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Drought and Property Prices: Empirical Evidence from Iran

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Abstract

This study demonstrates an economic consequence of climate change and water crises in Iran. It examines the effect of drought on housing prices, residential land prices, and housing rents in Iran. Using data from provinces of Iran from 1993 to 2015 and applying static and dynamic panel fixed effects estimators, we find evidence that an increase in the balance of water (reducing the severity of drought) within provinces has a positive effect on property prices. Our results have important implications for Iranian policymakers and property investors.

Keywords: Drought; Water Crisis; Property Prices; Housing; Iran

JEL Classification: R21, R31, Q54

1. Introduction

Iran is a country with significant cross-sectional variations in amenities and climate. While the country has been hit hard by drought, provinces of Iran are not equally affected by drought. Moreover, the provinces have different climates and are unlike Malaysia or Finland where regional areas have almost similar climates[1]. Thus, it is interesting to investigate how the regional property markets behave given such meteorological diversity. For example, our sample includes *Mazandaran* province with Caspian mild climate and *East Azerbaijan* province which has cold mountain climate. Therefore, Iran's geographic vastness offers significant spatial variation in climate-related variables and people in its different regions have been suffering from consequences of climate change particularly water shortage[2].

Iran has been experiencing long cycles of drought for the last 50 years. According to the Iranian Energy Minister "*334 cities with 35 million people across Iran are currently struggling with water stress*[3]" (Radio Farda, 2018). The UN Development Program Resident Representative in Iran Gary Lewis also acknowledges the crisis: "*The water shortage is currently Iran's most important humanitarian challenge*," (Radio Farda, 2018). In recent years, the water shortage and drought[4] in Iran have caused

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[1] Different climates of Iran include Caspian mild and wet, Caspian mild, Mediterranean with spring rains, Mediterranean, cold mountains, very cold mountains, cold semi-desert, hot semi-desert, dry desert, hot dry desert, hot coastal dry and coastal dry.

[2] For a critical review of water stress in Iran, see a comprehensive report by the Islamic Parliament Research Center of Iran (2017).

[3] According to the European Environment Agency, water stress happens when the "demand for water exceeds the available amount during a certain period or when poor quality restricts its use".

[4] For a review of definitions of drought and its conditions, see Hendy et al. (2018).

substantial economic costs, several social issues, health problems, and violent conflicts. In terms of water scarcity, Iran and other Middle Eastern and North African (MENA) countries have the highest expected economic losses from climate-related water scarcity, estimated at 6-14% of GDP by 2050 (World Bank, 2016). Salami et al. (2009) also estimate the direct costs of drought on the total value added of the agricultural sector of the Iranian economy and its indirect impacts on the rest of the economy. Their results show that a drought, such as the one that occurred in the crop year 1999–2000, decreases overall GDP by about 4.4%, leading to lower non-oil exports, rising food imports, and inflation.

Climatic change is frequently mentioned as the main driver of the severe water crises in Iran (see Shahi, 2019 for a review of drought situation in Iran). However, Madani et al. (2016) argue that the country is mainly suffering from a socio-economic drought, i.e., weak governance, disintegrated planning and managerial myopia in water management. Also, for a sample of Middle Eastern countries, Gholipour and Farzanegan (2018) and Farzanegan and Markwardt (2018) emphasize the importance of quality institutions in environmental resources management. Madani (2014) considers two more significant causes for the current water crisis in Iran, namely rapid growth of population and its improper spatial distribution and wasteful agriculture sector.

Drought has also driven many people from their homes in Iran. According to Hadi Ghaemi, the executive director for the Center for Human Rights in Iran (CHRI) "*Towns and villages around Isfahan have been hit so hard by drought and water diversion that* *they have emptied out and people who lived there have moved*" (Dehghanpisheh, 2018). Using Iran's national census data from 1996-2011, Shiva and Molana (2019) find that inter-province migration is significantly and consistently affected by province-level average levels of annual temperature and precipitation.

Using data from 36,787 patients at the emergency centres of Tehran in 2013, Motasedi et al. (2016) show that there is a significant association between the risk of respiratory diseases and carbon monoxide and sulfur dioxide pollutants. Iran's environmental challenges have attracted considerable attention from Iranian researchers in recent years. For example, using data for 16,586 firms from more than 80 counties of Iran over the 2003-2011, Birjandi and Yousefi (2018) find that dust emissions reduce manufacturing firm productivity. They argue that dusty days disrupt access to raw materials and increase the cost of transportation for manufacturing firms. In particular, they show that lowering the number of days with dust storm by 1 day nationwide would increase the average firm's gross output by 0.081% and increase gross output across all firms by $149 million.

Feizi et al. (2019) also provide evidence that rainfall shortage led to more violent and antisocial behavior across provinces of Iran from 2007 to 2014. The competition to get access to water resource, which has no substitute, could lead people to exhibit selfish and even hostile behaviors. Moreover, the shortage of precipitation might reduce the income of people, for example in the agricultural sector, and hence the associated tension and stress could drive people to violence.

A few works to date on global warming/climatic factors and property prices have attempted to examine the impact of changes in severity of drought on housing prices, residential land prices and housing rents in the MENA region. Our study addresses this gap in the literature. In this study, we extend the growing literature on the consequences of climate change by examining the effect of meteorological factors on housing prices, residential land prices and housing rents across provinces of Iran from 1993 to 2015. We hypothesize that those provinces with less water severity experience stronger growth in property prices. Our hypothesis is motivated by findings of studies, which argue that higher housing values are associated with better amenities such as environmental improvement (Polinsky & Rubinfeld, 1977; Roback, 1982).

The case of Iran, which has special climate features, would give us a unique design setting to conduct this study and provide new insights from the Middle East. We focus on property (especially residential land asset) because it is a very valuable asset class for Iranian households and investors that makes up a large fraction of household wealth and investors' portfolios. In addition, real estate accounts for about 40% of national net capital stock in 2015, according to the Central Bank of Iran[5]. The volume of residential land transactions was 137,477 units in 2006, with the volume climbing to 298,463 units in 2011, according to a series of surveys conducted by the Statistical Centre of Iran[6]. Therefore, any significant depreciation or appreciation of

[5] See https://tsd.cbi.ir/DisplayEn/Content.aspx (in Farsi)
[6] http://www.amar.org.ir/Portals/0/Files/abstract/1391/ch_bongah_91.pdf (in Farsi, access 13.06.2019)

property prices would have substantial impacts on the wealth of households and investors.

Changes in housing prices matter for non-performing mortgages (Tajaddini & Gholipour, 2017) which can have significant effects on bank balance sheets and the ability of banks to extend credit to households and businesses (Muellbauer, 2012). Additionally, the land trading market is also thick mainly because investors can change the residential land use (after the acquisition of land) for different purposes depending on business opportunities in various economic sectors (Gholipour & Lean, 2017). Moreover, land use regulations are not well developed and well implemented and there is a substantial level of corruption among public officials who should be implementing the existing land use regulations (Sodaei, 2015). It has also been shown that changes in property prices influence divorce rate, family formation, and income inequality in Iran (Farzanegan & Gholipour, 2016; Farzanegan et al., 2016; Gholipour & Farzanegan, 2015).

This paper makes two contributions to the literature. First, the effect of climatological factors, climate change and environmental disasters, especially pollution and flood, on property prices are not well explored in the literature out of the U.S. (e.g. Butsic et al., 2011; Galinato & Tantihkarnchana, 2018; Glaeser et al., 2008; Mendelsohn et al., 1994; Schlenker et al., 2005; Bunten & Kahn, 2014; Eichholtz et al., 2018; Petkov, 2018), Australia (Rajapaksa et al., 2017), Germany (Hamilton, 2007), Netherlands (De Vor & De Groot, 2011), China (Huang et al., 2015) and Japan (Zhai et al., 2003). In particular, this issue for Middle Eastern countries is under-investigated.

Second, previous studies examining the link between climatic factors and property prices have mainly focused on housing prices (Harrison et al., 2001; Bernstein et al., 2019) and farmland prices (Mendelsohn et al., 1994). Our research is the first to examine the effects of climatological factors on not only housing prices, but also residential land prices and housing rents in Iran. To the best of our knowledge, there is a lack of empirical work on the effect of drought on property prices for Iran.

Using static and dynamic panel fixed effects estimators, our results show that increases in housing prices, residential land prices and housing rents are higher in provinces with that less severity of drought, controlling for other key factors. These findings have implications for Iranian policymakers and property investors.

The remainder of this paper is structured as follows. Section 2 reviews the literature on climate change–property prices. Section 3 describes the data and our empirical strategy. The results and robustness checks are presented and discussed in Section 4. Section 5 concludes the paper.

2. Relationship between Climate Change and Property Prices

In this section, we summarize some related studies and explain the rationales on how climatic factors may influence property prices. The majority of related studies have focused on the effect of global warming and its consequences on property prices. These studies generally conclude that warming substantially undermines property prices. For example, Butsic et al. (2011) find that global warming and reduction in snowfall intensity reduce residential property prices around major ski resorts in the western United States and western Canada. Using data from the U.S. counties, Mendelsohn et al. (1994) show that a change in temperature and/or precipitation (which was interpreted as the impact of climate change) is associated with a change in farmland value. More specifically, they find that higher temperature in all seasons except the autumn reduce average agricultural land values, while more precipitation outside of the autumn increases land values.

Schlenker et al. (2005) also find a significant impact of climate change on farmland values in the U.S. Glaeser et al. (2008) note that climate-related amenity variables (temperature and precipitation) are important demand-side determinants of housing prices. Garretsen and Marlet (2017) find that Dutch cities that consolidate a desirable job neighborhood with a variety of urban amenities have significantly higher housing prices. Using a hedonic property value analysis, Yusuf and Resosudarmo (2009) find that air pollutants have an adverse relationship with property value, i.e., housing rental price, in Jakarta.

Huang et al. (2015) argue that better amenities affect the housing prices directly (as people are willing to pay for them), and indirectly, as an improvement of local amenities may enable the same group of employees to generate more output, as well as attract more capable people to that region and raise the aggregate income of the region. As housing is a durable and immobile consumption good, location and local amenities matter. Other things being equal, people prefer housing in locations that offer a higher quality of life. Huang et al. (2015) find that their measure of climate factors (which includes extreme temperatures, temperature difference, amount of annual sunshine, precipitation, and relative humidity) has a significant and positive impact on housing prices in China.

The other strand of literature in this area is related to the effect of flood and sea level rise (due to global warming) on property prices (e.g., Rajapaksa et al. 2017, Eves & Wilkinson, 2014; Bin & Landry, 2013; Samarasinghe & Sharp, 2010; Lamond et al., 2010; Speyrer & Ragas, 1991; Zhai et al., 2003; Harrison et al., 2001; Tobin & Newton, 1986; Ortega & Taşpınar, 2018; Bernstein et al., 2019). Commonly, these studies find a negative impact of flooding and sea level rise on housing and land prices. For example, using U.S. data, Bernstein et al. (2019) show that coastal properties exposed to sea level rise sell at about 7% less than observably equivalent unexposed properties equidistant from the beach.

3. Data and Model Specification

Our empirical analysis is based on annual data for 31 provinces of Iran from 1993 to 2015. We use average housing prices per square meter (1,000 IRR), average rent per square meter (1,000 IRR) (including 3% of deposits agreed in contracts concluded between property owner and leaseholder) and average land price per square meter of old houses[7] (1,000 IRR). Data for housing prices, rents and land prices are obtained from the Statistical Center of Iran.

[7] As defined by the Statistical Center of Iran, old houses are those residential buildings that have been traded in order to completely destroy the building and construct a new building on its land.

To measure the variability of drought conditions in Iran, we use the Standardized Precipitation-Evapotranspiration Index (SPEI). This index is based on the difference between precipitation and potential evapotranspiration. It is an improved drought index to study the consequences of global warming on drought severity (Begueria et al., 2014). The SPEI considers the effect of reference evapotranspiration on drought severity. In addition, the multi-scalar nature of the SPEI enables identifying, monitoring, and analyzing the initiation, length, and intensity of drought conditions and identification of different drought types and drought impacts on diverse systems. It values between -5 and 5, where smaller values indicate stronger degrees of drought and larger values indicate higher degrees of moisture.

The SPEI is used frequently in the related literature to study climate change (e.g., Abiodun et al., 2013; Yu et al., 2014) and the effects of drought on agriculture (Potop et al., 2012) as well as ecological systems (e.g., Vicente-Serrano et al., 2012; Barbeta et al., 2013; Cavin et al., 2013). This index is also used in drought monitoring systems (Svoboda et al., 2015). In our sample of Iranian provinces from 1993 to 2015, the SPEI varies from -2.5 to 1.4. The negative values show decreasing/drying trends in the SPEI while the positive figures indicate an increasing/wetting trend (Somorowska, 2016). Data on SPEI is collected from the Iran National Drought Warning and Monitoring Center[8].

[8] http://ndc.irimo.ir/far/wd/4625-SPEI.html (in Farsi, access 25.04.2019)

We expect that increasing SPEI (water balance) positively affects the environmental condition and its attractiveness for residents. In turn, this will have a positive effect on the value of real estate properties, keeping other factors constant. In contrast, decreasing values of SPEI indicate the worsening of the local climate and harsher climatic living situations; thus, by reducing accommodation, demand will negatively affect the value of properties[9].

In addition to our main variable of interest (water balance), we also control for major macroeconomic and amenity determinants of property prices involving economic activities, interest rate, construction costs, and leisure, cultural and sport (*LCS*). It is expected that an increase in economic activities through, e.g., an increase in employment (and resulting hikes in households' labor income) or real industrial production increases households' income and hence the demand for properties. Since the real estate stock (supply) cannot change in the short run, a shock in demand for real estate, reflected in rents increases, would lead to higher property prices (Adams & Füss, 2010). Real gross domestic product per capita (*GDP pc*) is used as a proxy for average household income. The GDP per capita series are obtained from the Statistical Center of Iran.

[9] For a review of calculations of the SPEI, the theory behind it and its comparison to other available drought indexes, see Vicente-Serrano et al. (2010a, 2010b) and Beguería et al. (2014).

In this study, we use real interest rate for construction and housing loans[10] by subtracting the nominal interest rate[11] from inflation rate of each province. We expect a negative relationship between long-term interest rate and real estate price. A higher long-term interest rate can reduce real estate prices in two ways (Adams & Füss, 2010). First, a higher long-term interest rate increases the return of other fixed-income assets (such as bonds) relative to the return of real estate, thus, shifting the demand from real estate into other assets, leading to lower real estate prices. Second, a higher long-term interest rate is reflected in higher mortgage rates, which reduces demand and decreases real estate prices.

Data on housing construction costs (IRR), e.g., construction materials or labor costs, per square meter are sourced from the Building Statistics section of Economic Statistics of the Central Bank of Iran. The higher construction costs lead to a decrease in construction and housing supply which in turn raises the property value. Thus, we expect that higher construction costs are positively associated with higher rents, housing and residential land prices.

We also control for an amenity variable in our estimations involving local leisure, cultural and sport infrastructure and facilities. It is expected that greater availability of these facilities and services positively affect the local living condition,

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[10] In Economic Times Series Database, this is called "Expected Rate of Return on Facilities," https://tsd.cbi.ir/DisplayEn/Content.aspx (in Farsi)

[11] The nominal fixed interest rates, on both deposits and lending, are determined by the Central Bank of Iran in the second month of each year in the Iranian Calendar (about April), and financial institutions are obliged to follow this rate in their operations" (https://www.imf.org/~/media/Files/Publications/CR/2017/cr1763.ashx (in Farsi, access 06.05.2019)

increase the demand for properties, and as a result boost the value of properties. As proxy for these facilities and services, we use the share of gross value added (*GVA*) of leisure, cultural and sport (*LCS*) in each province. The data are obtained from regional accounts of the Statistical Center of Iran.

We use a dummy variable related to *Maskan-e Mehr* building ("Affordable Housing") national project (2009-2015). The *Maskan-e Mehr* has entailed granting "preferential housing finance and construction tax exemptions to homes constructed on designated public lands for low-income households" (Alaedini & Ashrafzade, 2016, 17-18). By allocating free-of-charge land to low-income groups, the Iranian government aimed for lowering the construction costs and making the accommodation more affordable for the poor. We expect to observe a negative effect of this policy on housing prices.

Finally, we include province fixed effects in our panel regressions, controlling for other regional-specific factors which may be relevant for property prices.[12] Inclusion of province fixed effects helps to reduce the risk of omitted variable bias, increasing confidence on the effect of climate condition on property values. The standard errors are clustered at province levels. Table A1 in the Appendix presents the data and sources. Table A2 shows the summary statistics of variables in the panel analysis.

[12] Due to the included dummy variable, we do not control for year fixed effects.

Given the above discussion and following DiPasquale and Wheaton (1992) and Oikarinen et al. (2018), our empirical analysis lies in a conventional housing market stock-flow model that includes three key determinants of the long-term equilibrium for housing prices (*HP*) or land prices (*LP*): real income (log of *GDP p.c.*), real interest rate (*IR*) and real construction costs per square meter (log of *CC*).

$$HP_{it} = \beta_0 + \beta_1 GDPc_{it} + \beta_2 IR_{it} + \beta_3 CC_{it} + \delta_i + \varepsilon_{it} \quad (1)$$

We extend equation (1) by including our variables of interest, namely climate change, an important amenity variable, *LCS*, and finally an exogenous dummy variable to cater for the institutional structural changes, i.e., *Maskan-e Mehr* (2009 – 2015). It should be noted that we used province consumer price index (*CPI*) to calculate the real values of nominal variables.

$$HP_{it} = \beta_0 + \beta_1 GDPc_{it} - \beta_2 IR_{it} + \beta_3 CC_{it} + \beta_4 CLIMATE_{it} + \beta_5 AMENITY_{it} + \beta_6 \text{Maskan-e-Mehr\_Dummy} + \delta_i + \varepsilon_{it} \quad (2)$$

4. Empirical Results

The estimation results using housing prices, housing rents and residential land prices as the dependent variables are presented in Tables 1 to 3. In all these estimations, the first specification includes the three key variables, namely, log of GDP per capita, log of construction costs, and real interest rates. The subsequent specifications include SPEI, amenity, and the dummy variables.

Our main variable of interest, SPEI, which measured the balance of water in provinces, shows a robust and significant positive effect on housing prices, rents and land prices in all model specifications (Models 2-4 of Tables 1, 2, and 3). Improvement in the balance of water, i.e., reduction of drought severity, has a significant and positive effect on property values. One unit increases in SPEI value are associated with an increase of approximately 7%, 5% and 10% in housing prices, housing rents, and land prices, respectively, in the most general specification (Model 4) of Tables 1, 2, and 3. These findings provide support to our hypothesis that reduction of drought severity leads to higher property prices in Iran. In addition, our study is in line with findings of other research showing that climatic factors and climate change can have an important impact on property prices (e.g. Huang et al., 2015; Butsic et al., 2011; Harrison et al., 2001). The SPEI has the most effect on the land price as a better climate makes land more valuable. It has the least effect on the rent prices as it does not change the opportunity cost of the house.

Regarding the control variables, we observe that the level of GDP per capita is positive and statistically significant in predicting housing rents and prices (Tables 1 and 2), but not land prices. A 1% increase in within province level of GDP per capita increases within province levels of housing price and rent by 0.22% and 0.26% respectively in Model 4 of Tables 1 and 2. Once an income level of households increased, they may buy a house or rent a more expensive one. Income has more effect on rent as its demand has higher elasticity of income compared to demand to buy a house, which is more tradable. A wealthier family does not necessarily buy land in its province but rather may spend its income to purchase a villa north of Iran or a land in Tehran with higher expected return than local lands.

The effect of the real interest rate is negative and significant for the case of housing prices and land prices. Higher interest rates lower the effective demand of buyers in the real estate market and thus have a dampening effect on prices. Higher interest rates may also channelize the liquidity from the real estate market to the banking system, leading to lower prices in the real estate market. However, interestingly, the real interest rate has an opposite effect on the housing rent, since this rate is indeed the opportunity cost of buying a home for the owner (he could had put his money in a bank to get its interest instead of buying a house to get its rent). Therefore, the higher the real interest rate, the higher is the housing rent.

Table 1. Housing prices and climate: panel fixed effects

	(1)	(2)	(3)	(4)
	Dependent variable: Log of housing prices			
Log of GDP per capita	0.133	0.110	0.110	0.224*
	(0.56)	(0.46)	(0.45)	(1.76)
Interest rate	-0.396***	-0.435***	-0.337**	-0.312***
	(-3.10)	(-3.43)	(-2.72)	(-4.46)
Log of Construction costs	1.719***	1.807***	1.620***	0.761***
	(17.98)	(17.90)	(12.66)	(6.20)
SPEI		0.072***	0.058***	0.073***
		(4.29)	(3.42)	(5.04)
Share of value added of Leisure, Culture and Sport			0.269***	0.272***
			(3.55)	(5.10)
Maskan -e- Mehr dummy				-0.434***
				(-7.73)
N	304	304	304	304
R-sq	0.44	0.46	0.49	0.73

Notes: *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. Robust t statistics are in parentheses. Province fixed effects are controlled in all models.

The construction cost has a robust positive and statistically significant effect on housing prices, rents and land prices in all models. A 1% increase in construction costs increases housing prices, rents, and land prices by 0.76%, 0.67%, and 0.89%, in Model 4 of Tables 1, 2, and 3 respectively, controlling for all other explanatory variables. On the one hand, it has its highest effect on the land price as constructions and land are complementary goods and once the cost of the former increases, the latter also becomes more valuable. On the other hand, the construction cost has its lowest effect on the rent, since the house is now simply more valued.

Table 2. Housing rents and climate: panel fixed effects

	(1)	(2)	(3)	(4)
	Dependent variable: Log of housing rent			
Log of GDP per capita	0.217	0.199	0.199	0.263**
	(1.40)	(1.26)	(1.21)	(2.15)
Interest rate	0.177*	0.147	0.253***	0.268***
	(2.03)	(1.68)	(3.22)	(4.74)
Log of Construction costs	1.297***	1.365***	1.161***	0.677***
	(16.49)	(15.94)	(10.89)	(6.56)
SPEI		0.056***	0.040***	0.048***
		(4.31)	(3.13)	(4.50)
Share of value added of Leisure, Culture and Sport			0.294***	0.295***
			(4.50)	(5.92)
Maskan -e- Mehr dummy				-0.245***
				(-8.48)
N	304	304	304	304
R-sq	0.48	0.50	0.57	0.71

Notes: *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. Robust t statistics are in parentheses. Province fixed effects are controlled in all models.

As was expected, provinces with a higher share of value added of LCS in total value added of province show an increasing effect on housing prices, rents and land prices in all models. The national *Maskan-e Mehr* housing project also shows a significant negative association with housing prices, rents, and land prices in all models of Tables 1-3. This dummy variable has the highest effect on the land price since its aim was to supply free lands for housing projects of lower income classes. Therefore, this project boosted the land supply in the short run and had a remarkable dampening effect on the land price. However, as owners of houses in *Maskan-e Mehr* project were mainly lower income households, building these houses did not increase the supply of housing for rent in the market that much. Hence, the dummy variable for *Maskan-e Mehr* has its least effect on the rent price (Model 4 of Table 2).

Table 3. Residential land prices and climate: panel fixed effects

	(1)	(2)	(3)	(4)
	Dependent variable: Log of land prices			
Log of GDP per capita	-0.146	-0.179	-0.179	0.001
	(-0.45)	(-0.56)	(-0.57)	(0.00)
Interest rate	-0.371*	-0.425**	-0.271	-0.231*
	(-1.87)	(-2.15)	(-1.47)	(-1.82)
Log of Construction costs	2.413***	2.538***	2.242***	0.888***
	(13.28)	(13.52)	(11.68)	(5.01)
SPEI		0.102***	0.079***	0.104***
		(3.49)	(2.80)	(4.12)
Share of value added of Leisure, Culture and Sport			0.425***	0.429***
			(3.30)	(4.88)
Maskan -e- Mehr dummy				-0.684***
				(-8.93)
N	304	304	304	304
R-sq	0.36	0.38	0.42	0.67

Notes: *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. Robust t statistics are in parentheses. Province fixed effects are controlled in all models.

For sensitivity checks, we replaced SPEI with the log of average annual temperature and the log of annual rainfalls. We expect to observe a negative effect of higher temperatures and a positive effect of higher rainfalls within provinces on the property values. The results of panel fixed effects regressions are shown in Table 4, which are supporting our prior expectations. A 1% increase in rainfalls is associated with about 0.07%, 0.05%, and 0.03% increase in housing prices, rents, and land prices respectively, controlling for other factors (Models 2, 4 and 6 of Table 4). A 1% increase in temperature reduces the housing prices, rents and land prices by about 0.70%, 0.55%, and 0.99%, respectively (Models 1, 3, and 5 of Table 4). A higher temperature has the most negative effect on the land price as a worse climate makes land less valuable, not only to live but also to farm. It has the least negative effect on the rent prices as it does not change the opportunity cost of the house.

Table 4. Housing and Climate: Temperature vs. rainfalls

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Housing price		Log Housing rent		Log Land price	
Log GDP per capita	0.228*	0.244*	0.264**	0.277**	0.007	0.030
	(1.88)	(1.97)	(2.25)	(2.34)	(0.04)	(0.18)
Interest rate	-0.178**	-0.281***	0.366***	0.285***	-0.042	-0.167
	(-2.18)	(-3.92)	(5.92)	(5.26)	(-0.29)	(-1.26)
Log Construction cost	0.664***	0.707***	0.612***	0.647***	0.751***	0.768***
	(5.55)	(5.34)	(6.34)	(5.76)	(3.93)	(4.20)
Log Temperature	-0.697***		-0.547***		-0.989**	
	(-2.78)		(-3.64)		(-2.63)	
Log rainfall		0.066*		0.053*		0.027
		(1.78)		(1.76)		(0.43)
Share of value added of Leisure, Culture and Sport	0.300***	0.316***	0.313***	0.325***	0.469***	0.486***
	(5.76)	(5.89)	(6.53)	(6.68)	(5.71)	(5.83)
Maskan -e- Mehr dummy	-0.411***	-0.420***	-0.228***	-0.235***	-0.652***	-0.670***
	(-7.35)	(-7.30)	(-7.88)	(-7.82)	(-8.48)	(-8.73)
N	304	304	304	304	304	304
R-Sq	0.71	0.71	0.70	0.70	0.66	0.66

Notes: *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. Robust t statistics are in parentheses. Province fixed effects are controlled in all models.

As another robustness check, we re-estimate the models by using the growth rates of dependent variables. Panel unit-root tests are less reliable in short time dimensions as in our case (Farzanegan & Hayo, 2019). By using the growth rate of variables, we eliminate any possible stochastic and deterministic trends from our data at a province level. We also use up to two years lag of dependent variables (housing and land values) as predictors of property values. It can be reasonable to assume that earlier development of property markets may shape the current market situation regardless of climate conditions. We employ variables in differences. Therefore, the demeaning process in our fixed effects estimator should not lead to a correlation between lagged dependent variables and residual (Farzanegan & Hayo, 2019). Our climate variables are also orthogonal to the other variables. Table 5 presents these findings.

The fixed effects regressions using the first difference of variables as well as the inclusion of lagged dependent variables support our earlier findings: increasing balance of water within provinces has a positive and significant effect in increases of property values, ceteris paribus. The positive effect of growth rates of construction costs on property values is in line with earlier findings, though it does not translate into increases of housing rents. In addition, positive changes in value added of LCS in total value added of the region shows a positive impact on increases of housing prices within the regions.

The national project of *Maskan-e Mehr* is consistently related to lower growth rates of property prices and rents. Again, it has the most negative effect on the increases of land prices and the least negative effect on the increases of rent prices. The growth of real interest rate shows the same pattern as its level: it has a negative effect on the growth rate of the housing prices while a positive effect on the growth rate of the rent prices.

Table 5. Property values and climate change: Fixed effects estimations with growth rates of variables

	(1)	(2)	(3)
	D.log House price	D.log House rents	D.log Land price
L1.Dependent variable	-0.362***	-0.308***	-0.429***
	(-5.26)	(-4.42)	(-6.37)
L2.Dependent variable	-0.317***	-0.313***	-0.480***
	(-5.71)	(-6.37)	(-9.32)
D.log GDP per capita	0.013	0.097**	-0.202*
	(0.22)	(2.22)	(-1.87)
D. Interest rate	-0.284***	0.164***	-0.010
	(-4.19)	(4.44)	(-0.07)
D.log Construction costs	0.414***	0.040	0.904***
	(2.97)	(0.98)	(3.91)
D.SPEI	0.033***	0.018***	0.083***
	(3.33)	(3.54)	(4.83)
D. Share of value added of Leisure, Culture and Sport	0.067**	-0.018	0.059
	(2.16)	(-0.72)	(0.76)
Maskan -e- Mehr dummy	-0.287***	-0.238***	-0.491***
	(-6.26)	(-9.89)	(-5.41)
N	270	270	270
R-sq.	0.44	0.45	0.48

Notes: D represents the first difference. L is for a year lag. *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. Robust t statistics are in parentheses. Province fixed effects is controlled in all models.

Inclusion of lags of dependent variables in our fixed effects estimations may lead to the Nickell bias (Nickell, 1981). While the effects of other variables including the drought index are estimated consistently, it could be possible that the lagged dependent variables estimated in Table 5 are inconsistently estimated. To address the possibility of the Nickell bias, we re-estimate the model using the Arellano-Bond general method of moments (GMM) estimator (Arellano & Bond, 1991). We report both one and two-steps difference and system GMM estimation results. We treat the lags of the dependent variable as well as other explanatory variables except for drought index (SPEI) and dummy variable as potentially endogenous variables and use 2 to 4 year lags as internal instruments. The autocorrelation tests of first and second degrees are satisfactory: as expected, there is high first-order autocorrelation and no evidence for significant second-order autocorrelation. In addition, the null hypothesis of the validity of the over-identifying restrictions based on the Hansen test cannot be rejected, indicating a well-specified model across different specifications.

Table 6 presents the difference and system GMM (one and two steps) for the case of housing prices. Both difference and system GMM estimation results support our earlier findings in which a higher positive balance of water (higher growth of SPEI) is associated with a higher positive growth rate in housing values within provinces, controlling for other factors. Increasing drought severity can, therefore, reduce the property values significantly.

Table 6. Dynamic panel regressions: difference and system GMM estimations

	(1)	(2)	(3)	(4)
	Diff GMM 2 Steps	Diff GMM 1 Step	SYS GMM 2 Steps	SYS GMM 1 Step
	Dependent variable: D.log housing price			
L D.log house price	-0.272**	-0.286*	-0.283**	-0.321**
	(-2.21)	(-1.85)	(-2.69)	(-2.23)
D.log GDP per capita	0.310	0.422**	0.292	0.344*
	(1.24)	(2.05)	(1.37)	(1.89)
D. Interest rate	-0.628***	-0.634***	-0.616***	-0.634***
	(-4.04)	(-4.49)	(-4.53)	(-5.13)
D.log Construction costs	1.678***	1.746***	1.619***	1.611***
	(6.24)	(5.91)	(6.11)	(5.25)
D.SPEI	0.065***	0.069***	0.063***	0.061***
	(4.20)	(4.20)	(5.13)	(3.93)
D. Share of value added of Leisure, Culture and Sport	-0.032	-0.027	-0.031	-0.020
	(-0.33)	(-0.33)	(-0.36)	(-0.23)
Maskan -e- Mehr dummy	-0.035	-0.020	-0.043	-0.044
	(-0.68)	(-0.40)	(-0.83)	(-0.90)
N	242	242	273	273
Hansen test of overid. Restrictions (p-value)	0.274	0.274	0.508	0.508
AR (1) (p-value)	0.003	0.002	0.003	0.000
AR (2) (p-value)	0.730	0.697	0.673	0.570

Notes: D represents the first difference. L is for a year lag. *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. Robust t statistics are in parentheses.

The regional economic growth rate per capita increases the attractiveness of residential properties and pushes the prices upward (see Models 2 and 4 of Table 6). As in earlier cases, growth of construction costs increases the growth of the property prices as well. In dynamic panel estimations, our main results are robust[13], employing

[13] The estimation results using the SPI index are available upon request. Data on SPI are also collected from the Iran National Drought Warning and Monitoring Center.

wind speed as well as an alternative drought index, namely the Standardized Precipitation Index (SPI)[14].

5. Conclusion

Our study of 31 Iranian provinces from 1993 to 2015 shows that climate condition matters in housing and land prices and rents. Our panel fixed effects estimations, as well as dynamic GMM estimations, provide strong evidence on the importance of drought severity as a factor, which substantially reduces the value of properties. This finding is robust while controlling for other determinants of property prices, e.g., regional economic development, real interest rates, construction costs, regional value added in sectors such as sports, culture, leisure. Furthermore, we control for the implementation of the national housing project aimed to supply affordable houses for low-income groups.

Our results extend our understanding of the economic consequences of climate change in Iran, and provide important implications for Iranian policymakers and property investors. First, decreases in property prices in provinces, which have been experiencing drought, would significantly reduce aggregate consumption and investment through real estate wealth effect and collateral effect in those provinces. On the other hand, households in provinces with less of a water crisis would enjoy

[14] SPI and SPEI are closely related to each other. In the SPI, we only take into account the amount of precipitation as the main input for calculations. However, the SPEI is an index for "climatic water balance". It is a difference between precipitation and reference evapotranspiration, i.e., $P - PET$. In other words, it is a comparison between available water (P) and potential evapotranspiration (PET). Therefore, it is a more reliable measure of drought severity compared to SPI which relies only on precipitation.

higher consumption through real estate wealth and collateral effects. Therefore, we should expect a long-run consumption and investment inequality across provinces of Iran, assuming that the governments do not intervene in the water crisis and drought and do not change the re-distribution policies.

One possible suggestion is taxing property capital gains in provinces with significant growth in property prices and spending the obtained tax to fund water infrastructure in drought areas. It is a win-win situation for both drought and non-drought regions because provinces with more water (e.g. Mazandaran, Gilan and Golestan in Northern Iran) are receiving huge number of immigrants from drought areas (Southern provinces). The population density is very high in these Northern provinces and may cause significant tension between immigrants and local people. Finally, our analyses suggest that property investors can gain from investing in provinces with more precipitation.

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Appendices

Table A1. Data description

	Definition	*Data sources*
Housing prices	Average housing prices per square meter (1,000 IRR)	Statistical Center of Iran
Housing rents	Average rent per square meter (1,000 IRR) (including 3% of deposits agreed in contracts concluded between property owner and leaseholder) per square meter	Statistical Center of Iran
Residential land prices	Average land price per square meter of old houses (1,000 IRR)	Statistical Center of Iran
SPEI	Standardized Precipitation-Evapotranspiration Index	Iran National Drought Warning and Monitoring Center
SPI	Standardized Precipitation Index	Iran National Drought Warning and Monitoring Center
Temperature	Average temperature per year	Iran Meteorological Organization
Rainfall	Total annual rainfall per year	Iran Meteorological Organization
GDPpc	Gross domestic product per capita	Statistical Center of Iran
Real interest rate	Expected rates of return facilities (construction and housing)	Central Bank of Iran
Construction costs	Residential construction costs per square meter (rial)	Central Bank of Iran, Economic Statistics, Building Statistics https://www.cbi.ir/simplelist/4300.aspx
Sport value added (% total value added)		Statistical Center of Iran

Table A2. Summary statistics

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
log_housing prices	304	8.81	0.48	7.22	10.32
log_land prices	304	8.09	0.70	5.94	10.50
log_housing rents	304	10.27	0.44	9.27	11.73
SPEI	304	-0.47	0.74	-2.49	1.41
SPI	304	-0.40	0.73	-1.96	2.70
log_Tempreture	304	2.79	0.24	2.20	3.32
log_Rainfall	304	5.47	0.77	2.23	7.51
log_GDPpc	304	11.01	0.48	10.01	12.71
Real interest rate	304	-0.07	0.09	-0.26	0.05
log_Construction costs	304	15.06	0.16	14.49	15.54
Sport value added (% total value added)	304	0.82	0.42	0.06	2.31