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On the Relation between Innovation and Housing Prices – A Metro Level Analysis of the US Market

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Abstract
We examine the extent to which the quality of innovation created in different locations is related to subsequent changes in house prices in these metropolitan areas. Cities that foster a healthy quality of innovation are likely the home of many successful entrepreneurs and firms that provide high paying jobs. We hypothesize that the relation between innovation and changes in house prices is positive because, all else equal, locations with higher quality of innovation should not only be more desirable places to live, but also support higher rate of wealth and income growth, which allow for higher house price appreciation. We find results consistent with our hypothesis: there is a statistically and economically significant positive relation between innovation quality and subsequent house price appreciation. We find that this association runs from innovation quality to house price appreciation but not the reverse, and that the effect is stronger in areas with inelastic land supply.

Keywords Innovation quality · Patents · Housing · Real estate return

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Introduction and Literature Review

The Greek philosopher Heraclitus has been quoted as saying "change is the only constant in life," and much of the continuous change in our lives is driven by innovation. Capitalism as an economic environment combined with the American entrepreneurial spirit provides an incubator for innovation and, as a result, the number of patents issued in the U.S. alone recently surpassed 10 million.[1] While innovation is affecting lives everywhere, innovativeness differs significantly across cities. In this paper we examine whether or not, and the extent to which, local innovation quality (or local innovativeness) is related to changes in house prices and overall return on housing.[2]

Innovation as a research topic within the finance literature has gained significant momentum in recent years. He and Tian (2018) provide a detailed survey of the innovation literature and find that the top finance journals published only five articles on this topic between 2000 and 2008, but the number of published research on this topic in these same journals soared to 56 between 2009 and 2017. Most of the published research on this topic is related to efficient financing of innovation and managers' incentives for innovation investments.

While the finance literature has experienced a recent surge on the topic of innovation, innovation is still an underexplored topic within the real estate literature. Although a few papers discuss innovation as it is related to real estate products (see Benjamin & Chinloy, 1995; Benjamin et al., 2002; Wallace, 2005; Seiler et al., 2012; Kuzina, 2015; Benefield et al., 2019, among others), the relation between local innovativeness and real estate prices or returns is yet to be explored. This paper seeks to address this gap in the literature.

Kogan et al. (2017) examine the relation between innovation and economic growth and find significant positive medium-term relation between the two. Because economic growth is shown to affect real estate prices (Gyourko et al., 2013; Knoll et al., 2017 are two recent examples), it is reasonable to expect that innovation is directly positively related to real estate price appreciation and return. We employ the same patent dataset used by Kogan et al. (2017) in order to examine whether or not, and the extent to which, variation in innovation quality across metropolitan areas in the U.S. is related to house price changes and overall housing return.

The results of our analysis provide evidence of a statistically significant positive relation between local innovativeness and house price changes. This inference is robust to controlling for population, the level of educational attainment, and local economic conditions (measured by the unemployment rate) in the metropolitan statistical area (MSA). The positive relation between local innovativeness and house price appreciation retains its statistical significance even when we include MSA fixed effects to account for unobserved area-specific factors. This implies that the relation between local innovativeness and house prices is not simply a product of the

[1] According to the United States Patent and Trademark Office (USPTO) the number of patents issued in the U.S. surpassed 10 million in 2018.

[2] We use "local innovation quality" and "local innovativeness" interchangeably throughout our paper.

fact that innovation has been more robust in some cities/regions within the U.S., or that there may be unobserved MSA factors that jointly affect both local innovativeness and house price appreciation. Additionally, the results of our analysis reveal that the relation between local innovativeness and changes in house prices is more pronounced in areas where the supply of available land is constrained and during periods when the general housing market is booming. A test that explores the bi-directional relation between local innovativeness and house prices reveals that innovation predicts changes in house prices, but not the reverse.

This paper contributes to the existing real estate literature by serving as the first paper to explore the relation between innovation quality and the housing market at the local level. Our findings provide an additional important factor that can be used by academics or investors to predict changes in house prices at the local level as we show that the economic growth of the residential real estate market in a particular metropolitan area can stem from the quality of innovation within that area. Moreover, the results of our analysis carry important implications for policy makers as it allows them to better value the economic benefits, as they pertain to the local housing market, from attracting innovators in the form of businesses or individuals.

Hypotheses Development

Corporate innovation and entrepreneurship have long been regarded as crucial engines of economic growth (e.g., Solow, 1957) by developing new technologies, fostering knowledge spillovers, enhancing workers' skills and creating more jobs in the broad economy. The theory of endogenous growth in the economic literature (e.g., Aghion et al., 1998; Romer, 1990) has emphasized innovation and human capital flows as integral parts of growth. As such, much attention has been paid to investigating causes of innovation – the origin of growth – in the extant innovation literature (see a review in He & Tian, 2018), in sharp contrast to the paucity of research on the consequences of innovation. Glaeser et al. (2010) explain that this paucity, especially at the local level, is mainly because no one doubts that a relation exists between innovation and growth, and because identification is difficult to achieve. This might also explain why, to date, there has been little or no research on innovation and house prices in the real estate literature. Although the relation between innovation and growth is expected, to what extent this translates into housing market returns remains unclear. This is the gap that our paper aims to fill.

We argue that higher quality innovation will lead to higher future house prices through at least four channels. First, on the extensive margin, higher quality innovation will attract more talented human capital (and entrepreneurs) into the region, as individuals and companies seek to exploit and combine the resources (capital and high-skill workers) that are essential for engaging in product innovation and new businesses formation, and to achieve greater individual career success. The legendary success story of Silicon Valley is one clear example that illustrates the plausibility of this channel. Porter (1990) also argues that the innovativeness of certain clusters accounts for their subsequent growth. As more high-quality human capital flows into the area, demand for housing would increase correspondingly, potentially driving up regional house prices.

Second, higher quality innovation will attract more capital from wealthy investors, who, knowing *ex ante* that greater innovativeness will translate into higher subsequent regional growth, encourage more infrastructure to be developed, which facilitates even more skilled human capital influx and retention. All of these factors will lead to higher demand for housing and thus higher house prices. Investors would not only invest in local businesses and start-ups, but also make investments in local real estate, further amplifying the upward price pressure in these real estate markets. Recent studies suggest that relocating corporate headquarters into a district significantly pushes up local house prices through an information channel (Chen et al., 2020; Hu et al., 2020).

Third, on the intensive margin, house price appreciation as a result of greater local innovativeness increases households' overall wealth, which might further drive up demand for purchasing second or third homes and/or making more real estate investments. Finally, there is ample evidence that better innovation tends to be carried out by individuals with high levels of formal education (Florida, 2002). These individuals will in turn demand more and higher quality educational institutions such that areas with dense clusters of innovative individuals are likely to be associated with a higher density of high-quality schools and other cultural amenities. There is ample evidence that amenities within an area, especially higher quality schools, are associated with higher residential property prices (see, for example, Beracha et al., 2017b; Beracha & Hardin, 2018).

Through these four channels, we expect a positive correlation between local innovation quality and future changes in house prices. Therefore, the first hypothesis that we formally test is stated as follows.

> Hypothesis 1: The quality of local innovation activities is positively related to future changes in house prices.

Our main hypothesis emphasizes that local innovativeness contributes to house price appreciation mainly from the demand-side. If this is indeed the case, this relation should be more pronounced within local areas with more constrained housing supply. This is because when housing supply is limited and is not able to meet increased demand, house prices will simply absorb more impact from the growth in demand and will appreciate in a more efficient and quicker manner. As such, we expect that higher innovation quality will lead to higher house prices when there is a limited land supply. Our second hypothesis is stated as follows:

> Hypothesis 2: The positive relation between local innovation quality and future house prices is more pronounced in areas with more limited land supply.

The demand for residential real estate is significantly and closely related to business cycles (Leamer, 2007). Strong demand is observed during economic booms, whereas during economic downturns, consumer demand usually wanes.

Therefore, if the relation between local innovativeness and house prices is driven by demand-side factors, we should observe an even stronger association when demand is strong, that is, during economic expansionary periods. As such, our third hypothesis is stated as follows:

> Hypothesis 3: The positive relation between local innovation quality and future house prices is stronger during booming economic periods.

Our main hypothesis implicitly assumes that local innovation quality drives up future house prices. However, it is at least conceivable that the direction can go the other way – higher house prices may lead to greater future innovativeness, making it difficult to draw causal inference. This potential reverse causality – that house prices can affect innovation quality – may occur for at least two distinct reasons. On the one hand, higher house prices mean greater home equity for homeowners to cash out or use as collateral in order to obtain financing as initial capital to start businesses. This suggests that rising house prices could foster more entrepreneurship and innovation in the area. On the other hand, continuing house price appreciation will lower housing affordability, eventually making the area less attractive due to affordability reasons. This means that, at a certain point, excessively high house prices may result in outmigration of skilled workers from the region to places where housing is more affordable. This brain drain could be a drag to local innovativeness. As a result, whether house prices will foster or hinder local innovation quality is an empirical question by itself, and in additional analysis, we formally test this to address the potential reverse causality issue that presents an obstruction to making causal inference.

Data and Methodology

In this study, we define local areas at the MSA level. As such, our key variable of interest is a measure of MSA innovativeness, which captures the quality of innovation in an MSA. Following the innovation literature, we employ patenting activity to construct the proxy for MSA innovativeness. We obtain patent-level information from the patent database constructed by Kogan et al. (2017). This database provides information about each patent granted by the United States Patent and Trademark Office (USPTO) from 1926 to 2010, and importantly, the patent's lifetime citations up to 2010. To determine the geographical location of the patent, we obtain patent-inventor level data from the latest version of the Harvard Business School (HBS) patent and inventor database (Li et al., 2014). We use zip code data of inventor residence to assign inventors into the corresponding MSAs. Building on the notion that patents receiving more future citations are more valuable (e.g., Trajtenberg, 1990), we construct a measure of innovation quality at the MSA level as the number of citations scaled by the number of patents filed during each year in a given MSA:

$$ncites\ per\ patent_{t-m} = \frac{\sum_{j=t-m}^{t-1} \sum_{i=1}^{p_j} citation_i}{\sum_{j=t-m}^{t-1} p_j} \quad (1)$$

where m denotes the number of years prior to year t, and p_j represents the number of patents filed in year j.[3] As widely recognized, converting R&D activities into successful innovations requires at least one to two years. Given that the housing market is less than perfectly efficient (Case & Shiller, 1988, Gatzlaff, 1994; Beracha & Skiba, 2011, among many others), the impact of local innovativeness on housing market performance, if any, could also take time to materialize. To capture this possible delay, we perform our analysis using previous m years, where m ranges from 1 to 5. Based on this definition, we define our key variable of interest as:

$$MSA\ Innovativeness_{t-m} = \ln\left(1 + ncites\ per\ patent_{t-m}\right). \quad (2)$$

To give readers some sense about our measure of MSA innovativeness, we list the five most and five least innovative MSAs in our sample in Table 1. We sort MSAs by the average number of patents per quarter in Panel A and sort MSAs by the average number of citations per quarter in Panel B. We provide the cumulative number of citations, cumulative number of patents, average citations per patent as well as the rank by average citations per patent for each of the MSAs in both panels. As shown, MSAs like San Jose, CA, Minneapolis, MN, and San Diego, CA are all ranked high among the 371 MSAs in our sample in terms of their innovativeness. Panels A and B of Fig. 1 provide a graphical illustration of the 30 MSAs with the highest cumulative number of patents and the highest cumulative number of citations, respectively. Overall, the rankings in Table 1 and Fig. 1 are consistent with conventional perceptions of the most innovative cities.

Our primary measure of house price appreciation relies on the House Price Index (HPI) published by the Federal Housing Finance Agency (FHFA). The FHFA HPI data document quarterly HPI for each MSA in the U.S. After combining the FHFA HPI data with our innovation data, we end up with a dataset that covers 371 MSAs from Q1 1990 to Q4 2010. Based on this measure, we calculate net house price appreciation, $Net\ Appreciation_{i,t+n}$, for each MSA i for quarter t as follows:

$$Net\ Appreciation_{i,t+n} = \left(\frac{HPI_{i,t+n} - HPI_{i,t}}{HPI_{i,t}}\right) - \left(\frac{HPI_{national,t+n} - HPI_{national,t}}{HPI_{national,t}}\right) \quad (3)$$

where t donates the focal quarter t, n denotes the number of year(s) ahead of the focal quarter, $HPI_{i,t}$ is the index from MSA i in quarter t, and $HPI_{national,t}$ is the average national index. We subtract the average national appreciation to mitigate the concern that our measure may merely captures a national trend. As an alternative measure, we also obtain data on rent-to-price ratios from Zillow in order to perform

[3] As robustness checks, we also performed our analysis using alternative definitions of MSA innovativeness based on number of citations per inventor and number of citations per capita (we report these results in Table 10).

Table 1 The Most and Least Innovative MSAs

MSA Name	Number of Citations	Number of Patents	Citations per Patent	Rank by Citations per Patent
Panel A. by Average Number of Patents				
Top 5				
San Jose-Sunnyvale-Santa Clara, CA	426,579.01	25,084.30	17.01	7
Minneapolis-St. Paul-Bloomington, MN-WI	193,282.37	13,048.21	14.81	17
San Diego-Carlsbad, CA	142,338.10	11,810.68	12.05	47
Austin-Round Rock, TX	131,077.30	10,240.48	12.8	30
Atlanta-Sandy Springs-Roswell, GA	73,382.80	6,491.62	11.3	61
Bottom 5				
Hot Springs, AR	19.97	4.83	4.14	353
Enid, OK	34.08	4.08	8.35	155
Hinesville, GA	0.1	2.68	0.04	371
El Paso, TX	15.31	2.23	6.88	240
Yuma, AZ	3.08	1.54	2	368
Panel B by Average Number of Citations				
Top 5				
San Jose-Sunnyvale-Santa Clara, CA	426,579.01	25,084.30	17.01	7
Minneapolis-St. Paul-Bloomington, MN-WI	193,282.37	13,048.21	14.81	17
San Diego-Carlsbad, CA	142,338.10	11,810.68	12.05	47
Austin-Round Rock, TX	131,077.30	10,240.48	12.8	30
Cincinnati, OH-KY-IN	76,008.04	6,070.52	12.52	38
Bottom 5				
Pine Bluff, AR	26.27	13.6	1.93	369
Hot Springs, AR	19.97	4.83	4.14	353
El Paso, TX	15.31	2.23	6.88	240

Table 1 (continued)

MSA Name	Number of Citations	Number of Patents	Citations per Patent	Rank by Citations per Patent
Yuma, AZ	3.08	1.54	2	368
Hinesville, GA	0.1	2.68	0.04	371

This table reports the cumulative number of citations, cumulative number of patents, average citations per patent as well as rank of the MSA by average citations per patent for the most and least innovative MSAs in our sample. Panel A reports the statistics for top five and bottom five MSAs in terms of the average number of patents filed within the MSA. In Panel B, we sort MSAs by the average number of citations received by these patents

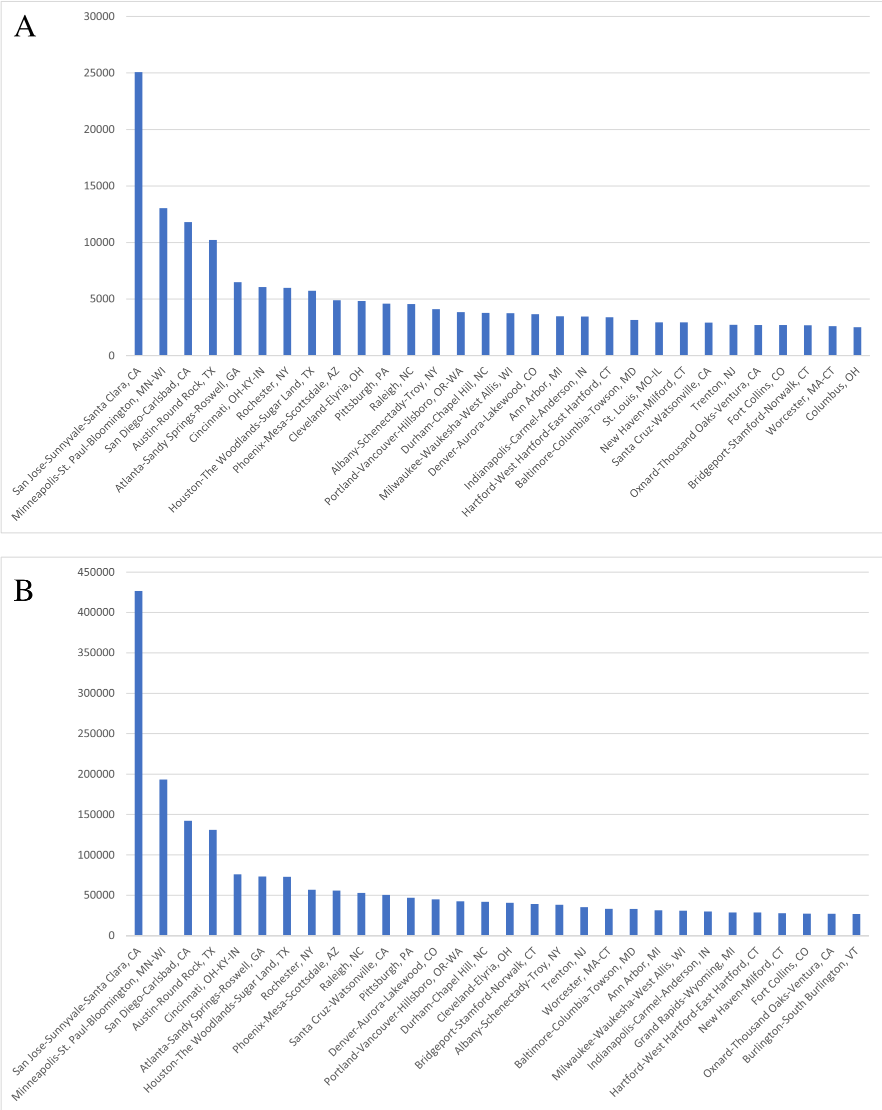

Fig. 1 Top MSAs by Innovativeness. Panel **A**: Top 30 MSAs with the highest cumulative number of patents. Panel **B**: Top 30 MSAs with the highest cumulative number of citations

our analysis using a measure that estimates the total return on housing, rather than just price appreciation, at the MSA level.

In addition to these two main data sources, we obtain data on MSA population from the U.S. Census Bureau, data on educational attainment for the population in a state from the National Center for Educational Statistics, and data on the state unemployment rate from Federal Reserve Bank of St. Louis's website. We also incorporate, in the relevant analyses, a widely used measure for land supply constraints

Table 2 Summary Statistics

Variable	N	Mean	S.D	25th Percentile	Median	75th Percentile
Net $Appreciation_3$	26,498	0.0047	0.1168	-0.0600	-0.0055	0.0605
MSA $Innovativeness_1$	29,867	8.60	9.24	1.43	6.32	12.94
MSA $Innovativeness_2$	30,042	8.85	8.74	1.62	7.00	13.34
MSA $Innovativeness_3$	29,817	9.16	8.49	2.00	7.64	13.68
MSA $Innovativeness_4$	29,407	9.46	8.30	2.43	8.15	13.97
MSA $Innovativeness_5$	28,760	9.74	8.14	2.95	8.59	14.17
Population	26,163	464,206	647,451	129,302	218,808	470,511
Education (%)	30,243	26.36	8.69	21.35	24.50	27.90
Unemployment (%)	30,243	6.24	2.52	4.60	5.60	7.10
Elasticity	20,175	2.65	1.42	1.64	2.35	3.40

This table reports the summary statistics of our main sample, which covers 371 MSAs from Q1 1990 to Q4 2010. *Net $Appreciation_3$*is the net house price appreciation in the following three years for each MSA defined as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. *MSA $Innovativeness_1$, MSA $Innovativeness_2$, MSA $Innovativeness_3$, MSA $Innovativeness_4$,* and *MSA $Innovativeness_5$,* are the natural logarithm of one plus the average number of citations per patent during one year, two years, three years, four years, and five years, prior to the current year, respectively. *Elasticity* is the population-weighted land supply elasticity (LSE) constructed at the MSA level. *Population* is the MSA population obtained from the U.S. Census Bureau. *Education* (%) is the percentage of people over age 25 with at least a Bachelor's degree in the state; the data is obtained from National Center for Educational Statistics. *Unemployment (%)* is the state unemployment rate from the website of Federal Reserve Bank of St Louis

developed by Albert Saiz (2010) – the land supply elasticity (LSE) – which covers 269 U.S. cities. Because the LSE data are measured at the city level, we convert it to the MSA level using the weighted average based on 2010 population. Table 2 shows the summary statistics for these variables in our study.

The main analyses in our paper relies on a panel regression in which we regress MSA house price returns (i.e. *Net Appreciation*) on our measures of MSA innovativeness. Our sample period spans the period from 1990 to 2010, with quarterly frequency. Specifically, our regression model is specified as follows:

$$\begin{aligned} Net\ Appreciation_{i,t+n} = \alpha + \beta MSA\ Innovativeness_{i,t-m} + \gamma' Controls \\ + MSA\ and\ Quarter\ Fixed\ Effects + \in_{i,t} \end{aligned} \quad (4)$$

where $Net\ Appreciation_{i,t+n}$ is the HPI return of the MSA net of national HPI over the following *n* years. *MSA Innovativeness* is our main measure of local innovativeness defined earlier. Our controls include MSA population, local educational attainment (measured as the percentage of population in a state with a Bachelor's degree or higher), and local economic conditions (measured as the state unemployment rate). We include these variables to mitigate concerns that demographics and local economic conditions may be correlated with local innovativeness but also directly affect house price appreciation. Our specification includes MSA fixed effects to account for other (time-invariant) unobservable heterogeneity at the MSA level, and we incorporate quarter fixed effects to absorb intertemporal shocks, and to account

Table 3 Univariate Correlations between Housing Returns, MSA Innovativeness, and Control Variables

	Net Appreciation$_1$	MSA Innovativeness$_1$	Δ Population	Δ Education	Δ Unemployment
Net Appreciation$_1$	1				
MSA Innovativeness$_1$	0.0288	1			
Δ Population	0.0669	0.0367	1		
Δ Education	0.0902	0.1815	-0.0175	1	
Δ Unemployment	-0.1042	-0.0271	-0.0231	0.1671	1

This table reports Pearson's correlations between house price appreciation (*Net* Appreciation), local innovativeness (MSA Innovativeness) and changes in our control variables. *Net Appreciation$_1$* is the net house price appreciation in the following year for each MSA net of change in U.S. national HPI. *MSA Innovativeness$_1$,* is the natural logarithm of one plus the average number of citations per patent over the year prior to the current year. *Δ Population*, *Δ Education*, and *Δ Unemployment* are changes in MSA *Population*, *Education* and *Unemployment*, respectively, over the previous year. *Population* is the MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. All correlations are significant at least at the 5% level

for economy-wide factors that may influence both housing market and local innovativeness across all MSAs.

We cluster the standard errors by both MSA and quarter to mitigate the concern that house prices tend to cluster within an MSA and each period of time. The key variable of interest in our analysis is *MSA Innovativeness$_{t-m}$*. A positive coefficient estimate of β in Eq. (4) above indicates a positive relation between MSA innovativeness and subsequent house price returns and may suggest the ability of local innovation quality to predict future house price appreciation.

As a prelude to our multivariate regression analyses (which we present in the next and subsequent sections), we examine the univariate relation between house price appreciation, innovativeness and our control variables. We report Pearson's correlations between these variables in Table 3 (all correlations shown are significant and positive at the 5% significance level or better). The table shows a positive correlation between house price appreciation over the next year (*Net Appreciation$_1$*) and MSA innovativeness over the previous year (*MSA Innovativeness$_1$*). This provides the first measured insight into the potential association between house price changes and local innovativeness. In addition, as economic intuition would suggest, we find a positive correlation between house price appreciation (*Net Appreciation$_1$*) and changes in both population and the level of higher education attainment in the MSA, as well as a negative correlation between house price appreciation and changes in unemployment in the MSA. We also find a similar set of univariate correlations between local innovativeness (*MSA Innovativeness$_1$*) and these variables: local innovativeness is positively associated with both changes in population and the level of higher education attainment, and is negatively correlated with unemployment. These univariate correlations provide further justification for including population, educational attainment, and unemployment as control variables in our subsequent multivariate analyses.

Results

Baseline Regression Results

We begin our empirical analysis by directly testing the relation between the quality of past innovation at the MSA level and changes in house prices that follow innovation activity. In Table 4, we present the results of the regression analysis specified in Eq. (4), and in which the dependent variable is $Net\ Appreciation_3$, calculated as the 3-year cumulative change in HPI for each MSA net of the 3-year cumulative change in national HPI, as defined in our Data and Methodology section.[4] We carry out the analyses with and without MSA fixed effects.

In Panel A, we present the regression results without MSA fixed effects. As shown, the coefficient estimates of the variables $MSA\ Innovativeness_1$ through $MSA\ Innovativeness_5$ are all positive and statistically significant at the 5% level. For example, the coefficient estimate of MSA Innovativeness_3 is 0.016 (*t-statistic* = 2.252). This result indicates that a one unit increase in the average number of citations per patent over the previous three years is associated with an abnormal house price change that is about 92% larger compared with the mean forward looking 3-year change in house prices.[5] Therefore, our finding of a positive relation between innovation at the MSA level and changes in house prices is not only statically significant, but also economically meaningful.

In Panel B, we present the regression results with MSA fixed effects. The coefficients of the variables $MSA\ Innovativeness_1$ through $MSA\ Innovativeness_5$ in Panel B all remain positive and statistically significant. The fixed effect results also suggest that the magnitude of the effect of local innovation (*MSA Innovativeness*) on house price appreciation (*Net Appreciation*) increases as we cumulate our innovativeness measure from the past one to five years, which is consistent with the idea that it takes time for the effect of local innovativeness to be fully reflected in house price appreciation. The results presented in Panel B suggest that our initial univariate findings (from Table 3), and OLS results from Panel A of Table 4, are robust to the inclusion of MSA fixed effects. This means that even *within* MSAs, an increase in local innovativeness is associated with an increase in home values.

Taken together, the results we present in Table 4 are consistent with our main hypothesis, and imply that innovation quality at the MSA level, measured by the number citations per patent over the previous one to five years, is positively related to future changes in house prices in the same MSA. The inclusion of MSA fixed effects allows us to control for MSA-specific factors' impact on our findings, so we only report results with MSA fixed effects in subsequent analyses.[6]

4 In subsequent robustness tests (reported in Table 6), we present results in which the dependent variable are changes in house prices over one or two years. The results are quantitatively and qualitatively similar to using house price changes over three years.

5 $(\ln(1+1)*0.016/0.0047)-1=92\%$.

6 The results are qualitatively and quantitatively similar when MSA fixed effects are removed.

Table 4 Local Innovativeness and Housing Returns

	(1)	(2)	(3)	(4)	(5)
Panel A. Results without MSA fixed effects					
MSA Innovativeness$_1$	0.0103**				
	(2.214)				
MSA Innovativeness$_2$		0.0139**			
		(2.237)			
MSA Innovativeness$_3$			0.0160**		
			(2.252)		
MSA Innovativeness$_4$				0.0171**	
				(2.249)	
MSA Innovativeness$_5$					0.0175**
					(2.255)
Population (Ln)	-0.00436	-0.00466	-0.00492	-0.00505	-0.00516
	(-1.499)	(-1.582)	(-1.636)	(-1.655)	(-1.660)
Education (%)	0.00210***	0.00211***	0.00212***	0.00213***	0.00214***
	(4.974)	(4.917)	(4.888)	(4.854)	(4.837)
Unemployment (%)	-0.0101***	-0.0101***	-0.0102***	-0.0103***	-0.0103***
	(-4.842)	(-4.744)	(-4.699)	(-4.652)	(-4.591)
MSA Fixed Effects	NO	NO	NO	NO	NO
Quarter Fixed Effects	YES	YES	YES	YES	YES
Observations	21,641	21,577	21,454	21,240	20,876
Adjusted R-squared	0.024	0.025	0.026	0.026	0.026
Panel B. Results with MSA Fixed Effects					
MSA Innovativeness$_1$	0.0100*				
	(1.935)				
MSA Innovativeness$_2$		0.0174*			
		(1.991)			
MSA Innovativeness$_3$			0.0246**		
			(2.105)		
MSA Innovativeness$_4$				0.0313**	
				(2.191)	
MSA Innovativeness$_5$					0.0361**
					(2.167)
Population (Ln)	-0.0226	-0.0237	-0.0251	-0.0261	-0.0284
	(-0.682)	(-0.708)	(-0.741)	(-0.759)	(-0.811)
Education (%)	-0.00424*	-0.00417*	-0.00404*	-0.00403*	-0.00409*
	(-1.986)	(-1.933)	(-1.838)	(-1.803)	(-1.777)
Unemployment (%)	-0.0231***	-0.0233***	-0.0235***	-0.0237***	-0.0238***
	(-3.752)	(-3.739)	(-3.741)	(-3.716)	(-3.657)
MSA Fixed Effects	YES	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES	YES
Observations	21,641	21,577	21,454	21,240	20,876
Adjusted R-squared	0.116	0.117	0.119	0.120	0.120

Table 4 (continued)

This table reports the results from regressions that examine the relation between house price appreciation (*Net Appreciation$_3$)* and MSA innovativeness. The dependent variable is *Net Appreciation$_3$*, the net house price appreciation in the following three years for each MSA, which is calculated as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. The key independent variables are *MSA Innovativeness$_1$, MSA Innovativeness$_2$, MSA Innovativeness$_3$, MSA Innovativeness$_4$,* and *MSA Innovativeness$_5$,* defined as the natural logarithm of one plus the average number of citations per patent during one year, two years, three years, four years, and five years, prior to the current year, respectively. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. Panel A reports the results without MSA fixed effects and Panel B shows the results with MSA fixed effects. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Land Supply Elasticity

Our hypothesis that local innovativeness is positively related to changes in house prices is based on the premise that MSAs with higher quality of innovation should be associated with a thriving economy and generate greater wealth for residents, which in turn create higher demand for housing. If this is a plausible channel, the observed phenomenon that we document in Table 4 should be more pronounced in MSAs that have more constrained housing supply. This is due to the fact that constrained markets have limited ability to respond to increased housing demand, which exacerbates pricing pressure.

In Table 5, we report the results of the analysis that employs the Saiz (2010) land supply elasticity measure as a proxy for constrained housing supply.[7] We define *Elasticity* as the land supply elasticity values provided by Albert Saiz, which are weighted by city population to construct MSA level measures. A lower *Elasticity* value is associated with areas that have greater land constraints. The regression results we present in Table 5 include an interaction between elasticity and our local innovativeness measure. *Elasticity* by itself (which is constant for each MSA) is dropped from the regressions because of the inclusion of MSA fixed effects. The results show that the coefficients of *MSA Innovativeness$_1$* through *MSA Innovativeness$_5$* remain positive and statistically significant. Additionally, the coefficients of the interaction variables *MSA Innovativeness$_2$ × Elasticity* through *MSA Innovativeness$_5$ × Elasticity* are negative and statistically significant. These results are consistent with our second hypothesis and suggest that the positive relation between the quality of MSA innovation and changes in house prices is more pronounced among MSAs with less elastic land supply.

[7] Saiz (2010) provides land supply elasticity values on 95 cities with population greater than 500,000. In our analysis we use an expanded dataset provided by Albert Saiz that includes land supply elasticity values for 267 U.S. cities.

Table 5 The Role of Land Elasticity as a Quasi-Exogenous Condition

	(1)	(2)	(3)	(4)	(5)
MSA Innovativeness$_1$	0.0315**				
	(2.037)				
MSA Innovativeness$_1$ × Elasticity	-0.00688				
	(-1.645)				
MSA Innovativeness$_2$		0.0434**			
		(2.284)			
MSA Innovativeness$_2$ × Elasticity		-0.00892*			
		(-1.914)			
MSA Innovativeness$_3$			0.0558**		
			(2.455)		
MSA Innovativeness$_3$ × Elasticity			-0.0113**		
			(-2.185)		
MSA Innovativeness$_4$				0.0684**	
				(2.629)	
MSA Innovativeness$_4$ × Elasticity				-0.0140**	
				(-2.471)	
MSA Innovativeness$_5$					0.0816***
					(2.761)
MSA Innovativeness$_5$ × Elasticity					-0.0178***
					(-2.865)
Population (Ln)	0.00221	0.00123	0.000236	-0.000795	-0.00266
	(0.0696)	(0.0386)	(0.00727)	(-0.0241)	(-0.0788)
Education (%)	-0.00352	-0.00354	-0.00357	-0.00362	-0.00366
	(-1.547)	(-1.548)	(-1.545)	(-1.541)	(-1.510)
Unemployment (%)	-0.0286***	-0.0294***	-0.0300***	-0.0306***	-0.0314***
	(-4.873)	(-4.992)	(-5.091)	(-5.152)	(-5.241)
MSA Fixed Effects	YES	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES	YES
Observations	15,998	15,969	15,889	15,748	15,495
Adjusted R-squared	0.108	0.111	0.115	0.118	0.123

This table reports results from regressions that examine the role of land elasticity on the relation between house price appreciation (*Net Appreciation$_3$)* and MSA innovativeness. The dependent variable is *Net Appreciation$_3$*, the net house price appreciation in the following three years for each MSA, which is calculated as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. The key independent variables are the interaction terms of MSA innovativeness and *Elasticity*. *MSA Innovativeness$_1$, MSA Innovativeness$_2$, MSA Innovativeness$_3$, MSA Innovativeness$_4$*, and *MSA Innovativeness$_5$,* are defined as the natural logarithm of one plus the average number of citations per patent during one year, two years, three years, four years, and five years, prior to the current year, respectively. *Elasticity* is the population-weighted land supply elasticity (LSE) from Saiz (210) constructed at the MSA level. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Table 6 Net Appreciation over Alternative Time Periods

	Net Appreciation$_1$		Net Appreciation$_2$	
	(1)	(2)	(3)	(4)
MSA Innovativeness$_3$	0.00610**	0.0153***	0.0149**	0.0372***
	(2.357)	(3.153)	(2.201)	(2.930)
MSA Innovativeness$_3$ × Elasticity		-0.00318***		-0.00770**
		(-2.748)		(-2.621)
Population (Ln)	-0.00727	-0.00231	-0.0177	-0.00340
	(-0.878)	(-0.280)	(-0.856)	(-0.170)
Education (%)	0.00171**	0.00196***	0.000707	0.00120
	(2.553)	(2.844)	(0.476)	(0.791)
Unemployment (%)	-0.00904***	-0.00966***	-0.0202***	-0.0230***
	(-5.965)	(-5.842)	(-5.396)	(-5.867)
MSA Fixed Effects	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES
Observations	24,325	17,752	22,890	16,821
Adjusted R-squared	0.086	0.100	0.100	0.110

This table reports results from regressions that examine the relation between house price appreciation and MSA innovativeness using alternative windows to calculate house price appreciation. The dependent variables in columns (1) and (2) are the 1-year net house price appreciation (*Net Appreciation$_1$*) and in columns (3) and (4) are the 2-year net house price appreciation (*Net Appreciation$_2$*). These two variables are calculated in a similar fashion as *Net Appreciation$_3$* used in Tables 4 and 5. The key independent variables are *MSA Innovativeness$_3$* and the interaction between *MSA Innovativeness$_3$* and *Elasticity*. *MSA Innovativeness$_3$* is the natural logarithm of one plus the average number of citations per patent during three years prior to the current year. *Elasticity* is the population-weighted land supply elasticity (LSE) from Saiz (2010) constructed at MSA level. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Alternative Time Windows for Housing Returns

In our analysis in the prior subsection, our measure of house price appreciation (*Net Appreciation$_3$*) was measured over three years. In Table 6, we present results that replicate the previous results with a shorter horizon with respect to future changes in house prices. The dependent variables are net house price appreciation over the following one year (*Net Appreciation$_1$*) in columns (1) and (2), and net house price appreciation over the following two years (*Net Appreciation$_2$*) in columns (3) and (4). For brevity, we only show results in which local innovativeness is measured using citations per patent over the previous three years (*MSA Innovativeness$_3$*).[8] We find that the relation between innovativeness and house

[8] The results are qualitatively and quantitatively similar when using MSA Innovativeness measured through one to five years as in Tables 4 and 5.

price appreciation is positive and statistically significant whether or not we measure price appreciation over the next one (column 1) or two years (column 3). We also continue to find that the positive association between house price appreciation and local innovativeness is more pronounced in areas with lower land elasticity (columns 2 and 4).

Overall, the results we report in Table 6 are consistent with previous results even when using shorter time horizons with respect to changes in house prices. In addition, the magnitude of the coefficient estimates on local innovativeness (*MSA Innovativeness*$_3$) appears to decrease as we shorten the horizon over which we measure house price appreciation. This supports our intuition that the effect of local innovativeness on house price appreciation appears to cumulate as we move from the short to medium term.

Alternative Measures of Housing Returns

If homeowners and investors evaluate the performance of homes as investments, they may consider changes in home value as well as the imputed rent of the home, which is the amount the home owner could have received in rent on their home or would have to pay to rent a similar home. Real estate located in areas with lower imputed rent relative to its value are on average, associated with higher price appreciation and vice versa (Beracha et al., 2017a). This possibility indicates that the total return homeowners and investors consider may include changes in both house prices and imputed rent. To address this issue, we run the regression specified in Eq. (4) while using an alternative definition of *Net Appreciation*$_{i,t+n}$ that considers both changes in house prices and imputed rent as the total accumulated abnormal return on housing in MSA i from time t through $t+n$. We estimate the total return by adding the average adjusted housing rent-to-price ratio[9] of the MSA to house price change in the same area during that period.

In Table 7, we report the results of the analyses that examine the relation between local innovativeness and the estimated total return on housing (again, for brevity we only show results in which local innovativeness is measured using citations per patent over the previous three years, *MSA Innovativeness*$_3$). Specifically, we regress the subsequent 3-year abnormal total return on housing on our innovativeness measure lagged by 3 years. Column (1) shows that the coefficient of our local innovativeness measure (*MSA Innovativeness*$_3$) is positive and statistically significant. The magnitude of the coefficient is also very similar to that in our baseline analysis reported previously. Column (2) reports a negative and significant coefficient on the interaction term of *MSA Innovativeness*$_3$ and the land elasticity measure, consistent with previous results. These results serve as additional evidence that local innovativeness is positively related to future housing performance.

[9] The adjusted rent-to-price ratio is calculated using the inverse of price-to-rent ratio for each MSA from Zillow and assuming 35% expenses relative to rent. For example, an area with a price-to-rent ratio of 12.5 will have an adjusted rent-to-price ratio of 5.2% ((100%/12.5)*(1–0.35)). This yield similar net rent income to values calculated using Himmelberg et al. (2005), suggesting that an individual annually faces property taxes of 1.5% of the property value and maintenance and insurance expenses of an additional 2% during the holding period. Moreover, our results are invariant to using a different expense ratio, given that different expense ratio assumptions simply result in a scalar shift to the total return variable.

Table 7 Total Housing Return with Rent, and Local Innovativeness

	(1)	(2)
MSA Innovativeness$_3$	0.0250*	0.0594**
	(1.969)	(2.410)
MSA Innovativeness$_3$ × Elasticity		-0.0135**
		(-2.330)
Population (Ln)	-0.0225	0.00567
	(-0.645)	(0.173)
Education (%)	-0.00337	-0.00309
	(-1.444)	(-1.272)
Unemployment (%)	-0.0226***	-0.0301***
	(-3.400)	(-4.964)
MSA Fixed Effects	YES	YES
Quarter Fixed Effects	YES	YES
Observations	19,829	14,754
Adjusted R-squared	0.092	0.088

This table reports results from regressions that examine the relation between house price appreciation and MSA innovativeness using total housing return as an alternative measure. The dependent variable is total housing return, which is calculated by adding the average adjusted housing rent-to-price ratio of the MSA to the house price change in the same area during the following three years. The key independent variables are *MSA Innovativeness$_3$* and the interaction between *MSA Innovativeness$_3$* and *Elasticity*. *MSA Innovativeness$_3$* is the natural logarithm of one plus the average number of citations per patent during three years prior to the current year. *Elasticity* is the population-weighted land supply elasticity (LSE) from Saiz (2010) constructed at MSA level. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Market conditions

Our first hypothesis is based on the premise that the demand for housing is higher in more innovative cities and, as a result, house price appreciation tends to be higher in such cities. However, because innovative areas are more attractive places to live and invest during overall healthy economic conditions, we expect that the relation between local innovativeness and house price appreciation is stronger during robust economic periods, which is the premise of our third hypothesis. In order to examine this hypothesis, we repeat the analysis performed in Table 4 for three different housing market conditions.

In Table 8, we present the results of the analysis that subdivides our sample into three different housing market periods. Columns (1), (2) and (3) report the results for the periods we define as *Normal* (1990–1999), *Boom* (2000–2006) and

Table 8 The Role of Market Conditions

	(1) Normal Period	(2) Boom Period	(3) Collapse Period
MSA Innovativeness$_3$	-0.00283	0.0376*	0.00437
	(-0.259)	(1.829)	(0.788)
Population (Ln)	-0.218*	-0.758**	-0.545*
	(-1.868)	(-2.244)	(-2.281)
Education (%)	-0.00683**	-0.0195***	-0.0124**
	(-2.342)	(-3.571)	(-3.128)
Unemployment (%)	-0.0336***	0.0146	0.0113**
	(-6.004)	(1.301)	(4.545)
MSA Fixed Effects	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES
Observations	9,614	10,041	1,799
Adjusted R-squared	0.367	0.300	0.976

This table reports results from regressions that examine the relation between house price appreciation and MSA innovativeness during subperiods. Normal Period is from 1990 to 1999; Boom Period is from 2000 to 2006; Collapse Period is from 2007 to 2010. The dependent variable is *Net Appreciation$_3$*, the net house price appreciation in the following three years for each MSA, which is calculated as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. The key independent variable is *MSA Innovativeness$_3$* defined as the natural logarithm of one plus the average number of citations per patent during three years prior to the current year. MSA fixed effects are included in all regressions. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Collapse (2007–2010), respectively. The coefficients of our local innovativeness measure *MSA Innovativeness$_3$* for the *Collapse* and *Normal* periods are statistically insignificant. For the *Boom* period, the coefficient of *MSA Innovativeness$_3$* is positive with statistical significance at the 10% level. The magnitude of the coefficient during the *Boom* period is quite large (0.0376) compared with that in the baseline analysis (0.0246, as shown in Panel B in Table 4).

Overall, the results we report in Table 8 suggest that the relation between local innovativeness and house price appreciation is more pronounced during periods when overall housing market conditions are robust. These results are consistent with our third hypothesis and imply that the relation between local innovativeness and house price appreciation is stronger during periods when overall economic and housing market conditions are healthy.

Additional Analyses: is Causality Reversed?

The results presented thus far provide support for our first hypothesis that MSAs associated with more high quality innovation are associated with higher future house price appreciation and overall future return on housing. However, it is possible that booming house markets lead to more innovation due to access to greater wealth and the ability of individuals to use higher residential real estate value as collateral to borrow money to finance innovation. In other words, it is possible that the direction of causality from local innovativeness to house prices may, in fact, be reversed or bi-directional. In Table 9, we present results from the analysis that directly addresses these possibilities. Specifically, we investigate whether or not our measure of MSA innovativeness (and its three lags) can predict future MSA house price appreciation and whether or not the measure of MSA house market price appreciation (and its three lags) can predict subsequent MSA innovativeness.[10]

Columns (1) and (2) examine the ability of lagged MSA innovativeness (*Innovativeness Lag1* through *Innovativeness Lag4*) to predict price appreciation over the next one or two years, respectively. For each specification, we report the *F*-statistics and the associated *p*-values for this joint test. The *F*-statistics of joint significance of all lagged innovativeness measures are statistically significant in the two specifications (p-values are 0.0083 and 0.0268). These results serve as an indication that the four measures of MSA innovativeness, together, can predict future house price appreciation with statistical power.

In columns (3) and (4), we report the results from an analysis that replicates the results from the previous two columns except that the dependent variable is now replaced with the measure of future MSA innovativeness in the following 1-year or 2-year period. As shown, the *F*-statistics for the joint test of the four measures of lagged house price appreciation at the MSA level (*Return Lag1* through *Return Lag4*) are statistically insignificant (*p*-values are 0.3458 and 0.8402). Overall, these results suggest that past house price appreciation does not predict future innovativeness at the MSA level. Therefore, the results mitigate the reverse causality concern, because we only find that MSA innovativeness predicts house price appreciation and not the reverse.

Alternative Definitions of Local Innovativeness

We have, thus far, measured MSA innovativeness using the number of citations per patent, which is a commonly used innovation metric in the literature because it captures the significance and importance of the innovation. While this measure is well-accepted in the literature, we also employ two alternative measures that take into account local innovative human capital. As the development of patents requires the involvement of many inventors, more valuable patents might require more inventors. We thus calculate the following two alternative measures: the number of citations per inventor and the number of citations per capita in the previous three years. These alternative measures mitigate a potential concern that greater local innovativeness might be driven by higher density of qualified human capital in the area, and serve as additional robustness tests of our findings.

In Table 10, we present the results from the regression analyses that employ these two alternative measures of innovativeness. The results in columns (1) and (3) show that the coefficient of $\textit{number of citations per inventor}_3$ is positive and statistically significant at the 5% level and $\textit{number of citations per capita}_3$ is positive but falls just short of statistical significance at conventional levels. We also interact these two innovativeness measures with *Elasticity* and report results in columns (2) and (4), respectively. We find the coefficients of the two interaction

[10] Note that we used only one observation from each year, instead of the quarter-level observations. The main reason for this choice is the inclusion of the lagged measures. Because both the innovativeness and the return measures are constructed using quarter-level data in a rolling-window fashion, using quarter-level observations for this purpose would lead to material overlap in the measures.

Table 9 Bi-Directional Tests

Dependent Variable	(1)	(2)	(3)	(4)
	Future returns		Future MSA innovativeness	
Innovativeness Lag1	0.00151**	0.00974***	0.183***	0.197***
	(2.619)	(3.284)	(7.641)	(5.443)
Innovativeness Lag2	0.000116	0.00856**	0.123***	0.0726*
	(0.141)	(2.282)	(4.780)	(1.776)
Innovativeness Lag3	0.00169	0.00366	0.0335*	-0.0541*
	(1.351)	(0.759)	(1.836)	(-1.759)
Innovativeness Lag4	0.00202	0.00225	0.00210	-0.117***
	(1.487)	(0.527)	(0.109)	(-4.172)
Return Lag1	0.592***	0.139	0.0596	0.0562
	(5.375)	(0.604)	(0.365)	(0.670)
Return Lag2	-0.0639	-0.400***	-0.149	0.0717
	(-0.669)	(-5.064)	(-0.749)	(1.065)
Return Lag3	-0.201**	-0.109	0.0505	0.0113
	(-2.783)	(-1.407)	(0.296)	(0.153)
Return Lag4	-0.0958*	-0.274***	0.230	0.0656
	(-1.860)	(-3.452)	(1.510)	(0.627)
Population (Ln)	-0.000696	0.0389	-0.0956	-0.0980
	(-0.116)	(1.351)	(-1.483)	(-1.358)
Education (%)	0.00116*	0.00394	0.000895	0.000837
	(1.837)	(1.186)	(0.283)	(0.228)
Unemployment (%)	-0.00552***	-0.0245***	0.00356	0.00900
	(-3.704)	(-3.988)	(0.611)	(1.615)
MSA Fixed Effects	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES
Observations	6,144	2,862	6,059	3,151
Adjusted R-squared	0.414	0.258	0.897	0.926
F-stat	4.62***	3.04**	1.19	0.35
p-value	0.0083	0.0268	0.3458	0.8402

This table reports bi-directional tests of the relation between house price appreciation and MSA innovativeness. Columns (1) and (2) test whether past MSA innovativeness predicts future house price appreciation while controlling for past MSA housing returns. The dependent variables are 1-year net house price appreciation in column (1) and 2-year net house price appreciation in column (2). Columns (3) and (4) test whether past MSA housing returns predict future MSA innovativeness while controlling for past MSA innovativeness. The dependent variables are *MSA Innovativeness* in the next year in column (3), and *MSA Innovativeness* in the next two years in column (4). *Innovativeness Lag1, Innovativeness Lag2, Innovativeness Lag3,* and *Innovativeness Lag4,* are the natural logarithm of one plus the average number of citations per patent during one year, two year2, three years, and four years prior to the current year, respectively. *Return Lag1, Return Lag2, Return Lag3* and *Return Lag4* are the one-, two-, three-, and four-year lagged housing net appreciation, respectively. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. F-statistics measure the joint significance of the *Innovativeness Lag1* through *Innovativeness Lag4* in columns (1) and (2), and *Return Lag1 through Return Lag4* in columns (3) and (4). The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Table 10 Alternative Measures of Local Innovativeness

	(1)	(2)	(3)	(4)
Number of Citations per Inventor$_3$ (Ln)	0.0231**	0.0610***		
	(2.221)	(3.054)		
Number of Citations per Inventor$_3$ (Ln) × Elasticity		-0.0130**		
		(-2.592)		
Number of Citations per Capita$_3$ (Ln)			0.302	1.550***
			(1.649)	(3.043)
Number of Citations per Capita$_3$ (Ln) × Elasticity				-0.653***
				(-2.932)
Population (Ln)	-0.0247	0.000477	-0.0240	-0.00820
	(-0.727)	(0.0145)	(-0.692)	(-0.237)
Education (%)	-0.00404*	-0.00351	-0.00396*	-0.00347
	(-1.835)	(-1.510)	(-1.807)	(-1.558)
Unemployment (%)	-0.0236***	-0.0304***	-0.0235***	-0.0290***
	(-3.751)	(-5.128)	(-3.718)	(-4.628)
MSA Fixed Effects	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES
Observations	21,454	15,889	21,472	15,901
Adjusted R-squared	0.119	0.119	0.118	0.114

This table reports results from regressions that examine the relation between house price appreciation and MSA innovativeness using alternative measures for local innovativeness — number of citations per inventor (in columns 1 and 2) and number of citations per capita (in columns 3 and 4). The dependent variable is *Net Appreciation$_3$*, the house price appreciation in the following three years for each MSA, which is calculated as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. The key independent variables are *Number of Citations Per Inventor$_3$*, *Number of Citations per Capita$_3$* and their interactions with *Elasticity*. *Number of Citations Per Inventor$_3$* is the natural logarithm of one plus the average number of citations per inventor during three years prior to the current year. *Number of Citations per Capita$_3$* is the natural logarithm of one plus the average number of citations per population in the MSA during three years prior to the current year. *Elasticity* is the population-weighted land supply elasticity (LSE) from Saiz (2010) constructed at MSA level. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

terms are both negative and statistically significant, consistent with previous results. Overall, the results presented in Table 10 mitigate the potential concern that our results are only specific to certain MSA innovativeness measures, and they confirm our previous finding that higher innovation quality is positively associated with subsequent house price appreciation.

The Effect of Large or Especially Innovative MSAs

Our analysis thus far has been based largely on 371 MSAs that cover cities and regions with both large and small populations. Regions with larger populations tend to have more talent and human capital (e.g., San Francisco or New York City), which is indeed part of our rationale for explicitly controlling for MSA population and the educational attainment of the population in our analyses. Nevertheless, it is possible that our findings are driven by a few large MSAs.

To address this concern, we repeat our analysis using the model specified in Eq. (4) while excluding the top ten largest MSAs by population.[11] We report the results in Appendix Table 11. As shown, our finding of a positive relation between MSA innovativeness and house price appreciation does not change even after removing large MSAs. This finding suggests that our results are not driven by large MSAs.

Another concern is that our results might be driven by a few extremely innovative MSAs. To address this concern, we repeat the analysis specified in Eq. (4) while excluding the ten most innovative MSAs from our sample. The excluded MSAs are San Jose (Silicon Valley), Minneapolis, San Diego, Austin, Atlanta, Cincinnati, Rochester, Houston, Phoenix, and Cleveland. We report the results in Appendix Table 12, which continue to show a positive and significant association between local innovativeness and house price appreciation. These findings mitigate the concern that our results are driven merely by a few especially innovative MSAs.

Conclusion

This paper investigates the extent to which the quality of local innovation is associated with housing demand as manifested through higher house price appreciation and overall housing returns. The results of our analysis provide convincing evidence that innovation quality is indeed positively related to future house price appreciation at the local level. Our results are robust to the inclusion of MSA fixed effects and appear to be stronger during periods of overall robust house price appreciation. We also provide evidence that the relation between local innovativeness and house price appreciation is more pronounced in MSAs where supply of available land is more constrained. Finally, we show that while local innovativeness can predict future changes in house prices, the relation is not bi-directional and changes in house prices do not predict future local innovativeness. These findings suggest that high-quality innovation spurs job creation and wealth that drive house prices, but local innovativeness is not a product of relaxed borrowing constraints due to increased residential real estate value.

Our study is the first to provide evidence that clearly establishes the association between local innovation quality and future house prices and carries policy as well as practical implications for investors. We view our study as the opening salvo in quantifying and understanding the relation between innovation and house price dynamics. Given that innovation is a significant driver of the U.S. economy as well as many other economies around the world, more research that dives deeper into how local innovation affects the dynamics in the housing market, such as housing costs and affordability, is vital.

[11] We also performed tests while removing the top 20 MSAs by population, and find similar results.

Appendix 1

Table 11 Local Innovativeness and Housing Returns – Removing Large MSAs

	(1)	(2)	(3)	(4)	(5)
MSA Innovativeness$_1$	0.0128**				
	(2.411)				
MSA Innovativeness$_2$		0.0217**			
		(2.412)			
MSA Innovativeness$_3$			0.0299**		
			(2.477)		
MSA Innovativeness$_4$				0.0374**	
				(2.539)	
MSA Innovativeness$_5$					0.0431**
					(2.477)
Population (Ln)	-0.0196	-0.0206	-0.0220	-0.0231	-0.0255
	(-0.586)	(-0.610)	(-0.644)	(-0.664)	(-0.718)
Education (%)	-0.00462**	-0.00457**	-0.00445*	-0.00446*	-0.00452*
	(-2.121)	(-2.070)	(-1.972)	(-1.942)	(-1.910)
Unemployment (%)	-0.0224***	-0.0226***	-0.0228***	-0.0230***	-0.0231***
	(-3.560)	(-3.539)	(-3.540)	(-3.519)	(-3.457)
MSA Fixed Effects	YES	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES	YES
Observations	21,005	20,945	20,826	20,617	20,268
Adjusted R-squared	0.115	0.116	0.117	0.119	0.119

This table reports results from regressions that examine the relation between house price appreciation (*Net Appreciation$_3$)* and MSA innovativeness after excluding the ten largest MSAs (measured by average population) from our sample. The dependent variable is *Net Appreciation$_3$*, the house price appreciation in the following three years for each MSA, which is calculated as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. The key independent variables are *MSA Innovativeness$_1$, MSA Innovativeness$_2$, MSA Innovativeness$_3$, MSA Innovativeness$_4$,* and *MSA Innovativeness$_5$,* defined as the natural logarithm of one plus the average number of citations per patent during one year, two years, three years, four years, and five years, prior to the current year, respectively. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

Appendix 2

Table 12 Local Innovativeness and Housing Returns – Removing Most Innovative MSAs

	(1)	(2)	(3)	(4)	(5)
MSA Innovativeness$_1$	0.00921*				
	(1.784)				
MSA Innovativeness$_2$		0.0164*			
		(1.869)			
MSA Innovativeness$_3$			0.0234**		
			(1.998)		
MSA Innovativeness$_4$				0.0297**	
				(2.075)	
MSA Innovativeness$_5$					0.0340**
					(2.033)
Population (Ln)	-0.0245	-0.0257	-0.0272	-0.0283	-0.0308
	(-0.731)	(-0.759)	(-0.793)	(-0.813)	(-0.867)
Education (%)	-0.00437**	-0.00431*	-0.00418*	-0.00416*	-0.00423*
	(-2.027)	(-1.974)	(-1.875)	(-1.839)	(-1.811)
Unemployment (%)	-0.0229***	-0.0231***	-0.0233***	-0.0235***	-0.0236***
	(-3.720)	(-3.709)	(-3.711)	(-3.687)	(-3.630)
MSA Fixed Effects	YES	YES	YES	YES	YES
Quarter Fixed Effects	YES	YES	YES	YES	YES
Observations	21,024	20,960	20,837	20,623	20,259
Adjusted R-squared	0.118	0.119	0.121	0.122	0.122

This table reports results from regressions that examine the relation between house price appreciation (*Net Appreciation$_3$)* and MSA innovativeness after excluding the ten most innovative MSAs (reported in Fig. 1) from our sample. These MSAs are San Jose, Minneapolis, San Diego, Austin, Atlanta, Cincinnati, Rochester, Houston, Phoenix, and Cleveland. The dependent variable is *Net Appreciation$_3$*, the house price appreciation in the following three years for each MSA, which is calculated as the 3-year cumulative change in MSA House Price Index (HPI) net of the 3-year cumulative change in U.S. national HPI. The key independent variables are *MSA Innovativeness$_1$, MSA Innovativeness$_2$, MSA Innovativeness$_3$, MSA Innovativeness$_4$,* and *MSA Innovativeness$_5$,* defined as the natural logarithm of one plus the average number of citations per patent during one year, two years, three years, four years, and five years, prior to the current year, respectively. *Population* is the natural log of MSA population. *Education* is the percentage of people over age 25 with at least a Bachelor's degree in the state. *Unemployment* is the state's unemployment rate. MSA fixed effects are included in all regressions. The *t*-statistics in parentheses are based on standard errors clustered by MSA and quarter. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

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