MARKOV SWITCHING MODELLING OF INTEREST RATE PASS-THROUGH

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To **Elba**
She made it possible

CONTENTS

List of Figures ... 6
List of Tables ... 7
Acknowledgements ... 9
Declaration ... 10
Abstract ... 11

1 INTRODUCTION ... 13

2 INTEREST RATE PASS-THROUGH AND FINANCIAL CRISES: DO SWITCHING REGIMES MATTER? THE CASE OF ARGENTINA ... 21

2.1 INTRODUCTION ... 21
2.2 BANK INTEREST RATE PASS-THROUGH ... 23
2.3 MARKET STRUCTURE OF INTEREST RATES ... 27
2.3.1 The term structure of interest rates ... 27
2.3.2 The risk structure of interest rates ... 29
2.3.3 The market structure of interest rates ... 30
2.4 ECONOMETRIC APPROACH ... 33
2.4.1 Single equations ... 33
2.4.2 Linear VAR/VECM models ... 36
2.4.3 Non-linear VAR/VECM models ... 38
2.5 BANK CREDIT MARKET IN ARGENTINA ... 46
2.6 DATA DESCRIPTION AND ANALYSIS ... 49
2.6.1 Graphical analysis ... 50
2.6.2 Descriptive statistics ... 51
2.6.3 Time series preliminary analysis ... 52
2.6.3.1 Unit root tests ... 52
2.6.3.2 Cointegration tests ... 53
2.6.3.3 Unit root and cointegration tests: revisited ... 54
2.7 ECONOMETRIC ESTIMATION AND RESULTS ... 57
2.7.1 Single equations ... 57
2.7.2 Linear VAR models ... 59
2.7.3 Markov switching VAR ... 64
2.8 CONCLUSIONS AND FURTHER RESEARCH ... 71
Figures ... 74
Tables ... 81
Appendix ... 91

3 MODELLING INTEREST RATE PASS-THROUGH WITH ENDOGENOUS SWITCHING REGIMES IN ARGENTINA ... 93

3.1 INTRODUCTION ... 93
3.2 MEASURING THE PASS-THROUGH: WHAT FOR? ... 96
3.2.1 The transmission mechanism ... 96
3.2.2 Banking system behaviour ... 100
3.3 PASS-THROUGH NONLINEARITIES ... 104

3.3.1 Where do they come from? ... 104
3.3.1.1 Nonlinear monetary policy ... 105
3.3.1.2 Financial crises and uncovered interest parity ... 106
3.3.1.3 Real business cycle ... 109
3.3.1.4 Adjustment costs ... 110
3.3.2 Modelling regime shifting ... 111
3.3.2.1 Markov switching models ... 112
3.3.2.2 Transition probabilities: constant and time-varying ... 118
3.3.3 Empirical evidence of regime shifting ... 120
3.3.3.1 Argentina ... 120
3.3.3.2 Euro zone ... 122
3.3.3.3 Others ... 125
3.4 THE BANKING SYSTEM IN ARGENTINA ... 126
3.4.1 Evolution of the banking system ... 126
3.4.2 International currency crises ... 129
3.4.3 Collapse of the currency board ... 130
3.5 PASS-THROUGH AND ENDOGENOUS REGIME-SWITCHING ... 134
3.5.1 Descriptive statistics ... 134
3.5.2 Modelling testing ... 136
3.5.2.1 Number of regimes ... 137
3.5.2.2 Model specification ... 141
3.5.2.3 Leading indicators and exogenous variables ... 142
3.5.3 Markov-switching VAR with TVTP ... 143
3.5.3.1 The model ... 143
3.5.3.2 Estimation procedure: the EM algorithm ... 144
3.5.3.3 Informational variables and TVTP ... 148
3.5.3.4 Main results: economic rationale ... 150
3.6 CONCLUSIONS AND FURTHER RESEARCH ... 157
Figures ... 159
Tables ... 165

4 REGIME SWITCHING IN INTEREST RATE PASS-THROUGH AND DYNAMIC BANK MODELLING WITH RISKS ... 174

4.1 INTRODUCTION ... 174
4.2 LINEAR PASS-THROUGH: STATIC MODEL ... 177
4.2.1 Optimisation proces ... 178
4.2.2 Interest rate pass-through ... 180
4.2.3 Observations and caveats ... 181
4.3 NONLINEAR INTEREST RATES: DYNAMIC MODEL ... 184
4.3.1 Optimisation constraints ... 186
4.3.2 The money market rate ... 187
4.3.3 Cost functions ... 193
4.3.4 Optimisation process ... 195
4.3.5 Nonlinear interest rates and the pass-through ... 199
4.4 NONLINEAR PASS-THROUGH: DYNAMIC MODEL WITH RISKS ... 204
4.4.1 Introducing credit and liquidity risks ... 204
4.4.2 Regime-switching pass-through ... 210
4.4.3 Product differentiation ... 213
4.4.4 Other nonlinearities ... 217

4.5 NONLINEAR PASS-THROUGH: EMPIRICAL APPLICATION 219
4.5.1 Data analysis 219
4.5.2 Markov switching modelling 221
4.6 CONCLUSIONS AND FURTHER RESEARCH 225
Figures 227
Tables 230
Appendix 235
5 CONCLUSIONS 238
References 243
Author Index 258

List of Figures

Figure 2.1 Lending Rates vis-à-vis the Interbank Rate 74
Figure 2.2 Nominal Interest Rates on Loans in Argentina: 1993:06 – 2000:12.......... 75
Figure 2.3 Autocorrelation (ACF) and Partial Autocorrelation (PACF) Functions..... 75
Figure 2.4 Nominal Interest Rates in First Differences... 76
Figure 2.5 Residuals from Cointegrating Equations 76
Figure 2.6 Response to Choleski One S.D. Innovations ± 2 S.E................................. 77
Figure 2.7 Accumulated Response to Choleski One S.D. Innovations ± 2 S.E. 77
Figure 2.8 Bank Lending Rate Pass-Through from VAR(1) 78
Figure 2.9 Bank Lending Rate Pass-Through from VAR(1) with Dummy 78
Figure 2.10 Regime Probabilities from MSVAR Interbank - Overdraft........................ 79
Figure 2.11 Regime Probabilities from MSVAR Interbank - Bills............................... 79
Figure 2.12 Regime Probabilities from MSVAR Interbank - Personal.......................... 80
Figure 3.1 Nominal Interest Rates (pesos) in Argentina: 1993:06 – 2003:12........... 159
Figure 3.2 Nominal Interest Rates (US dollars) in Argentina: 1993:06 – 2003:12.... 159
Figure 3.3 Nominal Interest Rates (pesos) in Argentina: 2001:12 – 2003:12........... 160
Figure 3.4 Nominal Interest Rates (US dollars) in Argentina: 2001:12 – 2003:12.... 160
Figure 3.5 Lending Rates vis-à-vis the Interbank Rate 161
Figure 3.6 Lending Rates in Pesos and Dollars... 161
Figure 3.7 Spread between Each Lending Rate and the Interbank Rate 162
Figure 3.8 Spread for Each Lending Rate in Pesos and US Dollars 162
Figure 3.9 Regime Probabilities from MSVAR with TVTP Interbank - Overdraft... 163
Figure 3.10 Regime Probabilities from MSVAR with TVTP Interbank - Bills........... 163
Figure 3.11 Regime Probabilities from MSVAR with TVTP Interbank - Personal 164
Figure 4.1 Nominal Interest Rates in France: 1984:04 - 2003:06 227
Figure 4.2 Nominal Interest Rates in Germany: 1984:11 - 2003:06 227
Figure 4.3 Transition Probabilities for German Lending Pass-Through.................... 228
Figure 4.4 Transition Probabilities for German Deposit Pass-Through..................... 229

List of Tables

Table 2.1 Loans to the Non-Financial Private Sector - Flows in Pesos 81
Table 2.2 Descriptive Statistics of Nominal Interest Rates in Argentina 81
Table 2.3 Correlation and Causality in Nominal Interest Rates 81
Table 2.4 Augmented Dickey Fuller Test 82
Table 2.5 Phillips-Perron Test 82
Table 2.6 Johansen Cointegration Test Summary 83
Table 2.7 Engle-Granger Test for Cointegration with Interbank Rate 83
Table 2.8 Unit Root Tests and Additive Outliers 84
Table 2.9 Johansen Cointegration Test Summary with Dummy for March 1995 85
Table 2.10 Interest Rate Pass-Through: Estimation with PcGets (up to 3 lags) 86
Table 2.11 Interest Rate Pass-Through: Single Equation 86
Table 2.12 Interest Rate Pass-Through: Linear VAR 87
Table 2.13 Interest Rate Pass-Through: Linear VAR with Dummy 87
Table 2.14 Interest Rate Pass-Through: Single Equation and Linear VAR 88
Table 2.15 Interest Rate Pass-Through: Bivariate Linear VAR 88
Table 2.16 Log-Likelihood Test for Linearity 88
Table 2.17 MSIAH(2)-VAR(1) Transition Matrix 89
Table 2.18 MSIAH(2)-VAR(1) Interests Rate Pass-Through 89
Table 2.19 Interest Rate Pass-Through: Linear Models vs. Markov Switching model.. 90
Table 2.20 MSIAH(2)-VAR(1) Contemporaneous Correlation 90
Table 2.21 MSIAH(2)-VAR(1) Regime Classification 90
Table 3.1 Number of Institutions with/without Operations per Interest Rate 165
Table 3.2 Loans to the Non-Financial Private Sector in Flows (in Millions) 165
Table 3.3 Loans to the Non-Financial Private Sector in Flows (in Percentage) 166
Table 3.4 Comparative Statistics of Nominal Interest Rates in Argentina 166
Table 3.5 Standardized LR Test for MSI(2)-AR(1) against Null of Linearity 166
Table 3.6 Standardized LR Test for Markov Switching Intercept Pass-Through 167
Table 3.7 J-test for Markov Switching Intercept Pass-Through 167
Table 3.8 Specification Selection for Markov Switching VAR 167
Table 3.9 MSIAH(2)-VAR(1) Regime Classification for Overdraft Rate 168
Table 3.10 MSIAH(2)-VAR(1) Regime Classification for Bills Rate 168
Table 3.11 MSIAH(2)-VAR(1) Regime Classification for Personal Rate 168

Table 3.12 Interest Rate Pass-Through in Argentina 169
Table 3.13 MSIAH(2)-VAR(1) with TVTP in Argentina: 1993:06 – 2003:12 169
Table 3.14 Overdraft Rate Pass-Through: MSIAH(2)-VAR(1) with TVTP............... 170
Table 3.15 Bills Rate Pass-Through: MSIAH(2)-VAR(1) with TVTP........................ 171
Table 3.16 Personal Rate Pass-Through: MSIAH(2)-VAR(1) with TVTP................. 172
Table 4.1 Unit Root Tests for French Interest Rates 230
Table 4.2 Unit Root Tests for German Interest Rates 230
Table 4.3 Hansen LR Statistics for French Interest Rate Pass-Through 231
Table 4.4 Hansen LR Statistics for German Interest Rate Pass-Through 231
Table 4.5 Specification Selection for MS-VAR on German Interest Rates 232
Table 4.6 Lending Interest Rate Pass-Through for Germany: 1984:11-2003:06 232
Table 4.7 Deposit Interest Rate Pass-Through for Germany: 1984:11-2003:06 233
Table 4.8 Mortgage Interest Rate Pass-Through for Germany: 1984:11-2003:06..... 233
Table 4.9 Nonlinear Pass-Through Induced by Interbank Rate in Germany 234

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Of course, all remaining errors in this thesis are the sole responsibility of the author.

Declaration

A reduced version of the first paper of this thesis has been published during my third year of studies as: Humala, Alberto (2005), "Interest rate pass-through and financial crises: do switching regimes matter? The case of Argentina", Applied Financial Economics, 2005, 15, 77-94. The other two papers have not been sent for refereeing anywhere yet. All three papers are my original work on the subject. I have conducted the research for them during my studies for the PhD at Warwick. This thesis has not been submitted for a degree at any other university.

Abstract

The first paper, "Interest rate pass-through and financial crises: do switching regimes matter? The case of Argentina", analyses the dynamic relationship between a money market (interbank) rate and different short-term lending rates by measuring their pass-through. Neither linear single-equation modelling nor linear multi-equation systems capture efficiently this relationship. Several financial crises alter the speed and degree of response to interbank rate shocks. Hence, a Markov switching VAR model shows the pass-through increases considerably for all market interest rates in a high-volatility scenario. The model identifies correctly the periods in which regime shifts occur, and associates them to financial crises.

The second paper, "Modelling interest rate pass-through with endogenous switching regimes in Argentina", extends the scope of the Markov switching modelling by including time-varying transition probabilities. Interest rate spreads are used as leading indicators. The model allows devaluation expectations and country risks, (measured by rate spreads) to signal regime switching. Estimation results suggest that the pass-through tends to overshoot with financial instability, but to decrease if that condition is sufficiently large and long-lived. Likewise, results show a quite heterogeneous credit market, with a highly efficient transmission mechanism in the corporate segment, but considerably less in the consumer segment.

The final paper, "Regime switching in interest rate pass-through and dynamic bank modelling with risks", builds a theoretical model of dynamic bank optimisation, which provides rationale to a regime-switching behaviour in the interest rate pass-through. It is shown that a regime-switching interbank rate induces a nonlinear behaviour in lending and deposit rates and (by further introducing interbank-alike regime-switching risk premiums) in the pass-through. Thus, the pass-through process is consistent with a nonlinear behaviour even if there are no asymmetric adjustment costs in the response to interbank rate shocks. An empirical application to France and Germany provide results that support these conclusions.

CHAPTER 1

1 INTRODUCTION

The interest rate pass-through could display nonlinearities of different kinds. The relationship between money market rates and bank rates might be subject to regime switching due to, among other factors, nonlinear monetary policies, to financial crises, to business cycle stances, or to nonlinear adjustment costs. If the pass-through were switching, the relationship parameters would be regime-dependent and no linear model would capture accurately the relationship. The objective of this thesis is to study in detail the application of Markov switching models to represent the pass-through from money market rates to lending and deposit interest rates. The stochastic nature of the regime shifts in this type of modelling accommodates appropriately the unknown timing of the alteration in speed and magnitude of the pass-through.

In order to study these feasible nonlinearities in the pass-through, the thesis follows first an empirical approach. The econometric model infers regime switches from data on the Argentinean financial system. Shifts in the pass-through parameters are clearly associated to financial crises. Estimation results from a Markov switching vector autoregression (MS-VAR) model are superior to those from linear representations of the pass-through. Fixed and time-varying transition probabilities explain alternatively the transition between regimes in the system.

Firmly establishing the presence of regime switching behaviour in the pass-through, the thesis follows then a theoretical approach to give rationale to such nonlinearities in a dynamic banking optimisation framework. Explicitly recognizing the possibility of a regime-switching pattern in the interbank rate, the dynamic model captures similar nonlinearities in bank interest rates. By further introducing risk premiums, which switch between regimes in a similar fashion than the interbank rate, the bank optimisation generates nonlinearities in the pass-through. There is no need for adjustment costs to be asymmetric to support this regime switching behaviour. The nonlinearity prevailing in the money market rate induces regime switching in risks premiums and, hence, in the interest rate pass-through.

The transmission of official rate impulses (or of money market conditions) to bank interest rates is usually sluggish and incomplete in the short-term but rather complete in the medium- and long-term. The speed of response is usually associated to the efficiency of the transmission mechanism, so it is crucial to measure the pass-through to enhance understanding of the whole process. Most standard literature has done so by using linear models, usually derived from a static industrial organisation approach. A sound theoretical start for the link among these interest rates is the expectations model of the term structure of interest rates. Of course, if there were nonlinearities in this structure then, a linear representation for the pass-through would feasibly over- or under-estimate the relationship parameter.

Linear models could include dynamics in the estimation by considering the time series properties of the interest rates under study. Hence, error correction models (either single- or multi-equation systems) usually provide the measure for the pass-through. Yet, most empirical studies concentrate on the linear nature of this transmission process. When nonlinearities are considered, it is often in the form of asymmetric adjustments.

The first two papers of this thesis are empirical in essence. The last paper is of a theoretical nature instead, although it also contains an empirical application to support the modelling. Each of these papers separately supports different aspects of the Markov switching modelling of the interest rate pass-through. All three together represent a detailed account of feasible nonlinearities in the transmission of money market rate impulses to bank interest rates.

The first paper analyses the dynamic relationship between the money market (interbank) rate and different short-term lending rates in Argentina. In order to capture the effects of financial crises over this transmission mechanism, a Markov switching-regime system models the interest rate pass-through. This paper addresses the issue of whether the banking system adjusts its pricing behaviour to highly volatile market conditions or remains unaffected by them. Since no a priory assumption of nonlinearity is made, the research first discusses and estimates linear models (both single-equation and multi-equation) to measure the pass-through. Nevertheless, as description of estimation results progresses, it becomes clear the need for a nonlinear modelling of the transmission process for the Argentinean interest rates.

The main econometric results support indeed the Markov switching estimation of the pas-through. In Argentina, from June 1993 to December 2000, the interest rate pass-through from the interbank rate to rates on overdrafts, bills, and personal loans show a notorious regime-switching behaviour. Regime shifts coincide with the international financial crises that hit Argentina and with the building up of the currency board collapse. In general, under turbulent times in the banking system, the pass-through accelerates substantially for all lending rates. Besides, not only the short-term pass-through is regime switching, but also the long-term pass-through.

Although including only domestic interest rates in the MS-VAR represents an advance from the linear modelling for this particular economy, there seems to be room for taking advantage of further market information. In particular, additional data could provide evidence of whether exogenous or endogenous factors explain a regime-dependent pass-through. Constant transition probabilities (CTP) are usually associated to the first possibility, while time-varying transition probabilities (TVTP) suggest endogenous switching. Thus, the second paper of this thesis postulates and estimates a Markov-switching model with TVTP (as opposed to the CTP used in the first paper).

The second paper studies the interest rate pass-through for Argentina including the period that preceded and followed the collapse of the currency board by the end of 2001. Interest rate spreads are used as leading indicators for TVTP, since they contain enough exploitable information about the risks bank faced in their optimisation process. Considering only interest rates in local currency might not be enough to capture banks' optimising behaviour in such a dual currency system. Hence, this paper also considers the relevance of lending interest rates in the foreign currency (US dollars); of depreciation expectations (as measured by interest rate differentials); and of country risk measures. Markov switching models have alternatively considered these variables as exogenous (MS-VARX) or as information variables in the TVTP.

The pass-through might change when greater volatility and unusual uncertain conditions in the financial markets make banks change their expectations of future adjustments in interest rates. It is relevant then to discuss and explore what are the possible sources of those changes. As some empirical papers have already shown for Argentina (as well as for the euro area), there could be nonlinearities in devaluation expectations which in turn would induce nonlinearities in interest rate differentials (through uncovered interest parity). This regime switching in money market rates might induce nonlinear behaviour into lending interest rates. Feasibly then, the interest rate pass-through might reflect this nonlinear pattern too.

The main econometric results from the Markov switching estimation of the VAR with TVTP indicates that the pass-through decreases when financial conditions become highly unstable for a long period. Furthermore, the use of information about devaluation expectations, country risk, and credit risk, indeed signal the occurrence of those regime switches. Therefore, in light of these results, further research should explain the seemingly contradictory behaviour in the pass-through found in these two first papers. Does the pass-through increase or decrease in volatile conditions?. In order to tackle this question, there is a need to turn into a more theoretical explanation of the transmission mechanism among interest rates in the bank optimisation process.

Interest rates reflect a banking system's features on market structure, operating costs, and risk management as well as loan demand and deposit supply characteristics. These microeconomic factors explain differences both in interest rates (lending and deposit) and in the corresponding pass-through (from money market rates to retail rates). Although banks consider these factors in the market segments in which they operate, they set their interest rates based on the information contents of the short-term money market rate they take as reference.

In particular, when a nonlinear pass-through is considered, the regime-switching behaviour is not necessarily linked to those factors but to the money market rate instead. Hence, if the interest rate pass-through were indeed regime switching then exploring where this nonlinearity comes from and how it affects banking optimisation would enrich the transmission mechanism analysis. Thus, the objective of the third paper is to build a theoretical model of dynamic bank optimisation that provides rationale to a regime-switching behaviour in the interest rate pass-through.

Two main sources of nonlinearity in the interest rate pass-through are considered. The first one operates through a nonlinear money market rate. A regime-switching behaviour in this interbank rate will induce a nonlinear pattern in the pass-through by prompting regime switches in the risk premiums considered in bank optimisation. As already pointed out, the data generating process for the interbank rate could be nonlinear if there is a regime-switching behaviour in monetary policy (interest rate smoothing vs. inflation fighting), in devaluation expectations (financial crises affecting agents' belief through uncovered interest parity), or in the term structure of interest rate (associated to business cycle stances). The second mechanism operates through asymmetric adjustment costs, which could induce a nonlinear pass-through even if the interbank rate is a linear stochastic process. Since this latter mechanism has been studied somewhere else, this study discusses it briefly as an extension to the main model.

The research presented in the last paper tries to answer two main questions. On one hand, it tries to analyse what kind of nonlinearity the pass-through displays. The goal is to derive a theoretical model of bank optimisation that could accommodate both a (Markov) switching regime process in the interbank rate and a nonlinear interest rate pass-through. The model should clarify the transmission mechanism by which a regime shifting nature of the interbank rate induces regime switching behaviour in the pass-through. On the other hand, the paper discusses why the interest rate pass-through is quite heterogeneous by market segments despite feasibly sharing the same initial impulse (the nonlinearity in the interbank rate).

The theoretical approach starts with a simple static model of banking optimisation, which has been widely used as theoretical support for linearity in the interest rate pass-through. Then, the paper introduces a nonlinear specification of the interbank rate into a dynamic banking model, thus incorporating the basis for a regime-switching pass-through. Yet, an actual nonlinear pass-through is only obtained once the model considers the risks premiums banks charge in their optimisation process. Most importantly, the model clearly shows a regime switching pass-through once feasible nonlinearities in those risk premiums are linked to those in the money market rate.

Furthermore, this mechanism makes possible for the pass-through to either increase or decrease when market conditions become highly unstable. In order to support these theoretical derivations, an empirical application to French and German interest rates is conducted. Once again, Markov switching models appropriately establish the existence or not of regime shifts. The data for these cases indeed support the main theoretical suggestions of the model.

CHAPTER 2

2 INTEREST RATE PASS-THROUGH AND FINANCIAL CRISES: DO SWITCHING REGIMES MATTER? THE CASE OF ARGENTINA

2.1 INTRODUCTION

This paper analyses the dynamic relationship between the money market (interbank) rate and different short-term lending rates by measuring the pass-through process between these interest rates in the banking system of Argentina. In order to capture the effects of international or national financial crises over this transmission mechanism, the interest rate pass-through is modelled using an endogenous (Markov) switching-regime system. This type of model allows for non-linearities in the adjustment process of lending rates to changes in the interbank rate.

The transmission mechanism of monetary policy (or of money market conditions) is usually sluggish and incomplete in the short term but rather complete in the medium and long-term. Thus, for example, changes in the interbank rate induced by monetary policy decisions or by changing conditions in the money market are transmitted to bank lending rates but only with lags. The speed of response is usually associated to the efficiency of the transmission mechanism, so it is crucial to measure the pass-through to enhance understanding of the whole process.

Although Argentina, due to her currency board regime, did not have an independent monetary policy for most of the 1990's, sound banking system reforms improved the signal transmission of short-term financial conditions. Liberalisation and opening of capital markets had fostered financial integration but it had also had the side effect of exposing the banking system to waves of international financial distress. On this context, this paper addresses the issue of whether the banking system adjusts its pricing behaviour to highly volatile market conditions or remains unaffected by them.

This chapter is organised as follows. The next section presents an overview of the interest rate pass-through literature. Section 3 summarizes the expectations model of the term structure of interest rates and an industrial organisation approach to the market structure of interest rate. Section 4 deals with the main econometric techniques used here to measure the pass-through process. Section 5 briefly describes the Argentinean banking system while that Section 6 introduces data description and preliminary time series analysis. Section 7 presents and discussed the econometric estimates. Finally, Section 8 reviews the main empirical findings and discusses further research topics.

2.2 BANK INTEREST RATE PASS-THROUGH

The pass-through mechanism involves the process by which impulses on interest rates administered by monetary authorities or on money market interest rates are transmitted to short-term bank lending rates. The pass-through measuring would involve assessing the extent of the impact (the short-term and the long-term effects) and the speed of the transmission (the adjustment process from the initial impact to its final effect).

The pass-through mechanism is usually suggested to be sluggish in the short-term but less so in the long-term. Cottarelli and Kourelis (1994) refer to the degree of stickiness of bank lending rates as the speed at which these rates adjust to their long-run equilibrium values after monetary shocks hit money market rates. Interest rates stickiness is associated to structural characteristics of the financial system such as the degree of competition, the stage of financial market development, and the ownership structure of the banking system.[1] Besides, there could be asymmetry in the speed of adjustment so that, for example, the interest rate pass-through would be lower when interest rates are falling than when they are increasing.

A bank will change its loan pricing in response to a monetary shock but only if it sees the change as permanent. In the short-run, the bank will take into consideration the adjustment costs involved (against the cost of being in disequilibrium). Generally, the more interest rate-sensitive (elastic) the demand for loans, the higher the cost of keeping misaligned interest rates.

[1] Ehrmann et al. (2001a) find, for the euro area, that credit market features are relevant to determine the extent of the response of bank loans supply to monetary policy actions. Bank lending falls significantly after a monetary contraction, with bank liquidity playing a prominent role.

The seminal contribution by Cottarelli and Kourelis (1994) focuses on the speed of response of bank lending rates to shocks in money market rates, assuming implicitly the existence of one long-run equilibrium relationship. With the more recent experiences of financial reforms as well as of hazardous episodes of international financial (currency) crises, the possibility of more than one equilibrium relationship or the absence of one at all needs to be addressed when modelling interest rate pass-through.

As Bondt (2002) remarks, a quicker and fuller interest rate pass-through strengthens monetary policy transmission. Following Cottarelli and Kourelis' argument that the financial structure is relevant in determining the interest rate pass-through, he suggests that the transmission mechanism of monetary policy could be enhanced by sound financial policies and reforms. Since bank pricing behaviour influences bank profits, monetary policy shocks on lending rates might also affect economic growth in the short run. Besides, this pricing behaviour would depend much upon market characteristics such as the degree of competition; demand features (interest rate elasticity); market risks; and cost structures, both at the market level and at every market segment.[2]

The financial structure might influence the pass-through mechanism in a number of ways. A monopolistic or oligopolistic banking sector would be more able to obtain larger interest rate margins so that pricing in such market structures might not transmit monetary impulses as smoothly as, for example, in a competitive banking system.[3] In

[2] Haan (2001) shows for The Netherlands that the lending channel of monetary transmission is active but not affecting lending to households as much as it is affecting lending to firms. Whereas Kakes and Sturm (2002) find for Germany that big banks are able to shield their loans portfolio against monetary contractions. Their analysis, nonetheless, is focused on the effects of monetary shocks in loan supply rather than in loan interest rates. In a study for interest rates, Heffernan (2002) shows that financial institutions exhibit indeed different pricing behaviour depending on the bank product.

[3] A seminal empirical research on the relationship between bank pricing and market concentration is found in Berger and Hannan (1989). A more recent contribution from Heffernan (2002) shows for the UK banking system that during the 1990's the presence of perfect competition is largely ruled out.

some emerging markets, for instance, such structures might be present in some credit segments (if not in the banking system as a whole), where financial development is at its initial stages. For the euro area, Lensink and Sterken (2002) recall the important differences in banking structures and suggest that they might explain the differential impact of monetary policy across countries. In particular, they argue, smaller banks might reduce more their lending in response to a monetary shock due to their deposit dependence. Nevertheless, this might not necessarily be the case for emerging markets, where small banks are also subsidiaries of international banks and only work in well developed market segments.

Along with market structure and demand features (such as interest rate elasticity), banks' costs and risk behaviour could influence interest rate levels. As Bean, Larsen, and Nikolov (2002) point out, the presence of financial frictions such as asymmetric information and moral hazard would increase uncertainty in the system and therefore might amplify the effects of monetary shocks to the market structure of interest rates. Empirical evidence indeed suggests the importance of financial structure and frictions for the transmission mechanism. See, for example, Altunbas, Fazylov, and Molyneux (2002); Bondt (2002); and Mojon (2000) for a revision of this evidence in Europe. For North America, see Moazzami (1999), and Morris and Sellon (1995).[4] Other references are Scholnick (1996) for Malaysia and Singapore; and Alfaro et al. (2002) for Chile.

Furthermore, financial disturbances such as international financial crises might further influence the speed and extent by which interest rates respond to monetary shocks. In this sense, the idea of a bank-lending channel for the transmission mechanism (in

[4] Nevertheless, they argue in the latter case that structural changes in the banking system might not affect the transmission mechanism.

addition to a more conventional interest rate channel) emphasises the importance of bank behaviour in intensifying the effects from monetary policy. It is an empirical issue whether this behaviour is altered under a financial crisis or remains unchanged with it.

This paper emphasises the short-term interbank rate as the one transmitting financial conditions impulses to the rest of the spectrum of interest rates. This approach is compatible with the marginal cost pricing models of banking behaviour.[5] Thus, interbank rate changes lead the dynamics of all other interest rates, assuming that there is a long-term relationship between them. Winker (1999), for instance, adds credit rationing due to asymmetric information to explain bank pricing and sluggishness of interest rates in following interbank rate movements. A bank will adjust its interest rates after a shock in the interbank rate since otherwise its returns will be reduced. Nevertheless, in adjusting the rate it will also incur costs due to adverse selection. It might then choose to adjust rates with lags (expecting more information as to the nature of the interbank rate movement) but following the long-term trend.

[5] For an application of these models to the euro area, see Corvoisier and Gropp (2001).

2.3 MARKET STRUCTURE OF INTEREST RATES

The expectations model of the term structure of interest rates is a theoretical appealing description of the relationship among interest rates with different terms to maturity but with similar credit characteristics. In a broader context, the market structure of interest rate (which involves both different terms to maturity and credit characteristics) is better modelled through an industrial organization approach that considers banks' optimising behaviour. In this sense, measuring the interest rate pass-through, from an interbank rate to various lending rates (with different risk and credit characteristics), could be seen as an attempt to model the market structure of interest rates assuming that all other factors remain unchanged. How persistent changes induced in lending rates are would importantly determine the dynamics of the process. Thus, in both the term structure and the market structure of interest rates it would be crucial to determine the stationarity (or non-stationarity) properties of the interest rates (time series) involved.

2.3.1 The term structure of interest rates

The term structure of interest rates refers to the relationship among interest rates with different terms to maturity but with similar or equal credit characteristics.[6] The expectations model considers short-term and long-term debt instruments perfect substitutes so that a long-term rate is a weighted average of the current and expected short rates plus a term premium.[7] Thus, the following expression applies to such rates:

$$r_t^n = (1/n)\left[r_t + \sum_{i=1}^{n-1} E_t r_{t+i} \right] + \gamma(n) \tag{3.1}$$

[6] The concept has been generally applied to a very short-term money market interest rate and rates for government-issued securities (such as bonds). But this does not need to be the only case.

[7] Alternatively, the segmented market hypothesis considers them highly imperfect substitutes and so interest rates spreads are determined by demand and supply in each end of the term structure.

where r_t^n is the long term rate (over a n-period of time), r_t is the current short term rate, E_t is the rational expectations operator conditional on information at time t, and $\gamma(n)$ is the term premium on the longer rate. The term premium could be a stationary stochastic process (possibly a constant, usually zero) or a nonstationary process, depending on its distributional properties being time independent or not. If interest rates are integrated of order one but the term premium is stationary then those rates would be cointegrated.[8] In particular, it is usually argued that if the expectations hypothesis holds then a cointegrating vector such as (1,-1) will relate any pair of rates from the term structure.

Indeed, there is usually strong empirical support for the term premium being a stationary process (if not constant at all). Thus, even if a financial system were undergoing periods of high volatility (such as those during financial crises) the term premium on any interest rate, although time-varying, could still be stationary.

Establishing the stationarity or non-stationarity of the interest rate series is an important empirical issue since it would determine the dynamic properties of the model employed to represent the term structure. Besides, the non-stationarity of interest rates is an empirical common result, especially for developed countries.[9] This fact allows modelling the term structure by, for instance, a Vector Error Correction Model (VECM). The VECM would represent the long-term equilibrium relationship as well as the short-term dynamics relating the rates on the term structure.

[8] A stationary term premium under the expectations hypothesis is usually associated to the degree of efficiency of the relevant financial market.

[9] In discussing the testing of the expectations hypothesis of the term structure Brooks (2002) asserts that "*there is a general acceptance that interest rates, Treasury Bill yields, etc. are well described as I(1) processes…*".

In financial theory, however, many interest rate models assume stationarity. Thus, they are more consistent with representing the interest rates in levels (rather than first differences), such as for instance in a Vector Autoregressive (VAR) system. As James and Webber (2000) argue, stationary models are mathematically simpler to deal with and they can accommodate behaviour at extreme values too (without having to rely upon non-stationarity). Nonetheless, there are some desirable consequences from having non-stationary models such as to allow them to be calibrated exactly to the yield curve. James and Webber discuss also the difference between the basic Vasicek[10] model that includes mean-reverting interest rates and the extended Vasicek model that allows for time-dependent reversion levels and, thus, contains non-stationary variables.[11]

2.3.2 The risk structure of interest rates

The risk structure of interest rates refers to the relationship among rates with the same term to maturity but with different credit characteristics (Mishkin (1986)). In this case, the factor connecting those interest rates would be a risk premium (different to the term premium):

$$g_t = i_t + \phi \tag{3.2}$$

where g_t is the riskier interest rate, i_t is the less risky interest rate, and ϕ is the risk premium that the credit market determines for different risk categories. Similar to the term structure case, under the assumption that this risk premium is a stationary process, it would still be possible to postulate a long-term equilibrium relationship among non-stationary interest rate series and, thus, use a VECM. The cointegrating vector would also be of the kind (1, -1) for every pair of rates. Again, the non-stationarity of the time

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[10] The Vasicek model assumes a Ornstein-Ulhenbeck stochastic process: $dr_t = \alpha(\mu - r_t)d_t + \sigma dz_t$, where the last term captures the volatility component of the interest rate dynamics.

[11] For an extended discussion on the Vasicek models and other interest rate models and their stochastic properties see James and Webber (2000).

series should be established first, otherwise a VAR system should be more appropriate to model the risk structure of interest rates.

2.3.3 The market structure of interest rates

What economic agents will observe at any given point of time in a financial market is a whole set of interest rates, spanning from very short-term to very long-term horizons and from low-risk to high-risk characteristics. Therefore, more generally, the market structure of interest rates would refer to the relationship among these interest rates with different terms to maturity and different risk characteristics. The spread between any pair of interest rates on the market could then be represented by:

$$r_t = i_t + \gamma + \phi \tag{3.3}$$

where r_t is the riskier, longer-term interest rate; i_t is the less risky, shorter-term interest rate; γ is the term premium, and ϕ is the risk premium. Again, stationarity of both the term premium and the risk premium would allow non-stationary interest rates to be cointegrated. Establishing the time series properties of interest rates would help to determine the existence and nature of a long-term relationship between them.

Nonetheless, these term and risk premium should not be taken as exhausting all possible relationships in the market structure of interest rates. Apart from the interest rates, banks consider some other factors in their profit maximising behaviour. For instance, banks might divide markets in customer segments and specialise on some of them to enhance efficiency, incurring probably in different costs.

Market equilibrium would reflect optimal behaviour from many competing banks that adapt themselves to changing financial conditions. For example, an oligopolistic model[12] of the banking industry would help to understand equilibrium relationships in the credit market and, thus, it will assess better the responses of market interest rates to shocks on the money market rate. Factors such as marginal cost of providing loans, market structure (market power), and loan demand's characteristics (demand elasticity) will also have, along with money market rate, term and risk premiums, a role to play in the determination of credit market rates.

Then, once more, if those additional factors are stationary processes, then cointegration could still be established if interest rates are nonstationary. Yet, being aware of those other factors might help us to understand the limitations of modelling structures of interest rates by including only interest rates in the system. If interest rate series are stationary then omitting the other factors in modelling the market structure of interest rates might distort, for instance, any impulse response analysis derived from a VAR.[13]

The usual approach to measure the pass-through assumes that the relationship between the bank rate and the interbank rate would not be affected by those other factors, but they will help to explain the differences in pass-through between different bank rates or between countries. Thus, using time series econometrics at a macroeconomic level, the pass-through is measure in bivariate systems of the bank rate and the money market rate. Thereafter, using panel data at the microeconomic level, all the other factors are considered to explain a particular value of that pass-through.

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[12] See, for example, Freixas and Rochet (1997), Chapter 3, for a description of such a model. A basic oligopolistic model of the banking industry will exclude initially any mention of risk, so that no term or risk premium is considered. Here it is also excluded the theoretical extreme cases of perfect competition and monopoly.

[13] Even if no other factors but interest rates are included, in a dual-currency financial system, leaving aside interest rates in the alternative currency might mislead the analysis.

There is no a priori or theoretical reason for the pass-through relationship to be linear. A broad market structure of interest rates might be subject to non-linear or unstable relationships if the optimising behaviour from banks changes under different regimes (regime switching) such as those derived from low-volatility and high-volatility periods in the financial markets. Furthermore, asymmetries in the pass-through and time-varying term premium should also be possible.

2.4 ECONOMETRIC APPROACH

Generally, economic theory has more to offer on the determination of equilibrium than on the nature of dynamic adjustments (which is more of an empirical nature). In measuring interest rate pass-through Bondt (2002), for instance, justifies using asymmetric adjustment by arguing "*the pass-through depends on whether money market rates are rising or falling or whether bank interest rates are below or above equilibrium levels as determined by cointegration relations*". Furthermore, in analysing the behaviour of the residuals in an error correction model (ECM), he argues that irregularities are due to misspecification coming from omitted variables. Other factors other than the money market rates might help to determine retail bank rates.[14]

Therefore, the exact nature of the empirical econometric approach to measure the interest rate pass-through will depend entirely on the particular set of interest rates under analysis. Whether it is bivariate or multivariate, single or multiple equations, cointegrated or non-cointegrated, linear or non-linear model, will depend on a thorough data analysis (which should suggest the relevant model). Good in-sample fit would help us to understand the pass-through process and out-of-sample performance would enhance our confidence on a particular model.[15]

2.4.1 Single equations

A fairly standard approach (Cottarelli and Kourelis (1994)) for measuring interest rate pass-trough is to regress the lending rate on a distributed lag of money market rate multipliers for a single country. Thereafter, the cross-country differences in speed

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[14] Such as those mention earlier from the oligopolistic models for the banking industry.

[15] James and Webber (2000) point out that any interest rate model should also allow pricing derivatives instruments consistently. Such an objective is not attempted here, since the goal is to measure the interest rate pass-through and not to model all the distributional properties on individual rates.

responses are explained by regressing them on a set of variables representing the financial system features.

Another simple approach to measure the response of short-term lending interest rates to changes in money market rates (or central bank rates) is to use a bivariate ECM that allows interest rates to be cointegrated. Mojon (2000),[16] for instance, analyses the interest rate channel of the monetary transmission mechanism in the European Community by using the following ECM equation:

$$\Delta r_t = c + \sum_{j=1}^{j\max} \alpha_j \Delta r_{t-j} + \sum_{k=0}^{k\max} \beta_k \Delta i_{t-k} + \gamma(r_{t-1} - i_{t-1}) \tag{4.1}$$

where r_t is a retail bank rate and i_t is the money market rate. The number of lags is chosen according to a general-to-specific approach. The coefficient β_0 reflects the impact or short-term pass-through, while γ stands for any feasible cointegration relationship. It is implicitly assumed that the final pass-through is 1, given a (1, -1) cointegrating vector. Results show that retail bank rates respond sluggishly to changes in the money market rates and that interest rates exhibit more downward stickiness than upward stickiness (asymmetry in the responses).[17]

Similarly, Bondt (2002) uses an ECM of the interest rate pass-through process based on a marginal cost pricing framework, including switching price costs and asymmetric information costs.[18] Robustness of his results is found through an impulse-response analysis from a bivariate VAR. He finds, in line with previous empirical works for the

[16] Mojon computes the response, after three months, of 25 credit rates and 17 deposit rates to changes in the money market rate for euro area countries and links these responses to differences in financial structures (using panel data analyses).
[17] For consistency, Mojon estimates additionally the pass-through in two interest rate cycles and (dividing the sample set) in sub periods in which the rates increase or decrease.
[18] Bondt allows though the cointegrating vector to be generally determined as (1, β), being β the final or long-term pass-through.

euro area, that the immediate pass-through of money market rates to retail bank rates is incomplete, especially on short-term interest rates. Besides, each lending rate and a comparable money market rate share a long-term equilibrium relationship.

On the other hand, if interest rate series are stationary, a single equation could be run on the level of the retail rate and the money market rate. See, among others, Cottarelli and Kourelis (1994) for a set of 31 developed and developing countries; Moazzami (1999) for Canada and US; and Berstein and Fuentes (2002) for Chile. The following single equation (autoregressive distributed lag model) is specified for several pairs of retail banking rates and the interbank rate:

$$r_t = \delta + \sum_{j=1}^{m} \beta_j r_{t-j} + \sum_{k=0}^{n} \alpha_k i_{t-k} + \sum_{l=0}^{p} \gamma_l \Delta MPR_l \tag{4.2}$$

where the last term stands for the change in monetary policy interest rate (as in Berstein and Fuentes (2002)). This equation could also include some dummy variables to account, for instance, for highly volatile periods. The retail rate (r_t) and the money market rate (i_t) are expressed in levels (rather than in first differences). Under this specification, the short run response from the bank rate to the money market rate is thus given by the parameter α_0 and the long run effect is capture by the coefficient $\lambda = \sum \alpha_k / \left(1 - \sum \beta_j\right)$.

This long-term effect parameter is expected to be positive and close to one. Usually, a general-to-specific approach is followed to determine the number of lags and the relevant coefficients left in the final equation. Again, the short-term response is expected to be sluggish, especially if there is some inefficiency in the transmission of information in the banking sector (as it could be thought of developing countries).

Nevertheless, in the case of Chile, Berstein and Fuentes (2002) found that there is a high speed of response from some bank rates to the interbank rate on impact.

2.4.2 Linear VAR/VECM models

The interest rate pass-through could also be assessed taking advantage of the simultaneous estimation of a multi-equation system. In the case of a K-variable system of non-stationary interest rate series, it is possible to determine up to K-1 cointegrating vectors. Thus, the spread between any bank interest rate and the money market (interbank) rate would be stationary. If those interest rates are indeed cointegrated, then, a VECM should be estimated to reveal the short-term dynamics for the pass-through.

The following is a general specification of a VECM, which considers variables in level as to include any long-term relationship and variables in differences as to model the short-term dynamics:

$$\Delta y_t = \Pi y_{t-1} + \Gamma \Delta y_{t-1} + \varepsilon_t \tag{4.3}$$

The left-hand side term is a vector of first-differenced variables, Π is the cointegrating matrix, and Γ is the coefficient matrix for the short-run dynamics.

Conversely, if interest rates were rather stationary then a specification that represents their dynamics could be the following general VAR system:

$$y_t = v + \sum_{j=1}^{p} A_j y_{t-j} + u_t \tag{4.4}$$

where the left-hand side term is a vector of variables in levels, v is a vector of intercepts, and A_j is the matrix of autoregressive coefficients. Notice out that the short-term pass-through, the coefficient on the current interbank rate in the equation for the lending rate, is not obtained directly from this standard form of the system. The original (primitive) form of the system needs to be obtained first, usually by assuming a Choleski decomposition. Thence, the short-term pass-through could be estimated as the ratio of the covariance between the respective lending rate and the interbank rate over the variance of the interbank rate. The long-term pass-through could be estimated with the corresponding autoregressive parameters.

The dynamic responses in each case (whether a VAR or a VECM) are quite different. Therefore, it is crucially important to address first the stationary condition of every interest rate series. The choice of lags to be considered, in both cases, is an empirical issue that depends upon the data set.

In either case, VECM or VAR, modelling interest rates into a multivariate, rather than bivariate, system would provide a better approach to the interrelationships among them. This specification will allow simultaneous determination of bank interest rates. It assumes no further ordering than the interbank rate coming first in the system. All the same, it could be the case that the segmented characteristic of the credit market would be better captured by estimating only bivariate systems (VAR or VECM) and not multivariate models.

Take, for example, the analysis of Winker (1999) for German interest rates. Using a three-variable system (the interbank, one lending, and one deposit rates), he finds cointegration among the variables and, correspondingly, estimates a VECM to explain the dynamics. Although he cannot reject the hypothesis that the cointegrating vectors, as expected, were of the kind (-1,0,1) and (0,-1,,1), he warns that the adjustment coefficients are not so straightforward interpretable as in the case of single bivariate error correction models.

It is particularly interesting to look at the response of lending rates to an impulse in the interbank rate. In a VAR, the ordering of the Choleski transformation is relevant since it will assume shocks in the money market rate affecting the bank rates and not the other way round (interbank rate comes first in ordering). Thus, it is possible to trace out the effect of an assumed exogenous shock[19] to the interbank rate on all the other variables in the system for some time (and assuming no further shocks occur). This multiplier analysis will reveal the impact response dynamics and the long-run effect.

The pattern of impulse responses will help to confirm the analysis of the stochastic characteristics of the data. If impulse responses die out after some time, then the series are stationary; otherwise, they are consistent with non-stationary processes. Still, as Lütkepohl (1991) indicates, given that all effects of omitted variables in the system are assumed to be in the innovations, if those variables being omitted are important, impulse responses might be distorted and their interpretation would be harder.

2.4.3 Non-linear VAR/VECM models

The presence of important discrete economic events (the so-called peso problems), as Ahrens (1999) argues, would distort econometric inference if it were not captured in nonlinear models (i.e. regime switching) of the short-term interest rates. Indeed, some authors have used non-linear regime-switching models for the term structure of interest rates, with usually good forecasting results. Ahrens himself finds that forecasts were

[19] Exogenous in the sense that they come from innovations to financial conditions on the short-term money market, which are independent from other bank optimising variables.

improved substantially (for German money market rates) by using univariate and bivariate (including the term spread) regime-switching frameworks.

More recently, using a multivariate approach, Clarida et al. (2002) estimate a non-linear VECM that allows for Markov switching regimes (MS-VECM) in the term structure of interest rates in US, Germany and Japan. Based on the expectations model of the term structure, they find that in-sample and out-of-sample performance of their model is superior to that of conventional linear VECMs. Forecasting interest rates is derived from the rational behaviour of utility-maximising individuals in informational efficient markets. Nonlinearities in interest rates are suggested to be the result of non-zero or asymmetric transaction costs, infrequent trading and the existence of regime shifts. Following Krolzig (1997) notation, their model corresponds to an MSIH-VECM.

Working with Swedish interest rates, Erlandsson (2002) similarly finds good forecasting performance of an endogenous switching regime model that includes a GARCH-effect.[20] Nonetheless, as he also points out, for the use of a switching regime model to be valid, it needs to have some kind of economic intuition that helps to explain the data generating process.

Whether it is appropriate to use a regime switching approach to model the market structure (rather than the term structure) of interest rates is an empirical issue. Thus, for example, Ang and Bekaert (1998) use regime-switching models trying to accommodate short-term patterns of interest rates for US, Germany and UK. They try to explain why the moments of interest rates vary across the business cycle; why the spread increases

[20] He recognizes that if the MS-VAR reduces autocorrelation in the residuals to non-significant levels it would be an indication that there is no need for introducing a GARCH effect in the system.

during expansions; and why mean reversion is significantly different across the business cycle. They too find that regime switching models forecast out of sample better than single-regime models.[21]

In Argentina, the presence of international financial crises might have made agents believe the currency board was about to collapse, although it did not actually fail until December 2001. This peso problem would provide evidence against the expectations theory if short-term interest rates were modelled lineally. If bank interest rates respond differently to money market interest rate, for instance, under financial crises, then modelling these time series with a stable linear VAR model would surely be inappropriate. Suitability of modelling should be assessed by comparing the results from the non-linear model to those from a linear one and the results from the bivariate case to those from a multivariate approach.

Boinet, Napolitano, and Spagnolo (2002) have recently tested a Markov-switching model of devaluation expectations for Argentina and found indeed strong evidence of nonlinearities in a data set comprise of devaluation expectations (interest rate differential), growth rate, deficit to GDP, real exchange rate, and trade balance to GDP. Switching regimes match jumps between multiple equilibriums explained by abrupt changes in devaluation expectations. Thus, they conclude, along the reasoning of the second-generation models of currency crisis, self-fulfilling prophecies might have played an important role in the currency crisis of 2001-2002.

[21] Conventionally, they assess their forecasting performance against single-regime models using the root mean squared error and the mean absolute deviation criteria.

In an interestingly revealing study for the European monetary system, Dahlquist and Gray (2000), using a regime-switching approach, find that the volatility, the level, and the speed of adjustment for short-term interest rates are all higher during speculative attacks and currency crises. The nonlinearities are suggested to come from reactions to different realignment expectations on the interest rates of a currency under stress. Using uncovered interest parity, it is argued that if there were nonlinearities (such as regime-switching) in exchange rates then they should also be present for interest rates.

For Japan, Girardin and Horsewood (2001) estimate a Markov switching VAR (MS-VAR) with 3 regimes to analyse the monetary transmission mechanism during the 1990s and the effect of near-zero interest rates (after the collapse of the bubble in asset prices). The model indeed differentiates the post-bubble period (after 1992) as a regime. Yet, in order to evaluate the pass-through from money market rates to bank loan rates, they do not use the estimated MS-VAR but rather assessed the impulse responses from a linear VAR estimated only for the post-bubble regime. Thus, they find that there is short-term stickiness in bank loan rates to shocks in money market rates.

Krolzig (2002) argues that regime-switching models represent a very general class which encompasses some alternative non-linear and time-varying models. The class of MS-VAR models is part of these non-linear econometric representations, where the non-linearity comes from the existence of switching regimes that account for time-varying parameters. Gray (1996) argues that, although a regime-switching representation might be complex, it is flexible enough as to model data generated by different economic mechanisms (regime-dependent) within a single unified model. For interest rate adjustments, for example, this might involve incorporating different speed of reversion to a different long-run mean and to a different degree of volatility.

In broad terms, as suggested by Franses and van Dijk (2000), regime-switching models could be classified in two main groups, depending on the nature of the underlying process that governs the regimes. In the first group, the regimes can be represented by an observable variable (usually an indicator function) such as that the regimes that have occurred in the past and present are known with certainty (although they have to be statistically determined). Models such as the Threshold Autoregressive (TAR) model; its variant, the Self-Exciting TAR (SETAR) model; and the Smooth Transition AR (STAR) are all in this group.[22]

In the second type of models, the regime the economy is at in any particular time cannot actually be observed. It is rather determined by an underlying unobservable stochastic process. Therefore, the researcher can only assign probabilities to the occurrence of the different regimes based upon the data set at hand. The class of Markov Switching VAR models (MS-VAR) falls withing this cathegory, in which the process governing the switch in regimes is stochastic and it is assumed to follow a Markov chain.[23] If the time series involved are non-stationary, the concept becomes a MS-VECM.

Franses and van Dijk (2000), discussing on nonlinear modelling of financial time series, point out that although there might be a large amount of feasible regime-switching models, the model selected for a particular data set should provide a clear interpretation

[22] See Krolzig (2002) for a detailed account on the assumptions and estimation techniques for these models.

[23] Alternatively, as Kim and Nelson (1999) remark, if the discrete variable that represent the unobservable regimes evolves independently of its own past values, the model is of independent switching (rather than Markov switching).

from an economic perspective. In particular, for financial time series, the level of volatility can be regarded as the regime-determining process. Obviously, this level in the future is not known with certainty. Therefore, this market uncertainty creates a number of risks for which banks can only form expectations and assign probabilities of occurrence.

In this sense, for the case of Argentina, if there were indeed some peso problems resulting from devaluation expectations switching between regimes (calm conditions and financial crises), then a regime switching modelling of interest rates and of the pass-through seems worth implementing. In order to select which type of regime switching model needs to be applied, the stochastic nature ("unknown timing") by which these crises affected the financial system is prioritised.

All this considered, the Markov switching modelling is then selected for evaluating the presence of regime shifts in the interest rate pass-through. If banks actually alter they behaviour and adjust differently their interest rates under increased market volatility, then the pass-through will show a non-linear, time-varying, pattern that should be captured by a model that infers those shifts from the data itself. The unknown time-ocurrence and durability features of financial crises and the feasible alterations of bank responses (actual and expected) to shocks on money market rates provide the economic rationale for estimating Markov switching models for the interest rate pass-through.

A MS-VAR model of a K-dimensional time series vector y_t is defined as a p-VAR model conditional upon an unobservable regime $s_t \in \{1 \ldots M\}$, as in:

$$y_t = v(s_t) + \sum_{j=1}^{p} A_j(s_t) y_{t-j} + u_t \tag{4.5}$$

where u_t is assumed to be a Gaussian innovation process, conditional on the regime s_t: $u_t \sim \mathrm{NID}(0,\Sigma(s_t))$, and the state s_t could take the values *0* or *1*. Note that this would be a more general case than the linear VAR from equation (4.4).

For this model to be complete, a crucial assumption is that the regime generating process is a discrete-state homogeneous Markov chain[24] defined by the transition probabilities:

$$p_{ij} = \Pr(s_{t+1} = j \mid s_t = i) \tag{4.6}$$

and the condition that:

$$\sum_{j=1}^{M} p_{ij} = 1 \forall i, j \in \{1,...,M\} \tag{4.7}$$

These probabilities[25] could also be represented in the transition matrix for an irreducible ergodic M state Markov process (s_t):

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1M} \\ p_{21} & p_{22} & \cdots & p_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ p_{M1} & p_{M2} & \cdots & p_{MM} \end{pmatrix} \tag{4.8}$$

where $p_{iM}=1-p_{i1}-\ldots-p_{i,M-1}$ for i=1,...,M.

As Krolzig (1998) points out, the linear time-invariant VAR remains the basis for the analysis of the relationship among the variables represented in the system, of the dynamic propagation of innovations to the system, and of the effects of changes in regime. Still, since a MS-VAR allows for a great wide choice of specifications in the

[24] The evolution of regimes could be inferred from the data.

[25] If the probabilities were independent of the previous occurring regime, then the model would be a simple (rather than Markov) switching model. That is, there would not be persistence in the states. See Hansen (1992).

parameters of the model, it is important to assess which one might fit the data best. This class of MS-VAR models allows for changes in intercept, $v(s_t)$; in the autoregressive coefficients, $A_j(s_t)$; and in variance, $\Sigma(s_t)$. Following Krolzig's notation for this class of models, a MSI-VAR will be used if only the intercept is regime-varying, a MSIH-VAR if additionally the variance is regime-dependent, and a MSIAH-VAR if the autoregressive parameters also change with regime.[26]

It is particular relevant, for example, to determine whether the autoregressive parameters are indeed subject to regime switching, because the long-term pass-through, $\lambda = \sum \alpha_k / \left(1 - \sum \beta_j\right)$, would depend on them. There is no a priori reason why the long term pass-through needs to be unique.[27] If banks adjust differently to money market shocks, depending on which regime the economy is at, then not only the impact effect will be regime-dependent but also the long-term effect. Of course, the number of times each regime occurs over a sample period would give the measure empirical support. Therefore, under a MSIAH-VAR specification, it will be sensible to refer to a regime-switching long-term pass-through. The measure of this pass-through would reflect the long term response from the bank interest rates as if the autoregressive parameters from any particular regime remain in place. The interpretation of such a measure, although slightly different to the linear VAR,[28] would mainly depend on the sum of autoregressive parameters on the money market rate ($\Sigma\alpha_k$) being positive and on the bank rates ($\Sigma\beta_j$) being less than one.

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[26] Erlandsson (2002) also includes some conditional heteroskedasticity for each regime (GARCH-effects) based on failure of a switching regime model to reduce autocorrelation in the standardized squared residual to non-significant levels.
[27] A unique long-term pass-through could be obtained from the regime-switching model by imposing the restriction that the autoregressive parameters being time-invariant.
[28] Since the rationale of the regime-switching modeling rests on the probabilities that the parameters switch indeed between regimes.

2.5 BANK CREDIT MARKET IN ARGENTINA

During the 1990s, financial liberalisation, globalisation, and development of capital markets have reshaped the financial system in Argentina. Banks have adapted themselves to new environments in which mergers, acquisitions, and withdrawals from market increased substantially. Lending pricing has been confronted with new dimensions on banking risks and market imperfections (i.e. non-competitive structures challenged by foreign banking or large information asymmetries). Thus, the relationship between the bank optimising behaviour and the process of financial or monetary transmission has most likely changed in the last two decades in this economy.

The number of banks in Argentina decreased, according to numbers reported by Delfino (2002), from 169 to 89 between 1993 and 2000, largely due to 28 failures and 65 mergers and acquisitions in that period. Although fewer banks, the degree of monetization increased significantly, including a large jump in the number of accounts (loans and deposits). Performance indicators show a significant decreased in operating cost along with efficiency improvements.

Most of these positive results in the banking system were prompted by economic reforms and financial liberalisation at the beginning of the 1990s. As Delfino (2002) also points out, regulatory reforms concerning capital adequacy, diversification of credit risks, provision of non-performing loans, and minimum auditing standards, all helped to build up a sound financial system.

With the introduction of the currency board by the beginning of 1991, the banking system in Argentina started to accept assets and securities in both local and foreign currency (US dollars). Indeed, around 35 percent of total new loans to the non-financial private sector by the banking system were denominated in dollars until 2000.[29] Even more importantly, according to Kamin and Ericsson (2003),[30] dollar currency holdings for Argentines are quite an important monetary aggregate. The hyperinflation experience had induced economic agents to heavily rely upon local and foreign currency to conduct financial operations. In some market segments, they are preferred to the banking system at all.

One important drawback from the financial reforms in the Argentinean banking system is that although interest rates on deposits have converged to international levels, lending rates remain quite high. There is also a relatively high spread between rates in local currency and those in foreign currency.[31] Catao (1998) argues that although financial reforms prompted a large increase in monetization of the economy, it remains low in international (developed-economy) levels. Thus, high administrative costs would partly explain large interest rate spreads.[32] In addition, institutional barriers to the dissemination of information might have induced large non-performing loan ratios that in turn had implied large credit risk and high provisioning expenses, all of which were passed onto lending rates.

With the opening of the financial system to international capital flows, the Mexican (1994), South East Asian (1997), and Russian (1998) episodes of financial crises might have had an important impact on lending market interest rates in Argentina. Also, the worsening of expectations about the validity of the currency board by the end of 2000

[29] See Table 2.1.
[30] Kamin and Ericsson (2003) estimate a measure of dollarization based on net currency flows between Argentina and US, according to US travelling information. It indicates that dollar currency holdings, up to 1992, amount to as much as all dollar deposits and all peso money together.
[31] This feature is common in countries that allow banks to operate in local and foreign currencies (i.e. Peru and Uruguay).
[32] Catao bases his results on estimating a partial equilibrium model of the banking system in a dual currency economy with imperfect competition in the credit markets.

and during 2001 (that eventually ended up in the collapse of the regime in December 2001) induced higher interest rate volatility.

Edwards (1998), for example, using an augmented GARCH model,[33] finds that there was indeed volatility contagion on nominal interest rates during the Mexican financial crisis for Argentina (but not for Chile, possibly due to the presence of short-term capital controls). He recalls that interest rate volatility changed markedly during the 1990s and, in particular, in turbulent periods such as that of the Mexican crisis.

[33] His model includes a Mexico-specific volatility variable in the estimation of the conditional variance equation for Argentina and for Chile.

2.6 DATA DESCRIPTION AND ANALYSIS

Data on interest rates for new loans (on any given period) has been selected from the Central Bank of Argentina's web page. Nominal monthly rates (express in annual percentage terms) in local currency are considered for the period June 1993 to December 2000.[34] These interest rates correspond to weighted averages of rates charged under fixed-rate and renegotiable-rate contracts (unless otherwise stated) on the following type of loans:

(i) Money market rate

- Interbank rate, loans to local financial institutions up to 15-days (fixed rates)

(ii) Short-term lending rates

- Overdrafts on current accounts
- Bills up to 89-day term
- Personal loans (including credit card loans) up to 180-day term

These rates were selected based on the relative importance of the corresponding loans in the total loans granted to the non-financial private sector in local currency. The interbank rate (on loans to local financial institutions) is taken as the rate representing liquidity conditions on the (short-term) money market.

Real interest rate series were estimated based on nominal rates and the annual rate of inflation, as a proxy for inflation expectations. The analysis has also been conducted on these real interest rates but results are not shown here, since they are qualitatively similar to results from nominal rates. It should be noted here that for most of the sample period (1993 – 2000), the currency board regime was credible and help to keep inflation

[34] Although, there is data available on these interest rates after that period, the collapse of the currency board regime has made information on credits granted to the non-financial private sector by Argentinean banks not reliable.

under control. Consequently, dynamics on both real and nominal interest rates are not very much different.

The period of analysis has been defined for the entire data sample, June 1993[35] up to December 2000. Given that this paper mainly deals with measuring the pass-through and that the sample size available is relatively small, no forecasting was conducted. More importantly, data available for later years (2001 and 2002) is not reliable since it is not yet accompanied by data on level of loans (most probably, economic agents stop using the banking system to intermediate funds). Extreme uncertain conditions about underlying economic rationale of the regime clearly induced a disruption of the optimising behaviour from banks, also reducing credit considerably.

The interest rate series span a period of time that includes the Mexican financial crisis in 1994, the East Asian financial turmoil of 1997, the Russian debt crisis of 1998, and the Brazilian crisis of 1999. The effects of the Mexican crisis over interest rates in Argentina are clearly stronger than those from the other crises. Nonetheless, as expectations of the collapse of the exchange rate regime grew stronger, the effects on the financial markets were even more serious during 2001 and 2002.

2.6.1 Graphical analysis

Lending interest rates seem to follow roughly the path marked by the interbank rate. Particularly, interest rate on bills, and to some extent on overdrafts, seem to follow more closely the path of the interbank rate during times of turbulence (such as the Mexican crisis) and rather less during less volatile periods. This suggests indeed the possibility of

[35] Unfortunately, there is no data available for previous years, especially those covering the hyperinflation period in Argentina.

(Markov) switching regimes based on interbank rate volatility. For the interest rate on personal loans, there was a rather large reaction to the interbank rate changes in 1995 that took longer than for the other lending rates to fade away (see Figure 2.1 and Figure 2.2). This might suggest asymmetry of response to money market rate shocks.

Graphs of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) indicate that they tend to zero; although with considerable lags (see Figure 2.3). This suggests stationarity of the series, but it might be difficult to determine it, since they seem to have a near-unit root. First differences' plots clearly show that they are mean reverting (see Figure 2.4). Yet, there is also clear indication of a higher mean and possibly time-varying variance in the series around the Mexican crisis.

2.6.2 Descriptive statistics

The interbank rate has the lowest average (7.3 percent), followed by the interest rate on bills (14.2 percent). Interest rates on overdrafts and personal loans are considerably higher on average (32.7 percent and 38.5 percent, respectively), probably showing a larger credit risk involved on those operations. In terms of relative variability (standard deviation over the mean), the least volatile rates are overdraft and personal. The interbank and bills rates more than double the others in that volatility coefficient.[36]

The null hypothesis of normality is rejected for all but the personal rate. The interbank rate shows the relative longest right tail and highest degree of leptokurtosis. Correlation between interbank and bills rates is the strongest during the sample period (0.62). A

[36] See all these descriptive statistics in Table 2.2.

moderate correlation is shown by the interbank and overdraft rates (0.43), while that the interbank and personal rates seem to be very little correlated (a mere 0.02).

Pairwise Granger causality tests are conducted alternatively for 4, 8 and 12 lags specifications.[37] The null hypotheses that the interbank rate does not Granger cause any lending rate is rejected in all cases, therefore suggesting that the interbank rate might indeed Granger cause these rates. All the same, causality and weakly exogeneity should be better assessed in a multivariate system (such as a VAR).

2.6.3 Time series preliminary analysis

2.6.3.1 Unit root tests

Preliminary standard unit root tests have been conducted for each interest rate series. The Augmented Dickey Fuller (ADF) test shows non-rejection of the null hypothesis of a unit root for all interest rates in levels and clearly rejection for those rates in first-differences. Therefore, evidence is consistent with interest rates being integrated of order one, I(1).[38] Table 2.4 reports results only for the relevant representation of the series (with a constant in the test equation). In all cases, residual correlation disappears at lag one of the testable equation.

The Phillips-Perron test also shows that for interest rates on overdrafts, bills, and personal loans the null hypothesis of a unit root cannot be rejected (Table 2.5). For the interbank rate, on the contrary, the hypothesis of a unit root is rejected even in levels. This result is opposite to the one obtained from the ADF test. Therefore, no conclusive

[37] See details in Table 2.3.

[38] A study from the Banco Central de Argentina (1998) found that non-stationarity could not be rejected by Dickey Fuller tests for similar interest rates than in this paper. Yet, the study could not conclude that interest rates contain a unit root, since it seemed that DF test were not distinguishing between the presence of a unit root and long persistence in interest rates.

evidence of the nonstationarity of the interbank rate could be reported. Of course, this uncertainty will also pose doubts on the nonstationarity of the other interest rates. They might rather be consistent with stationary time series.

Based on the results from the standard ADF test and on previous empirical work for developed countries, however, it is preliminary concluded and assumed that all four interest rates series are nonstationary. Therefore, the next obvious step is to test for the existence of cointegration among the variables.

2.6.3.2 Cointegration tests

The Johansen (1991) methodology is used to assess if there is any cointegrating vector among the four nonstationary interest rate series. Different specifications of the test and up to eleven lags in the first differenced terms of the VAR have been tried (Table 2.6). For parameter interpretability and for consistency with the series, the specification with an intercept in the cointegration relationships and no trends is preferred. With few lags included, the test suggests that there is no cointegration in the system.[39] When additional lags are included, test results tend to suggest that there is cointegration. Still, they are not conclusive enough as to the number of cointegrating vectors. Empirical evidence is, therefore, not clear as to the presence of cointegration among these interest rates. It rather suggests non-cointegration among the interest rates.

In order to assess the validity of the Johansen test's results, the two-step Engle-Granger test for cointegration is applied to these interest rates in pairs (Table 2.7). Again, the results show no clear support to the existence of cointegration between these rates. The residuals from the cointegrating equations show no evidence of stationarity (Figure

[39] Applying standard information criteria, the suggested lags are rather low (1 to 3).

2.5).[40] It is clear, though, that part of the nonstationarity on the residuals is due to the high volatility on the interest rates during the Mexican crisis.

Consequently, at this stage there are two alternative scenarios. First, the interest rates are indeed nonstationary time series but they are just not cointegrated. The second option is that the interest rates are rather stationary but the volatility of the interest rates during the Mexican crisis distorted the unit root tests applied to the time series (presence of outliers). The reaction to the Mexican financial crisis in 1995 might make them look like being nonstationary when in fact they are stationary (but possibly with a root close to unity). Further testing on the stationarity of the series (including feasible outliers) is then needed before proceding with the econometric modeling of these interest rates.

2.6.3.3 Unit root and cointegration tests: revisited

The large increases in the level of the interbank rate (followed by the other interest rates) at the end of 1994 and during the first months of 1995 suggest indeed the presence of additive outliers in the series (in common dates for them all). In order to test for non-stationarity, three methods are considered to deal with these outliers:[41]

(i) Run standard tests eliminating the outliers from the series;

(ii) Use robust tests (Ng-Perron, DF-GLS);

(iii) Add dummy variables to the estimated regression to remove the influence of the outliers.

[40] Monte Carlo simulations, based on the properties of the original series, indicated no particular lack of power on the tests applied to each pair of interest rates.
[41] Following Maddala and In-Moo (1998)

For the first and the third method, the observation at March 1995, which corresponds to the largest effect on the rates from the Mexican crisis, is considered as an additive outlier.[42] For the second method, the Ng-Perron test is used since it is, as suggested by Vogelsang (1999), very robust to the presence of additive outliers, both in terms of size and of power. It is also used for this second approach, the modified Dickey Fuller test, DF-GLS, which detrends series before running the test regression. Thus, for the first method, the observation for March 1995 is dropped for each series and then the following tests are applied: standard ADF, DF-GLS, and Ng-Perron (the latter two for robustness to any remaining outliers in the series). For the third method, an approach by Vogelsang (1999) is followed, adding a dummy variable to remove the outlier's influence in the standard ADF test. Lags are selected according to the modified Akaike (M-AIC) criterion.

In most of these tests, non-stationarity of the interbank rate is clearly rejected (Table 2.8). For the overdraft and bills rate, a couple of the tests reject the null of a unit root, although none of them rejects it for the personal rate. Therefore, including the additive outlier in the search for a unit root, the empirical evidence is more supportive of these interest rates being stationary time series.[43] Correspondingly, it seems sensible to conclude and assume stationarity for these interest rates.[44] It would then be appropriate and sufficient to model them in levels in order to find out the dynamic relationships among them. Autoregressive models are then a natural specification to follow.

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[42] For a discussion of a simple procedure for detecting additive outliers, that does not require full specification of the dynamic model and that does not require estimates of serial correlation parameters, but relies on the unit root null hypothesis, see Vogelsang (1999).

[43] Nelson, Piger, and Zivot (2001) show that not only the ADF test but also those tests designed to be robust to single structural breaks lack power to distinguish an I(0) process with Markov-switching breaks in trend growth from an I(1) process. Notwithstanding it, no alternative test is suggested.

[44] No further testing for cointegration is then needed. For the sake of experimenting, however, the Johansen test was applied including a dummy variable in the testing equation, but no interpretable results were obtained (Table 2.9).

For example, in analysing uncovered interest parity differentials and convergence for Argentina, Edwards (1998) applied ADF and Phillips-Perron unit root tests to short-term deposit interest rates (30 days) and rejected the null hypothesis of a unit root for a series from January 1992 to June 1998. Indeed, he could not reject the alternative hypothesis that the series converge through time. Contrary to, Grubisic and Escudé (1999), who using the ADF test with corrections for outliers (on the Mexican and East Asian crises)[45], could not reject the nonstationarity hypothesis over a similar sample (April 1993 to July 1998) for short term (30 to 60 days) interest rate on time deposits.

An interesting discussion of unit root test using economic theory, rather than just statistics, is found in Chumacero (2001). The statistical properties of interest rates coming from general equilibrium models are quite different if the argument variable (i.e, growth or consumption) is difference-stationary or trend-stationary. Clarida et al. (2002) mention the conflict between empirical literature finding nonstationary interest rates and most finance theory that considers them stationary processes.

[45] Correction was done including dummy variables for the outliers and estimating this equation through OLS. Then the unit root tests were conducted on the residuals of this regression.

2.7 ECONOMETRIC ESTIMATION AND RESULTS

In the following specifications, when a pairwise equation is considered, it involves one lending interest rate (overdraft, bills, or personal) and the interbank rate. When a multi-variable system is estimated, it involves the interbank rate and the three bank rates overdraft, bills, and personal (in that ordering).

2.7.1 Single equations

A single equation is applied to every lending interest rate in combination with the interbank rate as main explanatory variable. No possible feedback into the interbank rate from the interest rates is considered. The estimated equation is of the form:

$$r_t = \delta + \sum_{j=1}^{m} \beta_j r_{t-j} + \sum_{k=0}^{n} \alpha_k i_{t-k} \tag{7.1}$$

where r_t stands for the bank lending rate and i_t for the interbank rate. Notice that the bank rate is affected by its own past values and by past and contemporaneous values of the interbank rate. It should be bear in mind, that although there are other variables that might be as much important as the interbank rate to explain bank rates, they are not considered at this stage. The short-run pass-through is given by the coefficient α_0 and the long-run pass through by the coefficient $\lambda = \sum \alpha_k / \left(1 - \sum \beta_j\right)$.

A maximum of 6 lags is considered for each equation. This upper limit is set because of three reasons: to keep interpretability manageable, to save degrees of freedom, and because standard information criteria suggest the number of lags to be fairly low.

The class PcGets for Ox (Hendry and Krolzig (2001), (2002)) provides an automatic general-to-specific approach to reach the most parsimonious and congruent representation of each relationship, given the presence of only two variables.[46] Each equation is also estimated considering a dummy variable that accounts for effects from the currency crises, with PcGets selecting the dates automatically.

The resulting equations show that the impact multiplier for overdrafts is 0.579, for bills 1.3, and for personals a mere 0.228. Notice that the immediate pass-through for the rate on bills is more than complete (exceeds one hundred percent). This suggests an over reaction to changes in the interbank rate. The long-term impact on bills goes up to 1.8, accumulating further from the initial over impact. Surprisingly, the long-term effect for the overdraft and the personal rates is well in excess of completeness (4 hundred percent for the former and 5 hundred percent for the latter).[47]

The short-term pass-through for the overdraft rate reduces to 0.388 when outliers are considered, but the long-term effect is still in the region of four hundred percent. Meanwhile, for bills, both the short-term impact and the longer pass-through are reduced when outliers are considered (PcGets selects in this case, dummy variables for December 1994 and March 1995). Still, the long-term impact emphasizes the over reaction on impact for bills. For the personal rate, adjusting the equation for the presence of outliers does not change qualitatively or quantitatively the results. In fact, the automatic procedure from PcGets includes a dummy variable for January 1999 and fails to spot the large movement in early 1995 (March, for the other two cases).

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[46] Detail results are shown in Table 2.10.

[47] See Table 2.11 for a summary of the pass-through results from the PcGets estimation.

2.7.2 Linear VAR models

Following the conclusion that interest rate series are stationary, a multivariate linear VAR in levels is estimated for the interest rates interbank, overdraft, bills, and personal. As in the single equation approach, the system is estimated with and without dummy variables (outliers) that capture the currency crises.[48] Still, dummy variables were considered only for the Mexican crisis in the VAR.[49] Test analysis is discussed here to draw some attention to data characteristics. In addition, description of impulse responses functions is presented to assess dynamic relationships among these rates.

A 4-variable first-order linear VAR is estimated (Table 2.12). All equations show significant parameters on their own lags (the autoregressive part of each variable). In all of them, but in bills, the interbank rate parameter is significant.[50] While that for the interbank rate, only its own lag and the constant term are significant. Thus, the data is consistent with the hypothesis that each lending interest rate is explained by its own lags and the interbank rate, while that the interbank rate is only explained by its own lags.

A more formal test for the weak exogeneity of the interbank rate, the Wald test for Granger causality and block exogeneity, is applied. In the equation for the interbank rate, all variables but the interbank rate itself should be excluded. In the equations for overdraft and personal rates, their own lags and the interbank rate should be maintained, while all other variables should be excluded. With just one lag, this result is not shown for bills, but if a 3-order VAR is considered, then the interbank rate becomes relevant

[48] Standard packages, PcGive and Eviews, have been used for all estimations in this section. Although PcGets could estimate each equation in a VAR, it does not do it simultaneously.

[49] Different dates for one single dummy were tried, from December 1994 up to May 1995. However, the largest change to all rates (but for the personal rate) corresponds to March 1995. The alternative of using one dummy variable for this date against using several for all the possible months was preferred, since the latter option does not improve upon the results, neither quantitatively nor qualitatively.

[50] If another lag is added, then the equation for bills shows a significant interbank parameter too.

for this equation too. These empirical results suggest, and support, the fact that the money market rate influences bank interest rates (proving this rate exogenous to the system). Therefore, the Choleski decomposition is applicable validly to derive the pass-through and the impulse responses to shocks on the money market rate.

The stability condition of the VAR is checked out and, although it seems to have some roots of the characteristic polynomial close to 1 (interest rates nearly integrated), the system is stable. Since, any VAR of a higher order could always be reformulated as a first order system (by representing it by its companion form),[51] it could be concluded indeed that the system is stable and take this as a further proof that the interest rate series are indeed stationary.

A Wald test for lag exclusion in the system shows that it should only be considered up to 2 lags. If standard information criteria are applied, with a maximum of 12 lags, then the suggested number of lags is one (Schwarz and Hannan-Quinn criteria). As Lütkepohl (1991) argues, if the correct VAR order is a priority, it is reliable to choose a consistent criterion for the lag order and this is the case of these two estimators.

Despite these features, the first-order system does not seem to be congruent.[52] Autocorrelation functions show that residuals are indeed autocorrelated. Besides, residuals fail the normality test and the no-heteroskedasticity test in all cases. Nonetheless, since our main interest would be in identifying impulse responses to shocks in the interbank rate, we stick to the first-order VAR to estimate them, rather than increasing the VAR order pursuing a more parsimonious model.

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[51] See Patterson (2000).

[52] Criteria for the estimated model to be congruent are the residuals not being serially correlated; no residuals heteroskedasticity; and, innovations normally distributed (Patterson (2000)).

Applying a Choleski decomposition, responses to a one standard deviation shock to the interbank rate are estimated and plotted (Figure 2.6). Interest rates on bills show the more similar pattern of response to the interbank rate itself. It takes its response exactly a year to come to zero, but a further 2-year period to completely die out, changing from a positive effect during the first year to a slightly negative effect during the latter two. This might be consistent with the overshooting that the single equation estimation captured for the bills rate.

The overdraft and personal rates show between them a relatively similar shape for the impulse response function and somewhat different to the bills rate and to the interbank rate. The response from the overdraft rate comes to zero after 16 months (first at an increasing rate and then at a decreasing one); then it switches to a negative effect for a relatively long period of up to 3 years to finally die out. Although the personal rate's response changes in the same pattern, it does it with a different timing and degree. The response increases up to month 7 and then decreases till zero in month 32. Notice that the largest two standard error bounds correspond to the personal rate.

The relevant cumulated impulse responses are also estimated and plotted (Figure 2.7). Corresponding to stationary variables, the accumulated responses asymptotically approach its final non-zero long-term effect, although this level is different for each lending rate. Note the large two standard error bounds for all cases.

Next, the cumulated responses from each rate as a percentage of the cumulated response from the interbank rate are estimated so that completeness of the effect could be assessed (Figure 2.8). The final effect is reached after 20 months for bills and overdrafts (although it slightly increases further for both rates during two more years and, then, return to the previous level). For the personal rate, the final effect is reached after some 30 months. In all cases the long-term effect is, surprisingly and unconvincingly, much larger than one hundred percent of the shock to the interbank rate.

Interpretation of these impulse responses could be misleading if some important variables in the determination of the interest rates were excluded. Including a dummy variable that accounts for the outlier in March 1995 might help to reduce this effect. When a dummy variable is included, the coefficient for it is highly significant in every equation in the system (Table 2.13). The significance of the interbank coefficient in the equations for overdraft and for personal rates disappears though. Besides, a significant negative coefficient for the interbank rate appears in the equation for bills. Most of other characteristics from the linear VAR without the dummy are also present in this case: stability of the system and incongruence of the final model.

Impulse responses are quite similar to the case without a dummy variable. Although in this case, the presence of the outlier adds to the interpretability of the percentage share of the cumulated responses to the shock on the interbank rate (see Figure 2.9). Surprisingly, the accumulated effect on bills as a percentage of the accumulated response on the interbank rate is decreasing and it finally reaches zero after a couple of years. The initial effect is, however, rather close to one hundred percent. For overdrafts, the long-term effect of the shock on the interbank rate is practically complete. After the initial five months, the shock on the interbank rate is transmitted entirely to the overdraft rate, but it continues increasing further on till month 24. After that overshooting effect, it comes down to just a hundred percent response. The personal rate's response is different. It reflects a hundred percent pass-through after around 10 months. The effect continues increasing up till two and a half years and then asymptotically approaches two hundred percent long-term pass-through.

Given the clear different responses and the fact that for each rate only past values of the interbank and the rate itself are significant, modelling all variables together might be inappropriate. It could be distorting impulse response's analysis. Therefore, first-order bivariate VAR models are estimated in order to improve estimation of the relationships between the interbank rate and each lending rate.

Impulse responses from the bivariate VAR models do not seem to change or to improve upon those from the multivariate ones. For the overdraft and personal rates, the percentage share of the accumulated response is well beyond a hundred percent in the long run. Yet, it shows a more interpretable pass-through for the rate on bills (when a dummy is included) since the effect, although slightly decreasing remains above 70 percent in the long run.

The interest rate pass-through for each lending rate that can be derived from the bivariate VAR estimation is somewhat similar to the single-equation estimation (see Table 2.14 for a comparison). For the overdraft rate, the impact pass-through is 0.577; and for the bills rate, it shows the overshooting with a short-term pass-through of 1.228. For the personal rate, the pass-through is 0.16, somewhat lower than in the single-equation case. For the long-term, the pass-through for each lending rate is unconvincingly much larger than previously.[53]

[53] Details on all other coefficients derived from the standard VAR to identify the original form of the system could be seen in Table 2.15. Details on both forms of the system are given in the Appendix.

Summarising, the data show different behaviour from lending interest rates to shocks in the money market rate. Indeed, there is stickiness in the short-run, but apparently, it is not relevant (bills and overdraft) since the response is quite high from the start. Although for the personal rate, the degree of stickiness in the short-run is quite high, the long-run effect seems to be extremely large to be credible. It seems that neither the single-equation approach, nor the multi-equation models (both bivariate and multivariate) capture accurately the dynamic relationships among these interest rates over the period of analysis.

2.7.3 Markov switching VAR

In the case of the linear VAR, it seemed relevant to include one (or more) dummy variable(s) to account for the presence of outliers in early (March) 1995. Although, in doing so, some valuable information about the pass-through in highly volatile periods is discarded. In a linear model, given the invariance of dynamic multipliers with regard to the history of the system, the size and sign of the shocks (Krolzig (1998)) is not really a good description of the market rate responses to changes in the interbank rate. Therefore, a MS-VAR representation seems more suitable to model the interest rate pass-through, with the level of volatility being the regime-determining process (Franses and van Dijk (2000)). The MS-VAR model is an alternative to a deterministic approach to structural change and to the presence of outliers (i.e. including dummy variables).[54]

Non-linearity in the VAR system is first tested in order to see the adequacy of the MS-VAR model for the market structure of interest rates. Log-likelihood ratios are used here

[54] The non-normality of the errors in the linear VAR is most likely due to the presence of various "outliers".

to test against the alternative of a linear specification in the VAR.[55] Regime switching has been kept to only two possible states: normal market and turbulent (as in a financial crisis) market; the difference between the two regimes being the degree of interest rate volatility. The MS-VAR models are all of order one (to save degrees of freedom). All estimations have been made with the class MSVAR for Ox.[56]

Switching parameters are allowed alternatively for the intercept (MSI-VAR)[57]; the intercept and the covariance matrix (MSIH-VAR); and for the intercept, the covariance matrix, and the autoregressive parameters (MSIAH-VAR). Although these specifications are considered for both the multivariate and the bivariate cases, results that are more efficient are found with the latter. Thus, following the results from the linear modelling, here are presented the results from the pairwise MS-VAR models.

The log-likelihood test for linearity is shown in Table 2.16 for each bivariate system. In all cases, there is clear indication that linearity is rejected in favour of an unrestricted non-linear MS-VAR. Results show that not only the intercept is subject to changes under each regime but also the variance matrix and the autoregressive coefficients. Thus, the chosen Markov switching VAR specification for each case is the MSIAH(2)-VAR(1). The data supports modelling all parameters being regime switching.

Standard log-likelihood ratio tests, nonetheless, are not completely appropriate because of the presence of nuisance parameters (the regime transitional probabilities) in the null

[55] Notice that a MS-VAR could be seen as a generalization of a VAR model. Thus, the linear VAR could be treated as the restricted model.
[56] For an introduction to Ox see Doornik and Ooms (2001). For a review of Markov switching VAR using MSVAR for Ox see Krolzig (1997).
[57] Models with shifts in the intercept are consistent with a smooth adjustment of the time series after the change in regime (as it might be the case for interest rates), while that models with shifts in the mean are more consistent with a once-and-for-all jump in the time series (Krolzig (1997)).

hypothesis. Hansen (1992), (1996) suggested a generalized log-likelihood test, although its complexity has made it difficult to find it in empirical works. Ang and Bekaert (1998) applied it to a Markov-switching model of the term structure of interest rate for US, Germany and UK. More recently, Boinet, Napolitano, and Spagnolo (2002) have also applied it to test regime-switching modelling for devaluation expectations in Argentina. Although not entirely appropriate, the log-likelihood testing is taken at this stage as indication of regime shifting in the data. A more formal Hansen test is reserved for next chapter to confirm results.

The rationale for using a MS-VAR type of model rather than a linear VAR rests in the fact that the former captures the different responses from interest rate to the money market rate under different market stances. Thus, it is indeed expected than the pass-through would be different under normal market conditions than under a high-volatility context (such as those of a financial crisis). Therefore, assessing the validity of the MS-VAR representation focuses on its ability to distinguish periods of high volatility from those of stable financial conditions and to have more interpretable impulse responses.[58]

The transition matrix that defines the Markov switching regimes shows interestingly that there is a higher chance to remain in a "normal" credit market if that were the current state of the economy than in a more volatile environment once a financial crisis arises (Table 17). Therefore, the duration of a high-volatility episode is considerably less than that of a normal state. The personal rate has the highest probability of remaining in both regimes and, correspondingly, the lowest chance of changing from one regime to another. This is consistent with the fact that, once the toughest months of

[58] For a step-by-step estimation of regime-dependent impulse response functions for Markov switching models see Ehrmann, Ellison, and Valla (2001b).

the Mexican crisis were over for the other two rates, the level of the personal rate slowly came down and, thus, the effects took longer to fade away.

Thus far, results seem to indicate that there is indeed a gain in modelling the interest rates including regime shifts. Still, when those rates are considered in a 4-variable system, the model fails to distinguish the period before the Mexican crisis as a different regime to that during the crisis itself. Meanwhile when bivariate MS-VAR models are considered, these periods are indeed classified in different regimes: a normal situation followed by a turbulent scenario. Once again then, results for bivariate Markov switching VAR models are presented here (see Table 2.18). Similarly to the linear method, assuming a Choleski decomposition, the short-term and long-term pass-through can be derived from the Markov switching estimation.

The MSIAH(2)-VAR(1) clearly shows very different behaviour for the lending rates under each regime. The Markov switching modelling reveals indeed a higher pass-through for interest rates under a financial turmoil than in calm conditions in credit markets (Table 2.19). The pass-through for the overdraft rate is 0.2 under the calm regime and rises to 0.62 for the volatile regime. If a linear method is used to estimate this pass-through, the value is 0.57, so that it will be overestimated in the first regime and underestimate in the volatile conditions. For the rate on bills, the pass-through rises from 0.89 in normal conditions to 1.5 under unstable financial markets, while that the linear methods states a 1.3 overall pass-through. Finally, for the personal rate, the Markov switching estimation reveals a very low pass-through, 0.06, in the normal regime that increases to a moderate pass-through in the second regime. It could be seen, that for this period in the Argentinean credit market, the pass-through for different lending rates switches in regime according to volatility in money market rates (associated to uncertain financial conditions). Under such characteristics, linear methods of estimating the pass-through could prove to be inaccurate.

Relevant conclusions can also be drawn from the contemporaneous correlation matrix (Table 2.20). Correlation between the overdraft and the interbank rates in a normal credit market is around 28 percent. It increases to 77 percent in a high-volatility environment. This suggests that for the overdraft rate, the role of the interbank rate is far more important in a volatile context (as that of an international financial crisis) than in times that are more normal. Even though the role of the interbank rate is important, there is room for other variables to influence the overdraft rate in normal market situations.

The rate on bills is highly correlated with the interbank rate in both regimes (increases from 73 to 75 percent). This shows that although there might be some other variables influencing this rate, its evolution is mostly determined by the interbank rate. Correlation between personal and interbank rate is very little in the calm regime, but it increases substantially (to around 94 percent), when there is turbulence in the credit market. In normal times, there might be other variables affecting the personal rate, but mainly the interbank rate influences its path in financial crises.

The relevance of the MSIAH(2)-VAR(1) is judged by its ability to identify the periods falling into each regime. That is indeed the case for every pairwise model. The regime probability occurrences clearly identify the volatile periods for each rate (Table 2.21). For all lending rates, the Mexican crisis and the period of November-December 2000 are undoubtedly identified as being on regime 2 (high-volatility). The effects of the Russian crisis are recognized as well on this regime for the rates on overdraft and bills. Additionally, the South East Asian crisis is recognized as a turbulent period for the overdraft rate. Regime probabilities (Figure 2.10, Figure 2.11, and Figure 2.12) for each interest rate clearly indicate those periods of high volatility, where the pass-through process differs considerably from normal volatility conditions.

The MSIAH(2)-VAR(1) specification firmly identifies for each interest rate those periods with higher volatility, assigning to them a close-to-one probability of being in the regime 2. There is no ambiguity as to the classification and, correspondingly, the coefficients representing the effects or pass-through from the money market rate to the lending rate are quite different in each regime. Moreover, the switch in regime seems to be associated to the spread of effects from international financial crises. Espinosa-Vega and Rebucci (2002), for example, have found evidence for Chile[59], that neither changes in monetary policy targeting nor in exchange rate regime affects significantly the pass-through. Still, there is indeed some evidence that the South East Asian financial crisis affected the interest rate pass-through in Chile.

Although all these results seem more plausible than those obtained from the previous econometric approaches, it yet seems that some other variables might be influencing interest rates' behaviour.[60] Nevertheless, insofar as only interest rates in local currency are considered, the Markov switching approach definitely improves upon other

[59] They estimate the interest rate pass-through using an auto-regressive distributed lag model re-parameterized as an error correction model. In order to assess the effects of changes in monetary policy targets, exchange rate regimes, and international financial crises they split their sample period and evaluate the stability of their parameters.

[60] The long-term pass-through with the Markov switching estimation is still inexplicable high. This feature will be discussed in the theoretical part of Chapter 4.

alternative models for estimating the interest rate pass-through in Argentina. Besides, another advantage of the Markov switching specification for each pair of interest rate is that the system is now more congruent and parsimonious. Residual autocorrelation is no longer present, nor is normality longer rejected. This seems to disregard the need for incorporating GARCH-effects inside each regime.

2.8 CONCLUSIONS AND FURTHER RESEARCH

Interest rate pass-through has been assessed by a series of models including single and multi-equation systems, bivariate and multivariate specifications, and linear and non-linear approaches. Preliminary time series analysis indicated that the set of interest rates from the Argentinean banking system are consistent with the hypothesis of stationarity. Therefore, systems in levels of the variables were estimated.

Single equation systems show different pass-through for bank lending rates, with rates on higher credit-risk loans responding stickier to the interbank rate (from higher to lower pass-through: bills, overdraft and personal rates). However, long-term pass-through are implausible high (well above one hundred percent effect) under the single equation approach.

Multivariate linear VAR models reveal the dynamics among these interest rates and clearly show that each bank lending rate is affected by its own past values (not from those of other lending rates) and those from the interbank rate. The interbank rate is weakly exogenous to the system and, so it seems, it is influenced by other factors affecting financial and liquidity conditions in the money market. Nevertheless, estimated first-order linear VAR models are not congruent apparently due to the presence of several financial crises affecting interest rates' evolution. Even if dummy variables are included, residuals remain autocorrelated, heteroskedastic and not normally distributed.

Impulse responses show that there is indeed some degree of stickiness in the short-run, although the immediate effect is relatively high (especially for rates on overdrafts and bills). Again, the long-term effect is implausible high. There are significant differences in the responses from each lending rate to shocks in the interbank rate. These differences are better captured, and are more interpretable, with bivariate linear VAR models. Notwithstanding this, congruency is still not achieved.

Thus, it seems that neither single-equation modelling, nor multi-equation systems capture efficiently the dynamic relationships among lending rates and the money market rate. The presence of several episodes of financial crises alters the pass-through, affecting the speed and degree of response to shocks in the interbank rate. Discarding information over those periods (for example, by including dummy variables) reduces the ability of the models to explain the whole process over the study sample.

The class of Markov switching models provides a better in-sample fit for the dynamics on the market structure of interest rates. Bivariate MSIAH(2)-VAR(1) models greatly improve upon modelling the responses from bank lending rates to the interbank rate. Markov switching models allow capturing the different behaviour from lending rates to financial markets conditions. In normal times, the stickiness in the short-run is higher for those rates on loans with higher credit risk. While that with highly volatile financial markets the pass-through increases considerably for all rates. The chances of remaining in those regimes are lower than returning to more stable scenarios though.

Allowing parameters of the VAR model to be regime-dependent efficiently determines the periods in which regime switch occurs. The MSIAH(2)-VAR(1) identifies correctly periods of financial distress for lending rates. In particular, the Mexican crisis and the building up of the currency board's collapse are unambiguously spotted as high-volatility periods so that different parameters are assigned.

Furthermore, Markov switching assumptions on the regimes provide more congruent models than with linear approaches. All the same, it seems that although Markov switching models improve upon linear models to measure the pass-through, considering only interest rates in local currency might not be enough to capture rates' behaviour. Further research should address issues such as the inclusion of some other relevant variables in the pairwise MS-VAR. Variables such as interest rates in dollars, depreciation expectations, other assets' prices, and country or credit risk might need to be considered. In particular, it should be assessed if measures of interest rate pass-through change when these variables are included. On the econometric nature of the Markov switching modelling, a more comprehensive approach to the transition probabilities needs to be taken. Next chapter deals with these empirical extensions.

Similarly, more in line with industrial organization models for banking behaviour, other microeconomic variables such as operating costs and credit risk should be considered in the determination of interest rates. Therefore, a more formal theoretical framework should be built to accommodate feasible nonlinear features in the pass-through. Short-term and long-term differences in the pass-through need a more precise approach as to enhance understanding on its dynamics. In the fourth chapter of this thesis such a theoretical approach to the pass-through is assessed.

Figures

Figure 2.1 Lending Rates vis-à-vis the Interbank Rate

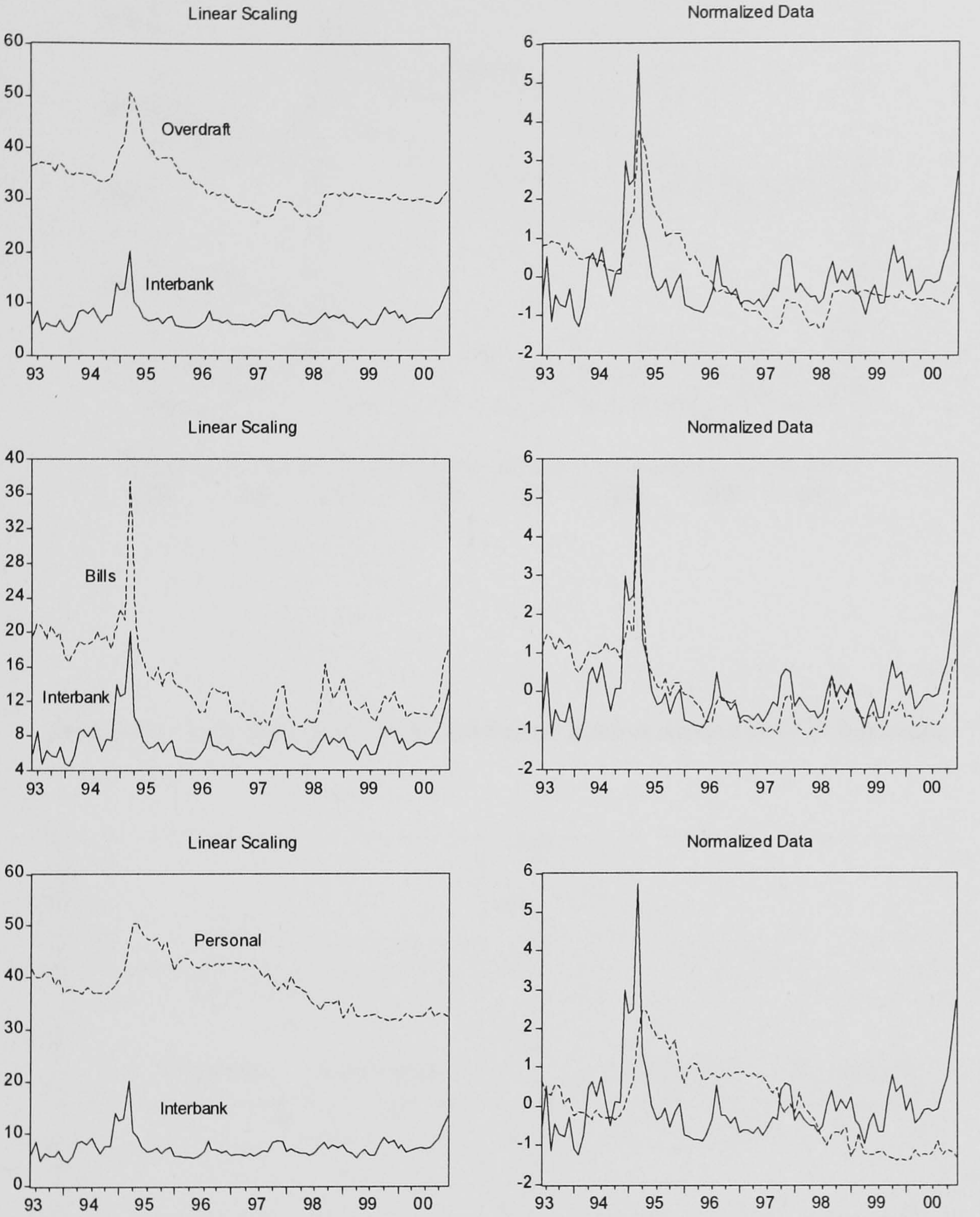


Figure 2.2 Nominal Interest Rates on Loans in Argentina: 1993:06 – 2000:12

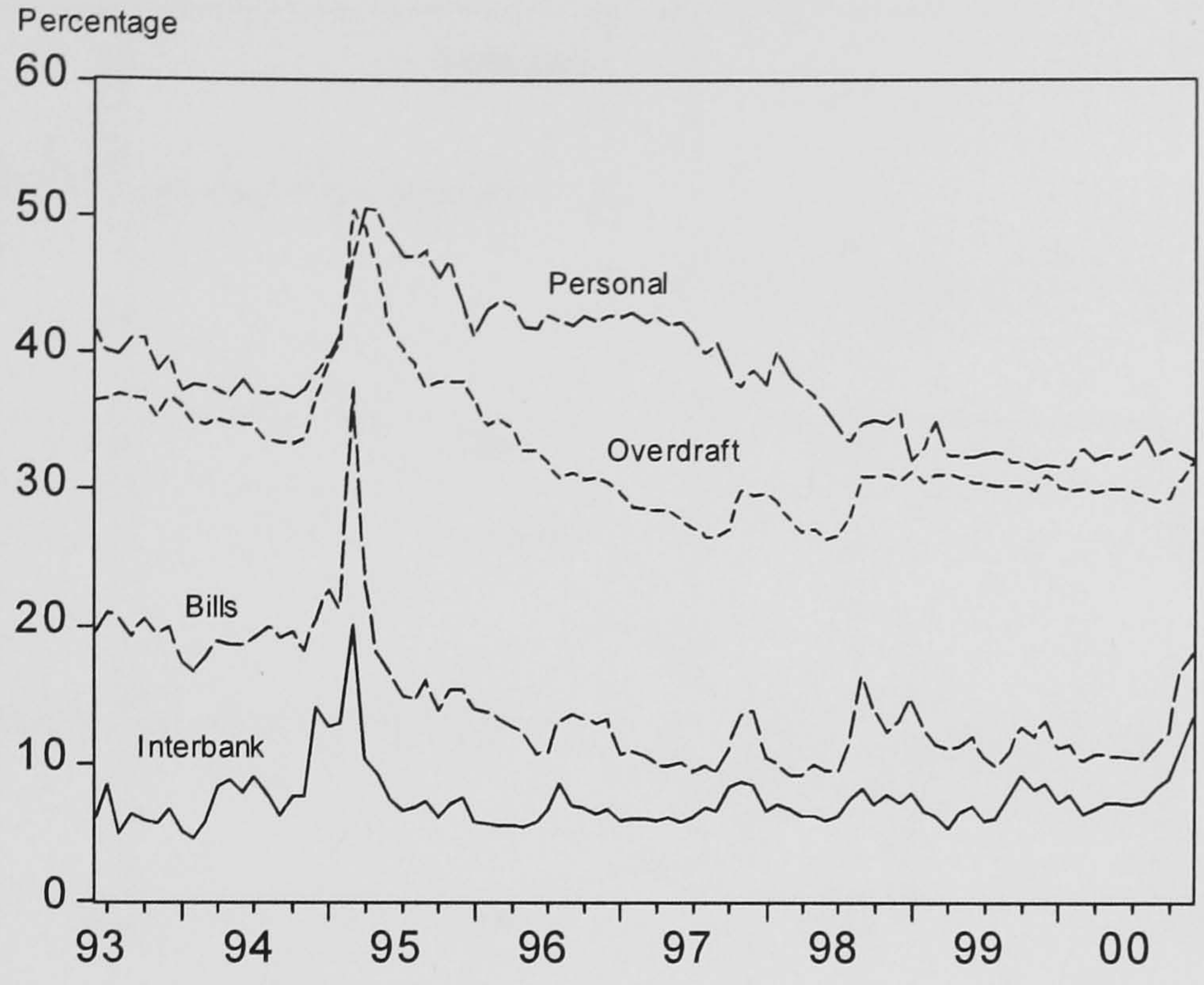


Figure 2.3 Autocorrelation (ACF) and Partial Autocorrelation (PACF) Functions

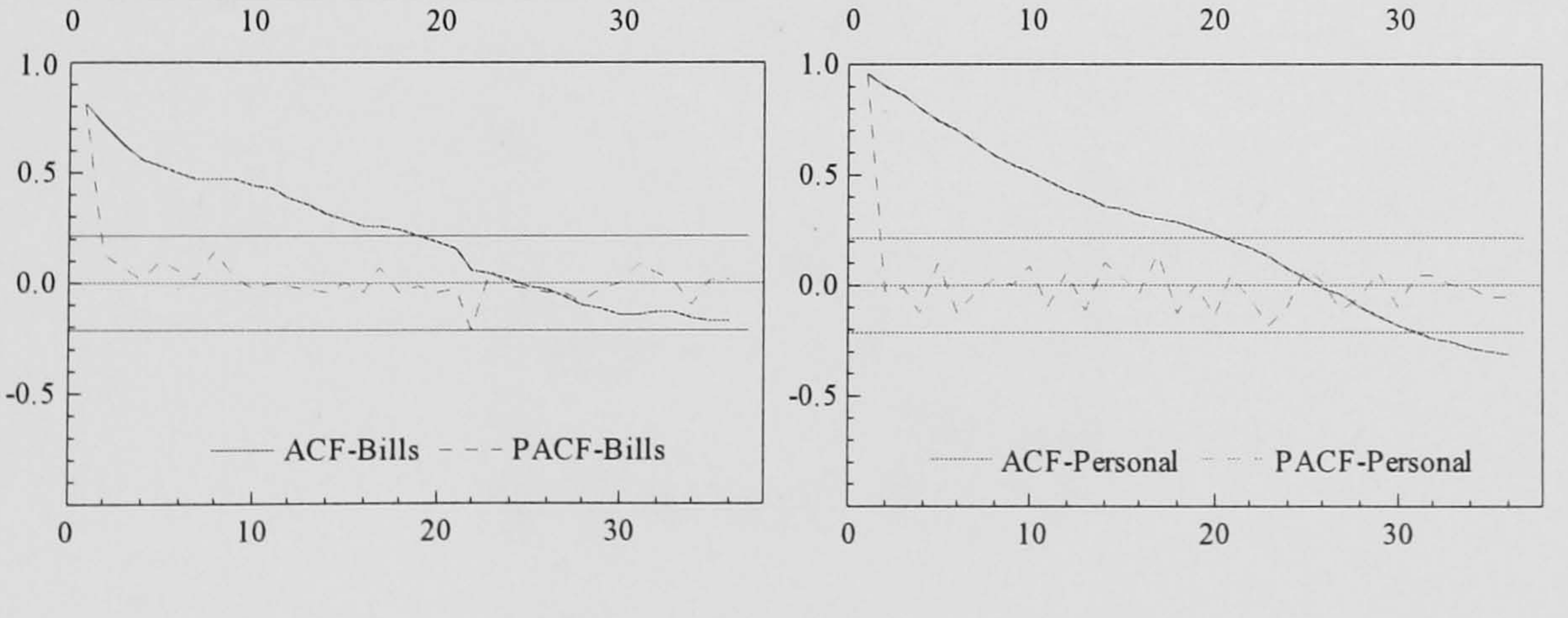


Figure 2.4 Nominal Interest Rates in First Differences

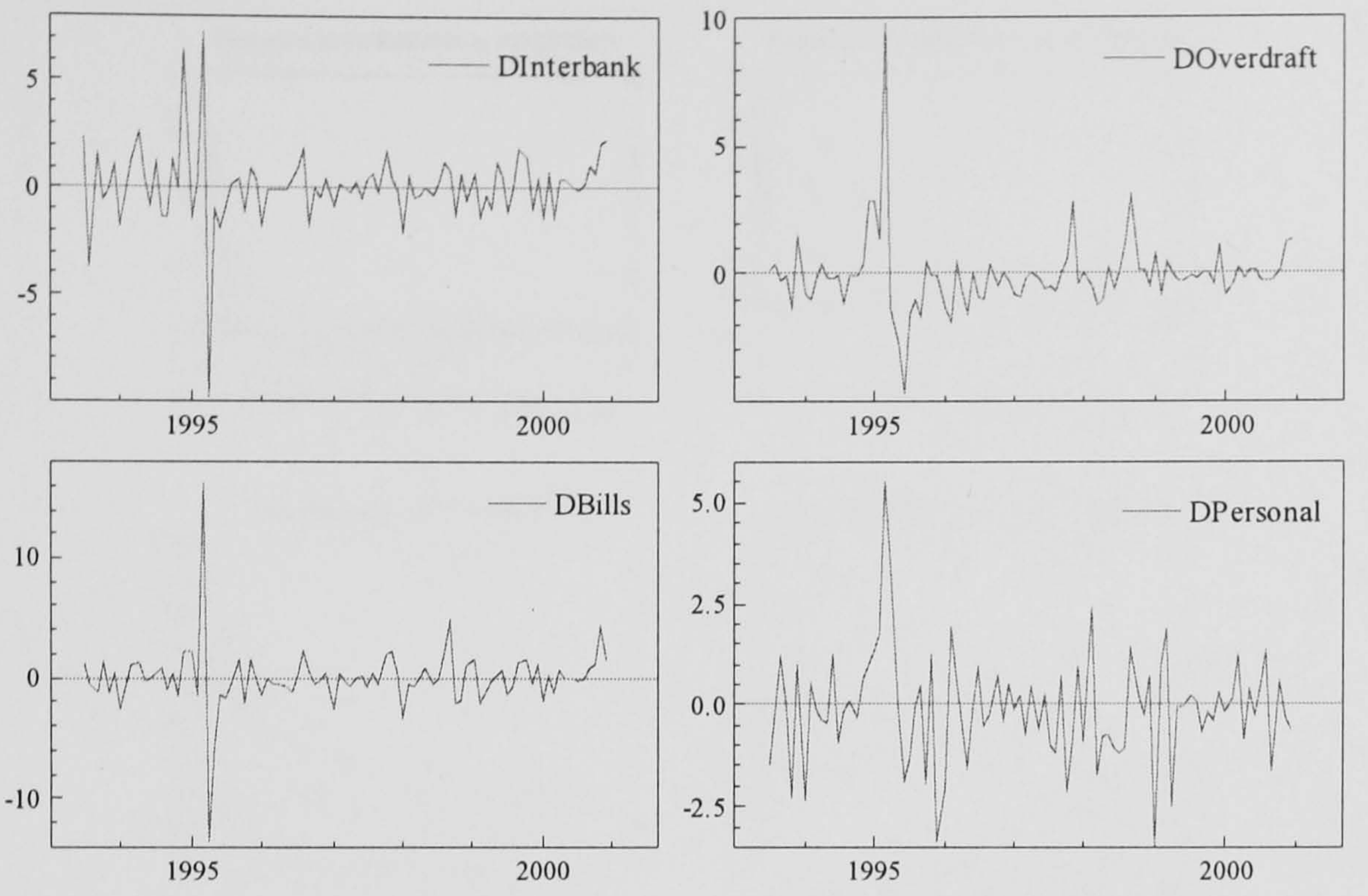


Figure 2.5 Residuals from Cointegrating Equations

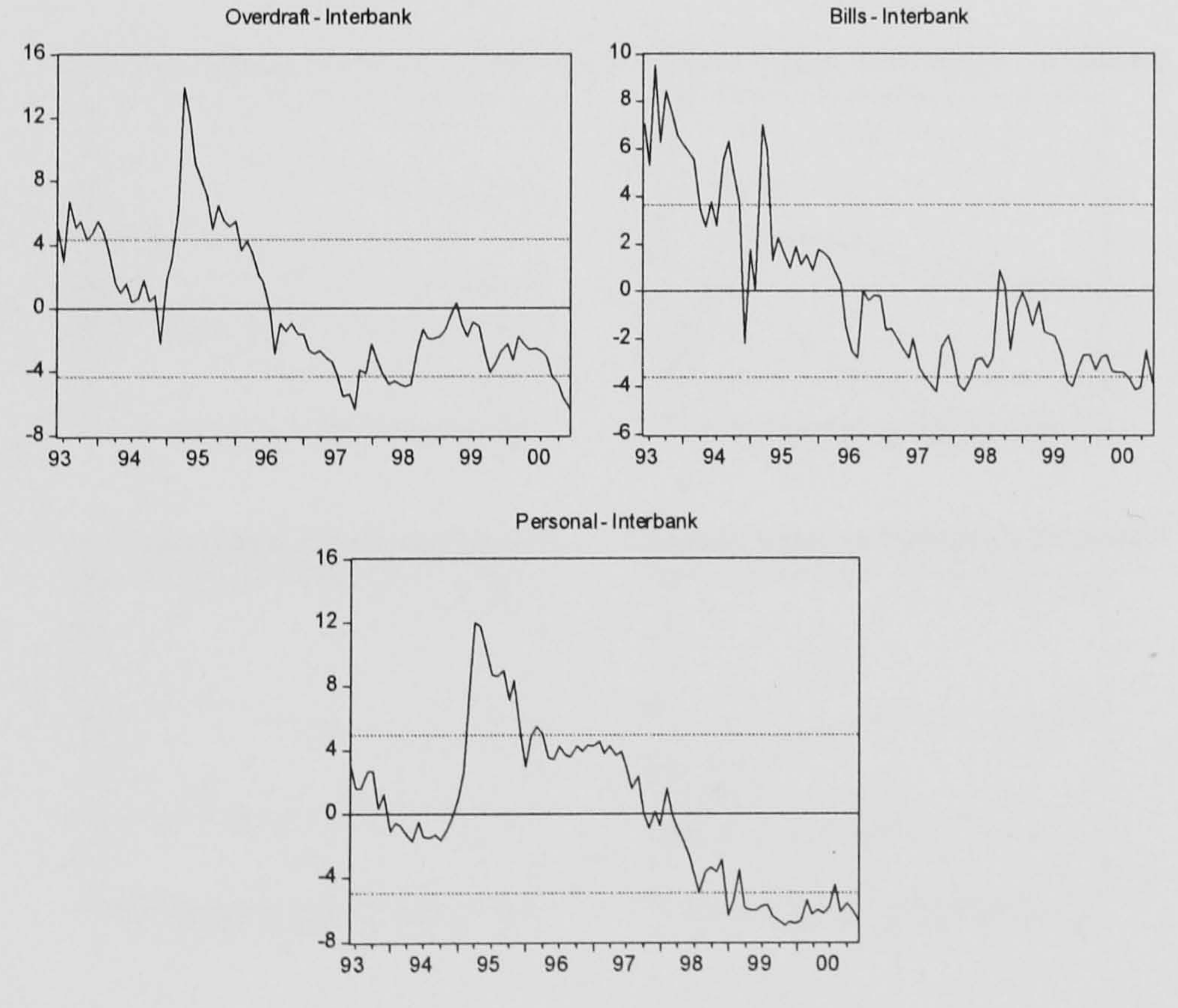


Figure 2.6 Response to Choleski One S.D. Innovations ± 2 S.E.

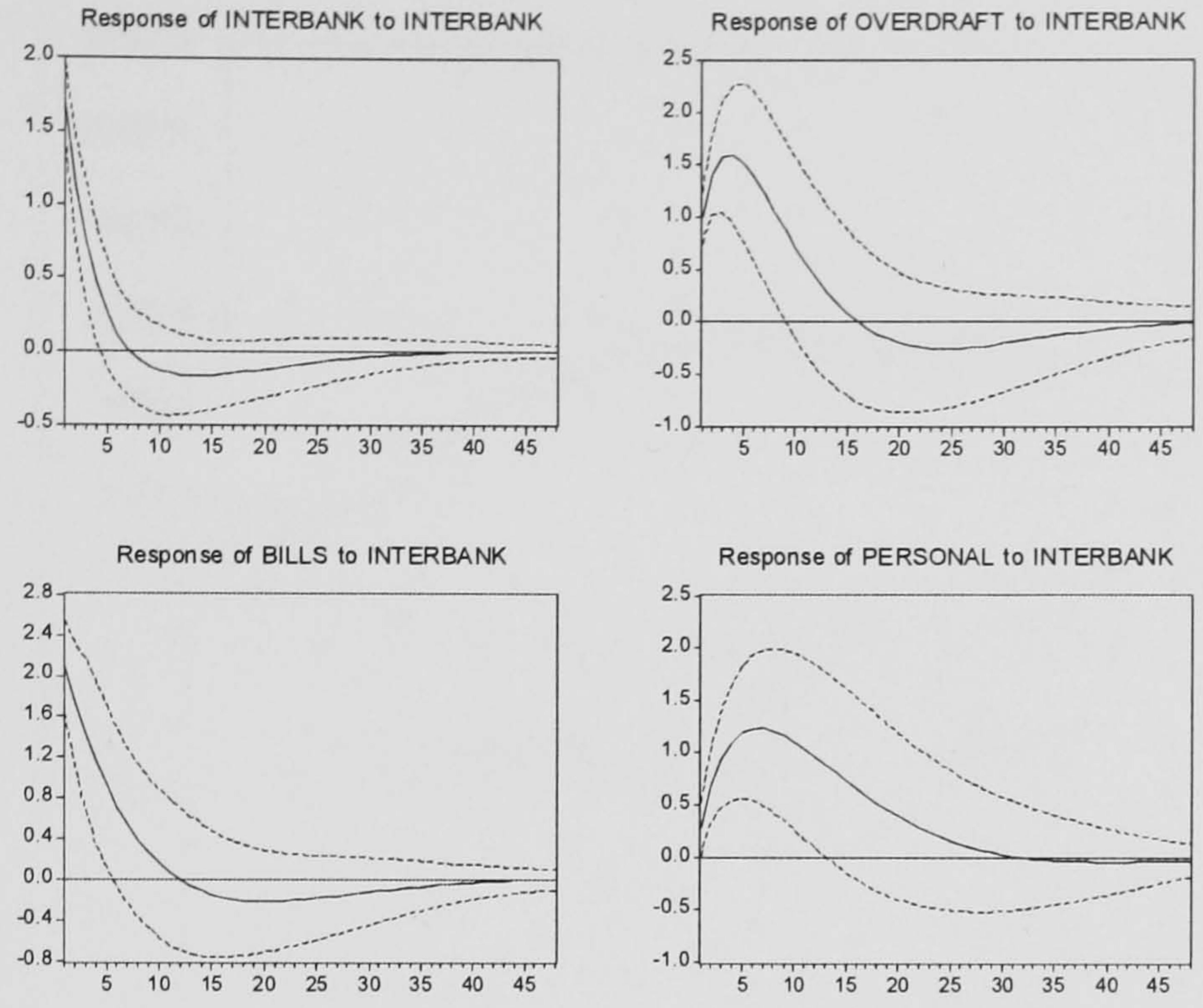


Figure 2.7 Accumulated Response to Choleski One S.D. Innovations ± 2 S.E.

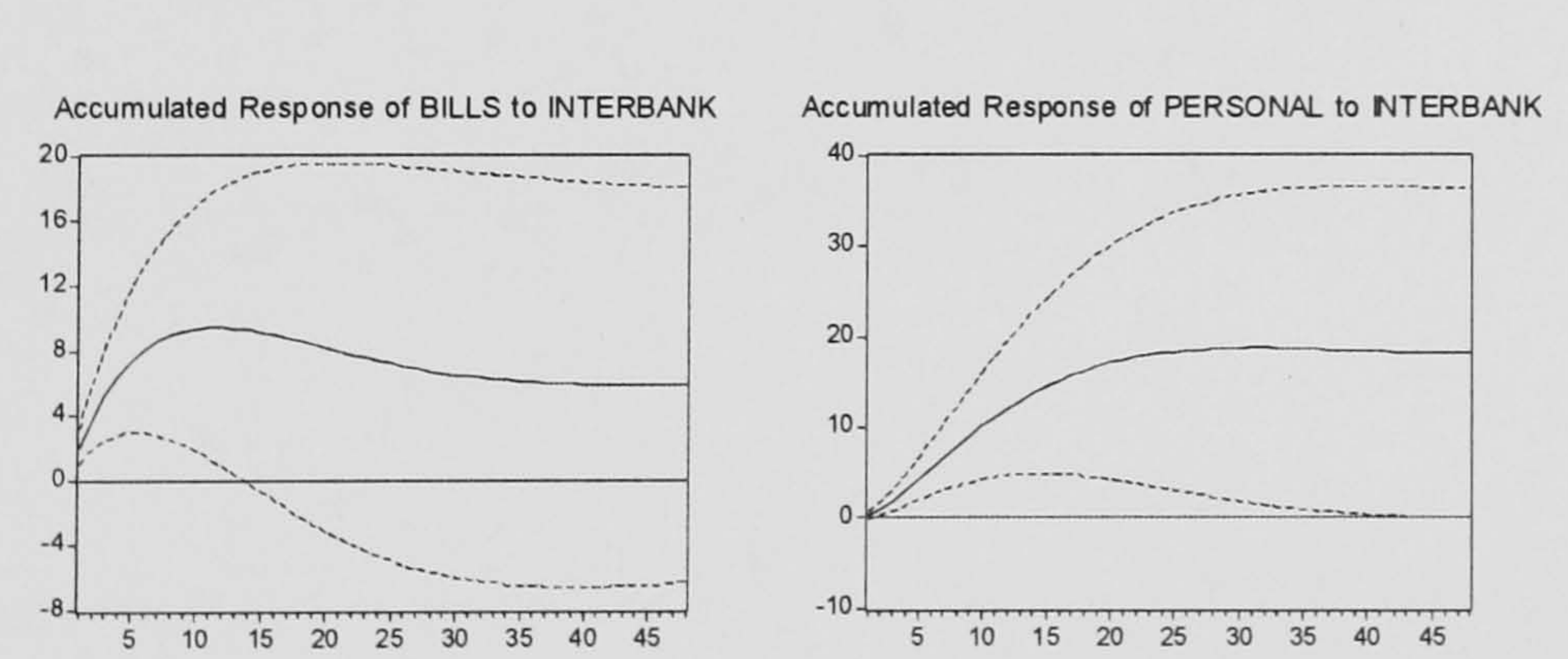


Figure 2.8 Bank Lending Rate Pass-Through from VAR(1)

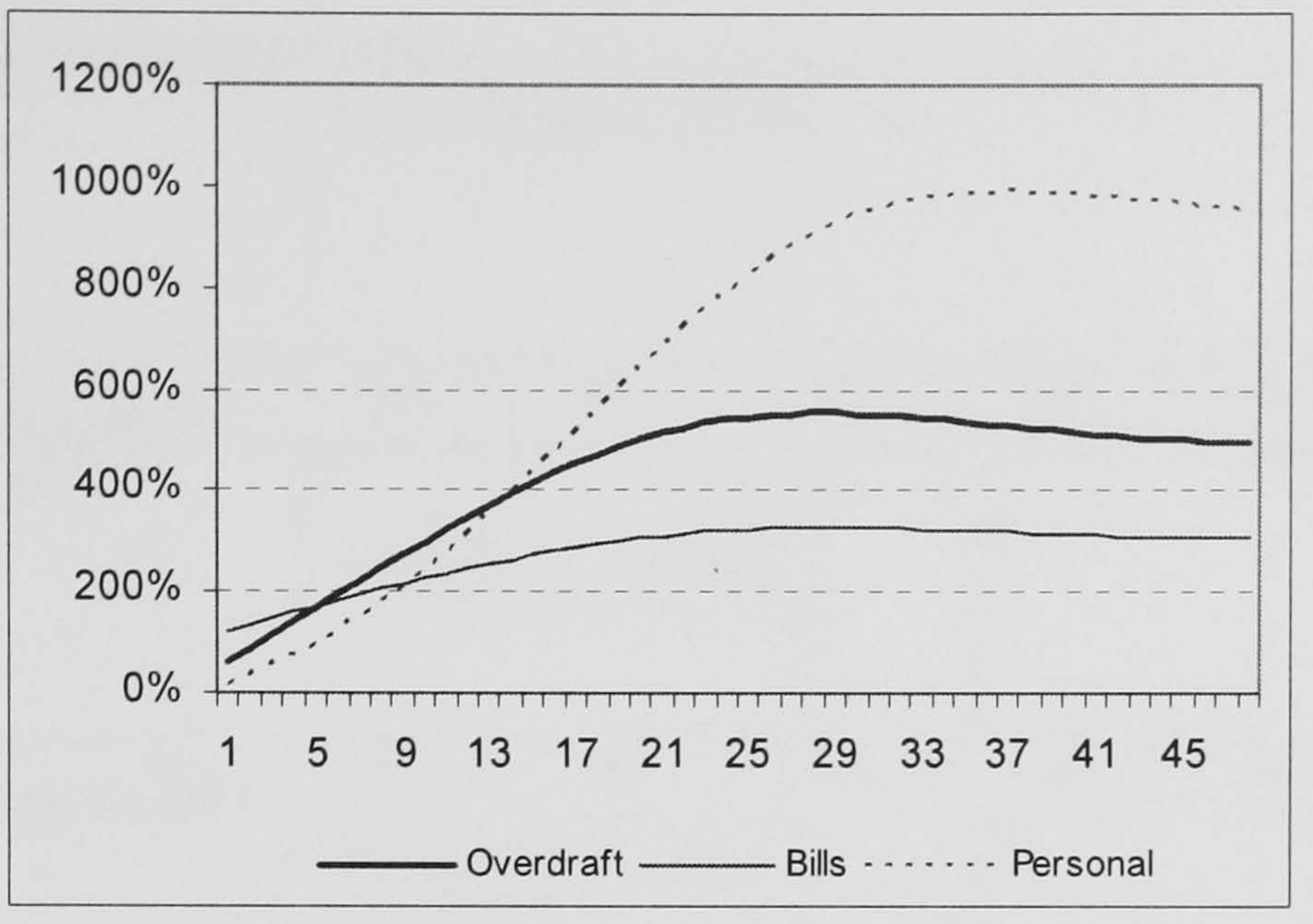


Figure 2.9 Bank Lending Rate Pass-Through from VAR(1) with Dummy

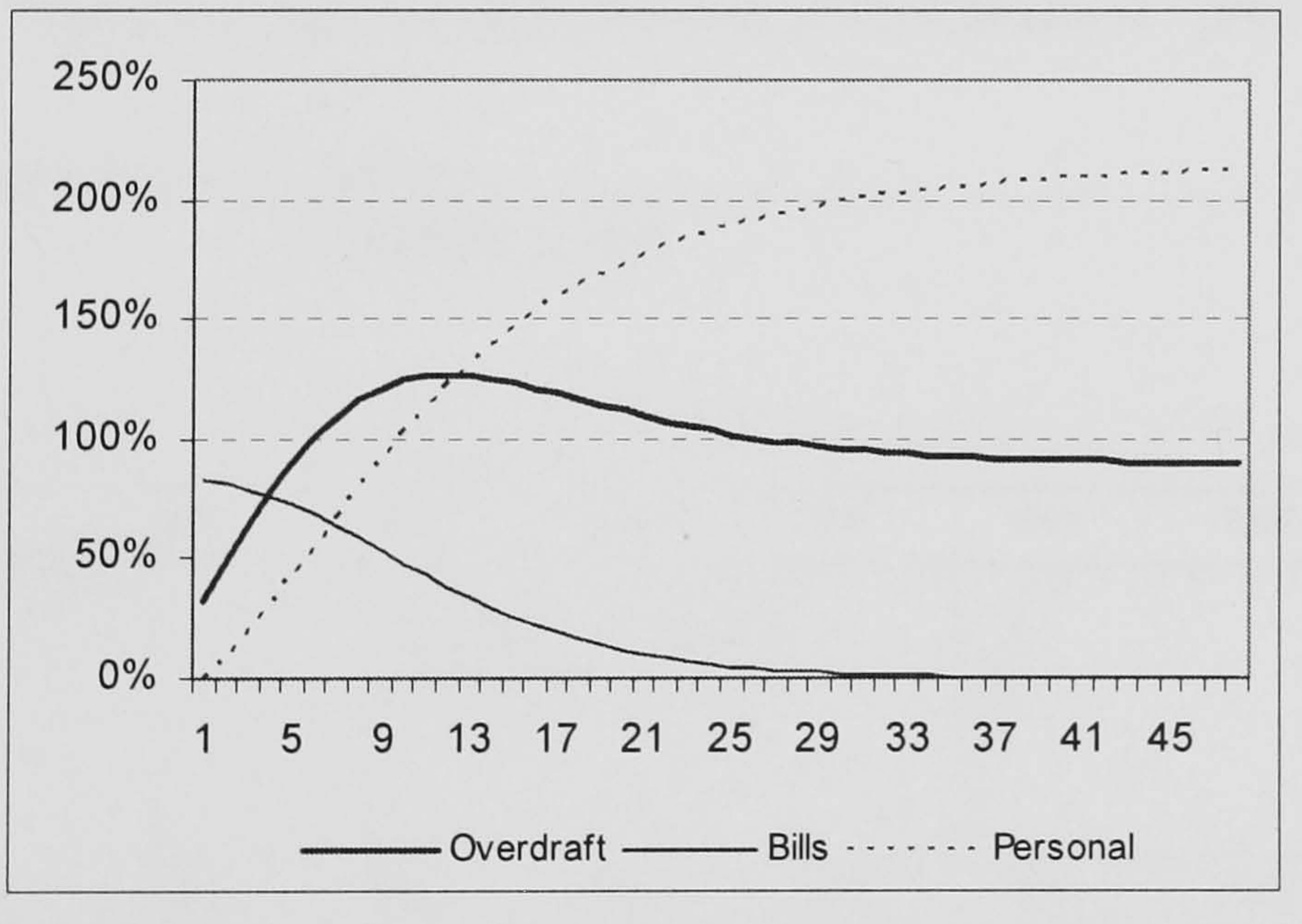


Figure 2.10 Regime Probabilities from MSVAR Interbank - Overdraft

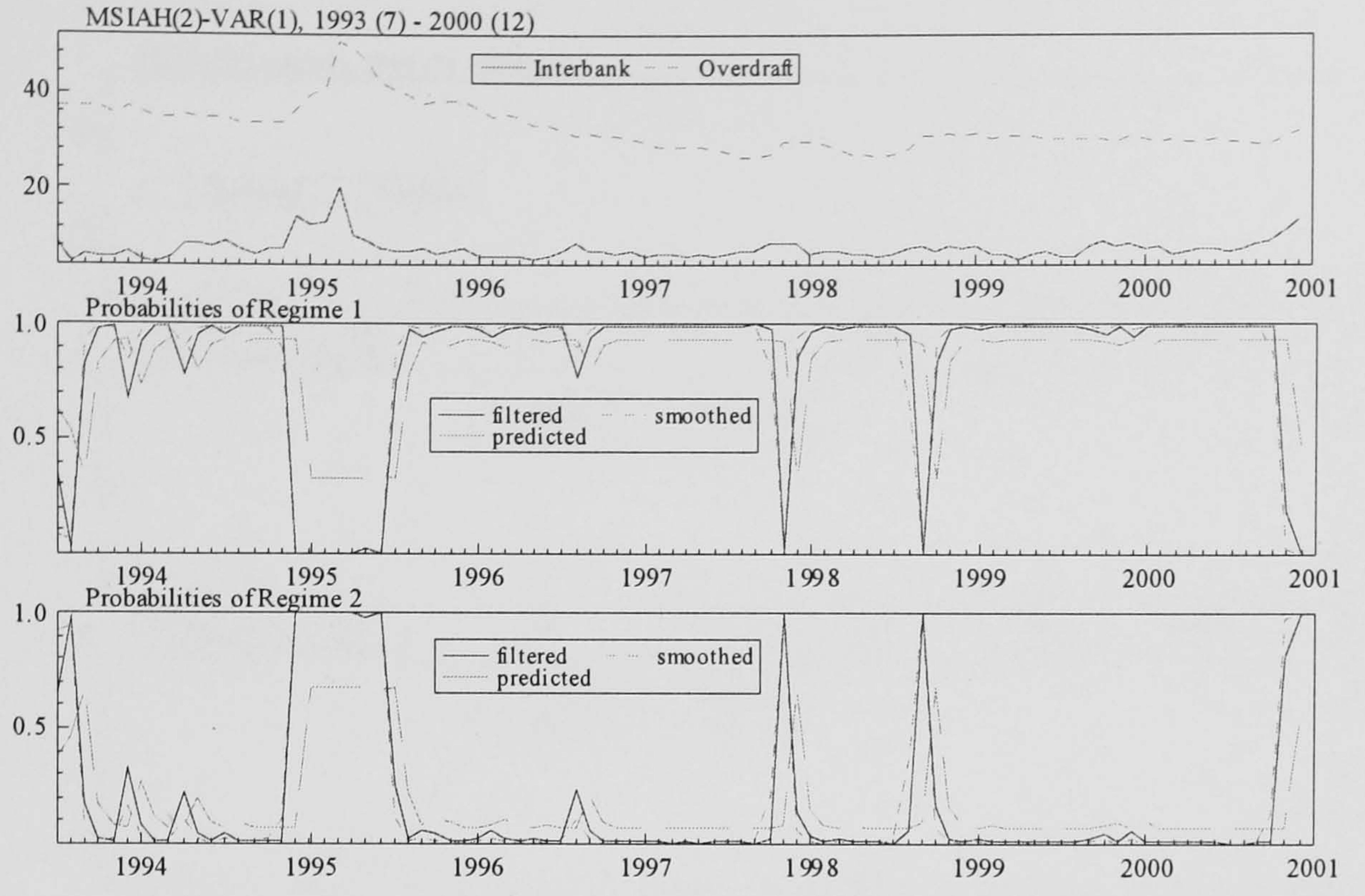


Figure 2.11 Regime Probabilities from MSVAR Interbank - Bills

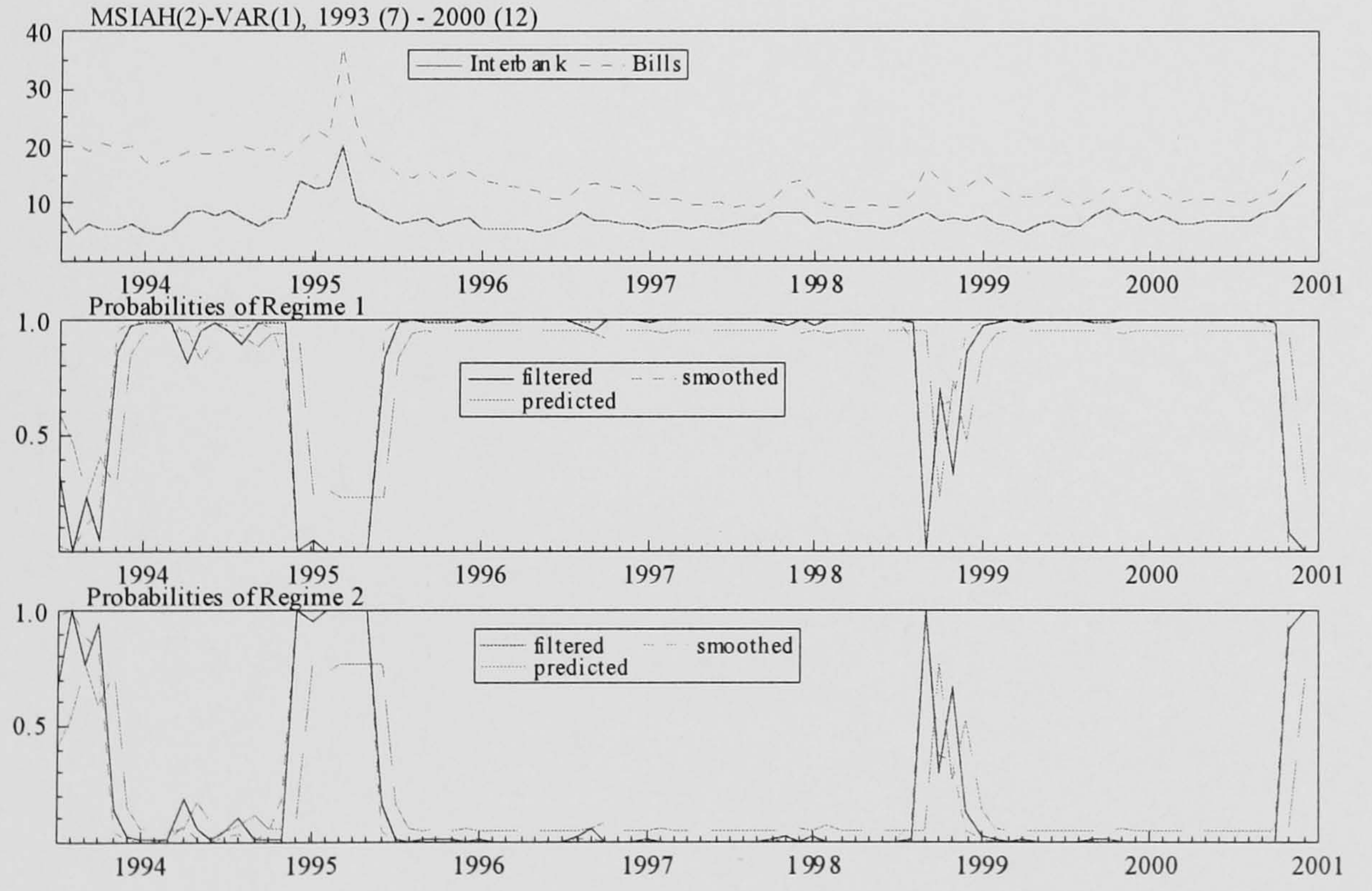
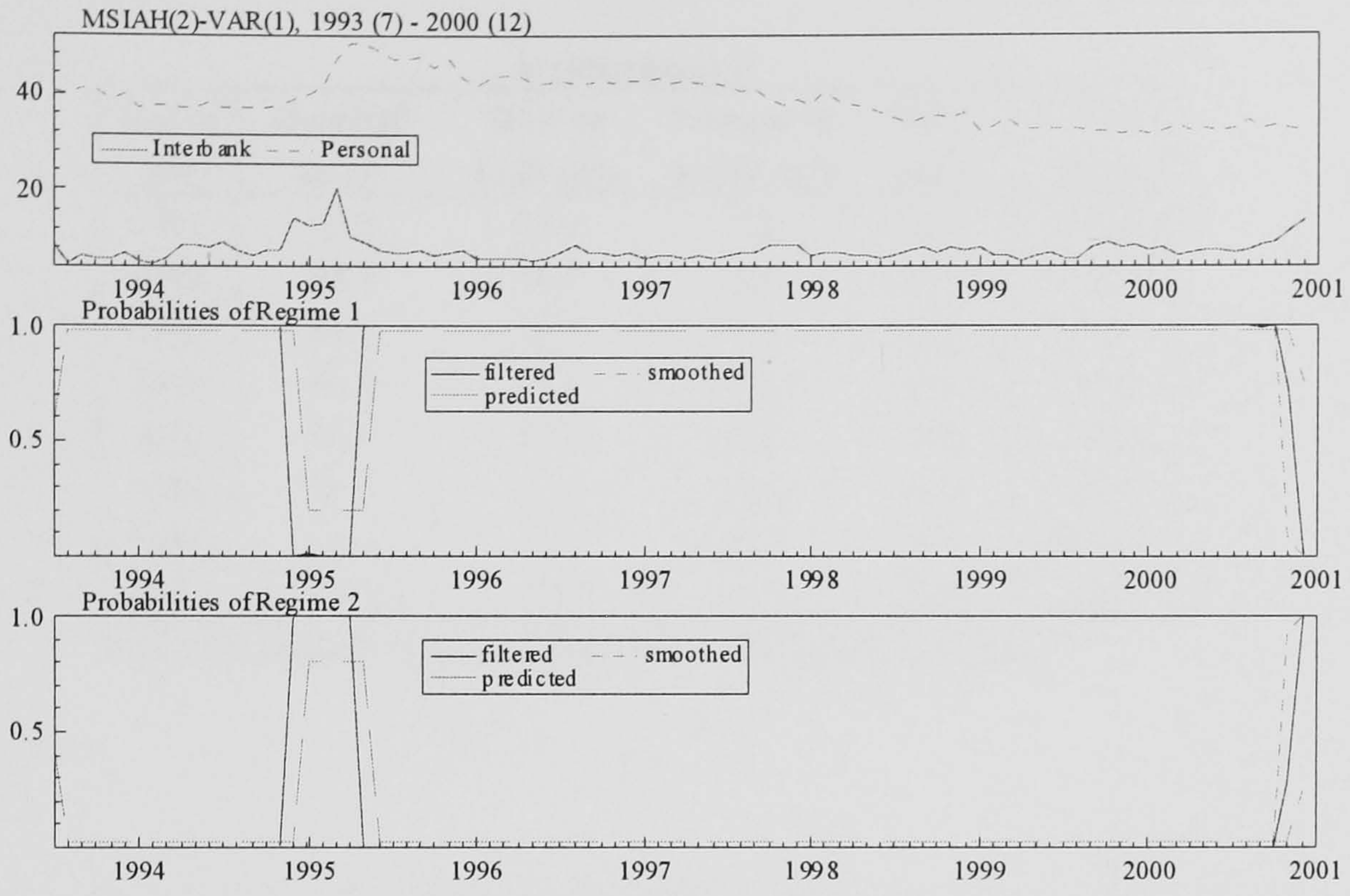


Figure 2.12 Regime Probabilities from MSVAR Interbank - Personal



Tables

Table 2.1 Loans to the Non-Financial Private Sector - Flows in Pesos

In percentages 1/

End of year	Overdraft on c/a	Bills up to 89 days	Personal up to 180 days	Other loans	Total in Pesos
1993	69.6	14.6	7.0	8.8	100.0
1994	68.4	18.0	7.2	6.4	100.0
1995	67.9	17.7	8.2	6.2	100.0
1996	68.2	15.4	9.1	7.3	100.0
1997	65.6	17.7	8.7	7.9	100.0
1998	65.1	17.8	11.4	5.7	100.0
1999	60.3	23.6	10.6	5.4	100.0
2000	60.7	22.4	11.7	5.3	100.0

1/ Source: Monetary and Financial Statistics Department - Banco Central de Argentina

Table 2.2 Descriptive Statistics of Nominal Interest Rates in Argentina

Interest rate	Mean (μ)	Std. Dev. (σ)	(σ) / (μ)	Skewness	Kurtosis	Jarque-Bera	Prob.
Interbank	7.33	2.23	0.3	2.89	14.72	647.42	0
Bills	14.23	4.57	0.14	1.76	8.61	166.25	0
Overdraft	32.69	4.74	0.32	1.42	5.61	56.5	0
Personal	38.5	4.92	0.13	0.35	2.35	3.41	0.18

Table 2.3 Correlation and Causality in Nominal Interest Rates

	Correlation with Interbank rate	Granger Causality Test (*)	
		F-Statistic	Probability
Overdraft	0.62	4.772	0.0017
Bills	0.43	10.75	5.40E-07
Personal	0.023	6.639	0.00012

Table 2.4 Augmented Dickey Fuller Test

Nominal Interest Rates 1993:06 - 2000:12	Test equation with constant	
	Level	First Difference
Interbank	-2.769	-7.592
Overdraft	-2.047	-5.246
Bills	-2.547	-8.072
Personal	-1.054	-6.403
Critical values:	1%	-3.506
	5%	-2.894
	10%	-2.584

Table 2.5 Phillips-Perron Test

Nominal Interest Rates 1993:06 - 2000:12	Lags	With constant	
		Level	First Difference
Interbank	4	-3.893	-12.544
	8	-3.746	-13.595
	12	-3.745	-13.941
Overdraft	4	-1.919	-7.307
	8	-1.759	-7.093
	12	-1.728	-7.063
Bills	4	-2.746	-12.322
	8	-2.770	-13.459
	12	-2.919	-13.922
Personal	4	-1.158	-8.956
	8	-1.220	-8.958
	12	-1.186	-8.941
Critical values	1%	-3.505	
	5%	-2.894	
	10%	-2.584	

Table 2.6 Johansen Cointegration Test Summary

Test Specification for Interbank, Overdraft, Bills and Personal Rates*						
Data Trend:		None	None	Linear	Linear	Quadratic
CE(s):		No intercept / no trend	Intercept / no trend	Intercept / no trend	Intercept / trend	Intercept / trend
Lags**	Test	Number of cointegrating vectors (5% level)				
1	Trace	0	0	1	1	2
	Max.Eigenv.	1	0	0	0	0
2	Trace	0	0	0	1	1
	Max.Eigenv.	0	0	0	1	1
3	Trace	0	0	0	0	0
	Max.Eigenv.	0	0	0	0	0
4	Trace	0	0	0	0	0
	Max.Eigenv.	0	0	0	0	0
5	Trace	1	1	0	0	0
	Max.Eigenv.	1	1	0	0	0
6	Trace	1	1	1	0	0
	Max.Eigenv.	1	1	1	0	0
7	Trace	1	1	1	0	0
	Max.Eigenv.	1	1	1	0	0
8	Trace	1	2	4	1	2
	Max.Eigenv.	1	0	0	0	0
9	Trace	2	2	4	2	2
	Max.Eigenv.	1	0	1	0	0
10	Trace	2	2	2	2	2
	Max.Eigenv.	2	1	2	2	2
11	Trace	2	1	1	2	2
	Max.Eigenv.	1	1	1	1	2

*1993:06 - 2000:12

**In first differences

Table 2.7 Engle-Granger Test for Cointegration with Interbank Rate

Variable	Coefficients		ADF t-test on residuals	Null of unit root in residuals
	c	beta		
Overdraft	25.994 (1.558)	0.914 (0.203)	-1.485	Non-rejected
Bills	4.911 (1.306)	1.272 (0.171)	-1.945	Non-rejected
Personal	38.138 (1.790)	0.050 (0.234)	-1.041	Non-rejected

* 1993:06 - 2000:12

Table 2.8 Unit Root Tests and Additive Outliers

Tests	Interbank	Overdraft	Bills	Personal
	Null Hypothesis of a Unit Root: 1993:06 - 2000:12			
Standard tests				
ADF	-2.769	-2.047	-2.547	-1.054
PP (4 lags)	-3.893 **	-1.919	-2.746	-1.158
Drop outliers				
ADF	-5.235 **	-2.802	-5.598 **	-1.322
DF-GLS	-5.161 **	-2.127 *	-3.182 **	-2.098
Ng-Perron (Mza)	-10.913 *	-3.822	-4.409	-6.574
Robust tests				
DF-GLS	-2.625 **	-1.734	-1.864	-0.783
Ng-Perron (Mza)	-15.412 **	-6.148	-6.543	-1.902
Add dummies				
Vogelsang	-1.457	-2.802	-1.888	-1.287

* Rejection at 5%

** Rejection at 1%

Table 2.9 Johansen Cointegration Test Summary with Dummy for March 1995

Test Specification for Interbank, Overdraft, Bills and Personal Rates*						
Data Trend:		None	None	Linear	Linear	Quadratic
CE(s):		No intercept / no trend	Intercept / no trend	Intercept / no trend	Intercept / trend	Intercept / trend
Lags**	Test	Number of cointegrating vectors (5% level)				
1	Trace	0	1	1	1	2
	Max.Eigenv.	0	1	1	1	1
2	Trace	1	1	1	1	1
	Max.Eigenv.	1	1	1	0	0
3	Trace	1	1	1	0	0
	Max.Eigenv.	1	1	1	0	0
4	Trace	1	1	1	0	0
	Max.Eigenv.	1	1	1	0	0
5	Trace	1	1	1	0	0
	Max.Eigenv.	1	1	1	1	1
6	Trace	1	1	1	1	0
	Max.Eigenv.	1	1	1	1	1
7	Trace	1	1	1	0	0
	Max.Eigenv.	1	1	1	0	0
8	Trace	2	3	4	3	2
	Max.Eigenv.	0	0	0	0	0
9	Trace	2	4	4	2	2
	Max.Eigenv.	2	4	2	1	1
10	Trace	2	2	2	2	2
	Max.Eigenv.	2	2	2	2	1
11	Trace	2	2	2	3	2
	Max.Eigenv.	2	2	1	1	1

*1993:06 - 2000:12

**In first differences

Table 2.10 Interest Rate Pass-Through: Estimation with PcGets (up to 3 lags)

	No outliers				Includes dummy variables for outliers			
	Coeff.	Std. Dev.	t-value	t-prob.	Coeff.	Std. Dev.	t-value	t-prob.
Overdraft								
i_{t-1}	0.9072	0.0142	64.0610	0.0000	0.9572	0.0139	68.8520	0.0000
m_t	0.5788	0.0502	11.5290	0.0000	0.3882	0.0424	9.1460	0.0000
m_{t-2}	-0.1770	0.0638	-2.7740	0.0068				
m_{t-3}					-0.2139	0.0487	-4.3920	0.0000
I1995:3					6.8339	0.9165	7.4560	0.0000
Bills								
i_{t-1}	0.8661	0.0431	20.1170	0.0000	0.7929	0.0486	16.3140	0.0000
i_{t-3}					0.1183	0.0356	3.3290	0.0013
m_t	1.3065	0.0870	15.0140	0.0000	1.1946	0.0823	14.5220	0.0000
m_{t-1}	-0.8425	0.1203	-7.0010	0.0000	-0.6997	0.1015	-6.8970	0.0000
m_{t-2}	-0.4202	0.1067	-3.9390	0.0002	-0.3480	0.0700	-4.9730	0.0000
m_{t-3}	0.2002	0.0877	2.2830	0.0250				
I1994:12					-4.9735	1.1711	-4.2470	0.0001
I1995:3					7.5879	1.2067	6.2880	0.0000
Personal								
i_{t-1}	0.9547	0.0105	91.3650	0.0000	0.9533	0.0100	95.5800	0.0000
m_t	0.2275	0.0528	4.3110	0.0000	0.2342	0.0504	4.6400	0.0000
I1999:1					-3.6633	1.1841	-3.0940	0.0020

Table 2.11 Interest Rate Pass-Through: Single Equation

Lending Rate	Equations in levels			
	No outliers		With outliers	
	α	λ	α	λ
Overdraft	0.579	4.331	0.388	4.072
Bills	1.306	1.821	1.195	1.654
Personal	0.228	5.018	0.234	5.019

Table 2.12 Interest Rate Pass-Through: Linear VAR

	Multivariate, Linear VAR(1) in levels 1/ 2/			
	Interbank	Overdraft	Bills	Personal
Interbank(-1)	0.7179 *	0.2058 *	0.0064	0.1998 *
	0.11	0.09	0.17	0.08
	6.55	2.31	0.04	2.49
Overdraft(-1)	0.0356	0.8353 *	0.0336	0.0257
	0.08	0.07	0.13	0.06
	0.43	12.44	0.26	0.43
Bills(-1)	-0.0472	0.1076	0.8179 *	0.0208
	0.08	0.07	0.13	0.06
	-0.58	1.63	6.54	0.35
Personal(-1)	-0.0670	-0.0263	-0.0746	0.9424 *
	0.05	0.04	0.08	0.04
	-1.35	-0.65	-0.98	26.01
C	4.2172 *	3.3281 *	4.2969	-0.4686
	1.72	1.40	2.65	1.26
	2.45	2.38	1.62	-0.37

1/ For each rate is shown: coefficient, standard deviation, and t-value (in that order).

2/ The * indicates the coefficient is significant.

Table 2.13 Interest Rate Pass-Through: Linear VAR with Dummy

	Multivariate, Linear VAR(1) in levels 1/ 2/			
	Interbank	Overdraft	Bills	Personal
Interbank(-1)	0.5702 *	0.0515	-0.2805 *	0.1286
	0.09	0.06	0.11	0.08
	6.30	0.88	-2.47	1.69
Overdraft(-1)	-0.0086	0.7891 *	-0.0523	0.0044
	0.07	0.04	0.08	0.06
	-0.13	18.39	-0.63	0.08
Bills(-1)	-0.0055	0.1511 *	0.8988 *	0.0409
	0.07	0.04	0.08	0.06
	-0.08	3.59	10.94	0.74
Personal(-1)	-0.0636	-0.0228	-0.0680	0.9440 *
	0.04	0.03	0.05	0.03
	-1.60	-0.89	-1.36	28.22
C	5.9042 *	5.0903 *	7.5723 *	0.3447
	1.40	0.90	1.76	1.18
	4.21	5.64	4.30	0.29
1993:3	9.9671 *	10.4109 *	19.3506 *	4.8047 *
	1.44	0.93	1.81	1.21
	6.92	11.22	10.70	3.97

1/ For each rate is shown: coefficient, standard deviation, and t-value (in that order).

2/ The * indicates the coefficient is significant.

Table 2.14 Interest Rate Pass-Through: Single Equation and Linear VAR

Rate	Short-term		Long-term	
	Single Equation	Linear VAR	Single Equation	Linear VAR
Overdraft	0.579	0.577	4.331	5.115
Bills	1.306	1.228	1.821	2.710
Personal	0.228	0.160	5.018	10.805

Table 2.15 Interest Rate Pass-Through: Bivariate Linear VAR

Standard form				Primitive form (assuming Cholesky decomposition)				
Coeff.	Overdraft	Bills	Personal	Coeff.	equal to:	Overdraft	Bills	Personal
A_{10}	3.5294	2.6222	4.6590	b_{10}	A_{10}	3.5294	2.6222	4.6590
A_{20}	1.5474	2.3926	-0.4790	b_{20}	$A_{20} - (\sigma_{12}/\sigma_{11})*A_{10}$	-0.4903	-0.8277	-1.2243
A_{11}	0.7260	0.7472	0.6901	b_{12}	$= 0$	0.0000	0.0000	0.0000
A_{12}	-0.0446	-0.0497	-0.0603	b_{21}	σ_{12}/σ_{11}	0.5774	1.2281	0.1600
A_{21}	0.2940	0.0402	0.2503	γ_{11}	A_{11}	0.7260	0.7472	0.6901
A_{22}	0.8858	0.8096	0.9626	γ_{12}	A_{12}	-0.0446	-0.0497	-0.0603
σ_{11}	2.7977	2.8018	2.7472	γ_{21}	$A_{21} - (\sigma_{12}/\sigma_{11})*A_{11}$	-0.1252	-0.8774	0.1399
σ_{12}	1.6153	3.4409	0.4395	γ_{22}	$A_{22} - (\sigma_{12}/\sigma_{11})*A_{12}$	0.9116	0.8706	0.9722
σ_{22}	1.8883	6.5804	1.4854	σ^2_y	σ_{11}	2.7977	2.8018	2.7472
				σ^2_z	$\sigma_{22} - b^2_{21}\sigma_{11}$	0.9557	2.3547	1.4150

Table 2.16 Log-Likelihood Test for Linearity

System	Overdraft - Interbank		Bills - Interbank		Personal - Interbank	
	Log - likelihood	LR linearity Test	Log - likelihood	LR linearity Test	Log - likelihood	LR linearity Test
Linear VAR(1)	-299.663		-340.309		-316.506	
MSI(2)-VAR(1)	-278.478	42.370	-325.250	30.118	-295.755	41.501
MSIH(2)-VAR(1)	-247.336	104.653	-273.838	132.942	-276.618	79.775
MSIAH(2)-VAR(1)	-244.896	109.534	-271.121	138.377	-267.597	97.817

Table 2.17 MSIAH(2)-VAR(1) Transition Matrix

Pairwise Systems	Regime 1	Regime 2
Overdraft - Interbank		
Regime 1	0.9360	0.0640
Regime 2	0.3225	0.6775
Bills - Interbank		
Regime 1	0.9560	0.0440
Regime 2	0.2343	0.7657
Personal - Interbank		
Regime 1	0.9762	0.0238
Regime 2	0.1956	0.8044

Table 2.18 MSIAH(2)-VAR(1) Interests Rate Pass-Through

Pairwise Systems	Regime 1		Regime 2	
	Interbank	Overdraft	Interbank	Overdraft
C	3.7238	1.2657	9.3902	7.4462
Interbank_1	0.5627	0.0440	0.5924	0.3898
Overdraft_1	-0.0240	0.9420	-0.1345	0.7213
SE	0.8374	0.5937	3.2200	2.6698
	Interbank	Bills	Interbank	Bills
C	3.2193	1.4854	8.7017	12.7181
Interbank_1	0.5984	-0.0613	0.8767	0.3987
Bills_1	-0.0371	0.9071	-0.3534	0.1975
SE	0.8399	1.1210	3.0850	4.7838
	Interbank	Personal	Interbank	Personal
C	4.7429	2.2716	4.0608	-14.2644
Interbank_1	0.5122	-0.0365	-0.6123	-0.1790
Personal_1	-0.0365	0.9408	0.4422	1.4736
SE	0.9086	1.0969	2.6437	1.1035

Table 2.19 Interest Rate Pass-Through: Linear Models vs. Markov Switching model

Rate	Short-term				Long-term			
	Single Equation	Linear VAR	MSIAH(2)-VAR(1) Regime 0	MSIAH(2)-VAR(1) Regime 1	Single Equation	Linear VAR	MSIAH(2)-VAR(1) Regime 0	MSIAH(2)-VAR(1) Regime 1
Overdraft	0.579	0.577	0.205	0.617	4.331	5.115	1.537	7.130
Bills	1.306	1.228	0.887	1.547	1.821	2.710	0.238	-3.373
Personal	0.228	0.160	0.059	0.444	5.018	10.805	2.333	6.493

Table 2.20 MSIAH(2)-VAR(1) Contemporaneous Correlation

Pairwise Systems	Regime 1		Regime 2	
	Interbank	Overdraft	Interbank	Overdraft
Interbank	1	0.2878	1	0.7739
Overdraft	0.2878	1	0.7739	1
	Interbank	Bills	Interbank	Bills
Interbank	1	0.7317	1	0.7511
Bills	0.7317	1	0.7511	1
	Interbank	Personal	Interbank	Personal
Interbank	1	-0.0196	1	0.9379
Personal	-0.0196	1	0.9379	1

Table 2.21 MSIAH(2)-VAR(1) Regime Classification

Regime 2: Financial Crisis	Volatility Periods in 1993:06 - 2000:12 for: Overdraft	Bills	Personal
Other 1/	1993:7 - 1993:8 [0.9315]		
Mexico	1994:12 - 1995:6 [0.9996]	1994:12 - 1995:5 [0.9995]	1994:12 - 1995:4 [1.0000]
South-East Asia	1997:11 - 1997:11 [0.9869]		
Russia	1998:9 - 1998:9 [0.9988]	1998:9 - 1998:9 [0.9968]	
Argentina 2/	2000:11 - 2000:12 [0.9891]	2000:11 - 2000:12 [0.9976]	2000:11 - 2000:12 [0.9643]

1/ This period does not correspond to any major international financial crisis.

2/ Market volatility increases substantially as market expectations of exchange rate's collapse arose.

Appendix

Bivariate Linear VAR

The original form of the system is given by the equations:

$$i_t = b_{10} + b_{12} r_t + \gamma_{11} i_{t-1} + \gamma_{12} r_{t-1} + \varepsilon_{it}$$

$$r_t = b_{20} + b_{21} i_t + \gamma_{21} i_{t-1} + \gamma_{22} r_{t-1} + \varepsilon_{rt}$$

where i_t is the interbank rate and r_t is the respective lending rate. Assuming cero the parameter b_{12} (Choleski decomposition), this system could be identified from the following standard form:

$$i_t = A_{10} + A_{11} i_{t-1} + A_{12} r_{t-1} + e_{it}$$

$$r_t = A_{20} + A_{21} i_{t-1} + A_{22} r_{t-1} + e_{rt}$$

The variance-covariance matrix from the standard form system is:

$$\Sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix}$$

Therefore, the short-term (impact) pass-through is given by the parameter b_{21} in the original form. It could be estimated as:

$$b_{21} = \frac{\sigma_{12}}{\sigma_{11}}$$

CHAPTER 3

3 MODELLING INTEREST RATE PASS-THROUGH WITH ENDOGENOUS SWITCHING REGIMES IN ARGENTINA

3.1 INTRODUCTION

Interest rate pass-through, from money market rates to lending rates, could involve nonlinearities of various kinds. The pass-through might change when greater volatility and unusual uncertain conditions in the financial markets make banks change their expectations of future adjustments in interest rates. Alternatively, regime-shifting behaviour in the pass-through could be the result of a nonlinear monetary policy. Whether exogenous or endogenous factors explain such a regime-dependent pass-through is an open empirical field. Constant transition probabilities (CTP) are usually associated to the first possibility, while time-varying transition probabilities (TVTP) suggest endogenous switching. Specification tests and data availability are criteria that would determine modelling one or another type of regime switching.

In Argentina, for instance, from June 1993 to December 2000, the interest rate pass-through from the interbank rate to rates on overdrafts, bills, and personal loans showed a marked regime-switching behaviour. A Markov-switching VAR represents the process appropriately, even with just constant transition probabilities. Regime switches coincide with the international financial crises that hit Argentina and with the building up of the currency board collapse. In general, under turbulent times in the banking system, the pass-through accelerated substantially for all lending rates.

This paper studies the interest rate pass-through for Argentina including the period that preceded and followed the collapse of the currency board by the end of 2001. A

Markov-switching model with TVTP is postulated and estimated. The objective is to seek further evidence of nonlinearities in the interest rate pass-through and to discuss the feasible sources of those nonlinearities. The study should provide, thus, a deeper understanding of banks' behaviour under highly uncertain scenarios.

If the interest rate pass-through is regime-dependent, it is then feasible that the probabilities of switching regimes were dependent upon some identifiable endogenous variables. A sound theoretical background should suggest which particular variables contain relevant information to explain TVTP as opposed to CTP. For instance, uncovered interest parity (UIP) indicates that interest rate spreads contain enough exploitable information about devaluation expectations to which, in turn, transition probabilities might be linked through time. Therefore, those spreads could be suitable leading indicators for TVTP. Empirical testing would select those variables more relevant to fulfil this role and test its validity.

A Markov-switching VAR improves upon linear models in measuring interest rate pass-through by considering two regimes and regime-varying parameters (intercept, autoregressive terms, and variance) for Argentina. Nonetheless, considering only interest rates in local currency might not be enough to capture banks' optimising behaviour in such a dual currency system. Hence, this paper also considers the relevance of lending interest rates in the foreign currency (US dollars); of depreciation expectations (as measured by interest rate differentials); and of country risk measures. Markov switching models have alternatively considered these variables as exogenous (MS-VARX) or as information variables in the TVTP.

An important discussion is about what the sources of the pass-through nonlinearity are. As some empirical papers have already shown for Argentina (as well as for the euro area), there could be nonlinearities in devaluation expectations which in turn would induce nonlinearities in interest rate differentials (through UIP). This regime switching in domestic money market rates (i.e., interbank rate) might also induce nonlinear behaviour into lending interest rates (given an industrial organization approach). As a result, the interest rate pass-through might reflect this nonlinear pattern too. Regime shifts might coincide in time for both relationships (mainly during financial crises). Nevertheless, the determinants of regime shifts or of TVTP, do not need to be the same for devaluation expectations and for the interest rate pass-through.

This chapter is organised as follows. Next section reports on the main objectives of this study. Section 3 discusses feasible sources for nonlinearities in the interest rate pass-through; applies the Markov switching approach to modelling the pass-through; and present some empirical evidence for regime shifting behaviour in interest rates. Section 4 overviews on the economic rationale of a nonlinear pass-through for the empirical case under evaluation. The following section reports on the modelling of the regime switching pass-through and presents the estimation results. Finally, Section 6 concludes and refers to further research agenda.

3.2 MEASURING THE PASS-THROUGH: WHAT FOR?

The objective of modelling the interest rate pass-through is twofold: assessing the efficiency of financial and monetary policy transmission, and understanding the banking system behaviour. On one hand, having an assessment of the magnitude and speed by which movements in the money market rates are transmitted to the market structure of interest rates provides an idea of how efficient the transmission mechanism could be. On the other hand, understanding the dynamics of the pass-through process would allow more accurate forecasting of banks' optimising behaviour so that authorities could design less distorting new policies.

This study focuses on the pass-through for lending interest rates, leaving aside that for deposit interest rates. In many Latin American banking systems, financial liberalisation and opening to international capital flows during the 1990s induced progressive international alignment for most deposit interest rates. This result is far from complete in the case of lending rates. Interest rates on loans to prime enterprises, which can alternatively access local or foreign capital markets directly, are mostly at, or very close to, international levels. In spite of this trend, interest rates on other type of loans are very much dispersed and, in many cases, well beyond comparable international levels.[1]

3.2.1 The transmission mechanism

It is usually assumed (and too often taken for granted) that monetary policy management of interest rate is smoothly but completely transmitted to the spectrum of market interest rates. Short-run stickiness in interest rates could differ substantially from one financial product to another due to different development stages in the banking system's segments. Nonetheless, with well-functioning banking systems, the long-term

[1] Even after adjusting for country risk, devaluation expectations, and other feasible risks.

impact of monetary policy actions should be complete. Even if the banking systems were not entirely competitive (as it is often the case),[2] monetary policy is considered powerful enough to transmit its financial signals to the markets.

The efficiency in the transmission mechanism is associated with the ability of transmitting (passing-through) impulses on a very short-term rate (money market rate) to the entire market structure of interest rates (first to short term rates, then to long-term rates). The policy objective would certainly be to reach real effects on the short term by affecting real interest rates and, then, consumption and investment. To decide upon a policy action, an important analysis is to determine the magnitude and lags of the expected effects on market interest rates. Moreover, this efficiency would be clearly linked to the financial market structure (market imperfections reducing policy efficiency) and agents' expectations about future evolution of market interest rates.

Taylor (1998), for example, studies monetary policy rules for a number of country and multi-country models in which the policy variable is the short-term interest rate, and in which there are alternative endogenous variables (to target) such as the rate of inflation, real output, and the exchange rate. He assesses robustness and efficiency of the monetary policy by evaluating how close the achievement of the final objective is.

Under a similar approach, Krause (2003) argues that monetary authorities follow a linear policy rule as a function of aggregate demand and supply shocks (rather than as a function of economic variables). He models the dynamics of inflation and output as functions of the interest rate (again the policy variable for the central bank). Then, he

[2] Most banking system models consider, indeed, oligopolistic markets.

measures macroeconomic performance by using a standard loss function for the monetary authorities and defining a single measure of increased stability (as the weighted sum of the observed variances of inflation and output). Thus, finally, he assesses monetary policy efficiency by looking at how close the actual performance is to the performance achievable under optimal policy.

This discussion about monetary policy efficiency is, nonetheless, well beyond the research objective of this study. The subject in this paper is the initial stage of the transmission process. Namely, how changes[3] in short-term money market rates are transmitted to the market structure of interest rates. Everything else given, the larger and speedier the effect of money market rates changes on market rates, the more likely the policy objectives from monetary authorities are to be met. In setting and evaluating their policy actions, central bankers take into consideration the lags and strength by which they can effectively affect market interest rates. Even without an independent monetary policy, determining the effects from financial conditions on short-term money market rates and, therein, into credit market rates is relevant to assess this market dynamics.

A number of transmission mechanisms might account for monetary policy effects in the economy.[4] In the traditional standard interest rate channel, a monetary contraction, for instance, leads to an increase on nominal short-term interest rates. Considering some sticky prices in the economy and rational expectations on the term structure of interest rates, there is going to be (at least at the short term) an increase in the real long-term interest rate, which in turn will push down investment and consumption of durable goods. Consequently, aggregate demand and output will decrease. This description does

[3] Whether induced by direct policy actions or by changing financial conditions.
[4] The literature on this is quite extensive. For a brief thorough review, see Mishkin (1995).

not usually mentioned though that actual investment and consumption decisions are based not on just one average interest rate, but rather on segment-specific interest rates.

The transmission mechanism actually works if the initial impact on short-term interest rates is transmitted completely (although not necessarily immediately) to the market structure of interest rates (first nominal, then real rates). That is, if interest rates on loans to enterprises, consumer spending, mortgages, overdrafts facilities and the like, respond to short-term interbank rate changes. Even if there are some other relevant monetary transmission channels, like the exchange rate channel, other asset price effects, or the credit channel (with all these channels possible enriched by a private sector expectations channel), the first link will still be related to the interest rate pass-through. In this study, the emphasis is on this initial link of the transmission mechanism, the effects of short-term money market rates on short-term market interest rates.

In the empirical case under consideration here (Argentina), the pass-through is studied from the interbank rate (rather than from an official rate) to several lending rates because of the presence of the currency board during most of the sample. Under a currency board regime for the exchange rate, monetary policy is non-independent. Therefore, there is less room for official interest rate management. What will become the benchmark for the spectrum of interest rates are the money market rates, which will be transmitting short-term financial conditions and banks' expectations on longer-term interest rates. Changes in a money market rate are transmitted in the same fashion as official rates.[5] Those changes could, for example, respond to pressures on the exchange rate market (through UIP) or from normal liquidity constraints. The type of exchange

[5] Actually, the first effect of official interest rate management should be on very short-term money market rates. In that sense, this study is picking up the link directly from those money market rates to the rest of interest rates.

rate regime might increase the probabilities of existence of nonlinear patterns in the pass-through, for example, if those nonlinearities come from financial crises stimulus.

3.2.2 Banking system behaviour

Comprehension of banks' behaviour and their optimisation procedures enhances understanding of the transmission mechanism and, thus, helps designing and implementing a particular monetary or financial policy. Empirical research should determine whether this behaviour is regime-dependent or independent of financial conditions. Nonlinear pass-through features might be entirely due to macroeconomic factors or correspond to nonlinear responses from banks to financial market conditions. Sander and Kleimeier (2003), for instance, study the pass-through in the euro zone and find asymmetries across countries possible due to structural differences such as the competitive environment in the banking market and the role of stable monetary regime.

A crucial link of the transmission mechanism is the way in which banks determine the interest rates they charge on their financial products. The opportunity cost of providing a short-term loan is the cost of those funds in the (interbank) money market. Therefore, banks will consider the interbank rate as a base cost upon which they would add some other factors. Banks will include in their loan prices (assuming non-perfect market structure) any risk they face (i.e. country risk or devaluation expectations). Thus, for example, in the dual-currency banking system in Argentina (herself a small open economy), local-currency denominated loans are priced at the corresponding foreign rate, plus a measure of country risk, of devaluation expectations, and of any particular credit risk involved in the loan.[6] Other than the credit risk, which might be sector-

[6] See Claessens and Glaessner (1998) for an example of decomposing lending rates in Argentina into macroeconomic and microeconomic risks.

specific, other factors are more generally linked to macroeconomic conditions. Shocks on those factors might very well induce a regime switching adjustment to interest rates. Accordingly, a nonlinear process should represent the pass though more appropriately.

Furthermore, microeconomic factors such as market power, demand elasticity, and operation costs could also be included in the final interest rate (depending on the market structure). Notwithstanding, at this stage, this paper assumes that all those microeconomic factors (including credit risks), although important, offer no sudden jumps that would justify a regime shifting behaviour in the interest rate pass-through.

Discussing how banks set their interest rates, Gambacorta (2004) argues that significant differences in pass-through among market interest rates are only present in the short term (but not in the long term). Besides, that short-term heterogeneity is due to segment and market characteristics mainly. He, in particular, finds that interest rate on short-term loans of liquid and well-capitalized banks respond less to money market changes.[7]

An important objective in studying the pass-through mechanism is to assess the degree of competition (or the lack of it) in the banking system. Sander and Kleimeier (2003), for example, argue that usually a less-than-complete pass-through would signal imperfect competition in the market. Moreover, if that were also the case for the long-term pass-through, it could even reflect credit rationing. Similarly, since integration seems to be a sufficient (although not a necessary) condition for pass-through convergence, pass-through heterogeneity would reveal the degree of financial integration among credit markets (or the structural differences between them). Indeed,

[7] Gambacorta studies this evidence through a panel data approach for Italian banks.

they find in their research that financial integration in euro countries is still an ongoing process, with the clear exemption of lending to enterprises. This latter result is quite similar to those found in several Latin American banking systems, in which interest rates in loans other than to prime enterprises remain largely above international levels and are quite different between countries and market segments.[8]

A bank's decision to adjust its interest rates, responding to changes on official rates or on its opportunity cost of funding, would generally be associated to whether it perceives the change as permanent or temporary. It would particularly be linked to further expectations of base rate changes (an initial shock could be reverted soon afterwards). As Hofmann and Mizen (2004) point out, when banks face adjustment costs on their rates, they might accumulate in a single rate change an expected sequence of minor official rate changes. Similarly, banks will try to anticipate turning points in the setting of official rates. In trying to anticipate monetary policy actions on interest rates, banks display a forward-looking behaviour. Therefore, how banks adjust their expectations will be crucial in determining any feasible nonlinearity in their interest rates.

In well developed and diversify financial systems, market expectations on future short-term interest rates might be inferred from money market rates (through implied forward rates).[9] Although, as Brooke, Cooper, and Scholtes (2002) argue, heterogeneity in credit specifications for money market instruments should place care in interpreting expectations inferred from those instruments.[10] A detailed assessment of those expectations might provide a helpful beforehand evaluation of what likely response

[8] Despite the fact that these economies opened their capital accounts and introduced financial liberalisation during most of the 1990s.
[9] Using the rational expectations hypothesis for the term structure of interest rates.
[10] These authors discuss the Bank of England's approach to inferring market expectations on interest rates from a number of money market rates.

market participants will show to a given policy action. Abrupt changes in those expectations, again, might induce a nonlinear behaviour from banks when adjusting their interest rates to money market rate changes.

Since banks in Argentina have the choice of operating in local currency or in foreign currency (US dollar-denominated loans), it is feasible the existence of an independent pass-through for interest rates in dollars if the market segments in which the bank operates are separated for each currency. Although this study has not estimated directly the pass-through for dollar-denominated interest rates, the relevance of these instruments is assessed as exogenous variables in the nonlinear models or as leading indicators in the TVTP.

This feature of the banking system might enlarge the probability of a regime change in the local interest rate pass-through (especially under devaluation pressures). In particular, in a dual currency banking system, the local interest rate denominated in the foreign currency will be approximately equal (assuming similar credit risk) to the foreign rate plus the country risk. Hence, the spread between the domestic rates in local and foreign currency could approximate devaluation expectations. Alternatively, the spread between the domestic interbank rate and the corresponding foreign rate might represent country risk and devaluation expectations together.[11]

[11] This is a particular important empirical issue, since most relevant measures of country risk for emerging markets are available only since 1998 (although indices are available from 1994). See Cunningham (1999) for a discussion on emerging market spread indices.

3.3 PASS-THROUGH NONLINEARITIES

The possibility that interest rate pass-through is regime-dependent is mostly important, from the economic point of view, because regime changes in financial market conditions would reasonably affect banks' behaviour. If that is the case, then monetary or financial transmission might as well be a nonlinear process. From an econometric perspective, as Filardo (1998) suggests, it is important because analysing regime switching demands inferring from the data when regime changes take place.

Most studies of interest rate pass-through have limited themselves to linear relationships, although an already large empirical literature discusses nonlinearities in short-term money market rates. A few studies, though, have indeed pointed out the nonlinearity feature in the pass-through process: Hofmann and Mizen (2004), and Sander and Kleimeier (2003) for the euro area; and Iregui, Milas, and Otero (2001) for a sample of Latin American countries.

3.3.1 Where do they come from?

If there were indeed a regime-dependent banks' behaviour, it would be relevant to discuss where the nonlinearity in that behaviour comes from. What make banks change their response to financial condition shocks would surely be associated to a nonlinearity of their expectations on future market stances or a nonlinearity of their response to those expectations. Then, feasible sources for that regime-switching behaviour are nonlinear monetary policy, financial crises, real business cycles, or asymmetric adjustment costs.

The interest rate pass-through in the case of Argentina, for instance, showed empirically a regime-switching behaviour in the period June 1993 to December 2000. It showed an increase in the pass-through for three lending rates for those occasions in which the banking system was hit, to different degrees, by three major international crises (Mexico 1994, South East Asia 1997, and Russia 1998) and by a highly domestic-generated uncertain period (that finally lead to the collapse of the currency board).[12]

3.3.1.1 Nonlinear monetary policy

Nonlinearities in interest rates could be the result of a nonlinear behaviour from monetary policy authorities. Under normal circumstances in the money market, monetary authorities could concentrate themselves in interest rate smoothing (so that the interest rate path is consistent with a random walk, unit root behaviour). Nevertheless, under highly volatile situations (shocks) policymakers might change into a more inflation-fighting response (a higher degree of mean reversion). Ang and Bekaert (2002) argue in this direction especially for the case of the US Fed interest rate management (over a sample from 1972 to 1996). They use a Markov switching bivariate VAR with TVTP to capture this nonlinear behaviour in the short-term rate. The spread between the short-term and long-term rate contains useful information about expected inflation and, thus, reflects feasible changes in regime.

Erlandsson (2002) also argues that nonlinearities in short-term interest rates could be the result of nonlinear monetary policy actions that aim at, for example, defending a fixed exchange rate regime. He focuses on the dynamics of the money market (interbank) rate rather than on interest rates on bonds. His regime-switching model, including ARCH effects, improves on fitting and forecasting the data for Swedish interest rates. As in Ang and Bekaert (2002), interest rate spreads include important information on the evolution of short-term rates, reflecting market expectations.

[12] Under similar considerations, Hofmann and Mizen (2004) find evidence of nonlinear behaviour in the adjustment of retail rates to official rates in England. They use a nonlinear error correction model.

The interest rate pass-through measures the response from (lending or deposit) market interest rates to shocks on money market rates or on official rates (transmitted through money market rates). Therefore, if those money market rates are subject to regime shifting because of monetary policy actions, then the interest rate pass-through should also show a nonlinear pattern.

3.3.1.2 Financial crises and uncovered interest parity

Several previous studies have discussed nonlinear relationships between exchange rates and interest rates. Most notably, Dahlquist and Gray (2000) linked nonlinear behaviour in interest rates (differentials) to exchange rate realignment expectations through UIP. Not only exchange rate movements and/or international reserves adjustments (especially if there is official intervention) but also interest rate differentials adjustments reflect pressures on the foreign exchange market. For this reason, changes in the money market rates would respond not only to domestic monetary policy but also to external factors exacerbating devaluation expectations (such as an international financial crisis that spills over the domestic financial system).

If the domestic money market rate moves nonlinearly because UIP, then the response of lending rates to those changes might as well be nonlinear. Namely, the pass-through might also be a nonlinear process. Although some authors have previously pointed out the presence of nonlinearities in the interest rate pass-through (mostly in the form of asymmetries in the response),[13] not many have emphasized this link through UIP.

The basic formulation for the UIP is:

[13] See, for instance, Bondt (2002) and Scholnick (1996).

$$(1+i_t) = \frac{(1+i_t^*)(1+\phi_t)S_{t+1}^e}{S_t} \tag{3.1}$$

This relationship equals the proceedings from a time investment in the local currency at an interest rate i_t (left hand side of the equation) with the yield of an investment, over the same period of time, on the foreign currency at an interest rate i^*_t, adjusted by country risk φ_t (right hand side). To make amounts equivalent, this investment is first transformed into foreign currency at the exchange rate S_t and, at maturity, transformed back into local currency with the yet unknown (expected) exchange rate S^e_{t+1}.

The following expanded form represents empirically the UIP relationship:[14]

$$i_t = i_t^* + \phi_t + E(\Delta s_t) + \gamma \tag{3.2}$$

where $E(\Delta s_t)$ represents the expected change in the exchange rate (devaluations expectations) and γ is a term included to represent any remaining risk premium. Therefore, this UIP formulation suggests that if there is a regime switching behaviour in devaluation expectations, then the process that governs short-term interest rates should also be nonlinear. This paper suggests that this behaviour in money market rates is also transmitted to the interest rate pass-through.

Nonlinear behaviour in interest rate (differentials) has also been studied through links to currency crises and speculative attacks, assuming implicitly that UIP holds. In particular, Martínez (2002) argues that speculative attacks apart from causing large depreciations could alternatively induce sharp falls of reserves or increases in interest rate differentials if authorities try defend the currency. Hence, under currency pressures, those variables will show high volatility in contrast to a more stable behaviour under

[14] Taking logarithms in both sides of the equation and using the approximation $log\,(1+i_t) = i_t$.

normal circumstances. Again, interest rate spreads (between local and foreign rates, rather than between short and long term rates) will reflect market (devaluation) expectations that might signal changes in the transition probabilities between regimes.

Interestingly, however, not only a direct speculative attack to a currency might generate nonlinear behaviour in domestic money market rates (in turn transmitted to other lending rates). International financial crises hitting by contagion a domestic economy might have the same effects in short term interest rates. In particular, major international financial crises during the 1990s (Mexico 1994, South East Asia 1997, and Russia 1998) translated into high degree of uncertainty in many emerging markets. Besides, those crises' effects were evident not only on financial prices but on quantity variables as well (such as the shortage of short-term international capital inflows). In some cases, those pressures induced also banking crises that put further pressures on bank pricing.

Whether the regime shifting is associated to the currency crisis in itself or to the banking crisis that accompany it is an empirical issue. In as far as both kinds of crises do not necessarily share causes, but might share similar market response in interest rates (a higher volatility), it is important to determine empirically which one is fundamental in inducing a nonlinear behaviour in bank price setting.

Recent studies emphasising nonlinear behaviour in either interest rates or exchange rates (under speculative attacks or financial crises) implicitly or explicitly assume UIP holds. See, for example, Dahlquist and Gray (2000), Fratzscher (2002), Mandilaras and Bird (2003), and Martínez (2002) for the euro zone; Jeanne and Masson (2000) for France; Frömmel, MacDonald, and Menkhoff (2002) for US, Japan, UK and Germany;

Alvarez-Plata and Schrooten (2003), and Boinet, Napolitano, and Spagnolo (2002) for Argentina; and Cerra and Saxena (2002) for Indonesia. Many of them adopt Markov switching models to describe the latent variable state, with either CTP or TVTP.[15]

3.3.1.3 Real business cycle

Other studies have associated nonlinearities of the term structure of interest rates to stages in the real business cycle. See for example Ahrens (2002), Hofmann and Mizen (2004), Sander and Kleimeier (2003), Clarida, Sarno, Taylor, and Valente (2002). The most common link between interest rates and the business cycle is the assumption that financial prices contain enough exploitable information on market expectations about the future path of the economy (expectations theory of the term structure).

Ahrens, for instance, points out that monetary policy action could induce changes in those expectations, in both short- and long-term rates. Since those actions would probably affect the real sector with longer lags than the financial sector, then movements in the term structure would give signals about turning points in the business cycle. In addition, since inflationary expectations are associated to long-term interest rates and recessions are usually linked to low inflation rates, a decrease in the slope of the yield curve might be reflecting expectations of a turndown in the economic cycle. Indeed, as Clarida, Sarno, Taylor, and Valente (2004) suggest, "*business cycle expansions and contractions may have statistically and economically important first-order effects on expectations of inflation, monetary policy and nominal interest rates*".[16]

[15] In modelling exchange rate pressures through a Markov switching model, the dependent variable might be a pressure index including the (change of) exchange rate, international reserves, and interest rate differentials, or these same variables but into a VAR specification.

[16] These authors also include, in their search for sources of nonlinearity in interest rates, price inflation as an objective variable in a Taylor-rule type logit model for the transition probabilities of an MSIH-VECM.

Therefore, turning points in the business cycle could be reliably preceded by regime shifts in interest rate term spreads. Once again, if money market short-term rates show nonlinear behaviour, then the process by which they are transmitted to the market structure of interest rates should also contain a nonlinear pattern. A change in the speed by which money market rate changes are transmitted into market lending rates might then be associated to changes in market expectations about the business cycle.

3.3.1.4 Adjustment costs

Banks could react to money market rates changes in a nonlinear fashion if there are non-negative adjustment costs. Beyond certain values of the spread to the official rate, the lending rate would be adjusted if the cost of doing so were surpassed by the cost (loss) of not responding to the change (Hofmann and Mizen (2004)). This nonlinearity could be asymmetric in the sense that for a given positive spread between the lending rate and the money market rate, it is more likely that a bank will adjust its retail rate if the money market rate is expected to fall (and the contrary if the spread is negative). Furthermore, the interest rate pass-through would accelerate if the expected differential in the money market rate (between its current level and the expected future level) widens and it would fall if that differential tightens.

It is worth noticing here that, changes in money market rates do not need to be nonlinear to generate a nonlinear response in interest rate. As far as there are menu costs in the adjustment of retail (lending) rates greater than those usually faced by central banks in changing their interest rates, then a nonlinear response from banks is likely. Hofmann and Mizen do not (explicitly or implicitly) mention any need for money market rate changes being nonlinear. Nonetheless, the required increase in the differential might imply unusually large shocks to accelerate the pass-through. This might correspond to a regime-shift in money market rates.

3.3.2 Modelling regime shifting

Given the nature of the nonlinearities discussed in the pass-through, an appropriate modelling is the Markov-switching type of models, in which the probability of being in a regime in any one period is conditional on a fixed (probably small) number of previous regime occurrences (persistence in states). Alternatively, standard linear models generally consider single or multi-equations lag distributed systems to estimate the pass-through. Importantly, if the pass-through were subject to regime shifting, linear models could underestimate or overestimate it depending on the market uncertainty. Using a regime switching model (as oppose to inserting dummy variables) would allow for the presence of an arbitrary number of structural breaks for which the timing is unknown (Garcia and Perron (1996)). Of course, if the structural break occurs only once and at a known date, there is no need to specify a nonlinear model.

Modelling the pass-through as a nonlinear process, where regime switches imply a time-varying pass-through, is consistent with a banking optimisation process that consider adjusting expectations at a different speed under normal conditions and in a situation in which uncertainty is greater. The seminal model of Hamilton (1994) considers an exogenous changing model in which the transition probabilities from one regime to another were constant or exogenous to the system (and not explicitly modelled). This model proved to be quite useful to represent the real business cycle, for which economic behaviour depends on being on an expansion or on a recession.

Markov switching models have also been applied to financial economics to detect nonlinear behaviour in the term structure of interest rates and in exchange rates. See for example Gray (1996), Hamilton (1994), Hamilton (1988), Gavin and Hausmann (1996), Jeanne and Masson (2000), Mandilaras and Bird (2003), and Martínez (2002). Indeed, the time series characteristics of regime-switching models make them suitable to accommodate, for instance, unit root regimes and remain covariance stationary (Ang and Bekaert (2002)). Thus, these models are appropriate to capture nonlinearities in short-term interest rates. Hence, this study advocates that Markov switching models are also suitable to capture the nonlinear behaviour in the interest rate pass-through.

3.3.2.1 Markov switching models

The initial application of regime switching models to dynamic macroeconomics is the constant transition probability (CTP) Markov switching model from Hamilton (1989). An appealing extension is the case with time-varying transition probabilities (TVTP), in which the feasibility of being in a particular regime varies along with some information variables. Most initial applications of Markov switching models referred to the business cycle. Financial economics applications are more recent and more oriented to the term structure of interest rates or to exchange rates. For a recent survey of contributions in Markov switching models, see Hamilton and Raj (2002). This section describes the Markov switching model, emphasising its application to the interest rate pass-through.

The relationship between one (or more) short-term retail interest rate and a short-term money market rate, whether in a single equation or a multi-equation system, is subject to regime switching if the relationship parameters change according to what state or regime the financial system is at in each period t. A general representation of the switching model for the interest rate pass-through would then adopt the following nonlinear (standard form) VAR representation:

$$y_t = v(s_t) + \sum_{j=1}^{m} A_j(s_t) y_{t-j} + u_t \tag{3.3}$$

where the error term u_t is assumed a Gaussian innovation process: $u_t \sim$ NID$(0, \Sigma(s_t))$.

The time series vector y_t contains observed endogenous variables (interest rates) and the regime is given by the unobservable variable s_t. If only two regimes, the state variable can take on the values *0* and *1*. In this general representation, all the parameters are regime-dependent (constant, autoregressive, and variance of errors). The model could also include a vector of observed exogenous variables (some other macro or micro economic variables) as in:

$$y_t = v(s_t) + \sum_{j=1}^{m} A_j(s_t) y_{t-j} + \sum_{i=1}^{n} B_i(s_t) x_{t-i} + u_t \tag{3.4}$$

where the error term is again a Gaussian innovation process conditional on s_t.

The short-term pass-through is the impact response of a lending rate to shocks in the contemporary money market rate. Therefore, estimating equations (3.3) or (3.4) will not directly provide the pass-through. It needs to be derived from those parameters by estimating back the primitive form of the nonlinear VAR system. For that purpose, the Choleski decomposition, with the interbank rate first in the ordering, is validly applicable since the money market rate is likely to be exogenous to the system. The long term pass-through will be determined from there by referring to the sum of the autoregressive parameters for the money market rate (from the contemporary to the last lag) divided by the factor one minus the sum of the autoregressive parameters in the lending rate. Given the nonlinear VAR system, both the short-term and the long-term interest rate pass-through will thus be regime-dependent.

The vector x_{t-j} of exogenous variables could comprise some other relevant variables influencing the level (or first difference)[17] of the retail interest rate. These exogenous variables are usually macroeconomic variables explaining market characteristics or microeconomic factors governing the bank optimisation process. The empirical literature has usually left aside this vector for estimating the pass-through. It has rather been used on a second stage to explain the differences in pass-through between different retail rates.[18] Nevertheless, this does not need to be the case. Those variables could also be used directly to estimate the interest rate pass-through, rather than just explaining (once it is estimated) its heterogeneity. Of course, it will be an empirical issue to determine which representation is suitable for a given set of interest rates.

If a regime-switching model is postulated to represent feasible nonlinearities in the data, then the change in regimes become itself a random variable (Hamilton (1994)) and, so, it needs to be modelled as well. A discrete random variable would describe the finite number of possible regimes. For realizations of the data, there would also be a time series realization of the regimes prevailing at each possible observation, although this variable will not be directly observable. All that can be done is to infer the probability that a particular regime has occurred at each observation period.

[17] Depending on the time series properties of the interest rates under study, the system could be represented in the level of the variables (the VAR representation) if there is mean-reversion on the rates or in differences (in which case it would become a Markov switching VECM) if they contain unit roots.
[18] Frequently, it has been used for panel data estimation or cross-section studies to determine different characteristics in the market segments for each retail rate (or differences between countries).

For the interest rate pass-through to be a nonlinear process, banks should face different states in the financial markets so that they derive different responses to those conditions. A major financial market feature is the level of uncertainty prevailing at any particular time. Therefore, the regimes or states under consideration would certainly be associated to either calm conditions or turbulent times in the market. Moreover, volatility of some observable market variables (prices and/or quantities) would certainly reflect those regimes. This study emphasises the price variables since they transmit more readily all available (or lack of) market information.

Appropriately, then, a two-regime model could describe efficiently any feasible nonlinear behaviour in the pass-through. Alternatively, of course, the model could add a third regime for those states in which volatility increases but not as much as under the turbulent regime. Estimating more than three regimes would probably represent efforts to over fitting the data. Therefore, this research considers models up to only three regimes.[19] Again, empirical testing or sound economic rationale, should guide the researcher to determine the number of regimes in the system.

The regime-switching model then needs to describe the laws governing the transition from one regime prevailing at any particular time to a regime occurring next period, the so-called transition probabilities. Once a regime changes, if there were some degree of persistence in the new one, then the transition probability would depend on past values of itself (which regime occurred before). A plausible description of such a pattern is to assume that the unobserved regime variable follows a Markov chain process.[20] A

[19] Also because with more parameters to estimate, the required amount of data increases considerably.
[20] For a brief, still thorough, introduction to Markov chains, see Hamilton (1994).

Markov switching regime assumes that the transition probability at any time t is related to the past only through the most recent realization of regime (at time t-1).

Assuming two possible regimes for the pass-through, the discrete random variable s_t could take the value 0 for the calm regime and the value 1 for the turbulent regime. Correspondingly, assuming the probability of s_t taking a particular value j depends only on the value i it took one period before (a Markov chain process), there would be up to four transition probabilities:

$$\Pr(s_{t+1} = j \mid s_t = i) = p_{ij} \tag{3.5}$$

alternatively, stating them out explicitly:

$$\Pr(s_{t+1} = 0 \mid s_t = 0) = p_{00} \tag{3.6}$$

$$\Pr(s_{t+1} = 1 \mid s_t = 0) = p_{01} \tag{3.7}$$

$$\Pr(s_{t+1} = 0 \mid s_t = 1) = p_{10} \tag{3.8}$$

$$\Pr(s_{t+1} = 1 \mid s_t = 1) = p_{11} \tag{3.9}$$

As they are, these would be constant transition probabilities. Note that it should necessarily be the case that:

$$\sum_{j=1}^{M} p_{ij} = 1 \forall i, j \in \{1, 2\} \tag{3.10}$$

That is, $p_{00} + p_{01} = 1$, and $p_{11} + p_{10} = 1$ (where M is the number of regimes, ie. 2). The so-called transition matrix P collects these probabilities to represent the 2-state Markov process s_t:

$$P = \begin{pmatrix} p_{00} & p_{10} \\ p_{01} & p_{11} \end{pmatrix} \tag{3.11}$$

This matrix assumes that each p_{ij} is less than one, so that although a regime could be persistent, it is not absorbent (once the system reaches a regime, it stays there indefinitely).[21] The possibility to change into the other regime is always positive. Another assumption for the transition matrix is that one of its eigenvalues is *1* and the other(s) is inside the unit circle.[22] Therefore, the eigenvector associated to the unit eigenvalue will define the vector of unconditional (ergodic) probabilities:

$$P(s_t = j) = \begin{pmatrix} (1-p_{11})/(2-p_{00}-p_{11} \\ (1-p_{00})/(2-p_{00}-p_{11} \end{pmatrix} \tag{3.12}$$

The first (second) element of this matrix of ergodic probabilities represents the (unconditional) probability that the Markov process will be in regime *0* (*1*) at any period. These two characteristics (assumptions) mean that *P* represents an irreducible ergodic Markov process.

The exact nature and specification of the pass-through process would definitely be an empirical issue, one that requires testing not only for the presence of the nonlinear behaviour (and how many regimes are involved) but also for which parameters switch between regimes. Furthermore, as it will be discussed below, it will also require determining if the transition probabilities are constant or time varying. Thus far, equations (3.3) (or (3.4)), (3.5), and (3.10) combined will give the representation of a Markov switching VAR with all regime-dependent parameters and with CTP.

In empirical studies, there has not been a single approach to testing for the existence of switching regimes. Some authors do not explicitly mention the issue and rely more on

[21] It would be equivalent to estimate a linear model, in which there is no regime shifting.
[22] Since the columns of P sum one, unity is one of its eigenvalues.

interpretation of their models, such as Ahrens (2002), and Mandilaras and Bird (2003). Others have focused more on testing a regime-switching model with TVTP against the alternative of CTP using a LR test, such as Ang and Bekaert (2002), and Dahlquist and Gray (2000). They implicitly assume the existence of regime switching and concentrate on describing the type of transition probabilities.

A major test for the presence of nonlinearities is usually the economic rationale behind the model and its data supporting features. It has to be related also to improvement on forecasting abilities of the models postulated as regime switching. It is similarly important to test about the significance of possible exogenous variables in the Markov switching model. See Franses and van Dijk (2000) and Hamilton and Raj (2002). Moreover, if the residuals remain non-normally distributed, testing for possible remaining ARCH effects is non-negligible (Erlandsson (2002)).

3.3.2.2 Transition probabilities: constant and time-varying

If the interest rate pass-through is regime-dependent, then there is no theoretical reason for considering the transition probabilities time invariant.[23] On the contrary, it seems plausible that the probability of changing regimes is associated to the evolution of some informational variables. Those variables should contain enough information as to foresee that a change in regime is more likely under certain variable values, acting indeed as leading indicators of the unobserved regimes. Actually, the lagged state in a Markov switching process would provide information necessary for identification (in the estimation) as long as it is uncorrelated with the current error on the main equation.

[23] Detailed discussion of modelling Markov switching with TVTP is found in Diebold, Lee, and Weinbach (1994), Filardo (1994), and Filardo (1993).

This extra information is obtained by including leading indicators for TVTP and, thus, endogenising the Markov regime switching process (Kim, Piger, and Startz (2003)).

Yet, it is important to be clear about the economic rationale of using TVTP rather than CTP. For interest rates, in particular, the probability of switching regimes might depend on interest rate spreads. See for example, Ang and Bekaert (2002), Dahlquist and Gray (2000), Hofmann and Mizen (2004), and Iregui, Milas, and Otero (2001). Even more, the short-term rate and the spread would Granger-cause each other. Since this research has emphasised price variables as to contain readily available market information, using these spreads as leading indicators of TVTP seems plausible.

The choice of the informational variables might consider the feasibility of applying the Expectations Maximisation (EM) algorithm to the TVTP case. Indeed, this is a non-trivial issue to account for. Filardo (1998) shows that conditional exogeneity between the leading indicators and the unobserved regimes make the EM algorithm valid to estimate the parameters in a Markov switching model with TVTP.[24]

Regime switches in the form of changes in volatility should reflect unusual market events, such as a financial crisis or a change in the exchange regime. Variations in banks' expectations about the risks more closely associated to those events would certainly reflect those unobserved switches. Accordingly, the probability of changing regimes would be linked to the evolution of what banks perceive to be their risks.

[24] Feasibility of maximum likelihood estimation of TVTP models derives from the conditions necessary to factor the joint likelihood into a concentrated likelihood (one which obviates the need to estimate all the parameters in the likelihood function jointly). See a detailed explanation in Filardo (1998).

Therefore, the transition probabilities in the Markov process[25] would be time-dependent, and they could be modelled as a logistic function of the leading indicators:

$$p_t^{00} = \frac{\exp(x_{t-1}^{'}\beta_0)}{1+\exp(x_{t-1}^{'}\beta_0)} \tag{3.13}$$

$$p_t^{11} = \frac{\exp(x_{t-1}^{'}\beta_1)}{1+\exp(x_{t-1}^{'}\beta_1)} \tag{3.14}$$

$$p_t^{01} = (1 - p_t^{00}) \tag{3.15}$$

$$p_t^{10} = (1 - p_t^{11}) \tag{3.16}$$

where x_{t-1} is the (k x 1) vector containing the leading indicators (interest rate spreads) of regime shift, and β_0 and β_1 are the (k x 1) vector of parameters for the TVTP. Whether these variables are the same that explain the regime-dependent parameters in the main equation of the regime-switching model is an empirical matter. It requires assessment based on a sound theoretical rationale. As it can easily be seen, these probabilities are, of course, bound to be between *0* and *1*. Diebold, Lee, and Weinbach (1994) point out that if only the first term of β_0 and β_1 are allowed to be different from zero, then the transition probabilities collapse to the Hamilton's case (constant).

3.3.3 Empirical evidence of regime shifting

3.3.3.1 Argentina

Over the period from June 1993 to December 2000, interest rate pass-through in Argentina showed a nonlinear behaviour.[26] The pass-through increased for periods associated to higher volatility conditions. In some of those periods, a similar type of external cause was present: a currency crisis hitting the system by contagion. In other

[25] Although it will not be a Markov process anymore, since the probability of a regime will depend not only on the previous regime but also on some other indicators. See Krolzig (1997).
[26] See Chapter 2 of this thesis for a detailed account of this nonlinear process.

periods, there were rather domestic-generated frictions in the banking system that caused the pass-through to rise.

It was only in the case of the Mexican crisis, however, that the regime switching caused a major banking crisis (around 25 per cent of banks collapsing as a result). During the South East Asian and Russian crises, although the money market rates reacted promptly to the crises, the banking system as a whole was in a better shape to absorb the externalities. By the end of 2000, when negative expectations about the peg were starting to grow, the highly uncertain environment did not lead to major bank failures.[27] It seems that, whatever the cause for greater uncertainty (whether an external currency crisis or a domestic financial crisis), an increase in the pass-through because of regime shifting was the likely outcome.

For lending and deposit interest rates, Iregui, Milas, and Otero (2001) find evidence of regime-switching behaviour, where the transition from one regime to the other is controlled by the interest rate spread difference (this study surveys on a number of Latin American economies, including Argentina). One of the two regimes is associated to negative deviations of interest rate spreads relative to an estimate threshold, and the other regime is linked to positive deviations. The first one occurs during periods of financial liberalisation and the second one during periods of financial inefficiency and increasing government intervention. The authors use a STAR-type model to represent this nonlinear behaviour in interest rates.

[27] Later on, during 2001 and 2002, although many banks were caught in trouble, official intervention prevented them from collapsing.

A number of recent studies have explored nonlinearities in devaluation expectations and (the term structure of) interest rates in Argentina. Alvarez-Plata and Schrooten (2003) use a univariate Markov switching model to show that not only deteriorating fundamentals explain the Argentinean crisis but also exogenous shifts in agents' beliefs. Similarly, Boinet, Napolitano, and Spagnolo (2002) find that switch across regimes in a 2-regime Markov switching model corresponds to jumps between different equilibrium explained by abrupt shifts in devaluation expectations.

3.3.3.2 Euro zone

Sander and Kleimeier (2003) investigate if the pass-through in the Euro zone has changed during the period 1993-2002. They report that the pass-through process for most retail rates has undergone considerable structural changes in that period (and not only due to the introduction of the euro in 1999) and has increased both in size and in speed (for lending rates but not for deposit rates). After determining endogenously the occurrence of a structural break (rather than imposing it exogenously), they estimate the pass-through partitioning the sample in pre-break and post-break periods. The authors implicitly assume that the increase in pass-through is permanent due to progressive structural convergence after the unification of monetary policy.[28] They also identify the occurrence of several previous structural breaks, probably due to regulatory efforts.

Sander and Kleimeier (2003), in revising empirical literature for the European Union (EU), acknowledge that the pass-through might be subject to nonlinear asymmetries, although modelling in this fashion has not been common for the EU. Therefore, they

[28] Unsurprisingly they find that different market segments show different breakpoints. Yet, the pass-through differences among EU countries are larger that what could be explained by structural differences in their financial system. They attribute those further differences to the empirics in the studies: the choice of the exogenous money market rate, the length and timing of the sample, and the chosen methodology.

suggest incorporating threshold and asymmetric adjustment features in modelling the interest rate pass-through. They use alternatively different specifications of a threshold autoregressive model,[29] with the retail rate being above or below its equilibrium level.

Although Sander and Kleimeier do not discuss explicitly reasons why rates would deviate from equilibrium beyond certain threshold spreads, they clearly see that the pass-through will be at a different speed than when deviations are below that threshold deviation. The nonlinear behaviour in the pass-through process is reported to be related to asymmetric adjustment of interest rates, advancing from a less-than-complete pass-through to a still less-than-complete but larger pass-through. It seems that there is not a common form of asymmetry but it is rather dependent on specific patterns and circumstances for different rates and market segments. An important conclusion from this study is that reduced volatility in money market rates leads to a speedier pass-through, as it would have been the case with the adoption of the single currency.

Hofmann and Mizen (2004) for the UK report similar evidence on nonlinearity based on asymmetric adjustment of interest rates (deposit and mortgage rates) to changes in money market rates during the period 1985 – 2001.[30] The speed of adjustment depends on whether the spread between the retail and the base rate is widening or narrowing (endogenous drivers) or on some exogenous drivers such as the size of the money market rate change. They use a menu-cost argument (from an industrial organization approach) to explain this type of adjustment and use a nonlinear error correction model to represent the pass-through. The authors conclude that the main driver of interest rate

[29] They consider a zero (introducing asymmetry in the response), a non-zero (response comes beyond certain minimum deviation from equilibrium), a band (adjust only when deviations are sufficiently large), and momentum (when banks try to smooth out large rate movements) threshold autoregressive model.
[30] They use detailed monthly data on retail rates set by individual UK banks. Other authors that have reported nonlinear asymmetric error correction models are Bondt (2002) and Scholnick (1996).

pass-through is the expected change in money market rate when the spread between the base and retail rates is growing in absolute size.

A number of studies for the euro zone have also detected nonlinearities in interest rates (rather than in the pass-through). Dahlquist and Gray (2000) use a Markov regime-switching model for the dynamics of short-term interest rates. They argue that, through UIP, the process that generates exchange rates switches between different regimes might be the process that generates regime switching in interest rates.

Martínez (2002) studies speculative episodes for the euro zone. She models exchange rates, foreign exchange reserves, and interest rates as time series subject to discrete regime shifts. Regime switching coincides with the occurrence of a currency crisis or the prevention of it (through official intervention). The probabilities of switching between states are allowed to be a function of fundamentals and expectations (Markov switching model with TVTP). Although episodes of currency crises inducing these nonlinearities are scarce for individual countries, stacking several country data together extends data availability.[31]

Mandilaras and Bird (2003) also review regime-switching modelling of foreign exchange market pressures under financial crises in the euro area. Contemporaneous error correlations among market pressure indexes (comprising exchange rate depreciation, change in interest rate differentials, and change in foreign exchange reserves) in the EU countries shift between a tranquil regime and a crisis regime. A two-regime Markov-switching VAR model captures this nonlinear behaviour.

[31] Ang and Bekaert (2002) argue indeed that "*because of the extremely high persistence of short rates, using information from other countries is a much more effective way to increase the sample size than lengthening the sample itself*" (Page 1245).

It is worth mentioning here that most empirical studies on EU countries find interest rates to be consistent with nonstationary processes. This result is in contrast with reported cases of stationarity in interest rates in some Latin American economies.[32]

3.3.3.3 Others

Some studies for other financial markets have reported evidence of nonlinear behaviour in interest rates too. For instance, Dahlquist and Gray (2000) for US; Abiad (2003) for the South East Asian countries involved in the 1997 crisis (Indonesia, Korea, Malaysia, Philippines, and Thailand); Fratzscher (2002) for Asian and Latin American countries (analysing the contagion effects of the Asian crisis); and Cerra and Saxena (2002) for Indonesia. All these studies have applied Markov switching models to represent switching behaviour, linking foreign exchange market pressures and interest rates.

[32] Chile and Argentina, for example. See Chapter 2 for a discussion on this issue.

3.4 THE BANKING SYSTEM IN ARGENTINA

After the hyperinflation period at the end of the 1980s and the adoption of the fixed exchange rate regime (under a currency board type) the banking system expanded considerably during the 1990s. Nevertheless, this was, by no means, a continuous, linear process.[33] The response from the Argentinean financial system to the main international financial crises during the 1990s was heterogeneous and showed different stances of banking evolution and soundness. Thus, for instance, after the Mexican crisis there was a large fall in the number of banks and financial institutions in Argentina. Differently though, and despite all the uncertainty brought by the collapse of the currency board, there was only a minor effect in the number of banks during 2001 and 2002.[34]

3.4.1 Evolution of the banking system

The number of banks decreased considerably during the period of study.[35] The first reduction took place after the Mexican crisis, when a large number of banks and other financial institutions fall into insolvency, and either went bankrupt or were absorbed (See Table 3.1). The system recovered afterwards, with the introduction of further regulatory reforms and of improvements in market risk management. Many mergers and acquisitions took place, reducing the number of banks, but in a smoother pattern than during 1995. Since mid-1998, banks had faced a deep recession that made many of them insolvent, though government intervention through financial bailouts avoided further reduction in the number of banks.

[33] The time path of interest rates (discussed below) reflects that nonlinear evolution of the banking system. It could also be inferred from the statistics on loan values and the number of financial institutions.
[34] This difference is partly due to large bank bailouts from the government in the aftermath of the currency board collapse.
[35] The number of total financial institutions, according to central bank data, was 206 by December 1993. By the end of 2003, there were only 96 institutions (of which 76 were banks).

De la Torre, Yeyati, and Schumukler (2002) argue that although the financial system improved significantly during the 1990s (especially after the Mexican crisis had showed the need for a stronger system given the lack of a lender of last resort) it kept important hidden weaknesses. Insufficient prudential norms to deal with effects of real exchange rate realignments in the non-tradable sector; large exposure to the public sector (and thus to a sovereign debt crisis); and not enough liquidity safeguards to face depositor runs were factors that proved crucial in worsening the effects of the regime breakdown.

The other variable that shows the irregular evolution of the financial system is the flow of loans to the non-financial private sector (See Table 3.2). By December 1994, the flow of loans in local currency to the private sector was 7 386 millions of pesos plus 3 593 millions of dollars in loans denominated in the foreign currency. Summing up at the prevailing one-to-one exchange rate, it totalled 10 979 millions in new loans in a month. One year later, after the Mexican crisis hit the Argentinean financial system, the flow of loans was 5 515 millions in pesos (a decrease of around 25 per cent) and 3 003 millions in dollars (a decrease of 16 per cent). That is, 8 518 millions in new loans in that month, 22 per cent less than twelve months before.

In subsequent years, once the impact of the international crisis was absorbed, the level of loans to the non-financial private sector recovered, reaching its peak during 1998. Nevertheless, after this year, the macroeconomic instability and recession started to reduce monthly loan flows. Differently though, the decreased in credit up to December 2000 was not as deep as in the case of the 1995 slowdown. It continued during 2001 and, as expectations of abandoning the currency board were mounting, there was a shift in the proportion of loans in local currency towards dollar-denominated loans. From representing roughly 65 per cent of the total, loans in pesos went down to represent 35 per cent in total new loans in December 2001. Once the currency board was officially dismantled, the evolution of new credit during 2002 and 2003 was extremely harsh. Loans in local currency started to recover slowly from its fall in 2001, but remained quite low in respect to previous standards. Loans in foreign currency almost disappeared, although it is worth noticing that the central bank prohibited dollar-denominated loans not matched by dollar-denominated income from the debtor.

The dynamics of new credits to the private sector by type of loans and by currency were quite heterogeneous during all these years. In local currency, overdraft loans represented around 70 percent of the total in pesos at the beginning of the sample, but drop to around 60 percent by the end of 2000 (See Table 3.3). Bill loans went up from 15 percent to around 22 percent in that same period, while personal loans increased from 7 to 12 percent. All together, these loans represented more than 90 percent of the total in local currency (increased their participation from 91 to 95 percent in those years).

By the end of 2001, overdraft loans rose up to represent 70 percent of new credits in local currency but came down to 45 percent and 49 percent in 2002 and 2003. Bill loans sharply decreased in those years, to represent only 3 percent at the end of 2003. Surprisingly, personal loans gained much importance coming to represent 33 percent of total new loans in local currency at the end of 2003.

Those patterns were quite different for monthly new credits to the private sector in the foreign currency. Overdraft credits rose from 5 percent to roughly 15 percent between

1993 and 2002, but practically disappeared by 2003. Bill loans drop from 41 percent to roughly 1 percent in that same period. Personal loans kept representing around 2 percent of the total new credits. All together, these loans fall down from representing around 48 percent of the total in foreign currency to around just 4 percent. In this currency, mortgage and pledge loans are much more important.

3.4.2 International currency crises

The Mexican crisis in 1994, the South East Asian crisis in 1997, and the Russian crisis in 1998 hit the Argentinean economy and financial system to different extents. In term of interest rate volatility, by far, the largest effects correspond to the Mexican crisis. While that in terms of declining capital inflows, the Russian crisis was more damaging (and longer lasting). The Brazilian crisis of early 1999 did not have a noticeable effect in neither the money market nor the credit market.

Reflecting the impact of the Mexican crisis, interest rates rose substantially during the first half of 1995. In addition, there was a deposit run during the same period (around 20 percent of total deposits fleet the system),[36] as well as a loss of international reserves in the central bank (around 30 percent of liquid reserves). These shocks proved too much for some banks. The number of financial institutions decreased from 205 in December 1994 to 158 in December 1995. The currency board system and the supporting regulatory framework deprived the central bank of enough flexibility to face the banking system failures (especially in its role of lender of last resort). This experience proved crucial for deciding upon the introduction of some specifically-design regulatory amendments that gave the central bank back some of its liquidity support mechanisms.

[36] Damill, Salvatore, and Simpson (2003) points out that it was initially a "flight to quality" movement of deposits, from small banks to more solvent and bigger banks, and from local-currency to foreign-currency denominated deposits.

By the time the South East Asian financial crisis started, in the second half of 1997, the Argentine banking system had recovered from the Tequila shock. The financial system seemed sound, evolving along a growing economy. Besides, the system adhered to international-standard banking regulations. The impact on interest rates was rather short (compared to the Mexican crisis) both in magnitude and in duration. Yet, it was large enough to raise the lending pass-through (see Chapter 2).

The Russian debt crisis of August 1998 also motivated a considerable increase in interest rates, but again, not as large or long as in the Mexican crisis. The biggest consequence of the Russian debt's default was the large reversal of international capital inflows to emerging markets that followed it. This factor contributed to form negative expectations about maintaining the peg in Argentina. Calvo, Izquierdo, and Talvi (2002) argue that the country was indeed extremely vulnerable to a sudden stop in those capital inflows. The closeness to international trade, the increasing size of the external debt, the large dollarization of both public and private sector, and the potentially large balance sheet effect on the financial and non-financial sectors, were all factors that made real exchange rate misalignments larger than expected. Besides, the capital inflow reversal proved to be a much longer-lived event than, for example, the Mexican crisis.

3.4.3 Collapse of the currency board

Given the restrictions in international capital inflows,[37] the appreciation of the US dollar against most currencies, and the deterioration of fiscal accounts, De la Torre, Yeyati and Schumukler (2002) argue that Argentina fell into a currency-growth-debt trap. It eventually led to the events that caused the exchange rate regime breakdown.

[37] De la Torre, Yeyati, and Schumukler (2002) argue (based on Perry and Servén (2002)) that, in the case of Argentina, this capital contraction might have not been entirely due to exogenous factors. Endogenous domestic factors would be more important in explaining it.

Volatility in the short-term money market rate increased substantially since the end of 2000. In April 2001, the introduction of some amendments in the central bank charter removed limits on it as lender of last resort. In addition, the government proposed to change the convertibility law to peg the peso to a basket of US dollars and euros (rather than just to the US dollar). This undermining of the currency board continued with the setting of a preferential exchange rate for trade, which actually implemented a dual exchange rate (the so-called convergence factor), involving the dollar and the euro.

Devaluation expectations were escalating during most of 2001 and economic agents started to realize that the government was ready to loosen the shackles of the fixed exchange rate regime and devalue (Calvo, Izquierdo, and Talvi (2002)). Although the government implemented several policies to avoid the collapse, negative expectations started to show off in the form of a large decrease in bank deposits and the loss of international reserves.

By the beginning of December 2001, restrictions in the withdrawal of deposits were established, the so-called "corralito" (little fence), that brought in practice an end to the fixed exchange rate regime. In addition, interbank loans in local currency were restricted and only allowed in US dollars.[38] A political turmoil followed these policy measures. It ended up with the resignation of the elected President (in power since December 1999). On January 2nd 2002, the currency board was officially dismantled and a floating exchange rate regime adopted.

[38] That is why the observation on interbank rate in local currency for December 2001 is unavailable. A level of the rate is estimated considering the change and level of the corresponding rate in US dollars.

An overvalued currency, increasing foreign debt, and mounting fiscal deficits were among the direct causes of the currency board collapse. Despite all these, the system was not abandoned earlier (even though it might have reduced the negative impacts on growth) because of fears of returning to high inflation periods (Feldstein (2002)). Argentina suffered a hyperinflation by the end of the 1980s. The adoption of the convertibility law (which established the one-to-one peg to the US dollar) helped reducing it and brought financial conditions necessary to promote growth.

The highly uncertain scenario during most of 2001 impinged upon the financial markets. Volatility on all interest rates rose substantially, in magnitudes well beyond those experimented during the Mexican crisis. Interestingly, the evolution of the interbank rate showed large increases one month only to fall down largely the next one and up again the following; a pattern that was to be common during 2001 and 2002 (but not seen before at those levels). Deposit runs triggered by deterioration in expectations about the soundness of the currency board deeply marked the banking crisis. Gabrielli, McCandless, and Rouillet (2003) attribute the causes of the runs to bank fundamentals. Variables like interest rates, non-performing loans, and exposure to public risk, have all significant parameters in a panel data and cross section study to explain those deposit runs (real shocks followed by insolvency problems).

Despite abandoning the fixed exchange rate, uncertainty remained high for a long period (most of 2002). This feature has to do with the type of exit chosen and the materialization of insolvency problems for the corporate sector and the banking industry. As Damill, Salvatore, and Simpson (2003) brief it up, the abandoning of the currency board posed a number of problems in the banking system that was to be dealt with. The balance sheet effects of devaluation on businesses; the conversion of dollar-denominated liabilities into peso-denominated ones; reprogramming term deposits;[39] and the asymmetric distribution of the crisis' costs.

An important action taken by the government in trying to soften the costs of the currency board collapse was the asymmetric conversion of bank assets and liabilities from dollars to pesos. Corporate debts to banks were converted at the rate of one peso-one-dollar, while deposits were converted at the rate of 1.4 pesos per dollar. This caused the government to end up paying for large bank capital losses through bond issuing.

By 2003, the effects of the currency board breakdown in terms of financial uncertainty were over. The interbank rate went even further down than its pre-crisis levels, and it remained at their lowest level on the entire study sample.[40] Credits to the non-financial private sector from financial institution rose up 38 percent between the end of 2002 and of 2003. Most lending rates followed the downward trend, although at different paces.

[39] The so-called "corralon" (big fence), by early January 2002, made term deposits unavailable and introduced the need for reprogramming them.
[40] According to the Central Bank of Argentina (2004), by the end of 2003, the liquidity ratio of the system was at around 24% (8 percentage points higher than required). Bank capital losses were refinanced and additional capital was paid in. Banks deposits started to return to the system.

3.5 PASS-THROUGH AND ENDOGENOUS REGIME-SWITCHING

From June 1993 to December 2003, there are two clearly different periods involving the evolution of money market rates and lending rates, both in local-currency and foreign-currency loans in the Argentinean financial system. The first period runs for most of the 1990s. The latter period correspond to the breakdown of the currency board and the immediate turmoil that followed it (and lasted around two years). In any case, there is a need for assessing whether the previous episodes of high-volatility environment, such as those of the international financial crises (in particular the Mexican crisis) that hit the Argentinean system during the 1990s, remain as a second high-volatility regime (as the second chapter of this thesis has shown).

3.5.1 Descriptive statistics

The period from January 2001 to December 2003 shows indeed a much higher mean and (relative) volatility for all interest rates, roughly keeping the same relative order among them than in the previous period (See Table 3.4). Besides, it is worth recalling that the volatility in the money market rate more than triples during this period and only (roughly) doubles for the other interest rates. The correlation between the lending rates and the interbank rate is much higher for the bill and overdraft rates but it is lower (becomes even negative) for the personal rate than in the previous period.

Over the entire sample, the periods of higher volatility are associated to increasing uncertainty coming either from an international crisis or from domestic instability. Furthermore, although the South East Asian and Russian crises changed somewhat interest rates trends, their effects are much less clearer when compared to the effects from the collapse of the currency board and from the Mexican crisis (See Figure 3.1).

Similar broad trends are present in interest rates for foreign-currency denominated loans (See Figure 3.2). After the government officially suspended the currency board, by the beginning of 2002, the close link between these rates and the corresponding rates in local currency was to some extent broken.[41] Regarding the period 2001:12 – 2003:12, evolution of interest rates in local and foreign currency is somewhat different though (See Figure 3.3 and Figure 3.4). The interbank rate in foreign currency is slightly less volatile than the one in local currency. Moreover, it is clear that both of them reached at the end even lower levels that the pre-collapse standards. Although, after the breakdown of the currency board, the interest rates denominated in foreign currency might have lost all their informational content.

It is worth noticing that when comparing each lending rate with the interbank rate in the same currency, patterns are similar in both currencies. The most closely linked lending rate to the interbank rate is still the rate on bills and, then, the overdraft rate. Although the personal rate follows the broad trend of the interbank rate, it seems to evolve very much at its own dynamics (See Figure 3.5). Despite that, for all cases, the dynamics of the interest rates in local and foreign currency is very much similar, they evolve somewhat differently in some periods, especially after 2002 (See Figure 3.6).

It is surprising that the spreads in local currency between each lending rate and the interbank rate become largely negative for some months between mid-2001 and mid-2002 (See Figure 3.7). Before that period, for all cases, that spread show a downward trend. All the same, during 2003, the spreads grew much larger for several months, although it seems to have regained its decreasing trend.

[41] Moreover, the amount of loans in foreign currency diminished considerable, and even disappeared for some type of operations.

The heterogeneity in bank pricing is more notorious in the dynamics of the spread between each rate and its counterpart in the foreign currency. The interbank and bills rate show similar levels in both currencies for most of the sample, but notably the spread widens during the Mexican crisis and the collapse of the currency board. It seems that for these rates, the spread is indeed an indication of country risk and devaluation expectations.

The overdraft rate shows a much volatile spread even before the collapse of the currency board and with levels that seem to be beyond reasonable measures of either country risk or devaluation expectations. For the personal rate, although the spread was at very high levels at the beginning of the sample, it had a clearly decreasing trend. Yet, during the collapse of the currency board, it went quite high. Notwithstanding this rise, both these spreads showed less volatility than the interbank and bills rate during the period that lead to the abandoning the fixed exchange regime (See Figure 3.8).

3.5.2 Modelling testing

Assuming that there is indeed enough economic rationale to postulate a nonlinear interest rate pass-through, this section conducts a set of test for assessing the appropriateness of such a pattern and the compatibility of the data to this kind of models. The first type of testing is for the number of regimes. If the tests suggest a nonlinear pattern, the next step is to investigate the exact specification of the model. Finally, to enrich the representation, the presence of exogenous variables is tested, as well as the possibility of TVTP as oppose to the CTP case.

3.5.2.1 Number of regimes

The initial step is to determine if there is indeed need for specifying at least two regimes as an alternative to a single-regime (linear) model. Standard specification tests based on likelihood ratios are not applicable because of the well-known problem of presence of nuisance parameters under the null of linearity.[42] Instead, empirical applications of Markov switching models take a number of procedures to search for evidence of nonlinearities. There is no widespread consensus upon which method to use for testing the suitability of specifying a second regime though. The econometric discussion about testing alternative nested models could be found in Hansen (1992), Garcia (1998), Garcia and Perron (1996), and others. In this type of testing, the null hypothesis of a linear model is confronted against the alternative of a non-linear, Markov switching, model. Thus, the restricted version of the nonlinear model is the linear model.

In his original contribution of Markov switching models to time series macroeconomics, Hamilton (1988) spotted the problem of presence of nuisance parameters under the null hypothesis. Still, Hansen (1992) treated it in detail. He proposed a standardized likelihood ratio test for which he estimated upper bounds. The inapplicability of hypothesis testing, such as the likelihood ratio (LR) test, arises because it does not meet the standard conditions for testing. The first condition, that the likelihood surface must be locally quadratic is usually violated if there are some (nuisance) parameters that are unidentified under the null hypothesis. That is the case of the transition probabilities of the regime-switching model under the null of linearity; the likelihood function becomes flat with respect to the nuisance parameters at the optimum. The second condition, that the score must have a positive variance is also violated when the null hypothesis yields a local optimum or inflection point (with respect to the nuisance parameters).

[42] See Hansen (1992) for a discussion on this.

Hansen (1992) avoids these problems by taking an approach that works directly with the likelihood surface as an empirical process of the unknown parameters. He derives a bound for the asymptotic distribution of a standardized LR statistics (but not asymptotic values).[43] Nonetheless, he recognizes that having only a bound for the statistics can lead to under-rejection of a false null (loss in effective power of the test). Therefore, the test should only be used when it is feasible that the conventional assumptions are invalid.

Hansen (1992) also recognizes that his test is highly demanding in computational terms. This last characteristic has indeed prevented a much more extended use of the test.[44] A recent example of its application is found in Boinet, Napolitano, and Spagnolo (2002), who applied the test for a two-state Markov switching model of devaluation expectations. Alternatively, Gray (1996) recognizes that he did not adjust the χ^2 distribution for the likelihood ratio test to account for the presence of nuisance parameters (the Hansen's test) but relied in the empirical large difference in the log-likelihood values he had obtained. Erlandsson (2002) points out that the Hansen's test would be hard to apply to a *N*-state Markov switching model, so he uses instead a bootstrapping technique to approximate the distribution of the LR statistic (although this method is itself also quite computationally demanding).

Hamilton (1988) in his application to the term structure of interest rate argues that the Lagrange multiplier test is immune to the problem of nuisance parameters under the null of linearity. All the same, Hamilton (1989) in his application to business cycle did not attempt a formal hypothesis test to support his Markov switching model against the null

[43] Garcia (1998) derives analytically the asymptotic null distribution of the likelihood ratio test for a number of two-regime Markov switching models. However, since this distribution is conditional on the data and parameters, generic tabulation is not possible (Krolzig (1997)).
[44] Gray (1996) points out that the procedure involves optimization over a grid of the nuisance parameters, which is computationally demanding unless the model is quite simple or the grid is coarse.

of a linear autoregressive model. He favoured his proposed model based on the better description it offered of the dataset under study. Later on, Engel and Hamilton (1990) offered an alternative solution to sidestep the problem of nuisance parameters by testing against a more general null hypothesis that includes them but one that makes regimes not persistent.[45] Then, they rely on standard distribution theory and use a Wald test and a LR test. Frömmel, MacDonald, and Menkhoff (2002), and Martínez (2002), for instance, have used empirically these approximate tests of no switching.

In this study, the Hansen's standardized LR test is applied, to the interbank rate and to each lending rate separately, to search for evidence of nonlinearity. The results (See Table 3.5) show that a simple MSI(2)-AR(1) model improves on describing each rate's dynamics against the null of a linear AR(1) representation.[46] The null of linearity is clearly rejected in all cases. This evidence suggests indeed the presence of two regimes in the interest rate dynamics. Although no causality is tested, the data is thus consistent so far with the hypothesis that with a regime shifting interbank rate, all the other rates also display a nonlinear behaviour. This does not necessarily mean, however, that the pass-through would also be nonlinear.

Therefore, the Hansen test is next applied to a single pass-through equation (See Table 3.6) to confirm that single rates transmit their nonlinearity into the pass-through process.[47] The p-values show a (non-decisive) non-rejection of the null of linearity by little margins. It might be the case that the documented low power of the test is unable to provide further evidence of two regimes in the pass-through or, of course, that there

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[45] That is, the probability of regime s_t is independent of s_{t-1}.

[46] The Laurent and Urbain (2003)'s M@ximize class for OxGauss have been used to run the Hansen's Gauss codes. For details on the test, see Hansen (1992) and Hansen (1996).

[47] The number of regimes for each interest rate in the VAR is used here to select the number of regimes for the multivariate times series vector (Krolzig (1997)).

is no regime-switching behaviour in the pass-through (despite the fact that each rate presents two regimes). Further testing is required.

Alternatively, then, non-nested hypothesis testing could be used to search for evidence of neglected nonlinearity. That is, a number of portmanteau-type nonlinearity tests could be applied to detect Markov switching dynamics.[48] These tests are constructed without a specific nonlinear parametric alternative. Psaradakis and Spagnolo (2002) show, that in general, these tests have good power features for rejecting a false null of linearity in time series generated by Markov switching models. Nonetheless, results from these tests will not provide definitive evidence in favour of Markov switching models. That is because a rejection of the null of linearity could be due to a number of different features of the data, such as nonlinearities other than Markov regime switching or conditional heteroskedasticity.

Instead, another type of non-nested test is used here to complement, rather than replace, the Hansen test. Garcia and Perron (1996) suggest estimating the model with the larger number of regimes and run the so-called *J*-test for non-nested models. It uses a *t*-test for the parameter on the estimated value of the endogenous using the model with the highest number of regimes in an equation that also have that value from the alternative model to explain the endogenous variable.[49] They also use two other tests that rely on giving a range of values to the nuisance parameters under the alternative hypothesis (thus avoiding the need for estimating them): the Davies' test and the Gallant's test.[50]

[48] Among them, for instance, RESET-type tests, the Tsay test, the neural network test. See Psaradakis and Spagnolo (2002) for a description of these tests. They have used Monte Carlo simulations to examine the performance of these tests to detect Markov switching autoregressive models.

[49] They use an equation of the form $y_t = (1-\delta) f_t(\beta) + \delta g_t + u_t$ and apply a *t*-test on the parameter δ. Where $f_t(\beta)$ is the estimated endogenous from the restricted model and g_t is from the unrestricted model.

[50] See Garcia and Perron (1996), and the references therein, for a detailed description of these two tests.

Still, on their application to real interest rates and inflation rates, they find contradictory results from these three tests, deciding upon two- or three-state switching models. They favour the three-state model because the interpretation of it is richer and more appealing from an economic perspective.

Therefore, given the non-decisive results from the Hansen test, the J-test, as described in Garcia and Perron (1996), is applied to the single pass-through equation. This time, results are decisive and they clearly favoured the existence of two regimes in the pass-through process (See Table 3.7). With the evidence provided by the Hansen test and the J-test, this paper concludes that there is enough evidence to support a two-regime shifting representation for the interest rate pass-through.[51] Another relevant testing is, of course, the interpretability of the results and how well the model fit (or forecast) the data.

3.5.2.2 Model specification

It certainly makes sense to start testing for the simplest two-regime model against the linear one. However, once a second regime is established, the next step is to compare between different alternative two-regime models, in order to determine which parameters are regime-dependent. Krolzig (1997) discusses a "bottom-up" approach to determine specification relying on standard tests applied to alternative Markov switching models (with the same number of regimes under the null). Although he discusses the problem testing against linearity, he points out the need for further

[51] The possibility of a third regime is also tested and although the results of the LR test show that it would indeed improve fitting, an extra regime has been discarded (See Appendix in Table 16). What the addition of the third regime does is to split the magnitude of the effects of any given shock to the financial system, rather than differentiating among different episodes of market uncertainty.

research on this issue. Clarida, Sarno, Taylor, and Valente (2004), for instance, have followed the bottom-up procedure.

Therefore, following the "bottom-up" strategy from Krolzig (1997), general specifications of the MS-VAR are tested sequentially against each other, including a MSIH(2)-VAR(1) and a MSIAH(2)-VAR(1) against the initial representation MSI(2)-VAR(1). Thus, LR tests are used to determine the appropriate specification between alternative models but with the same number of regimes. Table 3.8 shows a summary of the relevant results.

The selected specification is an MSIAH(2)-VAR(1). The two regimes that are thus modelled correspond to a calm regime, in which the mean and volatility of interest rates is low (or normal), and to an unstable regime, in which both the mean and volatility are much larger (possible linked to a crisis period). The regime-dependency of the autoregressive parameters is linked to the switching behaviour in the long-term pass-through (and not only to the impact multiplier).

3.5.2.3 Leading indicators and exogenous variables

The next step is to test whether the selected specification MSIAH(2)-VAR(1) is more appropriate with CTP or with TVTP. Similarly then, a LR test is used to select the more relevant specification for the transition probabilities. Results from Table 3.8 show that a MSIAH(2)-VAR(1) with TVTP is the suitable pass-through representation for all three lending rates.

The selected specification was also tested against the null hypothesis of a model with exogenous variables in the vector autoregression, that is a MSIAH(2)-VARX(1). The variables consider as exogenous were different specifications of interest rate spreads (see section 3.5.3.3. for details on them). Test results show that none of the postulated spreads seems to improve on the models if included in the VAR (Appendix in Table 3.8), but they are relevant when consider as leading indicators in the TVTP.

3.5.3 Markov-switching VAR with TVTP

3.5.3.1 The model

Following the specification tests from the previous section, the selected model is a MSIAH(2)-VAR(1) with TVTP. There are two variables in the system, the lending rate and the interbank rate. The interest rates on overdrafts, bills, and personal loans are modelled in turns with the interbank rate. The estimation period goes from June 1993 to December 2003 (monthly data).[52] Note that the period includes the break of the currency board and the aftermath of it.

The following two equations represent the original VAR:

$$i_t = \alpha_0^i(s_t) + \alpha_1^i(s_t)i_{t-1} + \alpha_2^i(s_t)r_{t-1} + \sigma(s_t)u_t^i \tag{5.1}$$

$$r_t = \alpha_0^r(s_t) + \alpha_1^r(s_t)i_{t-1} + \alpha_2^r(s_t)r_{t-1} + \sigma(s_t)u_t^r \tag{5.2}$$

where i_t is the interbank rate and r_t corresponds to the lending (overdraft, bills, or personal) rate.[53] All the parameters (constant, autoregressive, and error variance) are regime-dependent. The regime s_t can take the values of *0*, for the calm regime, and *1*,

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[52] In order to increase the number of observations under the volatile regime, it is feasible to stack up the data from several countries as in Martínez (2002). Although, as Abiad (2003) points out, this is not a plausible procedure for emerging markets since the internal economic structure is likely to be quite different from one to another country. This factor is particular important for the leading indicators in the TVTP case.

[53] Standard tests suggest a very low number of lags for the VAR. Following estimations in the second chapter of this thesis, this chapter considers a single lag in the VAR.

for the volatile regime. Thus, for each variable in the system, there would be two equations, one for each regime.

The parameters of the structural form should be derived from the estimated parameters of this reduced form of the VAR representation. The short-term pass-through shows the impact effect of a change in the interbank rate on the lending rate and so, in the structural form, it is given by the parameter accompanying the current interbank rate in the lending rate equation. The long-term pass-through shows the accumulated effect and, therefore, it is estimated considering the interbank rate's current and lagged values and the lending rate's lagged values in the lending rate equation.[54]

3.5.3.2 Estimation procedure: the EM algorithm

The Expectation Maximisation (EM) algorithm is based on a two-step iterative process, the expectation step and the maximisation step, aimed at estimating the conditional likelihood function.[55] The choice of information variables is a crucial feature of the modelling, since conditions for applying the EM algorithm to the case of TVTP should be met. See Filardo (1998) for a discussion on the selecting criteria.

The conditional density describing the observable endogenous variable, y_t, is:[56]

$$f(y_t / s_t = j, x_t, Y_{t-1}; \theta) = \frac{1}{\sqrt{2\pi}\sigma_j} \exp\left\{ \frac{-(y_t - v_j - A_j y_{t-1})^2}{2\sigma_j^2} \right\} \tag{5.3}$$

[54] The MSIAH representation of the model is not needed to establish different short-term pass-through, since they depend on the covariance matrix and not on the autoregressive parameters. Yet, it is an appropriate representation if the long-term pass-through is also regime-dependent.

[55] The EM algorithm for the estimation of the regime-dependent parameters and the TVTP is described here following Hamilton (1994) and Diebold, Lee, and Weinbach (1994).

[56] Assuming a first order autoregressive process.

for $j = 0, 1$. Vector θ contains all parameters in the model (constant, autoregressive, error variance, and transition probabilities) and Y_{t-1} contains all observable (endogenous and exogenous) variables. Equations (5.3) and (3.5) will represent the Markov switching model for this time series system. The objective of the EM algorithm is to estimate the parameter vector θ based on all the observable variables Y_t.[57]

Since the regime state variable, s_t, is unobservable, the Markov chain process has to be inferred conditional on the observables. This conditional distribution of the regime, using the Bayesian condition,[58] generalizes from:

$$P(s_t = j / y_t; \theta) = \frac{p(y_t, s_t = j; \theta)}{f(y_t; \theta)} \tag{5.4}$$

The joint density in the numerator, using again the Bayesian condition, is given by:

$$p(y_t, s_t = j / x_t, Y_{t-1}; \theta) = f(y_t / s_t, x_t, Y_{t-1}; \theta) P(s_t = j / x_t, Y_{t-1}; \theta) \tag{5.5}$$

where the first term in the right hand side is the density of y_t conditional on the regime s_t, (equation (5.3)) and the second term is the probability that given the observed data, a regime j happens.

The unconditional density of y_t, the denominator in equation (5.4), is found out by summing up all the possible realizations of the endogenous and the regimes. This is equivalent to get a weighted average for the endogenous variable conditional on the regime, with the weights being the probability of each regime happening.

[57] Alternatively, the Gibbs-sampling algorithm could approximate the joint and marginal distributions by sampling from conditional distributions. It is a Markov chain Monte Carlo simulation method. For a description (and examples), see Kim and Nelson (1999).
[58] For which, the probability of occurrence of an event A given an event B is: P(A/B) = P(A∩B)/P(B).

Once an initial regime happens as a starting point of the Markovian process, in order to forecast the next regime, the algorithm needs an assumption about the parameter vector θ (including the transition probabilities). Iteratively then, for each period t, it can be inferred what the most likely regime is to have generated the observed data. This is the expectations step of the algorithm. The optimal inference and forecast for the regime is a result of this filtering process. If the information used for forecasting the regime in each period t includes the observables up to that same period, the results are the filtered probabilities. A more efficient use of all available information is to base the forecasts in the observables for the entire sample set instead (the so-called smoothed probabilities).

The log-likelihood function for θ is calculated as a by-product of the expectation step of the algorithm as:

$$L(\theta) = \sum_{t=1}^{T} \log f(y_t / x_t, Y_{t-1}; \theta) \tag{5.6}$$

This can then be maximised (the maximisation step) with respect to the parameters. Given some separability conditions on the likelihood function, the transition probabilities could then be calculated as the number of times the regime j followed the regime i divided by the number of times the regime i happened:

$$\hat{p}_{ij} = \frac{\sum_{t=2}^{T} P(s_t = j, s_{t-1} = i / Y_t; \hat{\theta})}{\sum_{t=2}^{T} P(s_{t-1} = i / Y_t; \hat{\theta})} \tag{5.7}$$

The other parameters can be estimated from the solution to the weighted OLS orthogonality conditions from the likelihood function. That is, from an OLS regression in which the regressors are weighted by the probability that they came from regime j.

With TVTP, the probabilities are a (logistic) function of some time series acting as leading indicators and so they are not constant anymore. For the EM algorithm to be applicable to this case, the leading indicators need to be exogenous to the unobserved regimes so that first order conditions derived from the log-likelihood still allow separate estimation of the probabilities' parameters from the rest of parameters. As Filardo (1998) points out, the difficulty that arises from including TVTP is the presence of the additional data (the informational variables) in the unconditional likelihood function. It implies the need for jointly estimating the parameters in the main equation and the transition probabilities. Closed-form solutions to the $2k$ non-linear first order conditions corresponding to the probability parameters will be found by linearly approximating the transition probabilities via Taylor expansions around those parameters.[59]

In order to ease the computation of the EM algorithm, this paper applies a Choleski transformation to the system in order to estimate the short-term pass-through directly .[60] Standard tests support the evidence from the second chapter that the interbank rate is exogenous to the system. Therefore, the next equations represent the transformed VAR to be estimated:

$$i_t = \alpha_0^{'i}(s_t) + \alpha_1^{'i}(s_t) i_{t-1} + \alpha_2^{'i}(s_t) r_{t-1} + \sigma(s_t) u_t^{'i} \tag{5.8}$$

$$r_t = \alpha_0^{'r}(s_t) + \alpha_{1t}^{'r}(s_t) i_t + \alpha_{1t-1}^{'r}(s_t) i_{t-1} + \alpha_2^{'r}(s_t) r_{t-1} + \sigma(s_t) u_t^{'r} \tag{5.9}$$

For the lending rate, the impact pass-through is given by the second parameter in equation (5.9) A Matlab code[61] is used to implement the EM algorithm that estimates

[59] See Diebold, Lee, and Weinbach (1994) for details.
[60] Following Martínez (2002).
[61] It is based on a code from Martínez (2002). The author is thankful to her for sharing her codes.

the parameters, including TVTP. The initial values to start iterations depart from the linear estimates of the parameters.[62]

3.5.3.3 Informational variables and TVTP

Considering possible departures from UIP, in equation (3.2), some interest rate spreads are included as leading indicators for the TVTP. Those spreads should contain information as to whether interest rates are driving apart from expected equilibrium. The further away from those expected values, the more likely a regime-shift would occur. The selected interest rate spreads are relevant proxies for country risk, devaluation risk (expectations), and credit risk. Depending on the choice, these spreads would be reflecting different types of risks that banks face in their optimising behaviour. Large increases in these risks might highlight a greater chance of changing into a higher volatility regime (such as those prevailing in a financial or currency crisis). The choice of leading indicators is based on the relationships that are usually considered by banks when setting their different interest rates (Claessens and Glaessner (1998)). For the money market rate, the two following equations, for foreign and local currency, are considered:

$$i_F = i^* + country\ risk \tag{5.10}$$

$$i_L = i^* + country\ risk + devaluation\ risk \tag{5.11}$$

where i_F is the domestic interbank rate in foreign currency (US dollars), i_L is the domestic interbank rate in local currency (Argentinean pesos), and i^* is the foreign (Eurodollar) interbank rate. The difference between the two national rates gives a proxy for devaluation risk:

[62] Although in few occasions the algorithm seems to find itself into a singularity (where the log likelihood becomes infinite), in most cases the values converges to seemingly local maximums by changing the starting values. See Hamilton (1994) for a discussion on this. In addition, several starting values were used to check convergence (Krolzig (1997)).

$$i_L - i_F = devaluation\ risk \tag{5.12}$$

For the lending rates, two similar equations are considered:

$$r_F = r^* + country\ risk \tag{5.13}$$

$$r_L = r^* + country\ risk + devaluation\ risk \tag{5.14}$$

where r_F is the domestic lending rate in foreign currency, r_L is the domestic lending rate in local currency, and r^* is the foreign lending rate. This paper assumes implicitly that all these three interest rates correspond to loans with similar credit risks.[63] Hence, the following interest rate spread is another proxy for devaluation risk:

$$r_L - r_F = devaluation\ risk \tag{5.15}$$

Similarly, the following interest rate spreads could approximate country risk, devaluation risk, and credit risk:

a) Country risk: $i_F - i^*$

b) Devaluation risk: $i_L - i_F$

c) Devaluation risk: $r_L - r_F$

d) Country risk plus devaluation risk: $i_L - i^*$

e) Credit risk: $r_L - i_L$

f) Country risk plus devaluation risk plus credit risk: $r_L - i^*$

These spreads are considered alternatively as informational variables for the TVTP.[64] Thus, having extra information on interest rates on loans denominated in dollars gives not only a proxy variable for some of the risks banks face, but also completes the

[63] This will not necessarily be the case, especially if the foreign country has a well-developed financial system and the local country is an emerging market.

[64] The spreads enter the estimation with one lag in order to validate conditions of the EM algorithm.

information on bank pricing. Since banks have the chance to operate in both currencies, the local-currency pass-through also incorporates information on this alternative bank's optimising behaviour. It is assumed implicitly that these leading indicators should indeed add to interpretability of the regime shifting behaviour.

The interpretation of the sign and magnitude of the TVTP is as following. Under calm conditions in credit markets, an increase in country risk, in devaluation expectations, or in credit risk would reflect an increase in the probabilities of switching to a higher volatile regime. Thus, the parameters on the leading indicators in β_0, from equation (3.13), are expected to be negative: the larger the spread, the lower the probability of remaining in the calm regime and, correspondingly, the larger chance of going into the higher volatility regime. In the case of being already in the unstable regime, the larger the spread, the more chances to remain in that state and the lower probability of returning to a calm regime, so that the parameters in β_1 are expected to be positive.

By testing whether the model with TVTP is superior to the model with CTP, the joint significance of the leading indicators is being assessed. A log LR test should confirm that these variables are jointly significant. Although it might turn out that none of the parameters in the leading indicators is individually significant. This result could be associated to the fact that after the collapse of the currency board, interest rates in dollars did not contain any longer useful information on the risks faced by banks.

3.5.3.4 Main results: economic rationale

The interest rate pass-through in Argentina, during the period 1993-2000, behaved nonlinearly, according to a Markov switching VAR with CTP (see Chapter 2). In high-volatility market conditions, the short-term pass-through increased considerable for all lending rates. Moreover, those increases corresponded mainly to the financial crises that hit the Argentinean financial market (Mexico, South East Asia, and Russia).

Estimating a Markov switching VAR with TVTP for a longer period (up to December 2003) shows somewhat different results. There is definitely a nonlinear behaviour in both the short-term and the long-term interest rate pass-through. However, it seems that under periods of extreme market volatility and uncertainty, the response of lending rates to changes in the interbank rate is less pronounced on impact, but stronger on longer terms than under normal conditions. That is, the short-term pass-through decreases in the volatile regime (rather than increases), while in the long-term it might be stronger than in the calm regime.

The period preceding the collapse of the exchange regime and the period afterwards were much more volatile, for all interest rates, than the periods corresponding to the international financial crises (except for the Mexican crisis). The up- and down-movements on the interbank rate during 2001 and 2002 were very much larger than the changes seen during the financial crises.[65] These patterns on the pass-through could suggest the existence of three regimes, rather than just two. A low volatile environment, with a normal pass-through; a highly volatile market, with a much higher pass-through; and a moderate volatile market, in which the pass-through reduces from the previous stage, but remains above the first one. Nevertheless, different specifications of the Markov switching VARs, and different sample periods, show clearly the presence of

[65] Abiad (2003) points out that in a nonlinear threshold model the sample-dependent nature of the threshold definition could lead to the "disappearing" of a crisis. In this case, the Markov switching model is dropping out the South East Asian and Russian crises from the volatile regime due to the much larger volatility during the currency board collapse.

tranquil periods and highly volatile periods associated to financial crises (either domestic or international). The three-regime Markov switching model does not contribute to distinguish among those periods, but it seems to be over fitting the data (and so it does not add interpretability to the results).

When the estimation period is up to December 2000, the volatile period for the overdraft rate include the three major international financial crises and the last months of 2000. Sequentially including twelve additional months in the sample, up to December 2001, 2002 and 2003, the Mexican crises remain classified in the volatile regime. However, the South-East Asian and Russian crises "disappear" from the volatile state to be included in the tranquil regime. The model clearly spots the turbulence and high uncertainty during most of 2001 and 2002 in the volatile regime (See Table 3.9). Similar regime classifications are found for interest rates on bills and personal loans. The Mexican crisis remains considered as a highly volatile period along with most of 2001 and 2002 (See Table 3.10 and Table 3.11).

An important feature to understand the apparent contradictory behaviour in the pass-through (accelerates or contracts under a financial crisis?) is the time durability of the unstable conditions. The financial crises effects on interest rates were short-lived, except for the Mexican crisis (lasted several months). By the time the South East Asian and the Russian crises hit Argentina, the banking system was much more prepare to face the risks involved, due to the Mexican crisis experience (in which many banks collapsed). Price setting rapidly absorbed the instability, and the effects were more long-lived in terms of quantities rather than prices (the setback of credit, due to constraints in external funds, for example). The pass-through increased substantially on those short-lived events, but only for very few months.

On a different scenario, the abandoning of the currency board proved a large alteration of financial conditions that lasted for many months (for most of 2001 and 2002). Banks were adjusting their expectations continuously but they remained largely uncertain about the outcome of the breakdown. Therefore, in their price setting, banks followed interbank rate changes relatively less (although, in magnitudes, those changes were much larger than in previous periods). This reduced pass-through seems to be associated to the fact that movements in the interbank rate were extremely large in both directions (compared to previous periods). In many occasions, for the interbank rate, large increases were followed by sharp declines only to rise again abruptly (notice the saw-form in the interbank rate evolution, Figure 3.1 and Figure 3.3). Meanwhile, during the financial crises, there were initial increases that a few months later mean-reverted.

It is also worth noticing than money market rate changes could also be followed by non-price adjustments in the products offer by banks (a quantity-related feature of the loan, for example), which could be alternate with price adjustments. In particular, considering the long recession period affecting Argentina before and during the breakdown of the currency board, some kind of credit crunch could have affected the financial sector. The excessive exposure to currency and term mismatches in their balance sheets might have made banks over conservative in taking new risks (Central Bank of Argentina (2004)).

The Markov switching VARs with TVTP have up to four different sets of leading indicators to estimate for each lending rate. The model with one of those sets is presented here.[66] On this model, the informational variables are proxies for credit risk and for country risk and devaluation risks (together).[67] A constant is also included to allow for the possibility of the representation to collapse to the Hamilton case. The graphs of the transition probabilities for each bivariate MS-VAR could be seen in Figure 3.9, Figure 3.10, and Figure 3.11.

A first important feature is that the impact response and the longer effect are quite different for each lending rate considered (See Table 3.12). There is no homogenous behaviour across lending rates. Banks seem to optimise considering separable market segments. Given the time series properties for interest rates in Argentina, the transformed VAR representation has only one lag and, correspondingly, the long-term pass-through derived from this specification actually refers to quite few periods.

The short-term pass-through for the overdraft rate is 0.318 under the calm regime, and 0.244 under the volatile regime (See Table 3.13). These parameters are both significant at the usual levels. The long-term pass-through is 0.657 and 1.208, respectively. Note that, although the impact pass-through is greater under calm conditions, the longer-term effect is considerably higher in the volatile regime. As for the TVTP parameters, although they are jointly significant, none of them is individually significant. The signs of the parameters are the expected for the calm regime, but not for the volatile regime.

For the interest rates on bills, the impact pass-through is 0.956 in the low-volatility regime and 0.638 in the high-volatility state. In the long-term, this difference remains

[66] Results with the other sets are quantitatively and qualitatively similar. They are available from the author upon request.
[67] Since this paper focuses on the pass-through, this paper presents only the results for the second equation of the transformed VAR (for the lending rate) in each case.

similar, with a larger pass-through for the calm regime than for the volatile state. The price setting behaviour in this case shows a near-complete impact effect of money market rate changes on the lending rate under normal conditions in the credit market, but less so when there is extremely high uncertainty in that market (even in the long-term). No individual parameter of the TVTP seems to be significant, (again, they are jointly significant) although the signs are as expected.

Interest rates on personal loans show a much different behaviour from the other two rates. They follow changes in the interbank rate moderately in calm conditions, but do not follow at all changes under high volatile market conditions. The short-term pass-through is 0.472 in the first state[68] and practically zero in the second one. The long-term effect shown an implausible over reaction, but this is due to the nearly-unity autoregressive parameter for this rate. TVTP parameters are jointly significant but not individually, and their signs are partly as expected.

In order to assess how sensitive these results are to the sample size, the model has been estimated sequentially for samples up to 2000, 2001, 2002, and 2003 (See Table 3.14, Table 3.15, and Table 3.16). In all three cases, this procedure confirms that the pass-through increased when the high volatility regime is short-lived (such as during the international financial crises), but it rather decreases when it is a longer lasting state (such as during the collapse of the currency board).

The interest rate that most closely follows the money market rate, the bill rate, is the one that shows a more regular pattern for the pass-through under both regimes over all

[68] This pass-through is between 32 and 36 percent from the Markov switching VARs with all the other sets of leading indicators.

samples. The short-term pass-through for the tranquil regime is between 0.925 and 1.077, over all the different sample estimations. It indeed shows a very high impact effect of the interbank rate on this lending rate. This pass-through accelerates and overshoots up to 1.291 for the financial crisis episodes, but diminishes to around 0.64 during the breakdown of the exchange rate system. The long-term pass-through shows overshooting up to 1.882 in the calm regime, but it surprisingly shows a less-than-complete effect under the volatile regime.

3.6 CONCLUSIONS AND FURTHER RESEARCH

Regime switching in the interest rate pass-through has been a feature of the financial system in Argentina. A multivariate approach using Markov switching models is appropriate to represent this nonlinearity in the pass-through. Furthermore, a number of interest rate spreads are associated to the probability of a given regime changing into another one, so that their information content on the risks banks face could signal a regime shift. Therefore, interest rate spreads are used to represent time-varying transition probabilities (as opposed to constant ones). Still, further empirical research should indicate if a particular set of spreads or some other alternative variables (representing bank risks) are more appropriate for this role.

The credit market in Argentina is heterogeneous and banks seem to optimise their behaviour by market segments. Thus, different degrees of financial development impinge upon interest rates behaviour on every type of credit operation. The modern private enterprise sectors (towards which bills loans are directed) show a greater degree of response to shocks in the financial market conditions (represented by interbank rate changes). Their pass-through under normal conditions is stable and is very close to being complete on impact. Under uncertain market conditions, the pass-through increases if the shocks to the interbank rate are unusually (but not extremely) large and short-lived. On the contrary, the pass-through diminishes (in relative terms) if those shocks are rather extremely large and more long-lived. However, once a tranquil regime is reassumed, the pass-through returns to its normal levels. Those normal levels seem to have reached a high degree of efficiency in the transmission mechanism.

Meanwhile, interest rates on personal loans reveal a much different behaviour in as much as its pass-through is rather low. These interest rates seem to reflect a different structure on this market segment, by which banks are less prone to adjust to money market conditions, probably because they rather absorb changes in their margins.

The nonlinearities in the interest rate pass-through in Argentina are associated to financial crises, either international or domestically generated, that affect the banking system to different degrees and to different variables (prices and/or quantities). They do not seem to be particularly associated to the business cycle, whose effects seem to be smoother or at least overshadow by the magnitude of the financial crises effects.

Figures

Figure 3.1 Nominal Interest Rates (pesos) in Argentina: 1993:06 – 2003:12

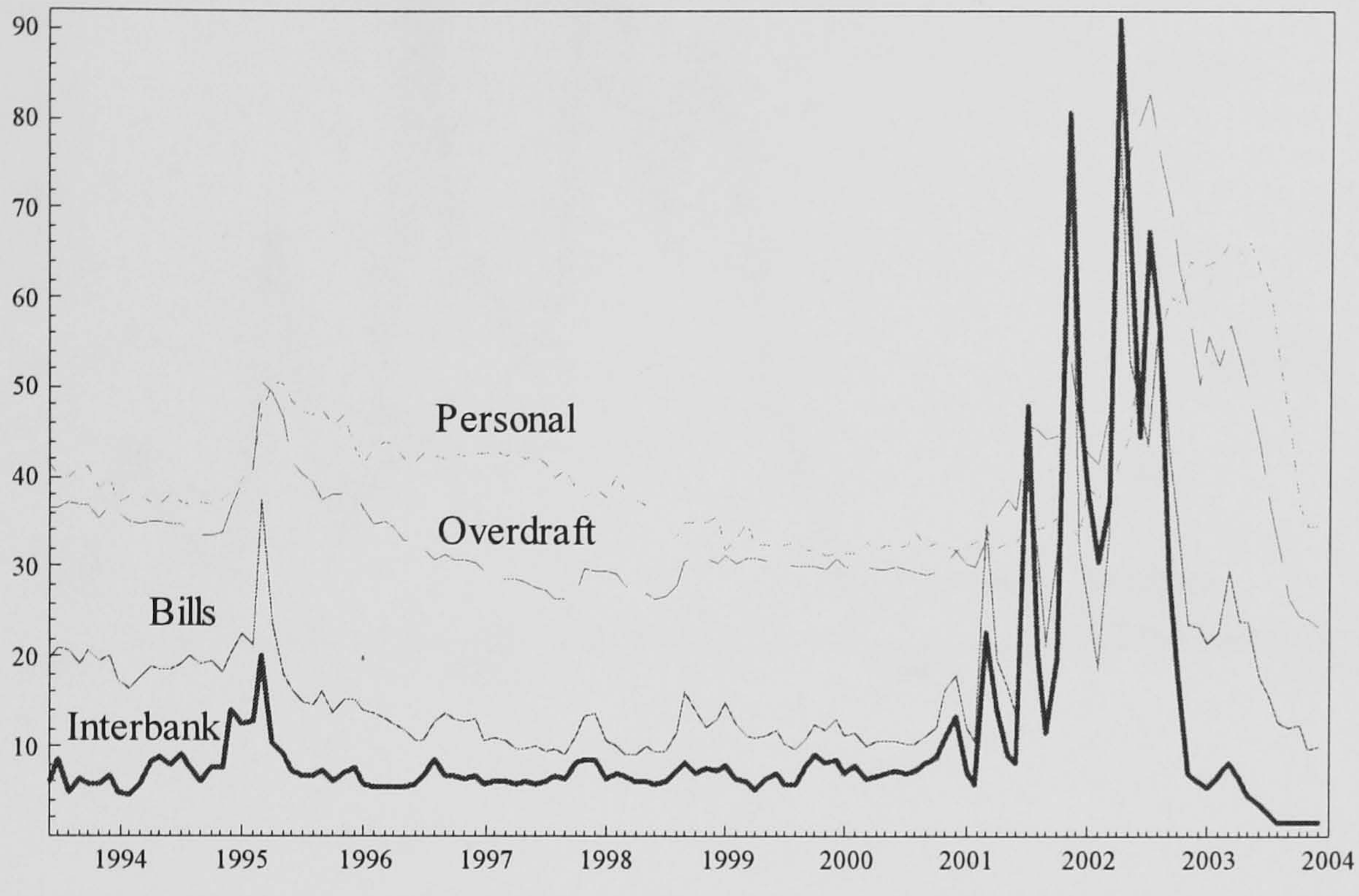

Figure 3.2 Nominal Interest Rates (US dollars) in Argentina: 1993:06 – 2003:12

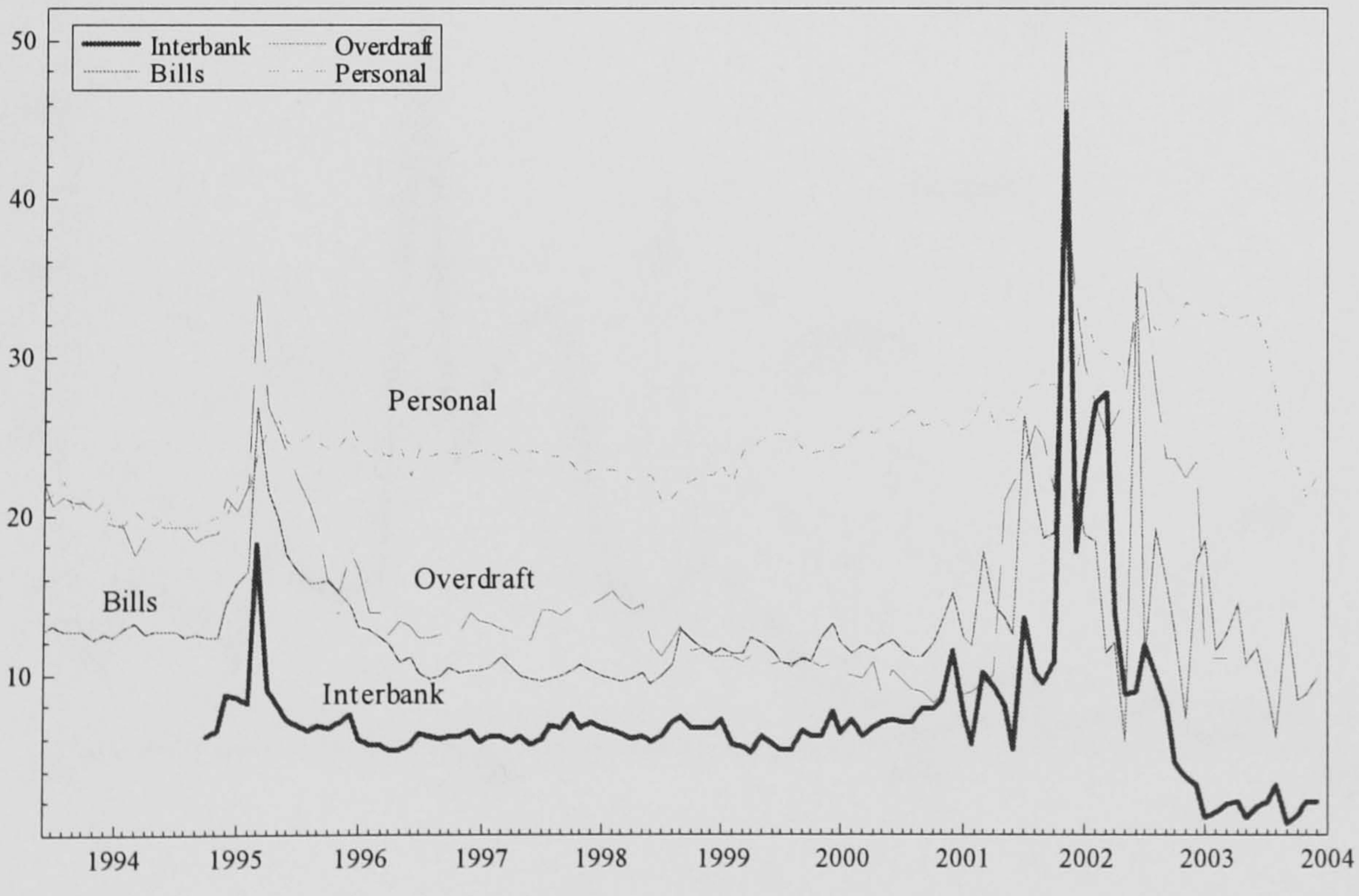

Figure 3.3 Nominal Interest Rates (pesos) in Argentina: 2001:12 – 2003:12

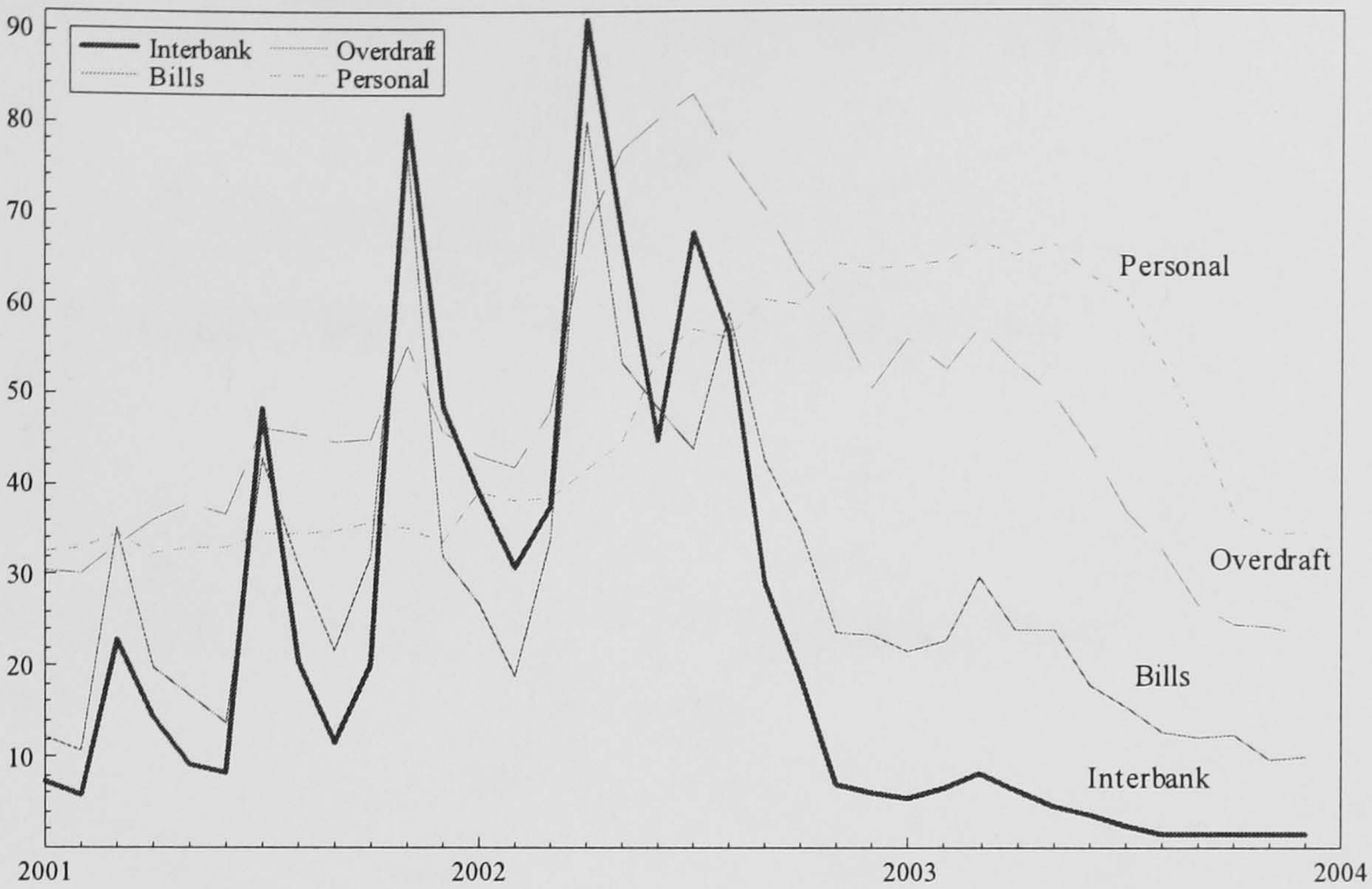

Figure 3.4 Nominal Interest Rates (US dollars) in Argentina: 2001:12 – 2003:12

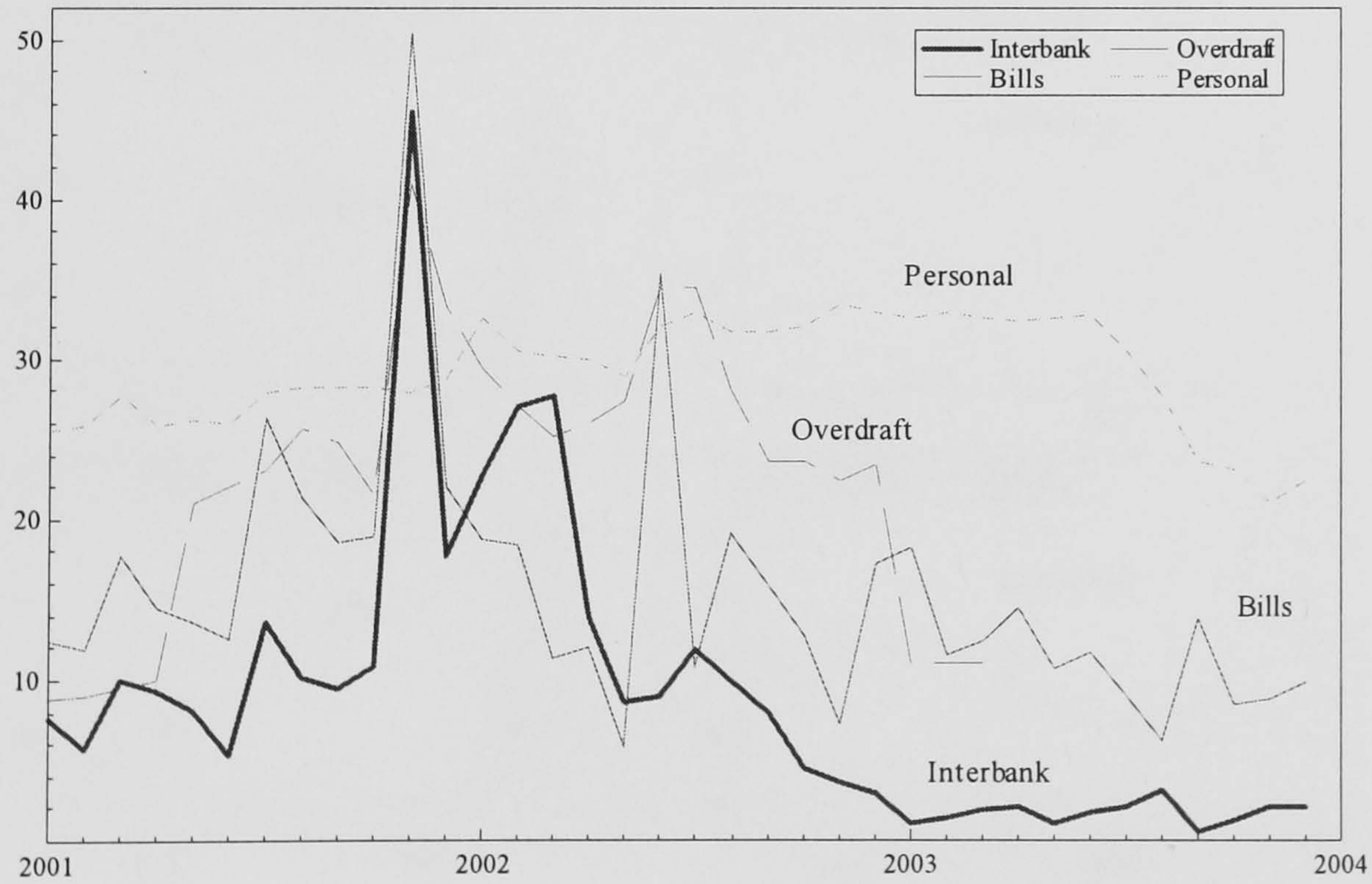

Figure 3.5 Lending Rates vis-à-vis the Interbank Rate

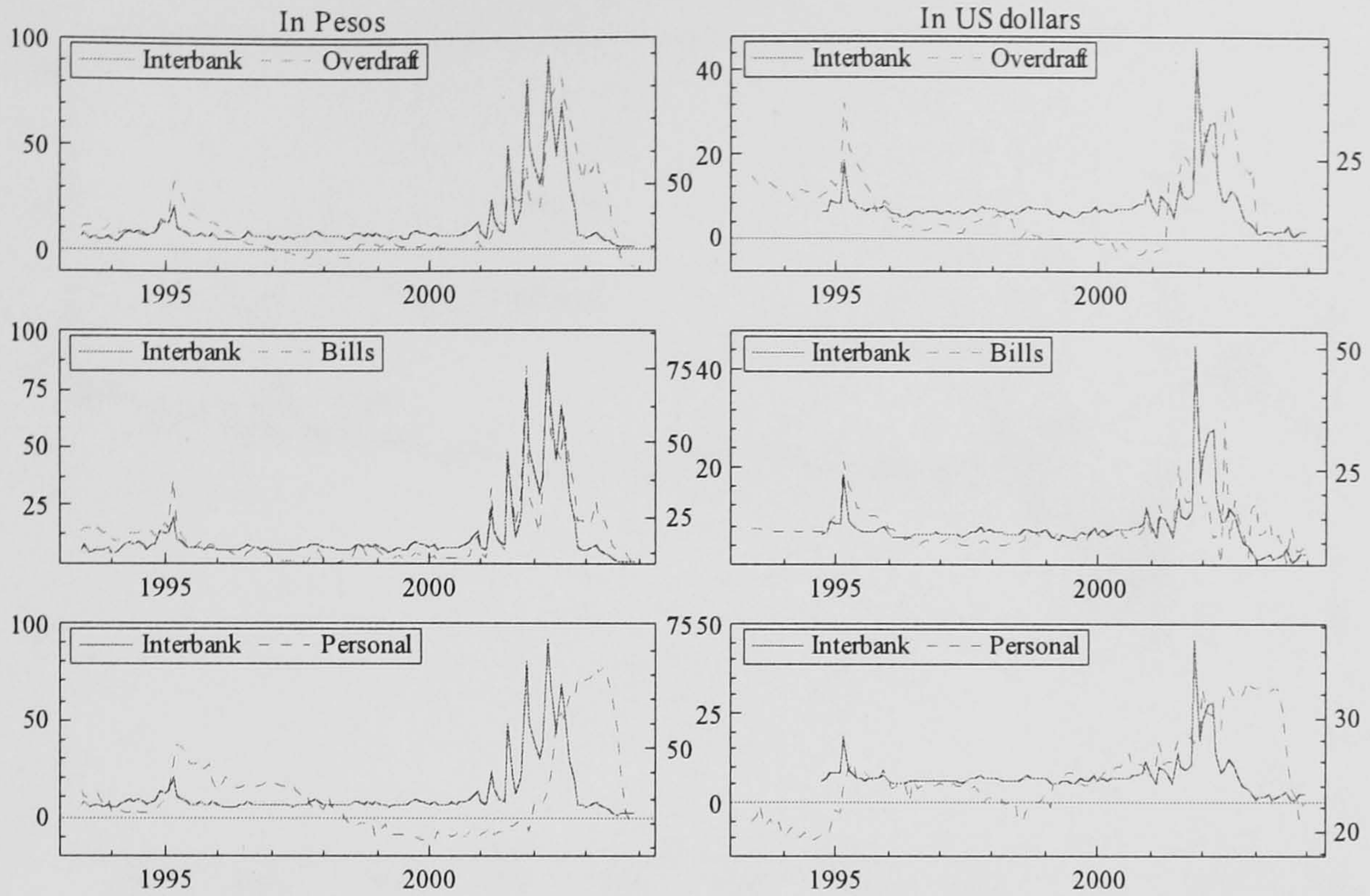

Figure 3.6 Lending Rates in Pesos and Dollars

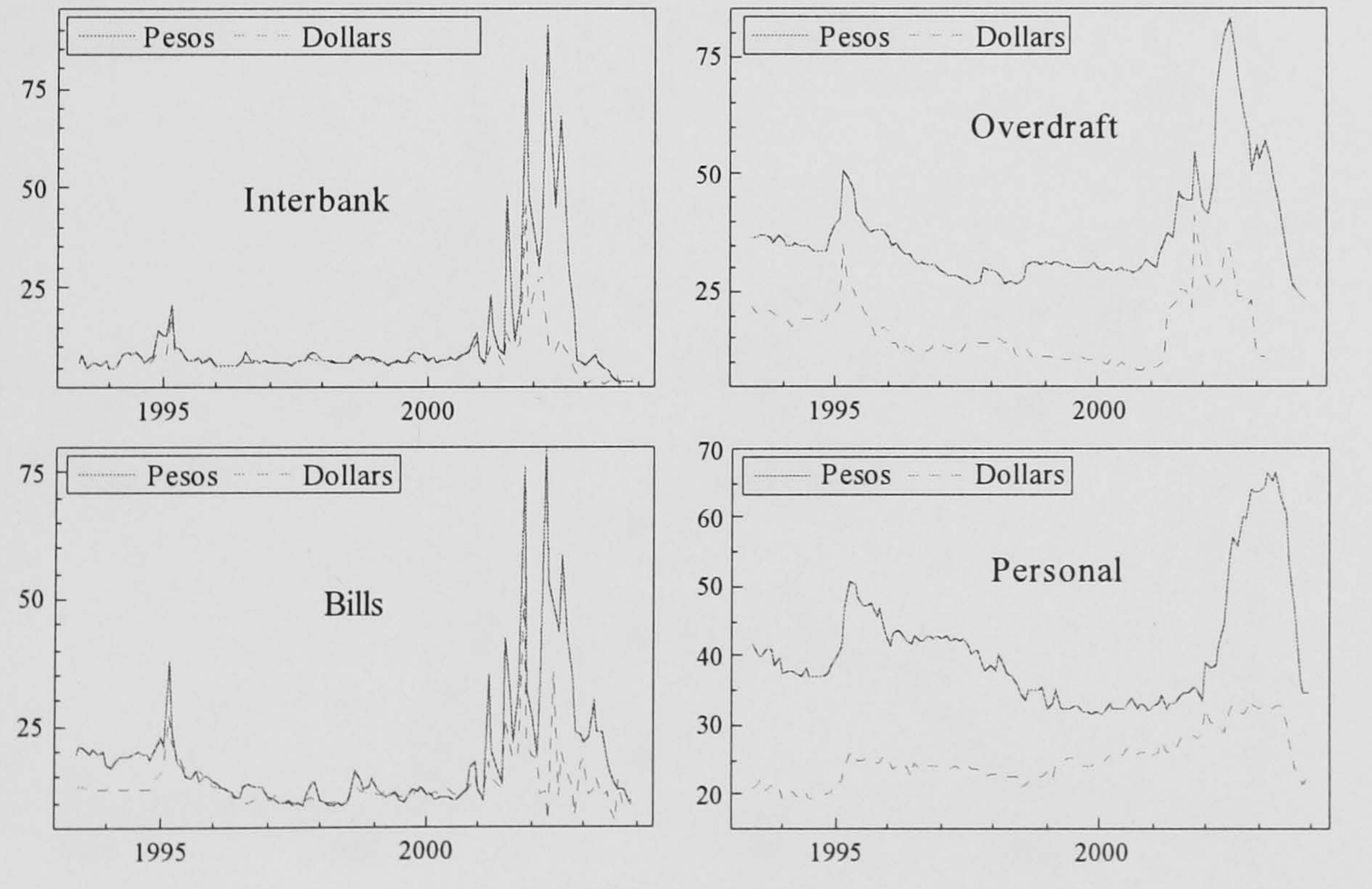

Figure 3.7 Spread between Each Lending Rate and the Interbank Rate

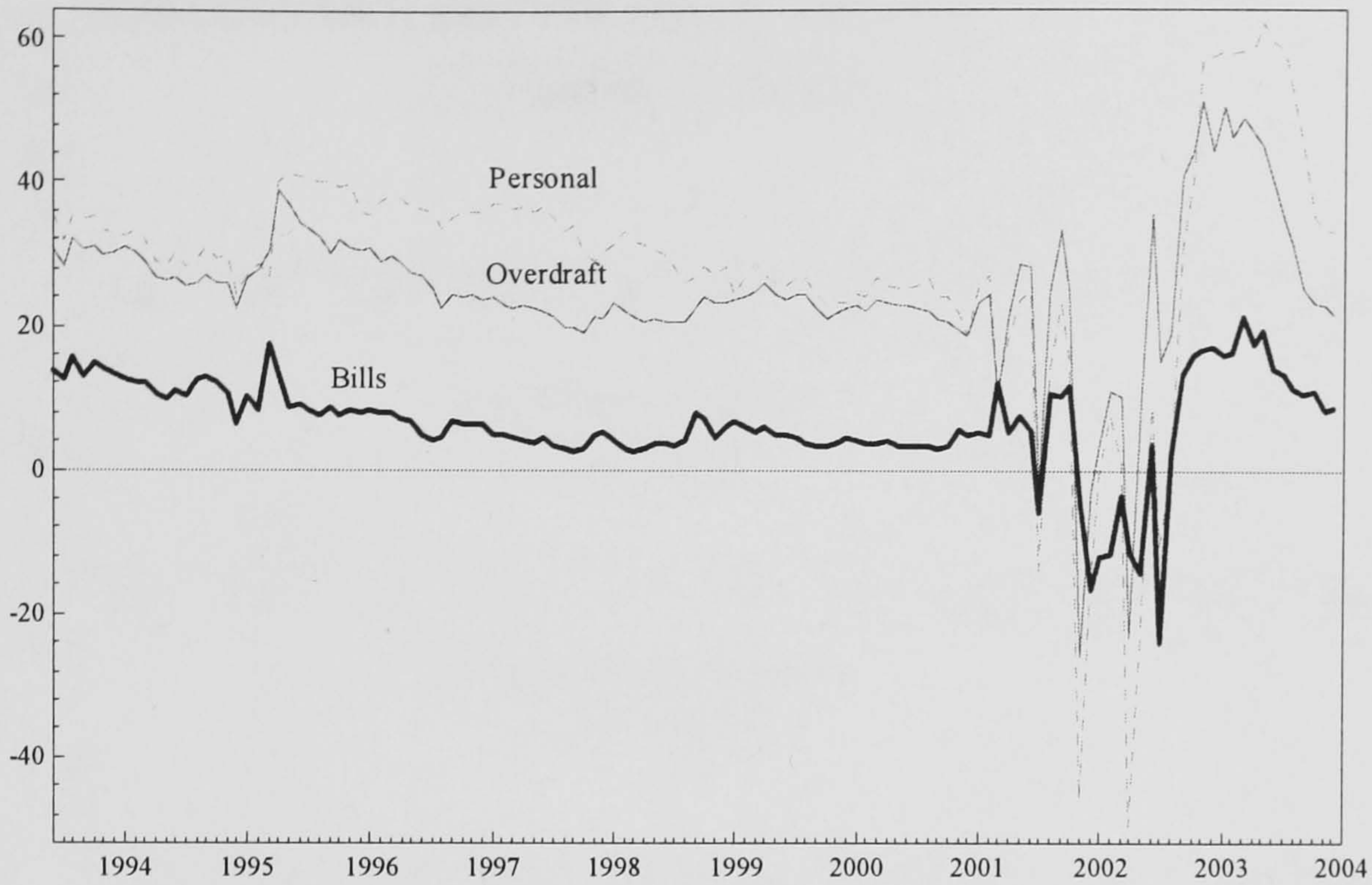

Figure 3.8 Spread for Each Lending Rate in Pesos and US Dollars

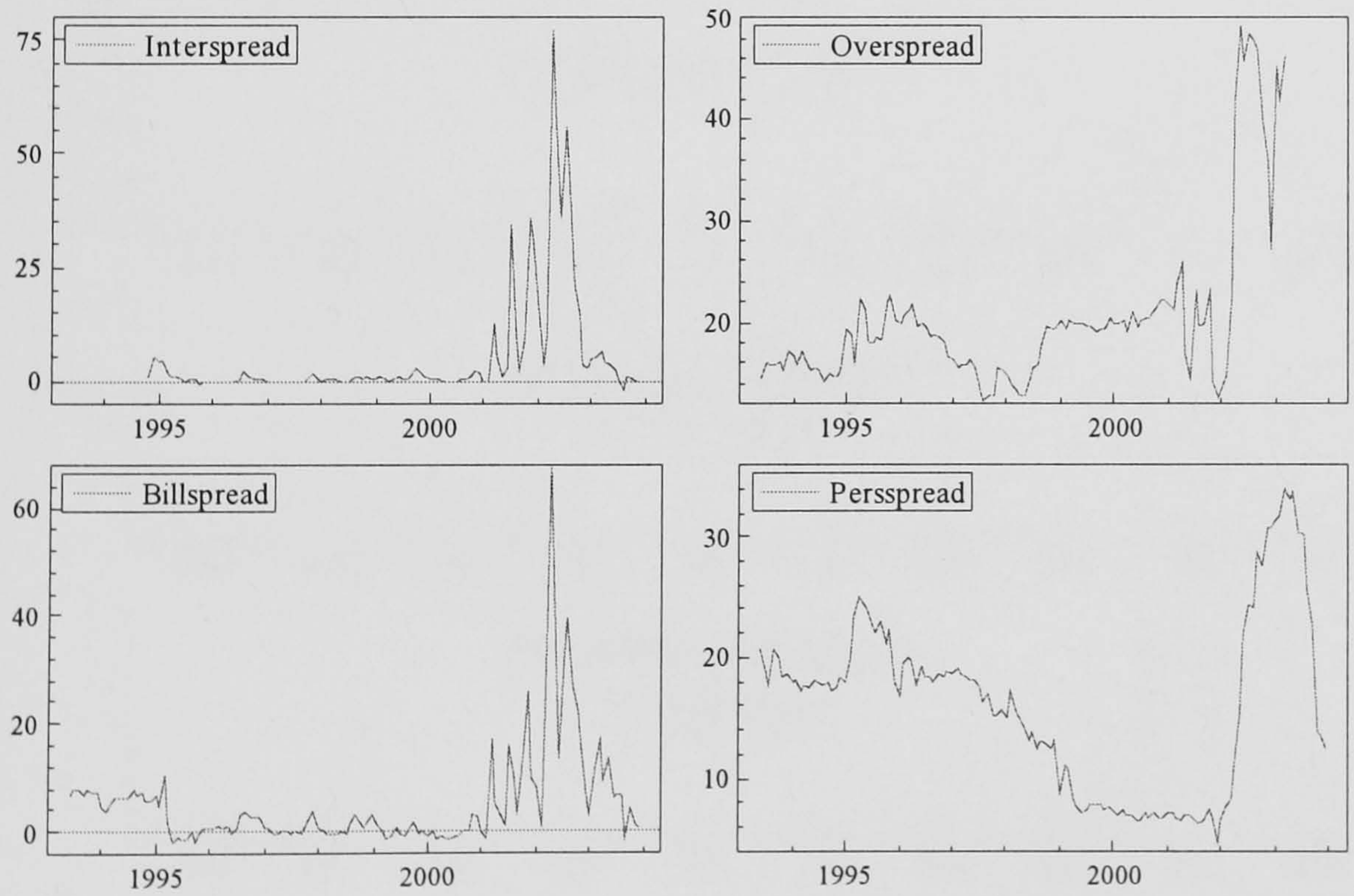

Figure 3.9 Regime Probabilities from MSVAR with TVTP Interbank - Overdraft

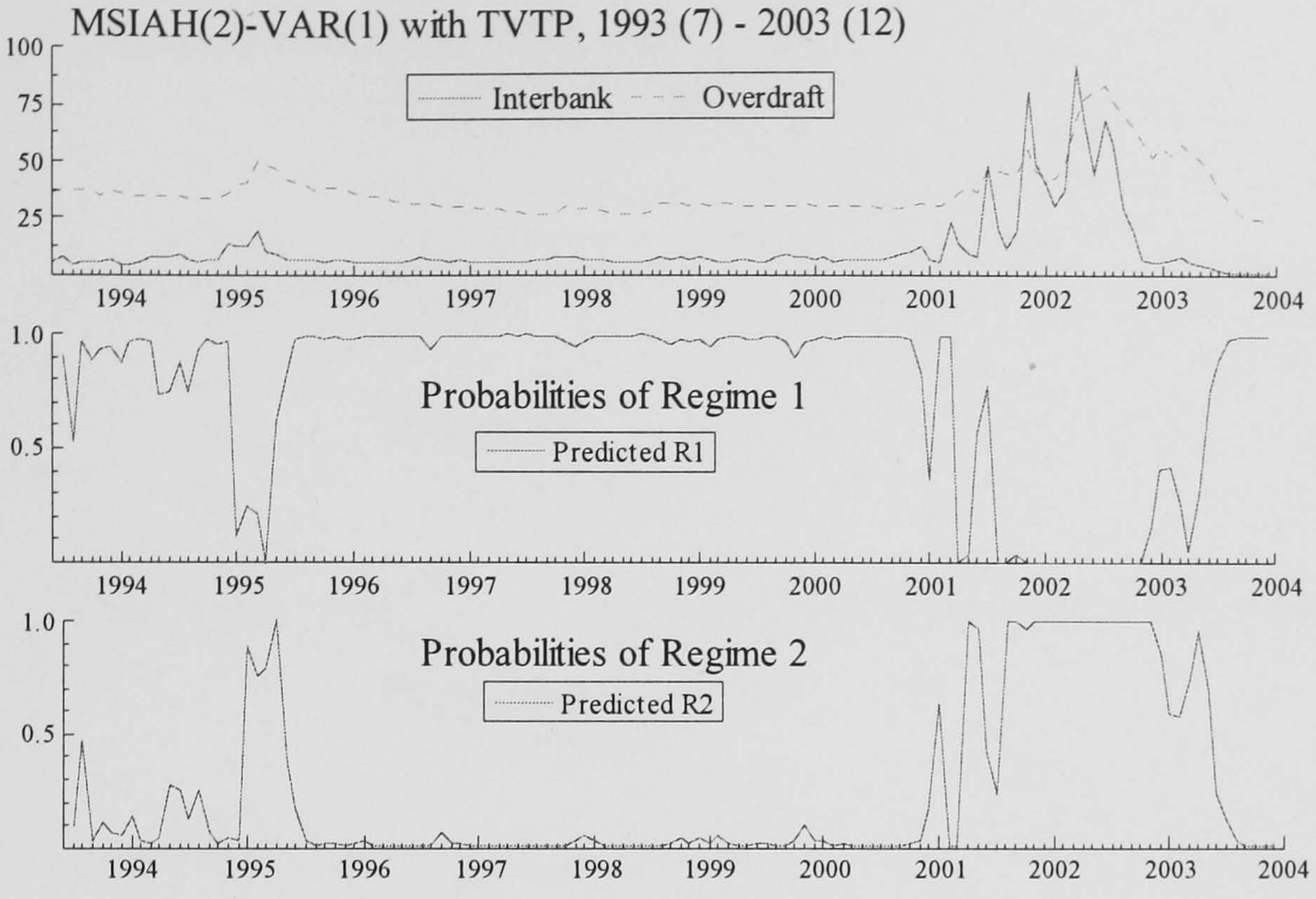

Figure 3.10 Regime Probabilities from MSVAR with TVTP Interbank - Bills

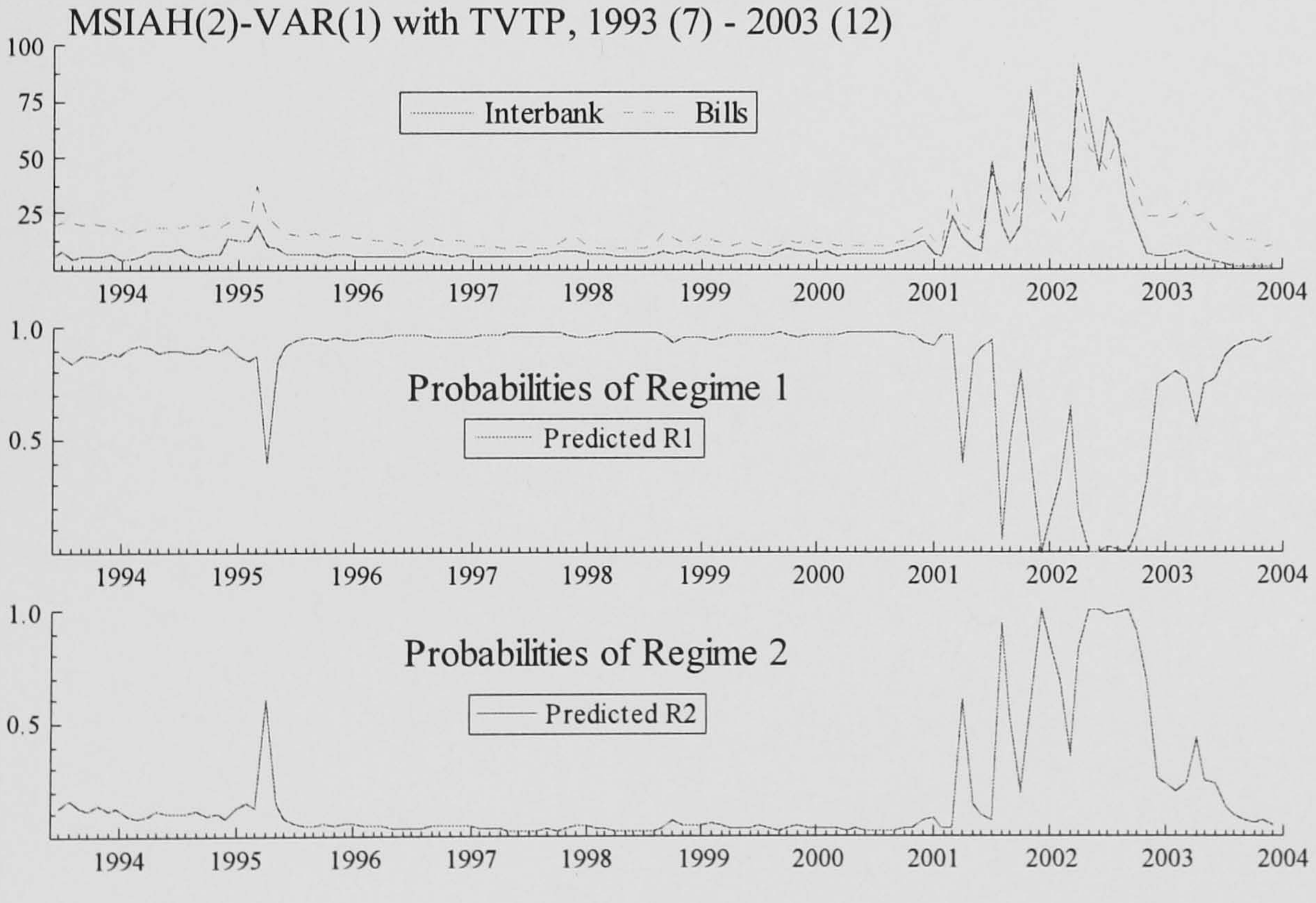

Figure 3.11 Regime Probabilities from MSVAR with TVTP Interbank - Personal

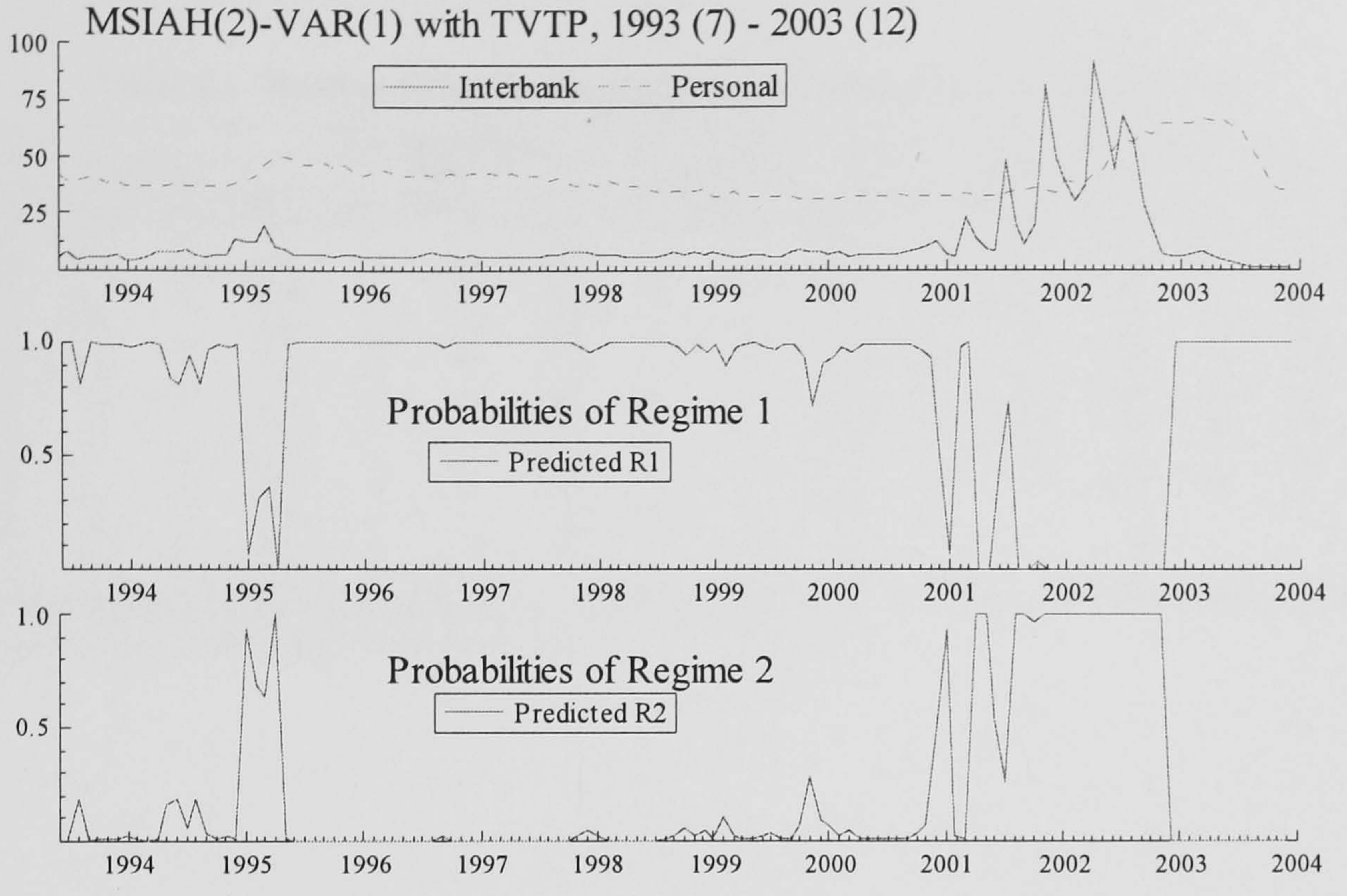

Table 3.1 Number of Institutions with/without Operations per Interest Rate

End of Year	Fixed Interest Rates									Variable Interest Rates					
	Overdraft			Bills			Personal			Bills			Personal		
	With	Without	Total	With	Without	Total	With	Without	Total	With	Without	Total	With	Without	Total
1993	157	49	206	109	97	206	71	135	206	80	126	206	57	149	206
1994	155	50	205	105	100	205	65	140	205	79	126	205	59	146	205
1995	114	44	158	70	88	158	40	118	158	50	108	158	36	122	158
1996	110	37	147	68	79	147	44	103	147	43	104	147	40	107	147
1997	101	37	138	59	79	138	46	92	138	38	100	138	37	101	138
1998	87	43	130	50	80	130	47	83	130	33	97	130	32	98	130
1999	76	41	117	45	72	117	43	74	117	18	99	117	30	87	117
2000	71	42	113	41	72	113	35	78	113	14	99	113	21	92	113
2001	56	52	108	12	96	108	21	87	108	6	102	108	13	95	108
2002	62	37	99	25	74	99	33	66	99						0
2003	60	36	96	26	70	96	33	63	96						0

* As from January 2002, data on fixed interest rates correspond to fixed and re-negotiable rates together.

Source: Monetary and Financial Statistics Department - Central Bank of Argentina

Table 3.2 Loans to the Non-Financial Private Sector in Flows (in Millions)

End of year	Peso-denominated loans					Dollar-denominated loans				
	Overdraft	Bills 1/	Personal 2/	Other	Total	Overdraft	Bills 1/	Personal 2/	Other	Total
1993	5043	1060	504	640	7248	175	1428	66	1776	3445
1994	5052	1332	533	470	7386	226	1710	43	1614	3593
1995	3744	978	454	340	5515	366	1209	67	1361	3003
1996	3949	891	530	423	5792	387	1001	267	1661	3316
1997	4758	1283	631	576	7248	375	1427	234	1982	4017
1998	4826	1324	845	422	7417	496	1468	182	1741	3887
1999	4463	1747	786	401	7397	504	1082	176	1679	3441
2000	3923	1445	757	341	6467	457	1580	156	1385	3577
2001	2230	137	744	69	3180	1038	4512	72	692	6315
2002	1792	89	1480	657	4018	20	1	0	109	130
2003	2715	182	1807	842	5546	0	2	3	113	117

1 Loans up to 89 days.

2 Loans up to 180 days.

Source: Monetary and Financial Statistics Department - Central Bank of Argentina

Table 3.3 Loans to the Non-Financial Private Sector in Flows (in Percentage)

End of year	Peso-denominated loans					Dollar-denominated loans				
	Overdraft	Bills 1/	Personal 2/	Other	Total	Overdraft	Bills 1/	Personal 2/	Other	Total
1993	69.6	14.6	7.0	8.8	100.0	5.1	41.4	1.9	51.6	100.0
1994	68.4	18.0	7.2	6.4	100.0	6.3	47.6	1.2	44.9	100.0
1995	67.9	17.7	8.2	6.2	100.0	12.2	40.3	2.2	45.3	100.0
1996	68.2	15.4	9.1	7.3	100.0	11.7	30.2	8.0	50.1	100.0
1997	65.6	17.7	8.7	7.9	100.0	9.3	35.5	5.8	49.3	100.0
1998	65.1	17.8	11.4	5.7	100.0	12.8	37.8	4.7	44.8	100.0
1999	60.3	23.6	10.6	5.4	100.0	14.7	31.4	5.1	48.8	100.0
2000	60.7	22.4	11.7	5.3	100.0	12.8	44.2	4.3	38.7	100.0
2001	70.1	4.3	23.4	2.2	100.0	16.4	71.5	1.1	11.0	100.0
2002	44.6	2.2	36.8	16.3	100.0	15.1	0.6	0.0	84.3	100.0
2003	49.0	3.3	32.6	15.2	100.0	0.0	1.4	2.2	96.3	100.0

1 Loans up to 89 days.

2 Loans up to 180 days.

Source: Monetary and Financial Statistics Department - Central Bank of Argentina

Table 3.4 Comparative Statistics of Nominal Interest Rates in Argentina

Interest rate	1993:06 - 2000:12				2001:01 - 2003:12			
	Mean (m)	Std. Dev. (s)	(s) / (m)	Correlation to Interbank	Mean (m)	Std. Dev. (s)	(s) / (m)	Correlation to Interbank
Interbank	7.33	2.23	0.30	1.00	23.28	24.89	1.07	1.00
Bills	14.23	4.57	0.32	0.62	29.04	17.46	0.60	0.91
Overdraft	32.69	4.74	0.14	0.43	47.95	16.20	0.34	0.64
Personal	38.5	4.92	0.13	0.02	46.62	13.16	0.28	-0.18

Table 3.5 Standardized LR Test for MSI(2)-AR(1) against Null of Linearity

Interest Rate	Hansen's LR*	p-value				
		M=0	M=1	M=2	M=3	M=4
Interbank	3.8955	0.0000	0.0010	0.0020	0.0040	0.0040
Overdraft	4.3930	0.0010	0.0020	0.0040	0.0020	0.0060
Bills	3.4954	0.0030	0.0060	0.0090	0.0110	0.0190
Personal	5.6107	0.0000	0.0000	0.0010	0.0000	0.0010

1/ Implemented for grid 3. See details in Hansen (1992 and 1996).

Table 3.6 Standardized LR Test for Markov Switching Intercept Pass-Through

Pass-Through Equation	Hansen's LR*	p-value				
		M=0	M=1	M=2	M=3	M=4
Overdraft	2.6998	0.0750	0.1140	0.1510	0.1550	0.1530
Bills	2.3859	0.1360	0.1420	0.1540	0.1590	0.1740
Personal	2.0557	0.2470	0.2340	0.2690	0.2840	0.2960

1/ Implemented for grid 3. See details in Hansen (1992 and 1996).

Table 3.7 J-test for Markov Switching Intercept Pass-Through

Pass-Through Equation	J-test δ	Std. Error	t-statistic	p-value
Overdraft	1.0053	0.1042	9.6513	0.0000
Bills	1.0487	0.1449	7.2383	0.0000
Personal	1.0139	0.1593	6.3626	0.0000

Table 3.8 Specification Selection for Markov Switching VAR

Pass-Through Model	Overdraft - Interbank		Bills - Interbank		Personal - Interbank	
	Log Likelihood	LR Test 1/	Log Likelihood	LR Test 1/	Log Likelihood	LR Test 1/
With CTP						
MSI(2)-VAR(1)	-714.713		-805.199		-693.749	
MSIH(2)-VAR(1)	-515.498	398.430	-549.592	511.213	-529.676	328.145
MSIAH(2)-VAR(1)	-515.153	0.689	-540.123	18.938	-522.459	14.435
With TVTP						
MSIAH(2)-VAR(1)	-506.723	16.860	-530.168	19.912	-518.964	6.990
Appendix						
MSIAH(3)-VAR(1) 2/	-486.037	58.232	-499.572	81.103	-503.309	38.299
MSIAH(2)-VARX(1)	-792.932	-555.558	-813.488	-546.730	-861.935	-678.952

1/ The test is estimated for each model against the null of the previous selected model. Except in the Appendix, where models are tested against the null of MSIAH(2)-VAR(1).

2/ Although significant, it is not selected for economic interpretation.

Table 3.9 MSIAH(2)-VAR(1) Regime Classification for Overdraft Rate

Regime 2:	Estimation periods			
Events	1993:06 - 2000:12	1993:06 - 2001:12	1993:06 - 2002:12	1993:06 - 2003:12
Other 1/	1993:7 - 1993:8			
Mexico	1994:12 - 1995:6	1994:12 - 1995:3	1994:12 - 1995:3	1994:12 - 1995:4
South-East Asia	1997:11 - 1997:11			
Russia	1998:9 - 1998:9			
Argentina:	2000:11 - 2000:12	2000:11 - 2000:12	2000:11 - 2001:3	2000:12 - 2001:5
		2001:3 - 2001:3		
		2001:7 - 2001:7	2001:7 - 2002:12	2001:7 - 2002:5
		2001:10 - 2001:12		
				2002:7 - 2003:3
				2003:7 - 2003:9

Table 3.10 MSIAH(2)-VAR(1) Regime Classification for Bills Rate

Regime 2:	Estimation periods			
Events	1993:06 - 2000:12	1993:06 - 2001:12	1993:06 - 2002:12	1993:06 - 2003:12
Other 1/	1993:7 - 1993:10	1993:8 - 1993:8		
Mexico:	1994:12 - 1995:5	1994:12 - 1995:5	1994:12 - 1995:5	1994:12 - 1995:1
				1995:3 - 1995:5
South-East Asia				
Russia	1998:9 - 1998:9	1998:9 - 1998:9		
Argentina:	2000:11 - 2000:12	2000:11 - 2000:12		
		2001:3 - 2001:4	2001:3 - 2001:4	2001:3 - 2001:4
		2001:7 - 2001:12	2001:7 - 2001:12	2001:7 - 2001:12
			2002:3 - 2002:11	2002:3 - 2002:11
				2003:3 - 2003:3

1/ This period does not correspond to any major international financial crisis.

Table 3.11 MSIAH(2)-VAR(1) Regime Classification for Personal Rate

Regime 2:	Estimation periods			
Events	1993:06 - 2000:12	1993:06 - 2001:12	1993:06 - 2002:12	1993:06 - 2003:12
Other 1/				
Mexico	1994:12 - 1995:4		1994:12 - 1995:4	1994:12 - 1995:4
South-East Asia				
Russia				
Argentina:	2000:11 - 2000:12		2000:11 - 2001:3	2000:12 - 2001:3
		2000:12 - 2001:12	2001:7 - 2001:11	2001:7 - 2001:11
			2002:1 - 2002:9	2002:1 - 2002:9
			2002:11 - 2002:11	2002:11 - 2002:11
				2003:8 - 2003:10

1/ This period does not correspond to any major international financial crisis.

Table 3.12 Interest Rate Pass-Through in Argentina

	Short-term		Long-term	
	Regime 0	Regime 1	Regime 0	Regime 1
Overdraft	0.318	0.244	0.657	1.208
Bills	0.956	0.638	1.882	0.575
Personal	0.472	0.001	9.870	-0.084

Table 3.13 MSIAH(2)-VAR(1) with TVTP in Argentina: 1993:06 – 2003:12

	Overdraft	t-stat	Bills	t-stat	Personal	t-stat
Regime 0						
Intercept	3.292	3.71	-0.098	-0.18	-1.294	-1.04
Interbank	**0.318**	**2.74**	**0.956**	**8.75**	**0.472**	**2.49**
Interbank(-1)	-0.233	-2.29	-0.851	-9.11	-0.144	-0.78
Lending(-1)	0.870	47.36	0.944	25.52	0.967	45.27
S.E.	0.748	6.76	1.080	7.71	1.571	7.36
Regime 1						
Intercept	2.583	0.90	19.613	3.42	-3.425	-1.01
Interbank	**0.244**	**6.20**	**0.638**	**6.93**	**0.001**	**0.03**
Interbank(-1)	-0.112	-3.02	-0.022	-0.11	0.009	0.28
Lending(-1)	0.891	13.61	-0.071	-0.27	1.119	12.75
S.E.	3.864	3.46	6.338	1.71	2.330	3.51
TVTP						
Regime 0						
Constant	7.323	2.75	4.139	2.88	-0.618	-0.04
InterLending (-1)	-0.068	-0.86	-0.123	-1.11	0.226	0.55
InterlocalUS (-1)	-0.981	-1.69	-0.173	-1.55	-0.932	-0.92
Regime 1						
Constant	6.329	2.65	-7.786	-1.20	9.847	0.93
InterLending (-1)	-0.145	-2.16	0.458	1.30	-0.312	-0.76
InterlocalUS (-1)	0.003	0.04	0.318	1.16	-0.074	-0.29

Table 3.14 Overdraft Rate Pass-Through: MSIAH(2)-VAR(1) with TVTP

	MSIAH(2)-VAR(1) with TVTP							
Variables	Up to 2003		Up to 2002		Up to 2001		Up to 2000	
	Parameter	t-stat	Parameter	t-stat	Parameter	t-stat	Parameter	t-stat
Regime 0								
Intercept	3.292	3.71	4.360	4.17	1.178	1.81	0.409	0.48
Interbank	**0.318**	2.74	**0.150**	1.03	**0.178**	2.19	**0.235**	3.03
Interbank(-1)	-0.233	-2.29	-0.155	-1.40	-0.052	-0.83	-0.053	-0.65
Overdraft(-1)	0.870	47.36	0.857	35.65	0.927	59.56	0.939	51.66
S.E.	0.748	6.76	0.874	5.26	0.595	5.94	0.537	5.21
Regime 1								
Intercept	2.583	0.90	6.279	2.27	8.633	0.91	4.906	0.24
Interbank	**0.244**	6.20	**0.223**	5.69	**0.172**	0.90	**0.691**	1.01
Interbank(-1)	-0.112	-3.02	-0.032	-0.58	-0.170	-1.50	-0.022	-0.01
Overdraft(-1)	0.891	13.61	0.792	10.18	0.804	2.44	0.724	0.82
S.E.	3.864	3.46	3.316	2.82	2.516	1.33	1.541	0.25
TVTP								
Regime 0								
Constant	7.323	2.75	4.379	0.54	2.971	0.69	6.401	0.62
InterOver (-1)	-0.068	-0.86	0.078	0.28	0.036	0.22	-0.094	-0.22
InterlocalUS (-1)	-0.981	-1.69	-1.156	-1.70	-0.784	-1.57	-0.772	-0.76
Regime 1								
Constant	6.329	2.65	3.501	1.41	3.551	0.60	-1.817	-0.19
InterOver (-1)	-0.145	-2.16	-0.072	-1.01	-0.172	-0.75	0.029	0.08
InterlocalUS (-1)	0.003	0.04	-0.022	-0.55	0.049	0.23	0.124	0.23
Long-Term Pass-Through								
Regime 0	0.657		-0.036		1.716		3.006	
Regime 1	1.208		0.920		0.012		2.420	

Table 3.15 Bills Rate Pass-Through: MSIAH(2)-VAR(1) with TVTP

Variables	Up to 2003		Up to 2002		Up to 2001		Up to 2000	
	Parameter	t-stat	Parameter	t-stat	Parameter	t-stat	Parameter	t-stat
Regime 0								
Intercept	-0.098	-0.18	0.024	0.04	0.114	0.11	0.665	0.91
Interbank	**0.956**	8.75	**0.925**	7.54	**1.077**	6.02	**0.941**	7.16
Interbank(-1)	-0.851	-9.11	-0.827	-8.01	-0.892	-9.28	-0.244	-1.26
Bills(-1)	0.944	25.52	0.939	21.80	0.884	22.81	0.490	6.15
S.E.	1.080	7.71	1.075	7.14	1.006	6.73	0.570	2.32
Regime 1								
Intercept	19.613	3.42	18.808	3.16	15.403	1.42	-4.014	-1.58
Interbank	**0.638**	6.93	**0.657**	6.31	**0.772**	3.79	**1.291**	6.24
Interbank(-1)	-0.022	-0.11	0.036	0.17	-0.244	-0.35	-0.512	-3.01
Bills(-1)	-0.071	-0.27	-0.140	-0.53	0.028	0.03	0.926	8.06
S.E.	6.338	1.71	6.593	1.61	4.854	1.11	1.257	2.81
TVTP								
Regime 0								
Constant	4.139	2.88	3.531	2.01	4.578	1.71	2.618	0.78
InterBill (-1)	-0.123	-1.11	-0.061	-0.36	-0.016	-0.05	0.162	0.44
InterlocalUS (-1)	-0.173	-1.55	-0.132	-0.98	-0.843	-1.38	-0.993	-0.77
Regime 1								
Constant	-7.786	-1.20	-17.750	-0.65	0.586	0.15	-3.131	-0.48
InterBill (-1)	0.458	1.30	1.167	0.73	-0.158	-0.38	0.809	0.70
InterlocalUS (-1)	0.318	1.16	0.750	0.61	0.073	0.36	-0.930	-0.72
Long-Term Pass-Through								
Regime 0	1.882		1.609		1.590		1.364	
Regime 1	0.575		0.607		0.543		10.572	

Table 3.16 Personal Rate Pass-Through: MSIAH(2)-VAR(1) with TVTP

Variables	Up to 2003		Up to 2002		Up to 2001		Up to 2000*	
	Parameter	t-stat	Parameter	t-stat	Parameter	t-stat	Parameter	t-stat
Regime 0								
Intercept	-1.294	-1.04	1.520	1.02	2.613	1.66	2.327	1.30
Interbank	**0.472**	2.49	**-0.251**	-1.61	**-0.005**	-0.04	**-0.025**	-0.15
Interbank(-1)	-0.144	-0.78	0.129	1.11	-0.074	-0.42	-0.028	-0.13
Personal(-1)	0.967	45.27	0.977	34.05	0.940	34.19	0.942	31.45
S.E.	1.571	7.36	1.179	6.03	1.087	6.69	1.184	6.53
Regime 1								
Intercept	-3.425	-1.01	-1.109	-0.25	-9.002	-0.71	-22.158	-0.15
Interbank	**0.001**	0.03	**-0.007**	-0.13	**-0.005**	-0.10	**0.343**	0.24
Interbank(-1)	0.009	0.28	0.031	0.83	-0.031	-0.26	-0.139	-0.10
Personal(-1)	1.119	12.75	1.057	9.73	1.297	3.35	1.537	0.42
S.E.	2.330	3.51	2.310	2.55	0.965	0.49	0.142	0.09
TVTP								
Regime 0								
Constant	-0.618	-0.04	-1.015	-0.25	-2.048	-0.15	n.a	n.a
InterPers (-1)	0.226	0.55	0.173	1.14	0.195	0.43	n.a	n.a
InterlocalUS (-1)	-0.932	-0.92	-0.262	-1.54	-0.110	-0.14	n.a	n.a
Regime 1								
Constant	9.847	0.93	4.561	1.14	7.304	0.54	n.a	n.a
InterPers (-1)	-0.312	-0.76	-0.098	-0.95	-0.169	-0.55	n.a	n.a
InterlocalUS (-1)	-0.074	-0.29	-0.073	-0.81	-0.155	-0.26	n.a	n.a
Long-Term Pass-Through								
Regime 0	9.870		-5.233		-1.318		-0.899	
Regime 1	-0.084		-0.427		0.122		-0.379	

* It corresponds to a model with different leading indicators for the TVTP. The original did not converge in estimation.

CHAPTER 4

4 REGIME SWITCHING IN INTEREST RATE PASS-THROUGH AND DYNAMIC BANK MODELLING WITH RISKS

4.1 INTRODUCTION

Interest rates reflect banks' features on market structure, operating costs, and risk management as well as characteristics from loan demand and deposit supply. These microeconomic factors explain differences both in interest rates (lending and deposit) and in the corresponding interest rate pass-through (from money market rates to retail rates).[1] Banks consider these structural factors in the market segments in which they operate but set their interest rates based on the information contents of the short-term money market (interbank) rate they take as reference.

In particular, when a nonlinear pass-through is considered, the regime-switching behaviour might not be linked necessarily to those factors but to the money market rate instead. Hence, if the interest rate pass-through were indeed regime-switching then exploring where this nonlinearity comes from and how it affects banking optimisation is a relevant aspect of the transmission mechanism analysis. This paper addresses this discussion from a theoretical perspective (though it conducts an empirical application too). The objective is to build a theoretical model of dynamic bank optimisation that provides rationale to a regime-switching behaviour in the interest rate pass-through.

Two main sources of nonlinearity in the interest rate pass-through are considered in this paper. The first one operates through a nonlinear money market rate. A regime-switching behaviour in the interbank rate will induce a nonlinear pattern in the pass-

[1] The average level of those rates in aggregate markets will, of course, be more associated to macroeconomic factors, such as the interbank rate itself.

through by prompting regime switches in the risk premiums considered in bank optimisation. The data generating process for the interbank rate could be nonlinear if there is a regime-switching behaviour in monetary policy (interest rate smoothing vs. inflation fighting), in devaluation expectations (financial crises affecting agents' belief through uncovered interest parity), or in the term structure of interest rate (associated to business cycle phases). The second mechanism operates through asymmetric adjustment costs, which could induce a nonlinear pass-through even if the interbank rate is a linear stochastic process. The latter mechanism has been studied somewhere else,[2] so it is only briefly discussed here as an extension to the main model.

This research tries to answer two main questions. On one hand, it tries to analyse what kind of nonlinearity the pass-through displays. The goal is to derive a theoretical model of bank optimisation that could accommodate both a (Markov) switching regime process in the interbank rate and a nonlinear interest rate pass-through. The model should clarify the transmission mechanism by which a regime shifting nature of the interbank rate is connected to a regime switching behaviour in the pass-through. On the other hand, this paper discusses why the interest rate pass-through is quite heterogeneous by market segments despite feasibly sharing the same initial impulse (the nonlinearity in the interbank rate).

This chapter is organized as follows. Section 2 presents a simple static model of banking optimisation, which has been used often as theoretical support for deriving a linear interest rate pass-through. In Section 3, resorting to a nonlinear specification of the interbank rate and to dynamic modelling incorporates the basis for a regime-

[2] Hofmann and Mizen (2004), for instance, discuss an application of asymmetric adjustment costs to show a nonlinear behaviour in the transmission of money market shocks to retail rates in UK.

switching pass-through. Theoretical derivation of an actual nonlinear pass-through is presented in Section 4. This section discusses important extensions to the basic dynamic model, such as the inclusion of risks and product differentiation. Empirical applications to French and German data are reported in Section 5. Finally, Section 6 concludes.

4.2 LINEAR PASS-THROUGH: STATIC MODEL

Along with a standard Monti-Klein-type static model of banking optimisation, it is assumed here that banks mainly provide two kinds of financial securities to the private sector: deposits (supplied by households) and loans (demanded by firms).[3] Banks obtain revenues by providing those securities, and incur management and operating costs. Additionally, banks get income (expense) from participating in the short-term money market. Crucially, the money market short-term rate is the banks' opportunity cost of funding and thus, it is the reference rate upon which banks will form their expectations in a dynamic context. Yet, market expectations on the interbank rate do not play any role in this static model. Banks' managers are assumed risk neutral.[4]

Empirically, in order to estimate accurately the pass-through for different retail rates, a correlation analysis might be conducted to determine what interbank rate is the closest related to a particular retail rate.[5] However, whether an individual bank takes different money market rates as opportunity cost or refers to only one is arguably. In any case, short-term interest rates and the interbank rate should relate to each other through a suitable term structure. In theoretical models, this distinction is unnecessary and the money market rate that is taken as reference is the relevant one for bank optimisation.

[3] Freixas and Rochet (1997) review most of this section's behavioural descriptions.

[4] Hence, the optimisation function would be linear in profits. Though the assumption is important for the maximising function, it is not for the understanding of the firm. See Santomero (1984) for a discussion of risk-neutrality and risk-averse behaviour in bank optimisation. As King (1986) argues, risk neutrality seems an obvious assumption since bank managers have a full range of possibilities for portfolio diversification.

[5] Bondt (2002), for example, studies correlation between retails rates and money market rates both in levels and in first differences. He alternatively includes short-term interbank rates up to 12 months and government bond yields at different long-term maturities.

A symmetric Cournot oligopoly is assumed as market structure.[6] [7] Therefore, since there are many banks competing in the market subject to each other's actions, demand for loans and supply of deposits for each bank are not perfectly elastic. Correspondingly, interest rates depend not only on the level of loans and deposits a bank provides but also on the levels of these securities the other banks issue. Bank capital is given and exogenous.[8] Neither credit risk nor other risks are considered. The same intermediation technology is available to all banks.

4.2.1 Optimisation proces

The profit function an individual bank optimises is of the type:

$$\pi(L_i, D_i) = r_L L_i + rM - r_D D_i - C(L_i, D_i) \tag{2.1}$$

where $r_L = f\left(L_i + \sum L_j^*\right)$ and $r_D = f\left(D_i + \sum D_j^*\right)$ are functions (rather than just values) of the amount of loans (deposits) the individual bank offers and the amount all the other banks offer optimally. Also, π are bank profits, i is the i-th bank in the market; r_L is the interest rate on loans (as a function, it is the inverse loan demand), L_i is the volume of loans for the individual bank, and $\sum L_j^*$ represent optimal loans from the other j banks in the market. Likewise, r_D is the interest rate on deposits (as a function, it is the inverse deposit supply), D_i is the volume of deposits for the individual bank, and $\sum D_j^*$ stands for optimal deposits from the rest of banks in the market. Finally, r is the short-term money market rate; M represents net interbank funds supply by the bank; and $C(L_i, D_i)$

[6] Although original contributions by Klein (1971) and Monti (1972) did not focus on oligopoly in the banking industry, their models are readily applicable to this case.
[7] The symmetric feature guarantees that marginal costs are equalized and that the industry cost of production is optimised. For details on alternative general oligopoly models see Tirole (1988).
[8] Although capital constraint could be explicitly modelled, it is assumed that banks hold no more that the institutionally required amount of equity capital. This is assumed a given amount and it is not explicitly included in the model.

represents the (management and operating) cost function. All these functions are continuously differentiable up to any order.

Banks maximise profits subject to their balance sheet constraint: $R+L=D$, where R represents reserve funds, made up of cash reserves (as a proportion a from deposits) and interbank funds. Notice here that the subscript i has been obviated. This constraint could be incorporated directly in the profit function by representing the net interbank funds as $M=(1-a)D-L$. Thus, the profit function turns into:

$$\pi(L_i,D_i)=[r_L-r]L_i+\left[r(1-a)-r_D\right]D_i-C(L_i,D_i) \tag{2.2}$$

The first order conditions (FOC) are:[9]

$$\frac{(r_L^*-r)-\partial C/\partial L}{r_L^*}=\frac{1}{n\varepsilon_L(r_L^*)} \tag{2.3}$$

$$\frac{r(1-a)-r_D^*-\partial C/\partial D}{r_D^*}=\frac{1}{n\varepsilon_D(r_D^*)} \tag{2.4}$$

where n is the number of banks in the market (considered as a market power indicator), $\varepsilon_L(r_L^*)$ is the elasticity of loan demand and $\varepsilon_D(r_D^*)$ is the elasticity of deposit supply. The amount of loans and deposits offered are such that the financial margin inversely depends both on price elasticity and on the market structure. If the cost function is separable, the maximisation problem is also separable by markets (credits and deposits). Each interest rate is independent of the value the other one takes.[10] The Cournot equilibrium implies that the optimal amount of loans (deposits) an individual bank

[9] See, for derivation details, Freixas and Rochet (1997).

[10] If credit risk (probability of default) is considered, it introduces a relationship between loans and deposits (even if the function cost is separable). See Freixas and Rochet (1997).

issues is equal to the total market loans (deposits) divided by the number of banks: $L_i^* = L^*/n$ and $D_i^* = D^*/n$.

4.2.2 Interest rate pass-through

From these generic FOC, it is usually derived the relationship between the lending (deposit) rate and the interbank rate.[11] Assuming a (linear) cost function of the type $C(L_i, D_i) = \phi_L L_i + \phi_D D_i$, the lending and deposit rates could be represented as:

$$r_L^* = \frac{1}{1-\frac{1}{n\varepsilon_L}} r + \frac{1}{1-\frac{1}{n\varepsilon_L}} \phi_L \tag{2.5}$$

$$r_D^* = \frac{(1-a)}{1+\frac{1}{n\varepsilon_D}} r + \frac{(1-a)}{1+\frac{1}{n\varepsilon_D}} \phi_D \tag{2.6}$$

If constant elasticities were assumed, it could be shown that both pass-through, for the lending and the deposit rates, are linear. Importantly, microeconomic factors such as demand and supply elasticities (ε_L and ε_D, respectively) and market structure (n) determine the pass-through. Since the model is static, there is no distinction between short-term and long-term pass-through.

This theoretical framework justifies the empirical approach of estimating the pass-through in an equation containing both the lending (deposit) rate and the interbank rate, and assuming, implicitly or explicitly, constant costs in either equation (2.5) or (2.6). The time series properties of the variables are considered by including current and lagged values of the lending (deposit) rate and the interbank rate either in levels or first-

[11] Manzano and Galmés (1996) discuss about the type of these relationships base on the loan demand and deposit supply functions.

differences (and either in a single equation or a system). Once a measure of the pass-through is obtained, the nature of the loan demand and the deposit supply functions are evaluated along with the cost function properties, so that these microeconomic variables explain differences in pass-through among market segments or countries (often in a panel data approach).

A crucial feature of these models is that the short-term money market rate is taken as exogenous to the system. Furthermore, even if the interbank rate is determined endogenously in a general equilibrium approach,[12] it is yet represented linearly. The generally accepted stylised fact for the interest rate pass-through is that it is sluggish in the short term, but complete in the long term.

4.2.3 Observations and caveats

The intuition behind the model is clear. In the banking industry, if the market structure were competitive, interest rates are set at levels where intermediation margins equal marginal costs for banks. More realistically, if the market structure were not perfectly competitive, those financial margins (net of costs) would depend inversely on the market structure and demand (supply) characteristics. Thus, differences in the interest rates banks charge for alternative market segments might be due to differences in demand characteristics (one segment demand being more elastic than other), in market structure (competition might be scarcer in some segments), or in management costs (differences between a modern-firm sector and a micro-enterprise segment). This simple model should be readily extended to include heterogeneity in both credit and deposit products. If the bank provides, for example, two different types of loans, and the

[12] As in Bolton and Freixas (2004).

demand for them and their costs are separable, then the optimisation process will reflect two subsidiary pricing problems.[13]

Despite the fact that this type of model is highly useful on displaying important bank patterns, it is confronted with some rigidity once the dynamic nature of the banking system is considered. Most strategic decisions and market expectations are time sensitive and, thus, no static model could capture accurately interest rate adjustments that accommodate those factors. Paisley (1994), for instance, in a study for the United Kingdom, recognizes the possibility of banks smoothing interest rate changes due to switching costs or asymmetric information cost.[14] Nevertheless, although results from the empirical error correction approach show some degree of smoothing rates, the study fails to report nonlinearities because of the static theoretical model assumed.

Furthermore, a static microeconomic model of banking, Green (1998) argues, will fail to distinguish between market-related interest rates and posted rates in the common two-tier pricing system banks operate. While banks try to adjust their posted rates following changes in their market rates (to avoid interest rate risks), the static modelling does not capture the difference between these rates. Hence, the interest rate management function is missing in the static approach.

Recent research has included some kind of nonlinearity into the bank optimisation process by considering asymmetric bank behaviour as a response to shocks in the

[13] Therefore, the FOC will be similar to the single-type loan case.
[14] Following a Stiglitz and Weiss (1981) argument by which, with high nominal interest rates, banks might avoid passing through entirely a change in a wholesale rate to its retail rates because of fears of attracting high-risk new borrowers.

interbank rate in a more dynamic approach.[15] That is, there is a need to represent an intertemporal bank optimisation to capture the presence of adjustment costs that might be asymmetric. Indeed, the pass-through might be different depending on whether the money market rate increases or decreases or, alternatively, the spread between the retail rate and the interbank rate widens or shortens. Those asymmetries are most generally associated to some kind of menu cost rationale.[16]

Notwithstanding that research, it is rather scarce the literature that associates feasible nonlinearities in the pass-through to regime switching behaviour in the interbank rate itself. Introducing dynamics into the bank's optimisation process could indeed account for other forms of nonlinearities. In particular, the presence of a regime switching behaviour in the pass-through could be exposed theoretically once dynamics is appropriately introduced in the model and the presence of credit and other risks is accounted for. Conversely, lineal modelling of the pass-through under the presence of switching regimes in the interbank rate could induce over- or under-statement of interest rates' responses to financial shocks.

[15] See, for instance, Hofmann and Mizen (2004) for the UK; Frost and Bowden (1999) for New Zealand; and Neumark and Sharpe (1992) for the US. Green (1998) suggests asymmetric adjustment in banks' posted rates as a response to changes in market-related rates (directly determined by the bank, but at market levels).

[16] Toolsema and Schoonbeek (1999) warn that introducing asymmetries in the cost functions of the banks or in their way of conduct (i.e. Stackelber representation of a leader and a follower) may imply counterintuitive effects on the individual bank's interest rates from shocks to the interbank rate.

4.3 NONLINEAR INTEREST RATES: DYNAMIC MODEL

The objective of this chapter is to provide a theoretical rationale for a regime-switching behaviour in the interest rate pass-through. This goal derives initially from the need to explain empirical results for the case of Argentina. Empirical evidence presented in the previous chapters show that the interest rate pass-through for Argentina has been subject to regime shifting. One main source of that nonlinear behaviour has been the presence of nonlinearities in the shot-term money market rate associated to financial crisis events. Market measures (interest rate spreads) of the risks banks face signalled those regime shifts alongside variations in market uncertainty. Pricing variables, rather than non-pricing quantity-related variables, have been assumed to reflect promptly how banks expectations responded to those shifting market conditions. Accordingly, a nonlinear econometric approach was followed to capture such a regime-switching pattern in the pass-through in Argentina. In order to make the analysis complete, those feasible nonlinearities in the interest rate pass-through should then need to be considered within the theoretical framework of the banking optimisation process.

In order to study the possibility of regime shifting in interest rate pass-through, this section introduces dynamics into the bank modelling. That is, each bank optimises its management subject to an ever-changing environment. There are, of course, a number of situations and market characteristics that make necessary to represent this behaviour as a (discrete- or continuous-time) dynamic optimisation problem. Bank contracts are usually design to last many periods, and the very essential nature of the business, providing liquidity and intermediating funds, are better understood in a dynamic set up. Dia (2004) argues, for example, that the long-term relationship established between a bank and its clients imposes indeed a need for a dynamic representation. Furthermore, Von Thadden (2000) discusses liquidity provision as a dynamic phenomenon.

Designing deposit contracts turns into an incentive-contracting problem when the possibility of repeated investment and ongoing uncertainty give way to arbitrage behaviour from depositors with potentially destabilizing effects to the bank.

In departing from the static model, an initial approach would be to consider all variables as times series and redefine correspondingly the optimisation problem. Regarding the dynamic representation, it is crucially important to define a state variable that includes at least an extra period. Most standard dynamic bank models do so by introducing (quadratic) adjustment costs in addition to the management and operating (linear or quadratic) costs.[17] Other models introduce dynamics by explicitly modelling the components on the asset and security sides of the balance sheet as time processes (either on expected value of the variables or through lags).[18] Some others include a dynamic constraint, which relate both sides of the balance sheets through time.[19] Most of these models consider the interbank rate exogenous to the system and either do not explicitly mention its dynamic properties or refer to it as a linear function (possible a random-walk-type generating process).

For this research, the first approach is adopted and so the dynamic model considers a discrete-time infinite-horizon optimisation problem with quadratic adjustment costs. It keeps the exogeneity of the interbank rate as an operating feature, but assumes a broader description of its data generating process. The model represents an (Cournot) oligopoly market structure for the banking industry. Nonetheless, since the focus of this paper is on the interest rate pass-through, the analysis focuses on interest rates rather than on the amount of loans and deposits (the actual control variables).

[17] Cosimano (1988) and Elyasiani, Kopechy, and van Hoose (1995).
[18] Van den Heuvel (2002), for instance.
[19] In particular, Dia (2004).

4.3.1 Optimisation constraints

The bank's main activities are still providing liquidity and intermediating funds to and between its clients. Thus, on the asset part of the balance sheet, the bank can either invest in loans or in the money market after holding aside compulsory reserves (if any).[20] In general, of course, banks could also invest in other securities such as (corporate or government) bonds in order to diversify their portfolio. All the same, given their main intermediation function, it is assumed that the interbank funds banks hold incorporate such asset-management options. On the liabilities end, the bank holds deposits and capital (which is now explicitly introduced). The bank lending activity is constrained by capital adequacy regulations and it is assumed that it will hold exactly the amount of capital that satisfies this condition.[21] Again, generally, banks could also issue non-deposit debt but, for simplicity, it has been restricted to deposits. Besides, considering capital as net worth (rather than just equity-based), it might also include subordinate debt.[22]

Consequently, the following constraints apply to the bank optimisation process:

Balance sheet constraint $$L_t + M_t + R_t = D_t + K_t \tag{3.1}$$

Bank reserves constraint $$R_t = aD_t \tag{3.2}$$

Capital adequacy constraint $$K_t = bL_t \tag{3.3}$$

where K_t is the bank's capital, and b is the capital requirement factor. For simplicity, as in Schneider (2001), net interbank positions and bank loans are one-period.

[20] Either as cash in its balance sheet or deposits in the central bank.

[21] As in Bolton and Freixas (2004). In general, the condition is $K_t \geq bL_t$, with the amount of loans being a risk-weighted measure which, in strict sense, would be different to the variable L_t in the rest of the optimisation problem. Here, for simplicity, all risk categories are weighted similarly.

[22] See Van den Heuvel (2002) for a discussion focused on the bank capital channel of monetary policy based on the capital requirements of the Basle Accord.

No particular functions or constraints are assumed for the demand of loans or supply of deposits. Still, it is assumed that both variables are homogenous in the sense that there is only one type of loans (demanded by firms with real investment opportunities) and one type of deposits (supplied by households).[23] Since the bank operates in a market structure in which it determines its optimal amount of loans and deposits by considering his own and other banks' choices, the demand for loans the bank faces is downward sloping and its supply of deposits is upward sloping.

4.3.2 The money market rate

The time series properties of the money market rate impinge on lending and deposit rates to determine the nature of their relationship.[24] The interest rate pass-through is not only affected by structural microeconomic factors but also essentially by expectations on (and recent history of) the interbank rate. Since no exact form of loan demand and deposit supply are known a priori, the pass-through relationship derived from generic FOC has been usually assumed linear. Moreover, what has been importantly assumed linear is the interbank rate itself (by far the usual assumption in the empirical literature). It is not surprising then that a linear pass-through is obtained. Alternatively, some studies have introduced nonlinearity in the form of asymmetric adjustment costs to shocks, but still keeping linearity in the money market rate.[25] Still, there is increasing evidence in the literature that both short- and long-term interest rates (from the yield curve) are characterized by stochastic regime switching processes.[26]

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[23] Dia (2004) makes the corporate sector to keep deposits in banks as a compensating balance to its loans, such as that a dynamic relationship between deposits and loans is introduced.

[24] A proxy for this interest rate could also be found in a bank's rate structure. Mester (1993) argues, for example, that prime rates play the role of a base rate in the domestic loan rate structure, with a competing bank following closely a change in the prime rate of a relevant bank.

[25] Hofmann and Mizen (2004) assume, for example, a random walk for the base rate.

[26] See, among others, Ang and Bekaert (2002); Bansal and Zhou (2002); Dahlquist and Gray (2000); Driffill, Kenc, and Sola (2003); Erlandsson (2002); Evans (1998), Garcia and Perron (1996); Gray (1996); and Hamilton (1988).

Economic processes such as the business cycle or economic policies such as central monetary decisions have indeed feasible regime switching effects on interest rates. In fact, the influential seminal paper by Hamilton (1988) suggests a regime shifting behaviour in the term structure of interest rates, for US data, because of the effects from the monetary experiment of October 1979.[27] Switches in regime are occasional, discrete changes in the parameters governing the stochastic behaviour of the interest rates in the yield curve (both, as univariate processes and as bivariate relationships between short- and long-term rates). Including those shifts in a yield curve model may, for example, render validity to the expectations hypothesis of the term structure of interest rates (which a linear model often fails to do).

Hamilton refers to three potential sources of nonlinearity in the stochastic behaviour of interest rates from the yield curve: nonlinearity in the utility function; nonlinearity coming from Jensen's inequality (when comparing yields from different terms); and optimal forecasts of future short-term rates being a nonlinear (rather than linear) function of past short rates. He focuses on the last source and shows indeed that for the period when the conduct of monetary policy changed,[28] short-term interest rates were much higher and more volatile than in any other period in the sample.

An empirical application by Gray (1996) of a generalized regime-switching model (that includes GARCH in the specification) nests standard interest rate models as special cases and allows time-varying regime-dependent parameters. The flexibility provided by a regime-switching model allows, for instance, a particular interest rate to have different speeds of mean reversion to different long-run means and at different variances

[27] This paper pioneered the methodology of regime-switching modelling of financial time series.
[28] From October 1979 to October 1982, the Fed switched from targeting short-term interest rates to targeting non-borrowed reserves.

during a given sample period. Gray shows that his model improves over the linear equivalent in terms of data fit and out-of-sample forecasting of short-term interest rates.

Nonlinearity in short-term interest rates is usually justified, when included in theoretical models, as being flexible enough to replicate empirical stylised facts for interest rates (namely mean-reversion and leptokurtosis) that are not sufficiently accounted for by a linear approach (even after including conditional heteroskedasticity). Gray (1996) argues that if the probabilities of regime shifting are linked to the interest rate level, then shifts from one regime to another may drive the empirically observed mean reversion and conditional heteroskedasticity in the short-term rate. Actually, he finds that US short term interest rates follow a random walk during low-volatility periods and a mean-reversion process during occasional periods of high rates and high volatility.[29] Besides, effects from individual shocks are greater on impact during highly volatile periods but are longer lasting during calm periods. This substantially different economic behaviour across regimes for short term interest rates could only be modelled by introducing regime switching (often with time-varying transition probabilities).

Along the general concept of adaptability of agents to an ever-changing environment, Dahlquist and Gray (2000) argue that it is feasible that the economic and political mechanism behind the data generating process for interest rates may indeed be time-varying. That implies that both the parameters of an interest rate model and the structure of the model itself may change with the economic and political environment affecting the financial markets. In particular, agents' expectations on exchange rate arrangements (in the euro area, for example) provide ground for interest rate differentials to reflect

[29] See also Dahlquist and Gray (2000) for the case of Germany.

credibility shocks (working through the interest rate parity relationship). Thus, they argue, in modelling interest rate changes, a measure of realignment expectations is captured. The volatility, the level, and the speed-of-adjustment are all higher when the financial markets increase their expectation of realignment.[30] Clearly then, the stochastic behaviour governing the data generating process for short-term interest rates is dependent on these expectations (regimes) and the monetary policy response they originate, so that modelling it through a linear approach would end up inappropriate.

One of such lineal models is the standard affine-type Cox-Ingersoll-Ross (CIR) model of the term structure of interest rates. The CIR model is an intertemporal general equilibrium asset-pricing model in which expectations, risk aversion, investment opportunities, and consumption preferences are all considered in determining bond prices. The differential equation that describes the interest rate dynamics is thus consistent with maximising behaviour and rational expectations:[31]

$$dr = \alpha(\theta - r)\,dt + \sigma\sqrt{r_t}\,dz \tag{3.4}$$

where α is the mean reversion parameter that indicates the adjustment speed; θ is the implied long-term mean for the interbank rate; σ is the variance (serves as a scale factor) of unexpected interest rate changes; and z is a Wiener process. Notice that the volatility of the interbank rate is parameterised as a function of its (square root) levels and so it does produce conditional heteroskedasticity.[32 33]

[30] For Germany, though, the standard deviation of interest rate changes is comparatively (to other weak currency countries) not very large. Empirically, it might be the case that those switches in regime are frequent but short-lived and so appropriate frequency data is needed to infer the shifting dates.

[31] See details of the underlying equilibrium model and the continuous-time version model of the term structure in Cox, Ingersoll, and Ross (1985).

[32] The limiting distribution of r_t is $N(\theta,\sigma^2/2\alpha)$, so that the larger value of α the tighter the stochastic process is bound to its long-term mean. See James and Webber (2000), Chapter 3, for details.

[33] The square root on the interbank rate ensures that the rate do not go negative.

Regarding the CIR model, Bansal and Zhou (2002) point out that much of its poor empirical performance (at lest for US data) is due to the fact that it does not consider the possibility of discrete changes in regime.[34] Therefore, they argue, a regime switching representation of the interbank rate could account for empirical violations of the expectations hypothesis, observed conditional volatility, and conditional correlation across yields in the term structure of interest rates. Indeed, for US data, they find regime shifts closely associated to business cycle phases. Similarly, Erlandsson (2002) shows that, even when accounting for conditional heteroskedasticity, a standard univariate model (CIR-type) does not describe well Swedish interest rate data. Hence, he resorts to a regime switching specification to fit the data and improve in the forecasting ability of the model. The relevance of extending the model by introducing a regime-switching mechanism is then obvious in economic and empirical terms.

This research's goal is to explore the consequences for the pass-through of including a regime shifting interbank rate in the banking optimisation process. For that, this paper considers a discrete-time version of the CIR model for the interbank rate (still exogenous to the bank) and extends it to accommodate regime-switching behaviour. That is, the model incorporates a Markov switching representation into a standard mean reverting square root process.[35] The money market rate is assumed to follow a stochastic process switching between two regimes (*0* and *1*). A Markov chain with fixed transition probabilities governs the unobservable regime variable (the discrete states are

[34] Evans (1998) argues, though, that by including regime switching, the evidence against the expectations hypothesis is considerably weakened but it is not entirely eliminated. Therefore, he combines it with a general equilibrium bond pricing model which generates time-varying risk premia. Both regime-switching and time-varying risk premia might explain the nonlinear behaviour in the term structure of interest rates.

[35] Different discrete-time versions of the model, including switching regimes, could be seen in Ang and Bekaert (2002), Bansal and Zhou (2002), Dahlquist and Gray (2000), Gray (1996), and Erlandsson (2002). For a continuous-time version, see Driffill, Kenc, and Sola (2003) and Elliott, Hunter, and Jamieson (2000).

independent of the interbank rate, for simplicity).[36] It is assumed also that participants in the financial market know the actual regime the economy is at.[37]

Then, the following stochastic difference equation represents the interbank rate as a regime-switching mean-reverting square root process:

$$r_{t+1} - r_t = \alpha(s_{t+1})\left[\theta(s_{t+1}) - r_t\right] + \sigma(s_{t+1})\sqrt{r_t}\,u_{t+1} \tag{3.5}$$

where $u_{t+1} \sim N(0,1)$ is a white noise distributed normal conditionally on r_t and s_{t+1}, and parameters α, θ, and σ are all subject to regime switching between the two regimes given by the unobserved variable s_t.

Driffill, Kenc, and Sola (2003) discuss that it is important to specify correctly the switching regime to fully benefit from the nonlinear representation; otherwise it may not represent an improvement over linear models, even if there are clear indications of switching behaviour in the data.[38] For the term structure, a model should not only have a good fit to the short-term data but also to the longer maturity rates (through forecasted short rates used for pricing bonds). In the case of the pass-through, having all parameters regime-dependent does not only mean that the short-term pass-through mean and volatility are subject to regime switching, but also the long-term pass-through. That is, the long-term effect of a shock in the interbank rate could also be regime-dependent and, thus, not necessarily be one hundred percent for all rates.

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[36] There is no theoretical rationale for this to be the case. Transition probabilities might be time-varying. Ang and Bekaert (2002) and Dahlquist and Gray (2000), for instance, find that interest rate spreads signal regime shifts.

[37] The researcher does not though. Hamilton (1988) actually assumes, working with bond yields, that bond traders recognize the chance of getting regime shifts and incorporate that possibility into their forecasts of interest rate evolution. Although they do not directly observe the current regime they are at, they form inference about it based on observation of some relevant variables.

[38] As they argue, a model that allows all the parameters to switch has typically a very flat likelihood.

Through the link to an interbank rate determined in an affine-type model, lending rates are consistent with other interest rates in the yield curve and, thus, are consistent with pricing interest rate derivatives.[39] Furthermore, an empirical analysis of interest rate series through Markov switching models should suggest a particular modelling of the pass-through derived from an industrial organization model and should point out feasible sources for the nonlinearity. This research follows this approach. The nonlinearity of the short-term money market rate could come (although not exclusively) from any of these directions: a nonlinear monetary policy, regime-switching devaluation expectations in the international capital markets (working through uncovered interest parity and, probably associated to financial crises), or the business cycle phases.[40]

In the case of Argentina, for example, econometric testing for nonlinearities in the money market rates showed indeed the presence of regime switching in the interbank rate associated to several financial crisis episodes. This empirical evidence justifies further the need to introduce a suitable representation of a nonlinear interbank rate in the optimisation process for banks. It needs to be a representation general enough as to collapse to the linear case if market uncertainty does not induce any regime switching in the interbank rate.

4.3.3 Cost functions

Banks face a number of costs to perform their intermediary activities. In fact, an important feature of the banking business is the interest rate risk (cost) that arises because of the maturity mismatch between liabilities and assets. If changes in interest

[39] Although, in this case, being a single factor model, it might only be suitable to price simple derivatives. See James and Webber (2000) for an extensive coverage of interest rate modelling.

[40] Gray (1996) cites, for example, oil crises, stock crises, and even wars as changes in the economic environment that coincide with higher volatility in US interest rates.

rate costs are ahead of interest rate revenues, banks need to decide whether to take an adjustment that leave profits unchanged based on the expectations they have on the nature of the shock (whether temporary or permanent). Thus, apart from the operating and management costs on the variables they control (quantities of loans and deposits), banks take into account the costs involved in adjusting their operations (on those variables) to sudden changes in the variables they do not control (market interest rates).

Actually, Hofmann and Mizen (2004) base their results on asymmetries and nonlinearities in the interest rate pass-through on this type of adjustment costs. They argue that banks could reduce costs by smoothing official interest rates through forward-looking expectations on the future path of those rates. Although this might indeed be a source of regime-switching behaviour in the pass-through, it is assumed here that these adjustment costs are symmetric and non-dependent on the regime the economy is at. That is, although the cost function is quadratic in the adjustment of the quantity-related variable, the parameters that govern that function are constant.

First then, the cost of servicing deposits and loans[41] are assumed linear in the quantity and the corresponding cost function is separable in the arguments:

$$C(L_t, D_t) = \lambda_L L_t + \lambda_D D_t \tag{3.6}$$

with $\partial C/\partial L_t > 0$, $\partial^2 C/\partial L^2 = 0$, $\partial C/\partial D_t > 0$, and $\partial^2 C/\partial D_t^2 = 0$. The coefficients λ_L and λ_D are the time-invariant parameters for operating costs on loans and deposits.[42]

[41] Here it is assumed for simplicity that there are not operating costs on the interbank funds. The existence of such costs introduces a link between the two sides of the balance sheet that might render loans and deposits depending on each other. See, for example, Elyasiani, Kopechy, and van Hoose (1995) for a discussion on the conditions under which cost separability is plausible.

[42] With time-varying coefficients, no closed-form solutions could be found. See Dia (2004).

Secondly, the adjustment costs are assumed quadratic for changes in the level of loans and deposits. This feature reflects increasing marginal intertemporal adjustment costs and that an expansion on the level of operations requires eventually investment expenditures to adjust the scale operations of the bank.[43] These costs are also separable. The complete cost function is then given by:

$$C(L_t, D_t) = \lambda_L L_t + \lambda_D D_t + \left(\frac{\gamma_L}{2}\right)(L_T - L_{t-1})^2 + \left(\frac{\gamma_D}{2}\right)(D_T - D_{t-1})^2 \qquad (3.7)$$

with γ_L and γ_D the time-invariant parameters for the scale-adjustment part of the cost function. There are, of course, costs associated to the asymmetry of information in the banking system in terms of liquidity and credit risks. Dia (2004), for example, includes a quadratic function for credit risk (rather than modelling it as affecting directly the rate of return on loans) to bring a dynamic constraint in the optimisation process. At this stage, for simplicity, it is assumed that there are neither default nor liquidity costs.[44]

4.3.4 Optimisation process

Banks maximise the expected value at time t of their profit function π at time $t+j$ by deciding on their level of loans and of deposits subject to the balance sheet restriction, the bank reserves restriction, and the capital requirement restriction.[45] The expected profits are thus optimised over an infinite time horizon. The bank's management is assumed risk-neutral. Notice here that the optimisation process does not include expanding capital beyond the capital adequacy constraint.[46] The optimisation problem

[43] Elyasiani, Kopechy, and van Hoose (1995).
[44] In the case of the credit risk, they can either be modelled as part of the costs or as diminishing the return on loans with a probability. The second approach is considered in the next section. In actual banking practice, it usually takes the form of a risk premium.
[45] For an analysis of alternative bank's objective functions, see the seminal paper by Monti (1972). For a thorough survey on bank modelling, see Santomero (1984).
[46] Implicitly, it is assumed that all profits are paid out as dividends as in Dia (2004).

will be solved for generic forms of the loan demand and deposit supply.[47] Thus, the general optimisation problem for an individual bank is:

$$V_t = \underset{\{L^i_{t+j}, D^i_{t+j}\}_{j=0}^{\infty}}{Max} E_t \sum_{j=0}^{\infty} \beta^j \pi_{t+j} \tag{3.8}$$

where $\beta \in (0,1)$ is a suitable discount factor that represents the temporal preferences from the bank (for instance, a function of equity return as opportunity cost) and E_t is the expectations operator. The superscript i stands for the individual bank choices, but they are next obviated. Including all restrictions directly into it, the profit function becomes:

$$\begin{aligned} \pi_{t+j} = & \left[r^L_{t+j} - (1-b) r_{t+j} \right] L_{t+j} + \left[(1-a) r_{t+j} - r^D_{t+j} \right] D_{t+j} \\ & - \lambda_L L_{t+j} - \left(\frac{\gamma_L}{2} \right) \left(L_{t+j} - L_{t+j-1} \right)^2 \\ & - \lambda_D D_{t+j} - \left(\frac{\gamma_D}{2} \right) \left(D_{t+j} - D_{t+j-1} \right)^2 \end{aligned} \tag{3.9}$$

Expanding the objective function to include the profit function the problem is given by:

$$\begin{aligned} V_t = Max\, E_t & \left\{ \begin{matrix} \left[r^L_{t+j} - (1-b) r_{t+j} \right] L_{t+j} + \left[(1-a) r_{t+j} - r^D_{t+j} \right] D_{t+j} - \lambda_L L_{t+j} \\ -\left(\frac{\gamma_L}{2} \right) \left(L_{t+j} - L_{t+j-1} \right)^2 - \lambda_D D_{t+j} - \left(\frac{\gamma_D}{2} \right) \left(D_{t+j} - D_{t+j-1} \right)^2 \end{matrix} \right\} \\ & + \beta E_t \left\{ \left(\frac{\gamma_L}{2} \right) \left(L_{t+j+1} - L_{t+j} \right)^2 + \left(\frac{\gamma_D}{2} \right) \left(D_{t+j+1} - D_{t+j} \right)^2 \right\} \end{aligned} \tag{3.10}$$

Notice that most assumptions taken on the microeconomics aspects of the optimisation problem are standard in the dynamic modelling of the banking industry. This model integrates them all into a simplify framework.

Optimising the expected value of profits with respect to the amount of loans and deposits, the FOC are obtained:

[47] Given particular specification for these functions, the Euler (difference) equation could be solved accordingly. Still, since the focus of this research is on price variables readily observable in the market, no a priori microeconomic knowledge on these functions is assumed.

$$\frac{\partial V_t}{\partial L_{t+j}} = 0 = \frac{1}{n} E_t \frac{\partial r_{t+j}^L}{\partial L_{t+j}} L_{t+j}^* + E_t r_{t+j}^L - (1-b) E_t r_{t+j} - \lambda_L$$
$$- \frac{\gamma_L}{n}\left(E_t L_{t+j}^* - E_t L_{t+j-1}^*\right) + \frac{\gamma_L \beta}{n}\left(E_t L_{t+j+1}^* - E_t L_{t+j}^*\right) \tag{3.11}$$

$$\frac{\partial V_t}{\partial D_{t+j}} = 0 = (1-a) E_t r_{t+j} - \frac{1}{n} E_t \frac{\partial r_{t+j}^D}{\partial D_{t+j}} D_{t+j}^* - E_t r_{t+j}^D - \lambda_D$$
$$- \frac{\gamma_D}{n}\left(E_t D_{t+j}^* - E_t D_{t+j-1}^*\right) + \frac{\gamma_D \beta}{n}\left(E_t D_{t+j+1}^* - E_t D_{t+j}^*\right) \tag{3.12}$$

where references to individual choices on loans and deposits have already been replaced by the Cournot equilibrium condition that $L_i^* = L^* / n$ and $D_i^* = D^* / n$.

Since there are not cross terms relating loans to deposits or vice versa, this system of difference equations could be solved for each interest rate independently. Thus, the Euler equations for loans and deposits are:

$$E_t L_{t+j}^* = \frac{\beta}{1+\beta} E_t L_{t+j+1}^* + \frac{1}{1+\beta} E_t L_{t+j-1}^* + \frac{1}{\gamma_L (1+\beta)} E_t \frac{\partial r_{t+j}^L}{\partial L_{t+j}} L_{t+j}^*$$
$$+ \frac{n}{\gamma_L (1+\beta)}\left[E_t r_{t+j}^L - (1-b) E_t r_{t+j}\right] - \frac{n \lambda_L}{\gamma_L (1+\beta)} \tag{3.13}$$

$$E_t D_{t+j}^* = \frac{\beta}{1+\beta} E_t D_{t+j+1}^* + \frac{1}{1+\beta} E_t D_{t+j-1}^* + \frac{1}{\gamma_D (1+\beta)} E_t \frac{\partial r_{t+j}^D}{\partial D_{t+j}} D_{t+j}^*$$
$$+ \frac{n}{\gamma_D (1+\beta)}\left[(1-a) E_t r_{t+j} - E_t r_{t+j}^D\right] - \frac{n \lambda_D}{\gamma_D (1+\beta)} \tag{3.14}$$

The expected optimal values of loans (deposits) depend on the one-period ahead value of loans (deposits), the lagged value of them, and the spread between the lending (deposit) rate and the interbank rate. Since this research is focused on the interest rate pass-through though, these equations are rather represented in terms of the lending and deposit rates:

$$E_t r_{t+j}^L = (1-b)E_t r_{t+j} + \lambda_L + \frac{\gamma_L}{n}\left(E_t L_{t+j}^* - E_t L_{t+j-1}^*\right)$$
$$-\frac{\gamma_L \beta}{n}\left(E_t L_{t+j+1}^* - E_t L_{t+j}^*\right) - \frac{1}{n} E_t \frac{\partial r_{t+j}^L}{\partial L_{t+j}} L_{t+j}^* \tag{3.15}$$

$$E_t r_{t+j}^D = (1-a)E_t r_{t+j} - \lambda_D - \frac{\gamma_D}{n}\left(E_t D_{t+j}^* - E_t D_{t+j-1}^*\right)$$
$$+\frac{\gamma_D \beta}{n}\left(E_t D_{t+j+1}^* - E_t D_{t+j}^*\right) - \frac{1}{n} E_t \frac{\partial r_{t+j}^D}{\partial D_{t+j}} D_{t+j}^* \tag{3.16}$$

These equations are valid for all $j > 0$, so that without loss of generality they could be stated as:

$$r_t^L = (1-b)r_t + \lambda_L + \frac{\gamma_L}{n}\Delta L_t^* - \frac{\gamma_L \beta}{n} E_t \Delta L_{t+1}^* - \frac{1}{n} E_t \frac{\partial r_t^L}{\partial L_t} L_t^* \tag{3.17}$$

$$r_t^D = (1-a)r_t - \lambda_D - \frac{\gamma_D}{n}\Delta D_t^* + \frac{\gamma_D \beta}{n} E_t \Delta D_{t+1}^* - \frac{1}{n} E_t \frac{\partial r_t^D}{\partial D_t} D_t^* \tag{3.18}$$

Considering equations (3.17) and (3.18), rearranging and replacing terms, the interest rates on loans and deposits are determined as:

$$r_t^L = \frac{n\varepsilon_L(1-b)}{n\varepsilon_L - 1} r_t + \frac{n\varepsilon_L}{n\varepsilon_L - 1}\lambda_L + \frac{\gamma_L \varepsilon_L}{n\varepsilon_L - 1}\left[\Delta L_t^* - \beta E_t \Delta L_{t+1}^*\right] \tag{3.19}$$

$$r_t^D = \frac{n\varepsilon_D(1-a)}{n\varepsilon_D + 1} r_t - \frac{n\varepsilon_D}{n\varepsilon_D + 1}\lambda_D + \frac{\gamma_D \varepsilon_D}{n\varepsilon_D + 1}\left[\beta E_t \Delta D_{t+1}^* - \Delta D_t^*\right] \tag{3.20}$$

where ε_L and ε_D are the loan demand and deposit supply elasticities, respectively.

Additionally, considering the stochastic (regime-switching) process for the interbank rate, there will be a system of three difference equations form by expressions (3.19), (3.20), and the following:

$$r_{t+1} - r_t = \alpha(s_{t+1})\left[\theta(s_{t+1}) - r_t\right] + \sigma(s_{t+1})\sqrt{r_t}\,u_{t+1} \tag{3.21}$$

4.3.5 Nonlinear interest rates and the pass-through

The crucial feature in describing the stochastic process for the lending (deposit) rate is transmitted by the stochastic process the interbank rate follows. Banks will recognize the presence of regime shifts in the interbank rate and will incorporate that information into their forecast of the rate evolution.[48] Thus, if the money market rate follows a regime-switching pattern, then the bank will endogenise it into its forecasts, and the lending (deposit) rate will similarly show a regime-switching behaviour. Importantly, the regime-switching behaviour in the lending (deposit) rate will be closely correlated to the shifting in regimes for the interbank rate. Of course, the description for the money market rate process is general enough as to incorporate linearity as an especial case.

That is the case, for example, of Argentina. The Hansen test for the null of linearity is clearly rejected for the interbank rate and, sequentially, for a set of lending rates. Given the empirical exogeneity of the interbank rate to this set of interest rates (banks consider it as their opportunity cost of funds) and the nonlinearity associated to the financial crises, there is a feasible synchronization in the switching of regimes in all these rates.

Since no particular form for the loan demand (deposit supply) is assumed, the solution for the lending (deposit) rate in equation (3.19) [(3.20)] is given in terms of the current and expected change in the amount of loans (deposits). Implicitly though, those quantities involve reference to lagged, current, and expected levels of the interbank rate and of the lending (deposit) rate. Thus, bank will fully incorporate their expectations of future changes in market rates in their current rates unless, of course, they have already reached their steady state equilibrium and no further changes are expected.

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[48] See Hamilton (1988). Banks might not know exactly when a regime shift will occur, but they will form inferences about those shifts based on some relevant variables (both, expected and past values of them).

The lending pass-through is the factor that connects directly the interest rate on loans to the interbank rate. The value of it that corresponds to the steady-state equilibrium is the long-term interest rate pass-through. As derived from equation (3.19), it is a function of microeconomic factors: the loan demand elasticity, the credit market structure, and the capital adequacy parameter. This pass-through could be stated as:

$$l\_irps_t^L = \frac{n\varepsilon_L(1-b)}{n\varepsilon_L - 1} \tag{3.22}$$

The short-term (or impact) interest rate pass-through for loans is the adjustment factor on the current interbank rate that considers expected changes in the scale of the bank's operations. In order to derive an expression for it, an actual form for the loan demand is needed. Hence, demand for loans is assumed to depend negatively on the interest rate for loans and positively on the money market interest rate (opportunity cost). Although it is clear that it depends also on the level of income, this will not be explicitly modelled, since it is a variable beyond the bank's control. Thus, the loan demand can be represented by the linear function:[49]

$$L_t = \alpha_y^L + \alpha_L r_t^L + \alpha_r^L r_t \tag{3.23}$$

such as that

$$\Delta L_t = \alpha_L \Delta r_t^L + \alpha_r^L \Delta r_t \tag{3.24}$$

and

$$\Delta L_{t+1} = \alpha_L \Delta r_{t+1}^L + \alpha_r^L \Delta r_{t+1} \tag{3.25}$$

where the intercept α_y^L is an income-determined parameter, α_L is the (negative) semi-elasticity with respect to the lending rate, and α_r^L is the (positive) semi-elasticity with

[49] Theoretically, this assumption simplifies the treatment for the pass-through. Besides, empirical research shows support for a linear representation for loan demand. See, for example, Calza, Gartner, and Sousa (2001) for a loan demand study in the euro area.

respect to the interbank rate. Equations (3.24) and (3.25) could be introduced in equation (3.19) to replace the last term in brackets there.[50] It is explicit then that the current lending rate does not depend only on current levels of the interbank rate, but also on past and expected levels of the interbank rate and the lending rate itself.

Rearranging terms,[51] the impact pass-through for the lending rate is:

$$s\_irps_t^L = \frac{n\varepsilon_L(1-b)+(1+\beta)\varepsilon_L\gamma_L\alpha_r^L}{(n\varepsilon_L-1)\;-(1+\beta)\varepsilon_L\gamma_L\alpha_L} \tag{3.26}$$

Notice the similarity between equation (3.22) and (3.26). Although the latter looks more complex, the main difference between them is the inclusion of the discount factor (because of the reference to expected future values of the rates), the adjustment cost parameter (which is not present, of course, in the steady state pass-through), and the semi-elasticity terms from the loan demand.[52]

In the case of deposits, the steady-state long-term pass-through is a function of similar microeconomic factors: the deposit supply elasticity, the market structure for the deposit market, and the reserve management parameter. This deposit pass-through could be derived directly from equation (3.20) as:

$$l\_irps_t^D = \frac{n\varepsilon_D(1-a)}{n\varepsilon_D+1} \tag{3.27}$$

For the short-term pass-through, a linear function for the deposit supply is assumed of the following type:

[50] This is not entirely correct because the term in brackets involves optimum amount of loans, rather than just the quantity demanded. Still, it is assumed that supply-related factors would not change importantly the final expression.
[51] See detailed procedure in the Appendix.
[52] Elasticity and semi-elasticity terms are, of course, related but the linear demand function is consistent with different elasticity values (not one in particular is assumed) so that both terms are kept separated.

$$D_t = \alpha_y^D + \alpha_D r_t^D + \alpha_r^D r_t \qquad (3.28)$$

where α_y^L is the income-related intercept, α_D is the (positive) semi-elasticity with respect to the deposit interest rate, and α_r^D is the (negative) semi-elasticity with respect to the money market rate (negative because of the opportunity cost as return for depositors). The respective changes could then be represented as:

$$\Delta D_t = \alpha_D \Delta r_t^D + \alpha_r^D \Delta r_t \qquad (3.29)$$

and

$$\Delta D_{t+1} = \alpha_D \Delta r_{t+1}^D + \alpha_r^D \Delta r_{t+1} \qquad (3.30)$$

Incorporating equations (3.29) and (3.30) into equation (3.20) to replace the last term in brackets, it is clear that the deposit rate also depends on the lagged and expected values of the interbank rate and of itself. The resulting short-term pass-through is:

$$s\_irps_t^D = \frac{n\varepsilon_D(1-a) - (1+\beta)\varepsilon_D\gamma_D\alpha_r^D}{(n\varepsilon_D+1) + (1+\beta)\varepsilon_D\gamma_D\alpha_D} \qquad (3.31)$$

Once again, notice out the similarity of the pass-through for the long and short-term. The latter include additionally the terms for discounting, the adjustment cost parameter, and the semi-elasticity terms from the deposit supply function.

The interest rate pass-through, either for loans or deposits, would be nonlinear if any of the microeconomic factors that explain it switched between regimes. However, thus far, it seems that no single factor displays such a stochastic behaviour; they do not jump between regimes neither in the short-term nor the long-term.[53] Recall that it has been

[53] Barnea, Kim, and Kliger (2003) find evidence of regime switching oligopolistic behaviour in Israel by decomposing mark-up pricing evolution into the oligopolistic-conduct part and its fundamentals (from a

assumed that the adjustment costs parameters are constant so that they cannot induce any feasible nonlinearity in the pass-through.

The market structure refers mainly to the number of institutions at any given moment in the credit or deposit market and, although it might evolve in time, it does not happen as a sudden change like in a Markov switching process. Similarly, there is no obvious rationale as to why the demand- or the supply-elasticity would switch between regimes. Therefore, the nonlinear interbank rate induces a nonlinear lending or deposit interest rate, but does not obviously affect the adjustment factor from the bank. The next section deals with some other factors and parameters that might indeed explain the presence of a regime-switching behaviour in the pass-through as well.

Cournot equilibrium). They differentiate a cooperative equilibrium from a non-cooperative one, but both ultimately depend on shocks to the fundamentals (mostly macroeconomic factors). Similarly, Hutchison (1995), using a dynamic general equilibrium model, focuses on a set of forces, essentially macroeconomic, that together with monopoly power explain interest rate (spreads) behaviour. He does not, however, focus on nonlinearities in the adjustment.

4.4 NONLINEAR PASS-THROUGH: DYNAMIC MODEL WITH RISKS

In the banking business, there are many risks due to financial market uncertainties and to information asymmetry between banks and their clients. This section expands the dynamic model to assess the impact of some of these risks in the interest rate determination and in the pass-through. Specifically, credit risk (asset-side of the balance sheet) and liquidity risk (liability-side) are next considered in the bank's optimisation.

Once again, in the case of Argentina, for example, including measures of different risks (devaluation risk, country risk, and credit risk) improved the nonlinear modelling of the interest rate pass-through. Banks definitely reflect their market expectations in these measures of risks. Any likely presence of nonlinearities in the money market rates seem to be captured as well by these risks.

4.4.1 Introducing credit and liquidity risks

Credit risk is associated to the probability of default in a credit operation.[54] Microeconomic and macroeconomic factors alike influence the magnitude of this risk. Among the former are the existing collateral, the information gathering process by the bank, and bankruptcy regulations. From the economy as a whole, the level of interest rates and the position in the business cycle could also affect borrowers' probability of default. Loan returns are random due to this type of risk. Besides, the management of this risk matters not only to individual-bank risk managers but to financial regulators and policy makers alike. As Herring (1999) points out, low-frequency, high-severity events associated to credit risks are likely the most serious threat to financial stability.

[54] Borrowers might be unable or unwilling to fulfil repayment under the initial terms of the loan contract.

The main difference with the initial dynamic model is, then, that under the presence of credit risk banks adjust their expected interest rate income accordingly. This might usually take the form of banks demanding an extra margin (risk premium) to cover them against credit risk. Otherwise, it would be preferable for them to invest somewhere else without taking such a risk. In practice, this risk premium is often defined as the difference between the risky-loan return and the free-risk return with equal maturity. For the empirical case presented in the previous chapter, in which lending pass-through was studied, credit risk (and devaluation and country risks) was approximated by interest rate spreads.

With credit risk, the financial margin banks obtain must also include the risk premium that prices that risk. Even if all other loan characteristics are the same, a bank will charge a higher interest rate to a group of borrowers if probabilities of default are higher on this group.[55] Thus, a wide diversified interest rate structure is partly due to differences in risk among groups of borrowers (which might give place to market segmentation).[56] It is worth noting, that separability of the credit and deposit markets might break down once credit risk is included.[57] Empirically, however, it is still valid to assume both markets as being independent of each other. For the following derivation on the dynamic model, it is assumed that this separability holds even with credit risk.

[55] Using credit risk analysis, Herring (1999) argues, risk managers could compare returns on capital allocated to each market segment and track in which ones they are earning the highest risk-adjusted returns for the shareholders.
[56] See next section.
[57] See, for example, Freixas and Rochet (1997) and Altman, Resti, and Sironi (2004) for details on this. A Merton-approach, by which the probability of default depends on the value of the firm, is considered to link assets and liabilities. Even without risks, there is a link between loans and deposits if, for example, banks ask their borrowers to keep a given fraction of the loan as deposits in the banks. Yet, it has been implicitly assumed here that this connection is rather weak.

Another important risk banks face is the liquidity risk, which could actually be originated in either side of the balance sheet. When borrowers want to cash on their deposits at a higher rate than on average expected by the bank, the bank needs to finance the outflow of funds by incurring in higher than expected cost (the contractual interest rate) on those deposits. This produces indeed a risk for the bank that needs to be taken into consideration when it optimises its operations. Another source for this liquidity risk is any unexpected credit commitment that the bank needs to cover by cashing up on other liquid assets. Still, important as it might be this source, it is assumed for the following derivation that the only source for liquidity risk is the liability-based risk.

These two types of risks (credit and liquidity) are particularly relevant because of the asymmetric-information feature in the banking business. Given that a bank does not know exactly the probabilities of success of the project its client is borrowing the funds for, it will not precisely know what the chances of repayment are. Neither will it know whether the depositor will claim his or her asset in the bank sooner than agreed. Importantly, both risks will be exacerbated if unstable conditions in the financial markets increase the uncertainty of the payoffs to the bank's borrowers and creditors.

Not surprisingly, a bank will try to capture any sudden change in the risks involve in its operations by following a price indicator that actually displays such switches in uncertainty. A relevant interbank rate from the short-term money market fulfils such a role. Sudden changes on that rate, associated to regimes shifts in financial conditions, will be displayed as a nonlinear stochastic behaviour on it (most probably in its mean, its adjustment speed, and its volatility). For the bank to take into consideration credit and liquidity risks, it needs to charge risk premiums that also evolve according to money market conditions. Therefore, if the money market rate that reflects those financial conditions follows a regime-switching stochastic behaviour, then the risk premiums a bank charges will also display a nonlinear pattern that is closely correlated to the interbank rate process.

Hence, with credit and liquidity risks, two interest rates (different to those already presented in the initial dynamic model) should be considered in the bank's optimisation problem. First, the base lending rate that compensates the bank for their costs of providing its services to the borrower. Second, the effective cost of keeping deposits from its clients. Both rates will influence the bank's expected profits, but in order to introduce them in the bank's profit function, some new definitions are needed first.

The effective rate charged by the bank on a credit operation is the one that includes a credit risk premium and the probability of repayment.[58] This effective rate is assumed equivalent to the expected rate of return on that operation:[59]

$$r_t^L = (1-p)\,(1+\phi)\,r_t^l \tag{4.1}$$

where p stands for the estimated probability of default (so that $1-p$ is the probability of repayment), ϕ is the risk premium charged on the loan (as a proportion of the base rate), and r_t^l is the base lending rate. The left-hand side of equation (4.1) is the effective

[58] Another element present in the credit risk is the recovery rate. Nevertheless, it is not explicitly included here because there is still ongoing debate about whether it depends exclusively on microeconomic factors or on systemic (macroeconomic) features and, therefore, whether it is independent of the probability of repayment or negatively correlated. See Altman, Resti, and Sironi (2004) for an updated review on empirical and theoretical literature on default recovery rates.

[59] The formula would include a few more terms if, for example, the bank charge any origination fee to the borrower, imposes a compensating balance requirement on the loan (that traduces as an noninterest-bearing deposit in the bank), or needs to keep legal reserves on its deposits. Implicitly, all these terms are assumed negligible or nonexistent. See, for example, Saunders (2000) for details on practical credit risk management.

rate and the right-hand side is the expected return on the loan (the contractual rate of return times the probability of repayment).

The rate that enters the optimisation process is the base rate for loans, which could be directly derived from equation (4.1):

$$r_t^l = \frac{1}{(1+\phi)(1-p)} r_t^L \tag{4.2}$$

The credit risk premium is defined here as a regime-switching function of the base rate for loans:

$$\Phi_t^L = \phi(s_t) r_t^L + \varepsilon_t \tag{4.3}$$

where ε_t is a white noise distributed Normal$(0, 1)$ and conditional on r_t^L and s_t. The risk premium parameter $\phi(s_t)$ is subject to regime switching between the same two regimes than for the interbank rate (given by the unobserved variable s_t): a calm regime and a volatile regime.

The probability of repayment $(1\text{-}p)$ follows a Stiglitz-Weiss pattern, by which it increases with the effective lending rate up to a certain threshold level of it. Beyond that level, the probability of repayment starts decreasing because the higher interest rate attracts lower-quality clients. Therefore, since the risk premium increases the effective lending rate charged by the bank, when it switches to a volatile regime, the probability of repayment eventually falls.

The effective cost (rate) on deposits (for the bank) includes the risk premium or extra cost the bank expects to face because of liquidity risk and it is given by:

$$r_t^d = (1+\eta)\ r_t^D \tag{4.4}$$

where η is the liquidity risk premium and it is defined as a proportion of the contractual interest rate on deposits r_t^D (the rate received by depositors). The right-hand side of equation (4.4) is the actual expected cost of deposits for the bank.

The liquidity risk premium is similarly defined as a regime-switching function of the contractual deposit rate:

$$\mathrm{N}_t^D = \eta(s_t)\, r_t^D + \xi_t \tag{4.5}$$

where $\xi_t \sim \mathrm{N}(0,\ 1)$ (conditionally on r_t^D and s_t) is a white noise. The risk premium parameter $\eta(s_t)$ is subject to switches between the same two regimes than in the case of the interbank rate and of the credit risk premium (given by the unobserved variable s_t). Those two regimes, once again, correspond to the calm and unstable regimes in the financial markets.

With the lending and deposit rates from equations (4.2) and (4.4), respectively, the profit function could then be redefined as:[60]

$$\begin{aligned}\pi_{t+j} = &\left[\frac{1}{(1+\phi_t)(1-p)} r_{t+j}^L - (1-b)\, r_{t+j}\right] L_{t+j} + \left[(1-a)\, r_{t+j} - (1+\eta_t)\, r_{t+j}^D\right] D_{t+j} \\ &- \lambda_L L_{t+j} - \left(\frac{\gamma_L}{2}\right)\left(L_{t+j} - L_{t+j-1}\right)^2 - \lambda_D D_{t+j} - \left(\frac{\gamma_D}{2}\right)\left(D_{t+j} - D_{t+j-1}\right)^2\end{aligned} \tag{4.6}$$

where, for simplification, the risk premium for credit risk is stated as ϕ_t, rather than $\phi(s_t)$, and the risk premium for liquidity risk is given by η_t, rather than $\eta(s_t)$, to represent the regime-switching behaviour in both premiums.

[60] This is considering everything else as given in the initial dynamic model.

Introducing the profit function in the objective function, the optimisation problem is then given by:

$$V_t = Max\ E_t \begin{Bmatrix} \left[\frac{1}{(1+\phi_t)(1-p)} r_{t+j}^L - (1-b) r_{t+j}\right] L_{t+j} + \left[(1-a) r_{t+j} - (1+\eta_t) r_{t+j}^D\right] D_{t+j} \\ -\lambda_L L_{t+j} - \left(\frac{\gamma_L}{2}\right)(L_{t+j} - L_{t+j-1})^2 - \lambda_D D_{t+j} - \left(\frac{\gamma_D}{2}\right)(D_{t+j} - D_{t+j-1})^2 \end{Bmatrix}$$
$$+\beta E_t \left\{\left(\frac{\gamma_L}{2}\right)(L_{t+j+1} - L_{t+j})^2 + \left(\frac{\gamma_D}{2}\right)(D_{t+j+1} - D_{t+j})^2\right\} \quad (4.7)$$

4.4.2 Regime-switching pass-through

Following a similar procedure as in the base dynamic model (optimising with respect to quantities and then deriving optimum interest rates) the lending and deposit rates are:

$$r_t^L = \frac{n\varepsilon_L (1-b)(1+\phi_t)(1-p)}{n\varepsilon_L - 1} r_t + \frac{n\varepsilon_L (1+\phi_t)(1-p)}{n\varepsilon_L - 1} \lambda_L + \frac{(1+\phi_t)(1-p)\gamma_L \varepsilon_L}{n\varepsilon_L - 1}\left[\Delta L_t^* - \beta E_t \Delta L_{t+1}^*\right] \quad (4.8)$$

$$r_t^D = \frac{n\varepsilon_D (1-a)}{(n\varepsilon_D + 1)(1+\eta_t)} r_t - \frac{n\varepsilon_D}{(n\varepsilon_D + 1)(1+\eta_t)} \lambda_D + \frac{\gamma_D \varepsilon_D}{(n\varepsilon_D + 1)(1+\eta_t)}\left[\beta E_t \Delta D_{t+1}^* - \Delta D_t^*\right] \quad (4.9)$$

Recall from equation (3.21) that the interbank rate follows a (Markov) regime-switching process and, thus, both lending and deposit rates follow a nonlinear process too. Alternatively, this time, the equilibrium pass-through for the lending rate includes the credit risk parameter and the one for the deposit rate includes the liquidity risk factor.

Then, it will be argued that with the presence of credit and liquidity risk, the interest rate pass-through also switches between regimes in either case. Moreover, the fact that the stochastic process for each risk premium is correlated with the regime-switching interbank rate, suggests that the timing for the switches in regime are relatively synchronized.[61] Although not directly, Pesaran et al. (2003), for instance, model the loss distribution of the credit portfolio with explicit conditioning on macroeconomic factors. Thus, they conclude, default probabilities are driven primarily by how firms are tied to business cycles, both at domestic and foreign levels. As it has been discussed in Chapter 3 of this thesis, the business cycle might induce regime-switching behaviour in the money market rates, so that both the interbank rate and credit risk might indeed share the nonlinear behaviour, with regime shifts being synchronized.

The long term and short term pass-through for the lending rate are given respectively by the following expressions:

$$l\_irps_t^L = \frac{n\varepsilon_L(1-b)(1+\phi_t)(1-p)}{n\varepsilon_L - 1} \tag{4.10}$$

$$s\_irps_t^L = \frac{n\varepsilon_L(1-b)(1+\phi_t)(1-p)+(1+\beta)(1+\phi_t)(1-p)\varepsilon_L\gamma_L\alpha_r^L}{(n\varepsilon_L-1) \qquad -(1+\beta)(1+\phi_t)(1-p)\varepsilon_L\gamma_L\alpha_L} \tag{4.11}$$

From equation (4.10) and equation (4.11), when the interbank rate switches to, let's say, the volatile regime, unstable financial conditions make the credit risk premium parameter jumps to a volatile regime too. Therefore, the pass-through rises and suffers also a shift in regime. This raise might even be reinforced if the probability of repayment also increases with higher interest rates (before the threshold value of it). Alternatively, with unsettle market conditions and enough higher interest rates, the probability of repayment decreases (the probability of default rises) to an extent that the pass-through might eventually diminish.

[61] There might be circumstances in which those risk premiums could switch in regime without the interbank rate having change similarly. For example, risk premiums shifting in regime could be due to some microeconomic factors that do not affect the interbank rate.

Therefore, when credit risk premium is considered,[62] the nonlinearity of the interbank rate will not only induce a regime-switching behaviour in the lending rate but also a nonlinear pattern in the pass-through. With a volatile environment in the financial markets, the lending pass-through might either increase or decrease depending on the level and magnitude of the change with respect to the asymmetric nature of the banking system (the well documented adverse selection problem). All the microeconomic factors that determine the pass-through do not produce this behaviour (not even the microeconomic elements present in the credit risk premium). The nonlinear pattern in the interest rate pass-through is solely related to the regime-switching process in the money market rate.

The interest rate pass-through for the deposit rate is given by the following equations for the long and short term, respectively:

$$l\_irps_t^D = \frac{n\varepsilon_D(1-a)}{(n\varepsilon_D+1)(1+\eta_t)} \tag{4.12}$$

$$s\_irps_t^D = \frac{n\varepsilon_D(1-a) \quad -(1+\beta)\varepsilon_D\gamma_D\alpha_r^D}{(n\varepsilon_D+1)(1+\eta_t)+(1+\beta)\varepsilon_D\gamma_D\alpha_D} \tag{4.13}$$

In this case, the shift in regime for the interbank rate rises the liquidity premium (η) considered by the bank because there is an increase in the probability of depositors walking (in extreme cases, running) away from the bank. This nonlinear behaviour for the parameter of liquidity risk will cause the deposit rate pass-through to shift in regime and actually fall. Conversely, the pass-through might rather increase if reserves (the

[62] Actually, the risk premium considered here does not need to be connected exclusively to credit risk. Part of the premium might be also associated to other types of risk such as devaluation risk or country risk (as it was the case with the interest rate spreads considered for Argentina in the previous chapter). As long as the premium switches in regime as a response to regime shifts in the interbank rate (systemic-risk type), the effect over the pass-through would be similar.

fraction a of deposits) held by the bank fall enough because of the liquidity management from the bank.

Therefore, a regime shifting behaviour in the interbank rate causes the pass-through for deposit rates to also switch between regimes when liquidity risk is considered. With an unstable financial scenario, the risk premium considered by the bank is higher and, thus, the pass-through would decrease (or increase) and actually switch in regime. Once again, no microeconomic factor in the determination of the pass-through will induce this nonlinear behaviour. It is entirely due to the switching in regimes in the financial markets (at a macroeconomic level).[63]

4.4.3 Product differentiation

The dynamic model has been designed so far to represent the behaviour of a bank offering just one type of loans and taking only one type of deposits (although to possibly different type of clients). In a more realistic set up of the banking industry, there will be heterogeneous market segments that banks will attempt to serve. In order to pursue their profit-maximising objective banks divide markets in different segments and specialise on particular groups of borrowers (or depositors) as to enhance efficiency. The bank's optimisation will now have to consider revenues not only from one type of loans (deposits) but from two or more of them.

One could immediately argue that at the margin the profit from each operation should be equal across market segments. This is not necessarily the case though. The very same characteristics that make market segments different (demand elasticity, market

[63] On a quality-related feature of the lending market, Bangia et al. (2002) also suggest that underlying macroeconomic volatility is a crucial link in stress testing credit portfolios. Furthermore, regime expected changes in the credit quality of debtors are subject to regime switching associated to the business cycle.

structure, operating costs, risk premiums) will prevent this from happening. The actual margin would be particular to the market segment the bank is at and, thus, the bank will need to take into account its features in order to care for the general profit-maximising objective.[64]

If borrowers were homogeneous (similar demand elasticity, for example) and there were only one type of loans, then the interest rate would be the same for all loans. However, in practice, a particular bank charges loan interest rates according to the borrower's price elasticity and all the other micro and macroeconomic features. In doing so, the bank follows an optimal behaviour, taking advantage of market structure to extract positive financial margins according to demand characteristics. The more heterogeneous the demand, the more diversified interest rate structure the market will have.

Here, it is assumed that the type of deposits taken by the banks are all similar, but that there are two types of market credit segments that the bank provide with loans. Banks will thus differentiate interest rates reflecting their optimisation process according to each segment characteristics. Some banks will serve both segments; some other will specialize in one or the other. Both market segments are completely separable (so that optimisation is independent). One such segment will have lower demand elasticity (for example, because borrowers have fewer alternative financing sources), higher marginal costs (due to less credit background of the clients), and a less number of banks (i.e., lack of adequate banking technology). Likewise, the credit risk premium is assumed higher for this segment because of the riskier nature of loans and the corresponding probability

[64] Heffernan (1997), using an (linear) error correction model of selected British retail rates, shows the heterogeneity in the response to official rates shocks from banks and banking products. There are variable lags and varying magnitudes in that response from different products inside an individual bank and even for the same product among different banks.

of default is also greater.[65] Risk premiums in both segments are still correlated with the regime-switching interbank rate.

The corresponding long-term pass-through for the lending rate in both segments is then given by the expressions:

$$l\_irps_t^{L1} = \frac{n_1\varepsilon_{L1}(1-b)(1+\phi_t^1)(1-p_1)}{n_1\varepsilon_{L1}-1} \tag{4.14}$$

$$l\_irps_t^{L2} = \frac{n_2\varepsilon_{L2}(1-b)(1+\phi_t^2)(1-p_2)}{n_1\varepsilon_{L2}-1} \tag{4.15}$$

where it is assumed that $n_1 > n_2$, $\varepsilon_{L1} > \varepsilon_{L2}$, $\phi_t^1 < \phi_t^2$, and $p_1 < p_2$. Similarly, for the impact pass-through, two expressions could be stated from equation (4.11). It is further assumed for them that $\gamma_L^1 < \gamma_L^2$. All other parameters in the long and short-term pass-through are assumed equal for both segments.

With these features, of course, neither the interest rate nor the pass-through is the same for both segments. The following table summarizes the effects on the second segment's (long- and short-term) pass-through of changes in each parameter as if departing from the initial values in the first credit segment. Any change in each row, assumes everything else given.

[65] In practice, for retail interest rates, for example, the risk premium a bank charges for its different credit operations are usually similar. It would be more likely that the premium differs for each segment if one belongs to the retail market and the other to a wholesale market. See Allen, DeLong, and Saunders (2003) for discussion of these and other issues in credit risk modelling.

Segment 1 (irps1)	Vs.	Segment 2 (irps2)	Change in parameter	Change in irps	
				l_irps	s_irps
n_1	>	n_2	<0	>0	>0
ε_{L1}	>	ε_{L2}	<0	>0	>0
ϕ_t^1	<	ϕ_t^2	>0	>0	>0
p_1	<	P_2	>0	<0	<0
γ_L^1	<	γ_L^2	>0	-	<0

The lending pass-through is negatively related to the competitiveness in the market structure and to the demand elasticity. Thus, the second segment will display a larger pass-through for both the long- and short-term. The pass-through depends positively on the risk premium, so that it is also larger in the second segment. Conversely, the larger probability of default in this segment will cause the pass-through to decrease. This effect might even be strong enough as to offset the effect of changes in the other parameters, so that the pass-through might fall overall in this second segment.[66] The increase in the adjustment cost parameter makes the pass-through fall in the short-term (the long-term pass-through, of course, is not affected by this parameter). It is worth mentioning that, in all cases, the short-term pass-through is less than the long-term equilibrium pass-through.[67]

Furthermore, considering these segments' characteristics, the lending rate in the second segment will be greater than the one in the first segment. Note out that the spread

[66] This effect might explain the apparent conflict between theory and empirics in the measure of the pass-through. It is usually derived a larger pass-through when the second segment's characteristics are present. Yet, empirically, it is often found that the opposite (larger pass-through for the first-segment).
[67] This feature is, of course, consistent with the short-term stickiness in the pass-through.

between these rates will not only be given by the differences in the pass-through but also be due to the marginal costs and the adjustment parts (see equation (3.19)).

4.4.4 Other nonlinearities

Some theoretical and empirical research has focused on the asymmetric and nonlinear nature of adjustment costs as the main source of a nonlinear interest rate pass-through. Many of them are based on the presence of positive trend inflation, as discussed in Ball and Mankiw (1994).[68] On a general corporate setting (not specifically for banks), a firm's relative prices decline automatically between adjustments if there is positive inflation. Therefore, considering a menu-cost rationale for adjusting prices, positive shocks are more likely to produce larger price adjustments than negative shocks to optimum relative prices (in which inflation erodes the price). Dell'Ariccia and Garibaldi (1998) also present a menu-cost type of argument for asymmetries in banking response to money market shocks but for the amount of lending, rather than for interest rates. As long as lending opportunities are found at a different speed than recalling existing loans, banks will respond asymmetrically to changes in the money market rate.

In order to see how nonlinear adjustment costs might indeed induce a nonlinear interest rate pass-through, let's refer to equations (4.11) and (4.13). There it could be seen that the pass-through, for loans and deposits alike, is indeed regime-switching if the parameter for cost adjustment were actually nonlinear. It might be the case that the adjustment is asymmetric, so that the parameter is one with expected positive changes in the bank's operations and another one when those changes are negative.

[68] See Footnote 15 for empirical references. Also, see Hannan and Berger (1991) for a discussion on price rigidity in the banking industry and the asymmetry in the adjustment for deposit rates. Similarly, Lim (2001) finds evidence of asymmetry in the short-term adjustment (but not in the long-run). Mester (1993) also uses a menu-cost argument to account for asymmetric adjustment in prime rates.

Alternatively, parameters might be regime switching if the adjustment takes place at different speeds and intensities. In either case, the resulting pass-through will be nonlinear. All the same, these mechanisms will only explain a nonlinear behaviour in the short-term pass-through, but not in the long term. Although there is widespread empirical support for short-run stickiness in the pass-through, it is usually assumed that in the long-run the pass-through is complete. Therefore, if there were any evidence of nonlinearity, this should be kept to the short run. This a-priori conclusion is not entirely correct since, from the model presented here, the pass-through could also be regime-switching in the long run.

Although the presence of regime-switching adjustment costs is a feasible explanation for a nonlinear pass-through, the argument is not stressed here because even if the adjustment costs switch between regimes there would not be a direct link to the regime shifting behaviour in the money market rate. It will not explain either the possibility of the pass-through decreasing or increasing when there is a switch to the volatile regime. The resulting effect will be exclusively in one direction or the other.

Another source for nonlinearity in the pass through is the existence of smooth transition of shocks to the money market rate. However, this is not further developed here because it rather represents an alternative modelling approach to the Markov regime switching and not an extra mechanism of regime shifting in the pass through.[69] Furthermore, the rationale to selecte the Markov switching model in the case of Argentina was the association to episodes of financial crises, in which the transition between regimes was reasonably expected to be sudden (rather than smooth).

[69] See Iregui, Milas, and Otero (2001) for an empirical application of a smooth transition autoregressive (STAR) methodology for the pass-through in selected Latin American markets.

4.5 NONLINEAR PASS-THROUGH: EMPIRICAL APPLICATION

Empirical studies have shown for some European countries that short-term money market rates follow regime-switching stochastic processes. If that is the case, it is postulated here (on the grounds of the above theoretical framework) that the interest rate pass-through, for lending and deposit rates alike, should also follow a regime-switching pattern. Moreover, regime shifts in the pass-through should occur on those dates on which the interbank rate switches regimes. Previous empirical applications for Argentina have indeed shown that is the case when shocks are caused by financial crises.[70] For the Argentinean case, a Markov switching VAR model captures this feature. Here, it is explored the cases of France and Germany, two of the biggest European financial systems, both with long enough detailed time series on interest rates.

4.5.1 Data analysis

Nominal interest rates on short-term loans to enterprises and time deposits are selected for France and Germany. Interest rates correspond to new business. Data on these rates is taken from the European Central Bank (national retail interest rates).[71] The representative money market rate is the 1-day lending rate on day-to-day money. The source for this interbank rate is the IMF's national statistics for France and Datastream for Germany. For France, lending rates correspond to discount, overdrafts, and other short-term loans while the deposit rate is the EURIBOR (3-month).[72] In this case, the data sample covers the period from April 1984 up to June 2003. For Germany, lending interest rates correspond to wholesale current account credits (floating rates) and deposit rates to 3-month time deposits. The sample runs from November 1984 up to June 2003.

[70] See previous chapters of this thesis for studies on the link between interest rate pass-through and financial crises in Argentina.

[71] The bank has stop producing statistics on these rates and has replaced them with the MFI (monetary financial institutions) interest rate statistics. For description of the data see the Methodological notes on National Retail Interest Rates from the European Central Bank.

[72] PIBOR after January 1999.

Preliminary standard unit root test (Augmented Dickey Fuller and Phillips-Perron) show that all these interest rates are integrated of order one. Cointegration tests, nevertheless, show no sign of long term equilibrium relationship among them. In order to get a more precise evaluation of their time series properties, further unit root tests are conducted on these rates. The Ng-Perron test and the modified Dickey Fuller test (DF-GLS) are used. The first one is very robust to the presence of additive outliers, both in terms of size and of power; and the second one detrends series before running the test regression. Although not conclusive, results from these tests show for both countries some evidence that their interest rates are rather stationary time series.[73]

Therefore, along with most Vasicek-type models for interest rates, it is concluded here (and assumed) that these time series are stationary. Hence, VAR models (rather than VECM) are estimated. Since the goal here is to establish the presence of nonlinearities in these interest rates and their pass-through, it should be enough to use variable levels instead of first-differences. A precise measure of interest rate pass-through for both financial systems would probably require defining appropriate dynamics for the short- and long-term.

The paths followed by the two sets of interest rates could be seen in Figure 4.1 for France and in Figure 4.2 for Germany.[74] Standard structural break tests[75] for the implementation of a single-currency in the euro area have been implemented. There is

[73] See Table 4.1 for France and Table 4.2 for Germany.
[74] It is worth mentioning that the level of the lending rate in Germany is significantly higher than in France, despite the fact that it broadly corresponds to the same type of loans and the data comes from the same statistic source. However, the rates in Germany are for domestic non-banks clients only.
[75] Considering that the testing date is the beginning of 2002, not enough remaining observation points are left as to conduct a point-break Chow test. Therefore, a Chow forecast test is used.

no evidence that this arrangement changed significantly the single-equation pass-through neither for the lending rate nor for the deposit rate.

4.5.2 Markov switching modelling

It is probably difficult to detect visually if there is any sign of nonlinearity in either the interbank rate or the pass-through relationship between that rate and the lending and deposit rates in any of these two countries. A formal testing of the presence of nonlinearities is needed. Therefore, the Hansen test is implemented for all individual rates independently and for the corresponding pass-through relationships.

In the case of France, the null of linearity could not be rejected at usual levels on individual rates. Ignoring this evidence, the test is conducted on both pass-through processes. As it is expected, neither the lending nor the deposit pass-through shows any sign of nonlinearity. Furthermore, for the sake of experimenting, various specifications of Markov switching VARs are estimated, but none of them produce interpretable or relevant results. In consequence, given that there is no evidence of nonlinearity in the interbank rate, the corresponding pass-through relationships do not show any sign of regime-switching behaviour either.[76] At least, not one related to the money market rate.

On the contrary, for the German case, results from the test show clearly the presence of nonlinearities in the interbank rate, the lending rate, and the deposit rate individually.[77] Testing the null of linearity on a single-equation pass-through for the lending rate provides no evidence of nonlinearity when just one lag is used in the structure. Standard

[76] See Table 4.3 for details on these tests for France.

[77] An empirical approximation of the CIR model assumed for the interbank rate is to consider a general Markov switching AR model.

specification tests suggest though that two lags should be considered in both linear and nonlinear specifications of the pass-through for the lending rate. Once those two lags are included, the Hansen test shows emphatically the presence of nonlinearities in the pass-through. In order to further assess this result for the lending rate, the J-Test from Garcia and Perron (1996) is conducted. This test confirms the presence of nonlinearity in the pass-through for the lending rate. For the deposit rate, even with one lag, the Hansen test provides strong evidence of nonlinearities in the pass-through.[78]

Therefore, for Germany, given the nonlinearity of the interbank rate, the pass-through for both the lending and deposit rates is also nonlinear. Correspondingly, a selection procedure for the appropriate Markov switching VAR (MS-VAR) representation of the pass-through is required. Following the "bottom-up" procedure, a MSIH(2)-VAR(2) model with time-varying transition probabilities (TVTP) is selected for the lending rate and a MSIAH(2)-VAR(2) model with constant transition probabilities (CTP) for the deposit rate.[79] Yet, for completeness, CTP and TVTP are considered in both cases (although only the latter results are shown here). For the TVTP, interest rates spreads are used as the regime-shifting indicators.[80] The spread between the German interbank rate vis-à-vis a similar US money market rate is considered as representing devaluation expectations[81] and the spread between the lending (deposit) rate and the interbank rate are taken as to represent credit risk. Regime switching is defined in terms of volatility conditions in the banking system. Thus, regime *0* corresponds to a tranquil scenario, while that regime *1* is consistent with a volatile environment.

---

[78] See Table 4.4 for details on these tests for Germany.
[79] See Table 4.5 for these results.
[80] In order to homogenise the treatment with TVTP, a MSIAH(2)-VAR(2) is estimated for both lending and deposit rate.
[81] Country risk is assumed negligible for Germany.

For the calm regime, the lending pass-through on impact is 33.9 percent (compared to a 27.7 percent from the linear VAR estimation). In volatile conditions, this pass-through reduces to 13.6 percent.[82] There is a similar probability of being in any regime (large number of regime shifts in the sample). There are indeed sudden stochastic switches in volatility, but their frequency do seem to rule out correspondence to just one particular type of economic or financial phenomena (financial crises, business cycle or the like).[83] From the total number of times the lending pass-through switches regime, 93 percent of those occasions correspond to periods in which the interbank rate (individually) is also classified into the volatile regime.[84] Likewise, in 73 percent of the times the interbank rate switches regime, it induces a regime shift in the lending pass-through.

The short-term pass-through for deposits is 46.6 percent in the calm regime, compared to 38.6 percent if estimated in a linear VAR. This pass-through falls to 35.7 percent if there is a shift to the volatile regime. Once again, the probability of being in any one regime is similar (although slightly biased towards the volatile regime).[85] In 85.5 percent of times the pass-through is classified in the volatile regime, it corresponds also to similar classification for the individual interbank rate. The interbank rate induces a shift in regime for the pass-through in 75 percent of times in which it is itself classified in the volatile regime.[86] Furthermore, the interbank rate transmits its nonlinearity in 63 percent of times towards both lending and deposit rates simultaneously.

[82] See Table 4.6.
[83] See the transition probabilities for the lending pass-through in Figure 4.3.
[84] Details for this are in Table 4.9.
[85] See Table 4.7 for details on the pass-through and Figure 4.4 for the transition probabilities.
[86] It is worth mentioning that the pass-through for interest rates on deposits seem to be higher (both in calm and volatile conditions) than for rates on loans.

Considering these results, it is concluded here that the presence of nonlinearities in the German interbank rate induces indeed a regime-shifting behaviour in the pass-through for the lending and deposit interest rates alike. Moreover, the timing of switching in the regimes is essentially similar when comparing the interbank rate and the pass-through for both lending and deposit rates. For France no such pattern is found either in the interbank rate or in the lending and deposit pass-through.

An additional interest rate is considered to explore further the nonlinearities of the pass-through in Germany. A 5-year mortgage rate on new business for domestic customers is used to estimate the corresponding pass-through. Interestingly, in this case, when the Markov switching model is estimated, the pass-through increases (rather than decreases) from 9.5 percent in the calm regime to 24.3 percent in the volatile regime, while that a linear estimation points out to a 16.5 percent.[87] The synchronization of the timing of regime switching is even stronger for this rate, since 91.3 percent of the cases in which it is classified as being in the volatile regime correspond to the same stance for the money market rate (with a similar percentage for the times in which the interbank rate induces the shift into the mortgage rate). This result makes clear the possibility that the pass-through for lending rates can either increase or decrease when financial conditions in the credit market become unstable.

[87] Estimation results for the mortgage rate are in Table 4.8.

4.6 CONCLUSIONS AND FURTHER RESEARCH

This paper has shown in the context of a dynamic bank optimisation model how a nonlinear, regime-switching, money market rate induces a nonlinear behaviour in lending and deposit rates and in their pass-through. It has been argued that the pass-through process is consistent with a nonlinear behaviour even if there are no asymmetries or nonlinearities in the adjustment costs from shocks to the interbank rate.

Regime switching behaviour in the interbank rate causes both lending and deposit rates to shift regimes at similar dates. More importantly, risk premiums for credit risk and liquidity risk (charged on banks' rates) display also a nonlinear pattern which is correlated to the interbank rate shifting pattern. With an initial shift to unstable financial conditions in the money market, the risk premiums switch to the same volatile regime inducing, as a result, a regime-switch in the pass-through (for lending and deposit rates alike). The direction of the change in the pass-through is not unique. In both cases, it could either increase or decrease with the volatile regime.

Considering the credit risk premium for lending rates, the pass-through in unstable conditions could either rise or fall. The direction of the switch will be determined crucially by the change in the probability of loan repayment. A Stiglitz-Weiss-type adverse selection mechanism in it makes either movement possible. Similarly, for the deposit rate, when a liquidity risk premium is considered, a change to the volatile regime in the interbank rate will cause a positive or negative shift in the pass-through. In this case, the liquidity crisis management (through bank reserves) plays an important role to determine the direction of the change.

Possible extensions to this research are both theoretical and empirical. First, introducing two currencies for bank operations should enhance understanding of dollarised financial system (such as in some emerging markets). Besides, bank technology and capital accumulation could be treated endogenously to introduce a more general approach in the dynamics of the model. An important assessment to make is whether financial integration and convergence in regulation could also induce nonlinearities in the pass-through process. Secondly, at the empirical level, alternative nonlinear models of the interbank rate should be studied for a richer characterization of the dynamics. Some GARCH effects would be worth evaluating. Finally, availability of high frequency data provides a natural extension for model empirical evaluation.

Figures

Figure 4.1 Nominal Interest Rates in France: 1984:04 - 2003:06

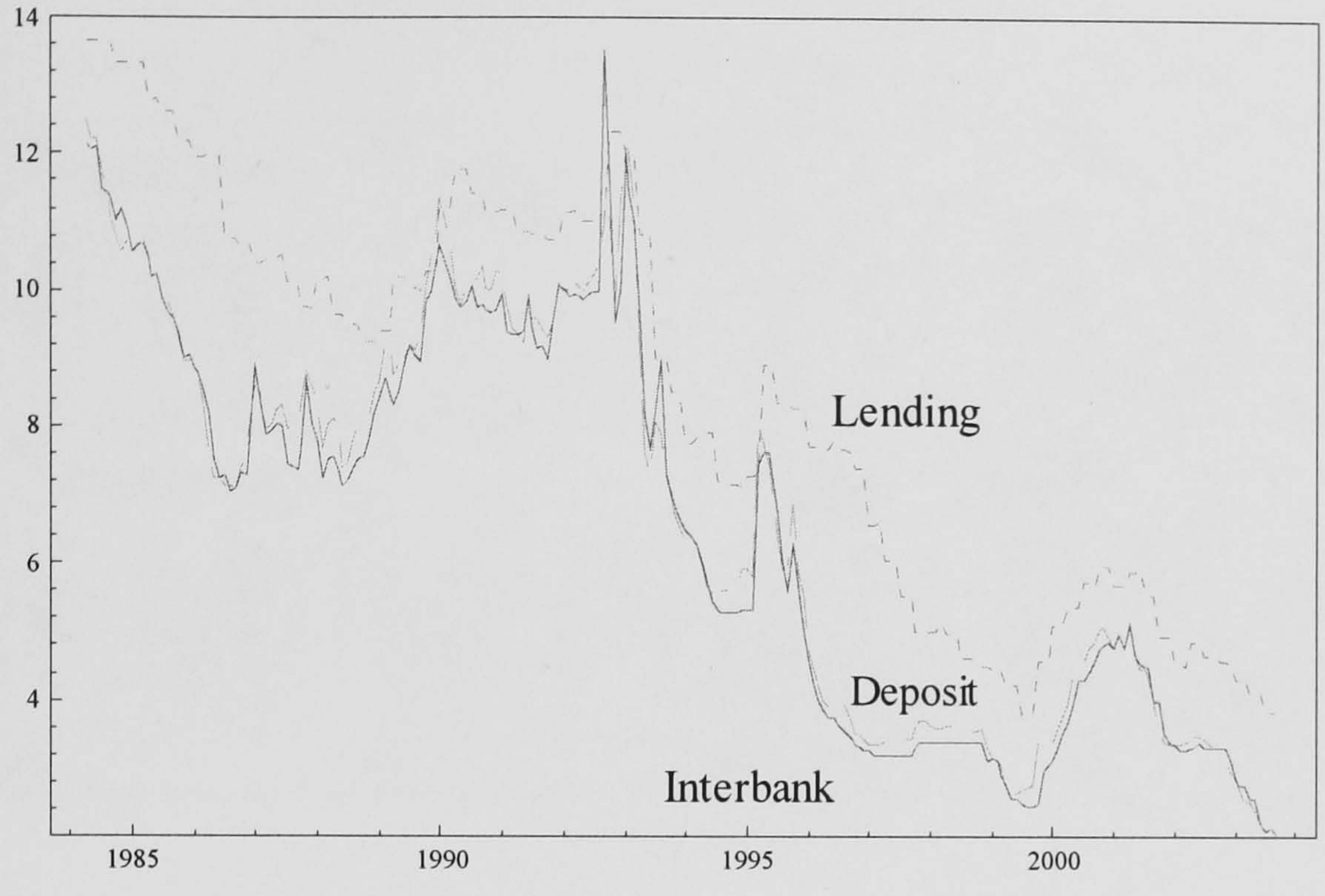


Figure 4.2 Nominal Interest Rates in Germany: 1984:11 - 2003:06

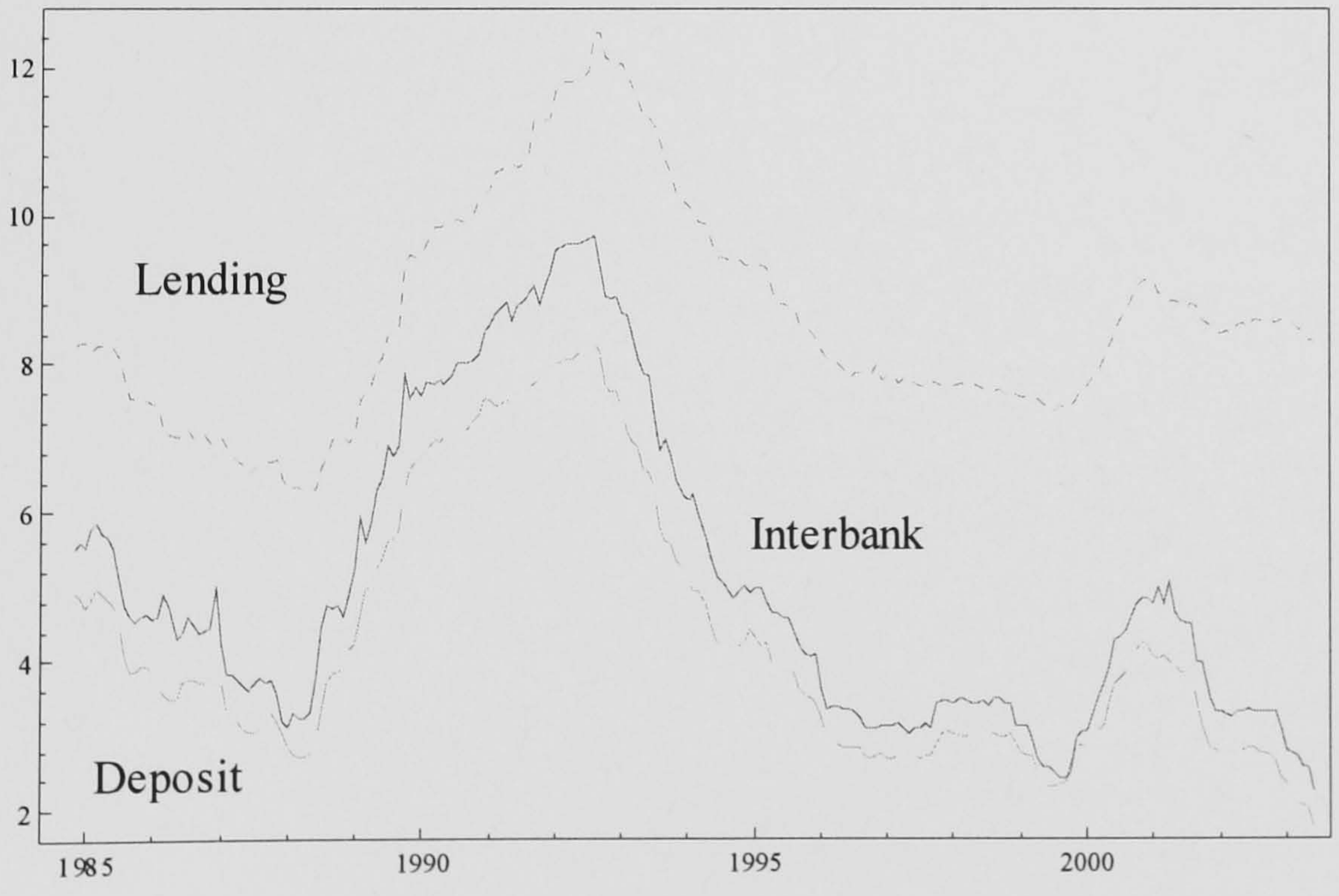


Figure 4.3 Transition Probabilities for German Lending Pass-Through

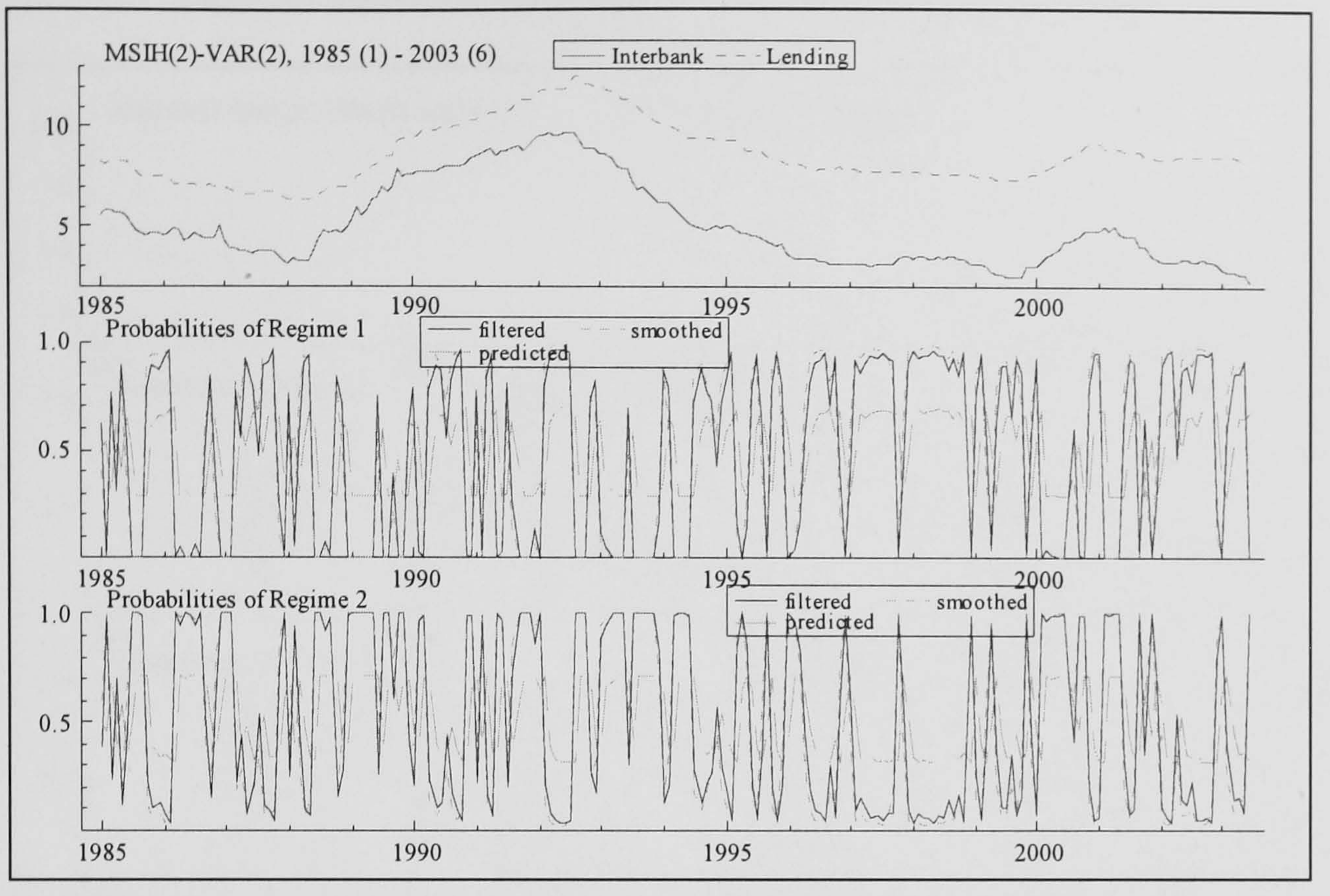
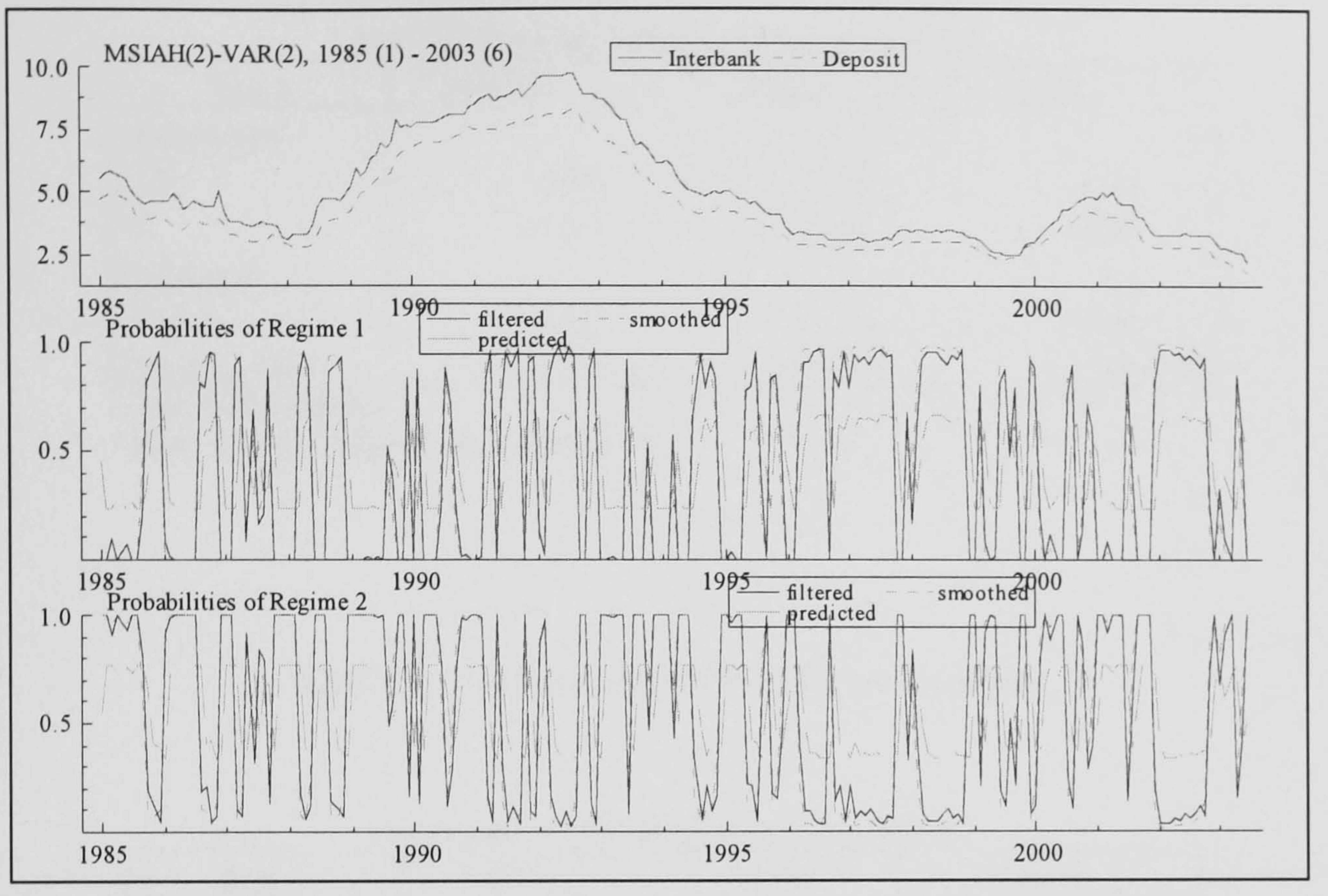


Figure 4.4 Transition Probabilities for German Deposit Pass-Through



Tables

Table 4.1 Unit Root Tests for French Interest Rates

Null Hypothesis of a Unit Root: 1984:04 - 2003:06

Tests 1/	Interbank	Lending	Deposit
Standard tests			
ADF	-1.996	-1.968	-2.255
PP	-2.482	-2.387	-2.403
Robust tests			
DF-GLS	-1.786	-1.911	-2.255
Ng-Perron (Mza)	-11.364	-43.089 *	-15.781 ***

1/ With constant and trend

* Rejection at 1%, ** rejection at 5%, rejection at 10%

Table 4.2 Unit Root Tests for German Interest Rates

Null Hypothesis of a Unit Root: 1984:11 - 2003:06

Tests 1/	Interbank	Lending	Deposit
Standard tests			
ADF	-1.446	-1.991	-1.068
PP	-1.041	-1.417	-1.016
Robust tests			
DF-GLS	-1.365	-1.965 **	-0.903
Ng-Perron (Mza)	-15.854 *	-16.542 *	-12.608 **

1/ With constant

* Rejection at 5%, ** Rejection at 1%

Table 4.3 Hansen LR Statistics for French Interest Rate Pass-Through

Interest rate/ Pass-Through	Hansen's LR* 1/	p-value M=0	M=1	M=2	M=3	M=4
MSI(2)-AR(1)						
Interbank	2.6900	0.0690	0.0830	0.0820	0.0890	0.1080
Lending	1.2544	0.6490	0.6660	0.6270	0.6430	0.6450
Deposit	1.5492	0.5410	0.5980	0.6080	0.5990	0.5870
Single pass-through equation						
Lending	1.6101	0.4580	0.4720	0.4520	0.4690	0.4720
Deposit	1.8774	0.4360	0.4250	0.3950	0.4050	0.3710

1/ Null of linearity, test implemented for grid 3. See details in Hansen (1992 and 1996).

Table 4.4 Hansen LR Statistics for German Interest Rate Pass-Through

Interest rate/ Pass-Through	Hansen's LR* 1/	p-value M=0	M=1	M=2	M=3	M=4
MSI(2)-AR(1)						
Interbank	4.0444	0.0020	0.0050	0.0090	0.0110	0.0130
Lending	5.8733	0.0000	0.0000	0.0000	0.0000	0.0000
Deposit	7.3922	0.0000	0.0000	0.0000	0.0000	0.0000
Single pass-through equation						
Lending	1.9524	0.4290	0.4030	0.4070	0.3910	0.4280
Lending 2/	114.5240	0.0000	0.0000	0.0000	0.0000	0.0000
Deposit	4.4940	0.0000	0.0000	0.0000	0.0000	0.0010

1/ Null of linearity, test implemented for grid 3. See details in Hansen (1992 and 1996).

2/ Considering up to two lags.

Memo:

J-test for a Markov switching intercept pass-through

Pass-Through Equation	J-test δ	Std. Error	t-statistic	p-value
Lending	1.0436	0.1466	7.1185	0.0000

Table 4.5 Specification Selection for MS-VAR on German Interest Rates

Pass-Through Model	Lending - Interbank		Deposit - Interbank	
	Log Likelihood	LR Test 1/	Log Likelihood	LR Test 1/
Linear VAR(2)	237.685		289.736	
With CTP				
MSI(2)-VAR(2)	257.553	39.737	302.021	24.569
MSIH(2)-VAR(2)	295.977	76.847	356.183	108.323
MSIAH(2)-VAR(2)	293.023	-5.908	373.262	34.159
MSIH(3)-VAR(2) 2/	315.240	38.526	394.099	41.673
With TVTP				
MSIH(2)-VAR(2)	315.288	38.624	368.047	-10.431

1/ The test is estimated for each model against the null of the previous selected model.

2/ Although statistically significant, it is not selected for economic interpretation.

Table 4.6 Lending Interest Rate Pass-Through for Germany: 1984:11-2003:06

Variables	Linear VAR		MSIAH(2)-VAR(2) with TVTP			
	Interbank	Lending	Interbank	t-stat	Lending	t-stat
Regime 0						
Intercept	0.317	0.020	1.093	2.99	-0.253	-1.34
Interbank		**0.277**			**0.339**	4.07
Interbank(-1)	1.159	-0.049	1.412	7.65	-0.128	-1.00
Interbank(-2)	-0.127	-0.216	-0.288	-1.43	-0.150	-1.63
Lending(-1)	-0.007	1.093	0.194	0.56	0.799	4.75
Lending(-2)	-0.050	-0.102	-0.379	-1.08	0.210	1.25
S.E.	0.207	0.099	0.133	4.02	0.070	3.59
Regime 1						
Intercept			0.263	2.50	0.078	1.45
Interbank					**0.136**	3.41
Interbank(-1)			1.019	16.01	0.065	0.99
Interbank(-2)			0.038	0.59	-0.177	-4.07
Lending(-1)			-0.110	-0.80	1.064	14.18
Lending(-2)			0.037	0.29	-0.090	-1.26
S.E.			0.200	8.98	0.081	9.72
TVTP			Regime 0		Regime 1	
Constant			0.899	0.73	-33.177	-0.64
Spread LendInter (-1)			0.497	1.03	8.303	0.68

Table 4.7 Deposit Interest Rate Pass-Through for Germany: 1984:11-2003:06

Variables	Linear VAR		MSIAH(2)-VAR(2) with TVTP			
	Interbank	Deposit	Interbank	t-stat	Deposit	t-stat
Regime 0						
Intercept	0.013	0.002	-0.056	-2.07	-0.005	-0.36
Interbank		**0.386**			**0.466**	7.15
Interbank(-1)	0.861	-0.066	0.593	7.33	-0.247	-3.75
Interbank(-2)	-0.168	-0.204	0.022	0.30	-0.090	-2.36
Deposit(-1)	0.642	1.077	0.787	7.70	0.997	14.41
Deposit(-2)	-0.288	-0.214	-0.321	-3.33	-0.146	-2.67
S.E.	0.199	0.082	0.071	4.95	0.037	4.82
Regime 1						
Intercept			0.089	0.85	0.008	0.24
Interbank					**0.357**	7.39
Interbank(-1)			0.922	5.69	-0.011	-0.13
Interbank(-2)			-0.235	-1.00	-0.245	-3.91
Deposit(-1)			0.654	2.25	1.164	9.42
Deposit(-2)			-0.312	-1.10	-0.286	-2.41
S.E.			0.269	7.07	0.105	5.27
TVTP			Regime 0		Regime 1	
Constant			0.440	0.45	2.063	2.58
Spread InterDepo (-1)			0.377	0.35	-1.568	-1.78

Table 4.8 Mortgage Interest Rate Pass-Through for Germany: 1984:11-2003:06

Variables	Linear VAR		MSIAH(2)-VAR(2) with TVTP			
	Interbank	Mortgage	Interbank	t-stat	Mortgage	t-stat
Regime 0						
Intercept	-0.226	0.137	-0.335	-2.72	0.008	0.10
Interbank		**0.165**			**0.095**	0.93
Interbank(-1)	1.118	-0.079	0.576	5.68	0.129	1.61
Interbank(-2)	-0.159	-0.066	0.391	4.22	-0.181	-2.72
Mortgage(-1)	0.214	1.455	0.182	1.34	1.368	19.92
Mortgage(-2)	-0.155	-0.490	-0.113	-0.81	-0.407	-5.74
S.E.	0.205	0.154	0.131	4.38	0.068	3.37
Regime 1						
Intercept			-0.157	-0.76	0.294	2.28
Interbank					**0.243**	2.67
Interbank(-1)			1.499	12.60	-0.288	-1.59
Interbank(-2)			-0.546	-4.64	0.060	0.51
Mortgage(-1)			0.218	1.61	1.442	11.44
Mortgage(-2)			-0.161	-1.18	-0.493	-3.93
S.E.			0.201	8.57	0.174	8.79
TVTP			Regime 0		Regime 1	
Constant			0.620	0.67	0.264	0.34
Spread MortInter (-1)			-0.043	-0.09	0.425	1.12

Table 4.9 Nonlinear Pass-Through Induced by Interbank Rate in Germany

Markov Switching VAR (Regime 1 = high volatility)

Interest rates	No. times in Regime 1	No. times in Regime 1 with Interbank	Times that follow Interbank (percentage)	Times Interbank induced shifts (percentage)
Interbank	126			
Pass-Through				
Lending	99	92	92.9	73.0
Deposit	110	94	85.5	74.6
Lending & Deposit		79		62.7
Memo:				
Mortgage	126	115	91.3	91.3

Appendix

Replacing expressions (3.24) and (3.25) into equation (3.19) to expand out the term in brackets:

$$
\begin{aligned}
r_t^L &= \frac{n\varepsilon_L(1-b)}{n\varepsilon_L-1}r_t+\frac{n\varepsilon_L}{n\varepsilon_L-1}\lambda_L \\
&+\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}\left[\alpha_L\left(r_t^L-r_{t-1}^L\right)+\alpha_r^L\left(r_t-r_{t-1}\right)-\beta E_t\left\{\alpha_L\left(r_{t+1}^L-r_t^L\right)+\alpha_r^L\left(r_{t+1}-r_t\right)\right\}\right]
\end{aligned}
$$

Rearranging terms inside the last term in brackets:

$$
\begin{aligned}
r_t^L &= \frac{n\varepsilon_L(1-b)}{n\varepsilon_L-1}r_t+\frac{n\varepsilon_L}{n\varepsilon_L-1}\lambda_L \\
&+\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}\left[\alpha_L(1+\beta)r_t^L+\alpha_r^L(1+\beta)r_t-\alpha_L\left(r_{t-1}^L+\beta E_t r_{t+1}^L\right)-\alpha_r^L\left(r_{t-1}+\beta E_t r_{t+1}\right)\right]
\end{aligned}
$$

Collecting everything on the left for the lending rate:

$$
\begin{aligned}
r_t^L-\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}(1+\beta)\alpha_L r_t^L &= \frac{n\varepsilon_L(1-b)}{n\varepsilon_L-1}r_t+\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}(1+\beta)\alpha_r^L r_t+\frac{n\varepsilon_L}{n\varepsilon_L-1}\lambda_L \\
&-\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}\left[\alpha_L\left(r_{t-1}^L+\beta E_t r_{t+1}^L\right)+\alpha_r^L\left(r_{t-1}+\beta E_t r_{t+1}\right)\right]
\end{aligned}
$$

$$
\begin{aligned}
\left[1-\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}(1+\beta)\alpha_L\right]r_t^L &= \left[\frac{n\varepsilon_L(1-b)}{n\varepsilon_L-1}+\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}(1+\beta)\alpha_r^L\right]r_t+\frac{n\varepsilon_L}{n\varepsilon_L-1}\lambda_L \\
&-\frac{\varepsilon_L\gamma_L}{n\varepsilon_L-1}\left[\alpha_L\left(r_{t-1}^L+\beta E_t r_{t+1}^L\right)+\alpha_r^L\left(r_{t-1}+\beta E_t r_{t+1}\right)\right]
\end{aligned}
$$

Finally, expressing everything in terms of the lending rate:

$$
\begin{aligned}
r_t^L &= \frac{n\varepsilon_L(1-b)+(1+\beta)\varepsilon_L\gamma_L\alpha_r^L}{(n\varepsilon_L-1)-(1+\beta)\varepsilon_L\gamma_L\alpha_L}r_t+\frac{n\varepsilon_L}{(n\varepsilon_L-1)-(1+\beta)\varepsilon_L\gamma_L\alpha_L}\lambda_L \\
&-\frac{\varepsilon_L\gamma_L}{(n\varepsilon_L-1)-(1+\beta)\varepsilon_L\gamma_L\alpha_L}\left[\alpha_L\left(r_{t-1}^L+\beta E_t r_{t+1}^L\right)+\alpha_r^L\left(r_{t-1}+\beta E_t r_{t+1}\right)\right]
\end{aligned}
$$

A similar procedure is followed to get the corresponding pass-through for deposit rates and for both pass-through in the model with risks.

CHAPTER 5

5 CONCLUSIONS

This thesis has assessed interest rate pass-through both empirically and theoretically. At the first level, a series of econometric models including single and multi-equation systems, bivariate and multivariate specifications, and linear and non-linear approaches were specified and estimated. The first empirical part studied the case of Argentina. Econometric results suggested regime switching stochastic behaviour in the pass-through. If volatile conditions last long enough, the pass-through decreases. If they are rather short-lived, the pass-through might increase instead. On the theoretical part, a dynamic bank model with risks displayed such nonlinearities if there is a regime switching stochastic process in the risks premiums that are linked to regime shifts in the interbank rate. Overall, it is the macroeconomic factors, rather than the microeconomic elements, that explain the regime switching process in the interest rate pass-through.

Preliminary time series analysis indicates that interest rates in Argentina are consistent with stationary stochastic processes. Therefore, econometric models should include in this case levels of the variables to estimate the pass-through. In general, though, whether to use an autoregressive distributed lag model in levels or an error correction model (either in a single equation or in a multi-equation system) depends on the time series properties of the interest rates and on the sample of the study.

For this initial empirical application, single equation systems show quite a remarkable heterogeneous structure of the pass-through for bank lending rates, with rates on higher credit-risk loans responding stickier to the interbank rate. Simple calculations of the long-term pass-through (which include lagged interbank and lagged bank rate parameters) produce quite implausible high values (well above the complete pass-through effect). Furthermore, the resulting model remains incongruent and does not capture precisely the occurrence of extreme events, even if dummy variables account for them.

Multivariate linear VAR models reveal the dynamics among interest rates more appropriately than single equations by considering possible interactions between market segments. For Argentina, however, this multi-equation approach clearly shows that only its own past values and those from the interbank rate affect each bank lending rate. The interbank rate is indeed weakly exogenous to the system and banks seem to optimise their operations by credit segments. Therefore, bivariate linear VAR models capture better the significant differences in pass-through between lending rates. Besides, their results are more interpretable. Yet, estimated first-order linear VAR models are still not congruent, apparently due to the presence of several financial crises affecting interest rates' evolution. Even if dummy variables are included, residuals remain autocorrelated, heteroskedastic, and not normally distributed. Pursuing a more parsimonious representation does not necessarily improve on these features, but comes at the cost of reducing degrees of freedom.

Impulse responses from the linear VAR representation show some degree of stickiness in the short-run, although the immediate effect is relatively high. Still, simple calculations of the long-term effect are implausible high. Thus, it seems that neither single-equation modelling, nor multi-equation systems capture efficiently the dynamic relationships among lending rates and the money market rate. Several episodes of financial crises alter the pass-through, affecting the speed and degree of response to shocks in the interbank rate. Discarding information over those periods (for example, by including dummy variables) reduces the ability of the models to explain the whole process over the study sample.

Regime switching in the interest rate pass-through has been a feature of the financial system in Argentina. Markov switching models are then more suitable to represent the pass-through in this empirical case. Bivariate MSIAH(2)-VAR(1) models greatly improve upon modelling the responses from bank lending rates to the interbank rate. In normal times, the stickiness in the short-run is higher for those rates on loans with higher credit risk. With short-lived volatile financial conditions, the pass-through tends to increase considerably for all rates.

Allowing parameters of the VAR model to be regime-dependent efficiently determines the periods in which regime switch occurs. The MSIAH(2)-VAR(1) identifies correctly periods of financial distress, associated to financial crises (either international or domestic) for lending rates. Furthermore, the Markov switching representation provides more congruent models than with linear approaches.

All the same, it seems that although Markov switching models improve upon linear models in measuring the pass-through and revealing its dynamics, considering only interest rates in local currency might not be enough to capture rates' behaviour. The information contents (on the risks banks face) of a number of interest rate spreads could signal regime shifts. Therefore, these interest rate spreads are used to represent time-varying transition probabilities (as opposed to constant ones).

The nonlinearities in the interest rate pass-through in Argentina are associated to financial crises, either international or domestically generated, that affect the banking system to different degrees and to different variables (prices and/or quantities). They do not seem to be particularly associated to the business cycle, whose effects seem to be smoother or at least overshadowed by the magnitude of the financial crises effects.

In the context of a dynamic bank optimisation model, this research has shown how a nonlinear, regime-switching, money market rate induces a nonlinear behaviour in lending and deposit rates and in their pass-through. It is argued that the pass-through process is consistent with a nonlinear behaviour even if there are no asymmetries or nonlinearities in the adjustment costs from shocks to the interbank rate. Noticeably, both short-term and long-term pass-through could be regime switching. The long-term pass-through parameter seems more complex to estimate than the simple calculation usually applied in empirical studies (considering lags from the lending or deposit rate and from the interbank rate).

The interbank rate stochastic properties are relevant to determine those for the pass-through. Indeed, regime switching behaviour in the interbank rate might cause both lending and deposit rates to shift regimes at similar dates. Even more important, risk premiums for credit risk and liquidity risk (charged on banks' rates) display also a nonlinear pattern, which is correlated to the regime-switching pattern of the interbank rate. With an initial shift to unstable financial conditions in the money market, the risk premiums switch to the same volatile regime inducing, as a result, a regime-switch in the pass-through (for lending and deposit rates alike).

The direction of the change in the pass-through is not unique. In both cases, it could either increase or decrease with the volatile regime. For instance, considering the credit risk premium for lending rates, the pass-through in unstable conditions could either rise or fall. The change in the probability of loan repayment will determine crucially the direction of the switch. A Stiglitz-Weiss-type adverse selection mechanism in it makes either movement possible. Similarly, for the deposit rate, when a liquidity risk premium is considered, a change to the volatile regime in the interbank rate will cause a positive or negative shift in the pass-through. In this case, the liquidity crisis management, through bank reserves, plays an important role to determine the direction of the change.

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Author Index

Abiad (2003)........ 125, 143, 151
Ahrens (1999)........ 38
Ahrens (2002)........ 109, 118
Alfaro et al. (2002)........ 25
Allen, DeLong, and Saunders (2003)........ 215
Altman, Resti, and Sironi (2004)........ 205, 207
Altunbas, Fazylov, and Molyneux (2002)........ 25
Alvarez-Plata and Schrooten (2003)........ 109, 122
Ang and Bekaert (1998)........ 39, 66
Ang and Bekaert (2002)........ 105, 112, 118, 119, 124, 187, 191, 192
Ball and Mankiw (1994)........ 217
Banco Central de Argentina (1998)........ 52
Bangia et al. (2002)........ 213
Bansal and Zhou (2002)........ 187, 191
Barnea, Kim, and Kliger (2003)........ 202
Bean, Larsen, and Nikolov (2002)........ 25
Berger and Hannan (1989)........ 24
Berstein and Fuentes (2002)........ 35, 36
Boinet, Napolitano, and Spagnolo (2002)........ 40, 66, 109, 122, 138
Bolton and Freixas (2004)........ 181, 186
Bondt (2002)........ 24, 25, 33, 34, 106, 123, 177
Brooke, Cooper, and Scholtes (2002)........ 102
Brooks (2002)........ 28
Calvo, Izquierdo, and Talvi (2002)........ 130, 131
Calza, Gartner, and Sousa (2001)........ 200
Catao (1998)........ 47
Central Bank of Argentina (2004)........ 133, 153
Cerra and Saxena (2002)........ 109, 125
Chumacero (2001)........ 56
Claessens and Glaessner (1998)........ 100, 148
Clarida et al. (2002)........ 39, 56
Clarida, Sarno, Taylor, and Valente (2002)........ 109
Clarida, Sarno, Taylor, and Valente (2004)........ 109, 142
Corvoisier and Gropp (2001)........ 26
Cosimano (1988)........ 185
Cottarelli and Kourelis (1994)........ 23, 24, 33, 35
Cox, Ingersoll, and Ross (1985)........ 190
Cunningham (1999)........ 103
Dahlquist and Gray (2000)........ 41, 106, 108, 118, 119, 124, 125, 187, 189, 191, 192
Damill, Salvatore, and Simpson (2003)........ 129, 132
De la Torre, Yeyati, and Schumukler (2002)........ 127, 130
Delfino (2002)........ 46
Dell'Ariccia and Garibaldi (1998)........ 217
Dia (2004)........ 184, 185, 187, 194, 195
Diebold, Lee, and Weinbach (1994)........ 118, 120, 144, 147
Doornik and Ooms (2001)........ 65
Driffill, Kenc, and Sola (2003)........ 187, 191, 192

Edwards (1998) 48, 56
Ehrmann et al. (2001a) 23
Ehrmann, Ellison, and Valla (2001b) 66
Elliott, Hunter, and Jamieson (2000) 191
Elyasiani, Kopechy, and van Hoose (1995) 185, 194, 195
Engel and Hamilton (1990) 139
Erlandsson (2002) 39, 45, 105, 118, 138, 187, 191
Espinosa-Vega and Rebucci (2002) 69
Evans (1998) 187, 191
Feldstein (2002) 132
Filardo (1993) 118
Filardo (1994) 118
Filardo (1998) 104, 119, 144, 147
Franses and van Dijk (2000) 42, 64, 118
Fratzscher (2002) 108, 125
Freixas and Rochet (1997) 31, 177, 179, 205
Frömmel, MacDonald, and Menkhoff (2002) 108, 139
Frost and Bowden (1999) 183
Gabrielli, McCandless, and Rouillet (2003) 132
Gambacorta (2004) 101
Garcia (1998) 137, 138
Garcia and Perron (1996) 111, 137, 140, 141, 187, 222
Gavin and Hausmann (1996) 112
Girardin and Horsewood (2001) 41
Gray (1996) 41, 112, 138, 187, 188, 189, 191, 193
Green (1998) 182, 183
Grubisic and Escudé (1999) 56
Haan (2001) 24
Hamilton (1988) 112, 137, 138, 187, 188, 192, 199
Hamilton (1989) 112, 154
Hamilton (1994) 112, 114, 115, 144, 148
Hamilton and Raj (2002) 112, 118
Hannan and Berger (1991) 217
Hansen (1992) 44, 137, 138, 139
Hansen (1992), (1996) 66
Hansen (1996) 139
Heffernan (1997) 214
Heffernan (2002) 24
Hendry and Krolzig (2001), (2002) 57
Herring (1999) 204, 205
Hofmann and Mizen (2004) 102, 104, 105, 109, 110, 119, 123, 175, 183, 187, 194
Hutchison (1995) 203
Iregui, Milas, and Otero (2001) 104, 119, 121, 218
James and Webber (2000) 29, 33, 190, 193
Jeanne and Masson (2000) 108, 112
Johansen (1991) 53
Kakes and Sturm (2002) 24
Kamin and Ericsson (2003) 47
Kim and Nelson (1999) 42, 145
Kim, Piger, and Startz (2003) 119

King (1986) 177
Klein (1971) 178
Krause (2003) 97
Krolzig (1997) 39, 65, 120, 138, 139, 141, 142, 148
Krolzig (1998) 44, 64
Krolzig (2002) 41, 42
Laurent and Urbain (2003) 139
Lensink and Sterken (2002) 25
Lim (2001) 217
Lütkepohl (1991) 38, 60
Maddala and In-Moo (1998) 54
Mandilaras and Bird (2003) 108, 112, 118, 124
Manzano and Galmés (1996) 180
Martínez (2002) 107, 108, 112, 124, 139, 143, 147
Mester (1993) 187, 217
Mishkin (1986) 29
Mishkin (1995) 98
Moazzami (1999) 25, 35
Mojon (2000) 25, 34
Monti (1972) 178, 195
Morris and Sellon (1995) 25
Nelson, Piger, and Zivot (2001) 55
Neumark and Sharpe (1992) 183
Paisley (1994) 182
Patterson (2000) 60
Perry and Servén (2002) 130
Pesaran et al. (2003) 211
Psaradakis and Spagnolo (2002) 140
Sander and Kleimeier (2003) 100, 101, 104, 109, 122
Santomero (1984) 177, 195
Saunders (2000) 207
Schneider (2001) 186
Scholnick (1996) 25, 106, 123
Stiglitz and Weiss (1981) 182
Taylor (1998) 97
Tirole (1988) 178
Toolsema and Schoonbeek (1999) 183
Van den Heuvel (2002) 185, 186
Vogelsang (1999) 55, 220
Von Thadden (2000) 184
Winker (1999) 26, 37