for changes in these attributes.

[10] We will use the terms environmental services and ecosystem services as synonyms. We recognize that this simplification may cause some problems. Air quality would be an environmental service and certainly contributes to ecosystems but would not ordinarily be defined as an ecosystem service unless the geographic scope used to define the ecosystem included the systems influencing atmospheric quality.

maximum? If most family members are away from home during the day, neighborhood nighttime temperatures may be more salient in terms of outdoor exposure as well as air conditioning costs. However, this measure may be less satisfactory for characterizing exposure on weekends.[11] Such questions of measurement are not easily resolved without other sources of information on homebuyer perceptions and related behaviors, such as time allocations across weekends and weekdays.

Another challenge in the measurement of many ecosystem services arises because many features of the urban landscape convey several distinct services simultaneously over multiple spatial scales. For example, neighborhood parks would be defined in economic terms as a bundled amenity that provides recreational services to those willing to walk or take other forms of transportation to access them. However, these parks may also provide views, moderate negative perceptions of urban density, ameliorate the effects of the urban heat island due to evapotranspiration and the reduction in impermeable surfaces, provide flooding mitigation services, and improve local air quality. Developing distinct measures for each of these services may be difficult. In practice, the analyst may be forced to settle for direct measurement of some (e.g., the temperature effects) and indirect and "bundled" measurement of others through proxy measures of spatial distance and access to parks (e.g., measures of park adjacency, numbers of acres within different radial distances, etc.).

The bundled nature of ecosystem services highlights another important aspect of urban ecosystem services – *spatial scale*. This includes both the character of the natural system that defines the services and the role of humans in modifying the scale of ecosystem service delivery processes and, therefore, capitalization. Some ecosystem services are connected to the

[11] A notable example of this distinction can be found in the case of difference in time use on weekdays and weekends and its implications for exposure to air pollution. See Black, Kuminoff, Van Buren and Van Buren [2014].

underlying bio-physical processes, so that for a given spatial distribution of physical and biological inputs, the footprint of the ecosystem service, while potentially complex, is essentially fixed. For example, the effects of urban land use—the quantity and distribution of cooling vegetation and impermeable surfaces—generate a landscape that, in combination with the external forcing of climatic variables generates the spatial footprint of the urban heat island. This footprint may contain considerable spatial patchiness (e.g., due to areas with high tree cover) but is fundamentally a continuously evolving phenomenon that no individual or group of individuals can exempt themselves from except by moving to another location or altering the physical inputs to the process (i.e. planting water-intensive irrigation).[12]

The scale of provision for many other ecosystem services is shaped by human action. In some cases these actions imply that the same biological and physical inputs to the service can provide quite different service flows. There are two notable ways this can occur. One way that humans can influence the scale of ecosystem service provision is through their roles as "ecosystem engineers". Consider, for example, the recreational ecosystem services conferred by a park. Some infrastructure, such as adequate road networks or the provision of trails or accessible public transportation, can effectively lower the cost of accessing a given park from a particular distance—widening the spatial dimensions of the recreational ecosystem services and likely the spatial domain for their market capitalization as well[13]. This is one example where this type of infrastructure enhancement acts as a complement to ecosystem services. However, infrastructure may also act to produce boundaries that truncate the transmission of ecosystem services. Busy streets, industrial areas, canals, and the lack of connectivity between neighborhood street networks can all contribute to the establishment of such boundaries.

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[12] Air pollution provides a similar ecosystem (dis)service in that its spatiotemporal footprint (fixing pollution inputs) is a function of physical variables such as elevation, prevailing winds, etc.

[13] The infrastructure contributes to the definition of what is a "nearby" home.

The second way that humans can alter the availability of ecosystem services is through a variety of different types of artificial boundaries. Usually these involve institutional arrangements that can augment the spatial demarcation of neighborhood areas. In some contexts it may be relatively easy for governments or other governance associations to exclude some private lots from accessing resources these groups pay to sustain. For example, homeowner associations can establish rules for how private homes in a subdivision use the lakes, parks and sporting facilities in their boundaries. As a result, the associated recreational services are delivered (and funded) as a good that may have some features of a club or toll good. The result of this institutional "barbed wire" may be a degree of spatial discreteness in the provision and the capitalization of certain ecosystem services. The same facilities could be administered as pure public goods, with different results for both the spatial footprint of service provision and the capitalization into housing prices.[14] However, the ability to exclude the ecosystem services providing a particular amenity will often vary substantially by the service in question. This observation is particularly important when considering the typical case of amenities that produce multiple services. A neighborhood may exclude access to its shady parks to its membership; however, the effects of these parks on local microclimate and air quality may not be as easily excludable.

These observations suggest two important principles for the estimation of ecosystem service values using hedonic price models. First, it may not be sufficient to simply understand the physical and biological processes behind ecosystem services. It is also important to understand how infrastructure and institutions influence the degree to which different households

[14] This does not imply that a move away from exclusivity would necessarily improve human welfare. If the public good is "congestible" (i.e. a park that gets crowded to the point that it degrades the quality of the recreational experience), then some degree of exclusion will likely help to head off a "tragedy of the commons". Thus institutional boundaries affect both the footprint of the services and their capitalization and the value of the service as well.

are excluded from access to ecosystem services. This qualification is particularly important for services that require active decisions to interact with features of the urban landscape as opposed to those that are consumed passively as a product of one's location. Second, the presence of institutional or infrastructural boundaries on ecosystem service provision can aid the analyst by providing discrete *a priori* boundaries for the provision of certain ecosystem services. This feature of the conditions of access can allow the analyst to utilize statistical tools that exploit boundaries as dividing lines between "treatment" and "control" groups.

V. Examples from Phoenix

As the discussion to this point has suggested, efforts to use the logic of the hedonic framework to evaluate the tradeoffs people would make to enhance ecosystem services requires integration of the details of land use into the definitions for variables that are intended to provide measure for these services. This spatial context also allows the analysis to take account of the boundaries affecting access to these resources. Thus, before describing our examples it is important to provide some context for the logic that underlies each application.

The first considers the interaction between character of residential land uses, landscape, and the urban heat island (UHI). The UHI is the localized warming of urban areas in comparison to areas surrounding the urban core. In this setting it is important to recognize how temperature influences households and how temperature measures are influenced at different times of the day and year by landscape conditions. These considerations influence both the variables we measure to reflect the direct effects of the urban heat island (i.e. nighttime temperatures which are more likely to be important at a residence) and the variables we introduce as controls for other spatially varying factors that residents also observe and price in a market. An example of one of these control variables is elevation, which is causally linked to microclimate but may be valuable in its own right (e.g., through its influence on view-scape). Therefore, failure to control for it could result in confounding a desire for lower temperatures with a desire for higher elevation.

For our second example, the focus is artificial lakes. The research required background from realtors and lake managers to understand the features of each community with these lakes as well as the features of the lake that are important to the ecosystem services it provides. The lakes are distinctive so any effort to extract measures of tradeoffs households would make for any one of them requires an understanding of the composite effects of how developers alter housing and landscape features for each urban lake community. The combination of housing characteristics, landscape characteristics, and lake attributes determine how much households would pay to locate in a lake community. Unlike a small change in nighttime temperatures, introducing a lake to a community comprises a discrete rather than a marginal change. As a result, this application focuses on characterizing “comparable” homes and neighborhoods without lakes and compares those homes to homes located in lake communities using the treatment and control strategy outlined above.

A. UHI and Housing Prices[15]

Several economic models have documented the potential importance of climatic conditions in influencing housing prices, wage rates, and migration patterns between metropolitan areas. One of the earliest is a paper prepared by Nordhaus and Tobin [1972] for the Fiftieth Anniversary of the Natural Bureau of Economic Research. They used aggregate information on per capita income at the county level for a single cross section and had to rely on

[15] This discussion is based on Klaiber, Abbott, and Smith [2014].

the crude proxy variables available at the time to account for dis-amenities hypothesized to be associated with urbanization. Hoch and Drake [1974] introduced more specifically measured climate variables into wagemodels using average wage rates across metropolitan areas. Cropper and Arriaga-Salinas [1980] and Smith [1983] used micro level information about individuals' labor market choices (including their wages and hours worked) and a wide array of measures for urban amenities and dis-amenities including temperature, air pollution, and crime rates as sources for differences in real wages. These studies rely on households adjusting by sorting among areas as we described earlier. Studies of migration patterns such as the recent paper by Plantinga et al. [2013] confirm this logic. This paper found that higher January temperatures and lower July temperatures are significant drivers of inter-metropolitan migration, after accounting for the effects of these amenities on rents and wage rates.[16] The analysis of UHI we describe here is the first analysis, to our knowledge, of the effects of temperature *within the same* metropolitan area.

Our results are broadly consistent with the inter-metropolitan area studies in that households recognize the local differences in temperature across the Phoenix metro area, and select areas with lower (summer) nighttime temperatures. In this local context we also expect that they adjust along several margins. In addition to selecting cooler neighborhoods, they can respond by using water intensive landscaping to mitigate the local heat island effects. This latter adjustment couples the production of local landscape amenities with the mitigation of heat island effects through increased evapotranspiration and shading from green landscapes (sse Gober et. al. [2010] for related research).

[16] See Blomquist et al. [1988] for an early study adopting a cross-metro area equilibrium logic to evaluate patterns of wage and rents. Biere et al. [2013] repeat the analysis with a more detailed set of site attributes and more recent data.

An empirical strategy to separately estimate how localized temperatures and landscape amenities affect housing prices requires considering how each influence varies at different spatial scales. The reason stems from the co-production of these outcomes as services available to those living in that location. Conventional hedonic methods can accommodate this co-production and explicitly account for it in the specification of the price function. However, they need to recognize the sale prices analysts observe result from many other factors—observed and unobserved—that may be correlated with temperature and landscape characteristics. To meet these challenges our strategy adapts the logic initially proposed by Abbott and Klaiber [2011]. It exploits two separate sources of unobserved heterogeneity in our housing transactions' prices. The first is associated with sales over time. The second recognizes that homes vary in their spatial locations and at the scale of a census tract this spatial variation can be used to define a neighborhood. This neighborhood delivers similar observed and unobserved local public goods and services including local ecosystem services to each home. Across tracts this variation identifies the variables varying at the level of the tract or above.

Our landscape measures were developed from research supported by the CAP-LTER. Stefanov et al. [2001] classified satellite imagery in the Phoenix area, using differences in reflectivity to assign one of 12 land cover types to 30 m^2 rasters. After parsing these categories into binary classifications of "irrigated" or "non-irrigated" (where xeric residential landscapes were included in the latter category), we overlaid these rasters with GIS parcel maps, assigning each parcel's land cover based on the intersection of its centroid. In addition to parcel-level measures, we also created neighborhood measures for green landscape. These are defined as subdivisions with at least 75% irrigated parcels—implying a total of 261 "green" or mesic subdivisions.

Monthly temperature measures at a 4-km resolution are provided by the PRISM database maintained by Oregon State University and aggregated to a Census tract level. We focus on July nighttime minimum temperatures, consistent with the focus of most UHI research. To obtain tract-level temperature measures for a given year, we assign temperatures to individual parcels that transacted in a given year based on proximity to PRISM observations, assigning each parcel the nearest July low temperature to the date we observe a transaction for each house. The temperature measure therefore reflects the timing and location of transactions within each tract.

This analysis confirms a key feedback loop hypothesized by urban ecologists and demonstrates that markets can reveal this link. We find households positively value green landscaping, particularly at a neighborhood level—a sort of collective value met once a community reaches a threshold of landscape conversion. We also find that households value a reduction in nighttime temperatures, a spatially varying attribute likely perceived across broader spatial scales. The positive valuation of linked landscape/climate attributes provides a key mechanism whereby households respond to urban ecosystems through markets while also altering these ecosystems to improve their well-being.

Estimates of the annualized value for green landscapes at the subdivision level help in explaining why water conservation policy through landscape change may be challenging to implement. Using the average housing price, an assumed five percent discount rate (to annualize the price of an asset), and our estimate for the percentage increase in the sale price for mesic subdivisions, this translates into nearly $1,300 per year more in equivalent rent for a typical home in a green (as compared to a xeric) neighborhood. When we aggregate this value to all the homes in a typical sized subdivision, this differential would likely more than offset the costs of the water to sustain green parcel level landscapes as well as those for maintaining internal open space.

We find that an increase of nighttime July temperatures of 1° F reduces housing prices by about 4 percent, or approximately $40 in terms of the equivalent change in monthly rents. To provide context for our estimate, we turn to the engineering literature to assess the economic costs of air conditioning resulting from increases in temperatures. We would expect that the costs of mitigating temperatures through air conditioning would provide a *lower bound* on a homeowner's willingness to pay for a given reduction in temperatures. Of course, these estimates depend on the features of the home, baseline indoor temperatures, age of the cooling equipment, and so forth. Nonetheless, some approximate calculations confirm our estimates for the incremental willingness to pay using this standard with the added cooling cost of an extra degree increase being approximately $38 for a slightly smaller than average home. This example thus confirms the tight feedbacks between humans' impacts on the delivery of multiple ecosystem services across space and the capitalization of these impacts within the Phoenix housing market – with market prices of differentiated housing providing useful signals of humans' valuation of these ecosystem services.

B. Constructed Ecosystems – Urban Lakes in the Desert[17]

Our second example also exploits the rich database linking housing sales to parcel information from Maricopa County assessor's records as well as a diverse array of geocoded information available through the CAP-LTER and online resources. As noted elsewhere in this volume, the Phoenix metropolitan area has over four million residents and must be sustained with water from diverse sources, including surface water from the Salt, Verde, and Colorado

[17] This section is based on research reported in Abbott and Klaiber [2013].

River watersheds. Residential use accounts for about two thirds of the potable water use. Most of this demand is associated with outdoor uses, including pools and mesic landscapes. Relatively low prices for water and a favorable climate for water based outdoor recreation lead to the development of more than 40 housing developments around substantial, private manmade lakes. For the most part, the lakes were constructed as part of each initial housing development and are maintained through homeowner association (HOA) dues. The magnitude of these fees depends on the number of housing units in the community and the water quality standards required for the recreation supported by each lake.

There is little doubt that these lakes alter local ecosystems—both in terms of the landscape and evapotranspiration effects and the complementary ecosystem services that would be associated with these resources—birds and other wildlife are likely attracted to each as a local oasis in the Sonoran desert. However, the design of these communities (with most lakes being internal to the community and not visible or adjacent to homes outside the community) and the nature of the property rights to lake access create clear spatial discontinuities in the services these lakes provide. Access to the lake in each subdivision is limited to community members (and their guests). As a result, the services they provide are not pure public goods. These cases are sometimes described as "club goods" where there is a mechanism to limit access that is separate from the amount of services a household can enjoy once a "member".[18] This distinction implies that the services could be non-rival for some households based on whether they live in a sub-division with one of these lakes.

Abbott and Klaiber exploit the use of subdivisions as club goods to leverage spatial discreteness in access to each of lake's ecosystem services as a part of their empirical strategy. They use lake community membership serves as a *treatment* that affects housing prices. To

[18] See Cornes and Sandler [1996] chapter 13 for discussion of club goods.

distinguish the effect of this large transformation to the area around a home for that home's price, we would prefer to observe a transaction for the exact same home in an identical neighborhood, *except for the lake itself.* The price difference in such a thought experiment, between the treated situation and this ideal control, would isolate the effect of the lake and all the services it conveys. Of course, this ideal experiment is not possible. Nonetheless, by drawing upon modern evaluation methods they find a plausible surrogate for the no-lake control by *matching* lake transactions to spatially proximate non-lake transactions with similar housing and neighborhood characteristics. Abbott and Klaiber also investigate within-community heterogeneity in the value of lakes by matching transactions of homes that are located on the lakes themselves to homes within the same community that are not lake-adjacent.

Before discussing some of the findings from Abbott and Klaiber, it is important to repeat the admonition from our discussion of the strategies used to recover measures of the tradeoffs household make for incremental changes in ecosystem services. Each application generates estimates that are specific to its context. They are not readily transferrable. Indeed, the issue of transferring estimates to a different context, sometimes labeled "benefits transfer", is a topic beyond our scope[19]. Thus, the estimates we present are intended to display how differences in lake ecosystems influence these tradeoffs within the context of the Phoenix metropolitan housing market. An especially important aspect of that context arises because the incremental values for the features described in our table for a specific lake community are <u>conditional to the existence of the other lake communities as substitutes</u>. Thus, with that background, Table 1 summarizes a subset of the estimates of the average annual value of lake maintenance distinguishing the effect for adjacency versus being in the lake community. We selected communities with annual total

[19] See Navrud and Ready[2007] for a collection of essays on the research challenges in developing transferrable benefit measures.

values that range from -$12,873 to +$15,309. As the Abbott and Klaiber note, the negative estimate does not imply the lake does not convey positive amenity services. Rather it implies the HOA maintenance fees exceed these positive effects.[20] Importantly, by apportioning the capitalization of lakes to community home values into their equivalent annual rents and then dividing these annualized values by the quantity of yearly water flows required to maintain lake levels[21], Abbott and Klaiber were able to calculate the average value of the service conveyed by an additional acre-foot of water to all homes in the development. These values were typically several thousand dollars an acre-foot for communities in which lakes are a net amenity – values that are one to two orders of magnitude greater than the prices paid for the same water. This finding suggests that large increases in the price of water would likely be required to alter the incentives of developers to provide this water-intensive form of development; the services provided to "clubs" of lake-community residents are apparently highly valuable on average, and these values are transmitted through the local real estate market.

VI. Using LTER's PASS Survey to "Test" Sorting Behavior

Both of our examples also illustrate how ex post analysis of households' decisions can be used to recover measures for the tradeoffs these people were willing to make for services related to different types of ecosystems. Our ability to extract these measures required attention to the sources for identification of the differential contributions that were being attributed to the variation in the indexes for ecosystem services across residential parcels. Because the analysis

[20] By purchasing a home in a lake community, homebuyers are committing to paying for the costs of lake maintenance through higher HOA dues. Therefore, the average difference in price between equivalent homes in and out of a lake community reflects the capitalization of the lake *net* of these extra costs of maintenance. A lake can be a *gross* amenity but a *net* liability.

[21] Evaporation from urban lakes in Phoenix is substantial – approximately 6 cubic feet for every square foot of lake surface area. The annual evaporation from a sample of 29 communities in Abbott and Klaiber's study would supply the yearly water needs of over 50,000 residential customers.

relies on past choices, the estimation challenge is one of distinguishing the effects of the multiple observable differences in parcels while recognizing the potential for differences in unobservable factors that influence housing choice as well.

The theoretical foundation of such analyses rests on an equilibrium process that envisions households sorting among different neighborhoods within a spatially delineated market area. They select the mix of land attributes and housing characteristics that best matches their preferences. This logic implies households with similar preferences are more likely to be located in the same neighborhoods. This outcome is an important implication of the sorting logic. Those who prefer the same types of neighborhood related services, all else equal, will tend to reside in similar areas.

This sorting logic is difficult to test and is typically treated as a maintained assumption of hedonic price modeling. An important reason for the challenge stems from the design of economic data collection processes. Population sampling practices focus on the observable demographic and economic characteristics of households, not their neighborhoods. Indeed neighborhoods are usually treated as unimportant (for telephone, e-mail, or Internet surveys) or selected for convenience to reduce interviewing costs for in-person surveys.

The logic of the LTER system may well offer opportunities to enhance both our understanding of the sorting process and our use of markets to recover tradeoffs. An important byproduct of the LTER program is social surveys where the sampling was designed to match the structure used for ecosystem measurement. The surveys seek to return to the same house or rental unit *because* of its physical location in relationship to these ecosystems rather than because of the type of household thought to live in an area. This process means the household selection is somewhat incidental to the survey design and therefore sorting can be tested[22]. It is not a maintained assumption conditioning the selection of the sample.

Currently the CAP-LTER process of selecting sampling units for measurement of different specific elements in the desert ecosystem is based on a mix of scientific judgment and informed “guesses” about the geographic margins likely to be important in observing change in the urban ecosystem. The focus is primarily on non-human species and vegetation that have direct scientific interest. The previous applications suggest much could be learned if we added the ecosystem services that households reveal they care about to these sampling designs.

This section provides further motivation for expanding the criteria used in defining the LTER’s monitoring goals. It illustrates how the geographic specificity of the sampling for the Phoenix Area Social Survey (PASS) can be used to evaluate plausibility of the sorting logic that underlies a more structural version of the hedonic model.

The hedonic price function relies on households using communities as the equivalent of a “spatial supermarket.” Tiebout [1956] suggested they select the mix of local public goods by moving across the jurisdictions that decide the amounts of these local public services. Equally important, on a finer spatial scale these households move across neighborhoods to select spatially delineated amenities and landscapes that best fit their preferred mix of environmental services. Often these services closely parallel the ecosystem services provided by different land uses.

Hedonic models that integrate the measurement of amenities with varying spatial sales exploit this type of sorting behavior. Of course, they rely on households recognizing the differences in location specific amenities and adjusting to them by selecting a neighborhood that best matches their preferences.

[22] This is approximately true. The design of the PASS sample attempted to represent different socio-economic groups, but this was a secondary consideration. It was not designed to be a statistically representative sample for the population within the CAP-LTER boundaries.

Here we use the coordination in the design of the Phoenix Area Social Survey (PASS) to test the logic underlying most hedonic models. Our summary will describe the research issue, the way in which the design of PASS survey and data collection allowed the test, and then discuss why it is potentially important.

When economic models describe how households sort among communities they must inevitably simplify the full decision process that underlies the hedonic price function. The class of model we will consider is among the most restrictive. We selected it because the assumptions it requires allow clear-cut predictions about sorting behavior. If we are able to find some support for the logic within the setting of this restricted model, it offers indirect support for the hedonic model. It doesn't guarantee a less restrictive model for sorting is also supported, but common sense suggests it is a good bet.

The two key restrictions of the model we summarize here are that households evaluate the services they acquire by changing neighborhoods in the same way. That is, each household can have a different preference for the services, but they all evaluate the "amounts" in the same way. The second key assumption implies that when the market is in equilibrium the price indices for an equivalent house across neighborhoods with varying amounts of the amenities will be ranked in the same way as the index for the amounts of the amenities in these same neighborhoods.[23] These assumptions provide specific predictions about how households would select neighborhoods that differ in local public services. The predictions are important because they offer some confirmation of the model's description of households' sorting behavior.

A key element in this logic is that the taste for local environmental services is negatively correlated with income within a given neighborhood (see below for an explanation). While the

[23] The formal condition that assures this ranking occurs is labeled the single crossing condition. For a discussion of the links to price equivalents see Smith and Banzhaf [2007].

past applications of this structural sorting model, using formal specifications to describe household preferences, have supported this assumption, there has been no independent test because the taste measure involved in the correlation is treated as an unobserved latent variable. This approach places a large burden on the specific functional form describing household preferences. Thus the available empirical findings must be assumed conditional to the maintained structure that describes the details of how the tastes, incomes, and diversity of neighborhoods' features contribute to households' choices.

The analysis we summarize here by Fishman and Smith adopts a more direct strategy for a test. They suggest that the New Ecological Paradigm (NEP) index can serve as a proxy for the taste measure that has been treated as unobserved in the structural models. The design of the PASS survey in 2011 allowed these measures to be linked to neighborhoods. This connection assures the average values for the index can also be associated with indexes for housing prices at this neighborhood level, along with the average household incomes, and local ecosystem services. This composite of conditions provides the first independent test of the logic for this class of sorting models.

The PASS survey was administered by the Institute for Social Science Research at Arizona State University from May 26, 2011 to January 6, 2012. The target population was heads of households age 18 or older who lived in one of the 45 neighborhoods defined based on the ecological and socio-economic criteria that underlie the sampling design. There were 806 completed surveys for a minimum response rate of 43.4 percent.[24]

The definition of the PASS neighborhoods was based on two criteria: the monitoring of local ecosystems in the Phoenix metropolitan area and the identification of local communities

[24] The minimum response rate is the number of complete interviews divided by the number of interviews (complete plus partial) plus the number of non-interviews (refusal and break-off plus non-contacts plus others) plus all cases of unknown eligibility.

based on demographic criteria including income, ethnicity, and retirement status. The first criterion uses the 204 ecological monitoring sites maintained as part of the CAP-LTER. These monitors study vegetation, soil, and other ecological variables on 30 x 30 meter sample plots distributed over all types of land uses in the study area (see Grimm and Redman [2004]). Initial definitions for neighborhoods were selected after examining aerial photographs of the areas surrounding 101 of the monitoring sites.[25] The remaining 94 sites (101 in residential areas less the 7 eliminated sites) were aligned with Census Block groups to identify the socio-economic groups for developing the sampling units based one the second selection criterion. Eight groups were specified, including: low income Phoenix core; low income suburban; middle to high income Phoenix core; middle income suburban; low to middle income fringe areas; high income suburban; high income fringe; and retirement communities. A total of 40 neighborhoods were selected. Five neighborhoods were selected from each group to reflect the demographic composition, the mix of owners and renters, as well as, to match the monitoring data. In 2011, five new neighborhoods were added using the same basic structure, recognizing the areas of population growth in Phoenix. These neighborhoods provide the observational unit for our test.

There are three steps to implement the test. The first step defines a set of spatially delineated neighborhoods. Our selection for these neighborhoods corresponds to those used in the 2011 PASS. The second step is the development of a price index for a homogenous unit of housing. Here Fishman and Smith follow Sieg et al. [2002] to estimate price indexes for the 45 CAP-LTER spatially defined neighborhoods as fixed effects (i.e. dummy variables) in a hedonic model. The last step requires an independent measure of tastes for local public goods. They use the New Ecological Paradigm (NEP) index. Originally proposed by Dunlap and Van Liere

[25] Seven sites of the sixteen visited were eliminated because the residents were not close to the plot used for monitoring.

[1978], the NEP was expanded and updated (Dunlap et al. [1992]) to enhance the questions used to elicit five dimensions of environmental attitudes.[26] These measures are: beliefs in limits to growth; sentiments against a focus on a human centered view of the environment; concern about the fragility of nature's balance; attitudes that question a view that implies humans are exempt from natural constraints; and concerns about the likelihood of an ecological catastrophe.

The Fishman-Smith test requires the spatially explicit links for summary measures of households' environmental attitudes and incomes at the neighborhood scale. Moreover, these neighborhoods must also be consistent with the housing price index developed from sales data. The independently estimated price index captures the effects of local public goods and amenities associated with these neighborhoods. The Fishman-Smith summary measures for the NEP and income provide the information at the same neighborhood level.

The new version of the NEP index is derived from 15 Likert scale (five points) questions. Response categories for each item are "strongly agree", "somewhat agree", "unsure", "somewhat disagree", and "strongly disagree." As Clark et al. [2003] explain, before combining the items into a single index it is desirable to check for the internal consistency of the responses. Fishman and Smith followed their strategy to assure consistency.

Table 2 summarizes the 15 questions in the NEP coded so the 1 to 5 scores are consistent with the way ratings contribute to the NEP. This format implies the questions where "strongly disagree" would be consistent with a high attitude level for environmental objectives were coded as 5. Similarly, questions where "strongly agree" would be consistent with a high attitude level for environmental objectives were coded as 5. That table reports the percentage of respondents providing the score 1 to 5 for each item and the number of respondents answering the question.

[26] The original NEP scale had 12 items (8 pro-trait and 4 con-trait) and was based on a four point Likert scale using test identifiers of strongly agree and strongly disagree for the anchors. The new items expanded the scope based on comments and is based on 15 questions with a 5 point Likert scale.

A test for consistency with the sorting model is straightforward once the specific price indexes for housing in each of the neighborhoods and the mean values for the NEP index are developed with the same neighborhood definitions. It requires that NEP be regressed on mean household income from the PASS survey (by neighborhood) and the price index. As we noted, the price index used in the Fishman-Smith analysis provides the measure that controls for differences in local public goods across neighborhoods. A negative effect of income on NEP confirms that the neighborhood choices of households are consistent with the logic of the sorting model. More specifically, given the NEP is accepted as a credible index for household's tastes for local environmental services, then this relationship implies neighborhood choice balances taste and ability to pay. The logic underlying hedonic price functions implies people will compete for the homes they want. This competition assures the price function provides a measure of the equilibrium tradeoff for small changes in each site specific feature. When we use this logic with the more formal sorting structure there is another insight. In order for analysts to observe households with a variety of income levels in the best neighborhoods there must be an underlying process that allocates households to homes in a way that trades off income and strength of taste for the services provided by these high amenity locations. The negative correlation confirms this explanation.

Table 3 provides our findings. Column (1) uses the neighborhood price index as a control for variations in local public services and environmental amenities across neighborhoods. Mean household income is clearly negatively related to NEP and significant at the five percent level. Column (2) repeats the model using a feasible generalized least squares (FGLS) estimator that exploits the properties of the dependent variable as a mean[27]. Thus, overall, we have strong

[27] Since there are different numbers of PASS survey respondents by neighborhood, this variation not taken into account with OLS and could have distorted the standard errors with this set of estimates. Fishman and Smith used

independent confirmation for the general logic underlying the hedonic model through the support for the sorting model's predictions for the factors affecting the heterogeneity of tastes and income across neighborhoods.

VIII. Implications

Nearly seventy years ago Hayek described why markets were remarkably effective institutions for conveying information in ways that allowed coordination of people in diverse areas undertaking a wide array of tasks. Markets are not perfect and the ability to realize their full potential in conveying information depends on the transaction costs of exchange and the properties of the goods and services traded. Nevertheless they play an important role in coordinating economic activity and disseminating information through complex economies.

Environmental economics has managed in the last sixty years to extend the Hayek message. When non-market services are conveyed, along with market goods in particular ways that allow the non-market services to be captured as if they were private goods, then analysts are able to recover information about the importance of these resources to people.

We have argued the reason this recovery of tradeoff values can be done is because the people involved are using market information along with the observation of location specific differences in environmental (and other services) to make decisions about where to live. Their behavior in response to these information sources is why the models "work." Thus, markets are a key element in the feedback mechanisms that shape urban form and alter urban ecosystems – feedbacks which alter the nature of the services these ecosystems provide to their human residents.

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the feasible generalized least squares estimates to take account of these differences. The estimates using this method suggest accounting for these differences did not change the conclusions.

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Table 1 Summary of the Abbott and Klaiber Study of Urban Lake Communities in Phoenix*

Community	Lake Area (acres)	Evap[a] (af/yr)	Houses[b] Adj	Houses[b] Non-Adj	Premium (dollars per acre ft.)[b] Adj	Premium Non-Adj	Premium Total
Wind Drift	5.9	35.4	53	581	3,244	12,065	15,309
Raintree Ranch	45.5	273.3	219	572	6,166	5,922	12,088
The Lakes	5.0	30.1	39	124	1,677	127	1803
Pecos Ranch	15.6	93.6	119	281	2,868	-2906	-38
Oakwod Lakes	6.8	40.8	62	138	8,590	-21,463	-12,873

[a] af/yr is acre feel per year

[b] adj is adjacent to lake; non-adj is within the lake community but not adjacent to the lake.

* This table is a composite of information reported in Abbott and Klaiber [2013], tables 1 and 5.

Table 2: Components of the New Environmental Paradigm for the 2011 PASS Survey in Phoenix

		Contribution to NEP					
		1	**2**	**3**	**4**	**5**	**n**
1	We are approaching the limit of the number of people the earth can support.	13.9	21.9	12.6	31.0	20.6	804
2	Humans have the right to modify the natural environment to suit their needs.	9.6	29.5	3.4	32.5	24.9	802
3	When humans interface with nature it often produces disastrous consequences.	4.1	15.8	4.5	39.3	36.3	804
4	* Human ingenuity will insure that we do NOT make the earth unlivable.	13.4	34.0	12.0	25.7	15.0	801
5	Humans are severely abusing the environment.	5.8	10.6	2.6	40.4	40.6	805
6	The earth has plenty of natural resources if we just learn how to develop them.	34.2	39.6	4.0	13.4	8.6	804
7	* Plants and animals have as much right as humans to exist.	5.7	9.5	1.7	27.3	55.8	803
8	* The balance of nature is strong enough to cope with the impacts of modern industrial nations.	7.3	25.2	9.3	30.2	27.9	805
9	Despite our special abilities and humans are still subject to the laws of nature.	2.2	3.7	3.0	31.8	59.2	802
10	* The so called "ecological crisis" facing humankind has been greatly exaggerated.	14.0	25.5	7.7	26.1	26.6	804
11	* The earth is like a spaceship with very limited room and resources.	14.4	22.5	5.6	36.4	21.1	801
12	Humans were meant to rule over the rest of nature.	13.1	20.3	5.5	25.7	35.4	802
13	* The balance of nature is very delicate and easily upset.	4.3	15.3	6.0	37.0	37.4	805
14	Humans will eventually learn enough about how nature works to be able to control it.	9.2	24.2	7.5	28.5	30.6	801
15	If things continue on their present course, we will soon experience a major ecological catastrophe.	9.7	17.0	9.1	36.6	27.6	804

Table 3: The Relationship of the New Environmental Paradigm and Household Income[a]

	Full NEP	
	(1)	(2)
Household Income	-0.038	-0.038
(Thousands)	(-2.79)	(-2.68)
Price Index	6.963	7.107
	(4.65)	(4.39)
Parsimonious NEP (2006)	——	——
	——	——
Intercept	54.335	54.423
	(56.96)	(54.08)
R^2	.334	.998
n	39	39

a. The numbers in parentheses are t-ratios for the null hypothesis of non-association with robust standard for (1); feasible GLS for (2).