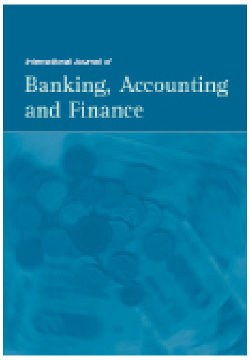

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Dynamic linkages among financial stress, house prices and residential investment in Greece

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Abstract: We examine the relationship between financial instability and real estate price fluctuation in Greece, whose experience during the last two decades makes it an ideal laboratory. Employing a VAR and a Bayesian VAR model, we demonstrate the ability of this measure to explain the phases of the housing market (in terms of both residential prices and investment). We find that an adverse shock in financial stability has prolonged adverse effects in the real estate market, with our findings offering a rigorous interpretation of how the 'perfect financial storm' hit the Greek market during the previous decade. Our findings also suggest that residential prices are more sensitive to changes in financial stress conditions than residential investment.

Keywords: house prices; residential investment; financial stability; uncertainty; Greek economy; Greece.

JEL codes: E6, E44, C10, C22.

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1 Introduction

It is widely accepted that real estate price and investment fluctuations affect consumption, savings, portfolio choice, and asset prices, as well as business cycle and monetary policy (Piazzesi and Schneider, 2016). Surging housing prices can also trigger social dissatisfaction and financial risks, as is usually the case during boom-bust episodes. All the above signify the vital role of the real estate sector on the economy, and clearly, more research is needed to shed light on what moves house prices. In that regard, the need to understand better what affects the housing market is still urgent.

Although the existence of a plethora of past literature on the determinants of house prices and residential investment for the case of Greece (see among others, Simigiannis and Hondroyiannis, 2009; Brissimis and Vlassopoulos, 2009; Kapopoulos et al., 2020), there is no prior study in the literature examining the impact of financial instability (stress) on housing market in Greece. Hence, we aim to fill this gap in the literature.

The present study develops a methodology for examining the role of the financial stress in explaining the housing market movements. In order to model the impact of financial instability on the Greek housing market we follow a two-step methodology; firstly, we construct a financial stress index by employing a variety of discrete financial indices and secondly, to incorporate for the first time in the literature a financial stress index in a VAR system oriented to the Greek housing market.

In particular, in this study we set out to:

1 Extend the already existing literature on financial stress indicators (Illing and Liu, 2006; Park and Mercado, 2014; Liu et al., 2020) by proposing a new financial stress index for Greece proxying for the economy's financial stability.

2 Examine for the first time the dynamic linkages between real estate market and financial stress (stability) in Greece.

3 Explore whether the proposed financial stress index exerts a symmetric impact on residential investment and prices.

The investigation of the dynamic linkages between house prices, investment, and financial instability presupposes the construction of an aggregate index of financial stability. Despite the existence of extended past literature on the construction of financial stability indices (see among others, Park and Mercado, 2014; Liu et al., 2020; Cardarelli et al., 2011; Moscone et al., 2014), there is no commonly accepted framework for its measurement. In addition, although there is some past evidence on the association between the real estate market and financial stability, the literature is still sparse (Liu et al., 2020; Zhang et al., 2018a). It should be mentioned though that this is an empirical paper addressing the specific topic, meaning it works more as a method to be applied in other markets as replication, than a new metric to have it as benchmark.

Employing a VAR and a Bayesian VAR (BVAR) model, our findings suggest that a shock in the proposed Greek financial stress index reflects a kind of financial instability, leading to an abrupt and persistent decrease in residential investment and prices. We also find that residential prices are more sensitive to changes in financial stress conditions than residential investment. These findings are an essential contribution to the literature, as to the best of our knowledge; no other papers are investigating the impact of financial stability on the Greek real estate market in such a context.

The adoption of a Greek financial stress index by monetary authorities and financial regulatory and supervisory bodies has far-reaching implications. First, unlike other measures of systemic financial risks, financial stress index may provide policymakers with an aggregate proxy for financial stability that is independent of the complexities of other measures' 'microlevel' assumptions. Second, it assists in determining how financial market disruption impacts the overall economic activity (Cardarelli et al., 2011; Park and Mercado, 2014).

The rest of the paper is structured as follows. Section 2 presents the previous literature on the determinants of house prices. Section 3 presents theoretical framework and the hypothesis development. Section 4 describes the data and the econometric methodology, while Section 5 discusses the empirical findings. Finally, Section 6 concludes.

2 Determinants of house prices in Greece

2.1 The received evidence

Apergis and Rezitis (2003) was the first empirical study in the real estate literature examining the effects of macroeconomic specific factors on house prices for the special case of Greece. The variables they examined were inflation rate, money supply, employment, and the mortgage interest rate. Employing a variance decomposition analysis, they suggested that all the macro variables they examined affect house prices, with the mortgage interest rate having the largest explanatory power.

Simigiannis and Hondroyiannis (2009) provided evidence of a bidirectional causal relationship between house prices and mortgage loans studying the Greek housing market by estimating a model where house prices were determined by the amount of loans that is offered to individuals based on their income and the mortgage interest rates, as well as by a parameter that depends on the demand and supply house price elasticity.

Brissimis and Vlassopoulos (2009) examined the interaction between house prices and housing loans in Greece and find that, although in the short run there is a bidirectional relationship between the two variables, a long-run causal relationship running from housing loans to house prices is not confirmed.

Katrakilidis and Trachanas (2012) employing an asymmetric ARDL cointegration technique found the presence of asymmetric long-run effects, from the consumer price index and the industrial production index, towards house prices. However, there seem to exist important differences, in the response of house prices to positive or negative changes of the explanatory variables.

Gounopoulos et al. (2012) employed an error correction model of house prices in Greece considering inflation, unemployment, the long-run interest rate, the production index and the Athens Stock exchange general index as explanatory variables. Their empirical results indicated inflation as the most important determinant of house prices.

Panagiotidis and Printzis (2016) examined the long-run determinants of the Greek housing market by employing a VECM. According to their findings, a long-run equilibrium relationship exists between the macro fundamentals and house prices. Specifically, the direction of causality runs from the mortgages and the retail trade to housing prices, both in the long-run and the short-run, while CPI inflation Granger-causes house prices only in the short run.

Iliopoulou and Stratakis (2018) analysed housing prices in the Greater Athens region employing data for the structural and locational characteristics of dwellings and a spatial regression model. When compared to structural factors, they found that most locational characteristics did not add significantly to the explanatory power of their regression model.

Kavarnou and Nanda (2018) created an index capturing the tourism penetration rate and then they examined the relationship between tourism penetration and house prices in the island of Crete in Greece during the period 2006–2012. Their results revealed a significant effect of the tourism penetration rate on house prices of the prefecture with the latter to be also affected by the tourism penetration of the neighbouring prefectures, indicating tourism spillover effect.

White and Papastamos (2018) focused on regional studies and urban markets in Athens and Thessaloniki to investigate the property market in Greece following the Global Financial Crisis. The findings show the relevance of macroeconomic variables in terms of the impact of disposable income, as well as considerable regional differences, with the results showing considerable disparities in the responsiveness of property prices to exogenous demand side effects in the main metropolitan markets.

Gounopoulos et al. (2019) employing advanced cointegration techniques, investigated the dynamic linkages between the real estate prices and the stock prices, focusing on two transmission mechanisms, namely the wealth and credit-price effects. Their findings supported the existence of both the wealth effect and the credit effect in the long-run while in the short-run only a one-way causal effect running from stock market towards house market was found.

The recent study of Kapopoulos et al. (2020) investigated the impact of property taxation and Airbnb listings on the Greek real estate prices. They also found that a Granger causality runs one-way from mortgage loans to RRE prices and not in the opposite direction.

Finally, the investigation of the dynamic linkages between real estate pricing and stock market pricing in Greece realises the existence of:

1 A 'wealth effect', which claims that households with unanticipated gains in share prices tend to increase the amount of housing[1] by rebalancing their portfolios in the short term (Kapopoulos and Siokis, 2005).

2 A credit price effect in the long run (Gounopoulos et al., 2019), which claims that a rise in real estate prices can stimulate economic activity, future profitability and stock market prices.

The previous research on the factors that affect house prices uses a main body of determinants that mostly includes inflation rate, interest rates, and real GDP as a proxy of income. Accordingly, the empirical literature identifies several macroeconomic drivers of house price volatility in Greece, with many studies have underlined the causal relationship of the house price cycle with the credit cycles, as mortgage loan expansion increases house prices while the higher collateral value strengthens borrowing capacity. Although the existence of a plethora of past literature on the determinants of house prices and residential investment, there is no prior study in the literature examining the impact of financial instability (stress) on the Greek housing market.

2.2 What makes Greece an ideal laboratory?

The housing sector has always also played a significant role in the Greek economy's overall growth. Dividing the house price index timespan of the last two decades into three main phases, i.e., boom (2000–2008), bust (2009–2017), and recent gradual recovery (2018–2020), we can easily see that the price fluctuations undoubtedly have produced substantial sometimes positive and sometimes negative wealth effect for homeowners (Kapopoulos et al., 2020).

In addition, the real estate market boom in the early '00s led to an overabundance of housing, with Greece reaching a very high homeownership ratio. During the 'bust' phase of the real estate price cycle, the house price index in Greece dropped cumulatively by 42.4% from its peak in iQ3 i2008 until the trough in iQ3 i2017. Disinvestment in residential property hiked up, and physical capital depreciation remained higher than fixed capital formation for a prolonged period.

3 Financial stress vs. house prices and investment

The following section provides the theoretical background to establish the interconnection between the financial stress indicator and the real estate market.

3.1 Theoretical framework and hypothesis development

The interconnection between financial stress and the real estate market (both in terms of prices and investment) can be formulated in a fourfold manner. Firstly, *the tightening of credit criteria*. Financial instability makes banks adopt more rigid lending policies, thus reducing credit supply and hampering residential prices and investment.

Second, *the increase in liquidity risk*. During a heightened financial stress period driven by – either a stock market collapse or/and a surge in sovereign bond yields – residential prices and investment are compressed. Under extreme circumstances – like those experienced in Greece in 2011 and 2015 – an increase in the spreads of the government bond yields could be transmitted to an extreme FX risk (Grexit), which lead to a collapse of deposits, jeopardising the ability of banks to support business liquidity, housing lending and consequently, residential prices and investment.

Third, *the wealth effect on housing consumption*. Given that households' total wealth consists of the sum of housing (non-financial) and financial wealth (Kapopoulos and Siokis, 2005), households are expected to stall their decision to buy a house during a financial stress period characterised by declining stock and bond prices. This is expected to hamper house prices and investment as well.

Fourth, *a fall in collateral values can increase banks' losses*. Borrowers with low income and low house prices are more likely to behave as strategic defaulters (Campbell and Cocco, 2015; Schelkle, 2018; Pavan and Barreda-Tarrazona, 2020) in the sense that they default on loan payments even though they afford to continue to repay their loans. This magnifies further the financial stress contaminating the banking balance sheets. Besides, there is strong evidence for a negative relationship between collateral value and strategic defaulting in Greece (Asimakopoulos et al., 2017; Kapopoulos et al., 2017).

Based on the previously discussed theoretical framework and the above discussion, we formulate the following testable hypotheses:

H1a Increase in financial stress will cause a decrease in real estate prices.

H1b Increase in financial stress will cause a decrease in residential investment.

H2 Increased financial stress leads residential prices to react more vigorously than residential investment.

3.2 On the construction of the financial stress index: some stylised facts

The financial stress index has been proposed to gauge financial stability in recent studies (Illing and Liu, 2006; Louzis and Vouldis, 2012; Park and Mercado, 2014; Zhang et al., 2018a, 2018b; Liu et al., 2020). Following this prior work, we construct the financial stress indicator for Greece.[2] For its construction, the first step is to employ a GARCH (1, 1) model on the following variables aiming at obtaining their volatility:

1 non-performing loans[3] (outstanding amounts)

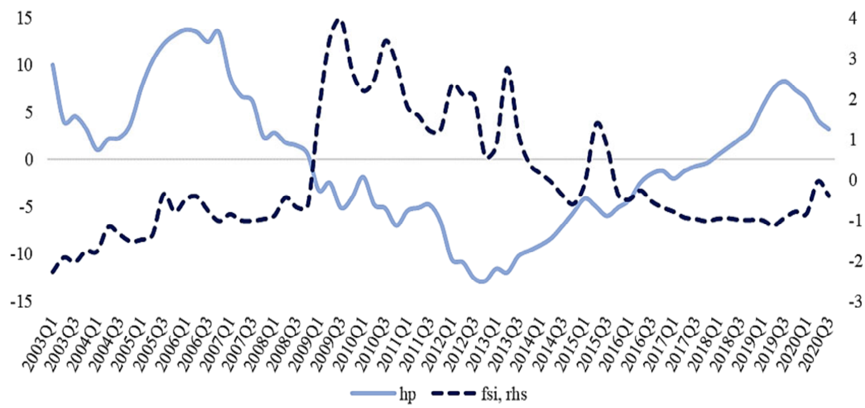
2 bank deposits (outstanding amounts)

3 Athens stock exchange general index

4 spread between the Greek and the German ten-year government bond yield.

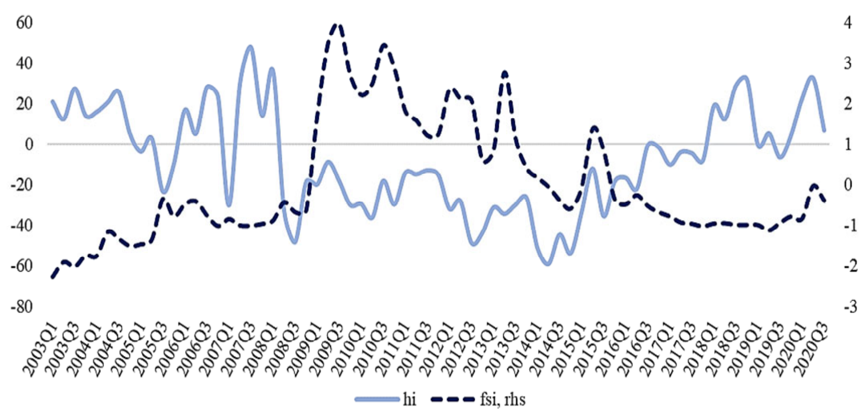
These variables capture all facets of the Greek financial system: banking stability, stock market stability, and sovereign risk. Then, we perform a principal component analysis (PCA)[4] on the volatilities of these variables as mentioned above to obtain the common factor. It might be argued that the PCA method has some drawbacks, namely the so-called problem of substitution and it is sensitive to outliers. However, apart from drawbacks, PCA has also several advantages. First, this analysis helps us aggregate the existing information of the five different financial variables into a unique composite index. Additionally, PCA can cope with multicollinearity problems that might exist when several highly correlated variables are separately introduced in the same regression. An additional advantage of the PCA is that it produces the weights of each variable automatically. Thus, it is not necessary to pre-determine the weights for each variable (Wooldridge, 2010) indicating that the financial stress index we construct explains as much of the variance in the set of the different financial variables as possible. In addition, PCA is still a popular methodological approach, not only in the financial stress but also in the general finance literature (see among others, Park and Mercado, 2014; Hubrich and Tetlow, 2015; Anastasiou et al., 2020, 2022; Anastasiou and Drakos, 2021). Then the first principal component is our financial stress indicator (*fsi*)[5] proxying for the financial stability in Greece. In particular, the details of the PCA are given in Table A1 in Appendix. As it can be seen, the cumulative proportion of the variance explained by the first two principal components is 80.1%, and by the first three, 92.9%, while the fifth component adds < 8% to the explanation of the variance. Hence, the last two components are considered as relatively unimportant, implying that the useful information is contained in the first two. This is also in line with the results depicted in the scree plot (Figure A1) in Appendix, where only the first two components are above the threshold line.

Figure 1 Trajectory between financial stress indicator-*fsi* (levels) and house prices-hp (annual growth rates) (see online version for colours) (see online version for colours)



Note: This figure depicts the trajectory between financial stress indicator-*fsi* (in levels) and house prices-hp (in annual growth rates) for the period under-scrutiny.

Figure 2 Trajectory between financial stress indicator-*fsi* (levels) and residential investment-hi (annual growth rates) (see online version for colours)



Note: This figure depicts the trajectory between financial stress indicator-*fsi* (in levels) and residential investment-hi (in annual growth rates) for the period under-scrutiny.

Figures 1 and 2 present the evolution of the *fsi* and *hp*, and *fsi* and *hi* over the examined period. Generally, a higher *fsi* suggests a more volatile financial system, indicating a less stable financial system in Greece. We observe a clear inverse association between *fsi* and each real estate component in both figures, thus providing preliminary evidence suggesting that the residential house prices and investment contract during more intense financial stress periods. Moreover, we observe an apparent abrupt upward inclination of the *fsi* at the beginning of the financial crisis in 2008 and a downward trajectory after 2015Q3 coinciding with the recovery of the Greek economy.

4 Data and econometric methodology

4.1 Data and variables

Our analysis is based on a quarterly dataset spanning from 2003Q1 to 2020Q3. The period under-scrutiny coincides with a period of substantial economic growth realised by the Greek economy (2003Q1-2008Q2) and a deep recession (2008Q3-2015Q2) caused by a deep financial and debt crisis.[6] Therefore, the Greek case is a perfect candidate to explore the association between financial stability and the real estate market. To fully capture the Greek housing market, we collected data for residential real estate prices (*hp*) and residential investment (*hi*) from reliable sources, namely the Bank of Greece and ELSTAT, respectively. In our analysis, both series are expressed in annual growth rates.

Apart from the three main under-examination variables, (i.e., *fsi*, *hp*, and *hi*) we also consider in our model the construction cost (*construct*), the real GDP (*rgdp*), the spread between the Greek and the German ten-year government bond yield (spread), the credit for mortgages (*credit*), and the harmonised consumer price index (HCPI) (*inflat*). All these series are expressed in annual percentage changes (apart from the variable *spread*), and their choice is based on the past housing literature (see among others, Tsatsaronis and Zhu, 2004; Adams and Füss 2010; Beltratti and Morana, 2010; Katrakilidis and Trachanas, 2012; Rahal, 2016; Gounopoulos et al., 2012, 2019; Anastasiou et al., 2021), as well as on the data availability. While other additional macroeconomic drivers are reported for previous studies, (such as property taxation and population growth) such variables are on an annual basis, and thus they were not selected for the purposes of our analysis (given the quarterly nature of our dataset).

Table 1 Descriptive statistics

	hp	*hi*	*rgdp*	*credit*	*inflat*	*construct*	*spread*	*fsi*
Mean	–0.01	–8.13	–0.89	6.65	1.64	1.03	5.30	0.00
Median	–0.34	–10.00	0.43	–2.28	1.54	0.61	3.46	–0.53
Maximum	13.71	47.61	6.77	33.49	5.60	6.61	29.03	3.96
Minimum	–12.84	–59.40	–14.21	–10.07	–2.20	–3.30	0.12	–2.28
Std. dev.	7.08	25.31	5.20	14.62	2.01	2.47	6.37	1.49

Notes: a. This table reports the main descriptive statistics of our variables, which are all expressed in annual percentage changes, with *fsi* and spread being in levels.
b. The sample is quarterly, covering the period between 2003Q1-2020Q3.

Table 1 offers some valuable information regarding our dataset and the Greek economy as well. Specifically, we provide the main descriptive statistics for all the under-examination variables (i.e., dependent variable, main explanatory variable, and other controls). A first look of the descriptive statistics reveals that the mean values are higher than the median in most of the cases. For the period under-scrutiny, the average real GDP growth was –0.89%, while house prices and residential investment had also a negative mean value of –0.01% and –8.13%, respectively. On a positive note, average credit growth during this period equals to 6.65%, and construction to almost 1%. It is also evident that during the period 2003Q1-2020Q3, Greece also experienced with large GDP growth rates, accompanied by high annual growth rates of house prices and residential investment (6.7%, 13.7%, and 47.6%, respectively), when in the same period credit expansion reached its maximum, recording an increase of almost 33.5%.

4.2 Econometric methodology

For our analysis, we operationalise a reduced-form VAR model of order one. The selection of the one lag was based on the conventional lag length selection information criteria (see Table 2). Our specification contains eight variables revolving around a core housing market-orientated VAR model. Before we proceed to the estimation of our VAR model, as a first step, we examine all the variables for stationarity by employing the unit root tests of Dickey and Fuller (1979) (ADF) and Phillips and Perron (1988) (PP). Table 3 contains the empirical results from the unit root tests, from which we conclude that almost all the variables described above are stationary. The initial variable *spread* (in levels) was only found to be non-stationary. For this reason, we include it in first differences in the VAR system.

Table 2 Lag length selection information criteria

Lag	*AIC*	*SBC*	*HQC*
0	28.319	28.584	28.424
1	17.538	19.927*	18.482*
2	16.978	21.490	18.761
3	17.043	23.678	19.665
4	17.102	25.860	20.563
5	14.726*	25.608	19.026

Notes: a. This table reports the three main lag length selection information criteria, namely the Akaike information criteria (AIC), the Swartz-Bayesian information criteria (SBC) and the Hannan-Quinn information criteria (HQC).
b. The sample is quarterly, covering the period between 2003Q1-2020Q3.
c. The asterisk (*) denote the minimum value of each criterion.

A reduced-form finite-order VAR representation reads as follows:

$$\boldsymbol{Y}_t = \boldsymbol{A}_o + \sum_{j=1}^{q} \boldsymbol{A}_j \boldsymbol{Y}_{t-j} + \varepsilon_t,\ \varepsilon_t \sim N(0, \boldsymbol{\Omega}) \tag{1}$$

where $\boldsymbol{Y}_t$ equals a $(n \times 1)$ vector of variables under-scrutiny, $\boldsymbol{A}_0$ equals an $(n \times 1)$ vector of constant terms, $\boldsymbol{A}_j$ denotes matrices of coefficients, and ε_t denotes the vector of residuals whose variance-covariance is **Ω**. The estimation method of the reduced-form VAR is OLS. Identification is achieved by Cholesky-decomposing the variance-covariance matrix of the VAR residuals, $\Omega = PP'$, where P is the unique lower-triangular Cholesky factor with non-negative diagonal elements.

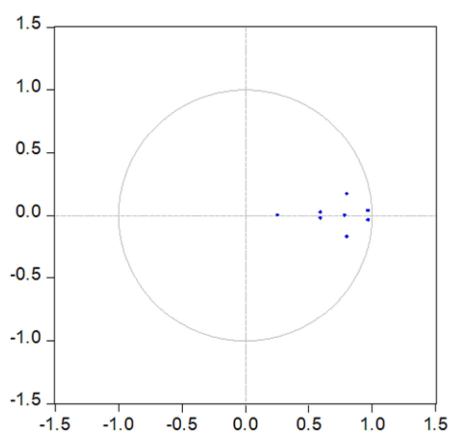
Figure 3 shows that the VAR model meets the stability conditions since the inverse roots of AR characteristic polynomial lie inside the unit circle, and thus, it is stationary.

Table 3 Unit root tests

	ADF	*PP*
hp	–1.958** (0.048)	–2.019** (0.042)
hi	–1.911* (0.054)	–3.293** (0.019)
rgdp	–4.861*** (0.000)	–1.630* (0.097)
credit	–1.735* (0.078)	–2.252 (0.024)
inflat	–1.678* (0.088)	–3.337* (0.068)
construct	–1.714* (0.082)	–1.676* (0.088)
spread	–2.423 (0.139)	–1.976 (0.296)
fsi	–1.946** (0.049)	–2.201** (0.027)

Notes: a. This table presents the results from the unit root test we conducted, where all variables are expressed in annual percentage changes, with *fsi* and spread being in levels.
b. ADF: Augmented Dickey-Fuller test; PP: Phillips and Perron test.
c. The sample is quarterly, covering the period between 2003Q1-2020Q3.
d. ***, ** and * denote significance at the 1%, 5% and 10%, levels, respectively.

Figure 3 VAR stability conditions (inverse roots of AR characteristic polynomial) (see online version for colours)



Notes: This figure depicts the inverse roots of AR characteristic polynomial of the VAR model. It confirms that the stability conditions hold and thus our VAR model is stable and stationary.

5 Results

Figure 4 depicts the ten-quarter impulse response functions (IRFs)[7] of the under-examination variables after estimating the VAR model. In particular, Figure 4 demonstrates the IRFs of a 1 s.d. shock on *fsi* with 95% confidence bands. Plotting IRFs allow us to trace the dynamic impact of shocks in the Greek real estate market. Specifically, we are interested in examining how the system's variables respond to one positive standard deviation shock to *fsi*. We observe that positive shock to *fsi* by one standard deviation (s.d.) leads to a strong immediate negative response of hp, which holds for the whole ten-quarter period. Furthermore, a positive shock to *fsi* induces a strong negative effect on the *hi* for three quarters until it stabilises. These permanent shocks on both housing market components indicate the large and extensive financial stability impact on the Greek housing market. Another interesting finding is that a shock to the *fsi* lowers real GDP and credit while it increases inflation rate and bond spread. The latter might indicate that higher financial instability negatively affects house prices and residential investment directly through the weakening of mortgage debt affordability (lower incomes) and less credit expansion. Additionally, increasing financial stress may lead to house price compression and postponement of investment decisions because of the uncertainty fuelled by increasing inflation or/and higher spreads on bond yields.

To investigate whether *fsi* has a predictive causal impact on the Greek housing market, we employ a pairwise Granger causality test. The results in Table 4 suggest rejection of the null hypothesis at the 10% confidence level that *fsi* does not Granger-cause the *hp*, but not the other way around. We also find that the null hypothesis of no Granger causality from the financial stress index to the residential investment (*hi*) is rejected at the 5% confidence level, but not the other way around. Hence, there is a unidirectional causal relationship from *fsi* to the Greek housing market, implying that our financial stability measure has predictive causality for both *hp* and *hi*. In other words, a sudden drop in house prices or residential investment will not destabilise the Greek financial system, while a sudden surge in the financial stress index will destabilise the Greek real estate market.

Table 4 Short-run Granger causality tests

	hp (probability value)	*hi (probability value)*	*fsi*
fsi does not Granger cause the *hp*	0.082	-	-
fsi does not Granger cause the *hi*	-	0.018	-
hp does not Granger cause the *fsi*	-	-	0.697
hi does not Granger cause the *fsi*	-	-	0.847

Notes: This table presents the results from the Granger causality test after the estimation of the unrestricted VAR model. As it shows, the financial stress indicator has predictive causality on house prices and residential investment but not the other way around. This implies that we find a unidirectional short-run relationship between *fsi* and the housing market.

This finding supports three out of four ways formulating the interconnection between financial stress and the real estate market; namely, the tightening credit criteria, the increase in liquidity risk and the wealth effect on housing consumption. On the contrary, the fourth possible interconnecting manner, which documents the impact of the declining collateral value on the formation of the non-performing loans, would imply a bidirectional causal relationship between financial stability and house prices investment.

We proceed to examine whether *fsi* exerts the same impact on *hp* and *hi*. To do so, we employ a seemingly unrelated regressions model (SUR) of Zellner (1962) to test for cross-equation constraints, and the results are reported in Table 5. We find that the hypothesis of symmetry of absolute effects is rejected, concluding that *fsi* exerts an asymmetric impact on house prices and residential investment. We also find that *fsi* exerts a more significant impact on *hp* than *hi*, suggesting that prices are more sensitive to changes in the system's financial stability than investment. In other words, we find evidence that prices react more vigorously in the event of higher financial stress. The finding that house prices are more sensitive to financial stress periods indicates that policymakers might need to pay more attention to the house prices than the residential investment when designing the appropriate policy measures.

Table 5 SUREG estimation results

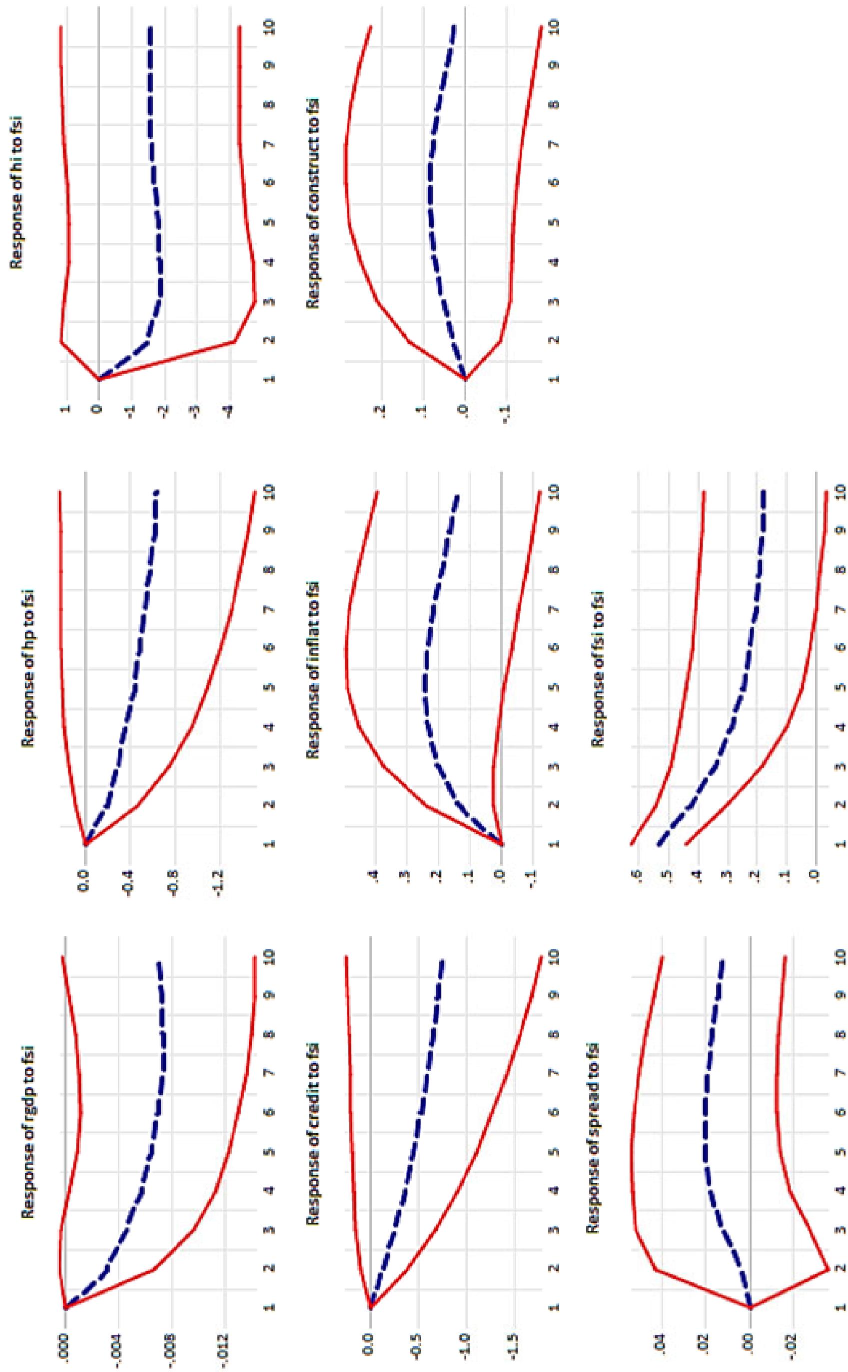
Variables	hp	hi
fsi	*–1.506****	*–0.602***
	[0.507]	*[0.261]*
Control variables	Included	
Constant	0.880	–0.643
	[0.851]	[0.437]
Observations	71	
Hypothesis testing		
Joint zero effect of *fsi* on the housing market (χ^2 statistic)	10.465***	
Symmetry of absolute effects *fsi* on the housing market (χ^2 statistic)	3.356*	

Notes: a. This table presents the results from the SUREG estimation methodology.
b. *, **, *** denote statistical significance at the 10%, 5%, and 1% level, respectively.
c. Numbers in brackets denote robust standard errors.

VAR models usually employ the same lag lengths for all variables in the system, indicating that one must estimate several parameters, including a number of them being statistically insignificant. This creates an over-parameterisation problem, which could lead to multicollinearity concerns and a loss of degrees of freedom, leading to inefficient estimates. Some researchers apply near VAR models, specifying an unequal lag structure for the variables in the system (Doan, 2007), while some others employ unrestricted VARs excluding lags that provide statistically insignificant coefficients (see Dua and Ray, 1995; Dua and Miller, 1996; Dua et al., 1999).

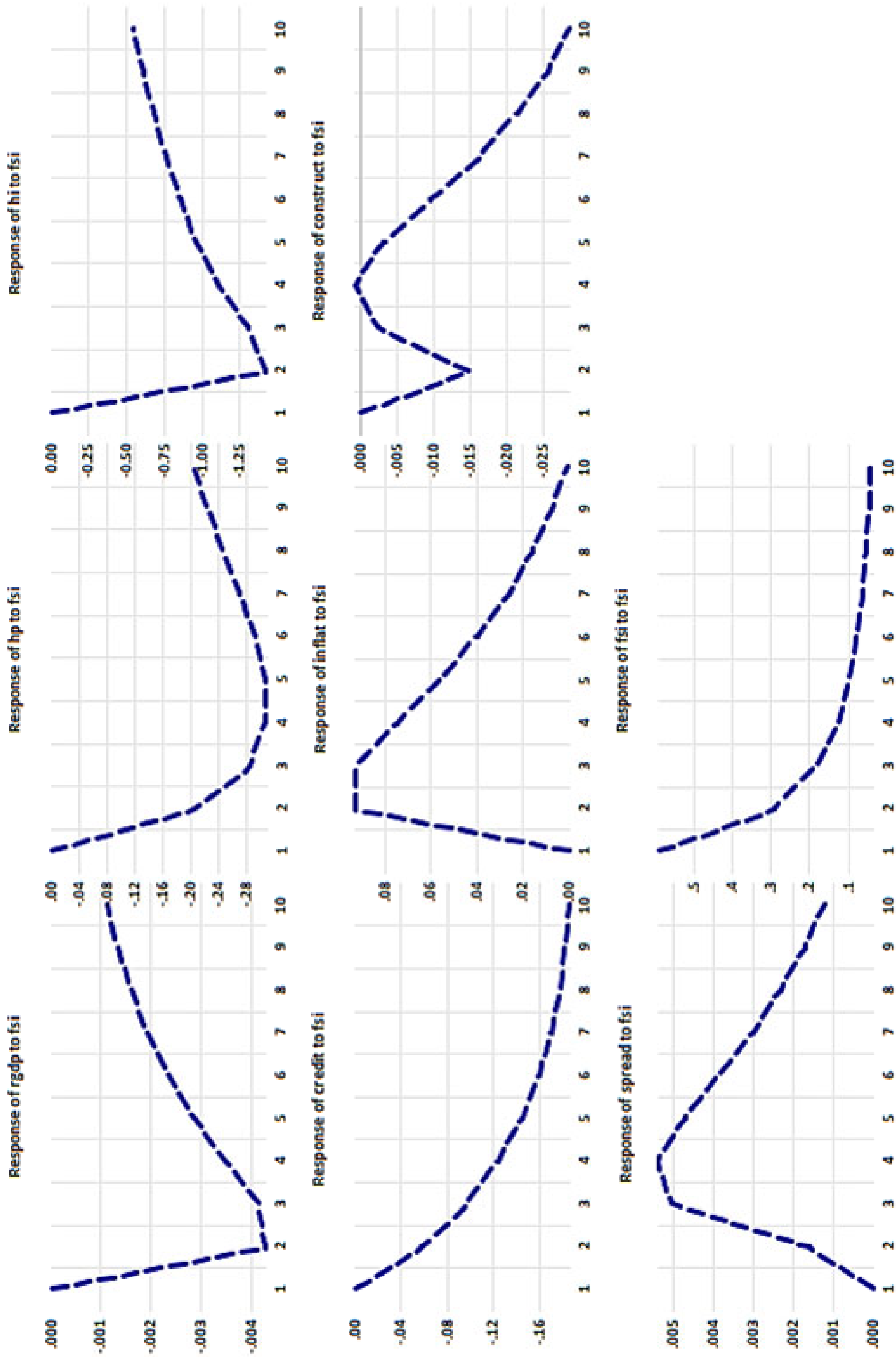
To overcome the over-parameterisation problem, Litterman (1981, 1986), Doan et al. (1984), Todd (1984), and Spencer (1993) use a BVAR model. As also stated by Gupta and Miller (2012), "rather than eliminating lags, the Bayesian method imposes restrictions on the coefficients across different lag lengths, assuming that the coefficients of longer lags may approach more closely to zero than the coefficients on shorter lags". If, however, stronger effects come from longer lags, the data can override this initial restriction.

Figure 4 Impulse response functions of a 1 s.d. shock on *fsi* with 95% confidence bands (VAR model) (see online version for colours)



Note: This figure depicts the impulse response functions of a 1 s.d. shock on *fsi* after the estimation of the unrestricted VAR model.

Figure 5 Impulse response functions of a 1 s.d. shock on *fsi* (BVAR model) (see online version for colours)



Note: This figure depicts the impulse response functions of a 1 s.d. shock on *fsi* after the estimation of the BVAR model.

For the estimation of the BVAR model, a prior distribution must be set. Litterman (1981) imposes a diffuse prior for the constant. Following Gupta and Miller (2012) and Cuestas (2017), we also utilise this 'Minnesota prior' in our analysis, where we implement a Bayesian variant of the previously discussed classical unrestricted VAR model. Mathematically, the means and variances of the Minnesota prior read as follows:

$$\beta_i \sim N\left(1, \sigma_{\beta_i}^2\right) \text{ and } \beta_j \sim N\left(0, \sigma_{\beta_j}^2\right) \tag{2}$$

where β_i equals the coefficients associated with the lagged dependent variables in each equation of the VAR model, (i.e., the first own-lag coefficient), while β_j equals any other coefficient. In sum, the prior specification reduces to a random-walk with drift model for each variable if we set all variances to zero. The prior variances $\sigma_{\beta_i}^2$ and $\sigma_{\beta_j}^2$, specify uncertainty about the prior means $\overline{\beta}_I = 1$ and $\overline{\beta}_J = 1$, respectively. In addition, the hyper-parameters employed in our analysis are in line with Gupta and Miller (2012).

In Figure 5, we display the IRFs based on the BVAR model. As we can observe, a positive shock by one s.d. on *fsi* leads once again to an abrupt and persistent negative response of both *hi* and *hp*. Hence, our results remain nearly unchanged, confirming the previously discussed findings obtained by the unrestricted VAR model, and therefore they are robust.

6 Conclusions

The paper in hands examines the relationship between financial stability and real estate price fluctuation in Greece, whose experience makes it an ideal laboratory. Following the prior literature, we propose a new methodology with which we construct a measure able to gauge financial stability in Greece for the period 2003Q1-2020Q3. We also formulate several aspects of the interconnection between financial stress and the real estate market. Our findings can be summarised as follows:

1 an adverse financial stability shock has prolonged negative effects in the real estate market, both in terms of house prices and residential investment

2 during periods of increased financial stability, residential prices react more vigorously than residential investment.

Additionally, our findings offer a rigorous interpretation of how the 'perfect financial storm' hit the real estate market in Greece during the previous decade. This storm has comprised by housing credit contraction, increasing spreads on government bond yields skyrocketing the so-called 'Grexit from euro' risk, which caused mass deposit outflows and lower household incomes and thus less affordability of mortgage debt. The latter has been further fuelled our financial sector stress index as it led to an increase of housing non-performing loans which is one of the elements of the *fsi*. A lower supply of housing loans has accompanied the subsequent less demand for housing loans because of the tightening of credit criteria and the exposure of banks to liquidity risk.

Finally, our results advance:

1 the understanding of the interconnection between financial stability, the house price movements, and the residential investment decisions

2 the debate on monitoring financial stability in the Greek financial system.

Therefore, for all these reasons, the proposed financial stress indicator can effectively support supervisory authorities and researchers in assessing financial stability in Greece. Furthermore, the nature and the direction of the causal relationship between the housing market (both in terms of prices and investment) and financial stability are important to be determined given that they are of great importance to analysts, practitioners, and policymakers.

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Notes

1 Bampinas et al. (2017) found that the housing wealth effect is larger than the financial wealth effect.

2 Our work provides a method to construct a financial stress index for the special case of Greece, but it can also be applied in other markets as replication.

3 Although data before 2003 are available for most of the variables under-scrutiny, data for NPLs are available since 2003Q1 from the Bank of Greece.

4 The main idea behind using the PCA is to represent each component of the financial stress index into a single variable by forming linear combinations of each component. Through this approach, the resulting stress index captures the most common information from all components. The resulting index is derived from both the first and second principal component which refers to the coefficients of the linear combination that maximises the variance of the resulting composite financial stress index.

5 It must be noted that this financial stress index was found to have a high positive correlation (around 0.77) between the Greek composite indicator of systemic stress (*ciss* of Hollo et al., 2012) and the country-level index of financial stress (*clifs* of Duprey et al., 2017). We believe that such a finding enhances our understanding of the ability of our index to capture financial stress in Greece.

6 Since 2010, Greek bond yields started to experience large increasing trends and tended to raise when its sovereign risks got higher and when its domestic financial sector worsened. Starting in 2010 and onwards, Greece (incl. Ireland and Portugal) had to withdraw from international bond markets (Philippas and Siriopoulos, 2013; Aielli et al., 2015).

7 Although the impulse responses are sensitive to the ordering of the variables entering the VAR system (Sims, 1980), our results are robust to different identification assumptions regarding the ordering of the variables in the VAR model. Following Baffoe-Bonnie (1998) and Lambertini et al. (2013), we tried many orderings. Changing the ordering did not significantly alter the results, and therefore we do not report the ordering.

Appendix

Table A1 Principal components analysis

Number	*Value*	*Difference*	*Proportion*	*Cumulative proportion*
1	2.193526	1.182365	0.5484	0.5484
2	1.011161	0.497025	0.2528	0.8012
3	0.514136	0.232960	0.1285	0.9297
4	0.281176	-	0.0703	1.0000
		Eigenvectors (loadings)		
Variable	*PC1*	*PC2*	*PC3*	*PC4*
ASE_VOLAT	0.534856	0.107638	–0.837240	0.037042
DEPOSITS_VOLAT	0.225425	0.910058	0.270673	0.218437
NPLS_VOLAT	0.551078	–0.392744	0.330658	0.657823
SPREAD_VOLAT	0.599522	–0.077209	0.341220	–0.719849

Notes: a. This table reports the results from the principal components analysis.
b. The sample is quarterly, covering the period between 2003Q1-2020Q3.

Figure A1 Scree plot from PCA (see online version for colours)