Master’s Degree in Finance

Master 2 Finance : Management des Risques Financiers

Final Thesis

The Effect of Monetary Policy on House Price Inflation

An Analysis of the US Housing Market, 1988-2006

Supervisor
Professor Eric Girardin

Graduand
Alessandro Salmaso

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1. Introduction

Monetary policy has guaranteed the financial stability of the world we live in from the classical gold standard, between 1880 and 1914, onwards.

After the early 1990s crisis and the global financial crisis (GFC) of 2007, the action of central banks has been pointed out as one of the major drivers of both the downturns.

This paper aims to analyze how the US monetary policy has driven US house prices in the period 1988-2006, focusing in particular on the two financial downturns of the early 1990s and 2007 (the GFC).

The objective is to whether and to what extent monetary policy influenced house price inflation in the period under analysis, and its role in the early 1990s crisis and in the GFC.

The analysis is focused on the relation between house price inflation and the Fed funds rate (a proxy for the monetary policy), the spread of the Fed Funds rate with respect to a monetary policy rule, the bank credit provision, and the 10-Y treasury rate.

The monetary policy rule adopted is the Taylor rule (Taylor, 1993), which computes the Fed funds rate as a function of the inflation rate and the output gap.

House prices have been under deep analysis by the literature, in particular after the global financial crisis, which started from the US housing bubble of the mid 2000s. According to Taylor (2007) the housing bubble of the mid 2000s was an effect of too low interest rates, while according to Dokko et al (2011) the bubble was caused mainly by a too accommodative mortgage credit concession policy.

According to Walsh (1993) the early 1990s crisis and consequent plunge of house price inflation was caused by a too restrictive monetary policy and other drivers.

House price inflation is measured by the Case Shiller house price index variation.

The effect of the Fed Funds rate, of the spread between the Fed Funds and the Taylor rate (the ‘spread’), of the Bank Credit variation and of the 10-Year treasury rate on the Case Shiller inflation is analyzed through an econometric regression approach.

The bank credit variation is used as a proxy for the mortgage credit concession policy (a higher bank credit variation suggests, among other factors, a more accommodative mortgage credit concession policy).

The Case Shiller housing price inflation is the regressand and the other variables are the regressors in the regression equation; all the data is provided by the FRED database St. Louis.

The variables under analysis have a different order of integration and display a cointegrated behavior: an ARDL model is fitted consequently.

The optimal number of lags inside the ARDL model is estimated through the Akaike Information Criterion (AIC).

The error correction model (ECM) and the long-run cointegration coefficients are estimated accordingly and the residuals diagnostic confirms the good-fitting of the model.

Brake testing suggests that there aren't structural brakes in the estimated equation.

Our main result is that the Fed Funds rate displays a negative effect on the Case Shiller house price inflation, while the bank credit variation displays a positive effect on the house price inflation.

There is a significant cointegration relationship between the house price inflation and both the Fed Funds rate and the bank credit variation. This is highlighted by the significant, long-term regression coefficients that the ARDL model estimates for the two regressors. This means that in the long run the regressand and each of the two regressors tend to move together. In particular, each regressor (Fed Funds rate, bank credit variation) significantly influenced the house price inflation in the long-term.

The measure of this influence is given by the absolute value of each long-term coefficient, and the sign is given by the sign each coefficient (negative for the Fed Funds, positive for the bank credit variation).

The long-term regression coefficient of the Fed Funds rate (in absolute value) is greater than the absolute value of the long-term bank credit variation coefficient.

This means that the Fed Funds rate effect is greater than the bank credit variation effect on the Case Shiller house price inflation.

The results confirm what Walsh (1993) suggested about what caused the early 1990s downturn and consequent house price inflation drop: a too restrictive monetary policy had a significant role among other factors. Walsh (1993) stated that the 1990 oil price

shock and the 1986 Tax Reform Act should be inserted between the causes of the early 1990s recession too.
At the same time, this result validates what Taylor (2007) states regarding the early 2000s housing bubble. Low interest rates had a leading role in generating the bubble and the major driver wasn't consequently the high bank credit provision as Dokko et al found (2011).

We also vindicate Dokko's (2011) view according to which the deviation of monetary policy with respect to a monetary policy rule isn't affecting house price inflation, since the effect of the spread variable is found uncertain. In fact, the long-run spread cointegration coefficient is significantly positive, while the short-run spread ECM coefficient for every lag is negative.

The dissertation is structured as follows. After a brief introduction, the previous literature is reviewed. Then, the dataset is fully analyzed and the methodology is chosen and explained according to the data characteristics. After that, the results are commented and linked to the previous literature. The conclusion and the appendix precede the bibliography and the sitography.

2. Review of Literature

One of the most important contributions regarding the relation between monetary policy and house prices is provided by John B. Taylor with a paper published in December 2007 and entitled *Housing and Monetary Policy*. The author is the creator of the famous Taylor rule, a monetary policy rule that can be used by central banks as a guide to set the short-term interest rate (Taylor, 1993).

In his 2007 paper Taylor addressed how too low short-term interest rates influenced the housing price boom during the years that preceded the global financial crisis. According to Taylor, 'a higher federal funds rate path would have avoided much of the housing boom' (Taylor, 2007).

Regarding the method, he used a counterfactual simulation where he assumed that the federal funds rate followed a Taylor rule.

Moreover, Taylor (2007) suggested that if the long-term rates were higher, they would have contributed to mitigate the house price increase.

Another important contribution is provided by Dokko et al in a 2011 paper intitled *Monetary Policy and the Global Housing Bubble*. This is another paper that focuses on the housing boom of the 2000s, addressing how monetary policy influenced house price inflation. Dokko et al (2011) stated that the past (negative) relation between housing price and Fed funds rate can't justify the housing boom of the mid 2000s, even if interest rates were low with respect to policy rules at that time. The main drivers of the bubble were the high bank credit provision and the high demand of houses, which together created a sort of 'loop' that made prices skyrocket. Dokko et al (2011) pointed out that even if the Fed funds rate was low, it was aligned with policymaker's goals and that its deviation from past patterns couldn't account for such an increase in housing prices. In fact, markets weren't strong at the time, and inflation was low. The accommodative monetary policy was a consequence of this economic scenario.

This is a very different story with respect to what Taylor depicted in his 2007 paper.

A marked loosening in standards for mortgage credit is associated with the skyrocketing in house pricing in the mid 2000s instead of the low Fed Funds rates.

Moreover, Dokko et al (2011) reminded us that housing price is influenced by interest rates, and other macroeconomic factors, and not by the spread between interest rates and policy rules.

The economic scenario of the early 1990s crisis was different.
Walsh (1993) suggests that the restrictive monetary policy was behind the early 1990s recession, along with other macroeconomic factors like the 1990 oil price shock and the 1986 Tax Reform Act.

3. Data and Methodology

3.1 Dataset presentation

The full dataset can be found in *paragraph A1* of the appendix, *table A1.1*.
The time interval studied is 1987 Q3 – 2006 Q4, the data is quarterly and measured at the end of each period.
The data has been downloaded from the FRED St. Louis database, and it refers to the USA exclusively.

A description of each variable (the reference is *table A1.1)* follows. *Column 1* represents the S&P/Case Shiller U.S. National Home Price Index Inflation. It's seasonally adjusted, in percent and annualized. *Column 2* is the percent Federal Funds effective rate. *Column 3* is the percent Taylor rate. A comparison between the original Taylor Rule and the Taylor rates used in this paper can be found in the appendix (*Paragraph A2*). *Column 4* is the difference between the Fed Funds rates and the Taylor rates (Fed Funds – TR). It's what will be called simply 'spread'. *Column 5* represents the bank credit percent variation considering all commercial banks. It has been seasonally adjusted and annualized. *Column 6* is the percent market yield on U.S. Treasury securities at 10-Year constant maturity, quoted on an investment basis.

3.2 Descriptive analysis of the dataset (stationarity, autocorrelation)

In this paragraph each variable of the dataset (*table A1.1*) is examined with descriptive and inference statistic tools.

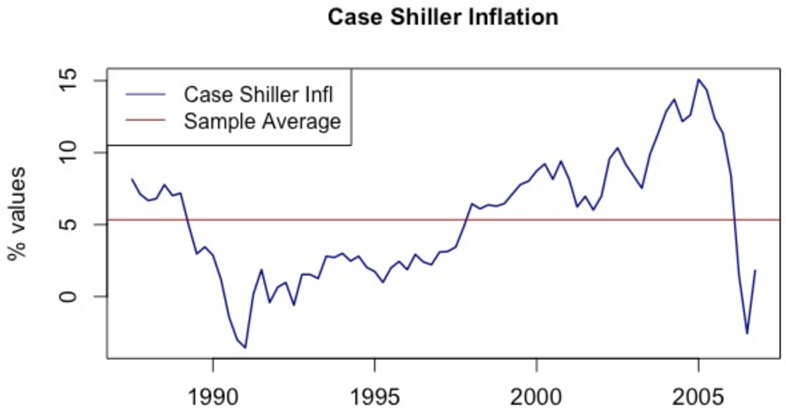

Figure 3.2.1: Case Shiller House Price Inflation Plot (1987-2006)

Statistics	Value (Case Shiller Inflation)
Sample Average	5.34
Sample Standard Deviation	4.26

Table 3.2.1: Case Shiller Inflation Sample Statistics (Values in Percent)

The Case Shiller house price inflation has a high volatility. In particular, there are two volatility clusters in the early 1990s and from 2006 respectively, in correspondence to the two financial downturns (*figure 3.2.1)*.

House price inflation starts to rise from the early 1990s until the sharp downfall that precedes the global financial crisis (early 2006). On average, it has always been positive (*figure 3.2.1*).

Figure 3.2.2 depicts the Fed Funds, the Taylor rate, and the spread between the two (spread = [Fed Funds – Taylor rate]).

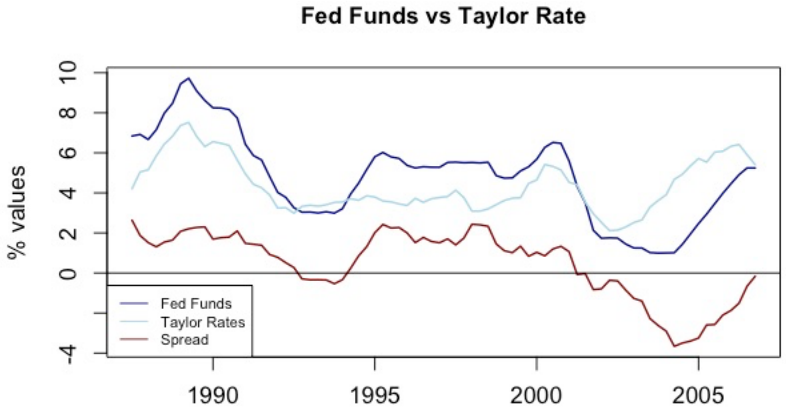

Figure 3.2.2: Fed Funds Rate, Taylor Rate and Spread plot (1987-2006)

Statistics	**Value (Fed Funds)**	**Value (Spread)**
Sample Average	4.83	0.45
Sample Standard Deviation	2.20	1.69

Table 3.2.2: Fed Funds and Spread Sample Statistics (Values in Percent)

Monetary policy was accommodative after the dot-com bubble and fed funds rates reached 'lows that had not been seen since 1950s' (Dokko et al, 2011).

The spread value is positive before the early 1990's crisis, and negative before the global financial crisis. This means that monetary policy choices were opposite in the two cases with respect to the Taylor rate (the policy rule). In the first case (early 1990s crisis) the Fed Funds rate was higher than the policy rule, while in the second one (GFC) it was lower. On average the spread has been positive between 1988 and 2006 (*table 3.2.2)*.

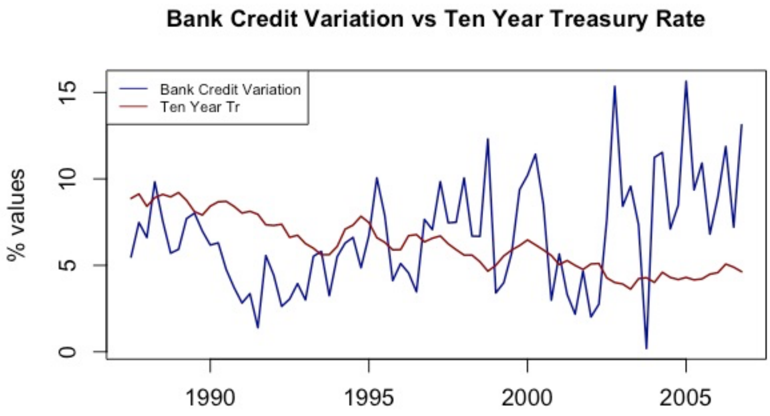

Figure 3.2.3: Bank Credit Variation and 10-Year Treasury Rate Plot (1987-2006)

Statistics	**Value (Bank Credit Var)**	**Value (10-Year Treasury)**
Sample Average	6.72	6.23
Sample Standard Deviation	3.14	1.58

Table 3.2.3: Bank Credit Variation and 10-Year Treasury Sample Statistics (Values in Percent)

The bank credit variation in the USA has been positive for all the analyzed period (*table 3.2.3*). There is a volatility cluster during the years that precede the global financial crisis. The 10-Y treasury rate has been decreasing for the majority of the time interval, with a small hike in the late 2005 (*figure 3.2.3*).

The following table resumes the Phillips-Perron unit root test results.

Variable	p-value	Outcome
Case Shiller House Inflation	0.44	Non-Stationary
Fed Funds Rate	0.70	Non-Stationary
Spread	0.68	Non-Stationary
Variation of Bank Credit	0.01	Stationary
10-Year Treasury Rate	0.05	Stationary

Table 3.2.4: Phillips-Perron Unit Root Test (p-values, alternative: stationary, alpha=0.05). If the p-value is lower than 0.05, the null hypothesis (non-stationary data) can be rejected.

The Case Shiller house price inflation, the Fed Funds rate and the spread are non-stationary time series, while the bank credit variation and the 10-Y treasury rate are stationary processes.

Definition 1:

the stochastic process $\{Y_t\}$ *is* $I(d)$*, i.e. it is integrated of order d, if it is non-stationary and the stochastic process* $\{X_t\}$ *defined as* $X_t = \nabla^d Y_t$ *is stationary.*

The Phillips-Perron unit root test is repeated on the first differences of the three non-stationary variables identified.

Variable	p-value	Outcome
Δ^1Case Shiller Inflation	0.01	Stationary
Δ^1Fed Funds Rate	0.02	Stationary
Δ^1Spread	0.01	Stationary

Table 3.2.5: Phillips-Perron Unit Root Test on First Differences (p-values, alternative: stationary, alpha=0.05)

It can be concluded that the Case Shiller inflation, the Fed Funds and the spread are I(1), i.e. integrated of order 1, time series according to *Definition 1*.
The bank credit variation and the 10-Year treasury rate are instead stationary, I(0) time series processes.

Figure 3.2.4 and *figure 3.2.5* depict the ACFs (autocorrelation functions) of the variables in the dataset.

Figure 3.2.4: Autocorrelation Function of the Case Shiller House Price Inflation

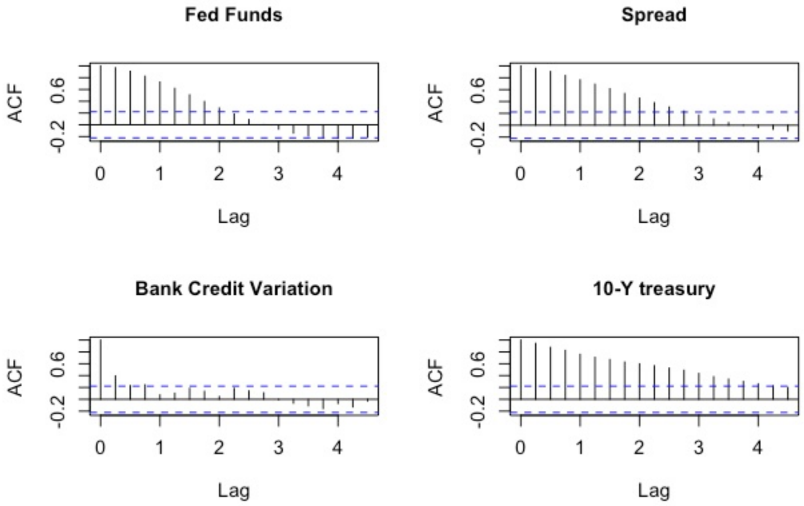

Figure 3.2.5: Autocorrelation Function of the Fed Funds, the Spread, the Bank Credit Variation and the 10-Y treasury

If the ACF value falls out of the boundaries it means that there is significant autocorrelation up to the corresponding time lag. The test is run until year 4 back in time and given that the data is quarterly there are four observations per year.

Table 3.2.6 shows the results of the Z-test, based on MLE of lag-one autocorrelation.

Variables	**p-value**	**Outcome**
Case Shiller House Inflation	0	Significant lag-one autocorr.
Fed Funds Rate	0	Significant lag-one autocorr.
Spread	0	Significant lag-one autocorr.
Variation of Bank Credit	8.77e-05	Significant lag-one autocorr.
10-Year Treasury Rate	0	Significant lag-one autocorr.

Table 3.2.6: Z-test of Lag-one Autocorrelation (p-values, alternative: significant lag-one autocorrelation, alpha=0.05)

We can conclude that all the variables are serially correlated up to lag-1 and further and that the ACF decreases with time in all the cases.

3.3 Methodology

The Case Shiller Inflation (regressand) is explained with the following regressors: Fed Funds rate, spread, variation of the bank credit, 10-Year treasury rate.
The basic OLS equation to fit is:

$$Equation\ 1: Y_t = \alpha + X_{1t} + X_{2t} + X_{3t} + X_{4t} + \epsilon$$

where Y_t is the Case Shiller home price index inflation, and the X_{it}'s are the regressors. More specifically: Fed Funds rate (X_{1t}), Spread (X_{2t}), variation of the bank credit (X_{3t}), 10-Year treasury rate (X_{4t}).
The OLS approach is not theoretically feasible in this case because the regressand and two of the regressors (Fed Funds, spread) don't follow a stationary stochastic process. The regressand and the regressors have a mixed order of integration: they are either I(1) or I(0) processes.
Moreover, given that all the time series involved are strongly serially correlated it's likely that the residuals of an OLS regression would be autocorrelated as well. The presence of I(1) variables doesn't allow on a theoretical basis the use of the GLS approach to fit an ARIMA scheme in the OLS residuals, in case they would be serially correlated.

Figure 3.3.1 illustrates the method selection criteria to analyze time series data according to the order of integration of the variables involved (source: Shrestha et al, 2018).

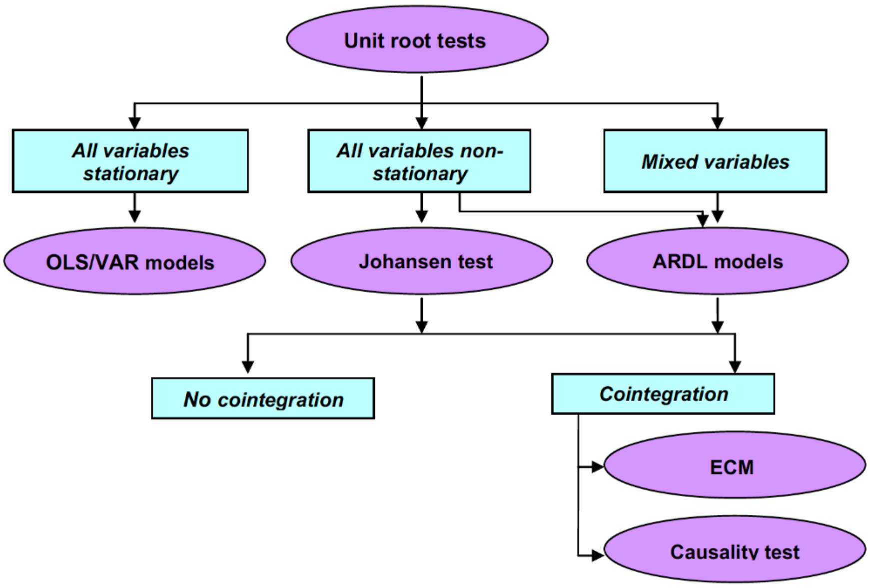

Figure 3.3.1: 'Method selection for time series data. OLS: Ordinary least squares; VAR: Vector autoregressive; ARDL: Autoregressive distributed lags; ECM: Error correction models' (Shrestha et al, 2018).

The ARDL model could be a feasible way to study the Case Shiller inflation, given that the variables involved in the analysis have a mixed order of integration.

Definition 2:

According to Shrestha et al (2018) the autoregressive distributed lag (ARDL) model is based on the ordinary least square (OLS) approach and it is applicable for time series with mixed order of integration. It takes an optimal number of lags for each time series and an error correction model (ECM) can be derived from the ARDL.

The ECM coefficients express the short-run dynamic of the relation without losing the long-run relationship (cointegrated relationship) that's represented by the long-run coefficients.

The ARDL approach is a solution to spurious relationship problem that stem from non-stationarity.

It must be checked if the relationship under analysis (*Equation 1*) is characterized by cointegration. If it is so, the ARDL model is fitted in error correction form and the long-run coefficients, which capture the cointegrating relationship, are computed.

The ARDL model involves inserting lags of both the dependent and the independent variables in the right-hand side of the regression. This is likely to remove eventual autocorrelation from the residuals.
The optimal number of lags is selected according to the Akaike information criterion (AIC) in this case, but it could be computed with the Bayesian information criterion (BIC), or any other criterion too.

The cointegration test that will be applied was firstly developed by Pesaran, Shin and Smith (2001) and it's called 'ARDL bounds test'.
It computes the F-statistics and two bounds for each critical value (10%, 5% and 1% critical values will be considered). If the F-statistics takes a value that is greater than the upper bound, for a given critical value, it can be stated that the relation under test is characterized by cointegration.

To summarize, the method applied to analyze the Case Shiller home price index inflation is the following. Firstly, an OLS equation is fitted into the dataset (*Equation 1*) and the residuals are analyzed; then, a cointegration test is run on the *Equation 1* relationship and the ARDL model is fitted. This is a correct approach under the econometrical point of view (*figure 3.3.1*). If there is a cointegrating relationship, the model is estimated in error correction form (ECM).
The last point is to test for structural breaks in the ARDL model to see if the coefficients change significantly during time.

If there is a structural break in a linear regression model, it means that the estimated coefficients change significantly over time, and precisely after the time-break.
Structural breaks can be identified using different techniques. For example, the M-fluctuation test can be implemented, where the null hypothesis implies no structural

breaks. It is based on the empirical fluctuation processes within the linear regression model.

Other techniques to test for structural breaks are the recursive CUSUM (cumulative sum) and MOSUM (moving sum) tests.

4. Results and discussion

The methodology described in *paragraph 3.3* is now implemented. The results are shown after each step, and a general discussion of the results can be found in *paragraph 4.5*.

4.1 OLS approach and residuals

Table 4.1.1 shows the OLS estimation of *equation 1* and *table 4.1.2* shows the model statistics.

Term	Estimate	Std. error	Statistics	p-value	Significance
Intercept (α)	7.0673	2.4158	2.925	0.00458	**
Fed Funds Rate (X_1)	0.5108	0.3728	1.370	0.17485	
Spread (X_2)	-1.2905	0.3975	-3.247	0.00176	**
Bank Credit Var (X_3)	0.2559	0.1378	1.857	0.06738	.
10-Y Treasury (X_4)	-0.8558	0.4362	-1.962	0.05360	.

Table 4.1.1: OLS Estimation of Equation 1 [1]

Statistics	Value (for the OLS estim.)
Multiple R-Squared	0.4249
Adjusted R-Squared	0.3934
p-value (F statistics)	2.805e-08

Table 4.1.2: Multiple R-squared, Adjusted R-squared and F Statistics (OLS Approach)

There is a significant positive relation between the bank credit and the Case Shiller house price inflation, and a significant negative relation between the 10-Y treasury rate and the house price inflation, according to the OLS estimation.

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[1] Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Moreover, the significant negative spread coefficient suggests that the more the Fed Funds is higher than the Taylor rule, the lower is the observed value of the Case Shiller house inflation.
What it is surprising is the finding of an insignificant Fed Funds coefficient.

An analysis of the residuals will show that these results aren't fully reliable.

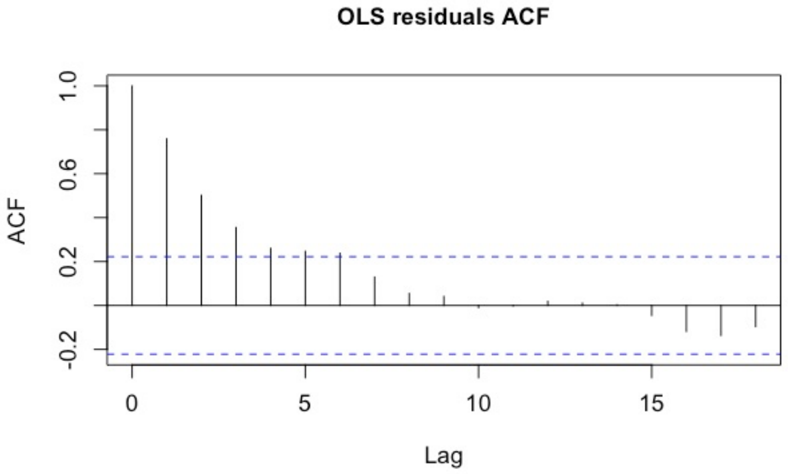

Figure 4.1.1: Autocorrelation Function (ACF) of the OLS residuals (equation 1 estimation)

It's clear that the residuals are autocorrelated up to lag 6 (*Figure 4.1.1*). Considering that the data is quarterly, they are autocorrelated up to one year and a half back in time (one lag equals a quarter of a year).

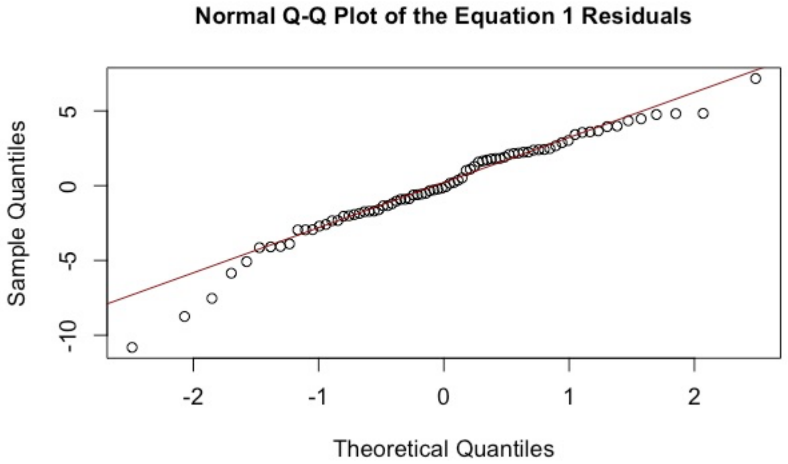

Figure 4.1.2: Normal Q-Q plot of the OLS residuals (Equation 1 Estimation)

While showing deviations from normality in the tails, the residuals all in all follow a Gaussian distribution in the shoulders and the center of the distribution (*figure 4.1.2*).

Table 4.1.3 shows the results of the Breusch-Pagan (BP) test run on the OLS residuals.

Test	**p-value**	**Outcome**
Breusch-Pagan Test	0.1838	Not Rejected

Table 4.1.3: BP test on OLS equation 1 residuals *(p-value, alternative: heteroskedasticity, alpha=0.05)*

Residuals don’t display heteroskedasticity (*table 4.1.3*).

Autocorrelated residuals aren’t consistent with the OLS theoretical assumptions and could make the results unreliable.
One explanation for this autocorrelation could be that the linear model isn’t capturing the autocorrelation structure of the dependent variable and its coefficients aren’t consequently describing properly the underlying econometric relationship .

4.2 The ARDL model

Inserting lags of the dependent variable among the regressors could fix the serial correlation problem. Given that the dependent and independent variables have a mixed order of integration, they are either I(1) or I(0), the ARDL model could be a feasible solution.

Moreover, it allows to deal with potential cointegration within the regression equation.

Definition 3:

According to Shrestha et al (2018) using the OLS method when the time series display non-stationarity could produce spurious results. This means that two uncorrelated given variables may display significant relationship.

On the other hand, two or more time series can be linked by a long-run equilibrium relationship despite deviating from this equilibrium in the short term. If two or more time series are linked by a long-term equilibrium relationship, they are said to be cointegrated.

As specified in *definition 2*, the autoregressive distributed lag (ARDL) model can be applied if the variables involved in the analysis have a mixed order of integration (as in the case of analysis), and the ARDL bound test can be run to detect the presence of cointegration. If cointegration is detected, the ARDL must be fit in error correction form (ECM) and the long-run coefficients are then also computed. This approach has been developed by Pesaran et al (2001) and it is relatively new with respect to the classical cointegration tests.

The long-run coefficients express the cointegration (long-term) relationship, while the ECM coefficients describe the short-term deviations from the long-term cointegration equilibrium according to each specific time lag.

The cointegration test according to Pesaran et al (2001) (‘ARDL bound test’) run on *Equation 1*, is displayed in *table 4.2.1*.

Critical Value	I(0)	I(1)
10%	3.16	4.23
5%	3.678	4.84
1%	4.89	6.164

F-statistic = 7.009

Table 4.2.1: Pesaran Cointegration Test. If the F-statistic is greater than the upper bound, there is a significant cointegrated relationship according to the specified critical value.

The test outcome suggests that *Equation 1* shows a cointegrated behavior according to all the critical values.

The ARDL model is consequently fitted in error correction form (ECM) and the long-term coefficients, which explain the cointegrated relationship, are also computed.

Table 4.2.3 displays the long-run (cointegration) coefficients.

The other coefficients (*table 4.2.4*) refer to the error correction model (ECM) and they are the short-term coefficients according to each time lag.

The number of lags for each variable in the ARDL model is chosen according to the AIC[2] (*table 4.2.2)*.

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[2] More about the Akaike information criterion (AIC) can be found in the appendix (*paragraph A3*).

Variable	Optimal Number of Lags (AIC)
Case Shiller House Price Inflation	5
Fed Funds Rate	4
Spread	5
Bank Credit Variation	2
10-Y Treasury Rate	5

Table 4.2.2: optimal number of lags, ARDL model dependent and independent variables; selected by the AIC. Given that the data is quarterly, 1 lag equals 1 quarter and 4 lags equal 1 year.

Equation 2 is obtained inserting the optimal lag structure, selected by the AIC (*table 4.2.2*) , into *Equation 1*.

Equation 2:

$$Y_t = \alpha + \sum_{i=1}^{5} Y_{\{t-i\}} + \sum_{k=0}^{4} X_{1\{t-k\}} + \sum_{z=0}^{5} X_{2\{t-z\}} + \sum_{j=0}^{2} X_{3\{t-j\}} + \sum_{p=0}^{5} X_{4\{t-p\}} + \epsilon$$

Y_t is the Case Shiller home price index inflation, and the X_{it}'s are the regressors: Fed Funds rate (X_{1t}); Spread (X_{2t}); variation of bank credit (X_{3t}); 10-Year treasury rate (X_{4t}). *Equation 2* is exactly *Equation 1* displaying the optimal lag structure, the rest remains unchanged.

Equation 2 is the reference for the ECM estimation (*table 4.2.4*).

Term	Estimate	Std.Error	Statistic	p.value	Significance
Case Shiller Infl (LT)	-0.1285	0.1087	-1.1826	0.2439	
Fed Funds (LT)	-0.8496	0.4114	-2.0649	0.0455	*
Spread (LT)	0.9418	0.3452	2.7281	0.0094	**
Bank Credit Var (LT)	0.3808	0.1563	2.4370	0.0194	*
10-Y Treasury (LT)	-0.2103	0.9275	-0.2268	0.8218	

Table 4.2.3: long-term (cointegration) coefficients estimation[3]*.*

This table includes the long-term coefficients, which refer to the cointegrated relationship ('LT' stands for 'long-term').

Term	Estimate	Std.Error	Statistic	p.value	Significance
(Intercept)	3.7564	0.6997	5.3684	0.0000	***
ec.1	-0.1285	0.0207	-6.2088	0.0000	***
Fed Funds (t)	0.2541	0.8226	0.3088	0.7589	
Fed Funds (t-1)	-1.5220	0.8741	-1.7412	0.0886	.
Fed Funds (t-2)	0.8243	0.8406	0.9806	0.3321	
Fed Funds (t-3)	-0.9064	0.8494	-1.0671	0.2917	
Fed Funds (t-4)	2.3270	0.7413	3.1389	0.0030	**
Spread (t)	0.8547	0.6145	1.3910	0.1712	
Spread (t-1)	-0.5738	0.5852	-0.9805	0.3322	
Spread (t-2)	-1.0881	0.5677	-1.9165	0.0618	.
Spread (t-3)	-0.3170	0.6064	-0.5228	0.6037	
Spread (t-4)	-2.8646	0.5885	-4.8678	0.0000	***
Spread (t-5)	-0.9476	0.4668	-2.0302	0.0484	*
Bank Credit Var (t)	0.0975	0.0546	1.7880	0.0807	.
Bank Credit Var (t-1)	-0.2730	0.0651	-4.1900	0.0001	***
Bank Credit Var (t-2)	-0.1340	0.0604	-2.2190	0.0317	*
10-Y Treasury (t)	-0.0643	0.5594	-0.1149	0.9090	
10-Y Treasury (t-1)	-0.6024	0.5674	-1.0616	0.2942	
10-Y Treasury (t-2)	0.1469	0.5492	0.2675	0.7904	
10-Y Treasury (t-3)	1.4950	0.5642	2.6498	0.0111	*
10-Y Treasury (t-4)	-0.9513	0.5717	-1.6640	0.1032	
10-Y Treasury (t-5)	0.9216	0.5325	1.7307	0.0905	.
trend.t	-0.0224	0.0078	-2.8820	0.0061	**

---

[3] Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Case Shiller Infl (t-1)	0.3528	0.1285	2.7452	0.0087	**
Case Shiller Infl (t-2)	-0.5371	0.1316	-4.0815	0.0002	***
Case Shiller Infl (t-3)	0.1032	0.1380	0.7474	0.4588	
Case Shiller Infl (t-4)	-0.2548	0.1290	-1.9742	0.0547	.
Case Shiller Infl (t-5)	-0.2235	0.1276	-1.7518	0.0868	.

Table 4.2.4: ECM estimation[4]

This table includes the ECM coefficients which display the deviation of each variable from the long-term relationship (cointegrated relationship), according to each time lag in the short term.

Statistic	**Value (ECM)**
Multiple R-Squared	0.7428
Adjusted R-Squared	0.585
p-value (F statistics)	2.855e-06

Table 4.2.5: ECM model multiple R-squared, adjusted R-squared and F statistics.

The R-squared of the model is largely improved with respect to the OLS approach, as the adjusted R-squared (*table 4.2.5*).

Residuals diagnostic will determine if the model is fit or not and if the autocorrelation problem that the OLS approach displays is fixed.

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[4] Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

4.3 Residuals diagnostic (ECM)

The ARDL in error correction form (error correction model, ECM) fits well the data and the relationship under study according to the residuals diagnostic. The residuals are normally distributed, homoscedastic and they aren't serially correlated (*figure 4.3.1*).

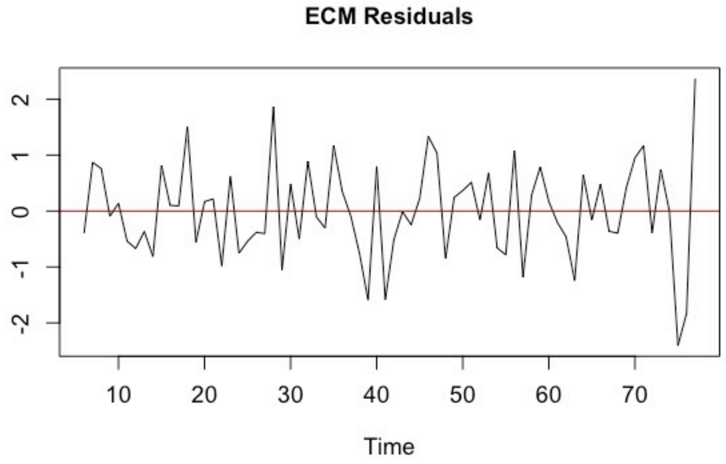

Figure 4.3.1: Plot of The Residuals (ECM)

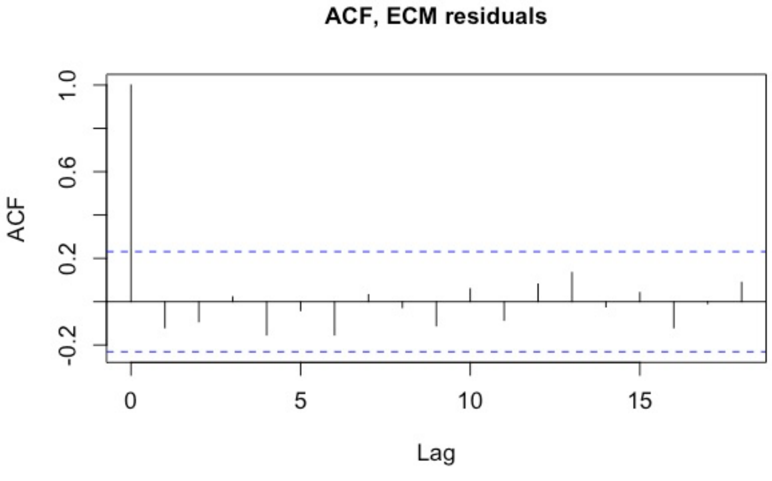

Figure 4.3.2: Autocorrelation Function (ACF) of the Residuals (ECM)

The autocorrelation function (ACF) (*figure 4.3.2)* confirms that the ECM model has solved the autocorrelation problem that characterized the OLS approach. ECM residuals aren’t autocorrelated.

The ECM residuals are normally distributed as can be appreciated in their normal QQ-plot (*figure 4.3.3)*.

The deviation from normality that the residuals show in their tails isn’t severe and normality can be assumed.

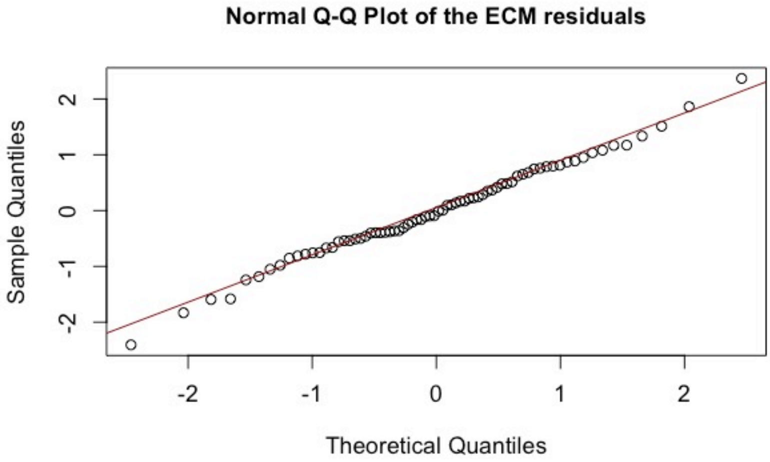

Figure 4.3.3: Residuals QQ-plot (ECM)

Test	p-value	Outcome
Ljung-Box Test (H0: No Autocorrelation)	0.2978	Don’t Reject
Breusch-Pagan Test (H0: Homoskedasticity)	0.05497	Don’t Reject
Shapiro-Wilk Test (H0: residuals are normally dist.)	0.9711	Don’t Reject

Table 4.3.1: Different Tests Run Over the ECM Residuals (alpha=0.05)

The Breusch-Pagan (BP) test shows that residuals (ECM) are homoscedastic (*table 4.3.1*). At the same time, the Shapiro-Wilk test and the Ljung-Box test confirm that residuals of the ECM are normally distributed and non-serially correlated (*table 4.3.1*).

Generally, the ECM model is fit and the results it provides are statistically acceptable.

4.4 Structural Break Testing (ECM)

Test	p-value	Outcome
M-fluctuation test	0.8547	Don’t Reject

Table 4.4.1: Structural Break Test (H0: no brakes, alpha=0.05) for the ECM

There are no structural breaks in the ECM model fitted according to the M-fluctuation test (*table 4.4.1*). The null hypothesis (no structural brakes) isn’t rejected.

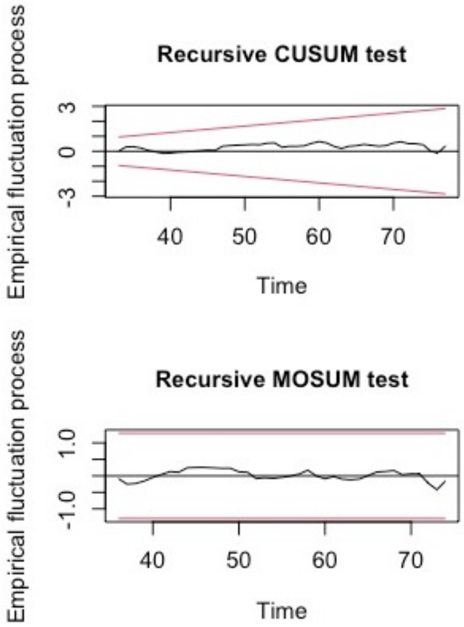

Figure 4.4.1: CUSUM and MOSUM tests for the ECM.
If the value of the test remains inside the given boundaries (red lines), it means that there aren’t structural brakes in the estimated relationship.

Recursive CUSUM and MOSUM tests confirm that there aren’t structural brakes and that the ECM coefficients don’t change significantly in the analyzed period (*figure 4.4.1*).

4.5 Discussion of the results

The first, important result is a negative, relatively strong, relation between the Case Shiller housing price inflation and the Fed funds in the long-term. It is emphasized by the negative, long-term cointegration coefficient (*table 4.2.3*).

This is aligned with what Taylor (2007) reports: loose monetary policy could have been one of the most important causes of the early 2000s US housing bubble. After all, the housing market is reported to be among the most sensitive to interest rates (Dokko et al, 2011).

Moreover, monetary policy could have been behind the early 1990s housing price decrease in the US. One of the causes of the early 1990s US crisis found by the literature (in particular, see Walsh, 1993) is the restrictive monetary policy indeed.

The short-term deviations reported by the ECM coefficients are worth a closer look.

The Fed funds short-term coefficient, lagged by 1 quarter, is negative, significant and equal to -1.5 (*table 4.2.4*).This means that exists a strong negative effect of the previous quarter Fed funds rate on the Case-Shiller inflation, and this is not a surprise. The interest rate effect takes some time (1 or 2 quarters) to show up on house prices.

The spread long-term coefficient is reported positive and significant (*table 4.2.3*). Remember that the spread is equal to [Fed funds – Taylor rate]. A positive and sufficiently high coefficient is rather surprising, given that it implies that an increase in the Fed Funds rate is associated with an increase in the housing price inflation.

Consider that the short-term spread coefficients (*table 4.2.4)* derived from the ECM all display a negative value in their lags: there is a significative short-term deviation from the long-run estimation, as the coefficients change sign and become negative.

While the positive, long-term coefficient refers to the cointegrated relationship between the housing price inflation and the spread, the coefficients of the ECM express the relationship between the two variables in the short term. The huge deviation between short-term and long-term effect (up to lag 5) could suggest an uncertain response of the Case Shiller housing price inflation to the spread variation, and this partially validates what Dokko et al (2011) state.

In fact, the literature (Dokko et al, 2011 in particular) finds that the housing price inflation isn't driven at all by the divergence of monetary policy from monetary policy rules.

The bank credit variation long-term coefficient (*table 4.2.3*) is positive, but not far from zero (it equals 0.3808).

Dokko et al (2011) suggest that the credit provision has largely contributed to the housing bubble of the early 2000s, more than the loose monetary policy. According to Dokko et al (2011) the loosening of mortgage credit standard, which could be proxied by an increase in the bank credit variation, made the demand of real estate skyrocketing and contributed to boost house prices. The housing market fell into a loop: the higher were the house prices, the higher was the bank credit conceded, and the higher was the demand for houses. This increased furthermore house prices and the housing price inflation surged consequently.

The second, important result is contrary to what Dokko et al (2011) stated.

The influence of the Fed Funds rate and the bank credit variation on the Case Shiller housing price inflation can be measured by the absolute value of their regression coefficients. Moreover, the sign of the effect can be measured by the sign of each coefficient. In absolute value, the bank credit variation long-term coefficient is lower than the Fed Funds long-term coefficient (0.3808 < 0.8496, *table 4.2.3*).

This implies a greater influence on the Case Shiller house inflation of the Fed Funds rate with respect to the bank credit variation and it contradicts what Dokko et al (2011) concluded.

Instead, it confirms what Taylor (2007) found: loose monetary policy had a primary role in the 2007 housing boom.

The short-term ECM coefficients (*table 4.2.4*) of the bank credit variation display both positive and negative significant values. Looking only at these results, the outcome would be not really defined, but what's valuable here is the cointegrated behavior of the Case Shiller house inflation and the bank credit variation which highlights how the dependent and independent variables move together in the long run. This allows to study the effect of the independent variable (bank credit variation) on the dependent variable (Case Shiller housing price inflation) considering a larger period, not only quarterly lags.

The 10-Year treasury long-term coefficient (*table 4.2.3*) isn't significant.
Looking at the short-term deviations of the 10-Y treasury coefficient (*table 4.2.4*), it can be observed a positive effect of this variable on the housing price inflation for every significant lag (3rd and 5th lags are significant).
Taylor (2007) affirmed that if long-run interest rates were higher, they would have slowed down the housing bubble. It can be derived that it should exist a negative relationship between 10-Year treasury rates and housing price inflation and there is not sufficient empirical evidence to suggest the opposite.

Considering the autoregressive of order 2 (AR 2) component (*table 4.2.4, Case Shiller Infl t-2 coefficient*), the coefficient is quite high in absolute value and significant (-0.5371). This signals that the Case Shiller house inflation time series is dependent on its past values, but this is not a surprise. *Figure 3.2.1* shows that this process exhibits a stochastic trend and a non-stationary behavior. This makes autoregressive coefficients significant, even if the ARDL model has been fitted in error correction form (ECM).

A last consideration is about the early 1990s crisis.
It has been reported by literature that a too restrictive monetary policy could have been the cause, among other macroeconomic events, of the downturn (Walsh, 1993). This is confirmed by the ARDL-ECM developed in this paper: in fact, the long-term Fed Funds coefficient (*table 4.2.3*) is negative and significant. Other macroeconomic events that contributed to the depression of house price inflation in that days are the 1990 oil price shock and the 1986 Tax Reform Act (Walsh, 1993).

5. Conclusions

The downturn of 1990s and the global financial crisis of 2007, which characterized the two main house price inflation drops in the 1988-2006 US market, stem from markedly different economic scenarios. Anyway, in both cases, one of the most relevant drivers of the crisis was monetary policy: in the first case, a too restrictive monetary policy while in the second one, a too loose monetary policy, which caused the housing bubble to inflate.

The bank credit provision had a significant but less important role, in particular in the mid 2000s housing bubble which explosion led to the global financial crisis.

The spread between the Fed Funds rate and a policy rule like the Taylor rate had an uncertain effect on the Case-Shiller house price inflation, while the literature (Dokko et al, 2011) reports that it doesn't influence at all the house market evolution.

Finally, the long-term interest rate effect on the Case Shiller house price inflation has been found not statistically significant. This is not considered enough to contrast what Taylor (2007) stated about long-term interest rates effect on house price inflation: there should be a negative significant effect.

Appendix

A1. Dataset

Table A1.1 contains the full dataset under study. The data is in percent and it refers to the end of the period (for example 1989-01-01 is the fourth quarter of 1988).

Obs Date	1. Case Sh Infl	2. Fed Funds	3. TR	4. Spread	5. Var Bank Cr	6. 10-Y Tr
1987-10-01	8.14	6.84	4.21	2.63	5.48	8.87
1988-01-01	7.12	6.92	5.05	1.87	7.48	9.13
1988-04-01	6.67	6.67	5.15	1.52	6.61	8.41
1988-07-01	6.80	7.15	5.85	1.31	9.83	8.91
1988-10-01	7.77	7.98	6.44	1.54	7.57	9.10
1989-01-01	7.02	8.47	6.83	1.64	5.70	8.96
1989-04-01	7.18	9.45	7.37	2.08	5.93	9.21
1989-07-01	4.96	9.73	7.52	2.21	7.70	8.76
1989-10-01	2.97	9.08	6.81	2.28	8.02	8.11
1990-01-01	3.45	8.61	6.31	2.30	6.98	7.91
1990-04-01	2.86	8.25	6.56	1.69	6.17	8.42
1990-07-01	1.18	8.24	6.48	1.76	6.30	8.67
1990-10-01	-1.45	8.16	6.37	1.79	4.76	8.70
1991-01-01	-3.01	7.74	5.64	2.10	3.71	8.41
1991-04-01	-3.56	6.43	4.95	1.48	2.82	8.02
1991-07-01	0.19	5.86	4.43	1.43	3.36	8.13
1991-10-01	1.87	5.65	4.26	1.39	1.39	7.95
1992-01-01	-0.42	4.82	3.90	0.92	5.57	7.35
1992-04-01	0.65	4.02	3.24	0.78	4.43	7.31
1992-07-01	0.98	3.77	3.26	0.51	2.63	7.38
1992-10-01	-0.60	3.26	2.99	0.27	3.05	6.62
1993-01-01	1.54	3.03	3.33	-0.29	3.94	6.74
1993-04-01	1.53	3.04	3.38	-0.34	3.00	6.26

1993-07-01	1.26	3.00	3.34	-0.34	5.52	5.99
1993-10-01	2.80	3.06	3.41	-0.35	5.81	5.62
1994-01-01	2.71	2.99	3.52	-0.54	3.24	5.62
1994-04-01	3.00	3.21	3.54	-0.33	5.50	6.09
1994-07-01	2.47	3.94	3.71	0.23	6.29	7.09
1994-10-01	2.80	4.49	3.63	0.86	6.61	7.33
1995-01-01	2.03	5.17	3.85	1.31	4.86	7.84
1995-04-01	1.73	5.80	3.79	2.01	6.73	7.47
1995-07-01	0.99	6.02	3.59	2.42	10.06	6.60
1995-10-01	1.99	5.80	3.55	2.25	7.88	6.33
1996-01-01	2.44	5.72	3.45	2.27	4.11	5.90
1996-04-01	1.87	5.37	3.38	2.00	5.10	5.91
1996-07-01	2.93	5.24	3.73	1.52	4.56	6.71
1996-10-01	2.40	5.31	3.53	1.78	3.47	6.78
1997-01-01	2.21	5.28	3.71	1.57	7.66	6.35
1997-04-01	3.09	5.28	3.77	1.51	7.07	6.57
1997-07-01	3.13	5.52	3.82	1.70	9.84	6.70
1997-10-01	3.44	5.53	4.13	1.40	7.46	6.24
1998-01-01	4.85	5.51	3.76	1.74	7.49	5.91
1998-04-01	6.45	5.52	3.09	2.43	10.06	5.59
1998-07-01	6.10	5.50	3.09	2.41	6.69	5.59
1998-10-01	6.37	5.53	3.20	2.33	6.68	5.21
1999-01-01	6.28	4.86	3.41	1.45	12.31	4.66
1999-04-01	6.46	4.73	3.62	1.11	3.40	5.00
1999-07-01	7.13	4.75	3.73	1.01	3.99	5.54
1999-10-01	7.79	5.10	3.76	1.34	5.71	5.88
2000-01-01	8.02	5.30	4.47	0.83	9.38	6.14
2000-04-01	8.73	5.68	4.64	1.03	10.21	6.47
2000-07-01	9.22	6.27	5.42	0.86	11.43	6.18
2000-10-01	8.15	6.52	5.32	1.20	8.53	5.89
2001-01-01	9.41	6.47	5.14	1.33	2.99	5.57

2001-04-01	8.16	5.60	4.53	1.07	5.66	5.04
2001-07-01	6.23	4.33	4.40	-0.08	3.31	5.28
2001-10-01	6.96	3.50	3.53	-0.03	2.18	5.00
2002-01-01	6.01	2.13	2.96	-0.83	4.68	4.76
2002-04-01	6.97	1.73	2.53	-0.79	2.01	5.08
2002-07-01	9.58	1.75	2.12	-0.36	2.75	5.11
2002-10-01	10.33	1.74	2.14	-0.40	7.65	4.27
2003-01-01	9.18	1.44	2.30	-0.85	15.35	4.00
2003-04-01	8.36	1.25	2.52	-1.27	8.41	3.92
2003-07-01	7.53	1.25	2.65	-1.40	9.58	3.62
2003-10-01	9.89	1.02	3.29	-2.27	7.35	4.23
2004-01-01	11.33	1.00	3.62	-2.62	0.19	4.29
2004-04-01	12.86	1.00	3.90	-2.90	11.24	4.01
2004-07-01	13.71	1.01	4.67	-3.66	11.53	4.60
2004-10-01	12.17	1.43	4.93	-3.50	7.10	4.30
2005-01-01	12.62	1.95	5.35	-3.40	8.47	4.18
2005-04-01	15.09	2.47	5.72	-3.25	15.65	4.30
2005-07-01	14.35	2.94	5.54	-2.59	9.37	4.16
2005-10-01	12.36	3.46	6.03	-2.57	10.91	4.22
2006-01-01	11.37	3.98	6.08	-2.10	6.81	4.49
2006-04-01	8.43	4.45	6.33	-1.87	8.94	4.58
2006-07-01	1.47	4.91	6.42	-1.51	11.87	5.07
2006-10-01	-2.56	5.25	5.90	-0.66	7.21	4.89
2007-01-01	1.82	5.24	5.41	-0.16	13.13	4.63

Table A1.1: Dataset Under Study (Values in Percent)

A2. The Taylor Rule

John Taylor firstly designed the so called ‘Taylor rule’ in 1993.

It’s a monetary policy rule intended to be a guide for policymakers in the setting of interest rates.

The Taylor rule (Taylor, 1993) is the following.

Equation 3:

$$r = \pi + 0.5y + 0.5(\pi - 2) + 2$$

Where: *r* is the Taylor (Fed funds) rate; *y* is the % deviation of real GDP from the target (output gap); Π is the rate of inflation.

In particular,

$$y = \frac{100(Y - Y *)}{Y *}$$

where: Y = real GDP; Y* = trend real GDP (assumed 2.2% per year given past performance).

And

$$\Pi = GDP\ deflator = \frac{Nominal\ GDP}{Real\ GDP} * 100$$

According to Taylor (1993) the Fed Funds rate increases if the inflation raises above its 2% target or if real GDP is greater than trend real GDP. If the inflation and the real GDP meet their target, the Fed funds rate would be 4%.

The spread variable worked in this paper equals [Fed funds – Taylor rate] and the Taylor rate source is the FRED database, St. Louis.

The Taylor rule followed by the FRED has the following characteristics: output gap = [real GDP – potential output[5]]; rate of inflation = changes in the CPI; inflation target = 2%.

The GDP deflator and the variation of the Consumer Price Index (CPI) can be both used as rate of inflation estimator. One main difference is that the GDP deflator isn’t built on

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[5] The potential output is published by the Congressional Budget Office

a fixed basket of goods and services. The reference basket changes year by year according to consumption trends. Often the difference between the two estimators is relatively small.

The output gap is measured in two different ways considering the 1993 Taylor paper and the FRED Taylor rule. Taylor used the deviation of real GDP from the trend real GDP to measure the output gap, while FRED used the deviation of real GDP from the potential GDP.

The inflation target is set at 2% in both the Taylor rules.

A3. ARDL Lag Selection Criteria

The ARDL lags are selected according to the AIC (Akaike information criterion).

The AIC is used as a criterion for model selection allowing to select the best model according to a trade-off between goodness of fit and simplicity (more parameters make a model more complex). In particular, the AIC estimates how much information is lost by a model and the best model is the one which has lost less information. There will never be a model in practice which doesn't lose some data information in the representation.

It is, along with the Bayesian Information Criterion (BIC) one of the most used model selection algorithms in statistical inference. It has been developed by the statistician Hirotugu Akaike, who gave the criterion his name.

The AIC formula is:

$$AIC = 2k - 2LN(L)$$

Where: *k* is the number of the model parameters; *L* is the maximum of the likelihood function of the model.

The best model is the one with the minimum AIC value and the AIC penalizes models with a high number of parameters (the more complex ones).

Bibliography

B1. Citations

Jane Dokko, Brian M. Doyle, Michael T. Kiley, Jinill Kim, Shane Sherlund, Jae Sim, Skander Van Den Heuvel and Jean-Paul L'Huillier, 2011, Monetary policy and the global housing bubble, *Economic Policy*, 237-287;

M. Hashem Pesaran, Yongcheol Shin and Richard J. Smith, 2001, Bounds testing approaches to the analysis of level relationships, *Journal of Applied Econometrics*, 289-326;

Min B. Shrestha, Guna R. Bhatta, 2018, Selecting appropriate methodological framework for time series data analysis, *The Journal of Finance and Data Science*, 71-89;

John B. Taylor, 1993, Discretion versus policy rules in practice, *Carnegie-Rochester Conference Series on Public Policy, 195-214*;

John B. Taylor, 2007, Housing and Monetary policy, *NBER Working Paper No. 13682;*

Carl E. Walsh, 1993, What Caused the 1990-1991 Recession?*, Economic Review, Federal Reserve Bank of San Francisco, number 2*, 33-48.

B2. Sitography

R Core Team (2021), *R: A language and environment for statistical computing,* R Foundation for Statistical Computing, Vienna, Austria,
URL: https://www.R-project.org/

Federal Reserve Bank of St Louis, Federal Reserve Economic Data (FRED),
URL: https://fred.stlouisfed.org/

About Akaike Information Criterion,
URL: https://en.wikipedia.org/wiki/Akaike_information_criterion

About the 1990s and global financial crisis (GFC) recessions,
URL: https://www.pewresearch.org/social-trends/2019/12/13/two-recessions-two-recoveries-2/

About US recessions,
URL: https://www.investopedia.com/articles/economics/08/past-recessions.asp

About monetary policy and the GFC,
URL: https://www.reuters.com/article/us-usa-economy-taylor-idUSN0144589820070901