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What Drives Eurozone House Prices?
A VECM Analysis from 1995 to 2025

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Table of Contents

Table of Figures

Table of Tables

Table of Equations

Table of Annex A Tables

Table of Appendix B Tables

1 Introduction

2 Theoretical Framework

This section describes the theoretical framework that informs the variables included in the model and their expected relationship. Following Gattini and Hiebert (2010), we aim to model house prices in the Eurozone as a demand and supply equilibrium.

On the *demand* side, inspired by McQuinn and O'Reilly (2008), cross-country housing demand is theorised to depend on income and interest rates. Firstly, income is theorised to positively affect housing demand, because an increase in income increases an individual's capacity to take on mortgages and to purchase real estate. Secondly, interest rates are theorised to negatively affect housing demand seen as interest rates directly affect the cost of external financing. As the interest rate increases, taking on credit to purchase real estate becomes more expensive, slowing down housing demand.

On the *supply* side, we follow Gattini and Hiebert (2010) in theorising housing supply depends on housing investment, which in turn depends on income, interest rates, and house prices. Firstly, income is thought to positively affect housing supply as it reflects the internal capacity of households and firms to finance new housing development. Secondly, interest rates are posited to negatively impact housing supply as they reflect the cost of external financing for new housing development. Thirdly, drawing on Kiyotaki and Moore (1997) and its application to the real estate market by Iacoviello (2005), we posit a financial accelerator mechanism linking housing prices to housing supply. This theoretically occurs since credit for real estate is typically collateralised by real estate itself, an increase in house prices raises the value of existing collateral, unlocking additional credit and thereby stimulating housing investment.

Based on these theoretical considerations, we propose that house prices in the Eurozone should be best modelled with a 4-variable system consisting of real house prices, real housing investment, the real interest rate, and real income. Additionally, since economic theory predicts a long-run equilibrium between house prices and their demand and supply fundamentals, with short-run deviations being corrected over time as housing markets adjust, a Vector Error Correction Model (VECM) is the natural modelling choice, as it captures both the long-run cointegrating relationship between variables and the short-run adjustment dynamics toward equilibrium.

3 Data

This section explains our operationalisation of the four theoretical variables and presents some stylised facts about their historical evolution. We include five indicators in our tests: real house prices (HPRR), real housing investment (HINR), real GDP per capita (Y2010PC), the nominal interest rate (IRN), and the real interest rate (IRR). The reason for the two interest rates is methodological issues explained in section 4, requiring a shift from the theoretically preferable real interest rate to the nominal interest rate so as to estimate the VECM.

We employ quarterly time series data from 1995Q1 to 2025Q3 across all variables. The reason for this period choice is data availability: quarterly OECD housing investment data is only available from 1995Q1 and quarterly BIS house price data until 2025Q3. While we lose 25 years compared to the 1970 start date of Gattini and Hiebert (2010), we add 16 years relative to their 2009 end date. Importantly, our new data allows us to investigate a much larger set of countries: where Gattini and Hiebert (2010) only have data on nine eurozone countries, our updated sample covers between 20 and 21 eurozone countries[1]. In summary, our paper has less observations than Gattini and Hiebert (2010) but expands upon their original analysis by including more recent data and more than twice the number of countries.

Our source data is nominal. In order to increase the validity of our results, we eliminate inflation-induced distortions by transforming every time series – save the nominal interest rate – into 2010 real terms. We do so by employing the consumption deflator provided by İpek and Kısacıkoğlu (2026) in their updated Area-Wide Model Database (AWMD). The reason for choosing this indicator rather than the broader GDP deflator is that household decisions about housing are ultimately made relative to other consumption goods – what matters is not the abstract price level in the entire economy, but on how much consumption a household gives up by committing resources to housing instead. This approach is consistent with Gattini and Hiebert (2010).

Afterwards, we follow Gattini and Hiebert (2010) in log-transforming the indicators. This is standard practice in time series modelling in order to remove larger variations in the data, i.e., to stabilise the variance of a time series (Lütkepohl & Xu, 2009). For real house prices, real housing

[1] As Bulgaria joined only recently on January 1, 2026, it is thus far only included in time series taken from the updated Area-Wide Model Database (AWMD) by İpek & Kısacıkoğlu (2026). While it would be ideal to have the same number of countries in every time series, the distortion should be negligible given Bulgaria's relatively small economic weight compared to the remaining 20 Eurozone economies.

investment, and real GDP per capita we do so by taking the natural logarithm ln(x). Yet, as ln(x) is undefined for negative numbers, it cannot be applied to our interest rate time series given historical negative rates. We thus log-transform the nominal and real interest rate using $\ln(1 + x/100)$.[2] This approach is, again, consistent with Gattini and Herbert (2010). In the following, we describe the five indicators in more detail.

Real house prices (HPRR). Eurozone house prices are based on the BIS residential property prices database. We employ the so-called selected residential property prices time series for the eurozone (BIS, 2026). It is a nominal index with 2010 as the base year, and subject neither to seasonal nor to calendar adjustment. We subsequently deflate it using the AWMD consumption deflator at 2010 prices (see Figure 1) and log-transform it.

Real housing investment (HINR). Eurozone housing investment is taken from the OECD quarterly gross fixed capital formation database (OECD, 2026). We use gross dwellings capital formation as our indicator, which is calendar and seasonally adjusted. The nominal data is deflated to 2010 prices using the AWMD consumption deflator (see Figure 1) and log-transformed.

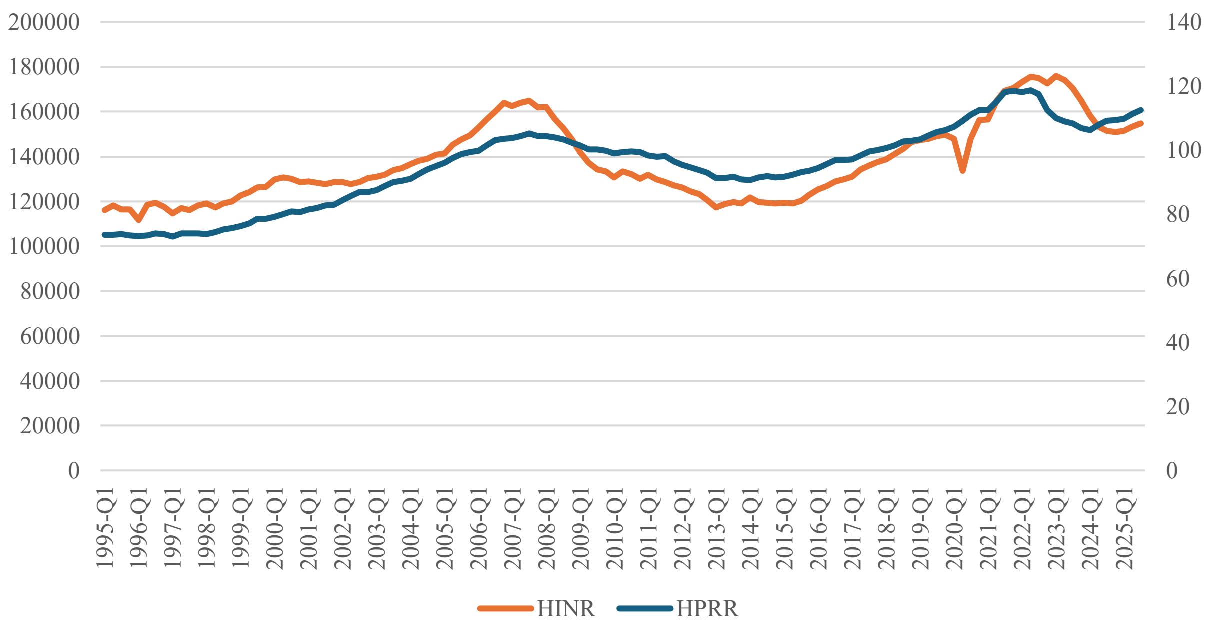

Figure 1: Eurozone Real House Prices (HPRR, right axis) and Housing Investment (HINR, left axis), 2010 Base, Quarterly, 1995Q1 to 2025Q3. Before log-transformation. Source: BIS (2026) and OECD (2026).

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[2] The division by 100 is necessary due to the expression of the source data interest rate in percentage points instead of decimals (e.g., 2 instead of 0.02).

Real GDP per capita (Y2010PC). We construct GDP per capita by dividing the AWMD calendar and seasonally adjusted eurozone GDP data (İpek & Kısacıkoğlu, 2026) by World Bank eurozone population data (World Bank, n.d.). The result is then, as before, transformed using the 2010 base year AWMD consumption deflator (see Figure 2) and natural logarithm.

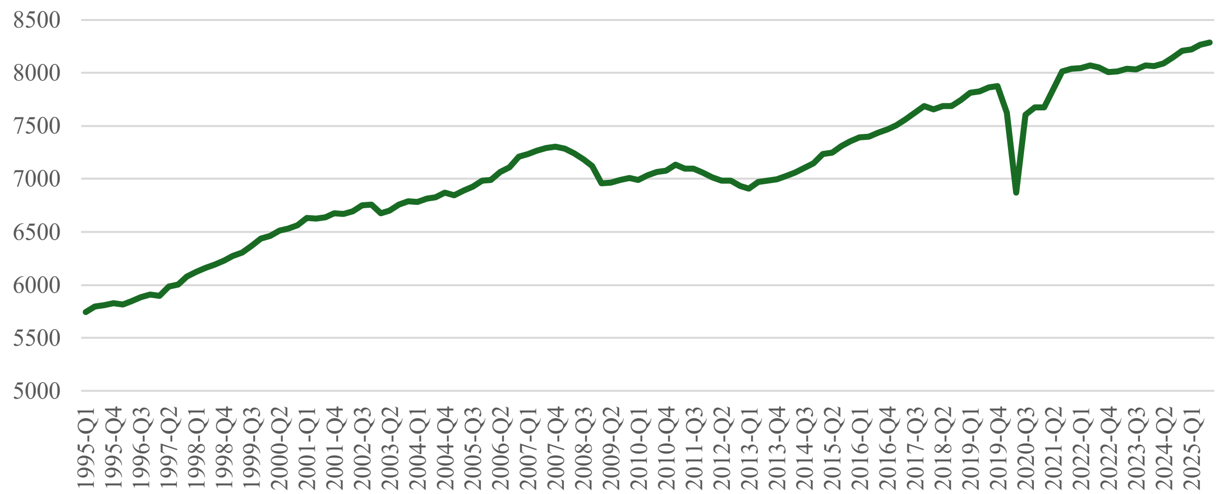

Figure 2: Eurozone Real GDP per Capita, 2010 Base, Quarterly, 1995Q1 to 2025Q3. Before log-transformation. Source: İpek & Kısacıkoğlu (2026).

Nominal interest rate (IRN). Following Gattini and Hiebert, we employ a mixed interest rate that contains both the short-term Euribor 3-month interest rate and the long-term average of eurozone ten-year bond yields from the AWMD dataset (İpek & Kısacıkoğlu, 2026). We obtain our mixed rate by calculating a dynamic weighted average between both rates, where we multiply the short-term rate by the share of variable rate loans in total loans for house purchase in each quarter (ECB, 2026) and the long-term rate by its complement. Our methodology thereby expands upon Gattini and Hiebert (2010), who assume a fixed share for the entire sample period. Our dynamic calculation captures more adequately what interest rate is decisive for housing purchases over time. In fact, one can see a strongly declining trend from the maximum value of 58% in 2004Q4 to 14% in 2025Q3 (see Figure 3) – demonstrating the necessity for a dynamic approach when modelling post-Global Financial Crisis (GFC) data. As the data for the weighting factor is only available from 2003, we use the sample average (29%) for quarters before that. The thereby obtained nominal interest rate (see Figure 4) is then log-transformed as described earlier.

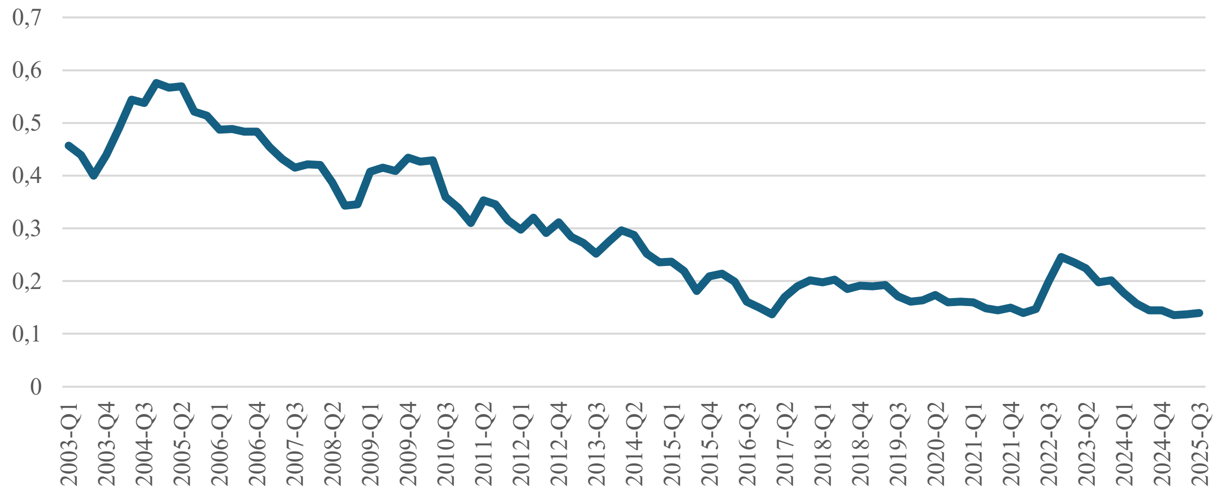

Figure 3: Eurozone Share of Variable Rate Loans in Total Loans for House Purchase, Quarterly, 2003Q1 to 2025Q3. Source: ECB (2026).

Real interest rate (IRR). In order to calculate the real interest rate, we deviate considerably from Gattini and Hiebert (2010). They assume that calculating ln(1 + x), with x as the nominal interest rate, automatically yields the real interest rate. We do not find this shortcut convincing and instead calculate the real interest rate via the Fisher equation, i.e., by subtracting the quarterly inflation rate – obtained by calculating period changes of the AWMD 2010 base year consumption deflator – from the quarterly nominal interest rate (see Figure 4). We then log-transform the resulting real interest rate following our aforementioned approach.

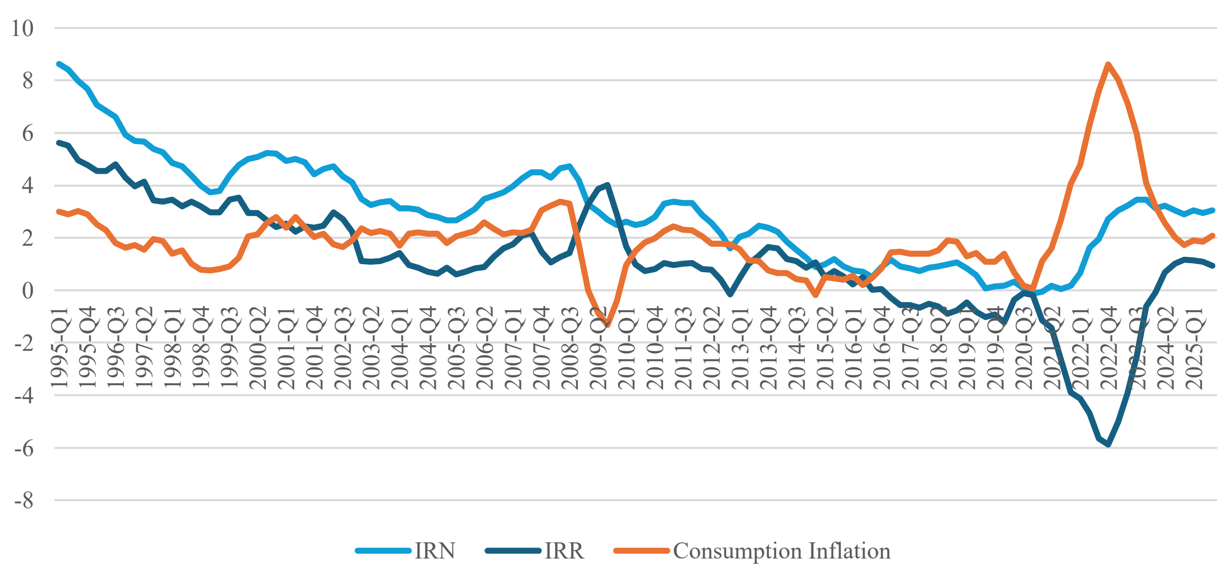

Figure 4: Eurozone Nominal Interest Rate (INN), Real Interest Rate (INR), and Consumption Inflation, 2010 Base where Applicable, Quarterly, 1995Q1 to 2025Q3. Before log-transformation. Source: İpek & Kısacıkoğlu (2026).

4 Model

This section outlines the VECM model used to estimate housing prices in the Eurozone. We continue by assessing the stationarity of the individual time series variables following the Holden and Perman (1994) procedure. Thereafter, we specify the VAR and VECM models using Johansen's (1988, 1995) procedure. Subsequently, we analyse the system's dynamics using static and dynamic forecasts, forecasting error variance decomposition, and identifying structural shocks via impulse response functions. Importantly, we always apply a 5% significance threshold, unless specified differently.

4.1 Unit Root Tests

Real housing prices (HPPR)

Real housing prices (HPPR) is suspected to have one unit root based on its correlograms: the level correlogram shows slowly decaying, persistent autocorrelations, while the correlogram in first differences cuts off abruptly with few significant lags (Annex A, Table 1; Annex A, Table 4). To test this suspicion, Holden and Perman (1994) prescribe a 7-step procedure.

In step 1, we estimate the optimal number of differenced lags to minimise residual correlation in the error term of the Augmented Dickey–Fuller (ADF) formula. Based on the Schwarz Information Criterion (SIC), 8 is the optimal amount of differenced lags (Annex A, Table 2). We confirm this by analysing the residual correlogram of the ADF with 8 lags, which shows no significant (partial) autocorrelation up to lag 20, and the Ljung-Box test fails to reject H0 at all lags, confirming that no significant autocorrelation remains in the residuals (Annex A, Table 3). In essence, the residuals look like white noise.

In step 2, we jointly test the presence of a unit root and a zero trend in the specified ADF formula. The resulting F statistic is below the critical threshold in absolute terms, meaning that we accept the null hypothesis of a unit root without deterministic trend (Table 1). The presence of a drift component cannot be ruled out at this stage.

Proceeding to step 5, we corroborate the presence of a unit root by testing it individually, assuming no deterministic trend as suggested by step 2, thereby increasing statistical power. The resulting T-statistic is below the critical threshold, leading us to accept the null-hypothesis that the series has a unit root (Table 1). Thereafter, in step 6, we examine whether a constant belongs in the specification by jointly testing a unit root, a drift, and a deterministic trend, assuming the presence of a unit root and absence of a trend. The resulting F-statistic leads us accept H0, suggesting the series is a pure random walk without drift (Table 1).

In step 7, we verify this conclusion by estimating the restricted ADF without trend or drift, which implies greater power. The output yields an F-stat below the relevant threshold, confirming the series is at least I(1) without drift and no deterministic trend (Table 1). Nevertheless, to exclude the possibility of an I(2) process, the procedure must be repeated on the first differenced series.

First differenced real housing prices seem stationary when analysing the correlogram, the autocorrelations drop off after lag 5, and show no persistent pattern (Annex A, Table 4) However, to confirm this, we continue with the Holden and Perman (1994) procedure. In step 1, we find that 5 is the optimal number of differenced lags to include to ensure white noise in the residuals based on the SIC (Annex A, Table 5). This seems to be corroborated by the residual correlogram of the specified ADF formula with no significant (partial) autocorrelation or Q-stat up to lag 20 (Annex A, Table 6).

In step 2, we perform the joint test of a unit root, and no deterministic trend present in the specifed formula. As expected, we reject the null hypothesis, implying stationarity (Table 1). Importantly, at this stage we only ruled the case of a unit root, and no trend. As such, in step 3 we test whether the process has a unit root and a trend, no unit root and no trend, or a trend and a unit root. We do so by simply testing individually for the presence of a unit root. Using the conventional critical values, the resulting T-stat leads us to reject the null hypothesis of there being a unit root present, implying that we are in the case of no unit root, with or without a drift (Table 1).

Finally, to choose between the two remaining options, in step 4 we test whether there is a trend present using conventional critical values. The resulting T-statistic leads us to accept the null-hypothesis of no deterministic trend in the series (Table 1). As such, we confirm that differenced housing prices is stationary without a trend. More importantly, we affirm that housing prices is an I(1) process.

Table 1: Holden-Perman Procedure Real House Prices (HPRR)

	HPRR			ΔHPRR		
Step	**Levels t/F stat**	**Critical Value**	**H0**	**I(1) t/F stat**	**Critical Value**	**H0**
2	4.10 (F)	6.49	Accept	9.59 (F)	6.49	Reject
3	N/A	±1.96	N/A	-4.38 (t)	±1.96	Reject
4	N/A	±1.96	N/A	-0.76 (t)	±1.96	Accept
5	-2.65 (t)	-3.45	Accept	N/A	-3.45	N/A
6	3.48 (F)	4.88	Accept	N/A	4.88	N/A
7	3.55 (F)	4.71	Accept	N/A	4.71	N/A

Note: We apply 5% significance levels throughout. The corresponding hypothesis testing outputs can be found in Appendix A, Tables 7-13.

Real housing investment (HINR)

Real housing investment (HINR) is thought to have one unit root based on its correlograms, seen as the correlogram slows slowly decaying autocorrelations (Annex A, Table 14). To test this suspicion, we proceed with the Holden and Perman (1994) procedure.

In step 1, we select 3 lags in the ADF specification based on the SIC and confirm that the resulting residuals are approximately white noise using standard residual diagnostics (Annex A, Table 15). Specifically, the residual correlogram shows no significant (partial) autocorrelations, and the Q-stat is high enough at each lag to accept the Ljung-Box null-hypothesis of no significant autocorrelation in the residuals (Annex A, Table 16).

In step 2, we jointly test the null of a unit root and a zero trend in the ADF regression. Based on the resulting F-statistic, we do not reject H0, implying that the data is consistent with a unit root process without a deterministic trend (Table 2).

Continuing step 5, we test for the presence of at least one unit root conditional on the preferred specification identified in step 2, where no deterministic trend is retained. The results affirm the presence of at least one unit root (Table 2). Thereafter, in step 6, we jointly test the presence of a constant, a trend, and a unit root. The results indicate that the series is consistent with a random walk process without a deterministic trend, and without a drift term (Table 2).

Lastly, in step 7, we confirm the presence of at least one unit root by estimating the appropriate ADF specification without a trend or drift to increase statistical power. The results indicate that HINR follows a random walk (integrated at least of order one) without drift (Table 2). However, to assess whether the series is integrated of an order higher than one, we must repeat the same testing sequence on HINR(1).

First differenced real housing investment (HINR(1)) seems stationary based on its correlogram, which has only a few significant lags (Annex A, Table 17). In step 1 of the procedure, we construct the first difference of the series and estimate the ADF specification with trend and intercept. Based on lag selection using the SIC, we include 2 lagged differences, which is enough to obtain white noise in the residuals (Annex A, Table 18; Annex A, Table 19).

Secondly, in step 2, we jointly test the null hypothesis of a unit root and a zero trend in the series. Based on the results, we reject H0, implying that the series does not have a unit root (Table 2). Continuing to step 3, we directly test for the presence of a unit root under using standard normal critical values. The results lead us to reject the null of a unit root (Table 2). In step 4, we test for the presence of a deterministic trend, which is not found (Table 2).

Overall, the results indicate that HINR(1) is stationary and does not contain a unit root or deterministic trend. This result confirms that the original series HINR is integrated of order one, I(1), as first differencing is sufficient to achieve stationarity.

Table 2: Holden-Perman Procedure Real Housing Investment (HINR)

	HINR			**ΔHINR**		
Step	**Levels t/F stat**	**Critical Value**	**H0**	**I(1) t/F stat**	**Critical Value**	**H0**
2	2.52 (F)	6.49	Accept	8.44 (F)	6.49	Reject
3	N/A	±1.96	N/A	-4.11 (t)	±1.96	Reject
4	N/A	±1.96	N/A	-0.20 (t)	±1.96	Accept
5	-2.24 (t)	-3.45	Accept	N/A	-3.45	N/A
6	1.84 (F)	4.88	Accept	N/A	4.88	N/A
7	2.07 (F)	4.71	Accept	N/A	4.71	N/A

Note: We apply 5% significance levels throughout. The corresponding hypothesis testing outputs can be found in Appendix A, Table 20-26.

Real interest rate (INR)

Real interest rate is suspected to be a process with a unit root, based on the correlogram showing a slow decay of autocorrelations (Annex A, Table 27). In the first step of the Holden and Perman (1994) procedure, we find that including 1 lag in the ADF equation elimates residual correlation according to the SIC (Annex A, Table 28). Analysing the residual correlogram confirms that the residuals are approximately white noise, even though one autocorrelation and partial autocorrelation seem significant at lag 4 and 3 respectively, the Ljung-Box test indicates serial correlation only at lag 4 when including 20 lags (Annex A, Table 29).

In step 2, we jointly test the null of a unit root and a zero trend in the ADF regression. Somewhat surprisingly, the resulting F-stat is higher than its corresponding critical value, leading us to reject the null of the process having both unit root and no deterministic trend (Table 3). Having only ruled out the case of a unit root, and no trend, in step 3 we individually test for a unit root using standard critical values. The resulting T-statistic is above the critical value, meaning that we must reject the null hypothesis of there being a unit root present (Table 3).

In step 4, we individually test the presence of a deterministic trend, using conventional critical values. The resulting T-statistic leads us to reject the null that there is no trend present (Table 3). Based on these tests, we conclude that the real interest rate is a stationary process evolving around a deterministic trend.

Table 3: Holden-Perman Procedure Real Interest Rate (IRR)

	IRR			**ΔIRR**		
Step	**Levels t/F stat**	**Critical Value**	**H0**	**I(1) t/F stat**	**Critical Value**	**H0**
2	7.06 (F)	6.49	Reject	N/A	6.49	N/A
3	-3.67 (t)	±1.96	Reject	N/A	±1.96	N/A
4	-2.53 (t)	±1.96	Reject	N/A	±1.96	N/A

Note: We apply 5% significance levels throughout. The corresponding hypothesis testing outputs can be found in Appendix A, Tables 30-32.

Nominal interest rate (IRN)

The correlogram of the nominal interest rate indicates there could be a unit root in the series, seen as the autocorrelations show high persistence (Annex A, Table 33). In step 1 of the Holden and Perman (1994) procedure, based on the SIC, we estimate that 1 differenced lag is necessary to ensure there is no serial correlation in the error term (Annex A, Table 34; Annex A, Table 35). In step 2, we jointly test the null hypothesis of a unit root with no deterministic trend in the series. The resulting F-statistic is below the critical threshold, leading us to accept the null hypothesis (Table 4).

In step 5 we verify this finding, by individually testing the presence of a unit root assuming no deterministic trend, leading to higher power. Results indicate there is indeed a unit root present (Table 4). To test whether the series has drift, in step 6 we jointly test for a constant, assuming a unit root and no trend. The output indicates that the series has no drift (Table 4).

Lastly, in step 7, we confirm the described non-stationary process without a drift or trend, by estimating the second Dickey Fuller equation, omitting the trend. We test the null that the series has a unit root and no drift. Indeed, the resulting F-statistic is below the relevant threshold, meaning that the nominal interest rate is a random walk without drift (Table 4). However, to rule out that it is an I(2) process, we must test the stationarity of the differenced nominal interest rate.

First differenced nominal interest rate appears stationary based on its correlogram, which shows rapidly decaying autocorrelations (Annex A, Table 36). In step 1 of the Holden and Perman (1994) procedure, we construct the first difference of the series and estimate the ADF specification with trend and intercept. Based on the SIC, no lagged differences need to be included to obtain white-noise residuals (Annex A, Table 37). The residual correlogram confirms this, as there is no significant Ljung-box test result at any lag (Annex A, Table 38).

In step 2, we jointly test the null of a unit root and zero trend. The resulting F-statistic exceeds the critical threshold, leading us to reject H0 (Table 4). Proceeding to step 3, we directly test a unit root using standard normal critical values and again reject the null (Table 4). In step 4, we test for a deterministic trend, which is not found (Table 4).

Overall, the results confirm that the first differenced nominal interest rate is stationary, implying that the original series IRN is integrated of order one, I(1).

Table 4: Holden-Perman Procedure Nominal Interest Rate (IRN)

	IRN			ΔIRN		
Step	**Levels t/F stat**	**Critical Value**	**H0**	**I(1) t/F stat**	**Critical Value**	**H0**
2	4.45 (F)	6.49	Accept	22.75 (F)	6.49	Reject
3	N/A	±1.96	N/A	-6.75 (t)	±1.96	Reject
4	N/A	±1.96	N/A	1.72 (t)	±1.96	Accept
5	-2.41 (t)	-3.45	Accept	N/A	-3.45	N/A
6	3.24 (F)	4.88	Accept	N/A	4.88	N/A
7	4.53 (F)	4.71	Accept	N/A	4.71	N/A

Note: We apply 5% significance levels throughout. The corresponding hypothesis testing outputs can be found in Appendix A, Tables 39-45.

Real GDP per capita

Real GDP per capita seems non-stationary based on the correlogram (Annex A, Table 46). To test this, we first specify the ADF formula with 1 differenced lag to minimise residual correlation according to the SIC (Annex A, Table 47). This is corroborated by the formula's residual correlogram showing no significant (partial) autocorrelation or significant Q-statistic up until lag 20 (Annex A, Table 48). Proceeding to step 2, we jointly test the null hypothesis that the specified ADF contains a unit root and no trend. The resulting F-statistic is below the critical threshold, indicating that the series follows a non-stationary process (Table 5). Based on this result, in step 5 we individually test for the presence of a unit root with increased power, restricting the trend to 0. Indeed, the output confirms that there is a unit root in the series (Table 5).

In step 6, we determine whether there is a constant, by jointly testing for a unit root, no trend, and no constant, already having tested for the latter two, it effectively only tests the constant. The results indicate that there is no drift present (Table 5). Lastly, to confirm this structure, we specify the series in the second Dickey Fuller formula, without trend, and test for a unit root and no drift. The resulting F-stat is below the relevant threshold, confirming that real GDP per capita is at least an I(1) process (Table 5)

To rule out the presence of two unit roots, we apply the procedure on first differenced real gdp per capita. Judging by the correlogram, the series seems to be stationary, with only 1 significant autocorrelation, and only 2 significant Q-stats at lag 1 and 2, when considering up to lag 20 (Annex A, Table 49). Firstly, the SIC suggests that 0 differenced lags need to be included to ensure white noise residuals, this is corroborated by the residual correlogram of the specified formula (Annex A, Table 50; Annex A, Table 51). As expected, in step 2, when jointly testing the null of a unit root and no trend, the F-stat is well over the critical value, and we can confidently reject the null (Table 5). Individually testing for the presence of a unit root in step 3 confirms this finding (Table 5). Lastly, we test for the presence of a trend. The resulting T-stat indicates there is no trend. As such, differenced real GDP per capita is stationary. More importantly, this confirms the suspicion that real GDP per capita is an I(1) process.

Table 5: Holden-Perman Procedure Real GDP per Capita (Y2010PC)

	Y2010PC			**ΔY2010PC**		
Step	**Levels t/F stat**	**Critical Value**	**H0**	**I(1) t/F stat**	**Critical Value**	**H0**
2	4.92 (F)	6.49	Accept	84.84 (F)	6.49	Reject
3	N/A	±1.96	N/A	-13.03 (t)	±1.96	Reject
4	N/A	±1.96	N/A	-0.50 (t)	±1.96	Accept
5	-3.10 (t)	-3.45	Accept	N/A	-3.45	N/A
6	5.06 (F)	4.88	Reject	N/A	4.88	N/A
7	3.55 (F)	4.71	Accept	N/A	4.71	N/A

Note: We apply 5% significance levels throughout. The corresponding hypothesis testing outputs can be found in Appendix A, Tables 52-58).

Based on the aforementioned Holden and Perman (1994) procedures performed, we can conclude that real housing prices, real housing investment, nominal interest rate, and real GDP per capita are processes integrated of order 1, while real interest rate is stationary. This has important implications for the VAR and VECM model we will propose, which will be discussed in the following section.

4.2 Model Specification

In this section, we specify a preliminary VAR, an unrestricted VECM, and a restricted VECM. We also test all major assumptions through robustness checks.

Following Gattini and Hiebert (2010), the theoretical framework calls for real house prices (HPRR), real housing investment (HINR), real GDP per capita (Y2010PC), and the real interest rate as the four variables of the system. Importantly, a VECM requires all time series to be I(1). However, our unit root analysis shows that while HPRR, HINR, and Y2010PC are all I(1), the real interest rate (IRR) is I(0) in our sample period 1995Q1 to 2025Q3. We therefore replace the real interest rate with the nominal interest rate (IRN), which our unit root tests confirm to be I(1).

While an extensive discussion lies beyond the scope of this paper, the stationarity of the real interest rate could be attributed to ECB efforts to keep it fluctuating – depending on business cycle dynamics – in a reasonable policy interval. The non-stationarity of the nominal interest rate might be caused by what is often referred to as the Global Savings Glut, i.e., an excess of global savings over investment (Bernanke, 2005). This has been argued to induce a strong downwards trend on the long-run natural interest rate r* since the 1990s (Del Negro et al., 2017). Relatedly, there is a considerable body of evidence that a potentially excess savings-fuelled global demand for US safe assets is responsible for the declining US nominal rate (Arora et al., 2014; Bertaut et al., 2012; Warnock & Warnock, 2009). The global financial cycle could reasonably have propagated this development to European nominal rates (Miranda-Agrippino & Rey, 2021), potentially causing their secular decline.

Yet, r* is often described as a real, inflation-adjusted, rate (Borio et al., 2019) – following the argument above, one would hence expect the real interest rate to be non-stationary as well. Moreover, it is important to note that the evolutions of the nominal and real rate in Figure 4 are quite similar, except for periods following Russia's invasion of Ukraine (from 2022Q1). It might just be that this latter – very idiosyncratic – disturbance is the cause of the divergence of both rates with regard to stationarity. But estimations excluding this recent episode did not yield different results. Hence, we seem to have found a puzzle on which no judgment can be made at this point.

While the nominal rate is a less precise proxy for financing costs than its real counterpart – as it does not account for the erosion of purchasing power – it nonetheless captures the primary driver of borrowing costs faced by households in the housing market. Given that our nominal interest rate is conceptually equivalent to Gattini and Hiebert's (2010) real interest rate (see section 3), we a priori do not expect this to cause large ceteris paribus deviations from their results.

Our preliminary VAR model can be written as follows:

$$\mathbf{X}_{\mathrm{t}} - \sum_{\mathrm{j}=1}^{8} \mathbf{\Phi}_{\mathrm{j}} \mathbf{X}_{\mathrm{t-j}} = \boldsymbol{\mu} + \boldsymbol{\varepsilon}_{\mathrm{t}}$$

$$\Leftrightarrow \qquad \mathbf{\Phi}(\mathrm{L})\mathbf{X}_{\mathrm{t}} = \boldsymbol{\mu} + \boldsymbol{\varepsilon}_{\mathrm{t}}$$

Equation 1: Preliminary VAR Model Specification

where $\mathbf{X}_{\mathrm{t}} = (\mathrm{HPRR}_{\mathrm{t}}, \mathrm{HINR}_{\mathrm{t}}, \mathrm{IRN}_{\mathrm{t}}, \mathrm{Y2010PC}_{\mathrm{t}})'$ is a 4×1 vector of time series variables for quarters $\mathrm{t} = 1995\mathrm{Q}1, \dots, 2025\mathrm{Q}3$, $\mathbf{\Phi}_{\mathrm{j}}$ are 4×4 coefficient matrices capturing the dynamic relationships among variables at each lag $\mathrm{j} = 1, \dots, 8$, $\boldsymbol{\mu}$ is a 4×1 vector of constants, and $\boldsymbol{\varepsilon}_{\mathrm{t}}$ is a 4×1 vector of white noise innovations with zero mean $\mathrm{E}(\boldsymbol{\varepsilon}_{\mathrm{t}}) = 0$, positive definite covariance matrix $\mathrm{Var}(\boldsymbol{\varepsilon}_{\mathrm{t}}) = \Sigma$, and no serial correlation such that $\mathrm{Cov}(\boldsymbol{\varepsilon}_{\mathrm{t}}, \boldsymbol{\varepsilon}_{\mathrm{t+h}}) = 0$ for all t and $\mathrm{h} \neq 0$.

We select eight lags (j=8) for multiple reasons. Firstly – and most importantly – it is the lowest lag specification to yield fully white noise residuals, with a non-rejection of the null of no serial correlation at lag j for the entire interval 1≤j≤12 at the 5% significance level (Annex B, Table 1). Secondly, when conducting lag exclusion tests, i.e., testing the null of zero predictive power of all variables at any given lag, the eighth lag is still significant at the 5% significance level (Annex B, Table 2). It thus cannot be ruled out that j=8 still holds predictive power for any given t. Thirdly, while the SC and HQ criteria regard j=2 as the most efficient specification, the LR, FPE, and AIC criteria prefer j=7, j=10, and j=11, respectively (Annex B, Table 3). Notably, three out of five criteria point toward substantially longer lag lengths, suggesting that j=8 is likely too short to capture the full dynamics of the system. In light of the ambiguity among criteria, the residual diagnostic takes precedence as the binding constraint, and j=8 represents the most parsimonious specification consistent with white noise residuals.

Eight lags are admittedly a lot and, given that each lag adds four coefficients to each of the four equations, lags account for 8×4×4=128 out of 132 estimated parameters across the system in total (the latter also includes the four equation-specific constants). However, since each equation is estimated individually by OLS on 123 observations with 33 regressors (8×4=32 lags plus one coefficient), each equation retains 90 degrees of freedom, which we consider sufficient for reliable estimation. Anything beyond eight lags, however, seems unreasonable considering both the degrees of freedom costs associated with it and the fact that white noise residuals are already achieved at that lag length.

Yet, there is also a theoretical argument in favour of a larger number of lags. Based on the SIC lag length tests conducted in the ADF tests for the individual time series in section 4.1, it is likely that house prices (8 optimal individual lags) drive the long VAR lag length. Since housing supply is inelastic due to the time it takes to plan, approve, and construct real estate, house prices can deviate from their long-term equilibrium as prescribed by more quickly changing fundamentals for longer episodes. It is thus not surprising that house prices might exhibit significant autocorrelation for up to two years – in fact, one could argue that this reflects exactly the type of path dependencies that also drive bubbles (ECB, 2003).

Importantly, since $\mathbf{X}_t$ is non-stationary in levels, the roots of the characteristic polynomial $\mathrm{Det}[\mathbf{\Phi}(\mathrm{L})] = 0$ in equation 1 are *not* of modulus strictly greater than one. Hence, the conditions for calculating a correctly specified VAR are not fulfilled. Moreover, the VAR specification is unable to account for the long-run equilibrium relationships theorised in section 2. This is demonstrated when displaying the inverse roots of the characteristic polynomial: several inverse roots lie on or near the unit circle, indicating non-stationarity and pointing towards one or more cointegrating relationships among the variables (Annex B, Table 1). In the following, we therefore specify a VECM which explicitly accounts for the unit roots and the long-run cointegrating relationships among the variables.

A VECM rests on three assumptions: 1) the roots of the characteristic polynomial are either equal to one or of modulus strictly greater than one, 2) its long-run parameter matrix Π has reduced rank $0 < \mathrm{rank}(\Pi) = r < n$ with $n = 4$ variables, and 3) the system contains no variables integrated of order greater than one (Johansen, 1988, 1995). Assumptions 1) and 3) have been confirmed by our unit root tests in section 4.1. In order to verify assumption 2), we now determine the rank of the matrix Π – and thereby the number of cointegration relationships – using Johansen tests.

We first conduct Johansen (1988, 1995) tests at the 5% significance level. The results, however, are ambiguous: while the Trace test indicates two cointegrating equations, the max-eigenvalue test points towards only one (Annex B, Table 4). In order to obtain a clearer picture, we re-do the tests at the 1% significance level. Now, both tests support the existence of only one cointegrating equation (Annex B, Table 5). This is consistent with the theoretical expectation of one long-run housing market equilibrium based on fundamentals.

As such, we estimate a VAR with one cointegration relation that we refer to as our unrestricted (since all variables are treated as endogenous) VECM from now on. It can be written as follows:

$$\Delta\mathbf{X}_t = \sum_{j=1}^{7} \mathbf{\Gamma}_j \Delta\mathbf{X}_{t-j} + \mathbf{\Pi}\mathbf{X}_{t-1} + \boldsymbol{\psi}D_t + \boldsymbol{\varepsilon}_t$$

Equation 2: Unrestricted VECM Model Specification

where $\Delta\mathbf{X}_t = (\Delta HPRR_t, \Delta HINR_t, \Delta IRN_t, \Delta Y2010PC_t)'$ is a 4×1 vector of first-differenced time series variables for quarters $t = 1995Q1, \dots, 2025Q3$, $\mathbf{\Gamma}_j$ are 4×4 short-run coefficient matrices capturing the transitory dynamic relationships among variables at each lag $j = 1, \dots, 7$, $\mathbf{\Pi}$ is a 4×4 long-run parameter matrix of reduced rank $r = 1$, with $\mathbf{\Pi}\mathbf{X}_{t-1}$ representing the error correction term (the extent to which the system deviated from its long-run equilibrium in the previous period and to which it subsequently adjusts), $\boldsymbol{\psi}$ is a 4×1 vector of coefficients on D_t which represents the deterministic constant, and $\boldsymbol{\varepsilon}_t$ is a 4×1 vector of white noise innovations with zero mean $E(\boldsymbol{\varepsilon}_t) = 0$, positive definite covariance matrix $Var(\boldsymbol{\varepsilon}_t) = \Sigma$, and no serial correlation such that $Cov(\boldsymbol{\varepsilon}_t, \boldsymbol{\varepsilon}_{t+h}) = 0$ for all t and $h \neq 0$.

The reason for the equation to be in first differences is to render the left-hand side of the equation stationary. As a result, the 8 level lags of the VAR are transformed into 8–1=7 first difference lags. The addition of the error correction term $\mathbf{\Pi}\mathbf{X}_{t-1}$ in turn makes the right-hand side of the equation stationary and models the long-run equilibrium theorised in section 2.

In the above model, we do not impose any restrictions beyond normalising the long-run coefficient of $HPRR_{t-1}$ to one in the cointegrating vector. This is standard practice with one cointegration relation in order to identify the long-run parameters clearly and thus be able to interpret estimated coefficients. Interestingly, only the long-run coefficient of $HPRR_{t-1}$ is significant at the 5% level – indicating that the fundamentals do not respond to deviations from the long-run housing market equilibrium (Annex B, Table 6). This provides preliminary evidence in favour of the weak exogeneity of $HINR_t$, IRN_t, and $Y2010PC_t$, which we formally test in the following.

Continuing, we impose three additional restrictions on what we from now on refer to as the restricted VECM. Concretely, this means that we treat $HINR_t$, IRN_t, and $Y2010PC_t$ as weakly exogenous variables. This is consistent with our theoretical framework in section , which regards these variables as fundamental drivers of $HPRR_t$ rather than as variables that adjust to restore equilibrium. If confirmed in testing, this step would not only support the aforementioned theory but also reduce the number of estimated parameters, improving the precision of the remaining estimates. The resulting restricted model can be written as:

$$\begin{pmatrix} \Delta Y_t \\ \Delta \mathbf{Z}_t \end{pmatrix} = \sum_{j=1}^{7} \begin{pmatrix} \Gamma_{YY,j} & \Gamma_{YZ,j} \\ \Gamma_{ZY,j} & \Gamma_{ZZ,j} \end{pmatrix} \begin{pmatrix} \Delta Y_{t-j} \\ \Delta \mathbf{Z}_{t-j} \end{pmatrix} + \begin{pmatrix} \Pi_Y \\ 0 \end{pmatrix} \mathbf{X}_{t-1} + \begin{pmatrix} \psi_Y \\ \psi_Z \end{pmatrix} D_t + \begin{pmatrix} \varepsilon_{Y,t} \\ \varepsilon_{Z,t} \end{pmatrix}$$

Equation 3: Restricted VECM Model Specification

where $Y_t = HPRR_t$ is the scalar endogenous variable, $\mathbf{Z}_t = (HINR_t, IRN_t, Y2010PC_t)'$ is the 3×1 vector of weakly exogenous variables, and $\mathbf{X}_t = (Y_t, \mathbf{Z}_t)'$ is the full 4×1 vector of time series variables for quarters $t = 1995Q1, \dots, 2025Q3$. Note that the weak exogeneity restrictions on $\mathbf{Z}_t$ are reflected in that the short-run coefficients Γ remain unrestricted for both Y_t and $\mathbf{Z}_t$, while the long-run coefficient is unrestricted only for Y_t. The rest is as in the unrestricted VECM.

The null hypothesis that $\mathbf{Z}_t$ is weakly exogenous cannot be rejected at the 5% significance level. The error correction term – which now only enters via Y_t – is also significant at the 5% level with a t-statistic of -5.45. This is higher than the -4.90 before imposing the restrictions, meaning that we have indeed improved the precision of our estimates (Annex B, Table 6, Annex B, Table 7).

The combined evidence supports our theoretical expectation that $HINR_t$, IRN_t, and $Y2010PC_t$, are weakly exogenous. Moreover, the restricted model can be transformed into a univariate equation to make various forecasts for the endogenous variable $HPRR_t$, which is done in the next section.

4.3 Forecasts, Error Variance Decomposition and Impulse Response Functions

This section describes the methodology and model specifications applied to analyse the model's dynamics. Firstly, we propose a conditional model, reduced to a single equation to preform static and dynamic forecasts. Secondly, we perform a forecast error variance decomposition to rank the variable from most exogenous to most endogenous. Lastly, we describe how we use this ordering to simulate exogenous shocks to the model and analyse their effects with impulse response functions. Importantly, the individual results will be presented in the results section.

Static and Dynamic Forecasts

Having established that real housing investment, the nominal interest rate, and real GDP per capita can be modeled as weakly exogenous, we can reasonably proceed with the one dimensional model of real house prices without sacrificing significant information. Based on the VECM model specified above, the unidimensional model proposed takes the following form:

$$\Delta log(HPRR)_t = \hat{\alpha}(log(HPRR)_{t-1} - 0.4002 \cdot log(HINR)_{t-1} + 0.8984 \cdot log(IRN)_{t-1} - 0.6637 \cdot log(Y2010PC)_{t-1} + 5.9924)$$
$$+ \Sigma^{8}_{i=1}\, \hat{\beta}_i \Delta log(HPRR)_{t-i} + \Sigma^{8}_{i=1}\, \hat{\gamma}_i \Delta log(HINR)_{t-i}$$
$$+ \Sigma^{8}_{i=1}\, \hat{\delta}_i \Delta log(IRN)_{t-i} + \Sigma^{8}_{i=1}\, \hat{\theta}_i \Delta log(Y2010PC)_{t-i} + \varepsilon_t$$

Equation 4: Univariate Restricted VECM Model Specification

where $\hat{\alpha}$ is the estimated error correction coefficient (-0.087) (Appendix), the term in parentheses is the estimated cointegrating relationship (long-run equilibrium), and $\hat{\beta}_i$, $\hat{\gamma}_i$, $\hat{\delta}_i$, and $\hat{\theta}_i$ capture the short-run dynamics of real housing prices, real housing investment, the nominal interest rate, and the real GDP per capita, respectively, for i = 1, …, 8. The corresponding coefficients can be found in Appendix

While some of the coefficients were not significant, this model is the best way to proceed to perform forecasts??

Error Variance Decomposition

To analyse the effects of exogenous shocks on the model using the Cholesky method, we must first determine the order of exogeneity of the variables. To this end, we employ forecast error variance decomposition. By doing so, we can determine how much of the variance in different variables can be explained by each variable. The most exogenous variable is the most explained by itself in this system.

The results clearly show that the forecast error variance of real GDP per capita is explained 100% by its own shocks in period 1 and remains strongly explained by itself over the entire time horizon considered (Figure 5). A similar thing, albeit to a lesser extent, can be said for the nominal interest rate, which explains 99.9% of its own forecasted variance in the first period, remaining relatively important throughout the entire horizon considered. Real house prices and real housing investment are more ambiguous. Real house prices explain themselves most in the short run, while real housing investment mostly seems to be determined by real GDP per capita in the short run, and only considerably starts explaining itself after a few quarters. However, based on the overall importance of the variables in the entire period considered, we suggest real housing investment is the more exogenous one, followed by real housing prices. Substantively, this means that the most exogenous variable is real GDP per capita, followed by the nominal interest rate, real housing prices, and lastly, real housing investment.

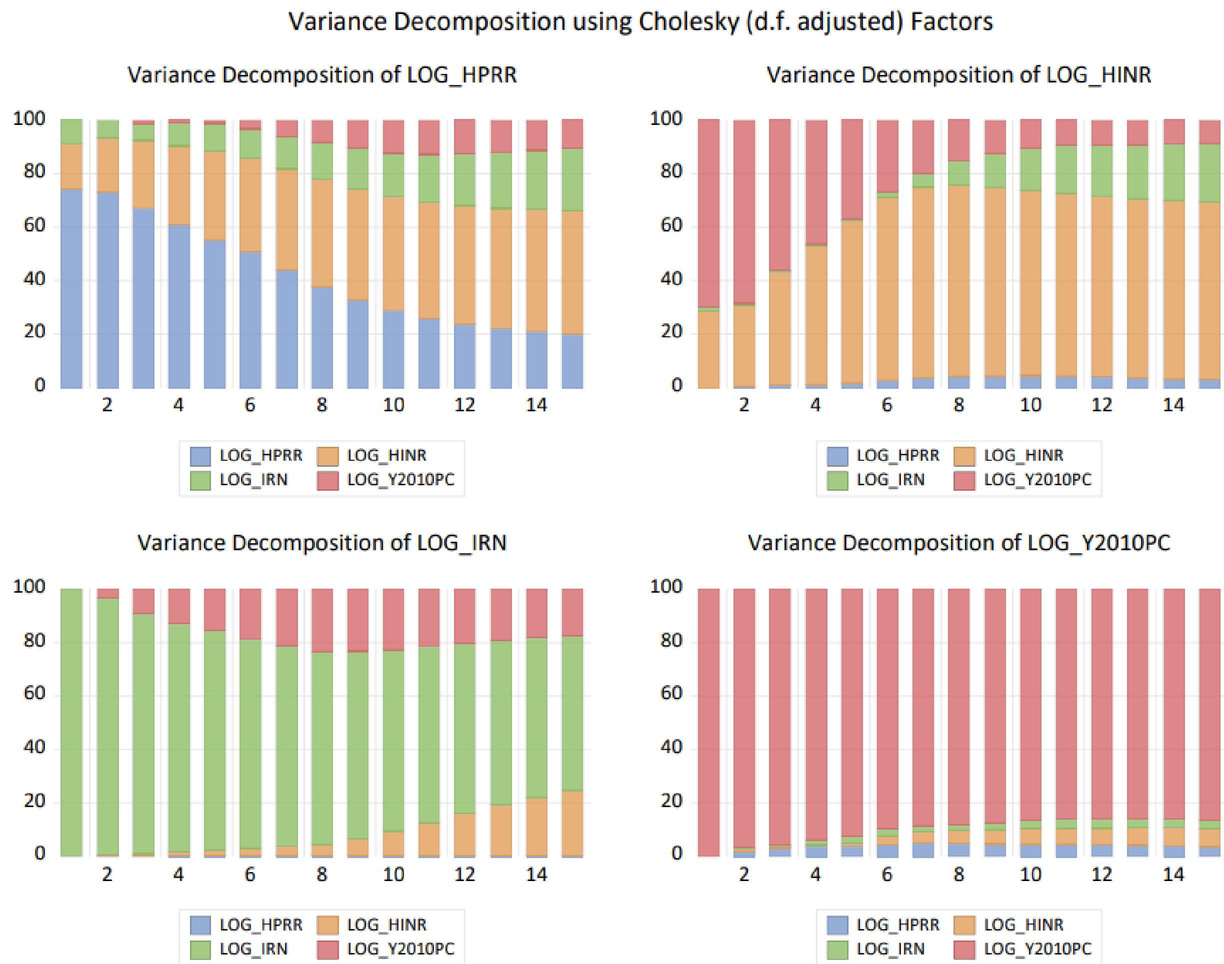

Figure 5: Cholesky Forecast Variance Decompositions

These results align well with our theoretical framework. Real GDP per capita explaining nearly all of its own forecast error variance is consistent with it being a broad macroeconomic fundamental, largely insulated from housing market developments in the short run. Similarly, the nominal interest rate explaining a large part of its own forecasted variance reflects its independence of housing market fluctuations, as the central bank adjusts it in response to developments in the economy at large. Real housing investment seems to be largely guided by income in the short run, potentially reflecting increased internal financing for housing investment, or suppliers anticipating increased demand for housing. Past the 1-year marker, investment is mostly explained by itself, potentially reflecting the long-run persistence of investment cycles and the role of expectations in capital formation. Lastly, housing prices in the short run seem to be substantially driven by house prices themselves, potentially reflecting a financial accelerator mechanism or the general short run persistence and stickiness of housing prices found in the literature. Past the 1,5-year marker, forecast error variance in housing prices seems better explained by real housing investment, and the interest rate, reflecting its responsiveness to fundamentals. All in all, the current ordering positioning housing prices as the final adjusting endogenous variable broadly aligns with theoretical expectations.

Impulse response functions

Impulse response functions essentially simulate the effects over time of a one-time shock to the innovation of any variable, keeping all else constant. Knowing the order of exogeneity of the variables in the model, we can estimate the effects over time of external shocks to the real interest rate, real housing investment, and real GDP per capita. This allows us to asses the magnitude, direction and persistance of different shocks over time.

5 Results

This section describes the results of the VECM model. Firstly, we discuss the coefficients and corresponding substantive meanings of the final VECM model. Subsequently, we analyse the models dynamics by presenting static and dynamic forecasts of the real housing prices in the Eurozone. Thereafter, we show the results from the impulse response functions, in which we shock the innovations of an individual variable, and see how it reverberates trough the system over time.

VECM model

The VECM model specified in section 4.2 forms the backbone of this study. The results have important implications for the short-term and long-term dynamics of the real housing prices in the Eurozone. Table 6 reports on the coefficients from the VECM model, interpreting the coefficients substantively shows that in the long-term dynamics, after accounting for normalisation, real housing investment positively affects real housing prices (coefficient = -0.4, t = -2.82). The nominal interest rate carries a negative long-run relationship after normalising the coefficient (coefficient = 0.898), though it does not reach conventional significance levels (t = 0.61). Real GDP per capita displays a positive and significant (α = 10%) long-run effect, after normalisation (coefficient = −0.664, t = −1.83).

As aforementioned, we tested the weak exogeneity of the three explanatory variables by imposing restrictions. As discussed, we fail to reject the null hypothesis of weak exogeneity at any conventional significance level, supporting the theoretical expectation that housing investment, the nominal interest rate, and real GDP per capita evolve independently of deviations from the long-run equilibrium. This is further supported by the significant negative long run error correction coefficient (t = -5.45), implying that it is housing prices that adjust towards the long run equilibrium (Table 6). Specifically, when house prices are above their long-term equilibrium, they slowly adjust downward, and vice versa.

Substantively, while acknowledging a few caveats, this broadly aligns with the theoretical framework. Firstly, the interest rate being insignificant can be explained as it is both a driver of housing demand and housing supply in the long-term equilibrium, essentially being both the financing cost of buying and building houses. The fact that the effect was negative may indicate a stronger effect through the supply channel, as increased interest rates may tend to increase supply more than demand; however, this is beyond this model to assess. Secondly, real income per capita positively affecting prices in the long run aligns with the theory as a long-term increase in income increases abilities to purchase real estate. Lastly, the finding that real housing investment drives up prices in the long term seems to contradict our theory. We expected it to increase housing supply, and as such, negatively impact the price. A potential explanation for this could be that housing investment strongly comoves with housing demand, and the way the model was specified could not isolate this effect.

Table 6 shows how, in the short term, house prices seem to respond overwhelmingly positively to past changes in house prices themselves, with the positive coefficients at lag 1 and 4 outweighing the negative coefficient at lag 6. Interestingly, contrasting the long-run findings, in the short run, past increases in GDP per capita tend to have a downwards effect on the house prices. This could reflect the supply effect of income outweighing the demand effect in the short run, whereby rising income increased internal financing for housing construction. Additionally, it could reflect business cycle effects and reversion to the mean, where GDP booms tend to overvalue housing prices, after which they re-adjust to their long-term value based on the economic fundamentals.

Table 6: Restricted Vector Error Correction Model Estimates for Real Housing Prices in the Eurozone (1997Q2–2025Q3)

	Coefficient	**t-statistic**
Table 6A: Long-Run Cointegrating Relationship		
log(HPRR)t−1	1.000	—
log(HINR)t−1	−0.400	−2.82***
log(IRN)t−1	0.898	0.61
log(Y2010PC)t−1	−0.664	−1.83**
Constant	5.992	2.82***
Error Correction Coefficient (α̂)		
CointEq1	−0.081	−5.45***
Table 6B: Short-Run Dynamics (Significant Coefficients Only)		
Lagged House Prices [Δlog(HPRR)t−i]		
Δlog(HPRR)t−1	+0.444	3.94***
Δlog(HPRR)t−4	+0.337	3.09***
Δlog(HPRR)t−6	−0.425	−4.37***
Lagged Real GDP per Capita [Δlog(Y2010PC)t−i]		
Δlog(Y2010PC)t−2	−0.238	−3.25***
Δlog(Y2010PC)t−4	−0.182	−2.93***
Δlog(Y2010PC)t−5	−0.136	−2.13***
Δlog(Y2010PC)t−6	−0.203	−3.02***
Δlog(Y2010PC)t−7	−0.143	−2.03***

Note. Sample: 1997Q2–2025Q3 (114 observations). The long-run relationship is normalized on log(HPRR). Only short-run coefficients significant at the 5% are reported. *** $p < .05$, ** $p < .10$.

Compared to Gattini and Hiebert (2010) we find both similar and diverging results. Considering the long-term dynamics, we corroborate their finding that real GDP per capita positively impacts the housing prices in the long run. However, we show that, in the short run, their relationship is negative. Furthermore, although our finding was not significant, we do align on the direction of the nominal interest rates, which they also found to negatively affect real house prices in the long run.

Additionally, our results counter their finding that real housing investment significantly negatively affects real housing prices in the long term. As discussed, we attribute this to the specific events considered in our sample size.

Static and Dynamic Forecasts

Firstly, to assess the accuracy of the single-equation Error Correction Model (ECM), we perform in-sample static and dynamic forecasts of the real housing prices in the Eurozone between 1995Q1 and 2025Q3 using the single-equation ECM specified in section 4.3. The results in Figure 6 show that the static and dynamic forecasts follow the data fairly well. This is unsurprising for the static forecast, which by construction stay close to real data since each prediction uses an actual observation at t-1. Yet, for the dynamic model, the fact that it follows the data closely over 30 years, albeit with some delay, affirms that the model is well-specified. Seen as dynamic forecasts only have the first entry of the series as anchor point and they rely on the predictor variables to drive them over time; this result indicates that the model is well-specified and choice of the exogenous variables was appropriate.

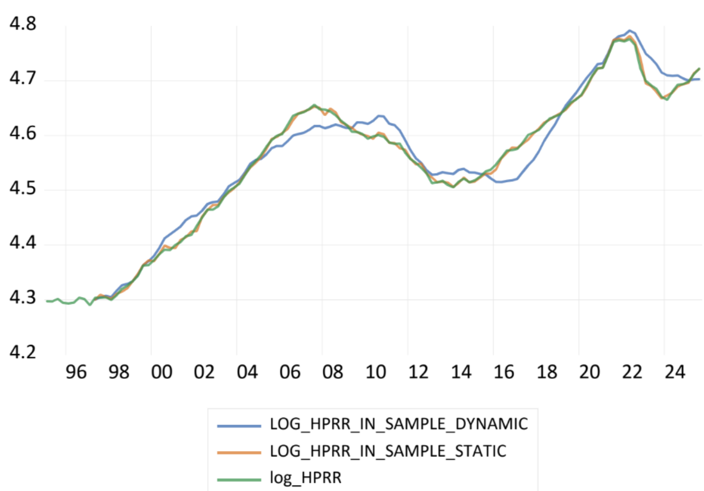

Figure 6: Static and Dynamic In-Sample Forecasts, with Actuals.

Secondly, the main strength of the single equation ECM is to forecast our variable of interest over the next period. As such, we use the equation to produce dynamic forecasts of the real housing prices in the Eurozone from 2025Q4. The results in Figure 7 show that based on the lagged values of real housing investment, the nominal interest rate, and real GDP per capita, the real housing prices are forecasted to increase in the Eurozone in the short run. This result can be explained by our model specifications, which indicate that past house prices are a strong driver of future house prices. Theoretically, this could be explained by the financial accelerator mechanism in which house prices increasing lead to more housing demand, as they open more credit possibilities.

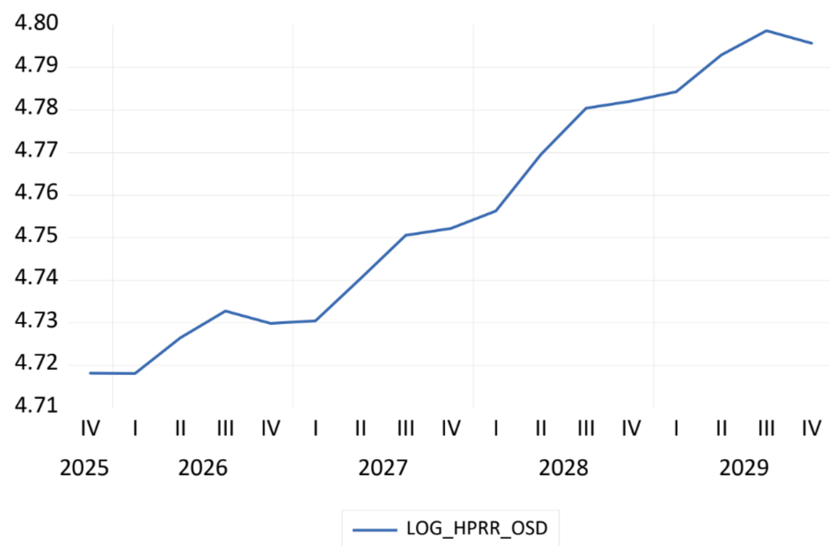

Figure 7: Dynamic Out-of-Sample Forecast from 2025Q4 to 2029Q4.

Impulse response functions

To assess how shocks to specific variables affect the variables in the VECM over time, we created impulse response functions. The graphs are presented below in Figure 8, map the response of all 4 variables to shocks in every variable considered, over a 15-quarter timeframe. Most importantly, looking at the response functions of real house prices, a one standard deviation shock to real housing prices, positively impacts real housing prices over the entire window considered, reaching its peak around the 1,5-year mark. This finding may reflect the financial accelerator mechanism proposed by Iacoviello (2005), whereby an increase in house prices may boost demand seen as it expands potential credit homeowners can take on. Similarly, a positive shock to real housing investment positively affects housing prices for the entire window considered, with an effect that gets stronger over time, and weakes slightly after period 10.

Conversely, a shock to both the real per capita income, and the nominal interest rate, negatively affect real housing prices. Notably, the effect of the interest rate gets stronger over time, while the effect of income reaches its peak around period 10, and then sharpy decreases, eventually reaching a small positive effect in period 15. The effect of the interest rate is consistent with the external financing channel proposed by Gattini and Hiebert (2010), implying an increase in interest rate reduces the external financing for housing demand enough to put negative pressure on the housing prices. At the same time, the unexpected and peculiar shape of response function to the income shock, could be explained by the income as internal financing operating at different time horizons. Specifically, it could be that housing suppliers (i.e construction firms) respond faster to income increases than housing demanders (i.e consumers), who only commence to increase their demand after nearly a year passed. Nonetheless this remains a peculiar result, more research is merited, looking at how housing supplies and demanders respond to changes in GDP.

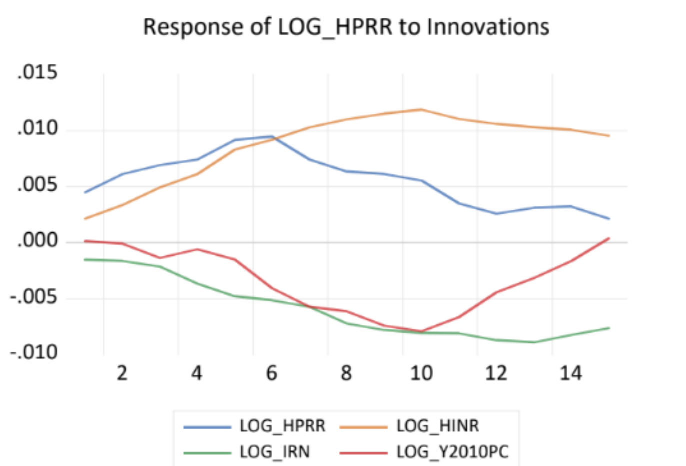

Figure 8: Impulse Response Function for Real Housing Prices (HPRR) to Cholesky 1 S.D innovations in four Variables.

6 Policy Recommendations

7 Conclusion

Further research on stationarity/nonstationariy of the different rates

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9 Appendix A

Annex A, Table 1: Correlogram Levels HPRR

Correlogram of LOG_HPRR_l

Date: 04/17/26 Time: 11:35
Sample (adjusted): 1995Q2 2025Q3
Included observations: 122 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.583	0.583	42.557	0.000
		2	0.336	-0.006	56.819	0.000
		3	0.441	0.375	81.578	0.000
		4	0.540	0.242	118.96	0.000
		5	0.200	-0.399	124.14	0.000
		6	-0.069	-0.297	124.75	0.000
		7	0.102	0.179	126.13	0.000
		8	0.196	0.105	131.22	0.000
		9	0.011	0.111	131.24	0.000
		10	-0.165	-0.106	134.94	0.000
		11	0.030	-0.001	135.06	0.000
		12	0.189	0.104	139.98	0.000
		13	0.021	-0.034	140.04	0.000
		14	-0.120	-0.064	142.04	0.000
		15	0.066	0.067	142.65	0.000
		16	0.163	-0.096	146.44	0.000
		17	-0.012	0.002	146.46	0.000
		18	-0.160	-0.061	150.18	0.000
		19	-0.028	-0.051	150.29	0.000
		20	0.037	-0.022	150.50	0.000

Annex A, Table 2: SIC Levels HPRR

Augmented Dickey-Fuller Unit Root Test on LOG_HPRR

Null Hypothesis: LOG_HPRR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 8 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.653874	0.2578
Test critical values:	1% level	-4.040532	
	5% level	-3.449716	
	10% level	-3.150127	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_HPRR)
Method: Least Squares
Date: 04/09/26 Time: 18:00
Sample (adjusted): 10 123
Included observations: 114 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_HPRR(-1)	-0.026039	0.009812	-2.653874	0.0092
D(LOG_HPRR(-1))	0.478263	0.092853	5.150734	0.0000
D(LOG_HPRR(-2))	0.181546	0.103797	1.749048	0.0833
D(LOG_HPRR(-3))	0.173459	0.095961	1.807604	0.0736
D(LOG_HPRR(-4))	0.309981	0.094737	3.272005	0.0015
D(LOG_HPRR(-5))	-0.244250	0.095240	-2.564586	0.0118
D(LOG_HPRR(-6))	-0.400609	0.097070	-4.127012	0.0001
D(LOG_HPRR(-7))	0.123664	0.102975	1.200915	0.2325
D(LOG_HPRR(-8))	0.210554	0.095898	2.195596	0.0304
C	0.115182	0.042546	2.707225	0.0079
@TREND("1")	6.59E-05	3.69E-05	1.785074	0.0772

R-squared	0.666291	Mean dependent var	0.003788
Adjusted R-squared	0.633892	S.D. dependent var	0.010194
S.E. of regression	0.006168	Akaike info criterion	-7.247420
Sum squared resid	0.003918	Schwarz criterion	-6.983401
Log likelihood	424.1029	Hannan-Quinn criter.	-7.140270
F-statistic	20.56520	Durbin-Watson stat	1.968503
Prob(F-statistic)	0.000000		

Annex A, Table 3: Residual Correlogram Levels HPRR

Correlogram of Residuals

Date: 04/09/26 Time: 18:06
Sample (adjusted): 10 123
Q-statistic probabilities adjusted for 9 dynamic regressors

	AC	PAC	Q-Stat	Prob*
1	0.003	0.003	0.0008	0.977
2	-0.037	-0.037	0.1585	0.924
3	0.032	0.032	0.2796	0.964
4	-0.045	-0.047	0.5226	0.971
5	-0.141	-0.139	2.9330	0.710
6	0.124	0.123	4.8186	0.567
7	0.057	0.050	5.2175	0.633
8	-0.174	-0.169	9.0134	0.341
9	0.010	-0.002	9.0261	0.435
10	-0.037	-0.056	9.1960	0.514
11	-0.104	-0.062	10.578	0.479
12	0.070	0.061	11.220	0.510
13	0.082	0.021	12.094	0.520
14	-0.158	-0.133	15.394	0.352
15	0.058	0.069	15.846	0.392
16	0.048	0.008	16.153	0.442
17	0.034	0.085	16.307	0.502
18	-0.017	-0.039	16.348	0.568
19	0.070	-0.008	17.024	0.588
20	-0.137	-0.089	19.667	0.479
21	-0.039	-0.006	19.886	0.528
22	0.013	-0.035	19.912	0.589
23	0.026	0.048	20.013	0.641
24	0.004	-0.005	20.016	0.696
25	0.012	-0.028	20.036	0.745
26	-0.055	-0.029	20.487	0.768
27	-0.212	-0.187	27.289	0.448
28	0.039	0.009	27.529	0.490
29	-0.062	-0.085	28.126	0.511
30	-0.051	-0.080	28.540	0.542
31	-0.040	-0.071	28.792	0.580
32	0.148	0.121	32.314	0.451
33	-0.162	-0.143	36.598	0.305
34	-0.033	-0.071	36.778	0.341
35	-0.008	-0.096	36.790	0.386
36	-0.082	-0.101	37.941	0.381

*Probabilities may not be valid for this equation specification.

Annex A, Table 4: Correlogram Differenced HPRR

Correlogram of LOG_HPRR

Date: 04/17/26 Time: 11:09
Sample (adjusted): 1995Q1 2025Q3
Included observations: 123 after adjustments

	AC	PAC	Q-Stat	Prob
1	0.976	0.976	120.15	0.000
2	0.950	-0.077	234.78	0.000
3	0.922	-0.028	343.78	0.000
4	0.891	-0.088	446.43	0.000
5	0.857	-0.084	542.09	0.000
6	0.822	-0.022	630.83	0.000
7	0.789	0.030	713.26	0.000
8	0.754	-0.054	789.18	0.000
9	0.714	-0.101	858.03	0.000
10	0.676	-0.013	920.15	0.000
11	0.636	-0.033	975.76	0.000
12	0.595	-0.067	1024.7	0.000
13	0.547	-0.136	1066.6	0.000
14	0.499	-0.042	1101.7	0.000
15	0.452	0.002	1130.8	0.000
16	0.405	-0.025	1154.3	0.000
17	0.357	-0.028	1172.8	0.000
18	0.311	0.007	1186.9	0.000
19	0.269	0.043	1197.6	0.000
20	0.228	-0.036	1205.4	0.000

Annex A, Table 5: SIC Differenced HPRR

Augmented Dickey-Fuller Unit Root Test on LOG_HPRR_I

Null Hypothesis: LOG_HPRR_I has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 5 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.374752	0.0035
Test critical values:	1% level	-4.039075	
	5% level	-3.449020	
	10% level	-3.149720	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_HPRR_I)
Method: Least Squares
Date: 04/09/26 Time: 18:37
Sample (adjusted): 1996Q4 2025Q3
Included observations: 116 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_HPRR_I(-1)	-0.370457	0.084681	-4.374752	0.0000
D(LOG_HPRR_I(-1))	-0.151485	0.103428	-1.464642	0.1459
D(LOG_HPRR_I(-2))	-0.110148	0.103245	-1.066857	0.2884
D(LOG_HPRR_I(-3))	0.122687	0.100406	1.221912	0.2244
D(LOG_HPRR_I(-4))	0.535749	0.091043	5.884580	0.0000
D(LOG_HPRR_I(-5))	0.315727	0.091070	3.466869	0.0008
C	0.002193	0.001433	1.529816	0.1290
@TREND("1995Q1")	-1.42E-05	1.87E-05	-0.760903	0.4484

R-squared	0.524001	Mean dependent var	9.86E-06
Adjusted R-squared	0.493149	S.D. dependent var	0.009238
S.E. of regression	0.006577	Akaike info criterion	-7.144065
Sum squared resid	0.004671	Schwarz criterion	-6.954162
Log likelihood	422.3558	Hannan-Quinn criter.	-7.066975
F-statistic	16.98448	Durbin-Watson stat	1.856631
Prob(F-statistic)	0.000000		

Annex A, Table 6: Residual Correlogram Differenced HPRR

Correlogram of Residuals

Date: 04/09/26 Time: 18:41
Sample (adjusted): 1996Q4 2025Q3
Q-statistic probabilities adjusted for 6 dynamic regressors

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.069	0.069	0.5680	0.451
		2	0.135	0.131	2.7631	0.251
		3	0.031	0.015	2.8833	0.410
		4	-0.063	-0.085	3.3688	0.498
		5	-0.131	-0.132	5.4764	0.361
		6	-0.015	0.020	5.5042	0.481
		7	0.032	0.077	5.6331	0.583
		8	-0.036	-0.040	5.7996	0.670
		9	0.092	0.064	6.8788	0.650
		10	0.019	-0.001	6.9239	0.733
		11	0.026	0.013	7.0116	0.798
		12	0.122	0.127	8.9614	0.706
		13	0.084	0.070	9.8977	0.702
		14	-0.096	-0.132	11.136	0.675
		15	0.099	0.094	12.464	0.644
		16	0.020	0.054	12.518	0.708
		17	0.033	0.060	12.668	0.758
		18	-0.080	-0.116	13.566	0.757
		19	0.002	-0.038	13.567	0.808
		20	-0.143	-0.100	16.474	0.687
		21	-0.048	-0.005	16.810	0.723
		22	-0.052	-0.047	17.205	0.752
		23	0.029	0.047	17.331	0.793
		24	0.025	-0.028	17.422	0.830
		25	-0.042	-0.102	17.684	0.856
		26	-0.107	-0.125	19.425	0.818
		27	-0.230	-0.214	27.560	0.434
		28	-0.016	0.010	27.602	0.486
		29	-0.102	-0.012	29.226	0.453
		30	-0.069	-0.085	29.984	0.466
		31	-0.068	-0.106	30.739	0.479
		32	0.121	0.115	33.133	0.412
		33	-0.144	-0.120	36.550	0.307
		34	-0.060	-0.105	37.146	0.326
		35	-0.082	-0.089	38.283	0.323
		36	-0.110	-0.068	40.362	0.283

*Probabilities may not be valid for this equation specification.

Annex A, Table 7: Step 2 Levels HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR

Test Statistic	Value	df	Probability
F-statistic	4.102093	(2, 103)	0.0193
Chi-square	8.204185	2	0.0165

Null Hypothesis: C(1) = 1, C(11) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.026039	0.009812
C(11)	6.59E-05	3.69E-05

Restrictions are linear in coefficients.

Annex A, Table 8: Step 5 Levels HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR

Test Statistic	Value	df	Probability
t-statistic	-2.653874	103	0.0092
F-statistic	7.043047	(1, 103)	0.0092
Chi-square	7.043047	1	0.0080

Null Hypothesis: C(1)=1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.026039	0.009812

Restrictions are linear in coefficients.

Annex A, Table 9: Step 6 Levels HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR

Test Statistic	Value	df	Probability
F-statistic	3.481607	(3, 103)	0.0186
Chi-square	10.44482	3	0.0151

Null Hypothesis: C(1)=1, C(10)=0, C(11)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.026039	0.009812
C(10)	0.116763	0.043307
C(11)	6.59E-05	3.69E-05

Restrictions are linear in coefficients.

Annex A, Table 10: Step 7 Levels HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR2

Test Statistic	Value	df	Probability
F-statistic	3.554438	(2, 104)	0.0321
Chi-square	7.108875	2	0.0286

Null Hypothesis: C(1)=1, C(10)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.010773	0.004859
C(10)	0.050120	0.022178

Restrictions are linear in coefficients.

Annex A, Table 11: Step 2 Differenced HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR_I

Test Statistic	Value	df	Probability
F-statistic	9.585113	(2, 108)	0.0001
Chi-square	19.17023	2	0.0001

Null Hypothesis: C(1) = 1, C(8) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.370457	0.084681
C(8)	-1.42E-05	1.87E-05

Restrictions are linear in coefficients.

Annex A, Table 12: Step 3 Differenced HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR_I

Test Statistic	Value	df	Probability
t-statistic	-4.374752	108	0.0000
F-statistic	19.13846	(1, 108)	0.0000
Chi-square	19.13846	1	0.0000

Null Hypothesis: C(1) = 1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.370457	0.084681

Restrictions are linear in coefficients.

Annex A, Table 13: Step 4 Differenced HPRR

Wald Test:
Equation: EQ_DF_LOG_HPRR_I

Test Statistic	Value	df	Probability
t-statistic	-0.760903	108	0.4484
F-statistic	0.578973	(1, 108)	0.4484
Chi-square	0.578973	1	0.4467

Null Hypothesis: C(8) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(8)	-1.42E-05	1.87E-05

Restrictions are linear in coefficients.

Annex A, Table 14: Correlogram Levels HPRR

Correlogram of LOG_HPRR

Date: 04/17/26 Time: 11:09
Sample (adjusted): 1995Q1 2025Q3
Included observations: 123 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.976	0.976	120.15	0.000
		2	0.950	-0.077	234.78	0.000
		3	0.922	-0.028	343.78	0.000
		4	0.891	-0.088	446.43	0.000
		5	0.857	-0.084	542.09	0.000
		6	0.822	-0.022	630.83	0.000
		7	0.789	0.030	713.26	0.000
		8	0.754	-0.054	789.18	0.000
		9	0.714	-0.101	858.03	0.000
		10	0.676	-0.013	920.15	0.000
		11	0.636	-0.033	975.76	0.000
		12	0.595	-0.067	1024.7	0.000
		13	0.547	-0.136	1066.6	0.000
		14	0.499	-0.042	1101.7	0.000
		15	0.452	0.002	1130.8	0.000
		16	0.405	-0.025	1154.3	0.000
		17	0.357	-0.028	1172.8	0.000
		18	0.311	0.007	1186.9	0.000
		19	0.269	0.043	1197.6	0.000
		20	0.228	-0.036	1205.4	0.000

Annex A, Table 15: SIC Levels HINR

Augmented Dickey-Fuller Unit Root Test on LOG_HPRR

Null Hypothesis: LOG_HPRR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 8 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.653874	0.2578
Test critical values:	1% level	-4.040532	
	5% level	-3.449716	
	10% level	-3.150127	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_HPRR)
Method: Least Squares
Date: 04/09/26 Time: 18:00
Sample (adjusted): 10 123
Included observations: 114 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_HPRR(-1)	-0.026039	0.009812	-2.653874	0.0092
D(LOG_HPRR(-1))	0.478263	0.092853	5.150734	0.0000
D(LOG_HPRR(-2))	0.181546	0.103797	1.749048	0.0833
D(LOG_HPRR(-3))	0.173459	0.095961	1.807604	0.0736
D(LOG_HPRR(-4))	0.309981	0.094737	3.272005	0.0015
D(LOG_HPRR(-5))	-0.244250	0.095240	-2.564586	0.0118
D(LOG_HPRR(-6))	-0.400609	0.097070	-4.127012	0.0001
D(LOG_HPRR(-7))	0.123664	0.102975	1.200915	0.2325
D(LOG_HPRR(-8))	0.210554	0.095898	2.195596	0.0304
C	0.115182	0.042546	2.707225	0.0079
@TREND("1")	6.59E-05	3.69E-05	1.785074	0.0772

R-squared	0.666291	Mean dependent var	0.003788
Adjusted R-squared	0.633892	S.D. dependent var	0.010194
S.E. of regression	0.006168	Akaike info criterion	-7.247420
Sum squared resid	0.003918	Schwarz criterion	-6.983401
Log likelihood	424.1029	Hannan-Quinn criter.	-7.140270
F-statistic	20.56520	Durbin-Watson stat	1.968503
Prob(F-statistic)	0.000000		

Annex A, Table 16: Residual Correlogram Levels HINR

Correlogram of Residuals

Date: 04/09/26 Time: 18:06
Sample (adjusted): 10 123
Q-statistic probabilities adjusted for 9 dynamic regressors

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.003	0.003	0.0008	0.977
		2	-0.037	-0.037	0.1585	0.924
		3	0.032	0.032	0.2796	0.964
		4	-0.045	-0.047	0.5226	0.971
		5	-0.141	-0.139	2.9330	0.710
		6	0.124	0.123	4.8186	0.567
		7	0.057	0.050	5.2175	0.633
		8	-0.174	-0.169	9.0134	0.341
		9	0.010	-0.002	9.0261	0.435
		10	-0.037	-0.056	9.1960	0.514
		11	-0.104	-0.062	10.578	0.479
		12	0.070	0.061	11.220	0.510
		13	0.082	0.021	12.094	0.520
		14	-0.158	-0.133	15.394	0.352
		15	0.058	0.069	15.846	0.392
		16	0.048	0.008	16.153	0.442
		17	0.034	0.085	16.307	0.502
		18	-0.017	-0.039	16.348	0.568
		19	0.070	-0.008	17.024	0.588
		20	-0.137	-0.089	19.667	0.479
		21	-0.039	-0.006	19.886	0.528
		22	0.013	-0.035	19.912	0.589
		23	0.026	0.048	20.013	0.641
		24	0.004	-0.005	20.016	0.696
		25	0.012	-0.028	20.036	0.745
		26	-0.055	-0.029	20.487	0.768
		27	-0.212	-0.187	27.289	0.448
		28	0.039	0.009	27.529	0.490
		29	-0.062	-0.085	28.126	0.511
		30	-0.051	-0.080	28.540	0.542
		31	-0.040	-0.071	28.792	0.580
		32	0.148	0.121	32.314	0.451
		33	-0.162	-0.143	36.598	0.305
		34	-0.033	-0.071	36.778	0.341
		35	-0.008	-0.096	36.790	0.386
		36	-0.082	-0.101	37.941	0.381

*Probabilities may not be valid for this equation specification.

Annex A, Table 17: Correlogram Differenced HINR

Correlogram of LOG_HPRR_I

Date: 04/17/26 Time: 11:35
Sample (adjusted): 1995Q2 2025Q3
Included observations: 122 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.583	0.583	42.557	0.000
		2	0.336	-0.006	56.819	0.000
		3	0.441	0.375	81.578	0.000
		4	0.540	0.242	118.96	0.000
		5	0.200	-0.399	124.14	0.000
		6	-0.069	-0.297	124.75	0.000
		7	0.102	0.179	126.13	0.000
		8	0.196	0.105	131.22	0.000
		9	0.011	0.111	131.24	0.000
		10	-0.165	-0.106	134.94	0.000
		11	0.030	-0.001	135.06	0.000
		12	0.189	0.104	139.98	0.000
		13	0.021	-0.034	140.04	0.000
		14	-0.120	-0.064	142.04	0.000
		15	0.066	0.067	142.65	0.000
		16	0.163	-0.096	146.44	0.000
		17	-0.012	0.002	146.46	0.000
		18	-0.160	-0.061	150.18	0.000
		19	-0.028	-0.051	150.29	0.000
		20	0.037	-0.022	150.50	0.000

Annex A, Table 18: SIC Differenced HINR

Augmented Dickey-Fuller Unit Root Test on LOG_HINR_I

Null Hypothesis: LOG_HINR_I has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.108068	0.0081
Test critical values:	1% level	-4.037668	
	5% level	-3.448348	
	10% level	-3.149326	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_HINR_I)
Method: Least Squares
Date: 04/08/26 Time: 18:19
Sample (adjusted): 6 123
Included observations: 118 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_HINR_I(-1)	-0.546018	0.132914	-4.108068	0.0001
D(LOG_HINR_I(-1))	-0.328427	0.119106	-2.757431	0.0068
D(LOG_HINR_I(-2))	-0.226720	0.091146	-2.487429	0.0143
C	0.002080	0.004305	0.483123	0.6299
@TREND("1")	-1.17E-05	5.94E-05	-0.196675	0.8444

R-squared	0.449833	Mean dependent var	0.000109
Adjusted R-squared	0.430358	S.D. dependent var	0.029103
S.E. of regression	0.021965	Akaike info criterion	-4.757278
Sum squared resid	0.054518	Schwarz criterion	-4.639876
Log likelihood	285.6794	Hannan-Quinn criter.	-4.709609
F-statistic	23.09802	Durbin-Watson stat	1.981814
Prob(F-statistic)	0.000000		

Annex A, Table 19: Residual Correlogram Differenced HINR

Correlogram of Residuals

Date: 04/08/26 Time: 18:19
Sample (adjusted): 6 123
Q-statistic probabilities adjusted for 3 dynamic regressors

Lag	AC	PAC	Q-Stat	Prob*
1	-0.012	-0.012	0.0184	0.892
2	-0.011	-0.011	0.0330	0.984
3	0.039	0.039	0.2190	0.974
4	0.038	0.039	0.3995	0.983
5	-0.015	-0.014	0.4295	0.994
6	-0.005	-0.006	0.4326	0.999
7	-0.006	-0.010	0.4380	1.000
8	-0.099	-0.100	1.7082	0.989
9	0.055	0.055	2.1025	0.990
10	0.029	0.030	2.2122	0.994
11	-0.085	-0.077	3.1699	0.988
12	-0.105	-0.105	4.6540	0.969
13	-0.047	-0.062	4.9515	0.976
14	0.013	0.014	4.9740	0.986
15	0.100	0.119	6.3422	0.973
16	0.051	0.061	6.7038	0.979
17	0.000	0.013	6.7038	0.987
18	-0.030	-0.046	6.8271	0.992
19	0.043	0.005	7.0931	0.994
20	-0.027	-0.041	7.1968	0.996
21	-0.038	-0.026	7.4052	0.997
22	-0.008	0.004	7.4141	0.998
23	-0.041	-0.038	7.6648	0.999
24	-0.022	-0.045	7.7360	0.999
25	-0.083	-0.110	8.7801	0.999
26	-0.024	-0.022	8.8675	0.999
27	-0.056	-0.008	9.3494	0.999
28	-0.056	-0.029	9.8354	0.999
29	0.101	0.112	11.472	0.998
30	0.001	-0.003	11.472	0.999
31	-0.081	-0.108	12.529	0.999
32	-0.024	-0.060	12.621	0.999
33	-0.087	-0.131	13.871	0.999
34	-0.017	-0.017	13.923	0.999
35	-0.069	-0.065	14.727	0.999
36	-0.007	-0.023	14.735	0.999

*Probabilities may not be valid for this equation specification.

Annex A, Table 20: Step 2 Levels HINR

Wald Test:
Equation: EQ_DF_LOG_HINR

Test Statistic	Value	df	Probability
F-statistic	2.521134	(2, 113)	0.0849
Chi-square	5.042268	2	0.0804

Null Hypothesis: C(1) = 1, C(6) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.045676	0.020386
C(6)	8.27E-05	7.04E-05

Restrictions are linear in coefficients.

Annex A, Table 21: Step 5 Levels HINR

Wald Test:
Equation: EQ_DF_LOG_HINR

Test Statistic	Value	df	Probability
t-statistic	-2.240487	113	0.0270
F-statistic	5.019784	(1, 113)	0.0270
Chi-square	5.019784	1	0.0251

Null Hypothesis: C(1) = 1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.045676	0.020386

Restrictions are linear in coefficients.

Annex A, Table 22: Step 6 Levels HINR

Wald Test:
Equation: EQ_DF_LOG_HPRR

Test Statistic	Value	df	Probability
F-statistic	3.481607	(3, 103)	0.0186
Chi-square	10.44482	3	0.0151

Null Hypothesis: C(1) = 1, C(10) = 0, C(11) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.026039	0.009812
C(10)	0.115182	0.042546
C(11)	6.59E-05	3.69E-05

Restrictions are linear in coefficients.

Annex A, Table 23: Step 7 Levels HINR

Wald Test:
Equation: EQ_DF_LOG_HINR2

Test Statistic	Value	df	Probability
F-statistic	2.067747	(2, 114)	0.1312
Chi-square	4.135493	2	0.1265

Null Hypothesis: C(1) = 1, C(5) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.031822	0.016653
C(5)	0.377684	0.196941

Restrictions are linear in coefficients.

Annex A, Table 24: Step 2 Differenced HINR

Wald Test:
Equation: EQ_DF_LOG_HINR_I

Test Statistic	Value	df	Probability
F-statistic	8.438156	(2, 113)	0.0004
Chi-square	16.87631	2	0.0002

Null Hypothesis: C(1) = 1, C(5) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.546018	0.132914
C(5)	-1.17E-05	5.94E-05

Restrictions are linear in coefficients.

Annex A, Table 25: Step 3 Differenced HINR

Wald Test:
Equation: EQ_DF_LOG_HINR_I

Test Statistic	Value	df	Probability
t-statistic	-4.108068	113	0.0001
F-statistic	16.87622	(1, 113)	0.0001
Chi-square	16.87622	1	0.0000

Null Hypothesis: C(1) = 1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.546018	0.132914

Restrictions are linear in coefficients.

Annex A, Table 26: Step 4 Differenced HINR

Wald Test:
Equation: EQ_DF_LOG_HINR_I

Test Statistic	Value	df	Probability
t-statistic	-0.196675	113	0.8444
F-statistic	0.038681	(1, 113)	0.8444
Chi-square	0.038681	1	0.8441

Null Hypothesis: C(5) = 0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(5)	-1.17E-05	5.94E-05

Restrictions are linear in coefficients.

Annex A, Table 27: Correlogram Levels IRR

Correlogram of LOG_IRR

Date: 04/10/26 Time: 11:25
Sample: 1995Q1 2025Q3
Included observations: 123

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.958	0.958	115.59	0.000
		2	0.890	-0.328	216.26	0.000
		3	0.812	-0.084	300.68	0.000
		4	0.729	-0.050	369.35	0.000
		5	0.657	0.119	425.60	0.000
		6	0.594	0.003	472.02	0.000
		7	0.538	-0.023	510.42	0.000
		8	0.492	0.048	542.82	0.000
		9	0.457	0.064	571.02	0.000
		10	0.425	-0.051	595.62	0.000

Annex A, Table 28: SIC Levels IRR

Augmented Dickey-Fuller Unit Root Test on LOG_IRR

Null Hypothesis: LOG_IRR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.674746	0.0279
Test critical values:	1% level	-4.035648	
	5% level	-3.447383	
	10% level	-3.148761	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_IRR)
Method: Least Squares
Date: 04/10/26 Time: 11:38
Sample (adjusted): 1995Q3 2025Q3
Included observations: 121 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_IRR(-1)	-0.108399	0.029498	-3.674746	0.0004
D(LOG_IRR(-1))	0.573935	0.077898	7.367746	0.0000
C	0.003808	0.001444	2.637853	0.0095
@TREND("1995Q1")	-4.63E-05	1.83E-05	-2.530893	0.0127

R-squared	0.342604	Mean dependent var	-0.000366
Adjusted R-squared	0.325748	S.D. dependent var	0.004934
S.E. of regression	0.004051	Akaike info criterion	-8.146972
Sum squared resid	0.001920	Schwarz criterion	-8.054550
Log likelihood	496.8918	Hannan-Quinn criter.	-8.109436
F-statistic	20.32498	Durbin-Watson stat	2.185299
Prob(F-statistic)	0.000000		

Annex A, Table 29: Residual Correlogram IRR Levels

Correlogram of Residuals

Date: 04/16/26 Time: 13:54
Sample (adjusted): 1995Q3 2025Q3
Q-statistic probabilities adjusted for 2 dynamic regressors

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.095	-0.095	1.1274	0.288
		2	0.074	0.065	1.8038	0.406
		3	0.181	0.196	5.9363	0.115
		4	-0.200	-0.178	11.014	0.026
		5	0.009	-0.057	11.023	0.051
		6	-0.017	-0.022	11.059	0.087
		7	0.077	0.161	11.843	0.106
		8	-0.142	-0.166	14.482	0.070
		9	-0.024	-0.081	14.559	0.104
		10	0.057	0.041	14.996	0.132
		11	-0.149	-0.030	18.009	0.081
		12	0.050	-0.021	18.354	0.105
		13	-0.091	-0.132	19.496	0.109
		14	-0.051	-0.025	19.862	0.135
		15	-0.114	-0.125	21.680	0.116
		16	0.017	0.041	21.721	0.152
		17	0.054	0.033	22.144	0.179
		18	-0.016	0.046	22.179	0.224
		19	0.012	-0.110	22.200	0.274
		20	0.072	0.082	22.956	0.291

*Probabilities may not be valid for this equation specification.

Annex A, Table 30: Step 2 Levels IRR

Wald Test:
Equation: EQ_ADF_LOG_IRR

Test Statistic	Value	df	Probability
F-statistic	7.064866	(2, 117)	0.0013
Chi-square	14.12973	2	0.0009

Null Hypothesis: C(1)=1, C(4)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.108399	0.029498
C(4)	-4.63E-05	1.83E-05

Restrictions are linear in coefficients.

Annex A, Table 31: Step 3 Levels IRR

Wald Test:
Equation: EQ_ADF_LOG_IRR

Test Statistic	Value	df	Probability
t-statistic	-3.674746	117	0.0004
F-statistic	13.50376	(1, 117)	0.0004
Chi-square	13.50376	1	0.0002

Null Hypothesis: C(1)=1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.108399	0.029498

Restrictions are linear in coefficients.

Annex A, Table 32: Step 4 Levels IRR

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-2.530893	117	0.0127
F-statistic	6.405419	(1, 117)	0.0127
Chi-square	6.405419	1	0.0114

Null Hypothesis: C(4)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(4)	-4.63E-05	1.83E-05

Restrictions are linear in coefficients.

Annex A, Table 33: Correlogram Levels IRN

Correlogram of LOG_IRN

Date: 04/16/26 Time: 10:05
Sample (adjusted): 1995Q1 2025Q3
Included observations: 123 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.954	0.954	114.78	0.000
		2	0.899	-0.131	217.48	0.000
		3	0.842	-0.043	308.22	0.000
		4	0.783	-0.041	387.41	0.000
		5	0.730	0.038	456.88	0.000
		6	0.680	-0.020	517.57	0.000
		7	0.632	-0.004	570.48	0.000
		8	0.595	0.083	617.75	0.000
		9	0.561	0.001	660.26	0.000
		10	0.528	-0.038	698.17	0.000
		11	0.498	0.017	732.17	0.000
		12	0.472	0.034	763.00	0.000
		13	0.452	0.045	791.54	0.000
		14	0.435	0.010	818.29	0.000
		15	0.425	0.058	843.96	0.000
		16	0.419	0.043	869.17	0.000
		17	0.418	0.040	894.47	0.000
		18	0.417	0.003	919.96	0.000
		19	0.410	-0.063	944.83	0.000
		20	0.396	-0.050	968.28	0.000

Annex A, Table 34: SIC Levels IRN

Augmented Dickey-Fuller Unit Root Test on LOG_IRN

Null Hypothesis: LOG_IRN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.411648	0.3717
Test critical values:	1% level	-4.035648	
	5% level	-3.447383	
	10% level	-3.148761	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_IRN)
Method: Least Squares
Date: 04/16/26 Time: 10:11
Sample (adjusted): 1995Q3 2025Q3
Included observations: 121 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_IRN(-1)	-0.049845	0.020668	-2.411648	0.0174
D(LOG_IRN(-1))	0.463888	0.081315	5.704856	0.0000
C	0.001815	0.001245	1.457934	0.1475
@TREND("1995Q1")	-8.91E-06	1.09E-05	-0.818712	0.4146

R-squared	0.284928	Mean dependent var	-0.000420
Adjusted R-squared	0.266593	S.D. dependent var	0.002908
S.E. of regression	0.002490	Akaike info criterion	-9.120590
Sum squared resid	0.000725	Schwarz criterion	-9.028168
Log likelihood	555.7957	Hannan-Quinn criter.	-9.083054
F-statistic	15.53994	Durbin-Watson stat	2.068399
Prob(F-statistic)	0.000000		

Annex A, Table 35: Residual Correlogram Levels IRN

Correlogram of Residuals

Date: 04/18/26 Time: 18:54
Sample (adjusted): 1995Q3 2025Q3
Q-statistic probabilities adjusted for 2 dynamic regressors

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.037	-0.037	0.1738	0.677
		2	0.032	0.030	0.3005	0.861
		3	0.105	0.108	1.7021	0.636
		4	-0.040	-0.033	1.9057	0.753
		5	0.012	0.002	1.9251	0.859
		6	0.048	0.041	2.2270	0.898
		7	-0.103	-0.095	3.6255	0.822
		8	-0.020	-0.033	3.6762	0.885
		9	0.079	0.078	4.5127	0.875
		10	0.070	0.103	5.1670	0.880
		11	-0.159	-0.169	8.5911	0.660
		12	0.062	0.029	9.1167	0.693
		13	-0.048	-0.033	9.4280	0.740
		14	-0.042	-0.022	9.6733	0.786
		15	0.066	0.035	10.285	0.801
		16	-0.045	-0.013	10.578	0.835
		17	-0.047	-0.020	10.898	0.862
		18	-0.051	-0.110	11.274	0.882
		19	0.024	0.032	11.355	0.911
		20	0.096	0.134	12.721	0.889

*Probabilities may not be valid for this equation specification.

Annex A, Table 36: Correlogram Differenced IRN

Correlogram of LOG_IRN_I

Date: 04/16/26 Time: 10:28
Sample (adjusted): 1995Q2 2025Q3
Included observations: 122 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.479	0.479	28.708	0.000
		2	0.273	0.056	38.091	0.000
		3	0.178	0.036	42.100	0.000
		4	0.035	-0.095	42.260	0.000
		5	0.004	0.006	42.262	0.000
		6	-0.022	-0.021	42.328	0.000
		7	-0.110	-0.105	43.910	0.000
		8	-0.059	0.044	44.377	0.000
		9	0.015	0.075	44.408	0.000
		10	-0.010	-0.034	44.422	0.000
		11	-0.132	-0.187	46.802	0.000
		12	-0.059	0.076	47.285	0.000
		13	-0.091	-0.055	48.435	0.000
		14	-0.084	-0.015	49.418	0.000
		15	-0.032	0.012	49.561	0.000
		16	-0.078	-0.047	50.439	0.000
		17	-0.077	-0.026	51.291	0.000
		18	-0.036	-0.029	51.482	0.000
		19	0.053	0.133	51.893	0.000
		20	0.110	0.082	53.703	0.000
		21	0.047	-0.090	54.033	0.000
		22	0.043	-0.015	54.309	0.000
		23	0.097	0.119	55.743	0.000
		24	0.081	-0.018	56.760	0.000
		25	0.100	0.034	58.306	0.000
		26	0.032	-0.024	58.470	0.000
		27	0.101	0.148	60.104	0.000
		28	0.091	-0.047	61.438	0.000
		29	0.079	-0.018	62.459	0.000
		30	-0.025	-0.071	62.563	0.000
		31	-0.120	-0.067	64.948	0.000
		32	-0.110	-0.031	66.983	0.000
		33	-0.149	-0.082	70.779	0.000
		34	-0.132	0.045	73.768	0.000
		35	-0.024	0.085	73.868	0.000
		36	-0.087	-0.093	75.193	0.000

Annex A, Table 37: SIC Differenced IRN

Augmented Dickey-Fuller Unit Root Test on LOG_IRN_I

Null Hypothesis: LOG_IRN_I has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.745546	0.0000
Test critical values:	1% level	-4.035648	
	5% level	-3.447383	
	10% level	-3.148761	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_IRN_I)
Method: Least Squares
Date: 04/16/26 Time: 10:29
Sample (adjusted): 1995Q3 2025Q3
Included observations: 121 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_IRN_I(-1)	-0.556546	0.082506	-6.745546	0.0000
C	-0.000952	0.000493	-1.933238	0.0556
@TREND("1995Q1")	1.18E-05	6.84E-06	1.718668	0.0883

R-squared	0.278300	Mean dependent var	2.38E-05
Adjusted R-squared	0.266068	S.D. dependent var	0.002965
S.E. of regression	0.002540	Akaike info criterion	-9.088606
Sum squared resid	0.000761	Schwarz criterion	-9.019288
Log likelihood	552.8606	Hannan-Quinn criter.	-9.060453
F-statistic	22.75139	Durbin-Watson stat	2.025739
Prob(F-statistic)	0.000000		

Annex A, Table 38: Residual Correlogram Differenced IRN

Correlogram of Residuals

Date: 04/17/26 Time: 10:53
Sample (adjusted): 1995Q3 2025Q3
Q-statistic probabilities adjusted for 1 dynamic regressor

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.016	-0.016	0.0325	0.857
		2	0.019	0.019	0.0794	0.961
		3	0.075	0.076	0.7937	0.851
		4	-0.070	-0.069	1.4230	0.840
		5	-0.027	-0.032	1.5153	0.911
		6	0.002	-0.002	1.5159	0.958
		7	-0.147	-0.136	4.3193	0.742
		8	-0.059	-0.065	4.7725	0.782
		9	0.043	0.044	5.0210	0.832
		10	0.036	0.062	5.1958	0.878
		11	-0.193	-0.211	10.214	0.511
		12	0.033	0.003	10.361	0.584
		13	-0.076	-0.072	11.153	0.598
		14	-0.060	-0.054	11.653	0.634
		15	0.051	0.007	12.022	0.677
		16	-0.051	-0.037	12.386	0.717
		17	-0.047	-0.041	12.705	0.756
		18	-0.041	-0.125	12.947	0.795
		19	0.043	0.030	13.211	0.828
		20	0.115	0.124	15.165	0.767

*Probabilities may not be valid for this equation specification.

Annex A, Table 39: Step 2 Levels IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	4.445212	(2, 117)	0.0138
Chi-square	8.890424	2	0.0117

Null Hypothesis: C(1)=1, C(4)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.049845	0.020668
C(4)	-8.91E-06	1.09E-05

Restrictions are linear in coefficients.

Annex A, Table 40: Step 5 Levels IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-2.411648	117	0.0174
F-statistic	5.816048	(1, 117)	0.0174
Chi-square	5.816048	1	0.0159

Null Hypothesis: C(1)=1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.049845	0.020668

Restrictions are linear in coefficients.

Annex A, Table 41: Step 6 Levels IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	3.235762	(3, 117)	0.0248
Chi-square	9.707286	3	0.0212

Null Hypothesis: C(1)=1, C(3) = 0, C(4)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.049845	0.020668
C(3)	0.001815	0.001245
C(4)	-8.91E-06	1.09E-05

Restrictions are linear in coefficients.

Annex A, Table 42: Step 7 Levels IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	4.531159	(2, 118)	0.0127
Chi-square	9.062317	2	0.0108

Null Hypothesis: C(1)=1, C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.036519	0.012719
C(3)	0.000861	0.000437

Restrictions are linear in coefficients.

Annex A, Table 43: Step 2 Differenced IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	22.75139	(2, 118)	0.0000
Chi-square	45.50278	2	0.0000

Null Hypothesis: C(1)=1, C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.556546	0.082506
C(3)	1.18E-05	6.84E-06

Restrictions are linear in coefficients.

Annex A, Table 44: Step 3 Differenced IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-6.745546	118	0.0000
F-statistic	45.50239	(1, 118)	0.0000
Chi-square	45.50239	1	0.0000

Null Hypothesis: C(1)=1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.556546	0.082506

Restrictions are linear in coefficients.

Annex A, Table 45: Step 4 Differenced IRN

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	1.718668	118	0.0883
F-statistic	2.953819	(1, 118)	0.0883
Chi-square	2.953819	1	0.0857

Null Hypothesis: C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(3)	1.18E-05	6.84E-06

Restrictions are linear in coefficients.

Annex A, Table 46: Correlogram Levels Y2010PC

Correlogram of LOG_Y2010PC

Date: 04/10/26 Time: 14:18
Sample: 1995Q1 2025Q3
Included observations: 123

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.955	0.955	114.93	0.000
		2	0.915	0.040	221.42	0.000
		3	0.879	0.021	320.50	0.000
		4	0.841	-0.040	411.87	0.000
		5	0.801	-0.037	495.53	0.000
		6	0.766	0.029	572.70	0.000
		7	0.733	0.002	643.89	0.000
		8	0.698	-0.025	709.08	0.000
		9	0.664	-0.020	768.54	0.000
		10	0.631	-0.003	822.78	0.000
		11	0.599	-0.008	872.11	0.000
		12	0.569	0.001	916.95	0.000
		13	0.538	-0.024	957.40	0.000
		14	0.506	-0.028	993.56	0.000
		15	0.476	-0.012	1025.8	0.000
		16	0.444	-0.024	1054.1	0.000
		17	0.412	-0.026	1078.8	0.000
		18	0.385	0.024	1100.5	0.000
		19	0.362	0.041	1119.9	0.000
		20	0.341	0.013	1137.2	0.000

Annex A, Table 47: SIC Levels Y2010PC

Augmented Dickey-Fuller Unit Root Test on LOG_Y2010PC_I

Null Hypothesis: LOG_Y2010PC_I has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.02627	0.0000
Test critical values:	1% level	-4.035648	
	5% level	-3.447383	
	10% level	-3.148761	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG_Y2010PC_I)
Method: Least Squares
Date: 04/16/26 Time: 11:05
Sample (adjusted): 1995Q3 2025Q3
Included observations: 121 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_Y2010PC_I(-1)	-1.179241	0.090528	-13.02627	0.0000
C	0.004695	0.002758	1.702672	0.0913
@TREND("1995Q1")	-1.93E-05	3.84E-05	-0.503011	0.6159

R-squared	0.589832	Mean dependent var	-4.89E-05
Adjusted R-squared	0.582880	S.D. dependent var	0.022838
S.E. of regression	0.014750	Akaike info criterion	-5.570675
Sum squared resid	0.025672	Schwarz criterion	-5.501358
Log likelihood	340.0258	Hannan-Quinn criter.	-5.542522
F-statistic	84.84365	Durbin-Watson stat	2.060361
Prob(F-statistic)	0.000000		

Annex A, Table 48: Residual Correlogram Y2010PC Levels

Correlogram of Residuals

Date: 04/18/26 Time: 19:03
Sample (adjusted): 1995Q2 2025Q3
Q-statistic probabilities adjusted for 1 dynamic regressor

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.112	-0.112	1.5816	0.209
		2	-0.076	-0.090	2.3130	0.315
		3	0.129	0.112	4.4325	0.218
		4	0.068	0.092	5.0199	0.285
		5	-0.110	-0.076	6.5748	0.254
		6	-0.005	-0.032	6.5774	0.362
		7	0.045	0.011	6.8465	0.445
		8	-0.018	0.004	6.8915	0.548
		9	0.013	0.034	6.9125	0.646
		10	-0.008	-0.017	6.9213	0.733
		11	0.013	0.006	6.9431	0.804
		12	0.012	0.014	6.9635	0.860
		13	0.031	0.037	7.0928	0.897
		14	-0.010	0.002	7.1066	0.931
		15	0.029	0.026	7.2270	0.951
		16	0.055	0.054	7.6617	0.958
		17	-0.027	-0.012	7.7686	0.971
		18	-0.038	-0.040	7.9778	0.979
		19	-0.021	-0.052	8.0421	0.986
		20	-0.019	-0.033	8.0971	0.991

*Probabilities may not be valid for this equation specification.

Annex A, Table 49: Correlogram Differenced Y2010PC

Correlogram of LOG_Y2010PC_I

Date: 04/16/26 Time: 11:10
Sample (adjusted): 1995Q2 2025Q3
Included observations: 122 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.177	-0.177	3.9289	0.047
		2	-0.130	-0.167	6.0571	0.048
		3	0.094	0.040	7.1851	0.066
		4	0.038	0.047	7.3744	0.117
		5	-0.143	-0.113	10.024	0.075
		6	-0.027	-0.075	10.118	0.120
		7	0.030	-0.031	10.237	0.176
		8	-0.031	-0.030	10.365	0.240
		9	0.002	0.006	10.366	0.322
		10	-0.016	-0.039	10.400	0.406
		11	0.006	-0.016	10.406	0.494
		12	0.007	-0.004	10.412	0.580
		13	0.028	0.027	10.521	0.651
		14	-0.012	-0.000	10.541	0.722
		15	0.032	0.031	10.685	0.775
		16	0.062	0.071	11.239	0.795
		17	-0.020	0.018	11.295	0.841
		18	-0.028	-0.009	11.406	0.876
		19	-0.010	-0.027	11.420	0.909
		20	-0.005	-0.013	11.424	0.934

Annex A, Table 50: SIC Differenced Y2010PC

Augmented Dickey-Fuller Unit Root Test on A

Null Hypothesis: A has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.02627	0.0000
Test critical values:	1% level	-4.035648	
	5% level	-3.447383	
	10% level	-3.148761	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(A)
Method: Least Squares
Date: 04/18/26 Time: 19:06
Sample (adjusted): 1995Q3 2025Q3
Included observations: 121 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
A(-1)	-1.179241	0.090528	-13.02627	0.0000
C	0.004695	0.002758	1.702672	0.0913
@TREND("1995Q1")	-1.93E-05	3.84E-05	-0.503011	0.6159

R-squared	0.589832	Mean dependent var	-4.89E-05
Adjusted R-squared	0.582880	S.D. dependent var	0.022838
S.E. of regression	0.014750	Akaike info criterion	-5.570675
Sum squared resid	0.025672	Schwarz criterion	-5.501358
Log likelihood	340.0258	Hannan-Quinn criter.	-5.542522
F-statistic	84.84365	Durbin-Watson stat	2.060361
Prob(F-statistic)	0.000000		

Annex A, Table 51: Residual Correlogram Differenced Y2010PC

Correlogram of Residuals

Date: 04/18/26 Time: 19:08
Sample (adjusted): 1995Q3 2025Q3
Q-statistic probabilities adjusted for 1 dynamic regressor

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.030	-0.030	0.1134	0.736
		2	-0.157	-0.158	3.1895	0.203
		3	0.082	0.074	4.0448	0.257
		4	0.029	0.009	4.1500	0.386
		5	-0.155	-0.134	7.2189	0.205
		6	-0.053	-0.063	7.5818	0.270
		7	0.019	-0.031	7.6306	0.366
		8	-0.032	-0.032	7.7681	0.456
		9	-0.010	-0.002	7.7802	0.556
		10	-0.020	-0.050	7.8318	0.645
		11	0.002	-0.015	7.8324	0.728
		12	0.012	-0.003	7.8512	0.797
		13	0.028	0.022	7.9572	0.846
		14	-0.003	-0.004	7.9585	0.891
		15	0.042	0.040	8.2094	0.915
		16	0.068	0.063	8.8619	0.919
		17	-0.017	-0.000	8.9048	0.943
		18	-0.039	-0.020	9.1196	0.957
		19	-0.018	-0.031	9.1678	0.971
		20	-0.022	-0.022	9.2363	0.980

*Probabilities may not be valid for this equation specification.

Annex A, Table 52: Step 2 Levels Y2010PC

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	4.921028	(2, 119)	0.0088
Chi-square	9.842057	2	0.0073

Null Hypothesis: C(1)=1, C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.134569	0.043420
C(3)	0.000315	0.000114

Restrictions are linear in coefficients.

Annex A, Table 53: Step 5 Levels Y2010PC

Wald Test:
Equation: EQ_ADF_LOG_Y2010PC

Test Statistic	Value	df	Probability
t-statistic	-3.099215	119	0.0024
F-statistic	9.605133	(1, 119)	0.0024
Chi-square	9.605133	1	0.0019

Null Hypothesis: C(1)=1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.134569	0.043420

Restrictions are linear in coefficients.

Annex A, Table 54: Step 6 Levels Y2010PC

Wald Test:
Equation: EQ_ADF_LOG_Y2010PC

Test Statistic	Value	df	Probability
F-statistic	5.060520	(3, 119)	0.0025
Chi-square	15.18156	3	0.0017

Null Hypothesis: C(1)=1, C(2)=0,C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.134569	0.043420
C(2)	1.175876	0.378093
C(3)	0.000315	0.000114

Restrictions are linear in coefficients.

Annex A, Table 55: Step 7 Levels Y2010PC

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	3.547530	(2, 120)	0.0319
Chi-square	7.095060	2	0.0288

Null Hypothesis: C(1)=1, C(2)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-0.020678	0.014486
C(2)	0.186211	0.128354

Restrictions are linear in coefficients.

Annex A, Table 56: Step 2 Differenced Y2010PC

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	84.84365	(2, 118)	0.0000
Chi-square	169.6873	2	0.0000

Null Hypothesis: C(1)=1, C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-1.179241	0.090528
C(3)	-1.93E-05	3.84E-05

Restrictions are linear in coefficients.

Annex A, Table 57: Step 3 Differenced Y2010PC

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-13.02627	118	0.0000
F-statistic	169.6836	(1, 118)	0.0000
Chi-square	169.6836	1	0.0000

Null Hypothesis: C(1)=1
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
-1 + C(1)	-1.179241	0.090528

Restrictions are linear in coefficients.

Annex A, Table 58: Step 4 Differenced Y2010PC

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
t-statistic	-0.503011	118	0.6159
F-statistic	0.253020	(1, 118)	0.6159
Chi-square	0.253020	1	0.6150

Null Hypothesis: C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(3)	-1.93E-05	3.84E-05

Restrictions are linear in coefficients.

10 Appendix B

Annex B, Table 1: Inverse Roots of AR Characteristic Polynomial

Roots of Characteristic Polynomial
Endogenous variables: LOG_HINR LOG_HPRR LOG_IRN LOG_Y2010PC
Exogenous variables: C
Lag specification: 1 2 3 4 5 6 7 8
Date: 04/10/26 Time: 17:20

Root	Modulus
0.984247 - 0.084486i	0.987866
0.984247 + 0.084486i	0.987866
0.966103 - 0.187919i	0.984210
0.966103 + 0.187919i	0.984210
0.982828	0.982828
-0.010805 + 0.964353i	0.964413
-0.010805 - 0.964353i	0.964413
0.863035 - 0.384012i	0.944613
0.863035 + 0.384012i	0.944613
0.749142 - 0.495004i	0.897910
0.749142 + 0.495004i	0.897910
-0.804564 + 0.314978i	0.864022
-0.804564 - 0.314978i	0.864022
-0.277164 + 0.776270i	0.824266
-0.277164 - 0.776270i	0.824266
0.376236 + 0.732310i	0.823305
0.376236 - 0.732310i	0.823305
0.586645 + 0.564847i	0.814373
0.586645 - 0.564847i	0.814373
-0.804667	0.804667
-0.387055 - 0.696769i	0.797057
-0.387055 + 0.696769i	0.797057
0.152112 - 0.749266i	0.764550
0.152112 + 0.749266i	0.764550
-0.541118 - 0.525862i	0.754546
-0.541118 + 0.525862i	0.754546
-0.619565 - 0.342062i	0.707719
-0.619565 + 0.342062i	0.707719
0.339220 - 0.094126i	0.352037
0.339220 + 0.094126i	0.352037
-0.350313	0.350313
-0.240748	0.240748

No root lies outside the unit circle.
VAR satisfies the stability condition.

Annex B, Table 2: Preliminary VAR Lag Length Test 1 – White Noise Residuals

VAR Residual Serial Correlation LM Tests
Date: 04/10/26 Time: 16:43
Sample: 1995Q1 2025Q3
Included observations: 115

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	22.14487	16	0.1386	1.407951	(16, 229.8)	0.1389
2	26.23318	16	0.0508	1.682593	(16, 229.8)	0.0510
3	12.96833	16	0.6751	0.808498	(16, 229.8)	0.6754
4	19.43617	16	0.2467	1.228584	(16, 229.8)	0.2471
5	24.44634	16	0.0802	1.561974	(16, 229.8)	0.0804
6	4.305640	16	0.9983	0.263535	(16, 229.8)	0.9983
7	17.45012	16	0.3571	1.098367	(16, 229.8)	0.3575
8	18.94785	16	0.2714	1.196465	(16, 229.8)	0.2718
9	9.342696	16	0.8986	0.577983	(16, 229.8)	0.8988
10	22.52115	16	0.1271	1.433031	(16, 229.8)	0.1274
11	19.21031	16	0.2579	1.213720	(16, 229.8)	0.2583
12	15.86622	16	0.4623	0.995297	(16, 229.8)	0.4627

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	22.14487	16	0.1386	1.407951	(16, 229.8)	0.1389
2	52.57391	32	0.0124	1.710869	(32, 263.4)	0.0126
3	71.99595	48	0.0141	1.569128	(48, 260.1)	0.0147
4	85.04331	64	0.0404	1.380790	(64, 248.9)	0.0432
5	96.98376	80	0.0951	1.247515	(80, 235.2)	0.1043
6	112.6936	96	0.1173	1.203379	(96, 220.4)	0.1348
7	130.5224	112	0.1114	1.193459	(112, 205.1)	0.1384
8	149.8153	128	0.0911	1.199187	(128, 189.6)	0.1277
9	165.2491	144	0.1086	1.163644	(144, 173.9)	0.1694
10	172.5150	160	0.2360	1.057435	(160, 158.2)	0.3627
11	185.5020	176	0.2970	1.007155	(176, 142.3)	0.4844
12	199.9604	192	0.3319	0.966097	(192, 126.5)	0.5886

*Edgeworth expansion corrected likelihood ratio statistic.

Annex B, Table 3: Preliminary VAR Lag Length Test 2 – Exclusion Tests

VAR Lag Exclusion Wald Tests
Date: 04/10/26 Time: 16:41
Sample (adjusted): 1997Q1 2025Q3
Included observations: 115 after adjustments

Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values

	LOG_HINR	LOG_HPRR	LOG_IRN	LOG_Y2010	Joint
Lag 1	60.23828 [0.0000]	212.8638 [0.0000]	135.8505 [0.0000]	40.64501 [0.0000]	509.9975 [0.0000]
Lag 2	5.292765 [0.2586]	10.06947 [0.0393]	3.433126 [0.4881]	2.212871 [0.6967]	34.99514 [0.0040]
Lag 3	4.850857 [0.3029]	12.86456 [0.0120]	0.444412 [0.9787]	2.600548 [0.6267]	16.62836 [0.4100]
Lag 4	3.510680 [0.4763]	13.69352 [0.0083]	2.492878 [0.6459]	2.563305 [0.6333]	24.15938 [0.0861]
Lag 5	2.141200 [0.7098]	20.13740 [0.0005]	3.423773 [0.4896]	2.338080 [0.6738]	44.07222 [0.0002]
Lag 6	2.433782 [0.6565]	13.01035 [0.0112]	2.780372 [0.5952]	2.779994 [0.5953]	24.98001 [0.0702]
Lag 7	1.936094 [0.7475]	20.98610 [0.0003]	3.133851 [0.5357]	1.763775 [0.7791]	33.68134 [0.0060]
Lag 8	1.988570 [0.7379]	15.27654 [0.0042]	7.353540 [0.1183]	1.263101 [0.8676]	28.34005 [0.0288]
df	4	4	4	4	16

Annex B, Table 4: Preliminary VAR Lag Length Test 3 – Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: LOG_HINR LOG_HPRR LOG_IRN LOG_Y2010PC
Exogenous variables: C
Date: 04/10/26 Time: 16:42
Sample: 1995Q1 2025Q3
Included observations: 111

Lag	LogL	LR	FPE	AIC	SC	HQ
0	799.5887	NA	6.99e-12	-14.33493	-14.23729	-14.29532
1	1512.447	1361.496	2.46e-17	-26.89094	-26.40274	-26.69290
2	1561.023	89.27464	1.37e-17	-27.47790	-26.59913*	-27.12141*
3	1585.329	42.91850	1.18e-17	-27.62755	-26.35822	-27.11262
4	1609.275	40.55634	1.03e-17	-27.77072	-26.11082	-27.09735
5	1626.285	27.58414	1.02e-17	-27.78892	-25.73846	-26.95711
6	1656.480	46.78941	8.02e-18	-28.04469	-25.60367	-27.05444
7	1675.946	28.76058*	7.67e-18	-28.10714	-25.27556	-26.95845
8	1692.792	23.67542	7.74e-18	-28.12239	-24.90024	-26.81526
9	1711.990	25.59740	7.55e-18	-28.18001	-24.56730	-26.71444
10	1732.613	26.00998	7.23e-18*	-28.26329	-24.26002	-26.63928
11	1749.833	20.47876	7.44e-18	-28.28529*	-23.89145	-26.50284
12	1758.761	9.972771	9.01e-18	-28.15785	-23.37345	-26.21696

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Annex B, Table 5: Johansen Cointegration Tests 5% Significance Level

Date: 04/18/26 Time: 14:49
Sample (adjusted): 1997Q2 2025Q3
Included observations: 114 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: LOG_HINR LOG_HPRR LOG_IRN LOG_Y2010PC
Lags interval (in first differences): 1 to 2, 3 to 4, 5 to 6, 7 to 8

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.292995	76.25615	54.07904	0.0002
At most 1 *	0.165672	36.73037	35.19275	0.0339
At most 2	0.098628	16.08173	20.26184	0.1706
At most 3	0.036546	4.244266	9.164546	0.3770

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.292995	39.52578	28.58808	0.0014
At most 1	0.165672	20.64864	22.29962	0.0836
At most 2	0.098628	11.83747	15.89210	0.1956
At most 3	0.036546	4.244266	9.164546	0.3770

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Annex B, Table 6: Johansen Cointegration Tests 1% Significance Level

Date: 04/10/26 Time: 17:25
Sample: 1995Q1 2025Q3
Included observations: 123
Lags interval (in first differences): 1 to 2, 3 to 4, 4 to 5, 5 to 6, 6 to 7, 7 to 8, 8 to
Endogenous variables: LOG_HINR LOG_HPRR LOG_IRN LOG_Y2010PC
Deterministic assumptions: Case 2: Cointegrating relationship includes a constant

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.01 Critical Value	Prob.** Critical Value
None *	0.292995	76.25615	61.26692	0.0002
At most 1	0.165672	36.73037	41.19504	0.0339
At most 2	0.098628	16.08173	25.07811	0.1706
At most 3	0.036546	4.244266	12.76076	0.3770

Trace test indicates 1 cointegrating equation(s) at the 0.01 level
* denotes rejection of the hypothesis at the 0.01 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Max-eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.01 Critical Value	Prob.** Critical Value
None *	0.292995	39.52578	33.73292	0.0014
At most 1	0.165672	20.64864	27.06783	0.0836
At most 2	0.098628	11.83747	20.16121	0.1956
At most 3	0.036546	4.244266	12.76076	0.3770

Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.01 level
* denotes rejection of the hypothesis at the 0.01 level
**MacKinnon-Haug-Michelis (1999) p-values

Annex B, Table 7: Unrestricted VECM Estimates (excluding first difference lag estimates)

Vector Error Correction Estimates
Date: 04/10/26 Time: 17:43
Sample (adjusted): 1997Q2 2025Q3
Included observations: 114 after adjustments
Standard errors in ( ) & t-statistics in [ ]
Lags interval (in first differences): 1 to 2, 3 to 4, 4 to 5, 5 to 6, 6 to 7, 7 to 8, 8 to
Endogenous variables: LOG_HPRR LOG_HINR LOG_IRN LOG_Y2010PC
Deterministic assumptions: Case 2: Cointegrating relationship includes a constant

Cointegrating Eq:	CointEq1
LOG_HPRR(-1)	1.000000
LOG_HINR(-1)	-0.318328
	(0.15593)
	[-2.04146]
LOG_IRN(-1)	0.640172
	(1.62853)
	[0.39310]
LOG_Y2010PC(-1)	-0.673881
	(0.39926)
	[-1.68781]
C	5.109710
	(2.34212)
	[2.18166]

Error Correction:	D(LOG_HPR	D(LOG_HINR)	D(LOG_IRN)	D(LOG_Y201
COINTEQ1	-0.072647	-0.065196	0.009370	-0.067460
	(0.01484)	(0.05192)	(0.00677)	(0.04383)
	[-4.89563]	[-1.25563]	[1.38483]	[-1.53912]

Annex B, Table 8: Restricted VECM Estimates (excluding first difference lag estimates)

Vector Error Correction Estimates
Date: 04/10/26 Time: 18:00
Sample (adjusted): 1997Q2 2025Q3
Included observations: 114 after adjustments
Standard errors in ( ) & t-statistics in [ ]
Lags interval (in first differences): 1 to 2, 3 to 4, 4 to 5, 5 to 6, 6 to 7, 7 to 8, 8 to
Endogenous variables: LOG_HPRR LOG_HINR LOG_IRN LOG_Y2010PC
Deterministic assumptions: Case 2: Cointegrating relationship includes a constant

Cointegrating restrictions:
A(2,1)=0
A(3,1)=0
A(4,1)=0

Convergence achieved after 5 iterations.
Not all cointegrating vectors are identified.

LR test for binding restrictions (rank = 1):

Chi-square(3)	5.021463
Probability	0.170232

Cointegrating Eq:	CointEq1
LOG_HPRR(-1)	35.62126
LOG_HINR(-1)	-14.25632
LOG_IRN(-1)	32.00502
LOG_Y2010PC(-1)	-23.64194
C	213.4555

Error Correction:	D(LOG_HPR	D(LOG_HINR)	D(LOG_IRN)	D(LOG_Y201
COINTEQ1	-0.002276	0.000000	0.000000	0.000000
	(0.00042)	(0.00000)	(0.00000)	(0.00000)
	[-5.44631]	[NA]	[NA]	[NA]