Norges Bank

1 | 2024

Documentation Note

Details on the models discussed in the box “A weaker krone exchange rate pushes up inflation – but by how much?” in Monetary Policy Report 3/24

About the publication

Documentation Notes provide concise documentation of analyses or calculations featured in the Monetary Policy Report, speeches, and other publications where opportunities for further elaboration are constrained. An important goal of the Documentation Notes is to make the analyses more accessible to a broader audience, thereby contributing to verifiability and transparency. In some cases, related code and datasets will also be included.

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The Models underlying the Box "A weaker krone exchange rate pushes up inflation – but by how much?" (MPR 3/24)

This Analytical Note provides a detailed description of the three empirical models used in the box on exchange rate pass-through in MPR 3/24, pages 42-45.

The ECM Model

The ECM model is an error correction model that assumes price growth (CPI-ATE) can be expressed as a function of the exchange rate (I-44), labor costs (ULC), capacity utilization (CAP), shipping costs (SHIPPING), and foreign prices of imported consumer and intermediate goods (IPK and IPI), see Table 1 in the appendix. The estimated equation is given by:

$$\Delta cpi\text{-}ate_t = -0.22 + 0.20\,\Delta_2 cpi\text{-}ate_{t-1} + 0.14\,\Delta ulc_t + 0.02\,\Delta i\text{-}44_t + 0.04\,\Delta_4 i\text{-}44_{t-1}$$

$$(7.51)\quad (4.40)\qquad\qquad (1.39)\qquad (2.40)\qquad (5.94)$$

$$-0.16\,cpi\text{-}ate_{t-1} + 0.08\,ulc_{t-1} + 0.06\,cap_{t-1}/100$$

$$(6.61)\qquad\qquad (6.62)\qquad (3.44)$$

$$+0.06\,i\text{-}44_{t-5} + 0.05\,(0.75\,ipk_{t-1} + 0.20\,ipi_{t-3} + 0.05\,shipping_{-2})$$

$$(6.13)\qquad (6.52)$$

$$R^2 = 0.818,\ \sigma = 0.00171,\ DW = 2.27$$

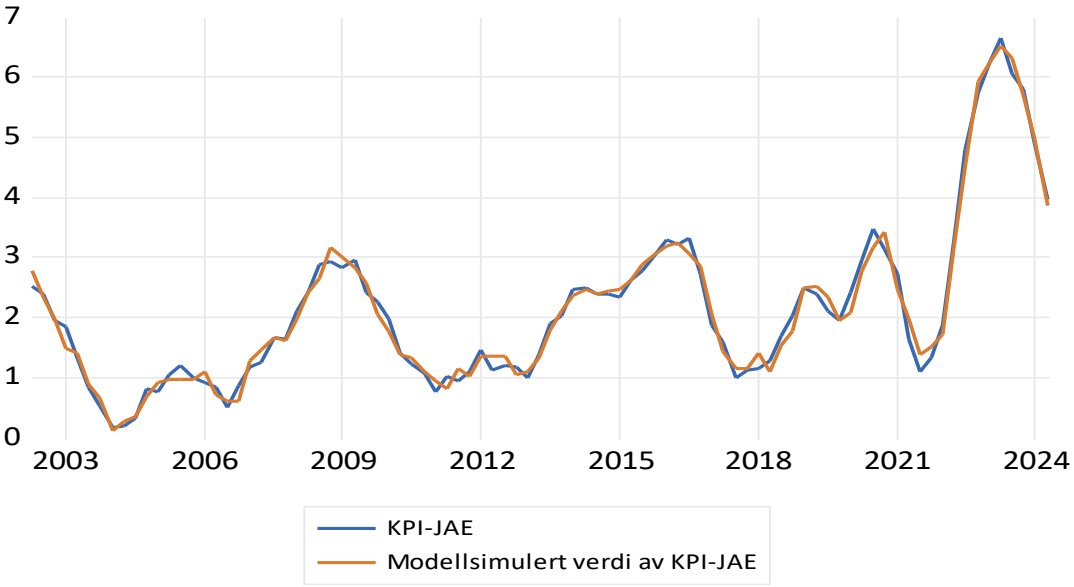
Here, Δ is a difference operator ($\Delta_k X_t = (X_t - X_{t-k})$, where X_t og X_{t-k} are the values of X in periods t and t-k), R^2 is the proportion of the variation in the dependent variable explained by the model, σ is the standard deviation of the regression residuals, and DW is the Durbin-Watson statistic. The model is estimated on data for the period Q2 2002 – Q2 2024 using the least squares method. Absolute t-values are given in parentheses below the estimates. Lowercase letters indicate that the variable is measured on a logarithmic scale.

The model implies that CPI-ATE increases by 0.37 percent in the long run if the exchange rate weakens permanently by one percent, assuming other explanatory factors remain constant. Figure 1 shows that the model fits well over the estimation period.

The exchange rate pass-through to price growth is obtained by looking at the difference between two simulated paths for CPI-ATE based on the estimated model. The reference path assumes Norges Bank's own projections for the right-hand side variables 10 quarters ahead. In an alternative simulation, all future projections from the reference path are retained, except for the exchange rate, which is assumed to be 1 percent weaker than in the reference path throughout the simulation period (10 quarters). The difference between the two paths can be interpreted as an impulse response of a 1 percent permanent weakening of the exchange rate. The model initially provides a set of impulse responses for quarterly inflation. In Figure 2, we show the

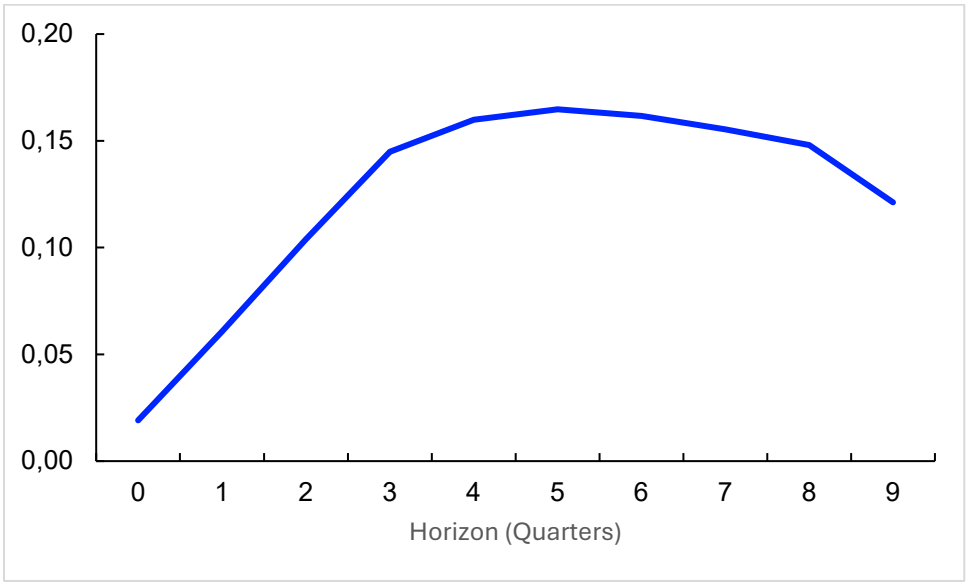
responses in terms of 4-quarter growth in CPI-ATE, as presented in Figure 3.H in the box (page 44, MPR 3/24).

Figure 1. Actual and Simulated Value of CPI-ATE. 4-quarter growth. Percent



Note: The simulated values are estimated with the estimates from the model, as well as forecasted and actual values of the explanatory variables, including lagged values of CPI-ATE.

Figure 2. Exchange Rate Pass-Through ECM Model



The SVAR Model

The starting point is a reduced-form vector autoregressive (VAR) model that can be written as follows:

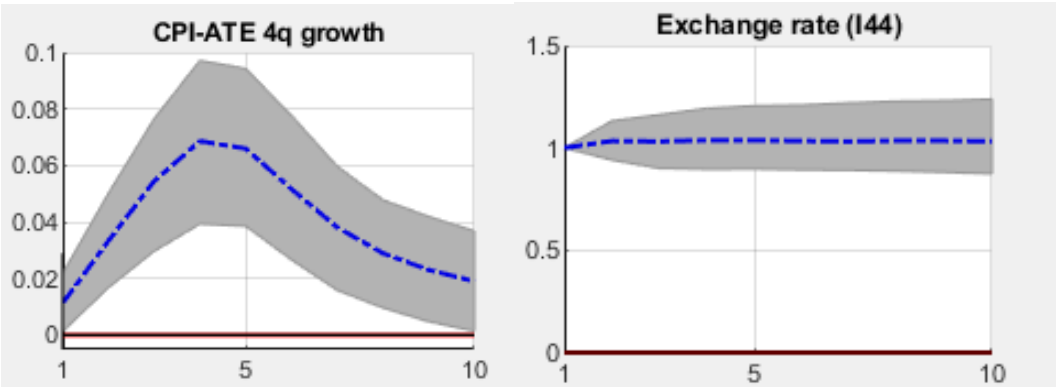
$$y_t = \mathrm{c} + \sum_{l=1}^{4} B_l y_{t-l} + e_t$$

where y is a vector that includes the following endogenous variables: consumer price (CPI-ATE), exchange rate (I-44), mainland Norway GDP, unit labor costs mainland Norway (ULC), policy rate, and the registered unemployment rate. Furthermore, c denotes a vector of constants, while B_l (l=1,2,3,4) is a 6x6 matrix of coefficients that determine how the endogenous variables at time t are affected by lagged values of the same variables, while e_t is a vector of residuals.

In the first step, c, B_l and the covariance matrix of e_t are estimated from a Bayesian perspective, as in Giannone et al. (2015). The model is estimated on quarterly data for the period Q1 1995 to Q4 2023. We assume that the residuals reflect various disturbances hitting the economy that can be given a structural economic interpretation. In the next step, we identify the underlying disturbances based on the estimated residuals. First, we identify the shock that jointly explains as much as possible of the total variation in interest rates, GDP, ULC, and unemployment over 6-32 quarters, which is often defined as the duration of a normal business cycle. This shock will thus explain most of the business cycle fluctuations in Norway. This disturbance is interpreted as a general business cycle disturbance. Then, we identify a shock that is well correlated with the exchange rate but independent of the business cycle shock. This is interpreted as an exchange rate shock. The identification method is further described in Angeletos et al. (2020).

The model is initially estimated on variables in levels. In Figure 3, we show the implicit response in 4-quarter growth in CPI-ATE, which also coincides with the figures shown in the elaboration in MPR 3/24.

Figure 3. Exchange Rate Pass-Through in SVAR Model



Horizon (quarters) Horizon (quarters)

The LP Model

The model estimates the historical co-movement between changes in the import-weighted exchange rate, I-44, and the development in price growth following a given change in the exchange rate, so-called local projections (Jordà, 2005). The model is local in the sense that the impulse response for each horizon is based on separate regressions estimated independently of each other. The model is specified as:

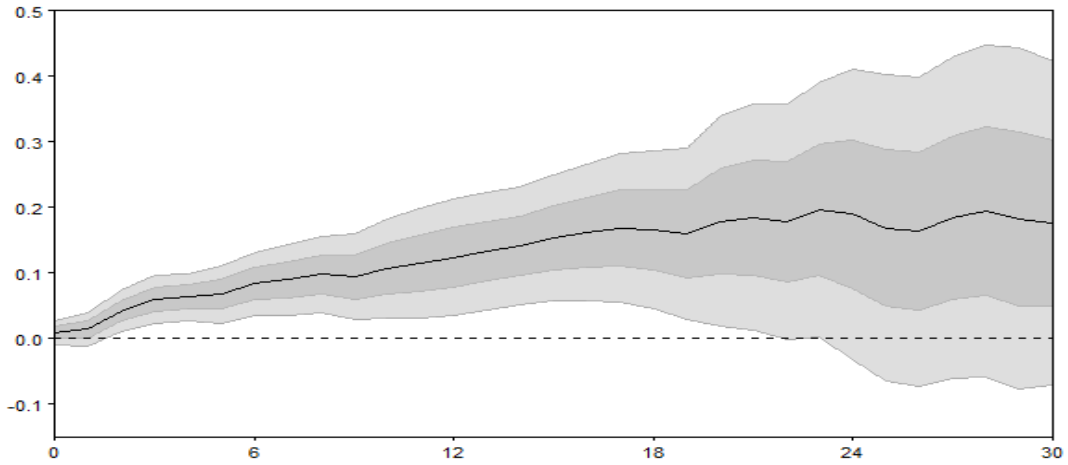
$$p_{t+h} - p_{t-1} = \alpha_h + \beta_h \Delta I44_t + \sum_{j=1}^{J} \gamma_{h,j} X_{t-j} + \epsilon_{t+h}$$

for h = 0, 1, ..., 30. The model is estimated on monthly data over the period January 2000 to April 2024. The impulse response for horizon h, β_h, indicates the change in CPI-ATE over h months ($p_{t+h} - p_{t-1}$) following a one percent change in the exchange rate. To avoid that the estimated

exchange rate effect also captures contributions from other factors that may affect future price growth, we include a set of control variables (X). Specifically, we include changes in the policy rate in Norway and the US, the price of North Sea Brent Crude oil, and unemployment as a percentage of the labor force, in addition to 12 months of lagged values of the mentioned variables, as well as changes in CPI-ATE and I-44.

Figure 4 shows the impulse response function (black line), i.e., estimated values of $\{\beta_h\}_{h=1,\ldots,30}$. In addition, we show the corresponding confidence bands for 68 and 95 percent confidence levels. As expected, uncertainty increases further out in the horizon.

Figure 4. Exchange Rate Pass-Through LP Model



In the box in MPR 3/24, the model's implied contribution to four-quarter growth in CPI-ATE is shown. The contribution is calculated as the difference between the impulse for period h and h-12. It is then converted to quarterly frequency by taking the average over three months.

An LP model imposes fewer constraints on the mechanisms at play than, for example, the related VAR models, which specify a complete system for all explanatory variables. This makes the LP model less vulnerable to misspecifications. At the same time, a possible weakness of the approach is that each impulse response individually is associated with greater uncertainty, as the confidence bands in Figure 4 illustrates.

References

Angeletos, G.-M., F. Collard, and H. Dellas. 2020. "Business-Cycle Anatomy." *American Economic Review*, 110 (10): 3030–70.

Jordà, Ò., 2005: «Estimation and Inference of Impulse Responses by Local Projections», American Economic Review, vol. 95(1), pages 161–182, March.

Giannone, D., M. Lenza and G. E. Primiceri, 2015. "Prior Selection for Vector Autoregressions," The Review of Economics and Statistics, MIT Press, vol. 97(2), pages 436-451, May.

Appendix

Table 1. Variable documentation

CPI-ATE: Consumer Price Index adjusted for taxes and excluding energy products. Seasonally adjusted. Source: Statistics Norway.
ULC: Labor costs per produced unit in Mainland Norway. Seasonally adjusted and smoothed. Sources: Statistics Norway and Norges Bank.
I-44: Import-weighted exchange rate index. A higher index value for I-44 implies a weaker krone. Source: Norges Bank.
IPK: Index for international price impulses to imported consumer goods. Measured by international producer prices and calculated in foreign currency. Seasonally adjusted. See Figure 1.B in MPR 3/24. Sources: LSEG Datastream and Norges Bank.
IPI: Index for international price impulses to imported intermediate goods. Measured by international producer prices and calculated in foreign currency. Seasonally adjusted. See Figure 1.B in MPR 3/24 and elaboration in MPR 4/23. Source: LSEG Datastream and Norges Bank.
SHIPPING: Index for international freight prices. Average over the last three quarters. See Figure 1.B in MPR 3/24. Source: LSEG Datastream and Norges Bank.
CAP: Norges Bank's estimate for capacity utilization (output gap) in the Norwegian economy. See Figures E, 3.B, and 4.1 in MPR 3/24. Sources: Statistics Norway and Norges Bank.
Mainland Norway GDP: Gross Domestic Product of Mainland Norway. Source: Statistics Norway.
Registered Unemployment: Number of registered unemployed as a percentage of the labor force. Source: NAV.
Policy Rate Norway: Banks' deposit rate (Folio rate) at Norges Bank, monthly average. Source: Norges Bank.
Policy Rate USA: Federal funds rate, monthly average. Source: Norges Bank.
Oil Price: Brent Blend USD per barrel, monthly average. Sources: Statistics Norway and Norges Bank.