The Increasing Value of Green for Residential Real Estate

Authors Ramya R. Aroul and Mauricio Rodriguez

Abstract Research has documented a premium for housing with green amenities, on average, over sample periods. Given the increasing efficiency of green features and growing awareness of the environmental concerns in society, we posit that the relation between green amenities and transaction prices is not stationary. We find that premiums associated with green features are growing through time for residential real estate. We explain that this could be driven by a variety of factors. Our results suggest that appraisers should be careful not to make adjustments based on outdated ''rules of thumb'' pertaining to green characteristics.

Environmental consciousness has grown over time. Harvard's Center for Green Buildings and Cities finds that support for green buildings is gaining traction.[1] Sanchez, Brown, Webber, and Homan (2008) document substantial savings associated with energy efficiency initiatives. Research indicates that commercial properties with green features are associated with higher rents, as well as higher transaction prices. Das and Wiley (2013) show that the green premiums for commercial properties change with changing market conditions. It is reasonable to expect that premiums for residential properties may also change with changing market conditions.

Green premiums for residential properties have been documented. Aroul and Hansz (2012) report a premium associated with homes with green amenities. Dastrup, Zivin, Costa, and Kahn (2012) find that premiums are paid for homes that have solar panels. These residential studies report the association between green features and transaction prices, on average, over specific time periods. However, evidence is lacking regarding how green premiums might change through time for residential real estate.

In this paper, we extend the literature by examining the temporal variations in green premiums for residential real estate over an eight-year period. There has been increasing concerns regarding the environment, resulting in increasing consumer demand for more environmentally friendlier options.[2] Furthermore, many individuals have started to focus on the environmental impact of their homes. Also, due to an increased awareness of the economic benefits as well as non-financial benefits of energy efficiency, green features have become a more prominent aspect in home purchase decisions. Therefore, we posit that the market's capitalization of benefits stemming from green features is evolving and is not constant over a long time period. Thus, in this paper we examine whether the green premium stays constant over an eight-year sample period and determine if these green premiums change over time.

Consistent with prior work, initially, we report that the properties that are green are sold at a premium of 2.27%, on average, over the eight-year sample period. In addition, we observe that there was a positive impact on transaction prices when green requirements increased during the sample period. Next, we examine the time-varying green premiums in residential transactions. First, we present a year-by-year analysis and observe that green premiums are significant and growing through time. Second, we present results derived from using eight, time-based, green-based variables to examine the temporal differences in valuation of green and find that the green premiums increase monotonically from 2003 to 2009. These results indicate the market may be putting an increasing value on green related amenities. We describe some factors that may be driving these results. For example, increasing premiums could be partially due to improving technologies that provide a relatively higher present value of benefits associated with green features. These results are also consistent with buyers putting increasing value on benefits that greener homes provide to society.

The paper is organized as follows. In the next section, we review the relevant literature. We then describe the study setting and data. Next, we discuss the methods and present our findings. The last section contains the conclusion.

Literature Review

There has been an increasing amount of research in real estate academia on green properties. Much prior work has focused on green initiatives for commercial buildings. Miller, Spivey, and Florance (2008) is one of the first organized studies on green buildings that explore research questions on the benefits of investing in energy savings and environmental design. Fuerst and McAllister (2009, 2011), in a similar endeavor, find consistent results to those by Miller, Spivey, and Florance (2008); all these studies used the same commercial real estate data source from CoStar.

Wiley, Benefield, and Johnson (2010) employ a hedonic estimation of sales price per square foot and find that eco-certified properties transact at a significant price premium when compared to a non-labelled property. Eichholtz, Kok, and Quigley (2013) report that green commercial buildings have higher rents and sell at higher prices. Das and Wiley (2013) document that the green premiums for commercial properties are not stationary, but change with changing market conditions. It is reasonable to expect that green premiums for residential properties may also change with changing market conditions, but this has not been empirically examined for residential real estate.

Studies on residential real estate indicate that green features have a positive impact on residential transaction prices. Aroul and Hansz (2012) examine residential transactions in two Texas cities and report premiums associated with green residential properties, on average, over the time period examined. Kahn and Kok

(2014) report that homes with green labels such as ENERGY STAR, LEED, and Green Point Rated located in California sell for 9% more than homes without labels, on average, over the time period examined. Brounen and Kok (2011) document the factors that influence whether or not a home has an energy rating and also find premiums associated with energy performance certificates in the Netherlands. Aroul and Hansz (2011) document a premium, on average, associated with dual-pane windows. Bloom, Nobe, and Nobe (2011) report that ENERGY STAR qualified homes sold for a premium, on average, in comparison with non-ENERGY STAR qualified homes in Fort Collins, Colorado. Deng, Li, and Quigley (2011) report a 4% premium for green amenities in multifamily residential buildings consisting of private condos and apartments in Singapore. Pivo (2014) documents that green amenities can help forecast lower mortgage default in multifamily rental housing.

Bond (2015) documents that new building codes and legislation have been introduced on a state-by-state basis to improve the energy efficiency of residential properties. Bently, Glick, and Strong (2015) indicate that Colorado's real estate appraisers are gradually incorporating sustainable building features in their appraisal projects despite the challenges encountered. Goodwin (2011) documents that green amenities play a significant role when potential home owners make a purchasing decision. Bond (2015) explains that states are adopting increasingly higher efficiency requirements. This suggests that premiums associated with more efficient green amenities could increase through time. Sanderford, McCoy, and Keefe (2018) document that ENERGY STAR adoptions for single-family homes are a function of the local public policies, climate variation, and medium-term energy prices. These findings were based on aggregate proportion of certified adoptions because individual adoption patterns were not available.

To date, the studies on the impact green features have on individual residential transaction prices have examined the average premium throughout the sample periods studied. We extend prior work by examining the time-varying nature of residential green premiums to illuminate the temporal differences on the impact of green feature in residential transaction prices.

Study Setting

The Dallas-Fort Worth metropolitan area is considered to be the financial hub of the Southwest, whose growth is attributed to high tech, manufacturing, and service industries. The City of Frisco has a mandatory residential green building program and is one of the fastest growing cities in the United States.[3] The City of Frisco falls within both Collin County and Denton County. Both Collin and Denton counties experienced tremendous population growth in the last decade. Collin County had an approximately 50% increase in population and the highest sustained growth rate in the U.S., at 73.9% since 2000, while Denton County had a sustained growth rate of 61.6% in the same time period (U.S. Census Bureau, 2014).

Frisco is one of the fastest developing cities in the Dallas-Fort Worth metropolitan region. In light of this exploding growth, the city decided to have a mandatory residential green building program to develop a sustainable community. In May 2001, Frisco became the first city in the U.S. to adopt a mandatory Residential Green Building Program. The efficiency of green amenities improved through time. The mandatory program requirements in Frisco were revised in 2007.[4] Hence, it is reasonable to expect that the capitalized benefits buyers could expect from green features were not stationary through time.

Data

The data on property transaction prices were obtained from the North Texas Real Estate Information System's (NTREIS's) Multiple Listing Service (MLS) dating from January 2002 through December 2009. The City of Frisco adopted the mandatory Residential Green Building Program in May 2001. Hence the starting year for this study was chosen to be 2002. After careful cleaning of data, the final dataset contained 25,272 data records for Frisco spanning over eight years from 2002 to 2009.

Green Variable

According to the green building ordinance passed on May 2, 2001, all residential plats accepted after May 23, 2001 are required to build to the mandatory green building program standards of the City of Frisco's Residential Green Building Program. The City of Frisco maintains a list of subdivisions that were platted after 2001. The green variable employed in this study is a dummy variable that gets the value of 1 if the property is deemed to be green and a value of 0 if the residential building is not green. First, we code residential buildings as green if they were in the subdivision that was platted as green.[5] The city updated and improved the Residential Green Building Program and the revised program was put into effect for all homes receiving a building permit on, or after, July 1, 2007. Therefore, all buildings that were built after 2007 are classified as green.[6]

The City of Frisco's Residential Green Building Program set forth minimum standards under four major categories: energy efficiency, water conservation, indoor air quality, and water recycling. For instance, under the energy efficiency category, the city mandated that single-family residences should have the Environmental Protection Agency's ENERGY STAR designation or a score of 83 or less on the Home Energy Rating Systems (HERS) index. With respect to indoor air quality, the city mandated every single-family residence to have a minimum standard of American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard of 62.2 or its amendment. Under the water conservation category, the city required each installed tree to have a portable drip irrigation bag or zoned bubbler system.[7]

We base our list of green identifiers from the city's green building program requirements and use them to determine if a home is classified as being green. Extensive key word searches are employed to capture green features and identify houses that were green outside of the mandated program. However, this constitutes only a small portion of the green houses in the sample. We find that the City of

Frisco had 11,094 green homes in the list out of 25,272 homes in the database, which is about 44%.

Methods and Findings

Hedonic pricing models have been applied to study relations between housing attributes like structural characteristics, environmental amenities and disamenities, neighborhood characteristics, time variables, financing options, and locational attributes on the property values. However, the extent to which green amenities are important housing characteristics has been largely overlooked by these models. The few residential studies that use a variable to capture the impact from green features have only used one variable over the entire period studied as described in the literature review section above.

Rosen (1974) argues that individual features and characteristics make up overall asset values. Furthermore, these features and characteristics can be imputed from transaction prices. We use a unique dataset that includes green residential transactions in a traditional hedonic framework to estimate the association between "green" and transaction prices for residential real estate.

Following the traditional housing literature, the dependent variable we employ is the natural log of sales price. Logs of sales prices are regressed against a set of typical control variables along with the green dummy variable as described below.[8] This allows us to estimate how the green features are related to a change in residential property values, holding other characteristics of the properties constant. Exhibit 1 lists the specific variables employed along with their description. Exhibit 2 provides descriptive statistics of the variables.

Similar to the literature, we first examine the impact of "green" on residential transactions, on average, by estimating the following model:

$$Ln(Sales\ Price) = Constant + \Sigma\beta_i X_i + \Sigma\beta_j Y_j + \Sigma\beta_k Z_k + \beta_g G + e, \quad (1)$$

where X_i denotes the vector of the physical characteristics of a property such as square footage, age, bedrooms, bathrooms, fireplaces, acres, and garage. In addition, X_i includes controls for foreclosures. Y_j denotes a vector of locational attributes such as county and school district. Z_k denotes a vector of time and seasonality controls such as year of sale, month of sale, and days on market.[9] Our primary variable of interest is the green characteristic variable, which has $G = 1$, if house is green, and $G = 0$ otherwise. Therefore, the null hypothesis we focus on is whether the coefficient for the green variable β_g is equal to zero.

Consistent with Aroul and Hansz (2012), we find β_g to be positive and significantly associated with the sales prices of residential real estate. We find that

Exhibit 1 | Variable Descriptions

Variable	Description
Lnsales	Natural log of sales price.
Green	Dummy variable equals 1 if property is green.
Program	Dummy variable equals 1 if property is green under revised program.
*Green*2002*	Dummy variable equals 1 if property is green and sold in 2002.
*Green*2003*	Dummy variable equals 1 if property is green and sold in 2003.
*Green*2004*	Dummy variable equals 1 if property is green and sold in 2004.
*Green*2005*	Dummy variable equals 1 if property is green and sold in 2005.
*Green*2006*	Dummy variable equals 1 if property is green and sold in 2006.
*Green*2007*	Dummy variable equals 1 if property is green and sold in 2007.
*Green*2008*	Dummy variable equals 1 if property is green and sold in 2008.
*Green*2009*	Dummy variable equals 1 if property is green and sold in 2009.
Beds	Number of bedrooms.
SqFt	Square footage.
Pool	Dummy variable equals 1 if there is a pool.
Age	Age of the property.
DOM	Days on market.
County	Dummy variable equals 1 if the property is in Collin County.
Jan	Dummy variable equals 1 if the sale was in January.
Feb	Dummy variable equals 1 if the sale was in February.
Mar	Dummy variable equals 1 if the sale was in March.
Apr	Dummy variable equals 1 if the sale was in April.
May	Dummy variable equals 1 if the sale was in May.
Jun	Dummy variable equals 1 if the sale was in June.
Jul	Dummy variable equals 1 if the sale was in July.
Aug	Dummy variable equals 1 if the sale was in August.
Sep	Dummy variable equals 1 if the sale was in September.
Oct	Dummy variable equals 1 if the sale was in October.
Nov	Dummy variable equals 1 if the sale was in November.
Dec	Dummy variable equals 1 if the sale was in December.
Y2009	Dummy variable equals 1 if the sale was in 2009.
Y2008	Dummy variable equals 1 if the sale was in 2008.
Y2007	Dummy variable equals 1 if the sale was in 2007.
Y2006	Dummy variable equals 1 if the sale was in 2006.
Y2005	Dummy variable equals 1 if the sale was in 2005.
Y2004	Dummy variable equals 1 if the sale was in 2004.
Y2003	Dummy variable equals 1 if the sale was in 2003.
Y2002	Dummy variable equals 1 if the sale was in 2002.

Exhibit 1 | (continued)
Variable Descriptions

Variable	Description
FullBath	Number of full baths.
HalfBath	Number of half baths.
Fireplace	Dummy variable equals 1 if there is a fireplace.
Fence	Dummy variable equals 1 if there is a fence.
School	Dummy variable equals 1 if the property is in Frisco ISD.
Garage	Dummy variable equals 1 if there is a garage.
Foreclosure	Dummy variable equals 1 if the sale is a foreclosure.

properties with green features sold for about 2.27% more, as shown in Model 1 in Exhibit 3.

It is reasonable to expect that increased mandatory green requirements could increase the value that buyers place on homes with green features. Therefore, we use an additional control variable to capture the revision of the mandatory program to see if the market attributed more value after the increased green requirements. The Program Revision variable equals one if the house is built after the program was revised in 2007 and zero otherwise. All homes that were built after 2007 were required to have all green features proposed by the city's green building program. Of course, sales of older homes with no green features as well as sales of other homes with various amounts of green features continued to be sold after 2007.

Model 2 in Exhibit 3 shows that the Program Revision time is significantly related to incremental values. Higher sales prices could be due to the improving efficiencies of green features, as well as increased awareness and attitudes towards green features. Next, we examine whether there are variations across time, apart from the described revision date in mandatory green requirements.

In Exhibit 4, we estimate the same hedonic model as Model 1, but on a year-by-year basis to see if the relation between green and transaction prices for residential real estate changed during our sample period. The coefficient for the green variable for each year is used to ascertain the green premium for each year. Exhibit 4 shows that the coefficient for the green variables were not significant at the start of our sample time period, but became significant and increased in magnitude during the latter years of our sample period. The increasing premiums for green features prior to 2007 could be driven by improving green features or increasing value being placed on green features during those years. The increasing premiums for green features after 2007 are more consistent with increasing value being placed on the improved mandated green features.

Exhibit 2 | Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Lnsales	12.12	0.25	11.52	12.61
Green	0.43	0.39	0	1
Program Revision	0.27	0.49	0	1
*Green*2002*	0.01	0.05	0	1
*Green*2003*	0.03	0.13	0	1
*Green*2004*	0.03	0.14	0	1
*Green*2005*	0.04	0.17	0	1
*Green*2006*	0.05	0.16	0	1
*Green*2007*	0.04	0.18	0	1
*Green*2008*	0.09	0.19	0	1
*Green*2009*	0.14	0.13	0	1
Beds	3.65	0.68	1	6
SqFt	2,415.45	657.65	490	5,095
Pool	0.07	0.25	0	1
Age	6.56	9.15	0	145
DOM	68.34	65.44	0	1,149
County	0.88	0.33	0	1
Jan	0.05	0.23	0	1
Feb	0.07	0.25	0	1
Mar	0.09	0.29	0	1
Apr	0.09	0.28	0	1
May	0.10	0.30	0	1
Jun	0.11	0.31	0	1
Jul	0.09	0.29	0	1
Aug	0.09	0.29	0	1
Sep	0.07	0.26	0	1
Oct	0.08	0.27	0	1
Nov	0.07	0.26	0	1
Dec	0.16	0.25	0	1
Y2009	0.06	0.21	0	1
Y2008	0.13	0.34	0	1
Y2007	0.15	0.36	0	1
Y2006	0.17	0.38	0	1
Y2005	0.18	0.38	0	1
Y2004	0.15	0.36	0	1
Y2003	0.14	0.34	0	1
Y2002	0.03	0.16	0	1

Exhibit 2 | (continued)

Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
FullBath	2.31	0.56	1	5
HalfBath	0.39	0.49	0	5
Fireplace	0.83	0.37	0	1
Fence	0.90	0.30	0	1
School	0.51	0.50	0	1
Garage	0.25	0.43	0	1
Foreclosure	0.09	0.29	0	1

Note: There are 25,272 observations.

We further examine the time-varying green premiums in residential transactions by interacting the green variable with the year dummies. Hence, the next model we estimate is as follows:

$$Ln(Sales\ Price) = Constant + \Sigma\beta_i X_i + \Sigma\beta_j Y_j + \Sigma\beta_k Z_k + \beta_{gy} G * Year + e, \quad (2)$$

where $G * Year$ is the vector of interaction variables obtained by multiplying the green variable by the year dummies. We therefore, generate eight temporal green variables: *Green ∗ 2002, Green ∗ 2003, Green ∗ 2004, Green ∗ 2005, Green ∗ 2006, Green ∗ 2007, Green ∗ 2008*, and *Green ∗ 2009*. The null hypothesis we focus on for these estimates is whether the coefficients for the green temporal interaction variables β_{gy} are each equal to zero.

In this analysis, we use the eight time-dependent green variables to examine the temporal differences in the valuation of the green amenities. We test to determine whether the coefficients are stationary and reject the null hypothesis that the coefficients are equal throughout the sample time period.[10] Exhibit 5 presents the temporal results. We find that the green premiums increase monotonically each year from 2003 to 2009. The increased requirements were not in place throughout this time period. Therefore, the observed increases from year-to-year cannot be attributed solely to the increased requirements in 2007. Moreover, the percentage of green homes that were new, which sold each year, went up and down during our sample period.[11] Therefore, the monotonic increases in green premiums that we report are not fully explained by just newer green homes being sold. The increasing green premiums also reflect increasing values placed on older homes that possess green features.

Exhibit 3 | Green Premiums for Overall Sample (2002–2009)

Variables	Model 1	Model 2
Green	0.0227***	0.0226***
	(0.0023)	(0.0023)
Program Revision		0.0566***
		(0.0020)
Beds	−0.0398***	−0.0399***
	(0.0016)	(0.0016)
SqFt	0.0003***	0.0003***
	(2.35e-06)	(2.36e-06)
Pool	0.120***	0.120***
	(0.0032)	(0.0032)
Age	−0.0006***	−0.0007***
	(9.74e-05)	(0.0001)
DOM	−5.28e-06	−4.45e-06
	(1.24e-05)	(1.24e-05)
County	−0.0880***	−0.0890***
	(0.0026)	(0.0026)
FullBath	0.0432***	0.0431***
	(0.0022)	(0.0022)
HalfBath	0.0053***	0.0054***
	(0.0020)	(0.0020)
Fireplace	0.0451***	0.0448***
	(0.0025)	(0.0024)
Fence	−0.0042	−0.0039
	(0.0031)	(0.0030)
School	0.0479***	0.0481***
	(0.0017)	(0.0017)
Garage	0.0254***	0.0280***
	(0.0022)	(0.0024)
Foreclosure	−0.123***	−0.122***
	(0.0029)	(0.0029)
Constant	11.49***	11.50***
	(0.0078)	(0.0078)
Seasonality	Yes	Yes
Year dummies	Yes	Yes
R^2	0.748	0.748

Notes: The coefficients are the results of OLS using residential transaction data from Frisco, Texas. The sample period is from October 2002 to June 2009. Model 1 includes an indicator for green for the overall sample period of 2002–2009. Model 2 includes the same green indicator variable, as well as a variable that captures the Program Revision. Both models include year dummy variables and month dummy variables to control for seasonality. There are 25,272 observations. Standard errors are in parentheses.

*$p < .1$

**$p < .05$

***$p < .01$

Exhibit 4 | Green Premiums for Year Wise Sub-samples

Variables	2002	2003	2004	2005	2006	2007	2008	2009
Green	−0.0076	0.0476	0.0127*	0.0138**	0.0187***	0.0202***	0.0219***	0.0291***
	(0.0165)	(0.0066)	(0.0065)	(0.0054)	(0.0055)	(0.0063)	(0.0065)	(0.0091)
Beds	−0.0073*	−0.0405***	−0.0490***	−0.0466***	−0.0470***	−0.0446***	−0.0394***	−0.0543***
	(0.0040)	(0.0045)	(0.0045)	(0.0040)	(0.0041)	(0.0048)	(0.0050)	(0.0076)
SqFt	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***
	(1.34e-05)	(6.12e-06)	(5.96e-06)	(5.52e-06)	(5.79e-06)	(6.50e-06)	(6.71e-06)	(9.86e-06)
Pooldummy	0.0633***	0.100***	0.118***	0.130***	0.112***	0.137***	0.125***	0.129***
	(0.0217)	(0.0082)	(0.0077)	(0.0078)	(0.0076)	(0.00856)	(0.0091)	(0.0132)
Age	−0.0009*	−0.0010***	−0.0005**	−0.0004*	−0.0007***	−0.0009***	−8.05e-05	−0.0004
	(0.0005)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0005)
DOM	6.21e-06	−1.13e-06	1.76e-05	1.69e-05	−2.24e-05	−0.0001***	1.03e-05	−3.63e-05
	(9.50e-05)	(3.09e-05)	(2.96e-05)	(2.89e-05)	(3.30e-05)	(3.62e-05)	(3.28e-05)	(4.54e-05)
County	−0.0549***	−0.0478***	−0.0954***	−0.103***	−0.0967***	−0.105***	−0.101***	−0.0893***
	(0.0155)	(0.0065)	(0.0065)	(0.0059)	(0.00647)	(0.0078)	(0.0074)	(0.0101)
FullBath	0.0599***	0.0239***	0.0390***	0.0412***	0.0481***	0.0563***	0.0351***	0.0288***
	(0.0132)	(0.0056)	(0.0055)	(0.0051)	(0.0053)	(0.0062)	(0.0065)	(0.0099)
HalfBath	0.0134	−0.0083*	0.0048	−0.0089*	−0.0204***	−0.0062	−0.0130**	−0.0112
	(0.0124)	(0.0050)	(0.0050)	(0.0046)	(0.0049)	(0.0055)	(0.0059)	(0.0085)
Fireplace	−0.0093	0.0121*	0.0412***	0.0725***	0.0512***	0.0440***	0.0518***	0.0338***
	(0.0155)	(0.0067)	(0.0057)	(0.0054)	(0.0059)	(0.0070)	(0.0070)	(0.0108)

Exhibit 4 | (continued)

Green Premiums for Year Wise Sub-samples

Variables	2002	2003	2004	2005	2006	2007	2008	2009
Fence	−0.0288	−0.0246***	−0.0124*	−0.0230***	0.0238***	0.0340***	0.0117	−0.00235
	(0.0198)	(0.0085)	(0.0066)	(0.0066)	(0.0073)	(0.0088)	(0.0095)	(0.0148)
School	0.0300***	0.0519***	0.0556***	0.0558***	0.0459***	0.0454***	0.0459***	0.0441***
	(0.0106)	(0.0041)	(0.0042)	(0.0038)	(0.0039)	(0.0047)	(0.0049)	(0.0075)
Garage	−0.0179	−0.0024	0.0038	0.0204***	0.0600***	0.0806***	0.0510***	0.0570***
	(0.0122)	(0.0050)	(0.0051)	(0.0048)	(0.0053)	(0.0073)	(0.0089)	(0.0138)
Foreclosure	−0.123***	−0.121***	−0.117***	−0.0706***	−0.0814***	−0.118***	−0.130***	−0.154***
	(0.0474)	(0.0108)	(0.0080)	(0.0080)	(0.0073)	(0.0073)	(0.0065)	(0.0094)
Constant	11.41***	11.42***	11.45***	11.49***	11.43***	11.48***	11.55***	11.59***
	(0.0377)	(0.0178)	(0.0168)	(0.0154)	(0.0166)	(0.0199)	(0.0201)	(0.0286)
Seasonality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	897	3,472	3,773	4,434	4,286	3,755	3,278	1,377
R^2	0.743	0.789	0.772	0.772	0.764	0.715	0.720	0.754

Notes: The coefficients reported in the table are the results of OLS using residential transaction data from Frisco, Texas. The sample period ranges from October 2002 to June 2009. In this analysis, we conduct the same analysis in Model 1 of Exhibit 3 but for sub samples. We report nine models (each for each year in the sample period 2002–2009). Model 1 includes an indicator for green using a sub-sample data time period 2002, Model 2 −2003 sub sample and so on. All models include month dummy variables to control for seasonality. Standard errors are in parentheses.

*$p < .1$

**$p < .05$

***$p < .01$

Exhibit 5 | Green Premiums over Time

Variables	Model 3
*Green*2002*	−0.0176 (0.0065)
*Green*2003*	0.0037 (0.0062)
*Green*2004*	0.0126* (0.0071)
*Green*2005*	0.0139** (0.0050)
*Green*2006*	0.0181*** (0.0049)
*Green*2007*	0.0223*** (0.0157)
*Green*2008*	0.0229*** (0.0052)
*Green*2009*	0.0234*** (0.0054)
Beds	−0.0398*** (0.0016)
SqFt	0.0003*** (2.35e-06)
Pool	0.120*** (0.0032)
Age	−0.0006*** (9.75e-05)
DOM	−7.34e-06 (1.24e-05)
County	−0.0892*** (0.0026)
FullBath	0.0435*** (0.0022)
HalfBath	0.0054*** (0.0020)
Fireplace	0.0452*** (0.0025)
Fence	−0.0036 (0.0031)
School	0.0478*** (0.0017)
Garage	0.0262*** (0.0022)
Foreclosure	−0.123*** (0.0029)

Exhibit 5 | (continued)
Green Premiums over Time

Variables	Model 3
Constant	11.49***
	(0.0080)
Seasonality	Yes
Year dummies	Yes
R^2	0.748

Notes: The coefficients reported in the table are the results of OLS using residential transaction data from Frisco, Texas. The sample period ranges from October 2002 to June 2009. Model 3 includes green interaction variables that interacts the green indicator variable with the year variables, for each year during the sample period. The model includes year dummy variables and month dummy variables to control for seasonality. There are 25,272 observations. Standard errors are in parentheses.
$^{*}p < .1$
$^{**}p < .05$
$^{***}p < .01$

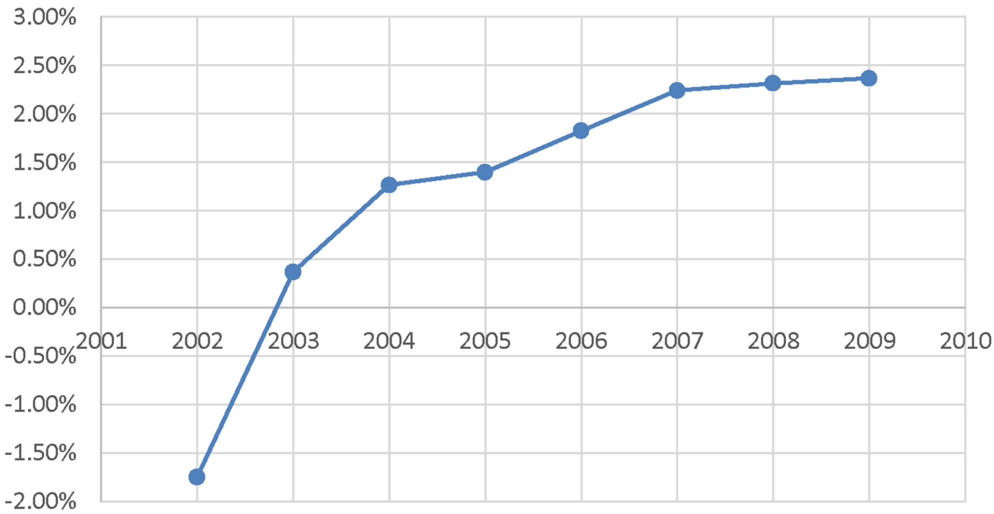
Sanderford, McCoy, and Keefe (2018) indicate that ENERGY STAR adoptions for single-family homes are a function of the local public policies, climate variation, and medium-term energy prices. This study captures the increased green requirements dictated by local policy. The climate was the same in this local area. Hence, climate differences do not drive our results. Energy prices were not constant during the time under study. The price of oil generally increased from 2002 through 2005. The price of oil did not change much in 2006 and then increased again in 2007. Then the price of oil significantly decreased during 2008 before recovering to some extent in 2009. Increased energy prices from 2002 through 2005 and in 2007 could have made green amenities more attractive, but the increased green premiums reported for 2006 and 2008 do not appear to be driven by energy prices given their decrease during those years. However, our results do not fully distinguish between the possibilities that some premiums increased for a set of constant green amenities versus premiums increasing due to improved more efficient green amenities or premiums increasing due to changing attitudes for green amenities. What is clear is that premiums increased for green amenities over our sample period.

Kennedy (1981) demonstrates how to correctly interpret dummy variables in semi-logarithmic equations. We use the Kennedy conversion[12] to convert the computed coefficients into price premium estimates attributable to green features. Exhibits 6 and 7 provide a summary of the changing green premiums across the years in our sample period.

Exhibit 6 | Green Premiums after Kennedy (1981) Conversion over Time

Year	Green Premiums
2002	−1.75%
2003	0.37%
2004	1.27%
2005	1.40%
2006	1.83%
2007	2.24%
2008	2.32%
2009	2.37%

Exhibit 7 | Green Premiums over Time



The green premiums in 2002 and 2003 are not statistically significant.

Conclusion

The literature has reported that homes with green features sell for more, on average over time periods examined, than homes without green features. Due to increases in the efficiencies of green features along with an increased awareness of the economic and other non-financial benefits of energy efficiency, we examine whether the market's perception on the value of green is evolving and is not constant over a large time period. We extend the literature by examining the temporal variations in green premiums.

We find that premiums associated with green amenities are not stationary. We also find that green premiums increased throughout our eight-year sample period. This is consistent with the notion that home buyers are capitalizing the benefits from increasingly more efficient green amenities. The results are also consistent with buyers becoming more conscious about the benefits green features can provide for society.[13] The State of the Nation's Housing (2015) report states that 185 out of 715 U.S. cities with populations above 50,000 have green building programs. Out of this group, 124 cities reportedly have programs specifically for residential construction. Most of the programs have been initiated in high population areas in California and Florida. Improvements in technology, combined with the growth of such programs suggests that premiums associated with more efficient green amenities could increase through time.

Theoretically, we should expect variation in green premiums across time and across markets based on different circumstances across time and across locations. All else equal, individuals who live in times of increased energy costs should find green amenities more attractive. The same is true when green amenities provide increased efficiency benefits to owners beyond any increases in the price of the amenities through time. Different green amenities produce different levels of benefits at different cost points. Therefore, we should expect different premiums for different types of green amenities. However, we leave it to future research to examine the benefit from "different shades of green."[14]

Lower green premiums should be expected in markets with relatively less need for energy efficiencies due to climates that require less heating or air conditioning than more extreme climates. Social attitudes regarding green amenities can also vary across time and markets.

Given the time-varying nature of green premiums that we report, appraisers should not use an old rule of thumb based on a historical average relation green features may have had with transaction prices, but should make adjustments that capture the evolving nature of how green amenities are valued within the market for residential real estate. Appraisers should also be careful not to blindly generalize findings for one market across markets that have different climates or attitudes regarding green amenities.

Lower income individuals can experience higher financial benefits, relative to their incomes, from the savings stemming from green amenities. However, individuals in lower income areas might lack the financial capacity to take advantage of the benefits available from green amenities. Therefore, policymakers should develop programs that help lower income individuals gain access to the growing benefits green amenities can provide.

Endnotes

1. See the State of the Nation's Housing (2015) report from the Joint Center for Housing Studies of Harvard University.
2. Rose Quint, "Housing Preferences across Generations (Part I)," Eye on Housing (March 7, 2016).

[3] U.S. Census Bureau, 2017: https://www.census.gov/newsroom/press-releases/2017/cb17-81-population-estimates-subcounty.html.

[4] It should be noted that what Frisco previously considered ‘‘green building’’ has been incorporated as minimum code by the International Code Council (ICC). Frisco’s residential green building program was evaluated by a group of home energy raters and the changes that they proposed were incorporated into the adoption of the 2012 International Residential Code. As of January 1, 2014, the minimum standards for energy efficiency–residential green building program in Frisco has been incorporated into its building codes and the separate green building program no longer exists.

[5] This coding by green subdivisions was confirmed using a GIS interactive map provided by the city.

[6] However, not all sales classified as green after 2007 were new homes because there were also sales of existing homes with green features. Age is used as a control variable in the models to help control for differences between newer and older homes.

[7] Aroul and Hansz (2012) provide a description of the mandatory green building standards adopted and revised in Frisco, Texas.

[8] See Sirmans, Macpherson, and Zietz (2005) for a review of the variables typically used in hedonic studies.

[9] The effects of seasonality have been found to be significant in property sales (Goodman, 1992).

[10] When we tested the equality of the yearly green coefficients post regression estimation, the null hypothesis of equality was rejected at the 1% level, indicating that the coefficients are significantly different from one another.

[11] In other words, the total sales of new green homes each year relative to the total sales of green homes (old or new) each year fluctuated during the years examined.

[12] Coefficient after Kennedy conversion = [exp(OLS estimator)/exp(0.5 * estimated variance of the OLS estimator)]-1.

[13] This could lead to increasing premiums even for green amenities that do not offer increasing benefits.

[14] We thank the reviewer comments for the term ‘‘different shades of green.’’

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Dr. Rodriguez is grateful for research support from the Tandy Center for Executive Leadership and the Luther King Capital Management Center for Financial Studies at Texas Christian University.

Ramya R. Aroul, Texas A&M University–Commerce, Commerce, TX 75429 or ramya.aroul@tamuc.edu.

Mauricio Rodriguez, Texas Christian University, Fort Worth, TX 76109 or m.rodriguez@tcu.edu.