Interest rate pass-through in the euro area: Are policy measures efficient in crisis periods? Evidence from a multi state Markov model on a panel dataset.

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by

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Abstract

Interest rates pass through mechanism is an important element of the monetary policy of a central bank, since it is used to achieve effectively the equilibrium among the inflation target, the money demand and the supply in the economy. In this paper we explore the dynamics of interest rate pass through in the euro area employing a novel multi state Markov model on a panel dataset, in order to determine the mechanics of the transmission of policy measures under both crisis and non-crisis periods. Empirical results, based on monthly data for the period 2003–2017, show that during periods of financial distress bank lending rates to non financial corporations show a reduction of their degree of pass-through from the money market rate. In addition the pass through mechanism is also affected by the sovereign credit risk and the dexterity of the domestic financial system. Moreover encompassing this behavior into a statistical framework, we obtain more robust out – of- sample forecasting results than the benchmark panel data regression specification.

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1. Introduction

One of the most important channels of monetary policy transmission is the interest rate channel. Central bank rates affect interbank interest rates, which are at the basis of the process of defining the cost of money lent by banks. In recessions or post a crisis event central banks tend to reduce interest rates so as to increase the net present value of investment projects and reduce the value of savings in order to boost consumption. Alternatively in order to face inflationary pressures in economic expansion central banks increase interest rates. The condition of stable prices represents the primary objective of the European Central Bank's (ECB) therefore the pass through mechanism from policy-controlled to retail bank rates is important for monetary policy an price and financial stability perspective.

As it was shown from the 2008 crisis financial turmoil episodes disrupt the function of interbank money market and threaten the stability of the financial system. This disruption may further propagate from the financial sector as it was shown in the case of European sovereign crisis which followed in 2011 and in some countries it lasted for over a business cycle (e.g Greece). In this framework the assessment and the monitoring of interest rate pass-through mechanism have become even more important for central banks' policy-making.

A significant research effort has been devoted in the recent academic literature in order to explore the most significant determinants of the short term and long term adjustments in lending and borrowing rates for better assessing the future profitability of commercial banks. In the majority of these studies the error correction model (ECM) (Darracq et al. 2014, Schlüter et al 2012, Leroy et al 2015) and to lesser extent panel data analysis (Perera et al 2016, Hristov et al 2014) are employed, in order to decompose the short and the long term impact in the interest rates of commercial banks and investigate the velocity that the pricing mechanism of banks adjust to new economic regimes. Furthermore, numerous articles are concentrated on country specific case studies such as Belgium (De Graeve et al 2007), Portugal (Rocha 2012), Germany (Schlüter et al. 2012), Czech (Havranek et al. 2016) and Italy (Zoli 2013). However a few academic studies have expanded the scope of analysis worldwide (Perera et. 2016, Gigineishvili,. 2011, Karagiannis et al. 2010) in order to investigate the differentiation among significant economic centers (e.g, Europe, USA, Asia). Finally, special focus has been placed on the euro-area, due to the economic specificities of the region given the complicated nexus of very diverse economies under the same currency (Van Leuvensteijn et al. 2013 and Leroy et al., 2016). Another category of studies focused on a specific period of time for analyzing the behavior of interest rates like the recent financial crisis (Hristov 2014). Moreover, several research efforts have been conducted in order to investigate the marginal impact of specific factors related to the interest rate pass through mechanism, like banking competition (Kopecky 2012, De Graeve 2007).

Empirical literature on interest rate pass-through has shown that the financial crisis has drastically affected and impaired the transmission mechanism from money market to retail rates in the Euro area (ECB, 2009). Based on that we explore the dynamics of interest rate pass through in the euro area employing a novel multi state Markov model on a panel dataset, in order to determine the mechanics of the transmission of policy measures under both crisis and non-crisis periods.

Our main objective is to investigate whether the rate of pass-through from money market rates to bank interest rates is influenced by periods of financial turmoil. Our results point out the existence of different magnitude pass through transmission mechanisms which vary with respect to different market conditions. Particularly during financial distress episodes the pass-through rate is reduced narrowing the pipeline through which monetary policy is transmitted. Also in crisis periods in particular the interest rate behavior is also influenced by the inflation level, the sovereign risk and the solvency of the domestic banking system. Finally, in the current literature the statistical models developed aimed only on explaining the determinants of interest rate transmission channel, without performing forecasting validation to ensure that the sensitivities of the model factors are similar in an out of time framework. These gaps in existing studies are attempted to be addressed in the current study.

In a nutshell, our contribution lies on the extended sample period from 2003 up to April 2017 for the Euro area capturing both periods of distress for the financial markets and periods of macroeconomic expansion. Our multi state Markov model provides adequate separation between crisis and non crisis periods whereas our panel data structure permits us to recognize crises in different time periods in different countries. The fact of properly recognizing different states in policy transmission mechanism permit us to outperform the benchmark fixed effect model both on in sample and out of sample comparison

The remaining structure of this study is organized as follows. In Section 2 we provide a brief overview of related empirical work and explore the most commonly used econometric models for tackling the problem of interest rate movements. In Section 3, we elaborate on the dataset used for developing and evaluating our model. In Section 4, the methodological framework employed is described. In Section 5, we elaborate on our experimental setup, and present all our empirical results with respect to the forecasting efficacy of our model. In addition, we assess our empirical findings against a benchmark econometric model and explore the generalization capacity of the suggested model. Finally, in Section 6 we draw our conclusions regarding the key factors that affect the interest rate pass though in the euro area and quantify the level of completeness in the transmission channels.

2. Literature Review

Interest rate determinants and pass-through transmission mechanisms were the focus of numerous studies in current academic literature. Andres and Billon (2016) provide an overview of the empirical literature related to the econometric techniques employed in order to examine the interest rate pass through in the euro area.

Gigineishvili (2011) examined the heterogeneity in the interest rate pass through mechanism across countries and markets. The long run pass through coefficients of 81 countries, calculated by the error correction model, were regressed against macroeconomic and financial variables. The analysis showed that per capita GDP, inflation, interest rates credit quality competition among banks, excess liquidity and market volatility have affected the strength of pass through. Kopecky et al. (2012) advocated that the change in the degree of competition affects the pass through mechanism in both deposit and loan markets. Similarly, Van Leuvensteijn, et al (2013) examined the role of the competition in the lending and deposit rates in eight euro countries. Both studies demonstrated evidence that the more competitive the market that the bank was operating the stronger the transmission mechanism was. Zoli (2013) unraveled the determinants of Italian banking system lending conditions and discovered, as expected, that among others the government credit spread was transmitted to customers. Illes et al. (2013) decomposed the lending spreads into interbank and sovereign components with the last one to be the most significant in explaining the ineffective transmission of policy rates to lending ones.

Darracq et al (2014) proved that the standard error correction models cannot explain the variation of pass through mechanism during the debt crisis and consequently they suggested that additional variables should be included in their models. Proxies for the supply (e.g. default frequencies, capital to asset, cost of equity etc) or the demand (unemployment rates, non-financial default frequencies etc) side risk factors were included in order to explain the previous noted heterogeneity. Hristov et al (2014) analyzed the completeness of the pass-through mechanism prior and after the financial crisis in the Euro area. They outlined that the mechanism of pass through is performed differently for various maturities of loans and deposits. More specifically, the longer the maturities the stickier the relevant relevant rates (longer maturities rates resist more). Moreover they found that tight collateral requirements, high costs of restoring the bank capital position and weak competition exacerbated the incompleteness of the pass through. Schlüter et al (2012) showed that in Germany the' cost efficiency of banks is one of the determinants in the estimation of credit loan markup as well as in the smooth set-up of the loan rates provided by the bank. Perera and Wickramanayake (2016) observed, based on panel data analysis, that in addition to macroeconomic and financial /banking variables the long run adjustment in retail interest rates depends also on institutional and governance factors, such as central bank transparency, independence and financial strength.

Heterogeneity and asymmetries across countries, time periods and products were also pointed out to a significant number of previous studies providing with useful knowledge on incorporating a regime switching panel data econometric framework. Darracq et al (2014) showed in their analysis that the interest rate pass through of European Central Bank monetary policy was stronger prior to the sovereign debt crisis (2011-2013). Leroy and Lucotte (2016) focused also on Eurozone countries and showed that although the monetary policy was common across the participating countries, the pass-through mechanisms were fluctuating significantly over the countries and the type of retail rates. Havranek et al (2015) conducted an analysis on interest rate pass through for the Czech banking sector for the time period 2004 – 2013. This analysis showed that the strong and almost complete long-term pass through from market to lending rates prior to the crisis weakened after the 2008.

Belke et al (2013) focused on 12 countries within the Euro area between 2003 and 2011. They have examined the pass through rates from money market to loan rates, using error correction models. They also detected asymmetries in most of the countries, since the pass through is incomplete and the money market rate increases affect differently the loan rates comparing to the money market rate decreases. They also confirmed cross country heterogeneity, in regards to the pass through mechanism.

Gropp et al (2007) examined the dynamics of banks' spread across various bank products, loans and deposits, in the euro area within the time window of 1994 to 2004. They concluded that transmission mechanism performs differently in deposit products comparing to loan products. Interest rates variations are transmitted differently into similar products such as deposits, with demand and saving deposits to be more stable. Moreover evidence of asymmetry was present; banks tend to adjust faster or slower the rates of the products so as to benefit in each case. Other components that affect the interest rate pass through mechanism are the competition among banks, the credit risk, the market volatility (through the interest rate risk) as well as the competition from domestic financial markets.

Karagiannis et al (2010) explored the behavior of the interest rate transmission mechanism in the Euro area and United States after the 2008 financial crisis. They showed that, while in the Euro area the money market rate is transmitted more effectively to the retail interest rates, in the US the central bank rate is passed through more effectively. They also examined the symmetry hypothesis, and, they showed that EU banks pass to depositors only the decreases of the money market rate changes and mainly the increases to their borrowers. On the contrary, the US banks tend to pass to depositors only the decreases of the central bank rate changes and mainly the decreases to borrowers.

3. Sample and data

Data on interest rates for new loans have been selected from the ECB under the MFI interest rate statistics[5] and refer to the whole period from January 2013 to April 2017. We focus on the pricing of loans to businesses[6] since as it was shown in previous studies (Horvath et al, 2018 – Rocha, 2012) the pass-through rate between money market and retail loans rates is found to be particularly weak, revealing that these rates are stickier and less impacted by monetary conditions. Belke et al. (2013) also find greater completeness of pass-through for firms than for households. This could be due to the fact that although the interbank interest rate reduces, retail bank rates remain relatively high, incorporating a high-risk premium which is related to the growing risks of deterioration in the creditworthiness of counterparties (Aristei and Gallo, 2014). Our dataset covers 11 euro area countries (Austria, Belgium, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Portugal and Spain) and includes both periods of adverse financial conditions (2008 financial crisis) and periods of low systemic uncertainty. Furthermore, as depicted in figure 1 during the period under investigation the central bank interest rate exhibits both rising and decreasing states.

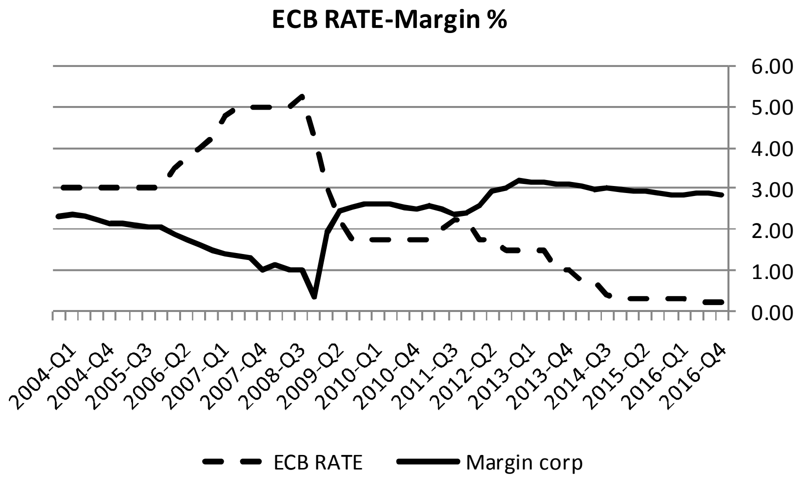

Figure 1: ECB key interest rate evolution and average interest rate margin

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[5] https://www.ecb.europa.eu/stats/financial_markets_and_interest_rates/bank_interest_rates/mfi_interest_rates/html/index.en.html

[6] We employ the interest rate on outstanding business since the time series has wider scope in periods and countries relatively to interest rates on new business. Especially in business loans the two series are pretty much interlinked since most business interest rates are floating based on a interbank base rate.

In particular at early 2006, after a period of substantial stability, the ECB started rising official interest rates again due to increases in inflation expectations over the short term. In 2007 with the emergence of money market tensions, the ECB implemented exceptional monetary policy in order to measures to allow banks restore stability in financial markets (ECB, 2010). After the collapse of Lehman Brothers, ECB repeatedly cut interest rates. However the increasing cost of risk impaired the effectiveness of pass through mechanism and banks only partially transferred the lower refinancing costs to customers as it can be seen from the sharp increase in loan margins over the interbank rate from the end of 2008 onwards (Figure 2). This evidence suggests asymmetries in the degree and speed of pass-through with respect to the pre-crisis period

In addition net interest margin exhibits a decreasing trend during the period 2003-2008, an increasing trend after the end of the financial crisis of 2008, and a stabilizing behavior between 2013 and 2016. This complicated clustering behavior in the evolution of interest rate pass through is difficult to be explored with conventional econometric models and hence under this study we explore the benign properties of multi state modeling.

We use the 3m EURIBOR to proxy the policy-controlled rate since the latter cannot be used directly because the ECB interest rate on the main refinancing operations does not change frequently. The use of 3m EURIBOR as an approximation for the ECB rate is supported in the literature (Abbassi and Linzert, 2011 and Aristei and Gallo, 2014) as it has the advantage that measures the cost of interbank funding which in turn depend on the expectations on banks' solvency whereas is also the base rate upon which the additional spread on business loans is applied.

We employ also a dummy variable taking the value of 1 when the spread of the respective 10 year government bond over the relevant swap rate exceeds 400 bps, approximately the market threshold for the bond to move from investment to non - investment grade based on Moody's rating scale (source: Bloomberg). Horvath et al. (2018) find that higher sovereign credit risk is associated with higher bank interest rates. This result reflects the effects of sovereign credit risk, potentially causing solvency problems due to valuation losses that need to be offset by bank interest rates.

We also include a metric of bank viability i.e. the level of capital adequacy ratio[7]. It is expected that banks suffering the greater losses from a financial crisis, as expressed in lower capital ratios, will be forced to translate the increased funding cost and cost of risk into interest higher rates impairing the pass through mechanism. We finally control for the inflation level as interest rates and prices are directly linked through the Fisher equation so that an increase in inflation must be accompanied by an increase in nominal interest rates provided that real interest rates are held constant.

The hidden function which determines the crisis state has as explanatory covariate the changes in the spread between EONIA and 3m EURIBOR which is purely driven by credit and liquidity risk. As pointed in Blot and Labondance (2011) in normal times, these two interbank rates move in a correlated way, but with the occurrence of financial market turbulence, this relationship breaks. For example following the collapse of Lehman Brothers in mid-September 2008, a very large and negative EONIA spread became apparent.

4. Methodological Framework

The proposed structure builds upon previous publications (Mishra et al. (2010), Perera et al. (2016)) and aims to model the long run adjustment in commercial interest rates. Our dependent variable Y_{it} is the quarterly change of banks business interest rates measured on a monthly rolling basis (dR) and the independent variables X_{it} include the quarterly change of interbank rate measured on the same basis (dEURIB), a dummy variable measuring sovereign risk, which takes the value of 1 when the spread of the respective 10 year government bond over the relevant swap rate exceeds 400 bps (GSPREAD), the respective inflation rate (INFLAT) and finally a bank solvency measure i.e. the domestic banking system capital adequacy ratio (CAR), which exhibits lower values when the risk profile of the bank deteriorates (either through increasing Risk Weighted Assets or through decreasing profitability given a high funding cost and cost of risk. In summary the pass – through equation can be summarized as follows

[7] The ratio is available on a yearly basis in Federal Reserve database.

$$dR = \alpha \text{ dEURIB} + \beta \text{ GSPREAD} + \gamma \text{ INFLAT} + \delta \text{ CAR} \qquad (1)$$

In (1) the parameter α measures the degree of transmission of monetary policy to bank interest rates. Our main argument is that in crisis periods the increasing cost of risk and the emergence of sovereign pressures impair the pass through mechanism of policy rates reduction since banks are forced to increase the risk premium over the base interbank rate in order to protect their profitability. Therefore the respective parameters in the abovementioned equation are different across crisis and non -crisis states

Departing from traditional econometric frameworks we adopt a Markov multi state panel data statistical setup. In this way we disentangle the details of policy transmission mechanism by employing a model which offers the flexibility to model non-linear relationships and to simulate the temporal nature of financial time series since sensitivities and the statistically significance of certain drivers can tend to change between states especially with the realization of adverse macroeconomic conditions. Moreover, the multi state model applied offers the ability to analyze panel behavior and recognize different states by country thus modeling the specificities that exist in various euro economies. Finally, the framework provides the functionality to produce confidence intervals for the forecasts based on the fitted Normal distributions corresponding to each state. Thus, we estimate a multi - state Markov model with embedded covariates establishing a linear relationship between the changes in bank interest rates and changes in interbank rates changes controlling also for covariates measuring the effects of sovereign risk, inflation and banking solvency

Therefore we expand the classic panel data model by incorporating a general hidden Markov model assuming the co-existence of two processes. A hidden process (S_{it}) which satisfies the Markov property and can evolve in discrete or continuous time and an observed process (Y_{it}) where in our setup is the evolution of the lending interest rates. The observed data are governed by some probability distribution (the emission distribution) conditionally on the unobserved state of the hidden process.

Under this setup, Markov multi state model offers a flexible and general purpose modeling framework for univariate and multivariate analysis, specifically for discrete time series and classification data. Figure 3 shows the general architecture of a Markov multi state model. The value of (Y_{it}) which is observed (measured) is normally distributed with parameters that depends on the value of the hidden process (S_{it}), which is inferred through its interaction with (Y_{it}). In our study, the fundamental state of the euro system is represented by a Markov process and the bank's products interests rates are the observed stochastic process. Usually the Markov process is assumed to evolve over an equally-spaced, discrete 'time' space. Therefore most of the theory of HMM estimation was developed for discrete-time models although they can be easily extended to continuous-time hidden Markov models with a variety of emission distributions except normal.

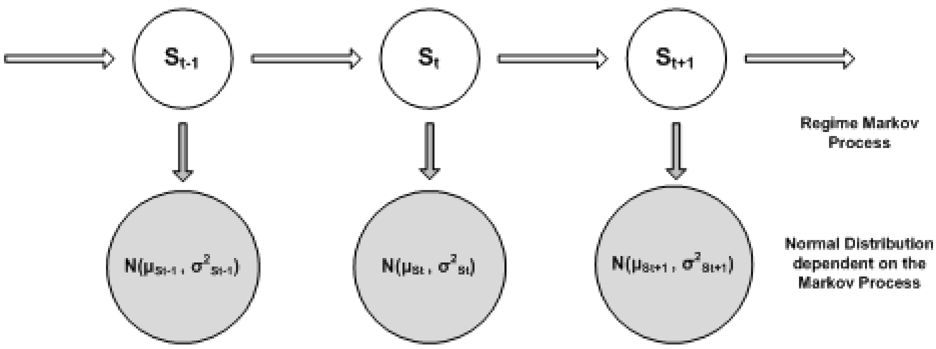

Figure 2: Architecture of the Multi State Hidden Markov Model with Normal Emission Probabilities

The two stochastic processes assumed under a Markov Switching Panel data model have the following properties:

- The hidden underlying stochastic process for each country i (S_t) satisfies the Markov property.

$$P(S_{t+1} = s_{t+1}|S_t = s_t) = P(S_{t+1} = s_{t+1}|S_t = s_t,\ S_{t-1} = s_{t-1}, \dots, S_0 = s_0) \quad (2)$$

- The observed stochastic process (Y_{it}) depends only on the current state of the hidden stochastic process and thus satisfies the conditional independence property i.e it does not depend on its lags values given the current hidden state. This property for each country i is described by the following mathematical relationship:

$$\mathrm{P}(Y_t = y_t | Y_{t-k}^{t-1} = y_{t-k}^{t-1}, S_t = s_t, \dots, S_0^t = s_0^t\ ) = \mathrm{P}(Y_t = y_t | S_t = s_t) \qquad (3)$$

In this empirical study the hidden underlying stochastic process (S_{it}) is dependent on the changes in the spread between EONIA and 3m EURIBOR which is purely driven by credit and liquidity risk.

According to this structure, the value Y_{it} is distributed normaly whose coefficients - parameters evolve in time according to the state S_t.

$$Y_{it} | \{\ S_{it} = k\} \sim \mathrm{N}(\mu k + \beta k{*}xit\ ,\ \sigma 2k) \qquad (4)$$

where,

i corresponds to the country,

t the respective time stamp (quarter),

k the current state of process S_{it},

μ_k, σ^2_k the parameters of the Normal distribution corresponding to state k,

β_k*x_{it} is a linear combination of covariates that correspond to the countries in the sample and β_k the coefficients estimated by the model which affect the location parameter of the normal distribution

The transition probabilities of the current (t) state from the previous (t-1) state ($P_{t-1,t}$) can be expressed in the case of a two state model by the probability matrix:

$$P = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \qquad (5)$$

Where: $p_{i1} + p_{i2} = 1, \quad p_{ij} = P(S_t = j | S_{t-1} = i)$

Model training and coefficient estimation are performed by employing the expectation maximization (EM) algorithm i.e. parameters are estimated via an iterative method that maximizes the log likelihood of the observations and overcomes the existence of latent variables by substituting them in each step by their posterior expected value.

This method is also known as Baum-Welch algorithm. Model estimation is performed using the MSM package in r statistical package[8] that supports the use of panel or longitudinal data. Furthermore, the package can fit continuous-time hidden Markov models with a variety of emission distributions. A generalization of the estimation algorithm to continuous time was described by Bureau et al (2000).

The Markov multi state statistical framework described above essentially employs mixture densities to model the dependent variable using covariates in its parametric setup. This way flexibility increases in order to capture more effectively the structural non-linear dynamics and temporal dependencies of commercial interest rates.

Forecasting the future changes in interest rates of each product category (Y_{it+1}) under this approach is performed following the next steps: Firstly, we perform inference for the state of the economy at time t_0 of each country using the Viterbi algorithm (1967) (decoding process) and in the second step the forward algorithm (Rabiner 1989 and Mcdonald & Zucchini 1997) is applied which assumes one transition ahead based on the estimated Markov chain to t+1 and a weighted average of the location parameters of the corresponding normal distributions fitted. Extending the forecast in multiple periods ahead, the forward algorithm takes also into account the realization of process (Y_{it+1}) along with the evolution of the process (S_{it}).

5. Empirical Application

Some summary statistics of our sample are presented in Table 1. We observe heterogeneity of the average business interest rate across countries where banks in northern European countries charge on average lower interest rate to businesses in comparison to southern peers. This could be due to the rising funding cost and cost of risk during and after the sovereign debt crisis as the banking systems of the latter exhibit lower capital ratios. The average inflation does not seem to differ across countries whereas from the perspective of sovereign risk mainly the bonds of Greece, Ireland and Portugal and to a lesser extend Italy and Spain had returns below the investment grade

[8] https://cran.r-project.org/web/packages/msm/

boundary. In addition on the examined period there is mainly a falling changing trend of interest rates as a result of policy actions in addressing crisis episodes and financial turbulence.

	No obs	Avg. Int. Rate	Max change	Min change	Std of change	Avg. CPI	% months Sov.Crisis	Avg. CAR
Austria	172	3.36%	0.28%	-1.35%	0.24%	1.9%	0%	15.1%
Belgium	172	3.79%	0.31%	-1.00%	0.18%	2.0%	0%	16.1%
Finland	172	2.98%	0.29%	-1.43%	0.27%	1.6%	0%	16.9%
France	172	3.66%	0.27%	-0.79%	0.16%	1.5%	0%	13.1%
Germany	172	4.11%	0.12%	-0.78%	0.13%	1.5%	0%	15.4%
Greece	172	5.66%	0.43%	-0.96%	0.22%	1.9%	49%	12.7%
Ireland	172	4.06%	0.36%	-1.81%	0.31%	1.2%	17%	16.3%
Italy	172	4.07%	0.32%	-1.45%	0.27%	1.8%	4%	12.1%
Netherl	172	3.85%	0.24%	-1.21%	0.19%	1.5%	0%	14.6%
Portugal	172	4.43%	0.51%	-1.29%	0.28%	1.7%	22%	11.4%
Spain	172	3.62%	0.35%	-1.05%	0.23%	2.0%	5%	12.4%
Total	**1892**	**3.96%**	**0.51%**	**-1.81%**	**0.23%**	**1.7%**	**9%**	**14.2%**

Table 1: .Summary statistics

We split our dataset into two parts: An in-sample dataset, comprising of data pertaining to the observation period 2003-2013; and an out of sample dataset, including the data pertaining to the period from January 2014 till April 2017. Multi state models perform well when the underlying training data are driven by state shifts. In order to capture this adequately, the data used for training should refer to all the possible states we aim to model. We employ first differenced series of bank rates and 3m euribor since the KPSS test rejects both the null of level and trend stationarity for the business bank rates (Table 2).

KPSS test	Level	Trend	Series
Bank Rate	0.922	0.561	Unit root
3M Euribor	0.061	0.032	Stationary
diff-Bank Rate	0.032	0.010	Stationary
diff-3M Euribor	0.010	0.009	Stationary

Table 2: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for the null hypothesis that the variable is level or trend stationary.

Regarding the forecasting period, the common practice is to use the most recent data as out sample in order to test the efficacy of the developed models under the most recent states. Thus, the in-sample dataset part covers 132 consecutive monthly-observations, while the out of time period spans 40 consecutive monthly observations ahead by country. The long time series employed assures a robust estimation increasing our understanding of the mechanics behind bank's pricing policies across the euro area.

In order to gain an initial insight on the pass through mechanism we estimate a fixed effect model (Table 3) with heteroskedasticity and serial correlation consistent covariance estimators (MacKinnon and White, 1985 and Arellano, 1987). The R package plm (Croissant and Millo, 2008) was used for Panel data estimations and testing.

	Estimate	Std Error	P-value	
dEURIB	0.415	0.037	0.000	***
GSPREAD	0.117	0.012	0.000	***
CPI	0.043	0.008	0.000	***
CAR	-0.527	0.213	0.013	*

Table 3: .Business Interest Rate changes (dR) estimation output. Fixed Effects estimators with heteroskedasticity and serial correlation consistent covariance estimators (MacKinnon and White, 1985). Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

for the examined period (2003-2013) from which we estimate the following pass through relationship

$$dR = \mathbf{0.415}\ \text{dEURIB} + \mathbf{0.117}\ \text{GSPREAD} + \mathbf{0.043}\ \text{INFLAT} - \mathbf{0.527}\ \text{CAR} \quad (6)$$

The pass through coefficient implies that a decrease of 1% in the interbank rate will lead to a decrease of 0.42% in bank interest rates (incomplete pass through) since there are effects which force the banks to increase their rates such the sovereign risk premium, inflation effect and a low bank solvency premium which can be translated in high funding cost and cost of risk. Attempting to dive deeper in the pass through dynamics in crisis periods we estimate we adopt a Markov switching panel data statistical setup where the hidden underlying stochastic process (S_{it}) which defines the respective state (crisis, non -crisis) is dependent on the changes in the spread between EONIA and 3m EURIBOR. For the estimation and evaluation of Markon multi state model the R package msm (Jackson, 2011) was employed. The respective states recognized are shown in Figure 3.

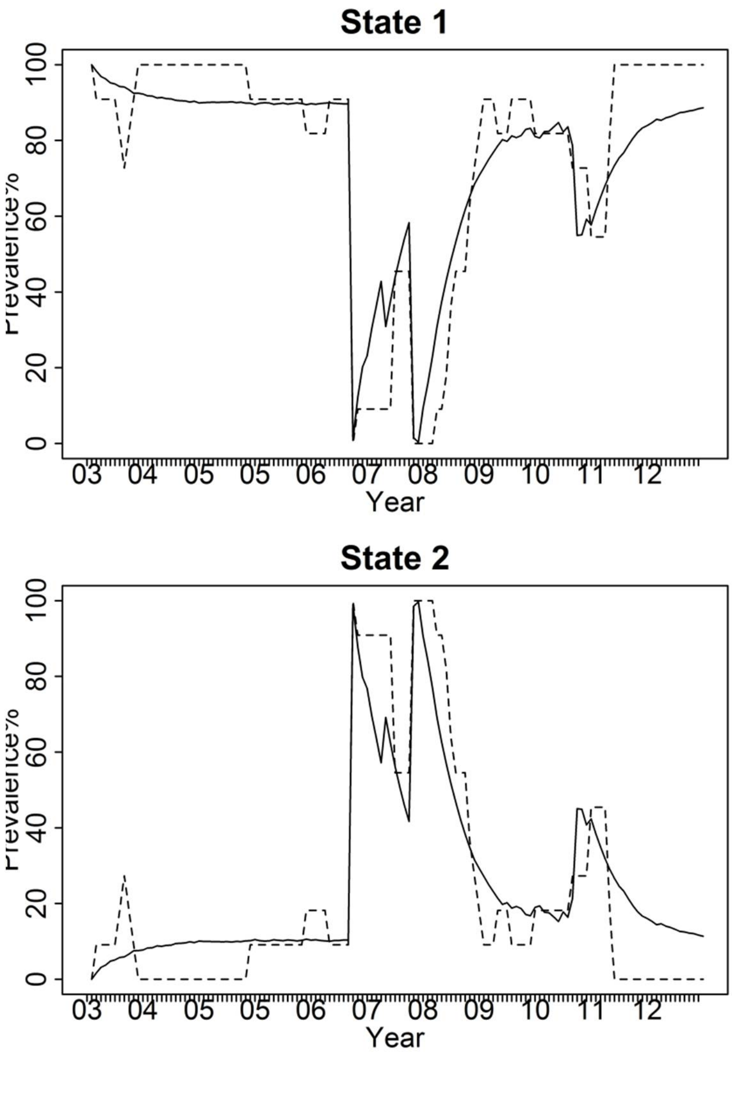

Figure 3: Prevalence Plot. Percentage of countries within each state. Dashed line: Observed Percentages. Solid line: Expected Percentages.

By comparing the observed data with fitted or expected data under the model (Figure 3) we deduce that the estimates percentage of countries within each state (prevalence) matches closely the observed percentage. We observe that there is an abrupt migration to crisis state for all European countries in 2007 with the emergence of money market tensions which continued in 2008 with the repercussions of the collapse of Lehman Brothers. In this course, ECB used among others conventional and unconventional measures of the monetary policy, in order to overcome the credit crunch and the liquidity consequences of the crisis in the Eurozone. The interest rate mechanism was one of the measures used. A second migration for some European countries in crisis state is observed in 2011 where the repercussions of subprime crisis led to European sovereign debt crisis. In contrast to the 2007 crisis where all European countries suffered in the more recent case only a limited number of European countries the one called GIPS (Greece, Italy, Portugal and Spain) were affected (as it is also evident from Figure 4).

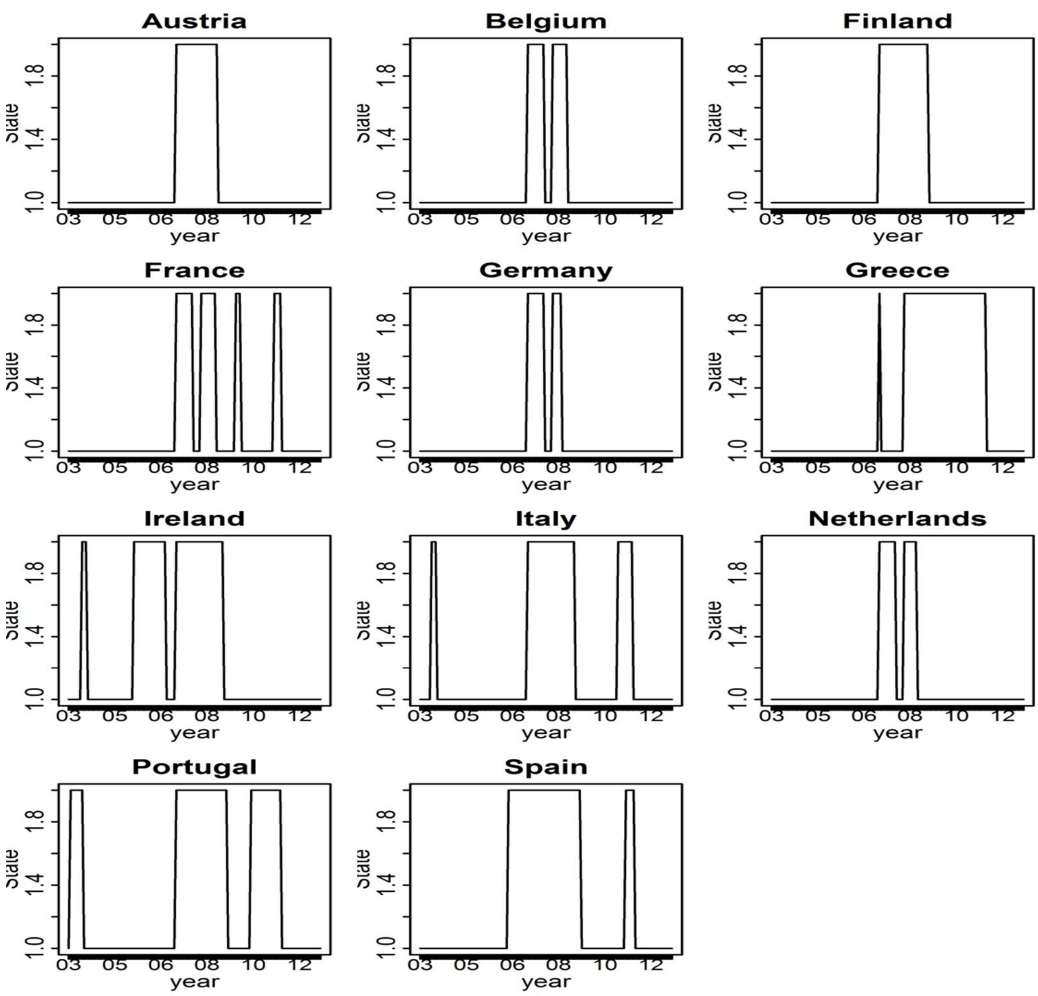

Figure 4: Hidden states inference for the in sample period. Evolution of states by country. State 1 Non crisis – State 2 Crisis.

The Markov multi state estimates (upper panel) and the respective transition probabilities across states (middle panel) are shown in Table 4. We observe that even though the average change in interest rates is similar across states, in state 2 (crisis state) there is larger standard deviation in interest rate movements. The majority of coefficients have stable signs and narrow confidence intervals providing us with significant insight on the dynamics of pass through, whereas the average crisis probability for the period 2003-2013 (i.e. the probability of migration from stage 1 to stage 2) reaches 4.4% which is comparable to similar metrics obtained in previous studies[9]. From the evolution of estimated crisis probability (Figure 5) we spot three peaks during the 2007-2008 global financial crisis and a smaller peak in 2011 during the sovereign debt crisis in Europe. The mean sojourn time in crisis periods ranges from 5 to 15 months which is a crucial empirical finding for regulatory purposes indicating the expected turbulence period after crisis triggering event.

State 1	Estimate	Lower Bound	Upper Bound
mean	-0.061	-0.067	-0.054
sd	0.079	0.075	0.084
dEURIB	0.530	0.500	0.560
GSPREAD	0.052	0.035	0.070
CPI	0.009	0.003	0.014
CAR	0.120	-0.091	0.331

State 2	Estimate	Lower Bound	Upper Bound
mean	-0.082	-0.116	-0.048
sd	0.254	0.234	0.276
dEURIB	0.340	0.302	0.378
GSPREAD	0.206	0.043	0.369
CPI	0.111	0.088	0.133
CAR	-2.266	-3.941	-0.592

	State 1	State 2
State 1	95.6%	4.4%
State 2	10.4%	89.6%

[9] See Aristei and Gallo (2014)
)

	Estimate	Lower Bound	Upper Bound
State 1	76.90	38.16	154.96
State 2	8.74	5.06	15.08

Table 4: (Upper panel) Interest Rate changes (dR) Markov Switching EM estimation output. (Middle panel) Average Transition probabilities across states for the period 2003-2013. (Lower Panel) Mean Sojourn times in each state. State 1: Non-Crisis period, State 2: Crisis period.

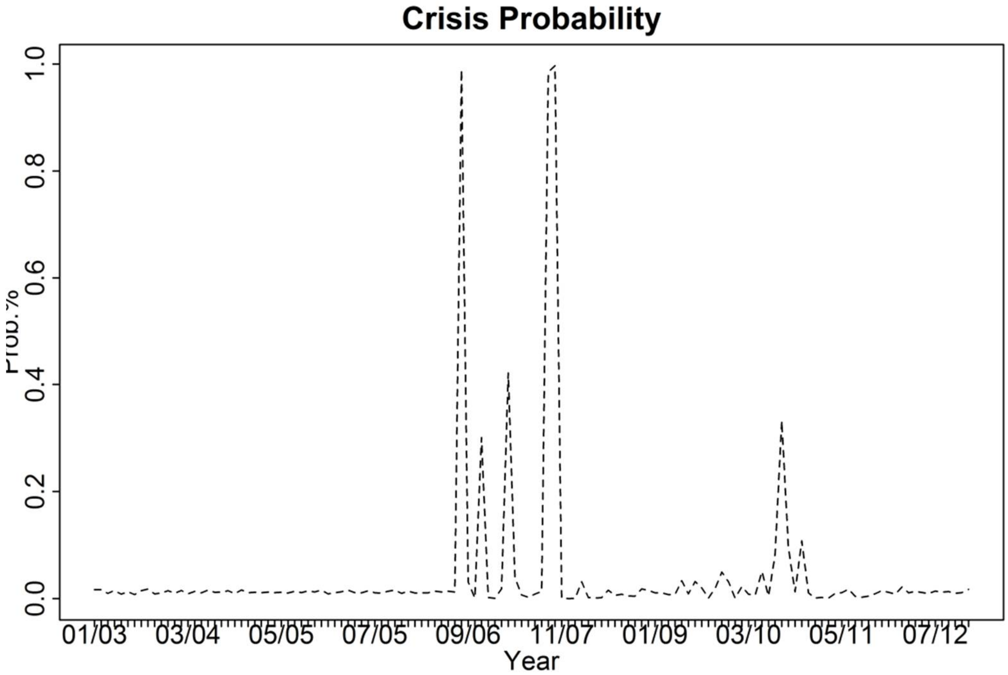

Figure 5: Crisis probability (i.e. the probability of migration from stage 1 to stage 2) evolution in the period 2003-2013.

Based on the estimates of Table 4 we deduce the following pass through relationship

$$dR = \begin{cases} \mathbf{0.530}\,\mathrm{dEURIB} + \mathbf{0.052}\ \mathrm{GSPREAD} + \mathbf{0.009}\ \mathrm{INFLAT} + \mathbf{0.120}\ \mathrm{CAR}, \text{in non} - \text{Crisis} \\ \mathbf{0.340}\,\mathrm{dEURIB} + \mathbf{0.206}\ \mathrm{GSPREAD} + \mathbf{0.111}\ \mathrm{INFLAT} - \mathbf{2.266}\ \mathrm{CAR}, \quad \text{in Crisis} \end{cases}$$

(7)

We deduce that even though in normal times there is a pass through rate of 53%, this mechanism is highly impaired in crisis periods where the pass through rate falls to

34% indicating that the policy transmission mechanism gets significantly impaired. This can only be partly attributed to opportunistic behavior by banks, which make take advantage of the reduction in central bank rates without transferring these benefits to borrowers, since the other determining factors in short term interest rate change in crisis periods start to exert larger influence. More precisely European banks in crisis periods were forced to keep an increased premium over the base interbank rate in order to protect their profitability from sovereign risk losses (where the relative coefficient is four times larger than normal times) and increased funding cost and cost of risk which impact the level of their solvency ratio. Conversely in normal periods solvent banks are those who possess the market power to keep relatively high lending rates.

These findings are in line with the recent literature confirming that financial distress episodes may impair the functioning of money markets and reduce the effectiveness of monetary policy transmission, causing a change in the responsiveness of financial intermediaries' pricing behavior. This can only be partly attributed to opportunistic behavior by banks, which make take advantage of the reduction in central bank rates without transferring these benefits to borrowers, but also on an attempt of the banks to shield their profitability from the repercussions of financial distress (e.g. sovereign losses, increasing cost of risk and funding cost).

Furthermore we examine the out –of sample forecasting performance of the multi state Markov model (msm) in the period from January 2014 till April 2017 and benchmark its accuracy versus a fixed effect model (FE). The in-sample dataset part covers 132 consecutive monthly- observations, while the out of time period spans 40 consecutive monthly observations ahead by country.

	In-sample (1/1/2003-31/12/2013)		**Out-of-sample (1/1/2014-30/4/2017)**	
	1-state (FE)	**2-states (msm)**	**1-state (FE)**	**2-states (msm)**
MSE	2.4%	2.1%	0.8%	0.4%
RMSE	15.6%	14.5%	9.1%	6.3%
MAE	10.6%	9.7%	7.6%	4.7%

Table 5: .Performance Metric: MSE – Mean Square Error, RMSE – Root Mean Square Error, MAE – Mean Absolute Error. FE: fixed effect model- mss: Multi State Markov model.

From the performance metrics in Table 5 we deduce that the multi state Markov model outperforms the one stage fixed effect model both on an in sample and an out of sample basis. The main weakness of the fixed effect model stems from the fact that the sensitivities of coefficients are averaged out during the in sample period 2003 – 2013, failing to address the different regimes in interest rate behavior. Based on the fitted multi state model, significance of covariates vary across time simulating more efficiently the different economic conditions in the euro area banking systems whereas the fixed effect specification allocates one coefficient for the whole period in each explanatory variable ignoring the economic tectonic movements during the financial crises of 2008 and 2011. In order to formalize model comparison we apply the Diebold and Mariano (1995) test (DM value equals -16.03) which rejects the null of model equivalence providing solid evidence that the multi state models performs has better forecasting power than the one state fixed effect model.

Thus panel regression modeling fails to capture important temporal dependencies in key financial and macroeconomic variables leading to poor forecasting results in the out of time period. Countries specificities are captured through the fixed effects coefficient which is stable of the in sample period while in multi -state model the hidden states decomposition lead to a more granular representation of the different economic regimes that euro area countries went through. As final test we examine the Mincer-Zarnowitz (1969) regression for testing forecast efficiency of the multi-state model which consists of regressing forecast errors on a constant by using autocorrelation-corrected standard errors and testing whether the latter is equal to zero. In that regression what is being tested is if the forecast errors have a zero mean, that is, if there is no systematic bias in the forecasts. We find the null of zero residual mean is not rejected (p-value equals 0.7085) therefore multi state forecasts do not systematically over or under-predict realized values.

This finding has significant policy implications since any hypothesis the transmission of monetary decisions to interest rates (pass through) constraint should not take into account solely the experience gained either under adverse or baseline circumstances, but rather combine them in weighted multi scenario manner that allows all the relevant interdependencies to unveil and the final result not to be either upwards or downwards biased.

6. Conclusions

In this paper we explore the dynamics of interest rate pass through in the euro area employing a novel multi state Markov model on a panel dataset, in order to determine the mechanics of the transmission of policy measures. The flexibility embedded in its structure offers the ability to model the temporal dependencies of interest rate pass through under different states i.e. crisis and non-crisis periods. We focus on the pricing of loans to businesses since a main target of the monetary policy measure is to boost business activity, through the reduction of business rates which will increase the Net Present Value of business endeavors, and to a lesser extend to reduce the retail interest rates as in the case of consumer loans the main pricing element is the cost of risk and in the case of mortgages a large proportion of customers books a fixed rate in the origination of the loan. This is verified from the weak the pass-through rate between money market and retail loans rates found in previous studies (Horvath et al, 2018 – Rocha, 2012).

Our main finding is that the transition to crisis state leads to a decrease of the influence exerted by money market rates on the pricing of business loans therefore the transmission mechanism of monetary interest rate reduction is significantly impaired. This can only be partly attributed to opportunistic behavior by banks, which make take advantage of the reduction in central bank rates without transferring these benefits to borrowers, but also on an attempt of the banks to shield their profitability from the repercussions of financial distress. More precisely the effects of sovereign valuation losses, increased funding cost and higher cost of risk provoke solvency problems to the banks which need to be offset by chagrining an increased premium in bank interest rates.

Our results stress the relevance of the role of monetary policy during turmoil periods where the responsiveness of the banking sector should be taken into account in restoring the functioning of the transmission mechanism. The financial crisis and the following sovereign debt crisis have highlighted the importance of sovereign risk, quality of bank capital and bank funding conditions which should be addressed through coordinated fiscal and monetary interventions.

Moreover encompassing this behavior into a statistical framework, we obtain more robust out – of- sample forecasting results than the benchmark panel data regression specification. As we showed, our approach consistently outperforms the one state fixed effect panel specification both in terms of in sample and out of sample forecasting. Forecasting efficiency of multi state model in the out time sample stems from the fact that countries at the end of the development period i.e fourth quarter of 2013 may end up in different state. Thus forecasting is boosted since our modeling takes account the different state while panel data fails to capture this fact. In addition simple panel regression assumes linearity in the relationship of the variables in the sample, while multi state model succeed to capture the non- linear behavior in the adjustment of interest rates.

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