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# Did Turkish Banks Sustain High Margins? Hidden Markov Evidence from the 2007–2011 Investigation Window

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**Abstract**

This paper examines whether the Turkish Competition Authority's 2007–2011 investigation window coincided with persistently high loan-deposit margins in Turkish banking. We use weekly data from the Central Bank of the Republic of Türkiye for 2 June 2006–28 March 2025. Consumer and commercial margins are constructed as the relevant loan rate minus the aggregate Turkish-lira deposit rate. We estimate separate two- and three-state Gaussian hidden Markov models for each margin. To reduce the risk of local optima, we standardize each series, use multiple deterministic and randomized starting values, and order regimes by their estimated mean margins. The results do not indicate a sustained high-margin regime during the investigation window. Mean margins are lower inside the window than outside it. In the preferred three-state models, the high state accounts for only 1.9% of consumer-margin weeks and 4.7% of commercial-margin weeks. The analysis is a descriptive economic screen and does not determine the existence, scope, participants, or legal characterization of any infringement. It does not corroborate the narrower aggregate outcome hypothesis that the full investigation window was characterized by continuous, cross-market margin elevation.

**Keywords:** hidden Markov model; collusion screening; banking competition; interest margins; Turkish Competition Authority; regime switching

**JEL Classification Codes:** C22; C58; G21; K21; L41

# Türk Bankaları Yüksek Marjları Sürdürdü mü? 2007–2011 Soruşturma Dönemine İlişkin Saklı Markov Bulguları

**Öz**

Bu çalışma, Türkiye Rekabet Kurumu'nun 2007–2011 soruşturma döneminin Türk bankacılığında sürekli biçimde yüksek kredi–mevduat marjlarıyla örtüşüp örtüşmediğini incelemektedir. Türkiye Cumhuriyet Merkez Bankası'nın 2 Haziran 2006–28 Mart 2025 dönemine ait haftalık verileri kullanılmaktadır. Tüketici ve ticari marjlar, ilgili kredi faizinden toplulaştırılmış Türk lirası mevduat faizinin çıkarılmasıyla oluşturulmaktadır. Her marj için ayrı iki ve üç durumlu Gauss saklı Markov modelleri tahmin edilmektedir. Yerel optimum riskini azaltmak amacıyla seriler standartlaştırılmakta, çok sayıda belirlenimci ve rastgele başlangıç değeri kullanılmakta ve rejimler tahmin edilen ortalama marjlarına göre sıralanmaktadır. Bulgular, soruşturma döneminde sürekli bir yüksek marj rejimine işaret etmemektedir. Ortalama marjlar, dönem içinde dönem dışına kıyasla daha düşüktür. Tercih edilen üç durumlu modellerde yüksek durum, tüketici marjı haftalarının yalnızca %1,9'unu ve ticari marj haftalarının %4,7'sini oluşturmaktadır. Analiz betimleyici bir iktisadi tarama olup herhangi bir ihlalin varlığını, kapsamını, katılımcılarını veya hukuki niteliğini belirlemez. Bulgular, soruşturma döneminin bütününün sürekli ve piyasalar arası bir marj yükselmesiyle nitelendiğine dair dar toplulaştırılmış sonuç hipotezini desteklememektedir.

**Anahtar Kelimeler:** saklı Markov modeli; kartel taraması; bankacılıkta rekabet; faiz marjları; Rekabet Kurumu; rejim değişimi

**JEL Sınıflandırması:** C22; C58; G21; K21; L41

## 1. Introduction

In Decision No. 13-13/198-100, the Turkish Competition Authority (TCA) imposed administrative fines on twelve banks after finding an infringement involving conduct in the deposit, loan, and credit-card markets during 2007–2011 (Turkish Competition Authority, 2013). The decision treated contacts concerning different banking products as components of a single continuous infringement rather than as wholly separate episodes. This characterization is closely related to the EU concept of a single and complex continuous infringement, under which acts across time or product markets may be treated as one infringement when they are linked by a common plan (Thomas, 2023). In the cited HSBC proceeding, subsequent judicial review emphasized the need for a more segmented and undertaking-specific demonstration of such a plan where the direct evidence linked different banks to different product markets (Council of State, 2022). This paper uses the authority's stated time window as an empirical benchmark; it does not independently assess the documentary record or take a position on legal liability. The legal background nevertheless makes the distinction between parallel conduct, plus factors, and proof of agreement especially relevant (Kovacic et al., 2011).

This paper asks a narrower economic question: Did aggregate interest margins move into a persistent high-margin regime during the TCA window? The question cannot resolve liability. Documentary evidence, intent, bank-level heterogeneity, product-specific coordination, and the legal attribution of conduct to individual undertakings remain separate issues. If the conduct generated a sustained and broad effect on both lending and deposit prices, however, one plausible outcome-level implication would be persistently elevated aggregate margins. Failure to observe that pattern cannot exclude coordination, because effects may be short-lived, product-specific, offset by costs or demand, or concentrated among particular banks.

Prior empirical work on Turkish banking has often used structural or conduct-parameter approaches and has reported evidence consistent with market power or anticompetitive conduct (Aydemir, 2013, 2014; Çelen, 2019). Other work documents dispersion in loan rates and market features that may facilitate strategic pricing (Baziki et al., 2022). This literature does not, however, ask whether the legally specified 2007–2011 window coincides with persistent latent states in high-frequency aggregate margins. The contribution here is therefore a timing-based descriptive screen rather than an estimate of a conduct parameter or damages. We use a regime-switching filter to classify observed aggregate margins into low, medium, and high states and

compare the timing of those states with the investigation period. HMMs are suitable for this purpose because they represent the observed series as generated by an unobserved Markov state process (Rabiner, 1989).

International studies illustrate both the value and the limits of latent-timing methods in cartel analysis. Hyytinen et al. (2018) use an HMM with Finnish manufacturing data from a period of legal cartels to infer unobserved cartel prevalence. Boshoff and van Jaarsveld (2019) use a Markov regime-switching model for the South African cement market to identify recurrent collusive episodes and estimate overcharges, while Boswijk et al. (2019) use multiple structural-break tests in the European sodium chlorate cartel to show that formal infringement dates need not coincide with the dates of observable market effects. These studies motivate attention to latent timing, but the present design is more limited: its states are labeled only by the level of the observed margin, not as "competitive" or "collusive," and it neither estimates overcharges nor identifies causal cartel dates.

The distinction between screening and proof is central. A collusion screen is valuable when it identifies patterns that are difficult to reconcile with independent conduct, but it is an evidentiary triage device rather than proof of agreement (Abrantes-Metz & Bajari, 2009; Kovacic et al., 2011). Examples include unusual price stability, break dates that coincide with cartel communications, and long high-margin episodes that cannot readily be explained by costs or demand. Variance-based and structural-break screens are useful because they translate such anomalies into replicable empirical signals (Abrantes-Metz et al., 2006; Crede, 2019). Screens do not replace the legal inquiry into agreement, participation, intent, market definition, or the attribution of conduct to particular firms. The analysis below therefore tests one outcome-level implication of a broad and persistent-effect interpretation of the TCA window: whether sustained aggregate margin elevation is visible in the data.

This question also matters for enforcement design. If high-frequency aggregate data show no persistent shift during a legally specified period, that absence does not negate documentary or participant-specific evidence. It does, however, make the transmission mechanism to the outcome under examination an empirical question. Conversely, when a high-margin regime aligns with documentary evidence, a quantitative screen can help discipline the temporal scope of further inquiry and identify the product markets in which the alleged conduct may have had measurable effects.

## 2. Data and methodology

The data are weekly interest-rate series published by the Central Bank of the Republic of Türkiye (CBRT). The sample begins on 2 June 2006 and ends on 28 March 2025. The TCA window is defined as 21 August 2007–22 September 2011 and contains 212 weekly observations.

All source series are publicly available from the CBRT's Weekly Flow Interest and Profit Rate Statistics pages. The loan variables are obtained from Interest Rates on Loans (Weekly Flow Data, Weighted Average), and the common deposit benchmark is obtained from Interest Rates on Deposits (Weekly Flow Data, Weighted Average); both pages provide direct access to the corresponding series in the Electronic Data Delivery System (EVDS). The analysis uses the published general-purpose consumer loan rate, the Turkish-lira commercial loan rate, and the aggregate Turkish-lira deposit rate. No proprietary data are used.

The sample is intentionally longer than the investigation window. HMMs estimate regimes from the distribution and persistence of the entire observed series. Later observations therefore help the model identify the empirical range of genuinely high and low margins in this market. At the same time, this feature means that HMM classifications are sample-dependent.

Two aggregate margins are constructed. The consumer margin is the general-purpose consumer loan rate minus the aggregate Turkish-lira deposit rate. The commercial margin is the Turkish-lira commercial loan rate minus the same aggregate deposit rate. In compact notation, the two margins are defined as

$$m_t^C = r_t^{consumer} - r_t^{deposit}, m_t^B = r_t^{commercial} - r_t^{deposit}. \quad (1)$$

These spreads are useful aggregate indicators of pricing conditions, but they are not exact net interest margins. They do not match loan and deposit maturities. They do not control for credit risk, collateral, or bank-level funding costs, and they cannot distinguish state-owned from private banks. These limitations are important because a short-lived or bank-specific episode of coordination could be missed in aggregate weekly data.

For each margin, we estimate a Gaussian hidden Markov model within the standard HMM framework, in which inference combines likelihood evaluation, state decoding, and parameter re-estimation (Rabiner, 1989). Let $S_t$ denote the unobserved state and $y_t$ the observed margin. Conditional on state $j$, the emission density is Gaussian:

$$y_t \mid S_t = j \sim N\left(\mu_j, \sigma_j^2\right). \tag{2}$$

The latent state follows a first-order Markov chain with transition probabilities

$$P\left(S_t = j \mid S_{t-1} = i\right) = p_{ij}. \tag{3}$$

We estimate two- and three-state specifications. After estimation, states are ordered by their estimated means, so the state with the largest mean is labeled the high-margin state. The two-state model is a binary screen contrasting lower with higher margins. The three-state model is more flexible because it can distinguish low, medium, and high regimes. This flexibility is useful when crisis episodes generate negative or very low margins as well as high-margin episodes.

The estimation procedure standardizes each series before fitting, runs each specification from multiple data-driven and randomized starting values, imposes a maximum of 2,000 EM iterations with a tight convergence tolerance, and retains the highest-likelihood solution. Multiple starts are necessary because Gaussian HMM likelihoods are non-convex. A single start can place a state on a small outlier cluster and produce economically misleading labels. We report information criteria, state means, state standard deviations, transition persistence, expected state durations, and the share of the investigation window assigned to each state.

The Gaussian emission assumption is a parsimonious device for state classification, not a claim that the unconditional margin series are normally distributed. Turkish interest-rate data contain extreme observations, and additional states can absorb some distributional heterogeneity but do not fully resolve heavy tails. Student-t emissions are a natural alternative because they are less sensitive to outliers and can change estimated state persistence (Bulla, 2011). The present paper retains Gaussian emissions for transparency and comparability; its conclusions should therefore be understood as conditional on the Gaussian-HMM specification.

Posterior probabilities are reported as smoothed probabilities conditional on the full sample, rather than as real-time one-step-ahead filtered probabilities. The Viterbi path is used for hard regime classification. Because the goal is a retrospective assessment of whether the legal window coincided with persistent high margins, smoothed probabilities are appropriate. The distinction among state decoding, smoothed probabilities, and real-time filtering follows the standard HMM taxonomy (Rabiner, 1989). The reported probabilities should not be interpreted as information that would have been available to an observer at time t.

**Table 1. Descriptive statistics for interest margins**

| Series | Mean | TCA mean | Outside mean | Minimum | Maximum |
|---|---|---|---|---|---|
| Consumer | 8.24 | 5.72 | 8.94 | -0.49 | 30.08 |
| Commercial | 3.51 | 1.65 | 4.02 | -17.55 | 13.98 |

Note. Margins are measured in percentage points. The TCA window is 21 August 2007 to 22 September 2011.

## 3. Findings

Table 1 conveys the central descriptive result. The average consumer margin is 5.72 percentage points during the TCA window and 8.94 outside it. The corresponding commercial-margin averages are 1.65 and 4.02 percentage points. These differences do not corroborate the hypothesis that the legally specified window, taken as a whole, was a period of unusually high loan-deposit spreads.

The HMM results reinforce this interpretation. Model-selection statistics favor the three-state specification for both margins. For consumer margins, the BIC falls from 1,292.75 in the two-state model to 736.38 in the three-state model; for commercial margins, it falls from 2,244.55 to 1,693.64. The three-state model is therefore the preferred descriptive segmentation, while the two-state results are retained as a simpler comparison.

**Table 2. HMM regime estimates and TCA-window classifications**

| Series | States | Regime | Mean | SD | $p_{ii}$ | Duration | TCA share | TCA posterior |
|---|---|---|---|---|---|---|---|---|
| Consumer | 2 | Low | 6.23 | 1.39 | 0.992 | 126.8 | 98.1% | 0.964 |
| Consumer | 2 | High | 14.12 | 4.57 | 0.981 | 52.3 | 1.9% | 0.036 |
| Consumer | 3 | Low | 5.12 | 0.89 | 0.974 | 39.1 | 64.6% | 0.644 |
| Consumer | 3 | Medium | 7.37 | 0.87 | 0.963 | 27.4 | 33.5% | 0.337 |
| Consumer | 3 | High | 14.45 | 4.53 | 0.978 | 46.4 | 1.9% | 0.018 |
| Commercial | 2 | Low | 0.60 | 2.76 | 0.988 | 81.8 | 81.1% | 0.826 |
| Commercial | 2 | High | 4.99 | 1.98 | 0.995 | 213.4 | 18.9% | 0.174 |
| Commercial | 3 | Low | 0.57 | 2.76 | 0.987 | 77.4 | 80.2% | 0.810 |
| Commercial | 3 | Medium | 4.22 | 0.99 | 0.982 | 55.3 | 15.1% | 0.143 |
| Commercial | 3 | High | 7.79 | 2.17 | 0.956 | 22.6 | 4.7% | 0.047 |

Note. Duration is $1/(1 - p_{ii})$, measured in weeks. TCA posterior is the mean smoothed posterior probability of the corresponding state during the investigation window.

In the preferred consumer-margin model, the estimated state means are 5.12, 7.37, and 14.45 percentage points. During the TCA window, 64.6% of weeks are assigned to the low state, 33.5% to the medium state, and only 1.9% to the high state. The average smoothed posterior probability of the high state in the window is 0.018. Thus, even when an intermediate state is allowed, the investigation window is overwhelmingly classified as low or medium rather than high.

For commercial margins, the preferred three-state means are 0.57, 4.22, and 7.79 percentage points. The TCA window is assigned 80.2% to the low state, 15.1% to the medium state, and 4.7% to the high state. The average high-state posterior probability is 0.047. The two-state commercial model assigns a larger share of the window—18.9%—to the higher state. That model, however, has substantially worse information criteria and combines normal positive-margin periods with more elevated episodes in one broad state. The three-state model provides a more granular descriptive separation among low or negative margins, normal positive margins, and high-margin episodes.

Figures 1–4 are consistent with the table. High consumer-margin regimes appear mainly outside the investigation window, especially during later macro-financial stress episodes. Commercial margins also display high-state episodes outside the TCA window, while much of the window is classified as low. The negative commercial margins around 2022 are assigned to the low regime. The model therefore captures broad macro-financial shifts as well as high-margin states. This interpretation is consistent with evidence that Turkish exchange-rate and inflation dynamics changed materially under a weak monetary-policy framework after the early 2010s (Gürkaynak et al., 2023).

Transition estimates also show that the states are persistent enough to be economically meaningful. In the preferred three-state consumer model, expected durations are approximately 39, 27, and 46 weeks for the low, medium, and high regimes. In the commercial model, the corresponding durations are about 77, 55, and 23 weeks. The model is therefore not merely reacting to one-week noise. It identifies multi-month or multi-quarter pricing environments and asks whether the legally specified dates fall within the high-margin environment. They generally do not.

A cautious interpretation is still required. Commercial margins during the investigation window are not uniformly low. In the two-state commercial model, 18.9% of window weeks are assigned to the higher state. That specification, however, has a much worse BIC and treats a broad range of positive margins as high. Once the model can distinguish normal positive margins from more elevated margins, the high-state share falls to 4.7%. The preferred reading is therefore not that the window was uneventful, but that it was not a sustained high-margin regime. Nor can the model determine whether any individual high-margin week resulted from coordination rather than costs, demand, regulation, or macroeconomic conditions.

**Figure 1. Consumer margin with three-state HMM regimes**

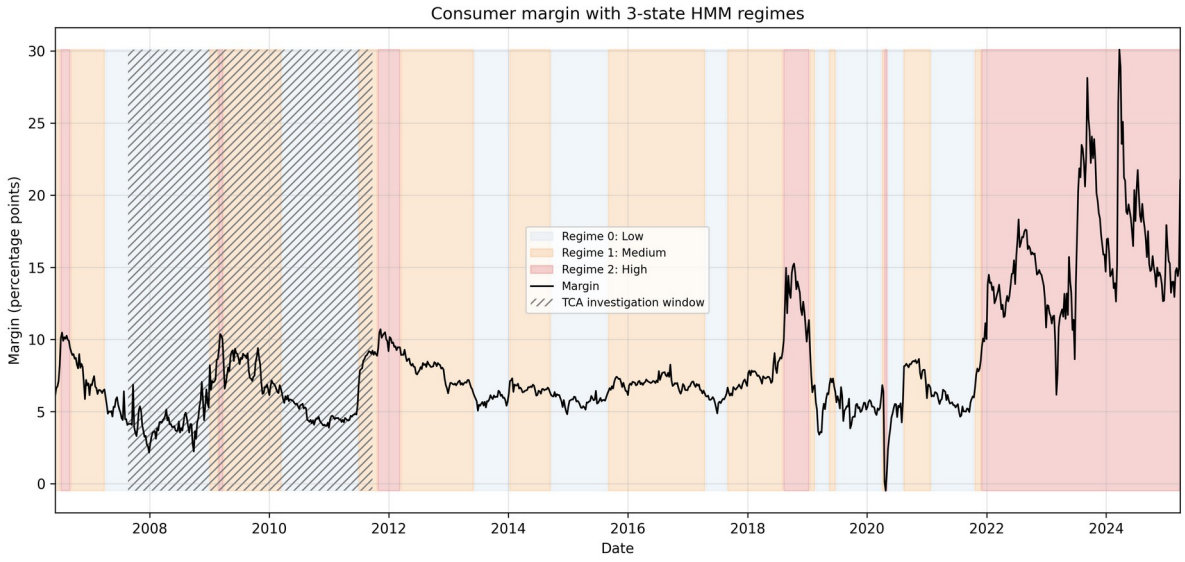



**Figure 2. Smoothed posterior probability of the high consumer-margin regime**

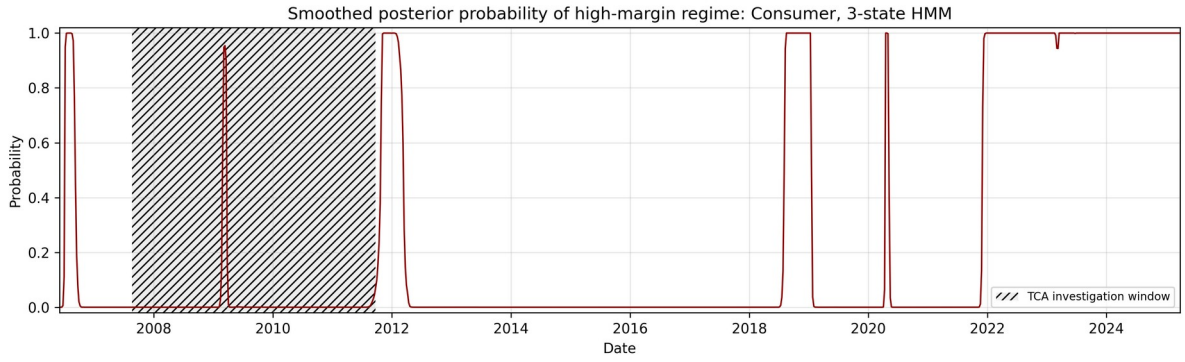


**Figure 3. Commercial margin with three-state HMM regimes**

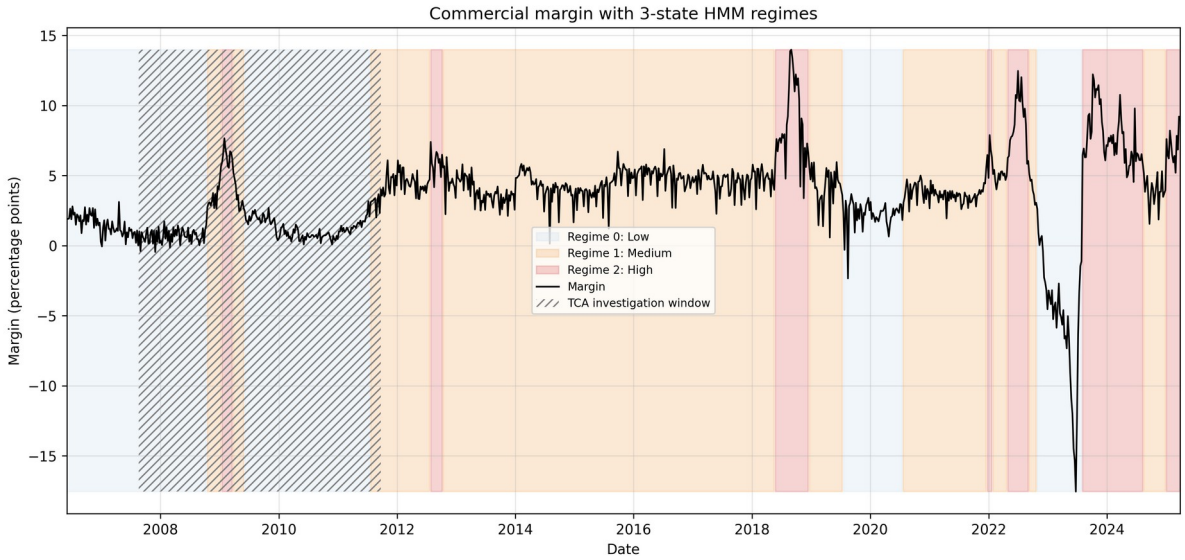
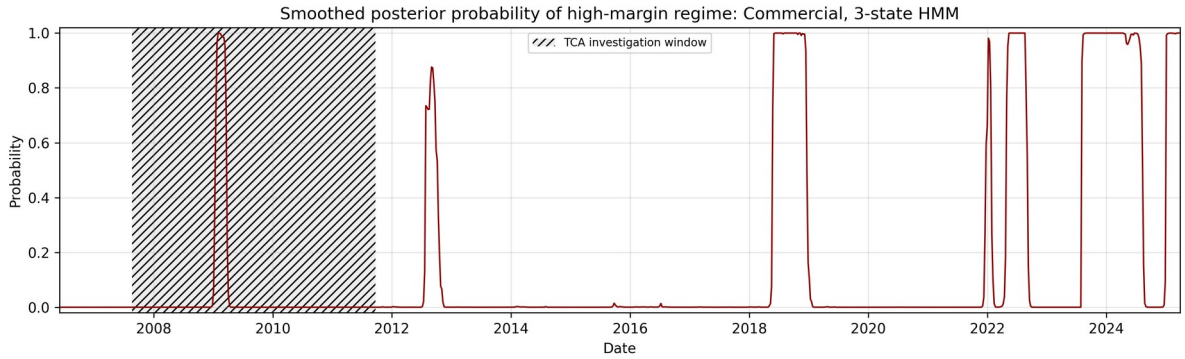



**Figure 4. Smoothed posterior probability of the high commercial-margin regime**




## 4. Conclusion

The HMM analysis does not indicate a sustained high-margin regime during the TCA's 2007–2011 investigation window. Both average margins are lower inside the window than outside it. The preferred three-state HMMs yield the same descriptive pattern: only 1.9% of consumer-margin weeks and 4.7% of commercial-margin weeks in the window are classified as high-margin weeks.

This finding should be interpreted with care. A descriptive HMM is not a structural cartel model, and aggregate margins cannot prove either the presence or the absence of collusion. The analysis cannot recover bank-level coordination, product-specific price changes, maturity-specific funding costs, or short-lived communications that may have legal significance. It also cannot determine whether later high-margin states were caused by market

power, inflation expectations, liquidity shocks, regulatory constraints, or monetary-policy shifts. Accordingly, the results do not corroborate the narrower aggregate outcome hypothesis that the entire investigation window was characterized by continuous, cross-market margin elevation; they do not resolve the legal characterization of the underlying conduct.

For enforcement and litigation, the implication is methodological. HMMs are useful as screening and corroboration tools because they identify persistent regimes and provide uncertainty measures, while cartel-screening studies emphasize that such tools should guide, not replace, legal proof (Abrantes-Metz & Bajari, 2009; Hyytinen et al., 2018). They should be combined with documentary evidence, bank-level data, and macroeconomic controls. Robustness work could also consider Student-t emissions, multivariate or covariate-dependent HMMs, hidden semi-Markov models with explicit duration dependence, and bank-level margins when those data are available.

A natural extension is a multivariate HMM in which consumer and commercial margins share a common latent state. Such a specification would speak more directly to whether multiple product markets move together into a common high-margin regime, while still not testing the legal elements of a single and continuous infringement (Thomas, 2023). Another extension is a model with macroeconomic covariates in the transition matrix. Such covariates would allow liquidity stress, policy-rate changes, inflation expectations, or exchange-rate shocks to explain switches between states, an especially relevant consideration in the Turkish macro-financial setting (Gürkaynak et al., 2023). These extensions would move the exercise closer to causal interpretation, whereas the present paper remains a transparent descriptive screen.

## Declarations

**Funding.** The author did not receive support from any organization for the submitted work.

**Conflict of interest.** The author declares no conflict of interest and no financial interests.

**Data availability.** The source interest-rate series are published by the Central Bank of the Republic of Türkiye. The cleaned data set can be supplied upon request.

**Code availability.** The Python script can be supplied upon request.

**Ethics approval.** The study uses secondary, publicly available aggregate data and did not require ethics committee approval.

**Authorship.** Single-authored study.

## References

Abrantes-Metz, R. M., Froeb, L. M., Geweke, J. F., & Taylor, C. T. (2006). A variance screen for collusion. International Journal of Industrial Organization, 24(3), 467–486. https://doi.org/10.1016/j.ijindorg.2005.10.003

Abrantes-Metz, R. M., & Bajari, P. (2009). Screens for conspiracies and their multiple applications. Antitrust, 24(1), 66–71.

Aydemir, R. (2013). Competition and collusion in the Turkish banking industry. *Emerging Markets Finance and Trade*, 49(sup5), 31–40. https://doi.org/10.2753/REE1540-496X4905S502

Aydemir, R. (2014). Empirical analysis of collusive behaviour in the Turkish deposits market. *Economic Research-Ekonomska Istraživanja*, 27(1), 527–545. https://doi.org/10.1080/1331677X.2014.970452

Baziki, S. B., Kılıç, Y., & Yılmaz, M. H. (2022). Consumer loan rate dispersion and the role of competition: Evidence from Turkish banking industry. *Central Bank Review*, 22(1), 27–38. https://doi.org/10.1016/j.cbrev.2022.01.001

Boshoff, W. H., & van Jaarsveld, R. (2019). Recurrent collusion: Cartel episodes and overcharges in the South African cement market. *Review of Industrial Organization, 54*(2), 353–380. https://doi.org/10.1007/s11151-018-9637-9

Boswijk, H. P., Bun, M. J. G., & Schinkel, M. P. (2019). Cartel dating. *Journal of Applied Econometrics, 34*(1), 26–42. https://doi.org/10.1002/jae.2660

Bulla, J. (2011). Hidden Markov models with t components: Increased persistence and other aspects. *Quantitative Finance, 11*(3), 459–475. https://doi.org/10.1080/14697681003685563

Central Bank of the Republic of Türkiye. (2025). *Weekly flow interest and profit rate statistics* [Data set]. https://evds3.tcmb.gov.tr/

Council of State, General Assembly of Administrative Litigation Chambers. (2022). Decision No. 2022/662 (HSBC Bank A.Ş.).

Çelen, A. (2019). Anticompetitive effects of the banking cartel in Turkish loan market. *Sosyoekonomi*, 27(40), 211–230. https://doi.org/10.17233/sosyoekonomi.2019.02.13

Crede, C. J. (2019). A structural break cartel screen for dating and detecting collusion. Review of Industrial Organization, 54(3), 543–574. https://doi.org/10.1007/s11151-018-9649-5

Gürkaynak, R. S., Kısacıkoğlu, B., & Lee, S. S. (2023). Exchange rate and inflation under weak monetary policy: Turkey verifies theory. Economic Policy, 38(115), 519–560. https://doi.org/10.1093/epolic/eiad020

Hyytinen, A., Steen, F., & Toivanen, O. (2018). Cartels uncovered. American Economic Journal: Microeconomics, 10(4), 190–222. https://doi.org/10.1257/mic.20160326

Kovacic, W. E., Marshall, R. C., Marx, L. M., & White, H. L. (2011). Plus factors and agreement in antitrust law. Michigan Law Review, 110(3), 393–436.

Rabiner, L. R. (1989). A tutorial on hidden Markov models and selected applications in speech recognition. Proceedings of the IEEE, 77(2), 257–286. https://doi.org/10.1109/5.18626

Thomas, S. (2023). The concept of a single and complex continuous infringement. In P. Whelan (Ed.), Research handbook on cartels (pp. 118–134). Edward Elgar Publishing. https://doi.org/10.4337/9781839102875.00016

Turkish Competition Authority. (2013). Decision No. 13-13/198-100.