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Predicting how Macroeconomic Factors can impact the Housing Market in Portugal

Using Machine learning Techniques

António João Nunes da Fonseca

Dissertation

presented as partial requirement for obtaining the Master Degree Program in Data Science and Advanced Analytics

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PREDICTING HOW MACROECONOMIC FACTORS CAN IMPACT THE HOUSING MARKET IN PORTUGAL USING MACHINE LEARNING TECHNIQUES

by

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Dissertation presented as partial requirement for obtaining the Master's degree in Advanced Analytics, with a Specialization in Data Science

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

António João Nunes da Fonseca

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ABSTRACT

Background: The Portuguese Housing Market has been growing in the last few years as OECD studies mention. However, there has been a lack of scientific research addressing this phenomenon in Portugal.

Objectives: This study seeks to fill this gap and to understand how Macroeconomic factors can impact the Portuguese housing market.

Methodology: In this study, the Vector Autoregression model (VAR) and Gated Recurrent Units model were applied, using two different variable approaches. One utilizing a dimensionality reduction technique, factor analysis, and the other using the original uncorrelated variables.

Results: The results of this study conclude that utilizing the Mean Squared Error that the VAR model using the factor analysis dataset outperforms the other VAR model and the GRU models, having an MSE of 0.11. In this model, the dependent variable has a positive relationship with lagged one-time economy and a negative relationship with lagged one-time nominal house prices and lagged four-times nominal house prices. The economy factor has high factor loadings with GDP, Euribor 3M (interest rate), and Tourism and there exists scientific research in other countries associating these three variables with the housing prices.

Conclusion: This study concludes that the macroeconomic variables impact the Portuguese housing market specifically economic-centric variables such as GDP, interest rates and, tourism.

KEYWORDS

Housing Market; Macroeconomic Variables; Vector Autoregression Model; Gated Recurrent Units.

Sustainable Development Goals (SGD):

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LIST OF ABBREVIATIONS AND ACRONYMS

FREI	Foreign Real Estate Investment
CBI	Citizenship by Investment programs
OECD	Organization for Economic Co-operation and Development
EUROSTAT	Statistical office of the European Union
ECB	European Central Bank
PORDATA	Statistics database of Fundação Francisco Manuel dos Santos
INE	Instituto Nacional de Estatística (Statistics Portugal)
GDP	Gross Domestic Product
PSI20	Euronext Lisbon
R&D	Research and Development
RPPI	Residential Property Prices Indices
PCA	Principal Components Analysis
FA	Factor Analysis
VAR	Vector Autoregression Model
GRU	Gated Recurrent Unit
MSE	Mean Squared Error

1. INTRODUCTION

The interest in developing a study on the housing market in Portugal is associated with the importance of this subject in shaping societal development and its impact on the living conditions and well-being of the population. This topic is related not only to the macroeconomic variables but especially to the quality of life of the population and the relationship between households and society. Housing is a determining factor in the development of contemporary societies contributing to generational and the economic stability of individuals. Therefore, studying this subject becomes imperative for defining policies aimed at stabilizing the housing market.

Several authors demonstrated a significant relationship between the housing market and the country's economy (Leung, 2004; Prüser & Schmidt, 2021). In this manner, a collection of macroeconomic variables which influence the Housing Market are observed, such as Tourism (Van-Hametner et al., 2019), Interest Rates (Ayan & Eken, 2021), Gross Domestic Product (GDP) (Chi-Wei et al., 2018), Household Income (Gutiérrez & Domènech, 2020), as well as Inflation and Employment Rate (Chatterjee, 2023).

Data provided by the OECD demonstrates that since 2015 housing prices have increased in OECD countries, and Portugal is no different. According to the OECD, the Real Estate Market in Portugal persists to expand as the house prices index, which measures the developments in house transaction prices in the country, continues to grow.

Some literature has shown that it is possible to use Machine learning Techniques in order to predict the Real Estate Market, specifically using VAR, Neural Networks, Gradient Boosting, and Random Forest algorithms (Rampini & Re Cecconi (2022), Almaslukh (2020), Levantesi & Piscopo (2020)). Thus, the use of statistical models/artificial intelligence should be used to have better insight into this topic. However, there are few studies that explicitly combine these techniques with the Housing Market in Portugal. This research, therefore, seeks to fill the gap of this noted lack of literature regarding this topic.

Given the previously described issue, it was deemed imperative to undertake a study with the objective of predicting how Macroeconomic factors can impact the Portuguese Housing Market, based on the development of the methodologies VAR and Gated Recurrent Units (GRU) utilizing data from national and international organizations that describe macroeconomic variables that may be associated with the Portuguese Housing Market, as a mean of addressing the formulated objective.

This dissertation is divided into six sections. Hence, in the second section, a literature review based on the relevance of Real Estate on the Economy was developed, as well as a systematic literature review of 20 selected articles out of a total of 236, that allowed us to better understand which macroeconomic factors contribute to changes in housing prices. The third section describes the methodology used employing VAR and GRU models based on the selected macroeconomic variables identified through the literature review. In the fourth section, the main results are described using the methodological models outlined, followed by a discussion of the results based on related scientific evidence. Finally, in the last section, it describes the main conclusions found, the limitations, and the proposal for new studies in the area of the Portuguese Housing Market.

2. LITERATURE REVIEW

Based on the objective delineated, to predict how Macroeconomic factors can impact the Portuguese Housing Market, there is a need for conducting a literature review aimed at understanding which macroeconomic factors contribute to changes in the prices of the housing sector. Therefore, performing a literature review is crucial in order to determine which variables should the study's models use.

2.1. THE RELEVANCE OF REAL ESTATE ON THE ECONOMY

The emergence of literature that investigates whether there is a connection between the Housing Market and Macroeconomics has been steadily increasing over the last few years as Leung (2004) suggests. As the study explains, the convergence between the two research topics is essential since the Real Estate Market represents "a large share of the overall macroeconomy". Thus, several new frontlines have appeared by merging these two subjects, and the following subsections will be exhibited in international literature.

As Renauld (1995) studied, the factors that influenced the real estate cycles between 1985 and 1994 are directly correlated with governmental macroeconomic policies and worldwide macroeconomic conditions. This theory has been corroborated by recent studies. Andrews (2010) concluded that the decline of real interest rates and the financial deregulation create demand shocks that impact positively the Housing Market in OECD countries.

Although financial deregulation is proven to affect the Housing Market it is not the only factor. As Rodríguez & Bustillo (2010) explained, 40% of the total foreign direct investment inflows in Spain are Real Estate investments. Therefore, foreign investment can be deemed as another important element to consider. The study concludes by mentioning that foreign real estate investment (FREI) has been important to support the Spanish economy specifically, the construction and the housing market sector. Additionally, Gunduz, Genc & Aysan (2022) also demonstrated the impact that FREI had in the Real Estate Market. As it is described in the paper, where their focus is on the Istanbul Housing Market, it is stated that the Turkish government in order to attract foreign investment to their country launched a Citizenship by Investment program (CBI) in 2017 and, as it is outlined by the study, in 2022 these programs resulted in a positive impact of 2% in the house prices in districts where at least 10% of the houses sold were bought by foreigners.

Moreover, Rodríguez et al. (2010),in order to conceptualize their model, used another variable that numerous scientific papers regard as relevant in this area of study: Tourism. As it is explained, in countries such as Spain, and where Portugal is inserted, Tourism is an extremely important sector in the economy since it accounts for more than 10% of GDP in those two countries, according to OCDE. Zhang & Yang (2021) researched the impact of tourism on the Icelandic Housing Market and the results revealed that a positive increase in tourism demand positively affected house prices. This is particularly important since, even though the share of tourism in the GDP of Iceland is higher than that of Portugal, it demonstrates that in Tourism-centric countries it is an extremely important variable to examine. Yıldırım and Karul (2022), also, corroborated this theory. Their findings confirmed that the excessive

demand for tourist accommodation in Turkey led not only to an increase in the prices of short-term and long-term rentals but also in housing prices as wealthier tourists started to buy vacation homes.

The study by Li, Li & Nuttapong (2022), in a systematic literature review between the years 2015 to 2020, describes the factors that influence the macroeconomic control of the housing market, identifying: Economic factors such as household income, employment situation, financial health of investment, industrial structure, tax revenues and expenditures on housing; Social factors including ageing, housing prices, household and number of children, and social safety; Psychological factors such as trends, customs, and cultural atmosphere; Bureaucratic factors namely legislation, government policies, taxes, planning, urban construction and public safety; Political factors mainly referring to political stability, military relations with other countries and inter-state politics; Environment factors such as energy security conditions, area, structure, housing conditions, solar exposure and external factors as the terrain geology, location and quality of the air; Restrictive policies as the One-child policy.

Zhang, Li, Hui, & Li, (2016) based on a study using the VAR (vector Autoregression model) methodology refer that housing prices are imminently related to macroeconomic factors and point out that the increase in interest rates has a negative impact on housing market prices. The same authors mention that this impact is lower in cities with a higher economic level compared to cities with a lower economic level.

For Applová (2012) serious macroeconomic imbalances are observed at the level of the European Union countries, with external surpluses, loss of competitiveness, indebtedness of families and states, with the consequent increase of real estate bubbles and financial imbalance.

According to Stanković (2022), the phenomenon of macroeconomic imbalances is a complex process and lists several factors that affect housing market prices such as GDP, real GDP growth rate, industrial production growth rate, GDP per capita, average wage level, external trade balance, household deposits, interest rates on housing loans, the level of financial illiteracy and government expenditure.

Financial ratios, sovereign debts in Europe especially in Portugal, Italy, Ireland, Greece and Spain, economic growth rates and interest rates have a significant impact on property prices (Abad-González, Gutiérrez-López & Salvador, 2018).

Cirman, Pahor, & Verbic (2015) describe the Time on the Market factor as also being a determinant, of housing price index, as well as the availability of properties and the interest rates applied.

For Caines (2016) the reason why the Real Estate Market continues to have a large and persistent price growth is justified by the continuous behaviour learning on the beliefs of house prices of all the agents involved in the sector: the people who demand assets and the individuals who deliver the credit. Moreover, the paper mentions that another variable that triggered this continuous growth was the decrease in mortgage rates.

Prüser & Schmidt (2021) concluded that by analysing specific states, namely coastal states, they were able to infer the nationwide Housing Market state. The common ground of these regions was that they all shared the same characteristics in important variables such as population density, unemployment rate, housing density and land supply elasticity.

Christou, Gupta & Nyakabawo (2019) studied the impact of macroeconomic uncertainty shocks on the Housing Market concluding that an uncertainty shock negatively impacts the market. The variables used to elaborate this study were GDP, taxes, government spending, unemployment, CPI, consumption and GDP deflator, short-term and long-term interest rates, stock prices, exchange rates, etc.

Throughout this subchapter, numerous macroeconomic factors influencing the real estate market prices have been identified, and based on these scientific studies it is recognized the complexity of studying this topic. Consequently, the development of a systematic literature review is imperative in order to extract the indicators influencing the housing market in a more coherent manner.

2.2. SYSTEMATIC LITERATURE REVIEW

Background

Data provided by the OECD demonstrates that since 2015 housing prices have increased in OECD countries, and Portugal is not different. According to the OECD, the Real Estate Market in Portugal persists to expand as the house prices index, which measures the developments in house transaction prices in the country, continues to grow. Thus, monitoring and analyzing this phenomenon is extremely important (Appendix A).

Objective

To identify which Macroeconomic factors contribute to changes in housing prices.

Review Question

This revision will answer the following question: Which macroeconomic factors contribute to changes in housing prices?

Materials and Methodology

The protocol was established in agreement with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Eligibility Criteria

The criteria for inclusion were the following: studies that include variables that influence price changes in the housing market sector. The review includes qualitative or quantitative empirical studies, whether they are cross-sectional, longitudinal, or observational studies.

Research Strategy

The research utilized the subsequent databases: Academic Search Complete, and Business Source Complete, and the search strategy used the descriptors from the 'Business Thesaurus' or similar terms. It included the studies written in English and German with the restriction of “Full text”, and “Peer review” and published between January 2018 and December 2023.

Search Terms and Boolean Operators

The search terms included the combination between the following subject headings, in accordance with the 'Business Thesaurus' or similar terms: [(real estate market OR house market OR housing

market) AND (INFORMATION economy OR economic factors OR economic) AND (tourism OR Unemployment OR Population OR Public Debt OR interest rate OR gross domestic product OR gdp OR Inflation OR Stock market OR Purchasing Power)].

Data Collection and Analysis

Study Selection

The selection of studies included several stages: the duplicates originated from the two databases were removed. To minimize the inadequacy of the studies, the research studies were subject to an inclusion assessment through the review of the titles, abstracts, and keywords. (Figure 1 – PRISMA Flow Diagram (Page et. al 2021)). Afterwards, the assessment of the full text was conducted, using the same methodology.

Data Collection and Assessment

In the data collection stage, a descriptive evaluation of each study was performed, in order to extract the necessary information to answer the research question.

Data Synthesis Strategy

Given that the review includes studies with a variety of qualitative and quantitative methodologies, the synthesis and analysis of the results used a narrative nature strategy. The indicators which influence the housing market prices were presented in a common table.

Results

The research delivered 236 results and, after removing the duplicates, 197 studies were selected. Based on the assessment of the abstract, 87 publications were selected for analysis (Figure 1 – PRISMA Flow Diagram).

The studies were excluded because of the following reasons: they did not contain information regarding the Housing Market, they did not describe a relationship between the real estate market and the macroeconomic variables, they lacked clarity in the abstract about conclusions or methodologically were inconsistent.

The revision of 20 studies, the majority of which were conducted in China (4 studies), was included. Studies from the following countries were also included in the review: United States of America (3 studies), Italy (2 studies) and one study from Germany, Australia, Croatia, England, Greece, Hong Kong, Hungary, Spain, Sweden, Taiwan and Turkey.

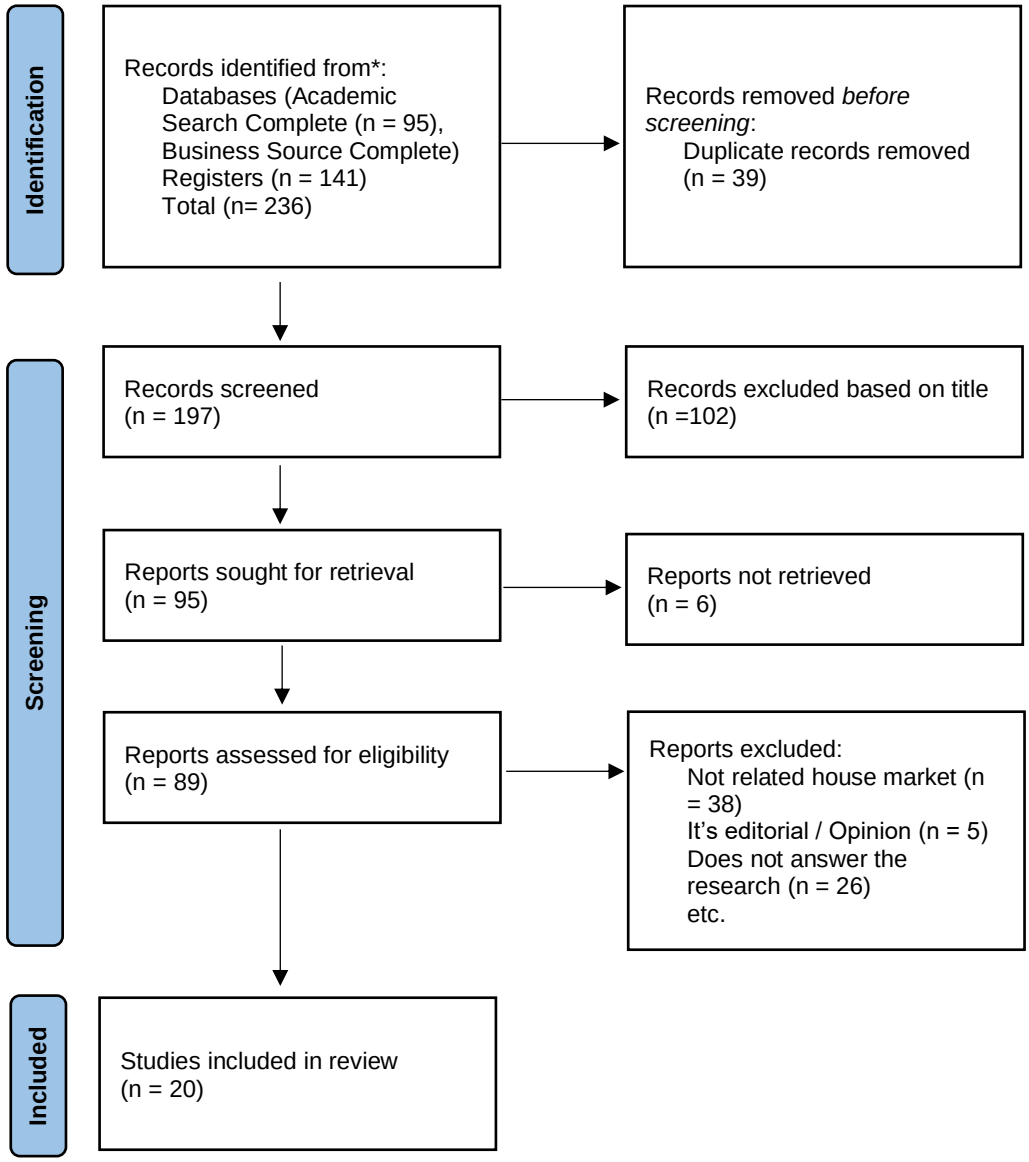

Figure 1 – PRISMA Flow Diagram

The data collected in each study were organized in Table 1 – Studies included in the review and Table 2 - Synthesis of the macroeconomic factors that influence the Housing Market.

Table 1 – Studies included in the Review

Title/Authors/Country/Database	Objectives	Results/Conclusion
Title: Forecasting Economic Growth: Evidence from housing, banking, and credit conditions. Corresponding author: Chatterjee, Ujjal Country: Italy Year: 2023 Database: Business Source Complete	Understand the relationship between housing prices, real estate investment, credit spreads, and aggregate bank liquidity in order to forecast economic growth	Observed that the influence of the growth of GDP, housing prices, and companies' credit spreads have a greater impact on the United States economy than the aggregate bank liquidity indicator. Moreover, it was concluded that the positive change in housing prices impacts positively inflation and unemployment rate.
Title: House price inflation may soon be running on empty. Corresponding author: Bank of England Country: England Year: 2021 Database: Business Source Complete	To Predict the influence of macroeconomic factors such as household incomes, unemployment, and the COVID-19 related support measures on short-term housing prices	The Bank of England concluded for the reference year 2020 that the increase in unemployment, the decrease in household income, and other factors influenced a correction in housing prices.
Title: South Bend and Elkhart forecast 2023. Corresponding author: HONG ZHUANG Country: United States Year: 2022 Database: Business Source Complete	The study reports on the economic view for the regions of South Bend-Mishawaka and Elkhart-Goshen for 2023.	The subjects analyzed include employment and unemployment, income, hours worked, and the real estate market. It also mentioned inflation, investment activities, and monetary policy.
Title: Die Wohnungsfrage abseits der Metropolen: Wohnen in Salzburg zwischen touristischer Nachfrage und Finanzanlagen. Corresponding author: Van-Hametner, Andreas Country: Germany Year: 2019 Database: Academic Search Complete	Analyze the influence of tourism on housing prices, using the city of Salzburg as reference.	The growth of tourism increases the prices in the housing sector, specifically in tourist-centric cities and neighborhoods, but also in non-tourist-centric cities.
Title: Endemic and Diverse: Planning Perspectives on Second-home Tourism's Heterogeneous Impact on Swedish Housing Markets. Corresponding author: Back, Andreas Country: Sweden Year: 2022 Database: Academic Search Complete	To describe the complex dynamic between the real estate market and how second home tourism influences the housing prices.	The results display how second-home tourism impacts differently the Housing Market depending on the growth rate and demand. However, it determines second-home tourism as a clear influence over the housing sector.
Title: Evaluation Model of Tourism-Driven Real Estate Economic Growth Point Based on AHP. Corresponding author: Zheng, Du Country: China Year: 2022 Database: Academic Search Complete	To understand how the growth of tourism impacts the Housing Market by establishing an assessment model to study this phenomenon.	Using the assessment model proposed, the authors concluded that housing prices are affected by tourism, but also by local politics developed to control the housing sector.
Title: Housing Commodification and Increasing Potential Ground Rents in Post-Socialist Budapest. Corresponding author: Olt, Gergely Country: Hungary Year: 2023 Database: Academic Search Complete	To describe the institutional, social, and political factors that influence the Dynamics of the housing market prices.	The study concluded that mortgage loan restrictions and the unplanned expansion of tourism have impacted the real estate market.

Title/Authors/Country/Database	Objectives	Results/Conclusion
Title: Tourism and housing prices in Santa Marta, Colombia: Spatial determinants and interactions Corresponding author: Garza, Nestor Country: Colombia Year: 2019 Database: Academic Search Complete	To analyze the impact of tourism developments in Santa Marta on the Housing market, using data from 2016	The authors concluded that the development of tourism impacts housing prices and contributes to the difficulty for locals to buy a house.
Title: Tourism housing price nexus. Corresponding author: Časni, Anita Čeh Country: Croatia Year: 2022 Database: Business Source Complete	To understand the impact of tourism in housing prices and its relevance in the economic development	The authors concluded that tourism has a clear impact on the housing market though, they verify a difference between the studied countries due to political decisions regarding this sector in each country.
Title: Understanding the spatiality of short-term rentals in Spain: Airbnb and the intensification of the commodification of housing. Corresponding author: Gutiérrez, Aaron Country: Spain Year: 2020 Database: Academic Search Complete	To understand the relationship between short-term rentals and macroeconomic indicators.	Using Spain as reference, it was concluded that areas with a high number of Airbnb's results in higher housing prices.
Title: Are housing prices improving GDP or vice versa? A cross-regional study of China. Corresponding author: Chi-Wei, Su Country: China Year: 2018 Database: Business Source Complete	To identify the relationship between the real estate market and GDP in China's provinces.	The authors concluded that the rapid industrialization, rapidly increases the GDP and promotes the investment in the housing market. This influence is even higher in provinces with low supply in the housing sector.
Title: Credit expansion, bank liberalization, and structural change in bank asset accounts. Corresponding author: Liu, Keqing Country: Hong Kong Year: 2021 Database: Business Source Complete	To study the relationship between the connections between the expansion of credit supply, structures of commercial bank asset accounts, and the explosion of the housing market before the 2007-2009 financial crisis.	In this study, it was concluded that the expansion of credit is linked to the surge of housing prices.
Title: Detection of price bubbles in Istanbul housing market using LSTM autoencoders: a district-based approach. Corresponding author: Ayan, Ebubekir Country: Turkey Year: 2021 Database: Academic Search Complete	To analyze the increase of housing prices in Istanbul between the years of 2017 and 2019.	The authors found differences in the surge of housing prices between Istanbul's neighborhoods. However, they concluded that several variables can be used to predict the housing market such as inflation, stock market index, exchange rates, interest rates, and General government debt securities.
Title: Housing price spillovers in China: A high-dimensional generalized VAR approach. Corresponding author: Yang, Jian Country: United States Year: 2018 Database: Business Source Complete	To study the fluctuations of the housing market between the years of 2005 and 2015 in 69 Chinese cities.	Taking into consideration all the differences between the development plans of each region, the authors concluded that the variables which influence the housing market the most are population, GDP, and the education levels of the population.
Title: Long-Term and Short-Term House Price Dynamics in China's First Tier and Second Tier Main 13 Cities.	To understand the main factors influencing the housing market in 13 cities in China between the years of 2007 and 2018.	The results suggest that housing prices have a positive relationship with macroeconomic factors such as the stock market index, interest rates and GDP.

Title/Authors/Country/Database	Objectives	Results/Conclusion
Corresponding author: Wang, JingJing (Justine) Country: Australia Year: 2020 Database: Business Source Complete		
Title: The role of informal housing in lowering China's urbanization costs. Corresponding author: Niu, Dongxiao Country: China Year: 2021 Database: Business Source Complete	To understand the role of informal housing with migration flows and economic growth.	The authors concluded that economic growth observed for the last 30 years in China was possible due to the migration flows from rural regions to cities. This migration only happened because of the high supply of informal housing, and it contributed to the increase of GDP, income, housing prices, and better conditions for the general population.
Title: A 10-Year Analysis of Housing Prices and The Influence of Economic Factors in Turkey. Corresponding author: Muddasir, Muhammad Country: United States Year: 2023 Database: Business Source Complete	To investigate the relationship between housing prices and inflation and exchange rate in Turkey using monthly data between the years 2010 and 2019.	The study concluded that there exists a positive link between inflation and the housing market and that the high housing prices were also influenced by the substantial decrease of the Turkish Lira.
Title: The cause and outcomes of the ripple effect: housing prices and transaction volume. Corresponding author: Tsai, I-Chun Country: Taiwan Year: 2018 Database: Business Source Complete	This study analyses four major United States regions, Northeast, Midwest, South, and West, in order to understand better the housing market.	The results show that inflation has a positive relationship with the housing prices and that it leads to an increase in the supply of homes. This boom in supply negatively affects interest rates.
Title: Time-varying role of macroeconomic shocks on house prices in the US and UK: evidence from over 150 years of data. Corresponding author: Plakandaras, Vasilios Country: Greece Year: 2020 Database: Business Source Complete	To understand the macroeconomic factors influencing housing prices in the United States and the United Kingdom.	The authors' main conclusion is that technological shocks influence the housing sector in the United States while this effect is not relevant in the United Kingdom.
Title: Experimental Research on the Impact of Interest Rate on Real Estate Market Transactions. Corresponding author: Chen, Chang Country: China Year: 2022 Database: Academic Search Complete	To identify the impact of interest rates on the Chinese housing market transactions.	The study concludes that the deposit interest rates influence housing prices. The authors observed that high deposit interest rates cause suppressions of housing market bubbles.

Discussion

Following the developed methodology, the goal was to identify the macroeconomic factors contributing to price changes in the real estate market. By analyzing the studies, it is possible to infer that several authors mention tourism as one factor, this indicator is extremely associated with the new short-term dynamics of tourism and rapid growth of short-term rentals in online platforms, such as

Airbnb (Gutiérrez & Domènech, 2020) (Table 1). In this regard Van-Hametner et al. (2019) refer to the impact that the tourism pressure implies on the Housing Market. Specifically in touristic-centric neighborhoods forcing locals from these neighborhoods reallocate to other areas. This phenomenon is also observed in less touristic regions. Moreover, Back, et al. (2022) denote the complex influence of second-home tourism in different housing markets which cannot be dissociated from the local real estate control policies followed by the municipalities (Zheng, 2022). Regarding the mentioned planning measures, Olt et. al (2023) draw attention to the mortgage restrictions loans and the unplanned growth of tourism as direct impacts on the growth of housing prices. In this sense, tourism affects several sectors of the economy, contributing to the rise in the cost of living in these regions, and having a special impact on low-income residents (Časni & Filić, 2022).

Additionally, interest rates are stated by several authors as a factor that greatly impacts housing prices (Ayan & Eken, 2021). This indicator is frequently associated with other macroeconomic variables such as the Stock Market index or GDP (Wang, et. al, 2020). The phenomena related to inflation stem from the increase in liquidity, contributing to the growth of housing prices and interest rates (Tsai, 2018). Chen et al. (2022) conclude that the rapid increase in interest rates causes an inhibitory effect on housing prices.

Furthermore, gross domestic product (GDP) is considered a key factor for studying the Housing Market also having a great influence on family consumption and levels of renumeration and employment (Chatterjee, 2023). The rapid industrialization of societies and, consequently, the migration of people from rural areas to cities promote the investment in regions' housing markets (Chi-Wei et. al, 2018), these regional developments increase the levels of literacy of the residents, standards of living as well as housing prices (Yang, Yu & Deng 2018; Yang & Guo, 2018). Wang (2020) corroborates the idea of the previous authors as Wang (2020) refers that there exists a positive correlation between housing prices and macroeconomic factors such as GDP, interest rates, and the Stock Market index. Several authors also refer to migration of the population between regions, higher demand for formal or informal homes, incomes, level of education, and improvement of living conditions as determined factors for studying the real estate market market (Niu, Sun & Zheng, 2021; Chatterjee, 2023).

Table 2 – Synthesis of the macroeconomic factors influencing the Housing Market

Variables	**Studies**	**Number of studies**
Tourism	Van-Hametner, Andreas. Germany. 2019. Back, Andreas. Sweden. 2019. Zheng, Du. China. 2022. Olt, Gergely. Hungary. 2023. Garza, Nestor. Colombia. 2019. Časni, Anita ČehCountry: Croatia. 2022. Gutiérrez, Aaron. Spain. 2020.	7 studies
Mortgage Interest Rates	Chatterjee, Ujjal. Italy. 2023. Wang, JingJing. Australia. 2020. Tsai, I-Chun. Taiwan. 2018. Chen, Chang. China. 2022. Ayan, Ebubekir. Turkey. 2021.	5 studies
Gross Domestic Product	Chatterjee, Ujjal. Italy. 2023. Chi-Wei, Su. China. 2018. Chatterjee, Ujjal. Italy. 2023. Yang, Jian. United States. 2018. Wang, JingJing. Australia. 2020.	5 studies
Income; Household Income; Living Conditions	Chatterjee, Ujjal. Italy. 2023. Garza, Nestor. Colombia. 2019. Gutiérrez, Aaron. Spain. 2020. Niu, Dongxiao. China. 2021. HONG ZHUANG. United States. 2022.	5 studies

Variables	Studies	Number of studies
Inflation	Chatterjee, Ujjal. Italy. 2023. HONG ZHUANG. United States. 2022. Muddasir, Muhammad. United States. 2023. Tsai, I-Chun. Taiwan. 2018. Ayan, Ebubekir. Turkey. 2021.	5 studies
Employment rate	Chatterjee, Ujjal. Italy. 2023. Bank of England. England. 2021. HONG ZHUANG. United States. 2022.	3 studies
Real Estate control policies	HONG ZHUANG. United States. 2022. Zheng, Du. China. 2022. Časni, Anita ČehCountry: Croatia. 2022.	3 studies
Stock Market index	Ayan, Ebubekir. Turkey. 2021. Wang, JingJing. Australia. 2020.	2 studies
Exchange rate	Ayan, Ebubekir. Turkey. 2021.	1 study
Government Debt Securities	Ayan, Ebubekir. Turkey. 2021.	1 study
Population Literacy level	Yang, Jian. United States. 2018.	1 study
Population	Niu, Dongxiao. China. 2021.	1 study
Second home tourism	Van-Hametner, Andreas. Germany. 2019.	1 study
Technology Shocks	Plakandaras, Vasilios. Greece. 2020.	1 study

By observing Table 2, it is possible to observe that some authors designate a wide range variety of macroeconomic variables which influence housing prices, specifically exchange rates, government debt securities, technology shocks, etc. However, several factors, such as Tourism and GDP, for example, are mentioned in more than one study.

To conclude, the Systematic Literature Review facilitated the identification of several variables that influence the housing sector. These variables allow the development of the empirical models which will study the Portuguese Housing Market, which will be described in the following chapter.

3. METHODOLOGY

Several studies recently published prove the relevance of applying traditional statistics (Stundziene, Vaida, & Andrius (2022)) and machine learning techniques (Almaslukh (2020)). This study intends to use such a combined approach to study how macroeconomic factors can impact the Portuguese Housing Market.

This chapter provides an overview of the collected variables considered for the study, based on the Systematic Literature Review and the data availability for the Portuguese scenario, the data treatment processes conducted, and the methods used to shed light on the impact of those factors in the Portuguese real estate market.

3.1. DATA COLLECTION

Several sources were used in order to gather the variables for this study, prevailing data from national or international statistics institutions (OECD, EUROSTAT, ECB, Banco de Portugal, INE, and PORDATA) and Investing.com, which is a financial market platform that collects real-time data.

Concerning the variables chosen, Nominal House Prices is the dependent variable, as for the independent variables, the selection was based on the importance that each variable has in association with the dependent variable and previous studies regarding this subject.

Tourism and Night Spent Tourism were selected due to the relevance that this economic sector has in the Housing Market. Zhang & Yang (2021) demonstrated this impact as they concluded that a possible change in the tourism numbers can impact the real estate market in Iceland.

Inflation, GDP, and Average Income are also relevant macroeconomic variables to perform this analysis as Okuta, Kivaa, Kieti & Okaka (2022) showed and, therefore, were selected. The use of energy inflation is corroborated by Breitenfellner, Crespo Cuaresma, & Mayer (2015) as the study concludes the effect of this factor in the correction of housing prices. Regarding the variables: Unemployment rate and Population, Rehman, Moutinho & Alves (2020) studied the impact that these phenomena have in the real estate market.

Euribor was also chosen due to the importance of interest rates in this field of study as Tan & Wu (2014) concluded by comparing and studying the impact of interest rates on the Housing Market in China and the United States. The Portuguese stock market index (PSI20) was another attribute selected since several articles, such as Kakes & Van Den End (2004) analyzed the relevant relationship between these two concepts. Regarding Public Debt, Micheli (2020) concluded that there exists a causal relationship between government indebtedness and the real estate market. Purchasing power and Research & Development were selected as they also are economically relevant attributes.

The table below provides a definition of the variables, their frequency, and sources. The data gathered ranges from the first quarter of 1995 and the fourth quarter of 2022. The period selected range was based on the availability of each variable.

Table 3 – Data Collection

Variable (Variables' Dataset name)	Frequency	Source	Description
Nominal House Prices (NOMINAL_HOUSE_PRICES)	Quarterly	OECD	Index that calculates the sales of newly and existing houses following RPPI with the base year of 2015
Inflation (INFLATION)	Quarterly	OECD	Index that measures the prices' change in a predetermined basket of goods and services with the base year of 2015
Energy Inflation Rate (ENERGY_INFLATION)	Monthly	EUROSTAT	Prices' change in the energy sector
Tourism (TOURISM)	Quarterly	BPSTAT	Tourism and travel transactions between residents and non-residents
Night Spent Tourism (TOURISM_NIGHT_SPENT)	Monthly	EUROSTAT	Number of nights spent at tourism accommodations
Euribor 3 months (EURIBOR_3M)	Quarterly	ECB	Interest rate which determines the rate a European bank borrows funds to others with a maturity of 3 months
Unemployment Rate (UNEMPLOYMENT_RATE)	Quarterly	BPSTAT	Percentage of people which are part of the labor force that do not have a job
Population (POPULATION)	Quarterly	EUROSTAT	Total population residing in Portugal
Public Debt (PUBLIC_DEBT_%PIB)	Quarterly	BPSTAT	Total debt of the Portuguese economy
GDP (GDP)	Quarterly	INE	Value created through the production of goods and services
PSI20 (PSI20)	Monthly	INVESTING.COM	Stock market index of companies which trade in Euronext Lisbon
Purchasing Power (PURCHASING_POWER)	Annual	EUROSTAT	Indicator which measures how much it costs to buy a selection of goods and services in Portugal
R&D (RD)	Annual	EUROSTAT	Expenses of all sectors in research and development
Average Income (AVG_INCOME)	Annual	PORDATA	Average monthly wage of employees

3.2. DATA TREATMENT

Due to the fact that the variables do not all have the same frequency, the next step in this study was to adjust all variables into a homogeneous time stamp. Quarterly frequency was chosen since the majority of them were already in this frequency. To transform the monthly variables, two forms of aggregation were applied, namely Sum and Mean. Sum was chosen to aggregate the Tourism Night Spent as the output is an absolute number, as for Energy Inflation and PSI20 given that they are indexes, the mean was privileged to aggregate them into quarters. The Interpolation technique was used to transform annual variables and missing values. Interpolation is the mathematical process of obtaining intermediate unknown values in an incomplete series (Sheppard, 1911) and the process used considers the index (time period) of the data frame to interpolate the missing values.

After preparing the data the Spearman correlation was performed to analyze the correlation between the variables and subsequently remove correlated variables by measuring the ranks' dependence of two variables (Dodge, 2008). Spearman was chosen over Pearson correlation as most of the variables did not have a normal distribution and, therefore, failed Pearson's normality assumption. Later the variables were standardized by using the z-score technique which measures the distance between the observation and the mean divided by the standard deviation (McLeod, 2023) that will allow the correct comparison of data.

3.2.1. Dimensionality Reduction Techniques

The subsequent course of action was to implement dimensionality reduction techniques as they simplify data frames and, therefore, improve the interpretation of the results. (Bork & Møller, 2018) corroborate this statement as they used these techniques to incorporate 128 economic variables in a smaller subset to study the United States housing market.

The two techniques selected were principal component analysis and factor analysis. As Sharma (1996) described PCA is a technique which creates new variables from the original data frame that are uncorrelated between themselves. The main objective of a principal components analysis is to capture the essential patterns within a data frame by understanding the directions (principal components) where the data varies the most, while being linear uncorrelated between themselves. The objective of this analysis is to aggregate the maximum variance possible in the first principal component, and so on. Following the application of PCA, a factor analysis was also performed.

As Sharma (1996) mentions FA is a statistical method used to reduce the original variables into a smaller number of factors by identifying the underlying factor which can explain the intercorrelation between the original variables. Factor Analysis has a set of key specific components which explain this statistical methodology, Factor Loadings which demonstrate the direction of the relationship between the original variables and the factors, Factor Rotation that by applying different methods, such as Varimax or Promax, the interpretability of the model can be enhanced and the covariance matrix which determines the variance explained by the factors. Therefore, these techniques are important in order to reduce the number of variables and simplify the interpretation of the results while maintaining the core information of the data frame. Reed (2016) illustrates the importance of using PCA as a first-step

technique in order to reduce the dimensionality while retaining the maximum variance for further analysis.

Although PCA and FA are both statistical methods applied for dimensionality reduction, there are several differences between them: while principal components in PCA are orthogonal (uncorrelated) to each other, factors in FA can be correlated. Also, as principal components are linear combination of the original variables it may be challenging interpreting the meaning of them, whereas FA factors are designed for interpretability as it provides the underlying factor between the original variables. For the sole purpose of interpretability, the FA data frame was chosen over principal components dataset and, as a result, the FA dataset was used for predicting the dependent variable.

3.3. TECHNIQUES TO PREDICT THE DEPENDENT VARIABLE

As this dissertation is based on two approaches to model and analyze the data (statistical and machine learning), the following paragraphs will explore and provide the definition of the technique used for each method.

Regarding the Statistical approach, the method selected was the Vector Autoregression Model known to be used in economic studies such as studying the impact economic variables have on the real per-capita income growth in South Korea (Ghatak, 1998) or analyzing the role of government revenues and expenditures in economic growth in Romania (Roşoiu, 2015). VAR models have also been applied to study the implications of macroeconomic factors in the real estate market, as Zhang, Hui, & Li, (2016) and Baradaran Motie & Zeng (2023) used to develop their analysis.

VAR is a statistical model used to capture the relationship of the dependent variable with all the variables over time (Lütkepohl, 2014). The author refers to relationships over time, meaning that all the independent variables in t and all the lagged variables are taken into account.

The following equation demonstrates the multivariate function of the VAR model:

$$Y_t = c + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \cdots + \beta_p Y_{t-p} + e_t$$

Where Y_t is a is a p-dimensional column vector of the observed variables at time t, c is the constant vector, β_p are the coefficient matrices corresponding to lags 1 through p and e_t is a p-dimensional vector of error terms at time t.

After estimating the VAR Model, the next step is to utilize the coefficients for the forecast. The technique used to perform the forecast was:

- Linear regression, which is a technique that infers the relationship between the dependent variable with the independent variables and it is the standard technique for forecasting using the VAR model output. The generic mathematical formula is:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 \ldots\ldots + \beta_n x_n + e$$

Where y is the dependent variable, β_0 the constant, n the number of independent variables and e the error.

As for the Machine Learning approach, the technique selected was Gated Recurrent Units (GRUs). It was introduced by Cho, van Merriënboer, Gulcehre, Bahdanau, Bougares, Schwen, & Bengio in 2014, and it is a type of recurrent neural network, which means that it is capable of storing information from previous inputs. It was developed in order to fulfill a problem of Recurrent Neural Networks (RNN), as common RNNs fail to learn from distant time steps in sequential data.

The difference is that it has two gates, a reset gate, which eliminates and determines how much information should be lost from past inputs (short-term memory), and an update gate, which evaluates how much information should the model preserve (long-term memory). The GRU process at time step t starts by selecting an input state and the hidden state from the previous time step. Following that, it calculates the update gate and the reset gate, which, as mentioned previously, determines how much information the model preserves and forgets from the previous hidden state, respectively. Afterward, it determines the candidate hidden state, by combining the previous hidden state with the reset gate in a tahn function. Finally, the hidden state is calculated by integrating the candidate hidden state with the update gate.

Reset gate: $r_t=\sigma(W_r\cdot[h_{t-1},x_t])$

Update gate: $z_t=\sigma(W_z\cdot[h_{t-1},x_t])$

Candidate hidden state: $\tilde{h}_t=\tanh(W_h\cdot[r_t\odot h_{t-1},x_t])$

Hidden state: $h_t=(1-z_t)\odot h_{t-1}+z_t\odot\tilde{h}_t$

where σ represents the sigmoid activation function, W_r, W_z, W_h are wheight matrices, $[h_{t-1},x_t]$ is combination of the input and hidden states, and tanh is the hyperbolic tangent activation function.

GRUs are a simplification of Long Short-term Memory networks and, as GRUs, LSTMs try to capture long-term dependencies between the data. Therefore, the common thing of these two models is that they use gates as a form of controlling the flow of information. Nevertheless, there are some differences between the two networks, as GRU has two gates while LSTM has three: a forget gate, which eliminates information that is no longer useful for the model, an input gate that adds useful information to the cell state, and an Output gate which extracts the meaningful information from the current cell state to be an output. Another difference is that unlike LSTM, which uses a cell state and a hidden state, GRU only uses a hidden state.

To the best of our knowledge, there are no scientific papers comparing the Housing market with macroeconomic factors using GRU. However, the use of broader types of neural networks is not

uncommon as Xu, Xiaojie, Zhang, Y (2022) demonstrate in their study which predicts the housing price index in several cities in China.

Moreover, the use of GRUs with Time-series data frames is already being applied in a wide range of fields such as wind-power forecasting (Ding et al., 2019), the price prediction of cryptocurrency (Patra & Mohanty, 2022) or electricity price prediction (Ugurlu et al., 2018) and, therefore, the application for forecasting the housing market.

4. RESULTS

4.1. DATA TREATMENT

4.1.1. Missing Values Treatment and Redundancy Analysis

Given the heterogeneity among all variables, several transformations were made to further analyze the results and findings. Monthly variables were transformed to have a quarterly frequency using aggregation techniques and annual indicators and missing values were adjusted to quarterly time stamp and filled, respectively, using the interpolation method. In order to maximize the amount of data and minimize the number of missing values the time series dataset starts from the 1st quarter of 1995 and finishes in the 4th quarter of 2022. The following table tries to summarize the missing value treatment.

Table 4 – Interpolation method

Variable	Missing values	Original frequency
Nominal House Prices	0	Quarterly
Inflation	0	Quarterly
Energy Inflation Rate	8	Monthly
Tourism	4	Quarterly
Night Spent Tourism	0	Monthly
Euribor 3 months	0	Quarterly
Unemployment Rate	0	Quarterly
Population	0	Quarterly
Public Debt	15	Quarterly
GDP	0	Quarterly
PSI20	0	Monthly
Purchasing Power	85	Annual
R&D	85	Annual
Average Income	86	Annual

To identify whether correlation was present among the data frame, a Spearman correlation was performed. As it is possible to check in Figure 2, several variables are highly correlated with each other.

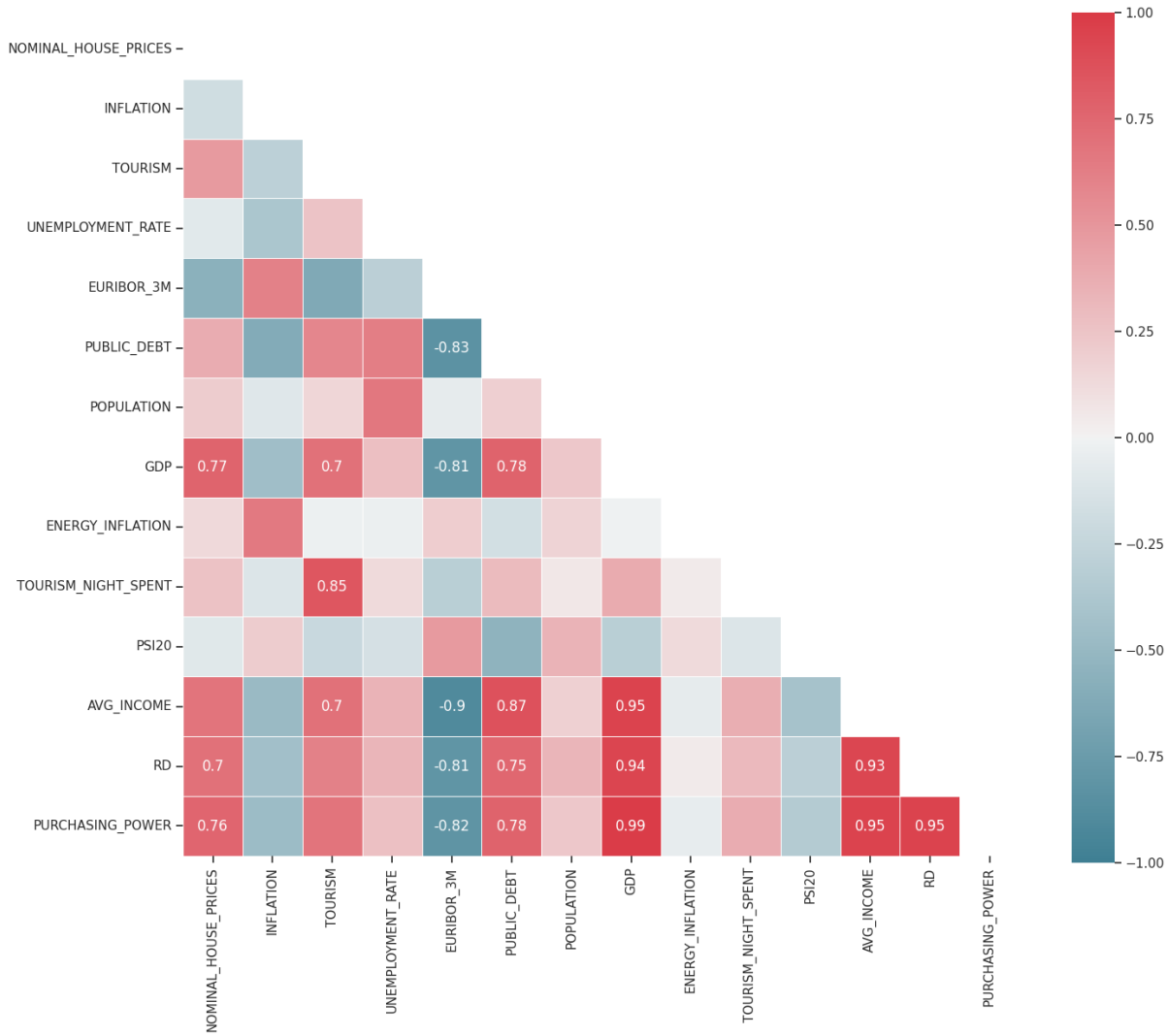

Figure 2 - Spearman Correlation

Assuming the 0.80 threshold, it is observed that GDP, Average Income, Research and Development, Public Debt, Purchasing Power, and Euribor 3 months are correlated with each other. The high correlation between these variables is somewhat expected as all of them are economic-centric metrics and, therefore, while capturing different economic conditions the core phenomenon of the economy is undeniably and, justified by the Spearman correlation graph, recorded by all of them. Tourism and Tourism night spent are also highly correlated as both indicators capture the tourism activity of Portugal, even if one calculates the tourism-related transactions between residents and non-residents and the other the number of nights spent in accommodations. PSI20, Unemployment rate, Population, Inflation, and Energy Inflation are not highly correlated with other variables. However, it is assumed that Energy inflation is included in Inflation.

A Principal Components Analysis (PCA) and a Factor Analysis (FA) were also performed in order to determine if these variables merged into the same components/factors and with those results plus the correlations matrix, a redundancy test was executed. Prior to performing these two analyses, the data was standardized.

As for the Principal Component Analysis and in order to decide how many principal components we should retain, a Scree Plot and a Variance Explained plot were created. According to the Screen plot criteria, the first "elbow" lies in the 2 components, and for the variance explained criteria, which states that the components should at least have a cumulative variance explained variance of 0.80, we should keep more than 2 components. Considering the results, the plots suggest between 2 and 6 components. However, by analyzing the loadings it was concluded that 3 components would be the most suitable given the retained variance and the underlying meaning of the resulting components given by the variables that most contribute to them.

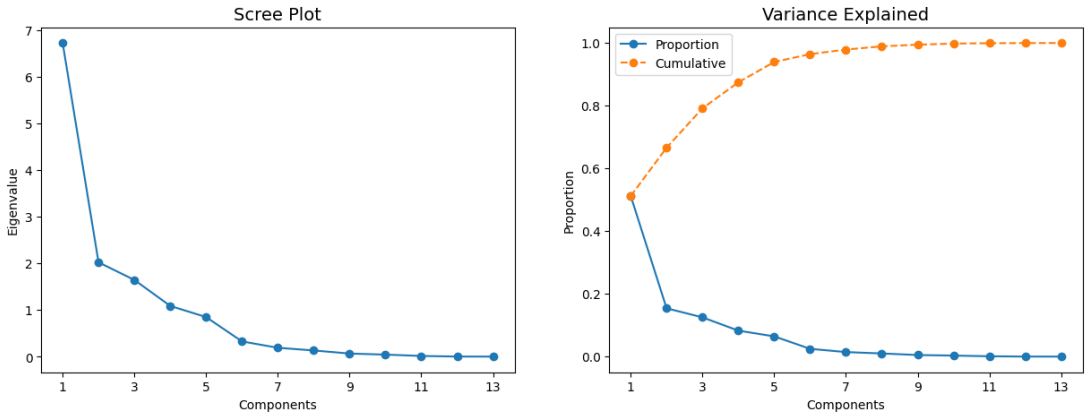

Figure 3 - PCA: Scree Plot and Variance Explained

	PC0	PC1	PC2
INFLATION	0.380733	0.804150	-0.248932
TOURISM	-0.685960	0.440227	0.377250
UNEMPLOYMENT_RATE	-0.486018	-0.435366	-0.327131
EURIBOR_3M	0.907113	0.146825	-0.103785
PUBLIC_DEBT	-0.910640	-0.109269	0.184293
POPULATION	-0.394031	-0.188901	-0.779101
GDP	-0.929945	0.180629	-0.156333
ENERGY_INFLATION	-0.015177	0.789826	-0.430167
TOURISM_NIGHT_SPENT	-0.446165	0.490302	0.368656
PSI20	0.451099	0.027105	-0.510565
AVG_INCOME	-0.975286	0.042793	-0.112864
RD	-0.935484	0.059931	-0.107902
PURCHASING_POWER	-0.951472	0.040588	-0.190667

Figure 4 - PCA: correlation between the original variables and principal components

The next step is to analyze which variables are more associated with each principal component. As it is possible to check in the figure above the majority of the variables are correlated with the first component apart from Inflation, Population, Energy Inflation, Tourism Night Spent, and PSI20. This result corroborates with the Spearman Correlation analysis.

Regarding the Factor analysis, the first step is to measure whether the data is suitable or not for this analysis. Bartlett's test determines if the correlation between the original variables justifies Factor Analysis. Since the p-value was 0, the test is statistically significant. Another relevant test, which

statistically proves the underlying assumption, is the Kaiser Meyer Olkin test (KMO). It measures the sampling adequacy of the data and as the value surpasses the 0.5 threshold (0.71), the data is appropriate (Sharma (1996)).

Following the validation of the feasibility of FA, a number of factors must be decided. The criteria states that we should use all factors with an eigenvalue above 1. Therefore, it was chosen 4 factors.

	Factor1	Factor2	Factor3	Factor4
INFLATION	-0.266981	0.000916	0.956154	-0.129269
TOURISM	0.445057	0.897220	0.026748	-0.064943
UNEMPLOYMENT_RATE	0.382404	-0.035374	-0.260287	0.366863
EURIBOR_3M	-0.852011	-0.208070	0.251887	-0.071747
PUBLIC_DEBT	0.910070	0.185905	-0.219757	-0.073812
POPULATION	0.229590	-0.025362	0.002694	0.985654
GDP	0.873976	0.280958	0.113818	0.245882
ENERGY_INFLATION	0.079524	0.060959	0.784019	0.075650
TOURISM_NIGHT_SPENT	0.163723	0.879188	0.051105	-0.010679
PSI20	-0.477634	-0.082117	0.121617	0.341409
AVG_INCOME	0.960639	0.195582	0.002101	0.204257
RD	0.922343	0.173096	0.023505	0.169676
PURCHASING_POWER	0.864931	0.236189	-0.003996	0.326434

Figure 5 - FA: Factor Loadings

Factor 1 is strongly associated with Euribor 3 months, Public Debt, GDP, Average Income, R&D, Purchasing Power, and PSI20. These variables were highly correlated with each other, and as mentioned previously all resemble economic features. Factor 2 is another factor corroborating the Spearman correlation analysis as Tourism and Tourism Night are the strongest indicators and they are highly correlated with each other. Even though Inflation and Energy Inflation' correlation do not meet the 0.80 threshold criterion when analyzing the Spearman Correlation plot, the assumption made previously is correct as both variables are strongly associated with the same factor (Factor 3). The fourth and last factor is associated with population. To summarize, FA results converge with the Spearman correlation and principal component analyses.

Finally, using the results retrieved from the three analyses illustrated above, the redundancy test was executed. Tourism Night Spent was discarded in favor of the variable Tourism as these variables were highly correlated and stayed in the same factor. Energy inflation was removed, since it was correlated and in the same factor as Inflation. Average Income, Research & Development, and Purchasing Power were removed in favor of GDP as the correlation was above 0.8. Public Debt and PSI20 were also removed due to the same fact in favor of Euribor 3 months. Therefore, after the redundancy test, the final data frame was composed of the following independent variables: Inflation, Tourism, GDP, Euribor 3 months, Unemployment Rate, and Population.

Table 5 – Summary of the original uncorrelated Dataset

Variable (Variables' Dataset name)	Frequency	Source	Description
Nominal House Prices (NOMINAL_HOUSE_PRICES)	Quarterly	OECD	Index that calculates the sales of newly and existing houses following RPPI with the base year of 2015
Inflation (INFLATION)	Quarterly	OECD	Index that measures the prices' change in a predetermined basket of goods and services with the base year of 2015
Tourism (TOURISM)	Quarterly	BPSTAT	Tourism and travel transactions between residents and non-residents
Euribor 3 months (EURIBOR_3M)	Quarterly	ECB	Interest rate which determines the rate a European bank borrows funds to others with a maturity of 3 months
Unemployment Rate (UNEMPLOYMENT_RATE)	Quarterly	BPSTAT	Percentage of people which are part of the labor force that do not have a job
Population (POPULATION)	Quarterly	EUROSTAT	Total population residing in Portugal
GDP (GDP)	Quarterly	INE	Value created through the production of goods and services

4.1.2. Factor Analysis

After completing the redundancy test, a Factor Analysis was performed over the new dataset, a data frame without highly correlated variables. The objective was to further reduce the dimensionality of the data frame in order to make it easier to interpret the results retrieved from the VAR model. As explained in the previous topic, Bartlett's test and KMO test were performed, having 0 and 0.53, respectively, and, therefore, successfully passing their minimum requirements.

3 Factors were chosen due to the percentage of cumulative variance rule, which states that it should be retained a number of factors that explain at least 70% of the variance. Several types of rotations were performed to enhance interpretability, such as varimax, promax, and quartimax. Quartimax was chosen as it maximizes the variance of each individual variable in a single factor and, therefore, minimizes the influence of other factors in that specific variable. Appendix B contains the results for the other rotations.

	Factor1	Factor2	Factor3
INFLATION	-0.238912	-0.104408	0.693021
TOURISM	0.691265	-0.107665	0.207487
UNEMPLOYMENT_RATE	0.235716	0.511044	-0.395963
EURIBOR_3M	-0.903109	-0.095212	0.371419
POPULATION	0.195285	0.983559	-0.020225
GDP	0.913451	0.235310	0.114047

Figure 6 - FA: Factor Loadings (reduced dataset)

	Factor1	Factor2	Factor3
SS loadings	2.278623	1.315483	0.831484
Proportion Var	0.379771	0.219247	0.138581
Comulative Var	0.379771	0.599018	0.737598

Figure 7 - FA: Cumulative Variance

By analyzing the factor loadings, it is possible to conclude that Tourism, Euribor 3 months, and GDP are closely linked with the first factor and, therefore, we can infer Factor 1 as the Economy Factor. Although the second factor has the biggest relationship with the Unemployment Rate of all the factors, the relationship that it has with population is much more relevant, thus, factor 2 can be considered as Population. As for the third factor, it is only strongly associated with inflation. In conclusion, we can name the factors as Economy, Population, and Inflation, respectively.

4.2. Vector Autoregression Model

After finalizing all the data process and treatment, it was now possible to undergo the construction of the Vector Autoregression Model. The first step was to standardize the dataset retrieved from the Factor Analysis, which is composed of the dependent variable, Nominal House Prices, and the independent variables, Economy, Population, and Inflation. Afterwards, an analysis of the time series of the variables was carried out. As it is possible to visualize in the following figure, for the recent periods all variables tend to grow apart from the Population attribute.

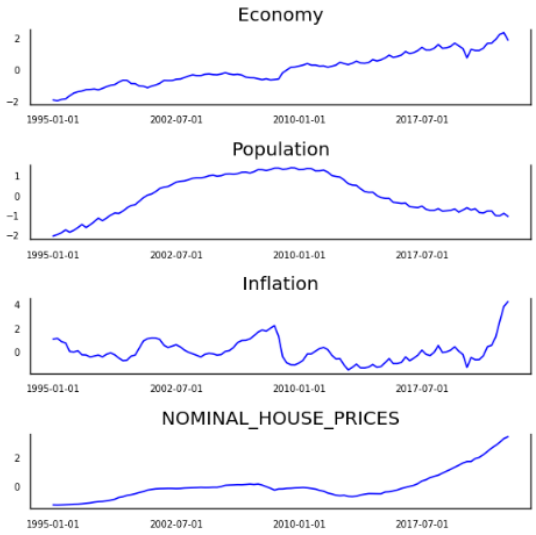

Figure 8 – VAR: Variables' analysis over time

As VAR models imply that there is causality between independent variables and the dependent variable, the Granger Causality test was applied to understand whether the independent attributes were good predictors of Nominal House Prices. The null hypothesis states that a certain variable does not provide additional information for forecasting the dependent variable compared to what is already gathered by the lagged values of the dependent variable. The test states that if the p-value is smaller than the significance value (0.05), it is assumed that there is evidence of causality between the variable and the dependent attribute, and therefore, the null hypothesis is rejected. The following figure demonstrates that all independent variables passed the test.

	Economy_x	Population_x	Inflation_x	NOMINAL_HOUSE_PRICES_x
Economy_y	1.000	0.0	0.0003	0.0988
Population_y	0.000	1.0	0.0000	0.0003
Inflation_y	0.001	0.0	1.0000	0.0000
NOMINAL_HOUSE_PRICES_y	0.000	0.0	0.0001	1.0000

Figure 9 – VAR: Granger Causality Test

Having the Granger Causality test analyzed and concluding that all independent variables are suited for the creation of the VAR model, the following step is to check whether the dataset is stationary since it is an assumption of the VAR model, and violating this assumption can result in unreliable statistical inferences. The term Stationary data implies that the time-series dataset does not have, for example, trends or seasonality. Therefore, a data frame to be considered stationary must remain statistically constant over time. The Augmented Dickey-Fuller (ADF) test was undertaken to check this VAR model assumption. The null hypothesis of the ADF test states that the time series has a unit root, meaning that there exists a random trend in the data, that is, over time the mean and variance of the data can be instable and, therefore, implying that the data is non-stationary. When the p-value is below 0.05, the data successfully rejects the null hypothesis and as a result, it is considered stationary.

The data frame failed the ADF test and, therefore, it was considered non-stationary. When this occurs, differencing must be performed in order to achieve Stationary time-series data. This process subtracts each data point from the previous data point ($Y_{t'}=Y_t-Y_{t-1}$), in order to remove trends and seasonality.

For this data frame, differencing was performed three times in order to achieve a stationary data frame (please refer to appendix C for the outputs of each ADF test).

The next step was to define the order p of the VAR model, that is, how many lagged data points the model would be using for creating the relationship between Nominal House Prices and the independent variables. One method used for determining the order p of a VAR model is the Akaike Information Criterion (AIC), which balances between capturing the underlying factors of the data and avoiding overfitting. AIC tries to maximize the likelihood of the model and the number of parameters the model uses ($AIC=-2\ln(L)+2k$, where L is the maximum likelihood and k is the number of parameters in the model). The statistical measure favors models with few parameters while achieving a good fit. To select the order p of the VAR model, it should be the order that gives the least AIC before it starts to increase again. In this case, it was selected the order 5 (please refer to Appendix D for the output of AIC). Finally, the VAR model resulting from the Factor Analysis data frame was fitted and the forecast was applied (please refer to Appendix E for the summary of the model fit). A comparison between the actual values and the forecasted can be seen in the figure below.

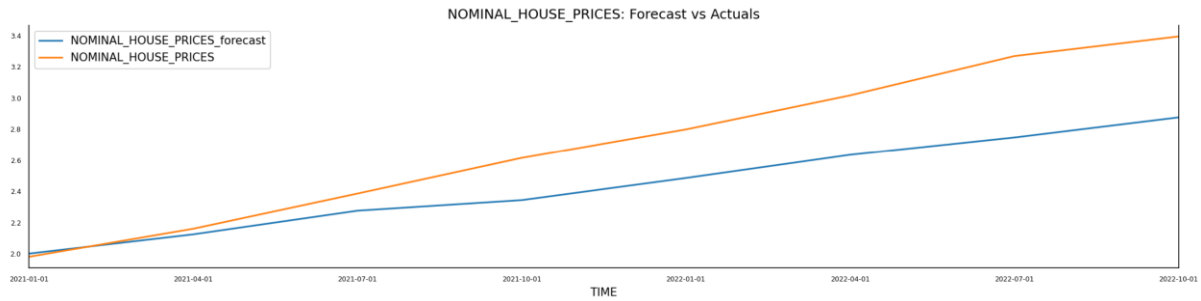

Figure 10 - VAR model: Forecast of FA dataset

Figure 10 clearly shows that the VAR model is capable of forecasting the test dataset. It is also corroborated by the low Mean Absolute Error (MAE) of 0.27 and the low Mean Squared Error (MSE) of 0.11. This is a common metric to measure the accuracy of the forecasting of a model. By calculating the average absolute difference between the actual and the forecasted values.

In order to compare which of the data frames (FA variables or original uncorrelated variables) is better to predict the dependent variable, a VAR model was applied using the original uncorrelated variables dataset. It followed the same steps as the latter and, therefore, the Granger Causality Test, Augmented Dickey-Fuller test, and Akaike Information Criterion were applied before the model was fitted. Please refer to Appendix F for the results of each test and the summary of the model fit.

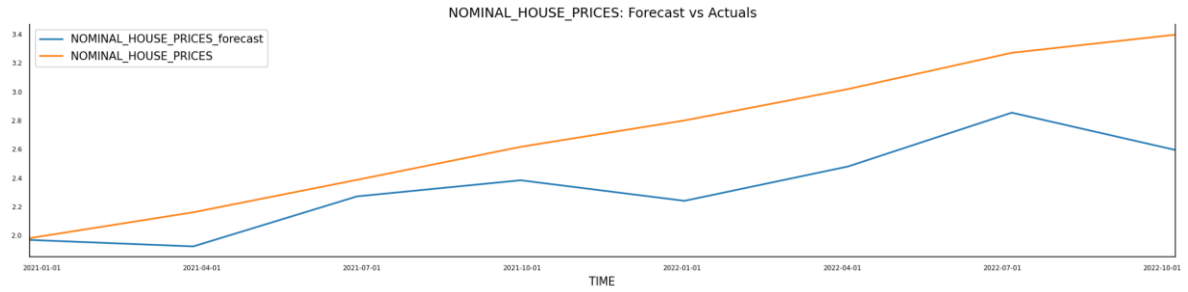

Figure 11 - VAR model: Forecast of original uncorrelated dataset

Figure 11 also shows that the VAR model using the original uncorrelated dataset can forecast the test dataset. In terms of the Mean absolute Error and Mean Squared Error, the results were 0.36 and 0.19, respectively. Both models achieved a fairly good MAE and MSE result. However, the VAR model using the FA dataset achieved a better error rate.

4.3. GATED RECURRENT UNITS

Following the performance of the Vector Autoregression models, the focus of the work shifted from traditional statistical methods to explore the capabilities of Gated Recurrent Units (GRUs). The objective is to better understand which model better forecasts the data.

Regarding the technical parameters, the data was split into 75% and 25% for training and validation, respectively. It was developed and tested several techniques of splitting the data frame for the time series model. Though, the best model was achieved by selecting two separate instances of the data and, subsequently, combining them. This provided the model to learn from different time windows, enabling a more comprehensive approach for the overall time series. The batch size used was 1 as the dataset is fairly small and, thus, the objective was for the model to capture specific features within the training data. The sequence length which refers to the number of data points used as input sequences in a neural network plays a similar role as the lag-order in Vector Autoregression Model.The sequence lengths of 2 and 4 were chosen since the first one represents the current quarter plus the previous quarter, thus, identifying possible short-term trends, whereas the latter represents all quarters forming a year and, therefore, trying to identify longer-term trends. As for other hyperparameters, the dropout rate considered was 0.2 in order to avoid overfitting and the learning rate was 0.001.

As for the architecture of the model, it comprises a Gated Recurrent layer with 16 units, a dropout layer to prevent overfitting, a second Gated Recurrent layer with 8 units followed also by another dropout layer. Finally, a dense layer with one unit and a linear activation function. The mean squared Error is used as the loss function and there was also constructed a callback function with a patience of 8, that is, if the validation loss does not improve in a number of epochs inferior from the predetermined patience it stops the training process.

After detailing the GRU model architecture, the results using the FA dataset with sequence length 2 and 4 are now presented (please refer to Appendix G).

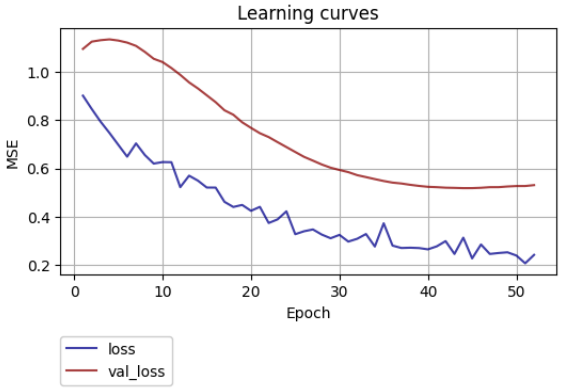

Figure 12 – FA dataset: GRU learning curves (sequence length 2)

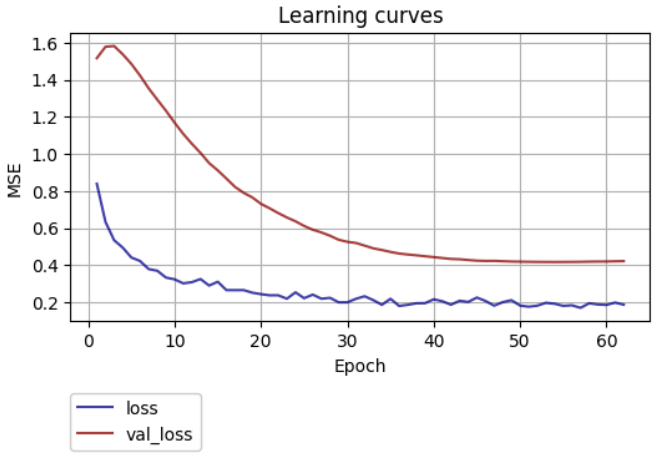

Figure 13 – FA dataset: GRU learning curves (sequence length 4)

The learning curves of the GRU model using the FA dataset and sequence length equal to 2 and 4 show the training loss decreasing over the number of epochs, implying that the model is learning over the input data. Moreover, a decrease of the validation loss which suggests that the model is generalizing its learning from the training set is also visible. The Mean squared error of the validation dataset was for sequence length 2 was 0.52 and for sequence length 4 was 0.42.

Following the results of the FA dataset, the GRU model was implemented using the original uncorrelated dataset (please refer to Appendix H for the results).

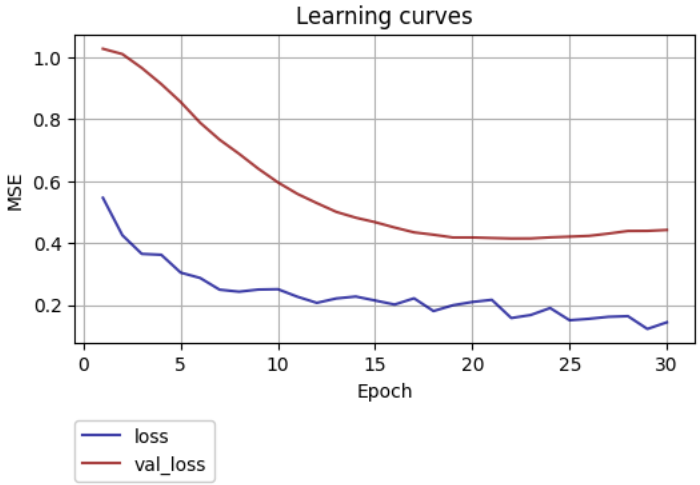

Figure 14 – Original uncorrelated dataset: GRU learning curves (sequence length 2)

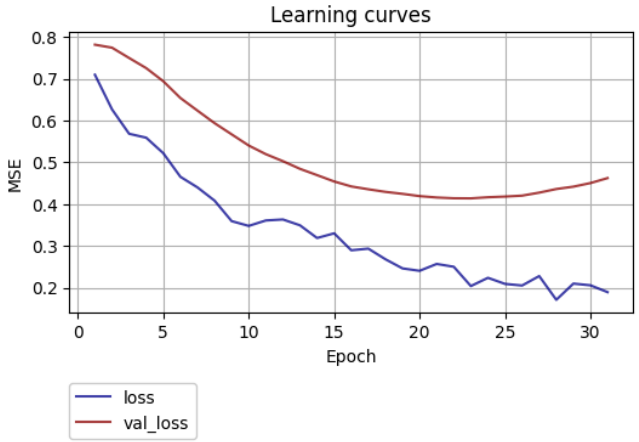

Figure 15 – Original uncorrelated dataset: GRU learning curves (sequence length 4)

Similar to the learning curves of the GRU model using the FA dataset, the models using the original uncorrelated dataset also show the training loss decreasing over the number of epochs and a decrease of the validation loss. The Mean squared error of the validation dataset for sequence length 2 was 0.41 and for sequence length 4 was also 0.41.

4.4. DISCUSSION

The objective of this study is to predict how Macroeconomic factors can impact the Portuguese Housing Market thus, through the Vector Autoregression Model which utilized the Factor Analysis dataset. It is possible to observe that there is a relationship between Portuguese housing prices with a Macroeconomic factor, the economy factor.

Through the analysis of the model fit of the VAR model (Appendix E), it is possible to observe that there exists a statistically significant relationship between the Economy and Nominal House Prices. In the model, it is inferred that lagged one-time economy has a positive relationship with the dependent variable of 0.11 and that there exists autocorrelation and a negative relationship between the

dependent variable and lagged one-time nominal house prices, 0.43, and lagged four-times nominal house prices, 0.30 (please refer to appendix E for the results).

The economy variable, which was formed using factor analysis, is strongly associated with the original variables: GDP, Euribor 3 months (interest rate), and tourism. The factor loadings for the economy factor were the following:

Table 6 – Factor Loadings of the economy factor

Algorithm	Economy factor
Inflation	-0.24
Tourism	**0.69**
Unemployment Rate	0.24
Euribor 3M	**-0.90**
Population	0.20
GDP	**0.91**

In terms of the other factors, inflation and population, which were not considered statistically significant in the VAR model, Yu & Huang (2016), using a GVAR model (Globe Vector Autoregression) and data from 35 Chinese cities, also found an inexistent relationship between the housing prices and consumer prices index (inflation). Other authors state that they did not observe a relationship between housing prices and monetary policy, credit conditions, and inflation when the real estate market is stable (Baradaran, Motie & Zeng, 2023).

4.4.1. Literature supporting the relationship between GDP and House prices

Plakandaras et al. (2020), using the VAR method between the periods of 1830-2016 and 1845-2016, observed that the monetary policy influenced greatly the evolution of housing prices in the United Kingdom and, concluded that there is a clear relationship between the increase the gross domestic product and the house prices index. Moreover, it was concluded that this relationship was further enhanced using the United States of America data instead of the United Kingdom one.

Şahin Kutlu (2021) mentions that there exists a relationship between the evolution of the housing market and the impact that it had in the buildup of the 2008 financial crisis. The author draws attention to the importance of closely monitoring monetary policy and the evolution of direct investment, industrial production index, GDP, and housing prices. Şahin Kutlu (2021) understood that there exists a clear relationship between the development of the Turkish economy and the housing prices between the period of 2010 and 2019.

Another study which applied a VAR model with stochastic volatility to United States data from 1970 and 2014, concluded that there is a strong relationship between the GDP, the financial market liquidity, and there influence on the development of the Housing Market and the pricing of the houses (Ellington, Florackis & Milas, 2017). It is also referred that symmetries exist between the growth of

GDP and the relationship of the stock and Housing market, between 17% and 35% during the great recession (Ellington, Florackis & Milas, 2017).

Mihaela & Vasile (2023) analyzed several macroeconomic indicators regarding Romania, Bulgaria, and Croatia between the time period of 2009 and 2021. The authors used a Vector autoregression model and inferred that there is a direct relationship between GDP, housing prices index, unemployment and investment.

Benati (2021) associated the economic crisis with housing prices in the United States, Canada, and the United Kingdom. The author understood that the impact of monetary shocks on real house prices is about three to five times higher than the GDP. In case of the United States and in a context of a linked increase of the housing prices, before the financial crisis, a decrease of 1% of the GDP was associated with a drop of 4% in the real estate market.

Lunsford (2016), with the use of a Factor-Augmented Vector Autoregression model (FAVAR), observed that an increase in the investment in the housing market leads to an increase in the GDP. This is related more to the number of new households and less to the dimension of the houses.

4.4.2. Literature supporting the relationship between Interest Rates and House prices

Bachmann & Rüth (2020) utilizing a VAR model concluded that real estate investment drops when there is a small increase in the interest rates thus, when the FED appoints more restrictive measures which result in the increase of the interest rates the authors observed that the house prices fluctuate in the same proportion as the measured applied by the authority entity.

Wu & Bian (2018) compared the prices of the Housing market with the interest rates in China and observed that in major cities, an increase of the interest rates leads to a negative effect on housing prices. In this study (2018), the authors concluded that the real estate market plays an important role in economic crisis (Wu & Bian (2018)).

In a study which utilized Vector Autoregression (VAR) and Vector error-correction model (VECM), the author observed a relationship between interest rates and the mortgage loans granted and, as a result, there is an impact on the real estate market (Deleidi, 2018).

Igan et al. (2017) analyzed through the use of a Factor-Augmented Vector Autoregression model (FAVAR) a collection of indicators from the private sector of the United States and understood that there is a direct effect between the increase of the interest rate and the will to control of the Housing Market.

In another study, the authors observed an empirical relationship between the financial markets, the macroeconomic models, and the loans granted (Palić, 2018). The same author (2018), in a study using the dynamic stochastic general equilibrium model (DSGE) and the VAR model using data from Croatia, observed a strong relationship between the increase of the interest rate and an impact on the Croatian housing prices. Also, Plakandaras et al. (2020) witnessed a sturdy bond between housing prices and short-term interest rates.

In a study which aimed to understand the dynamics of the real estate market in China (Bian & Gete, 2015), several factors were compared, including the granting of loans and the factor related to interest rates, private and public lead construction, flexibilization of granting credit, the population increase.The authors concluded that there is a relationship between those variables and the Chinese real estate market, the only variables where they did not find a bond with the housing prices was the public lead construction.

Karagöz & Özkubat (2021) studied whether macroeconomic factors can impact the housing prices in the Aegean region and, using the home prices index as the dependent variable and the gold price, the stock market index, exchange rates, interest rates, confidence measures related to the housing market and inflation as the independent variables, the authors concluded that there is a clear long-term relationship between them. According to the findings, it was inferred that the housing prices in the Aydin region had a strong bond with the gold price, the exchange rate and the interest rate (Karagöz & Özkubat, 2021). Similarly, in the Manisa region, the housing prices were also affected by the exchange rates and the interest rates.

A study conducted using data from the country of Namibia (Sunde & Muzindutsi, 2017) observed a very significant increase in housing prices which led to a significant doubt in the well-being of the Namibian long-term real estate market. The authors (2017), using an econometric model,concluded that housing prices have a direct connection with changes in population, loans, and interest rates.

4.4.3. Literature supporting the relationship between Tourism and House prices

The relationship between tourism and housing prices has aroused interest in the last decade because of the relevant influence it has in the real estate market and the investment in this sector. As the results of the VAR model show a relationship between the economy factor and nominal house prices and since the economy factor has an intrinsic connection with the original variable tourism, whether there is literature that also finds this relationship between housing prices and tourism.

However, Časni & Filić (2022) drew attention to the lack of international scientific research regarding the linking of these two topics and concluded that there exists a necessity for more studies centered around it it, as it is important to drive knowledge-based strategies for long-term political decision making.

Other authors consider that short-term rentals are causing a disruption in the Housing Market contributing to an increase in rental prices, and a decrease in the supply of housing which leads to an increase in housing prices (Hübscher & Ringel, 2020).

Back (2022) acknowledges that the development of second-housing tourism has repercussions in the housing market, leading to an impact on the residents of that region when they try to buy a house. The author lists a set of recommendations (2022) to be used by the municipalities. The study focused on twenty two municipalities in Sweden and observed the impact that second-housing tourism has in the local housing sector.

In a study conducted in Portugal, specifically in Alfama (a historical neighborhood of Lisbon) between the years of 2015 and 2017, the authors monitored that short-term rentals do not allow a connected

economy with the locals but instead lead to speculation processes which move away the locals from their residencies (Cocola-Gant & Gago, 2021). These authors (2021) recognize that the new local investors use those housings as an asset to increase their economic resources.

Moreover, Cunha & Lobão (2022) draw attention to the evidence that the use of short-term rental applications, such as Airbnb, are causing the general increase in prices in the main metropolitan areas of Portugal, Lisbon and Porto. The study concluded that the political decisions have lead to the disruption of the rental market and removed power from the municipalities to authorize the change long-term rentals to short-term.

Following the other studies, Yrigoy (2016), through a study focused on the historical neighborhood of Palma, Maiorca, concluded that the introduction of massive integration of short-term rentals is diminishing long-term residential rentals in favor of tourism, having an impact in the local real estate market. This problem was also studied in Santa Marta, Caribbean by Garza & Ovalle (2019) and these authors also concluded that the development of tourism directly affects housing prices.

Finally, Luo & Bao (2019), by studying a village in the south of China, observed the influence of tourism and the political decisions undergone by the municipality. The local government initially tried to reallocate the local residents into other neighborhoods in order to decrease the souring housing prices. However, it did not work and lead to an increase in the cost of living for the workers and the reallocation of their jobs from fishing and agriculture to the service sector.

4.4.4. Best Algorithm which explains better the main objective

As there is a lack of research in this area regarding Portuguese data, it was also necessary to investigate which algorithm better predicts the main objective, which is how Macroeconomic factors can impact the Portuguese Housing Market. The following table displays for each algorithm and dataset used, the evaluation of the test dataset using as a metric the Mean Squared Error which quantifies the average squared difference between the predicted values and the actual values.

Table 7 – Evaluation of the Algorithms and the dataset used

Variables	Dataset	MSE
VAR	Factor Analysis dataset	0.11
VAR	Original Uncorrelated Dataset	0.19
GRU	Factor Analysis dataset	0.42
GRU	Original Uncorrelated Dataset	0.41

By observing the mean squared errors for all the Vector Autoregression and Gated recurrent Units models, it is possible to infer that by analyzing the mean squared error, the model with the smallest MSE is the VAR model which utilizes the Factor Analysis dataset (0.11).In a study which analyzed the world financial crisis of 2008 by exploring the economic factor of the monetary policy and economic activity, Şahin Kutlu (2021) concluded that the Vector Autoregression Model (VAR) is the best model analyzing the relationship between housing prices and the other variables.

5. CONCLUSION

Throughout this study it was applied using the Vector Autoregression (VAR) and Gated Recurrent Units (GRU) methodologies two approaches where it was considered in the first the factors, resulted from the factor analysis, Economy, Inflation and Population and a second approach where uncorrelated features from the original dataset were extracted and used to predict the Housing Market in Portugal, these were Inflation, Tourism, Unemployment Rate, Euribor 3M, GDP and Population. Thus, the conclusion of this study occurs in response to the objectives: the first and main objective being to predict how Macroeconomic factors can impact the Portuguese Housing Market and the second being to determine which algorithm better predicts the first objective.

Regarding the main objective and following the Gated Recurrent Units (GRU) methodology, it is possible to conclude that a model utilizing longer-term trends (sequence length of 4) achieves better results than a model using a short-term trend (sequence length of 2).

The experimental results demonstrated that using VAR method with both the original uncorrelated dataset and the extracted factors, yields better fit when compared to the Deep Learning approach. The original uncorrelated features expectedly allowed to achieve better fit, as relevant explanatory capacity was lost during the factor analysis.

On the other hand, by applying the Vector Autoregression (VAR) methodology, an MSE of 0.11 is observed for the factor analysis dataset, while for the original uncorrelated dataset there is a mean squared error of 0.19. As the FA dataset provides better results, the relationship between the dependent variable and the explanatory variables was investigated in further detail. It is observed that the lagged one-time economy has a positive relationship with the nominal house prices while lagged one-time nominal house prices and lagged four-times nominal house prices have a negative relationship with the dependent variable.

Moreover, and focusing on the relationship observed between the economy factor and nominal house prices, it was investigated whether there exists literature corroborating this association. The factor economy has high factor loadings with GDP, Euribor 3M (interest rate) and Tourism and, therefore, it was verified and concluded that, in fact, exists scientific research associating these three variables, which compose the economy factor, with the housing prices.

Finally, it was investigated which algorithm better predicts how Macroeconomic factors can impact the Portuguese Housing Market. By observing the mean squared errors, it was possible to infer that the Vector Autoregression Models produced better results than the Gated Recurrent Units models. Also, by analyzing the VAR models it was possible to conclude that using a data frame originated from a dimensionality reduction technique, such as factor analysis, produces better results than using the original uncorrelated variables.

6. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

In this study, a series of limitations which lead to breaks for future research were encountered. From a theoretical standpoint, even though research using the Gated Recurrent Units methodology for time-series data already existed, it did not subsist for predicting the housing market field.

Moreover, a limitation on the existence of scientific evidence regarding the studying of the reality of the Portuguese housing market when applying machine learning or statistical methods was also noted.

Furthermore, another restraint in the data collection part was found, as there existed a clear temporal limitation of the data, only being concisely available for all variables starting in the first quarter of 1995.

Finally, and with the aim of proposing development ideas for further research in the housing market field, it is recommended that more studies are performed using statistical and machine learning techniques in order to better understand the Portuguese housing market. Moreover, further studies are also proposed especially using the variables such as GDP, interest rate, tourism, mortgage credit ratios and exchange rates to study the Housing Market.

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8. APPENDIX

8.1. APPENDIX A

Systematic Literature Review

Title: The influence of the Macroeconomic factors on the Housing Market: Systematic Literature Review

Background: The Housing Market has been increasing in the last few years as OECD studies mention however, scientific research studying this phenomenon in Portugal has not been following.

Objective: To identify which Macroeconomic factors contribute to changes in housing prices.

Review Question: Which macroeconomic factors contribute to changes in housing prices?

Methodology and Analysis: The protocol was built using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA[1]).

Population: The inclusion criteria will encompass all research studies published after 2018, written in English, and relevant to the topics in analysis. It is going to be excluded all secondary studies, such as revisions, and those lacking a full article, abstract or peer reviewed.

Databases and Search Query: A systematic literature review will be conducted. The following databases will be searched: EBSCOhost Research Databases: Academic Search Complete, EBSCOhost Research Databases: Business Source Complete. A strategy search will include the following descriptors from the 'Business Thesaurus' or similar terms: [(real estate market OR house market OR housing market) AND (INFORMATION economy OR economic factors OR economic) AND (tourism OR Unemployment OR Population OR Public Debt OR interest rate OR gross domestic product OR gdp OR Inflation OR Stock market OR Purchasing Power)]. After the inclusion of studies, a methodological assessment will be conducted, presenting their characteristics. Finally, a discussion and conclusion of the review will be formulated.

Data Extraction: An evaluation of each study will be carried using a set of instruments designed to gather information in alignment with the research question. Additional information, including the country of study, authors, year, study objective, methods, results, and conclusions, may also be collected.

[1] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. International Journal of Surgery, 88, 105906. https://doi.org/10.1016/j.ijsu.2021.105906

Interface - EBSCOhost Research Databases: Business Source Complete; Academic Search Complete;

#	Query	Limiters/Expanders	Last Run Via	Results
S20	S17 AND S18 AND S19	Limiters - Full Text; Peer Reviewed; Publication Date: 20180101-20241231 Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	236
S19	AB S4 OR S5 OR S6	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	1,970,912
S18	AB S1 OR S2 OR S3	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	91,753
S17	AB S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	3,078,050
S16	purchasing power	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	16,396
S15	stock market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	467,235
S14	inflation	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	302,988
S13	gdp	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	150,751
S12	gross domestic product	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	120,571
S11	interest rate	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	401,414
S10	public debt	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	53,835
S9	population	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	2,038,024
S8	unemployment	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	201,066
S7	tourism	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	342,742
S6	economic factors	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	58,256
S5	economic	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	4,586,885

#	Query	Limiters/Expanders	Last Run Via	Results
S4	INFORMATION economy	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	18,232
S3	housing market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	74,888
S2	house market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	11,696
S1	real estate market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete;Business Source Complete;	42,775

Interface - EBSCOhost Research Databases: Business Source Complete

#	Query	Limiters/Expanders	Last Run Via	Results
S20	S17 AND S18 AND S19	Limiters - Full Text; Peer Reviewed; Publication Date: 20180101-20241231 Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	141
S19	AB S4 OR S5 OR S6	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	890,498
S18	AB S1 OR S2 OR S3	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	49,360
S17	AB S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	1,007,362
S16	purchasing power	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	10,377
S15	stock market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	248,769
S14	inflation	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	170,561
S13	gdp	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	92,587
S12	gross domestic product	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	83,820
S11	interest rate	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	223,876
S10	public debt	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	37,090

#	Query	Limiters/Expanders	Last Run Via	Results
S9	population	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	201,602
S8	unemployment	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	94,653
S7	tourism	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	153,674
S6	economic factors	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	22,881
S5	economic	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	2,412,522
S4	INFORMATION economy	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	10,560
S3	housing market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	35,390
S2	house market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	3,813
S1	real estate market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Business Source Complete	16,077

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S19	AB S4 OR S5 OR S6	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	807,237
S18	AB S1 OR S2 OR S3	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	16,094
S17	AB S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	1,766,305
S16	purchasing power	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	3,637
S15	stock market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	80,502
S14	inflation	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	57,246
S13	gdp	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	35,100
S12	gross domestic product	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	25,817
S11	interest rate	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	48,835
S10	public debt	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	9,945
S9	population	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	1,712,343

#	Query	Limiters/Expanders	Last Run Via	Results
S8	unemployment	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	54,518
S7	tourism	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	88,754
S6	economic factors	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	29,906
S5	economic	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	1,560,965
S4	INFORMATION economy	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	5,646
S3	housing market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	12,811
S2	house market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	1,661
S1	real estate market	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - Academic Search Complete	5,719

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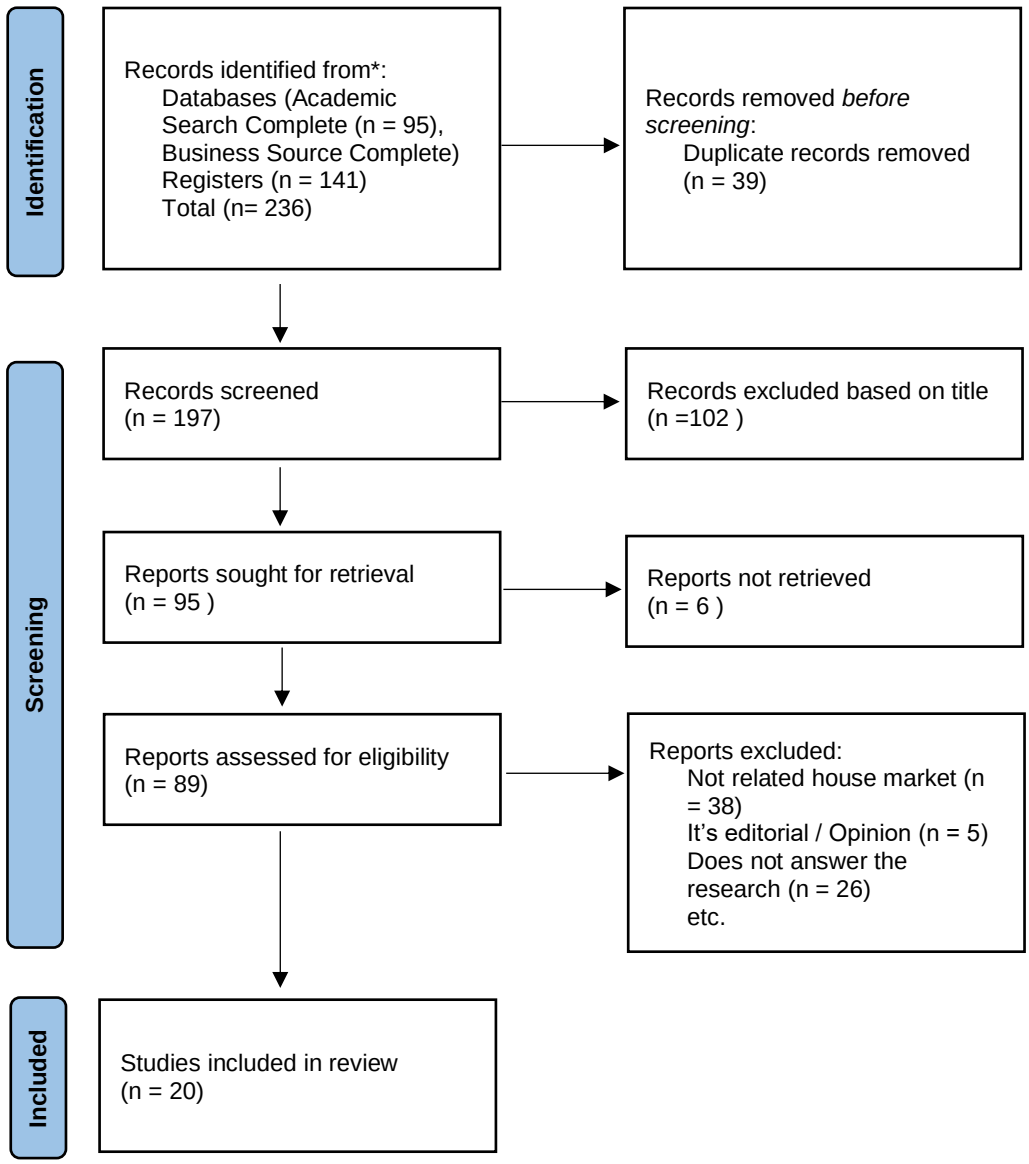
PRISMA Flow Diagram (2020)



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8.2. APPENDIX B

Results for the other rotations tested:

Varimax

	Factor1	Factor2	Factor3
INFLATION	-0.049887	-0.100503	0.731894
TOURISM	0.727344	-0.051355	0.028702
UNEMPLOYMENT_RATE	0.089433	0.514579	-0.448023
EURIBOR_3M	-0.771935	-0.148791	0.587027
POPULATION	0.107553	0.994014	-0.079380
GDP	0.892075	0.303767	-0.121237

	Factor1	Factor2	Factor3
SS loadings	1.942764	1.380008	1.102818
Proportion Var	0.323794	0.230001	0.183803
Comulative Var	0.323794	0.553795	0.737598

Promax

	Factor1	Factor2	Factor3
INFLATION	0.087033	0.092265	0.806236
TOURISM	0.779753	-0.114128	0.129842
UNEMPLOYMENT_RATE	-0.031556	0.443629	-0.365836
EURIBOR_3M	-0.698943	0.063047	0.517732
POPULATION	0.010529	1.077489	0.185756
GDP	0.895498	0.226371	0.075806

	Factor1	Factor2	Factor3
SS loadings	1.907133	1.434546	1.109009
Proportion Var	0.317856	0.239091	0.184835
Comulative Var	0.317856	0.556947	0.741781

8.3. APPENDIX C

Augmented Dickey-Fuller (ADF) test:

Original Data frame

```
ADF Statistic for Economy: -0.770110
p-value for Economy: 0.827745
ADF Statistic for Population: -2.762249
p-value for Population: 0.063872
ADF Statistic for Inflation: -2.133037
p-value for Inflation: 0.231440
ADF Statistic for NOMINAL_HOUSE_PRICES: 0.196196
p-value for NOMINAL_HOUSE_PRICES: 0.972047
```

First difference

```
ADF Statistic for Economy: -4.859737
p-value for Economy: 0.000042
ADF Statistic for Population: -1.706984
p-value for Population: 0.427518
ADF Statistic for Inflation: -4.363852
p-value for Inflation: 0.000344
ADF Statistic for NOMINAL_HOUSE_PRICES: -2.409103
p-value for NOMINAL_HOUSE_PRICES: 0.139183
```

Second difference

```
ADF Statistic for Economy: -6.064371
p-value for Economy: 0.000000
ADF Statistic for Population: -1.562012
p-value for Population: 0.502643
ADF Statistic for Inflation: -5.310015
p-value for Inflation: 0.000005
ADF Statistic for NOMINAL_HOUSE_PRICES: -7.438974
p-value for NOMINAL_HOUSE_PRICES: 0.000000
```

Third difference

```
ADF Statistic for Economy: -5.824338
p-value for Economy: 0.000000
ADF Statistic for Population: -5.055634
p-value for Population: 0.000017
ADF Statistic for Inflation: -5.794017
p-value for Inflation: 0.000000
ADF Statistic for NOMINAL_HOUSE_PRICES: -5.468913
p-value for NOMINAL_HOUSE_PRICES: 0.000002
```

8.4. APPENDIX D

Determining the order p of the VAR Model:

```
Lag Order = 1
AIC :  -16.66527099679675
Lag Order = 2
AIC :  -16.73929908828145
Lag Order = 3
AIC :  -19.235293641142086
Lag Order = 4
AIC :  -19.288369836911574
Lag Order = 5
AIC :  -19.288925152636796
Lag Order = 6
AIC :  -19.171633492826285
Lag Order = 7
AIC :  -19.356923324379938
Lag Order = 8
AIC :  -19.4032993517684
Lag Order = 9
AIC :  -19.470567269240924
Lag Order = 10
AIC :  -19.390647345608638
```

8.5. APPENDIX E

Summary of the model fit:

```
  Summary of Regression Results
=================================
Model:                         VAR
Method:                        OLS
Date:           Sat, 30, Dec, 2023
Time:                     15:59:48
---------------------------------------------------------------------
No. of Equations:         4.00000    BIC:                   -17.0593
Nobs:                     97.0000    HQIC:                  -18.3874
Log likelihood:           468.965    FPE:                4.31539e-09
AIC:                     -19.2889    Det(Omega_mle):     1.97051e-09
```

```
Results for equation NOMINAL_HOUSE_PRICES
=============================================================================================
                            coefficient       std. error           t-stat            prob
---------------------------------------------------------------------------------------------
const                         0.002348         0.004429            0.530           0.596
L1.Economy                    0.117129         0.048789            2.401           0.016
L1.Population                -0.139211         0.146043           -0.953           0.340
L1.Inflation                  0.012313         0.016586            0.742           0.458
L1.NOMINAL_HOUSE_PRICES      -0.432542         0.118428           -3.652           0.000
L2.Economy                   -0.007199         0.062347           -0.115           0.908
L2.Population                -0.234235         0.180381           -1.299           0.194
L2.Inflation                  0.029475         0.018045            1.633           0.102
L2.NOMINAL_HOUSE_PRICES      -0.111142         0.127304           -0.873           0.383
L3.Economy                    0.055597         0.060805            0.914           0.361
L3.Population                -0.179279         0.190942           -0.939           0.348
L3.Inflation                 -0.013882         0.019421           -0.715           0.475
L3.NOMINAL_HOUSE_PRICES      -0.157285         0.127760           -1.231           0.218
L4.Economy                    0.022538         0.066583            0.338           0.735
L4.Population                -0.187874         0.184956           -1.016           0.310
L4.Inflation                  0.006516         0.019269            0.338           0.735
L4.NOMINAL_HOUSE_PRICES      -0.295973         0.135153           -2.190           0.029
L5.Economy                   -0.060055         0.053611           -1.120           0.263
L5.Population                -0.012177         0.147832           -0.082           0.934
L5.Inflation                 -0.025200         0.018762           -1.343           0.179
L5.NOMINAL_HOUSE_PRICES      -0.072960         0.126227           -0.578           0.563
=============================================================================================
```

8.6. APPENDIX F

Granger Causality test:

	NOMINAL_HOUSE_PRICES_x	INFLATION_x	TOURISM_x	UNEMPLOYMENT_RATE_x	EURIBOR_3M_x	POPULATION_x	GDP_x
NOMINAL_HOUSE_PRICES_y	1.0000	0.0023	0.0001	0.0009	0.1019	0.0000	0.0000
INFLATION_y	0.0000	1.0000	0.0000	0.0000	0.0037	0.0000	0.0000
TOURISM_y	0.0003	0.0000	1.0000	0.0001	0.0000	0.0000	0.0000
UNEMPLOYMENT_RATE_y	0.0004	0.0045	0.0000	1.0000	0.0541	0.0000	0.0000
EURIBOR_3M_y	0.0057	0.0001	0.0613	0.0954	1.0000	0.0010	0.0343
POPULATION_y	0.0032	0.0008	0.0000	0.0000	0.0000	1.0000	0.0000
GDP_y	0.0007	0.5138	0.0000	0.0089	0.3223	0.0019	1.0000

The variable Euribor_3M was removed from the data frame has it failed the Granger Causality test.

Augmented Dickey-Fuller (ADF) test:

Original Data frame:

```
ADF Statistic for NOMINAL_HOUSE_PRICES: 0.196196
p-value for NOMINAL_HOUSE_PRICES: 0.972047
ADF Statistic for INFLATION: -1.749079
p-value for INFLATION: 0.406019
ADF Statistic for TOURISM: -1.934585
p-value for TOURISM: 0.315970
ADF Statistic for UNEMPLOYMENT_RATE: -1.716989
p-value for UNEMPLOYMENT_RATE: 0.422381
ADF Statistic for POPULATION: -3.789821
p-value for POPULATION: 0.003013
ADF Statistic for GDP: -2.270061
p-value for GDP: 0.181806
```

First difference

```
ADF Statistic for NOMINAL_HOUSE_PRICES: -2.409103
p-value for NOMINAL_HOUSE_PRICES: 0.139183
ADF Statistic for INFLATION: -6.705828
p-value for INFLATION: 0.000000
ADF Statistic for TOURISM: -2.853408
p-value for TOURISM: 0.051041
ADF Statistic for UNEMPLOYMENT_RATE: -3.448592
p-value for UNEMPLOYMENT_RATE: 0.009410
ADF Statistic for POPULATION: -1.523594
p-value for POPULATION: 0.521809
ADF Statistic for GDP: -2.993998
p-value for GDP: 0.035459
```

Second difference

```
ADF Statistic for NOMINAL_HOUSE_PRICES: -7.438974
p-value for NOMINAL_HOUSE_PRICES: 0.000000
ADF Statistic for INFLATION: -7.517528
p-value for INFLATION: 0.000000
ADF Statistic for TOURISM: -12.216730
p-value for TOURISM: 0.000000
ADF Statistic for UNEMPLOYMENT_RATE: -18.426395
p-value for UNEMPLOYMENT_RATE: 0.000000
ADF Statistic for POPULATION: -1.863056
p-value for POPULATION: 0.349635
ADF Statistic for GDP: -5.732265
p-value for GDP: 0.000001
```

Third difference

```
ADF Statistic for NOMINAL_HOUSE_PRICES: -4.339536
p-value for NOMINAL_HOUSE_PRICES: 0.000379
ADF Statistic for INFLATION: -6.454897
p-value for INFLATION: 0.000000
ADF Statistic for TOURISM: -3.844096
p-value for TOURISM: 0.002487
ADF Statistic for UNEMPLOYMENT_RATE: -6.222737
p-value for UNEMPLOYMENT_RATE: 0.000000
ADF Statistic for POPULATION: -10.463678
p-value for POPULATION: 0.000000
ADF Statistic for GDP: -6.548220
p-value for GDP: 0.000000
```

AIC test:

```
Lag Order = 1
AIC :  -21.692291534356134
Lag Order = 2
AIC :  -22.238128684567943
Lag Order = 3
AIC :  -27.745726170167593
Lag Order = 4
AIC :  -28.28155671186338
Lag Order = 5
AIC :  -28.187691886152997
Lag Order = 6
AIC :  -28.333859339594895
Lag Order = 7
AIC :  -28.683907882741202
Lag Order = 8
AIC :  -28.98814542514985
Lag Order = 9
AIC :  -29.458012665995323
Lag Order = 10
AIC :  -29.57099074399672
```

Lag order 5 decreases compared to lag order 4 and, therefore, the model was fitted using 4 lags.

Summary of the model fit:

```
  Summary of Regression Results
==================================
Model:                         VAR
Method:                        OLS
Date:           Sat, 30, Dec, 2023
Time:                     15:33:51
--------------------------------------------------------------------
No. of Equations:         6.00000    BIC:                   -24.3250
Nobs:                     98.0000    HQIC:                  -26.6812
Log likelihood:           701.460    FPE:                5.59109e-13
AIC:                     -28.2816    Det(Omega_mle):     1.43028e-13
--------------------------------------------------------------------
Results for equation NOMINAL_HOUSE_PRICES
================================================================================================
                               coefficient       std. error           t-stat            prob
------------------------------------------------------------------------------------------------
const                            0.002193         0.004268            0.514           0.607
L1.NOMINAL_HOUSE_PRICES         -0.412453         0.111932           -3.685           0.000
L1.INFLATION                    -0.005469         0.015321           -0.357           0.721
L1.TOURISM                      -0.044309         0.032054           -1.382           0.167
L1.UNEMPLOYMENT_RATE             0.092694         0.045692            2.029           0.042
L1.POPULATION                    0.099177         0.178725            0.555           0.579
L1.GDP                           0.198644         0.068524            2.899           0.004
L2.NOMINAL_HOUSE_PRICES         -0.108748         0.124379           -0.874           0.382
L2.INFLATION                    -0.003697         0.017134           -0.216           0.829
L2.TOURISM                      -0.048308         0.033029           -1.463           0.144
L2.UNEMPLOYMENT_RATE             0.034785         0.052046            0.668           0.504
L2.POPULATION                    0.009488         0.187778            0.051           0.960
L2.GDP                           0.306027         0.148061            2.067           0.039
L3.NOMINAL_HOUSE_PRICES         -0.222056         0.121864           -1.822           0.068
L3.INFLATION                    -0.013939         0.016594           -0.840           0.401
L3.TOURISM                      -0.046789         0.033242           -1.408           0.159
L3.UNEMPLOYMENT_RATE             0.052175         0.051900            1.005           0.315
L3.POPULATION                   -0.021755         0.188992           -0.115           0.908
L3.GDP                           0.258554         0.163892            1.578           0.115
L4.NOMINAL_HOUSE_PRICES         -0.233954         0.116955           -2.000           0.045
L4.INFLATION                     0.004129         0.015346            0.269           0.788
L4.TOURISM                      -0.048160         0.033701           -1.429           0.153
L4.UNEMPLOYMENT_RATE             0.083397         0.044209            1.886           0.059
L4.POPULATION                    0.014913         0.175901            0.085           0.932
L4.GDP                           0.307145         0.145505            2.111           0.035
================================================================================================
```

8.7. APPENDIX G

Model results for Sequence length equal to 2

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 gru (GRU)                   (None, 2, 16)             1008

 dropout (Dropout)           (None, 2, 16)             0

 gru_1 (GRU)                 (None, 2, 8)              624

 dropout_1 (Dropout)         (None, 2, 8)              0

 dense (Dense)               (None, 2, 1)              9

=================================================================
Total params: 1641 (6.41 KB)
Trainable params: 1641 (6.41 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
Epoch 1/1000
55/55 [==============================] - 5s 19ms/step - loss: 0.5312 - val_loss: 0.1059
Epoch 2/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.4078 - val_loss: 0.0784
Epoch 3/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.3429 - val_loss: 0.0622
Epoch 4/1000
55/55 [==============================] - 1s 9ms/step - loss: 0.3025 - val_loss: 0.0524
Epoch 5/1000
55/55 [==============================] - 0s 6ms/step - loss: 0.2377 - val_loss: 0.0462
Epoch 6/1000
55/55 [==============================] - 0s 6ms/step - loss: 0.2245 - val_loss: 0.0416
Epoch 7/1000
55/55 [==============================] - 0s 5ms/step - loss: 0.1893 - val_loss: 0.0387
Epoch 8/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.1772 - val_loss: 0.0364
Epoch 9/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.1523 - val_loss: 0.0349
Epoch 10/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1464 - val_loss: 0.0341
Epoch 11/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1316 - val_loss: 0.0335
Epoch 12/1000
55/55 [==============================] - 1s 9ms/step - loss: 0.1307 - val_loss: 0.0331
Epoch 13/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1028 - val_loss: 0.0334
Epoch 14/1000
55/55 [==============================] - 1s 9ms/step - loss: 0.1217 - val_loss: 0.0333
Epoch 15/1000
55/55 [==============================] - 1s 9ms/step - loss: 0.0957 - val_loss: 0.0343
Epoch 16/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.0992 - val_loss: 0.0347
Epoch 17/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.0842 - val_loss: 0.0361
Epoch 18/1000
55/55 [==============================] - 0s 6ms/step - loss: 0.0824 - val_loss: 0.0371
Epoch 19/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.0786 - val_loss: 0.0378
Epoch 20/1000
55/55 [==============================] - 0s 6ms/step - loss: 0.0843 - val_loss: 0.0389
```

Model results for Sequence length equal to 4

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 gru_8 (GRU)                 (None, 4, 16)             1008

 dropout_8 (Dropout)         (None, 4, 16)             0

 gru_9 (GRU)                 (None, 4, 8)              624

 dropout_9 (Dropout)         (None, 4, 8)              0

 dense_4 (Dense)             (None, 4, 1)              9

=================================================================
Total params: 1641 (6.41 KB)
Trainable params: 1641 (6.41 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
Epoch 1/1000
53/53 [==============================] - 6s 21ms/step - loss: 0.6413 - val_loss: 0.1085
Epoch 2/1000
53/53 [==============================] - 0s 9ms/step - loss: 0.5320 - val_loss: 0.0995
Epoch 3/1000
53/53 [==============================] - 1s 9ms/step - loss: 0.4831 - val_loss: 0.0916
Epoch 4/1000
53/53 [==============================] - 1s 11ms/step - loss: 0.3832 - val_loss: 0.0856
Epoch 5/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.3737 - val_loss: 0.0804
Epoch 6/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.3113 - val_loss: 0.0766
Epoch 7/1000
53/53 [==============================] - 1s 11ms/step - loss: 0.2812 - val_loss: 0.0737
Epoch 8/1000
53/53 [==============================] - 1s 11ms/step - loss: 0.2654 - val_loss: 0.0717
Epoch 9/1000
53/53 [==============================] - 1s 9ms/step - loss: 0.2346 - val_loss: 0.0706
Epoch 10/1000
53/53 [==============================] - 0s 8ms/step - loss: 0.2238 - val_loss: 0.0705
Epoch 11/1000
53/53 [==============================] - 0s 7ms/step - loss: 0.1949 - val_loss: 0.0716
Epoch 12/1000
53/53 [==============================] - 0s 8ms/step - loss: 0.1699 - val_loss: 0.0732
Epoch 13/1000
53/53 [==============================] - 0s 8ms/step - loss: 0.1749 - val_loss: 0.0753
Epoch 14/1000
53/53 [==============================] - 0s 8ms/step - loss: 0.1588 - val_loss: 0.0775
Epoch 15/1000
53/53 [==============================] - 0s 9ms/step - loss: 0.1358 - val_loss: 0.0802
Epoch 16/1000
53/53 [==============================] - 0s 9ms/step - loss: 0.1482 - val_loss: 0.0833
Epoch 17/1000
53/53 [==============================] - 0s 8ms/step - loss: 0.1381 - val_loss: 0.0878
Epoch 18/1000
53/53 [==============================] - 0s 7ms/step - loss: 0.1275 - val_loss: 0.0910
```

8.8. APPENDIX H

Model results for Sequence length equal to 2

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 gru_2 (GRU)                 (None, 2, 16)             1152

 dropout_2 (Dropout)         (None, 2, 16)             0

 gru_3 (GRU)                 (None, 2, 8)              624

 dropout_3 (Dropout)         (None, 2, 8)              0

 dense_1 (Dense)             (None, 2, 1)              9

=================================================================
Total params: 1785 (6.97 KB)
Trainable params: 1785 (6.97 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
Epoch 1/1000
55/55 [==============================] - 6s 32ms/step - loss: 0.6113 - val_loss: 0.1090
Epoch 2/1000
55/55 [==============================] - 1s 10ms/step - loss: 0.5237 - val_loss: 0.0905
Epoch 3/1000
55/55 [==============================] - 1s 10ms/step - loss: 0.4188 - val_loss: 0.0797
Epoch 4/1000
55/55 [==============================] - 1s 11ms/step - loss: 0.3839 - val_loss: 0.0727
Epoch 5/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.3334 - val_loss: 0.0672
Epoch 6/1000
55/55 [==============================] - 1s 9ms/step - loss: 0.2806 - val_loss: 0.0639
Epoch 7/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.2595 - val_loss: 0.0615
Epoch 8/1000
55/55 [==============================] - 0s 9ms/step - loss: 0.2349 - val_loss: 0.0604
Epoch 9/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.2373 - val_loss: 0.0592
Epoch 10/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.2023 - val_loss: 0.0588
Epoch 11/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.2006 - val_loss: 0.0591
Epoch 12/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1607 - val_loss: 0.0601
Epoch 13/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1584 - val_loss: 0.0607
Epoch 14/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1657 - val_loss: 0.0617
Epoch 15/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.1376 - val_loss: 0.0634
Epoch 16/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1511 - val_loss: 0.0653
Epoch 17/1000
55/55 [==============================] - 0s 7ms/step - loss: 0.1373 - val_loss: 0.0666
Epoch 18/1000
55/55 [==============================] - 0s 8ms/step - loss: 0.1446 - val_loss: 0.0682
```

Model results for Sequence length equal to 4

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 gru_8 (GRU)                 (None, 4, 16)             1152

 dropout_8 (Dropout)         (None, 4, 16)             0

 gru_9 (GRU)                 (None, 4, 8)              624

 dropout_9 (Dropout)         (None, 4, 8)              0

 dense_4 (Dense)             (None, 4, 1)              9

=================================================================
Total params: 1785 (6.97 KB)
Trainable params: 1785 (6.97 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
Epoch 1/1000
53/53 [==============================] - 11s 34ms/step - loss: 0.8226 - val_loss: 0.1819
Epoch 2/1000
53/53 [==============================] - 1s 13ms/step - loss: 0.4877 - val_loss: 0.1367
Epoch 3/1000
53/53 [==============================] - 1s 13ms/step - loss: 0.3566 - val_loss: 0.1008
Epoch 4/1000
53/53 [==============================] - 0s 9ms/step - loss: 0.2576 - val_loss: 0.0786
Epoch 5/1000
53/53 [==============================] - 1s 9ms/step - loss: 0.1808 - val_loss: 0.0662
Epoch 6/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.1740 - val_loss: 0.0597
Epoch 7/1000
53/53 [==============================] - 0s 9ms/step - loss: 0.1281 - val_loss: 0.0586
Epoch 8/1000
53/53 [==============================] - 0s 7ms/step - loss: 0.1155 - val_loss: 0.0605
Epoch 9/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.1068 - val_loss: 0.0622
Epoch 10/1000
53/53 [==============================] - 1s 11ms/step - loss: 0.0963 - val_loss: 0.0650
Epoch 11/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.0832 - val_loss: 0.0680
Epoch 12/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.0872 - val_loss: 0.0690
Epoch 13/1000
53/53 [==============================] - 0s 8ms/step - loss: 0.0896 - val_loss: 0.0717
Epoch 14/1000
53/53 [==============================] - 0s 9ms/step - loss: 0.0798 - val_loss: 0.0732
Epoch 15/1000
53/53 [==============================] - 1s 10ms/step - loss: 0.0795 - val_loss: 0.0718
```

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