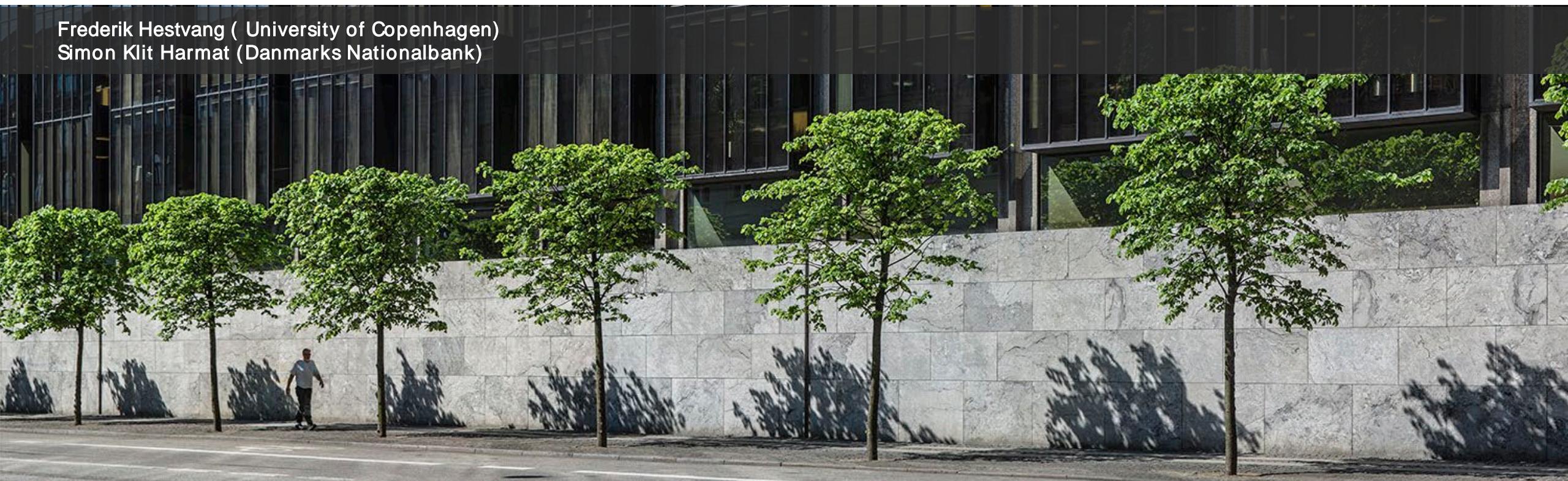


DANMARKS
NATIONALBANK

MODELLING DANISH INTERBANK PAYMENTS: AN AUTOREGRESSIVE APPROACH

Frederik Hestvang (University of Copenhagen)

Simon Klit Harmat (Danmarks Nationalbank)



Disclaimer

- The views expressed in this presentation are those of the authors and may not necessarily reflect institutions.

Agenda

- Introduction and motivation
- Data
- Approach
- Results
- Conclusion

Introduction: The Analysis

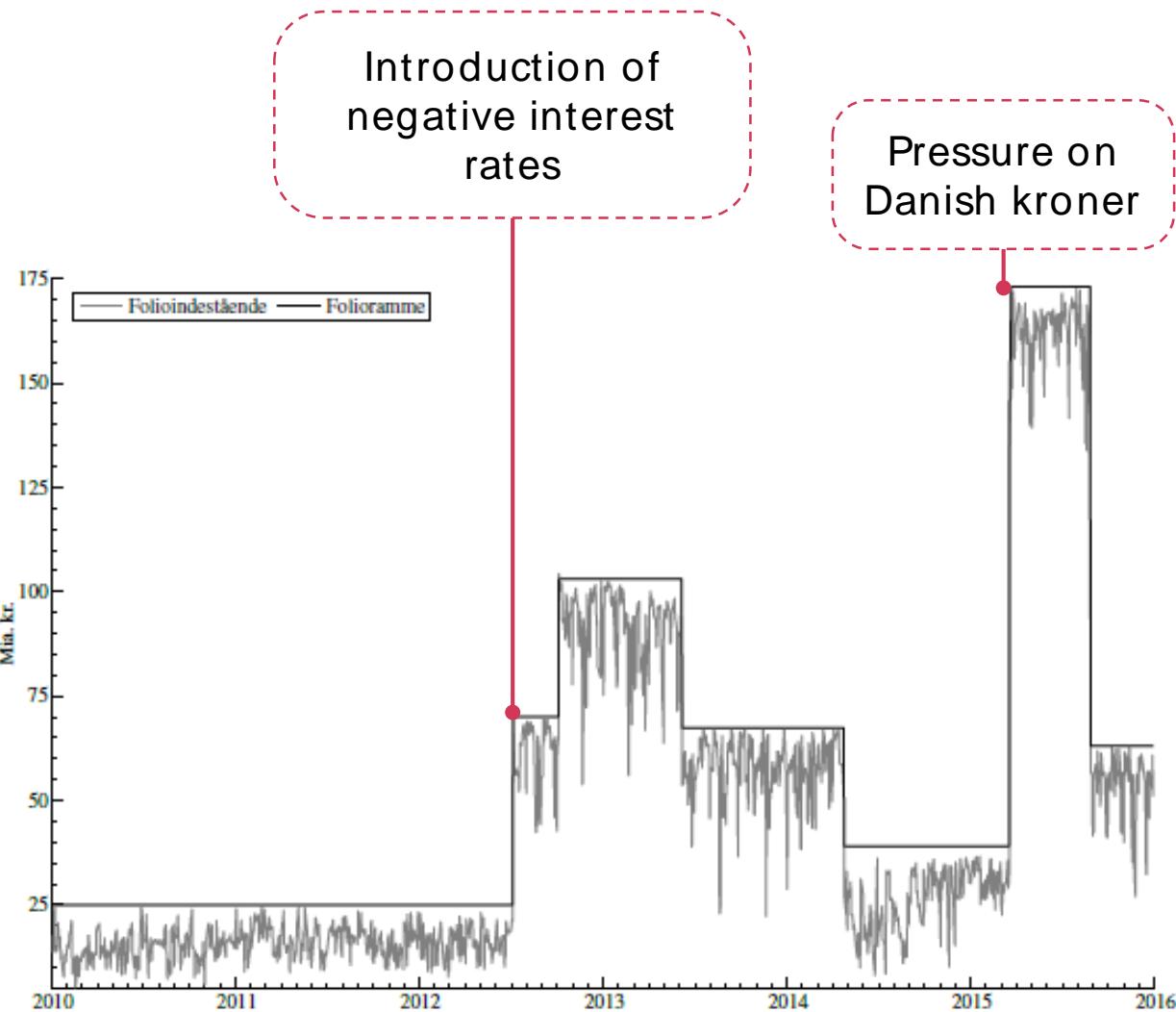
- Examine the day-to-day mutual payment flows made by Danish financial institutions with a univariate autoregressive model.
- The method was introduced in DNB Working Paper No. 74: "Modelling inter- and intraday payments flows" by Van Oord and Lin (2005)

Motivation

- Gain insight in the Danish interbank market:
 - Can the same model be applied 11 years later on Danish data?
 - Can we describe the pattern of the payment flows and analyze which events affect the flows ?
 - Furthermore can we spot changes in the patterns or market behaviour ?
 - Does monetary policy tools change the use of Kronos
 - Has changing current account limits affected payment flows?

So... what is the current account limit?

- An overall limit has been determined for the counterparties' total current account deposits with DN at the close of the day.
- Limits the sectors ability to speculate against the euro-peg
- If the counterparties' total current account deposits exceed the overall limit, the current account deposits will be converted into certificates of deposit.



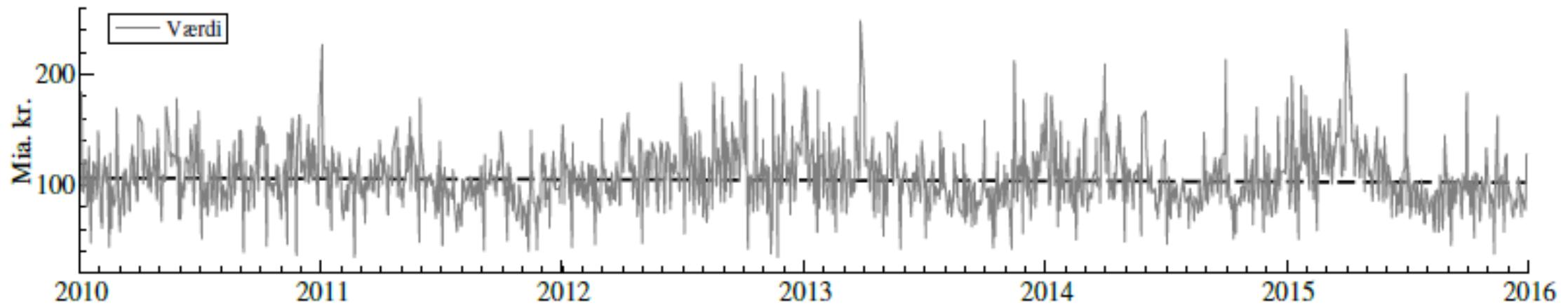
Data.. The Zoom In

- Time periode: 03-01-2010 – 30-12-2015
- Bank initiated payments made in Kronos (Danish RTGS-system)
- Aggregate daily levels for all participants
- Interbank payments: three variables
 - Total value of transactions
 - Total number of transactions
 - Average value per transaction



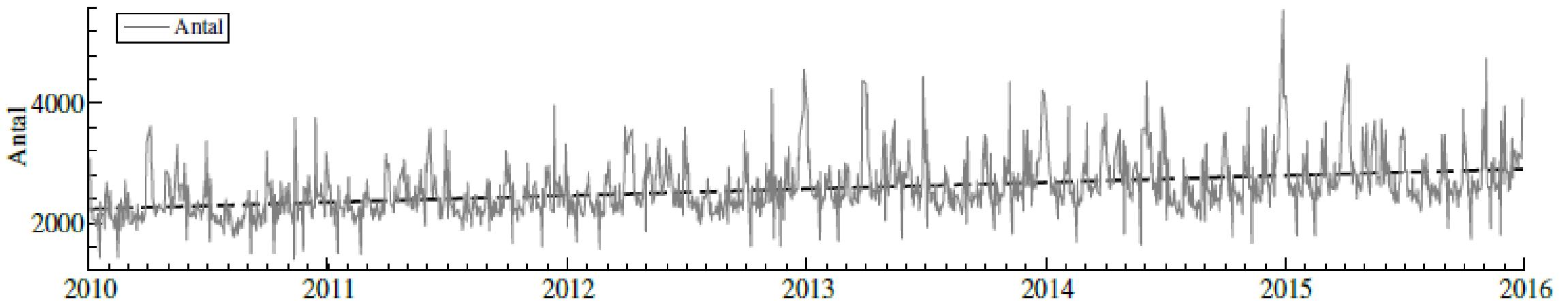
Total value of payments

- Daily average of DKK 104 bn (EUR 14 bn)
- Stationary properties
- Point of interest : Given that the number of transactions and available liquidity is fixed, higher daily value will result in rising liquidity risk



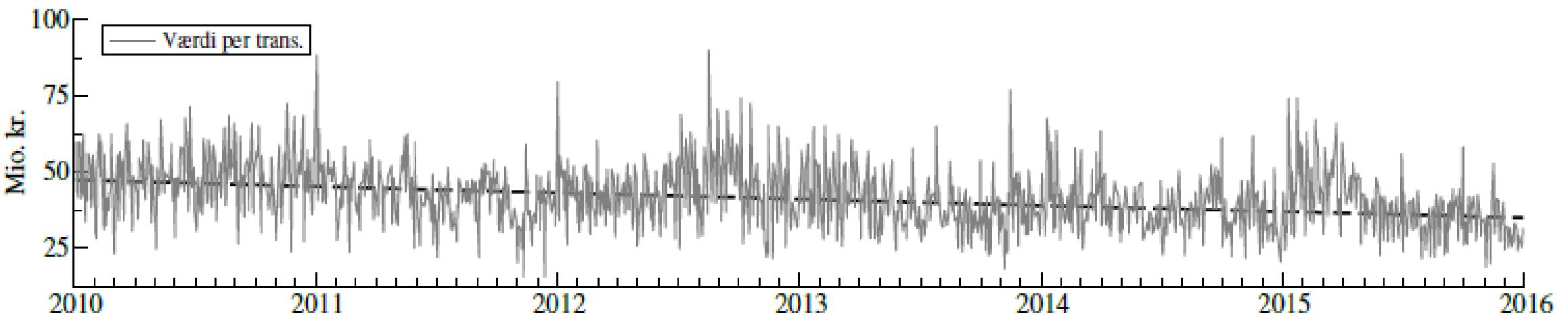
Total number of payments

- Daily average of 2,600 transactions
- Trend stationary properties
- Point of interest : Given that the value of transactions and available liquidity is fixed, lower daily number will result in rising liquidity risk



Average value per payment

- Daily average of DKK 41 mn (EUR 6 mn)
- Trend stationary properties
- Point of interest : Higher value per payment is caused by increasing value or decreasing number of transaction. Higher value per payment will result in rising liquidity risk.



Explanatory variables

- Trends
- Time patterns on weekly, monthly and yearly basis
- National and international closing days
- Debt markets: Government and mortgage
 - Auctions, settlement, coupons and redemptions
- Current account limit regimes
 - 7 different regimes
- Dynamics



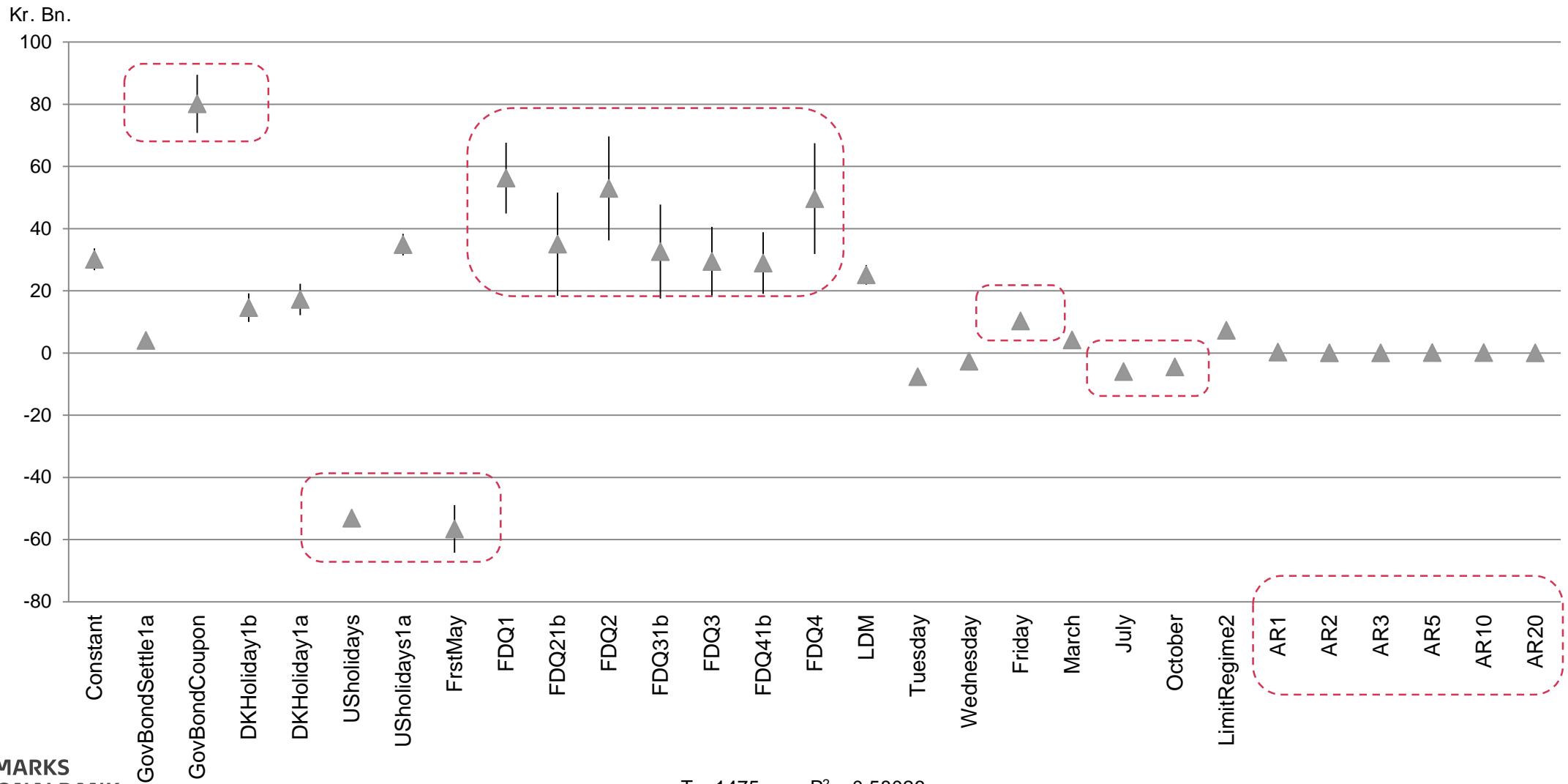
Approach

- Construct a static model
 - Purpose: i) Test relevance and structure for dummies ii) Benchmark for forecasting
- Test all variables for stationary
- Test for well specified models
- Current account limit regimes
- Forecasting ability

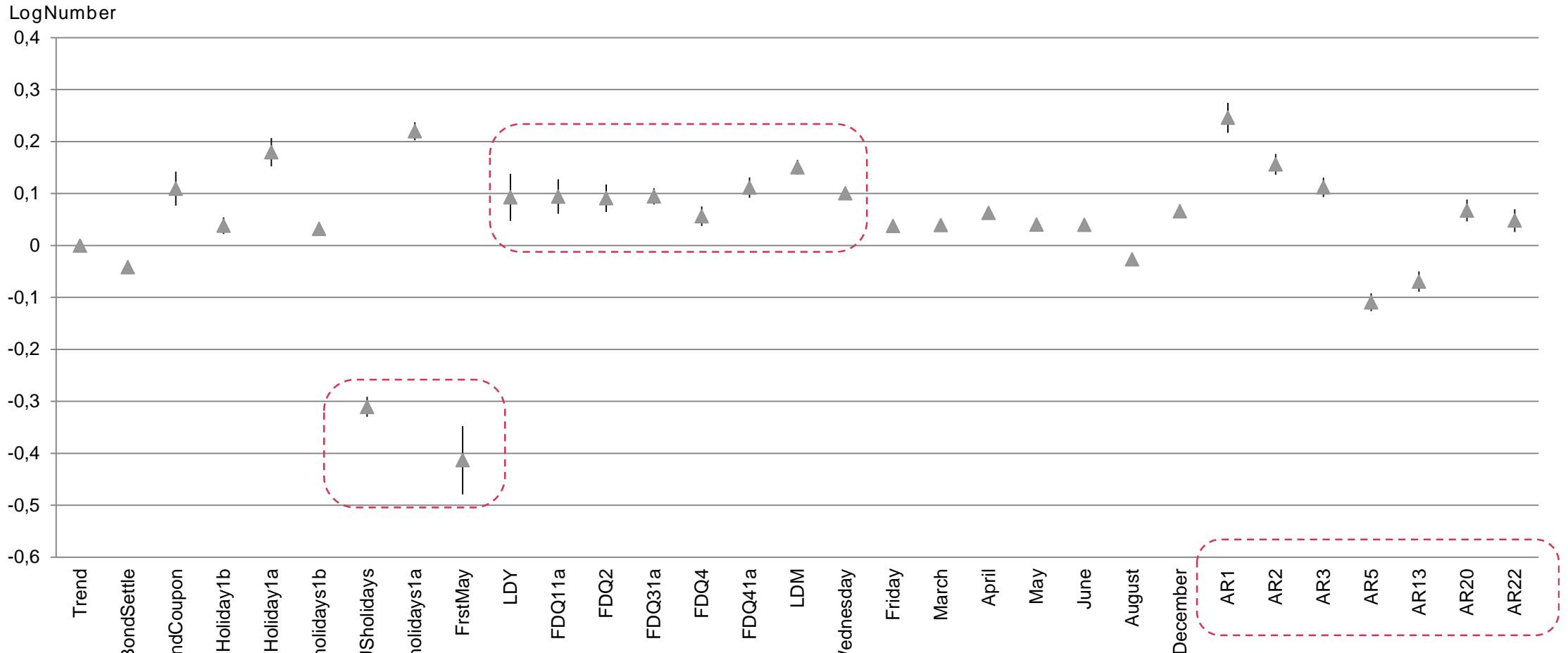
Results – where is the output table?

	Værdi			LogAntal			Værdi pr. transaktion		
	Koefficient	HCSE	p værdi	Koefficient	HACSE	p værdi	Koefficient	HCSE	p værdi
Constant	30.1219	3.517	0.00	4.18082	0.3547	0.00	16.6884	2.166	0.00
Trend				9.604E-05	9.237E-08	0.00	-0.0031103	0.0005844	0.00
StatsOblAktioner1b									
StatsOblAktioner									
StatsOblAktioner1a									
StatsOblValor1b									
StatsOblValor									
StatsOblValor1a									
StatsKupon1b									
StatsKupon1a									
StatsKupon									
StatsKupon1a	80.1277	9.321	0.00	0.109287	0.03275	0.00	26.1616	2.798	0.00
DKheldig1b	14.592	4.588	0.00	0.0380202	0.01613	0.02			
DKheldig1a	17.2253	5.047	0.00	0.179491	0.02728	0.00			
USheld1b				0.0321711	0.01272	0.01			
USheld1ys	-53.1417	2.85	0.00	-0.310527	0.01974	0.00			
USheld1a	34.8569	3.481	0.00	0.21991	0.01745	0.00			
FraMaj1	-56.5817	7.637	0.00	0.413279	0.02772	0.00	-11.3039	1.579	0.00
LDV				0.0926137	0.04522	0.04	-5.13891	3.115	0.01
FDQ1	56.2401	11.39	0.00	0.0942203	0.03314	0.00	21.2918	8.292	0.01
FDQ21b	34.9981	16.56	0.03	0.0912029	0.02646	0.00	8.83811	5.869	0.13
FDQ21a	52.9318	16.73	0.00						
FDQ21b	32.6023	15.1	0.03						
FDQ21	29.4159	11.19	0.01	0.0943367	0.01568	0.00	7.66513	3.535	0.03
FDQ3							-11.4202	2.869	0.00
FDQ31a									
FDQ31b	28.2004	9.811	0.00						
FDQ4	49.6351	17.83	0.01	0.0563747	0.01869	0.00	13.5738	4.832	0.01
FDQ41a				0.111434	0.01965	0.00			
LDM	25.1652	3.168	0.00	0.150469	0.01447	0.00	5.17958	1.092	0.00
Mandag									
Torsdag	-7.66487	1.337	0.00						
Onsdag	-2.64539	1.342	0.05	0.100553	0.006184	0.00	-2.57985	0.4911	0.00
Tirsdag									
Fredag	10.2558	1.593	0.00	0.0374367	0.009361	0.00	3.59559	0.6683	0.00
Januar							3.04333	0.9763	0.00
Februar									
Marts	4.22171	1.856	0.02	0.0392717	0.00841	0.00	1.60471	0.7585	0.03
April				0.0626395	0.009763	0.00			
Maj				0.04032	0.01197	0.00			
Juni				0.0597703	0.01216	0.00			
Juli	-5.96681	1.616	0.00						
August				-0.0265228	0.007798	0.00			
September									
Oktober	-4.50768	1.689	0.01						
November									
December				0.0657017	0.01347	0.00			
Folke regime1									
Folke regime2	7.28858	2.641	0.01				3.90788	1.159	0
Folke regime3									
Folke regime4									
Folke regime5									
Folke regime6									
Folke regime7									
AR1	0.252367	0.02265	0	0.24567	0.02899	0.00	0.247602	0.02487	0
AR2	0.0747163	0.02124	0.0004	0.156194	0.01999	0.00			
AR3	0.0701617	0.02077	0.0007	0.111931	0.01855	0.00	0.0770568	0.02295	0.0008
AR4									
AR5	0.101816	0.01931	0	-0.109352	0.01708	0.00	0.120928	0.02492	0
AR6									
AR7									
AR8									
AR9									
AR10	0.103461	0.01902	0				0.0465326	0.02683	0.083
AR11									
AR12									
AR13				-0.0694448	0.01957	0.00			
AR14									
AR15									
AR16									
AR17									
AR18									
AR19									
AR20	0.0828763	0.01847	0	0.067247	0.02108	0.00	0.123379	0.02408	0
AR21									
AR22				0.0479578	0.02181	0.03			
AR23									
T		1474			1474			1474	
R ²		0.58026			0.71563			0.429468	

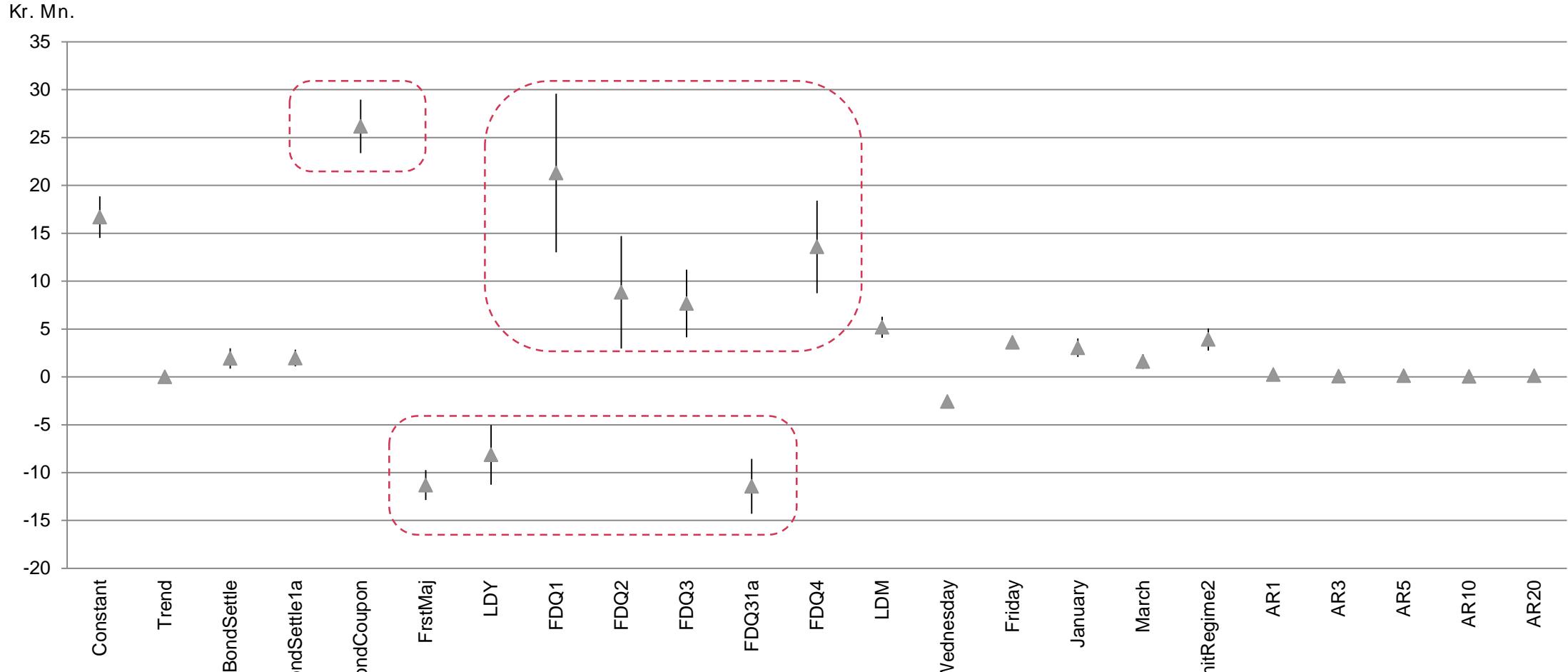
Dynamic Model: Value



Dynamic Model: Number



Dynamic Model: Value per transaction



Forecasting Error

- Benchmarking the dynamic model against the static model

**Root mean square error (RMSE) for the static and dynamic model,
100 days**

	Value	Number	Value per transaction
Static	17,315	0,123	6,173
Dynamic	15,716	0,111	5,940

- Dynamic model proves better

Improvements and Explorations

- Expand to multivariate framework by using some of the results:
 - Effective Exchange Rate
 - Interest rates: Certificates of Deposit, Money Market
 - Change in disposable liquidity or trading volume on bond markets
 - Model the variable Numbers of Transactions with a volatility model (ARCH)

Conclusions

- Trends: **Unambiguously positive** - But what drives this? FX swaps, algo-trading etc.
- Time patterns on weekly, monthly and yearly basis : i.e. **Friday and summer effects**
- National and international closing days: **Interconnectiveness** - 38 of 50 lowest observations is US Holidays
- Debt markets: Government and mortgage: **Settlement and efficient allocation of liquidity shocks**
- Current account limit regimes: Instant utilization of CA limit with a 2 Kr. bn. buffer, but no significant change in behavior
- Dynamics: **Monthly cyclical**. AR-terms has a distinct lag structure
- Forecasting ability : **Dynamic model proves better**

Thank you!

Simon Klit Harmat skh@nationalbanken.dk

Appendix

The Static Model

$$y_t = \alpha + \beta t + \sum_{k=1}^K \sum_{s=-1}^1 \kappa_{k,s} d_{k,t+s} + \sum_{s=-1}^1 \lambda_s f_{t+s} + \sum_{s=-1}^1 \gamma_s g_{t+s} + \tau + \epsilon_t$$

- y_t is the value, number or average value of payments at time t , α is a constant, βt is linear time trend, $d_{k,t+s}$ is the k^{th} institutional dummy, f_{t+s} is a dummy for holidays in Denmark, g_{t+s} is a dummy for the banking holidays in the United States and τ is a vector containing dummies for the first of May and the last day of a given month.

The Dynamic Model

$$y_t = \Omega + \sum_{s \in S} \theta_s y_{t-s} + \sum_{k=1}^K \sum_{s=-1}^1 \kappa_{k,s} d_{k,t+s} + \sum_{s=-1}^1 \lambda_s f_{t+s} + \sum_{s=-1}^1 \gamma_s g_{t+s} + \tau + \epsilon_t$$

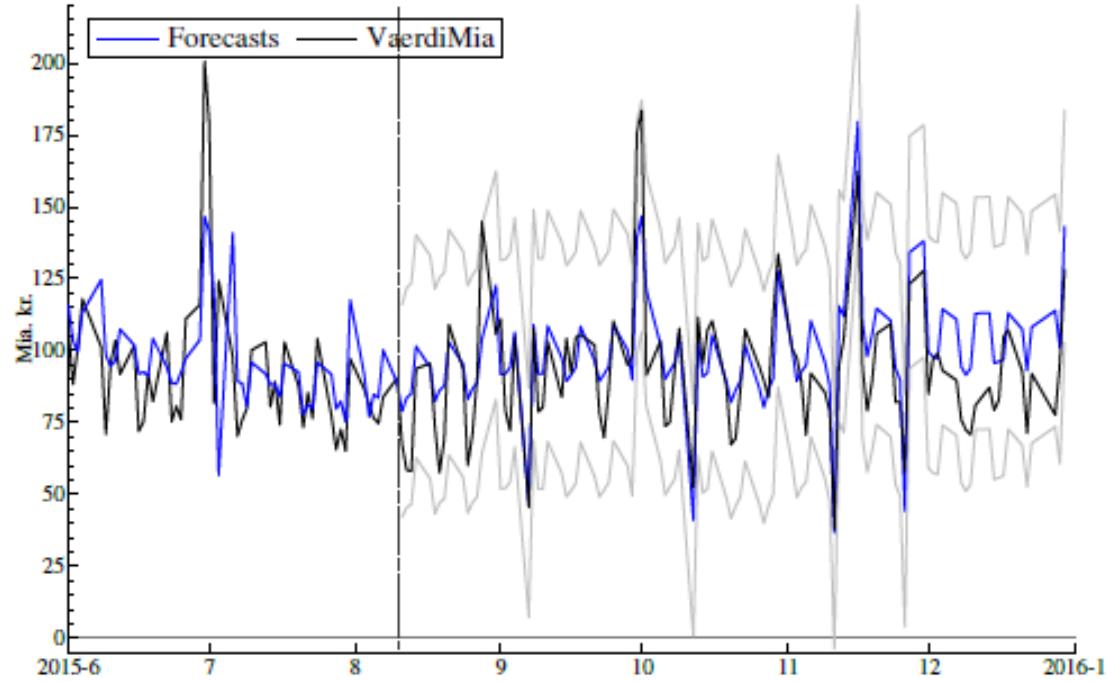
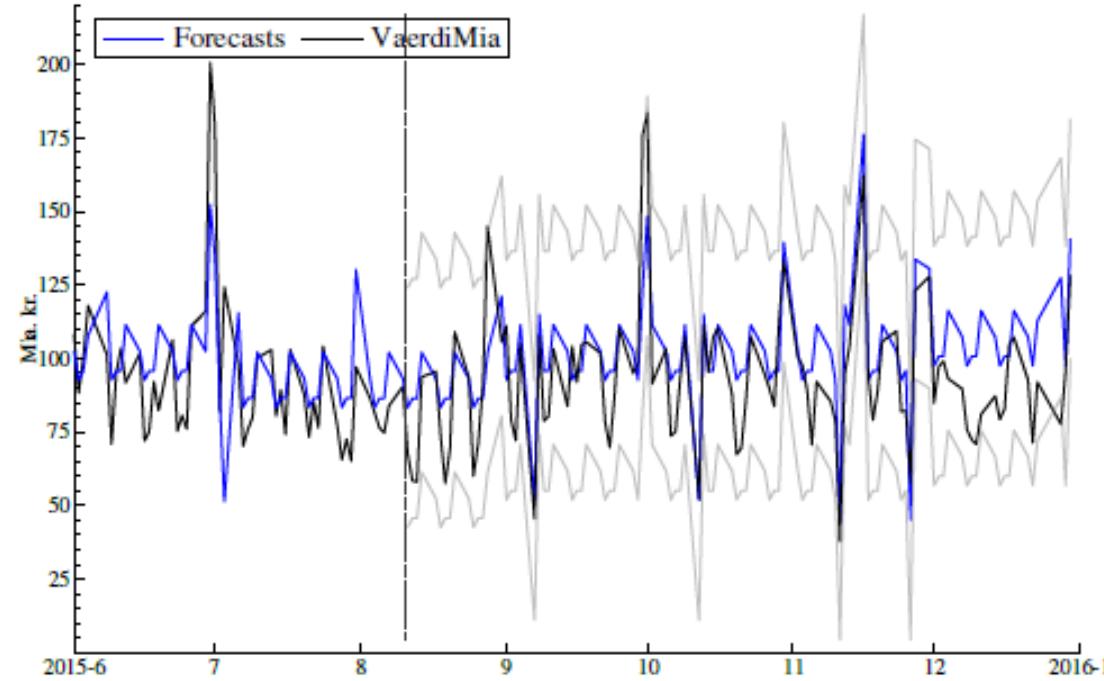
- Ω is a vector containing constant, linear time trend and dummies for weekdays, months and current-account limits regimes, $d_{k,t+s}$ is the k^{th} institutional dummy, f_{t+s} is a dummy for holidays in Denmark, g_{t+s} is a dummy for the banking holidays in the United States and τ is a vector containing dummies for the first of May and the last day of a given month.

Model Selection and Estimation

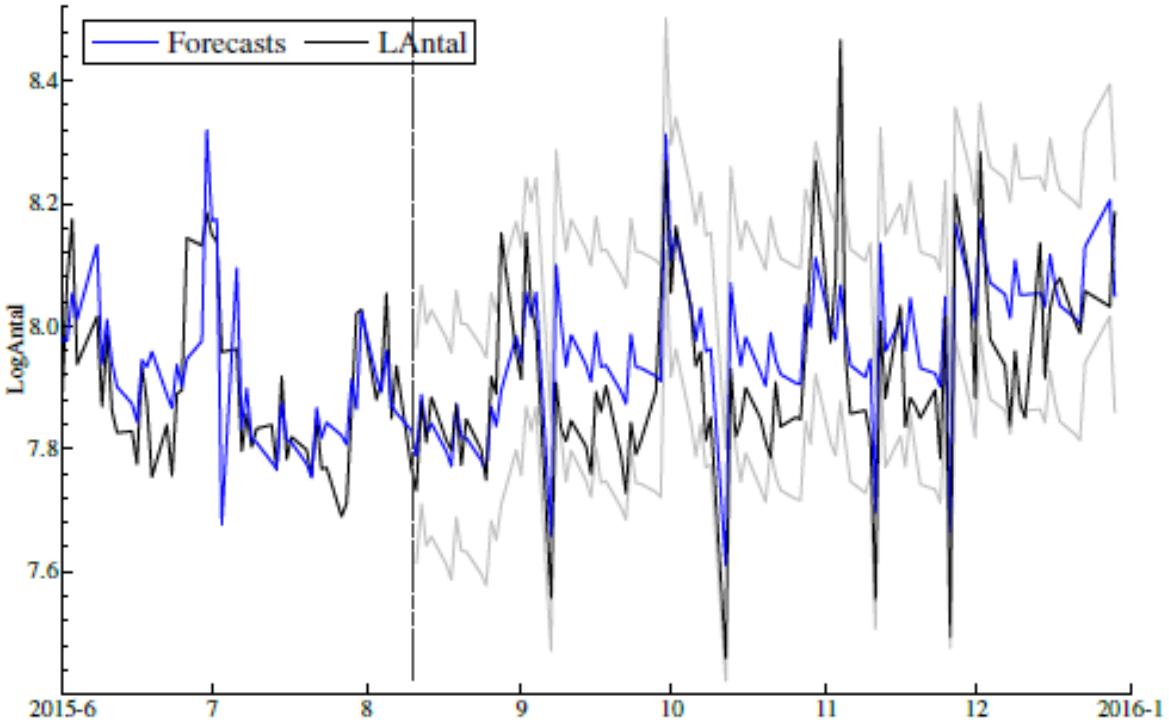
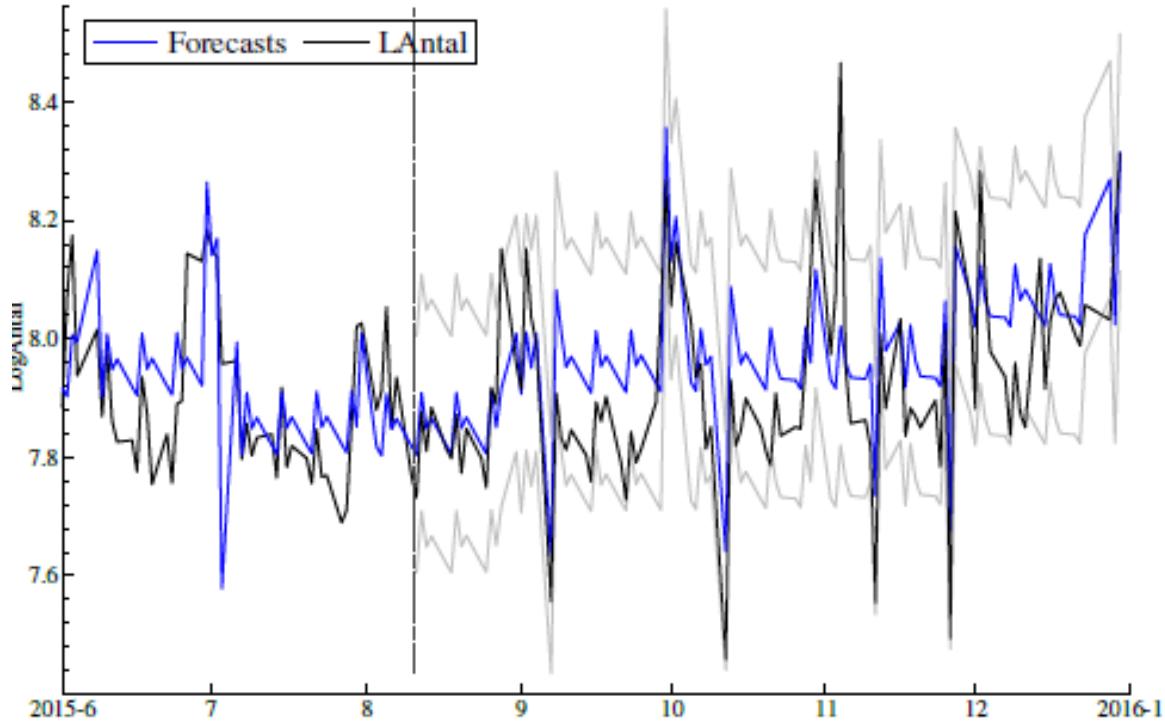
	Value		Number		LogNumber		Value per transaction	
	AR(23)	AR(20) - GtS	AR(23)	AR(23)	AR(22) - GtS	AR(23)	AR(20) GtS	
Test								
Autocorrelation	1.43 (0,24)	1.3364 (0,2631)	7,2365** (0,0007)	6,1741** (0,0021)	2.7601 (0,0636)	2.4716 (0,0848)	1.4328 (0,2390)	
ARCH	1.36 (0,24)	1.6989 (0,1926)	10,354** (0,0013)	13,845** (0,0002)	18,202** (0,0000)	1.4886 (0,2226)	1.64 (0,2005)	
Normality	90,9** (0,00)	94,196** (0,00)	372,63** (0,0000)	271,48** (0,0000)	242,03** (0,0000)	63,912** (0,0000)	47,78** (0,0000)	
Heteroskedacity	2,02** (0,00)	3,6931** (0,00)	2,1176** (0,0000)	1,9779** (0,0000)	2,7651** (0,0000)	1,4982** (0,0099)	4,1493** (0,0000)	
RESET	1.34 (0,26)	1.4868 (0,2264)	8,2957** (0,0003)	1.3498 (0,2596)	0.25646 (0,7738)	3,2139* (0,0405)	0.77474 (0,4610)	
AIC	5.82729	5.81488	11.0897	-4.83518	-4.75635	4.03365	4.02202	
SIC	5.98897	5.91907	11.2802	-4.6232	-4.64138	4.16299	4.09028	



Static vs. Dynamic Model, 100 Days Dynamic Forecast: Value



Static vs. Dynamic Model, 100 Days Dynamic Forecast: Number



Static vs. Dynamic Model, 100 Days Dynamic Forecast: Value per transaction

