Monetary policy rules for Switzerland. New evidence from a central banker perspective.[1]

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Monetary Transmission Mechanism in Transition Countries

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[1] This paper is co-authored with Thomas Nitschka.
The opinions expressed are those of the authors and do not necessarily reflect the views of the Swiss National Bank.

Background

- Hierarchical mandate with price stability as the main objective. In so doing, the SNB shall take due account of the developments of the economy.
- New SNB monetary policy concept introduced in December 1999.
- Key elements of the new framework:
  - Explicit definition of price stability.
  - Medium-term conditional inflation forecast.
  - Target range for the 3-month Libor rate on the Swiss franc. Announcement of the target level for the Libor rate.
- No explicit inflation targeting but a more flexible monetary policy concept as highlighted in Jordan, Peytrignet and Rossi (2010).

This paper contribution

- Uncover the best fitting SNB Taylor rule since the introduction of the new policy concept.
- Focus on real-time than on ex-post data following Orphanides (2001).
- Actual SNB Taylor rules based on real-time internal inflation forecasts and output gap estimates.
- Comparison of the SNB Taylor rules to market-perceived Taylor rules estimated with Consensus Economics survey data.
- Study how market participants understand the SNB's reaction function.

This paper contribution

- Stability analysis to study whether policy changed in the financial crisis or during the period of massive Swiss franc appreciation.
- The stability analysis is complemented by a semi-parametric estimation of the Taylor rules.
- The semi-parametric approach permits a more general and flexible modeling of the Taylor rules.
- The semi-parametric methodology accounts for a changing responsiveness to macroeconomic fundamentals.

Main findings

- Evidence for a stronger SNB's inflation reaction 3 and 4 quarters ahead than at shorter horizons.
- Higher perceived SNB's inflation reaction by market participants than found with the actual SNB Taylor rules.
- Empirical support for nonlinearities in the Taylor rules in particular with respect to the output gap and the exchange rate term.
- The best fitting specification is a semi-parametric Taylor rule augmented with an exchange rate term in addition to the inflation forecasts and output gap estimates.

Parametric Taylor rules

- John Taylor's (1993) seminal contribution to monetary policy rules.
- Forward-looking specifications with interest rate smoothing are presented in Clarida, Galí and Gertler (1998, 1999 and 2000).
- Research on Taylor rules with real-time versus ex-post data includes Sauer and Sturm (2003), Gerdesmeier and Roffia (2004), Gorter, Jacobs and de Haan (2008).
- Monetary policy rules for Switzerland are studied in Cuche (2000), Cuche-Curti, Hall and Zanetti (2008), Bäurle and Menz (2008).
- Regime switching specifications (MRS or LSTR) are estimated in Assenmacher-Wesche (2006), Perruchoud (2009), Gerlach and Lewis (2010).

Semi-parametric Taylor rules

- This is a new approach in the literature and the papers are scarce.
- Generalized Additive Model (GAM) framework based on Hastie and Tibshirani (1986 and 1990). The estimation is performed in the empirical support of the variables.
- Hayat and Mishra (2010) find evidence for a nonlinear policy rule for the Fed. They show that the Fed reacts more strongly to high inflation expectations while there is not a strong reaction to the output gap.
- Conrad, Lamla and Yu (2010) show evidence for nonlinearity of the policy rule for the Fed and the ECB and relate this result to asymmetric central bank preferences.

Data

- SNB's model-based internal data:
  - SNB's ARIMA inflation forecasts from 1 to 4 quarters ahead.
  - Real-time contemporaneous output gap estimates based on the production function approach.
- Survey-based data:
  - Consensus Economics Forecasts (CEF) inflation expectations 1 to 4 quarters ahead.
  - CEF contemporaneous output gap estimates constructed from the real GDP growth forecasts using an H-P filter.
- Nominal and real effective Swiss franc appreciation rates are from the SNB.
- The policy rate is the 3-month SNB Libor target rate.
- Quarterly frequency for the period 2000 Q3-2012 Q2.

Methodology, parametric rules

- OLS estimation of the forward-looking Taylor rules with real-time data following Gorter, Jacobs and de Haan (2008).
- OLS and GMM estimation of the backward-looking Taylor rules with actual data.
- Rolling and recursive window regressions for stability analysis.
- Chow (1960), Andrews (1993), Bai and Perron (1998 and 2003) tests for structural breaks.

Methodology, semi-parametric rules

- Generalized Additive Model (GAM) framework for the semi-parametric policy rules based on Wood (2006).
- The GAM is a generalized linear model in which the dependent variable is a sum of smooth functions of the explanatory variables.
- We need a method to represent the functions and estimate their smoothness.
- GAMs are represented with penalized regression splines and are estimated with a penalized regression.

Methodology, semi-parametric rules

- In a first stage, a Generalized Cross Validation (GCV) algorithm is applied to estimate the degree of smoothness of the splines.
- In a second stage, the splines are estimated with Penalized Iteratively Re-weighted Least Squares (PIRLS) using the *mgcv* package in R.
- More formally,

$$\min_{\beta} ||y - X\beta||^2 + \lambda \beta' S \beta$$

- Following Kim and Gu (2004) we apply an additional penalty term to rule out overfitting.

Forward-looking Taylor rules

We consider the following specification:

$$i_t = r^* + \pi^* + \beta_\pi E_t \left\{\pi_{t+k} - \pi^* | \Omega_t\right\} + \beta_y E_t \left\{y_{t+q} - y^*_{t+q} | \Omega_t\right\} + \beta_z z_t + \epsilon_t \quad (1)$$

and the rule with interest rate smoothing:

$$i_t = \rho i_{t-1} + (1-\rho)(r^* + \pi^* + \beta_\pi E_t \left\{\pi_{t+k} - \pi^* | \Omega_t\right\} + \beta_y E_t \left\{y_{t+q} - y^*_{t+q} | \Omega_t\right\} + \beta_z z_t) + \epsilon_t \quad (2)$$

where $k = 1, ..., 4$, $q = 0$, i_t denotes the 3-month Libor target rate, r^* and π^* is the equilibrium real interest rate and the SNB's inflation objective respectively. $E_t \left\{\pi_{t+k} - \pi^* | \Omega_t\right\}$ and $E_t \left\{y_{t+q} - y^*_{t+q} | \Omega_t\right\}$ are the expected inflation and output gaps in period t for a horizon $t+k$ or $t+q$, z_t refers to other relevant fundamentals (exchange rate...).

Ω_t denotes the available information set in period t based on either the SNB internal data, CEF expectations or actual ex-post data. ϵ_t is an i.i.d error term.

Taylor rules with inflation forecasts

	k=1	k=2	k=3	k=4
SNB data				
β_π	0.8315***	0.8970***	1.0882***	2.5397***
	(0.1291)	(0.1604)	(0.1855)	(0.3307)
$r^* + \pi^*$	1.3902***	1.4126***	1.4831***	1.9125***
	(0.2452)	(0.2532)	(0.2556)	(0.2459)
$Adj.R^2$	0.3324	0.3005	0.2639	0.4042
CEF data				
β_π	0.9796***	1.3143***	1.9849***	2.3907***
	(0.1953)	(0.2453)	(0.3447)	(0.5770)
$r^* + \pi^*$	1.3363***	1.3441***	1.2887***	1.1472***
	(0.2240)	(0.2154)	(0.1879)	(0.2041)
$Adj.R^2$	0.4161	0.4671	0.5642	0.4026
Observations	48	48	48	48

Note: OLS estimates, HAC corrected standard errors are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Taylor rules with inflation forecasts and output gap estimates

	k=1,q=0	k=2,q=0	k=3,q=0	k=4,q=0
SNB data				
β_π	0.5012***	0.5599***	0.7006***	1.6277***
	(0.1287)	(0.1179)	(0.1397)	(0.3279)
β_y	0.4557***	0.4706***	0.4857***	0.4315***
	(0.0688)	(0.0663)	(0.0648)	(0.0490)
$r^* + \pi^*$	1.6520***	1.6818***	1.7434***	1.9765***
	(0.2062)	(0.2011)	(0.1931)	(0.1909)
$Adj.R^2$	0.6218	0.6239	0.6211	0.6589
CEF data				
β_π	0.5285**	0.8152***	1.3849***	1.2507**
	(0.2256)	(0.2194)	(0.3388)	(0.5697)
β_y	0.2362***	0.2229***	0.1955***	0.2414***
	(0.0826)	(0.0682)	(0.0574)	(0.0688)
$r^* + \pi^*$	1.2642***	1.2818***	1.2560***	1.1627***
	(0.1700)	(0.1694)	(0.1617)	(0.1781)
$Adj.R^2$	0.5487	0.5974	0.6646	0.5419
Observations	48	48	48	48

Note: OLS estimates, HAC corrected standard errors are in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Taylor rules augmented with a nominal effective appreciation

	k=1,q=0	k=2,q=0	k=3,q=0	k=4,q=0
SNB data				
β_π	0.4189***	0.4471***	0.5430***	1.4142***
	(0.0952)	(0.0895)	(0.1326)	(0.2971)
β_y	0.4607***	0.4776***	0.4920***	0.4366***
	(0.0562)	(0.0592)	(0.0608)	(0.0482)
β_e	-0.0522***	-0.0485**	-0.0470**	-0.0502***
	(0.0181)	(0.0188)	(0.0195)	(0.0164)
$r^* + \pi^*$	1.8085***	1.8191***	1.8603***	2.0858***
	(0.2180)	(0.2156)	(0.2097)	(0.1993)
$Adj.R^2$	0.6728	0.6648	0.6576	0.7066
CEF data				
β_π	0.4107**	0.6640***	1.2041***	1.4129***
	(0.1754)	(0.2010)	(0.3514)	(0.4727)
β_y	0.2602***	0.2453***	0.2148***	0.2275***
	(0.0655)	(0.0620)	(0.0573)	(0.0686)
β_e	-0.0661***	-0.0614***	-0.0586***	-0.0810***
	(0.0207)	(0.0217)	(0.0209)	(0.0222)
$r^* + \pi^*$	1.4654***	1.4671***	1.4409***	1.4304***
	(0.1792)	(0.1692)	(0.1411)	(0.1555)
$Adj.R^2$	0.6355	0.6708	0.7329	0.6821
Observations	48	48	48	48

Note: OLS estimates, HAC corrected standard errors are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Parametric regressions results

- Increasing SNB's reaction to inflation along the forecast horizon as found in Hamilton et al. (2009) for the Fed.
- The market participants perceive the SNB to react more strongly to inflation than to the output gap.
- The Taylor principle is verified at shorter horizons with the CEF than with the SNB data.
- The empirical fit of the Taylor rules is improved by including an exchange rate term in the specifications.
- High level of interest rate smoothing but the estimation results point to specification problems (results are not presented).

Stability analysis

- The rolling and recursive window regressions do not point to considerable time variation in the Taylor rules.
- The structural break tests suggest the presence of a change after the Lehman Brothers collapse in 2008 Q3.
- Complementary analysis of nonlinearity is performed with a semi-parametric modeling of the Taylor rules.
- The nonlinearity is defined as a changing central bank responsiveness to the level of macroeconomic fundamentals.

Semi-parametric Taylor rules

- Univariate 1 FTR:
  $i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}\right) + \epsilon_t$
- Univariate 2 FTR:
  $i_t = c + s_1\left(E_t\left\{\pi_{t+k} - \pi^*\right\}\right) + s_2\left(E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$
- Univariate 3 FTR:
  $i_t = c + s_1\left(E_t\left\{\pi_{t+k} - \pi^*\right\}\right) + s_2\left(E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + s_3\left(\Delta e_{nom,t}\right) + \epsilon_t$
- Bivariate FTR:
  $i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}, E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$

where $k = 1, ..., 4$, $q = 0$ and $s(.)$ denotes a spline.

Univariate Taylor rules with inflation forecasts

$$i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}\right) + \epsilon_t$$

	SNB data	CEF data
$s\left(E_t\left\{\pi_{t+1} - \pi^*\right\}\right)$	1.000***/(1.08e-05)	1.792***/(9.29e-07)
$Adj.R^2$	0.332	0.456
$s\left(E_t\left\{\pi_{t+2} - \pi^*\right\}\right)$	1.248***/(0.000133)	1.837***/(9.7e-08)
$Adj.R^2$	0.309	0.511
$s\left(E_t\left\{\pi_{t+3} - \pi^*\right\}\right)$	1.380***/(0.000603)	1.642***/(1.31e-09)
$Adj.R^2$	0.279	0.585
$s\left(E_t\left\{\pi_{t+4} - \pi^*\right\}\right)$	1.000***/(7.21e-07)	6.117***/(1.22e-05)
$Adj.R^2$	0.404	0.519
Observations	48	48

Note: Estimated degrees of freedom of the splines in the GAM Taylor rules, P-values are in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Univariate Taylor rules with inflation forecasts and output gap estimates

$$i_t = c + s_1 \left(E_t \left\{\pi_{t+k} - \pi^*\right\}\right) + s_2 \left(E_t \left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$$

	SNB data	CEF data
$s_1 \left(E_t \left\{\pi_{t+1} - \pi^*\right\}\right)$	1.000***/(0.00357)	1.000***/(0.00907)
$s_2 \left(E_t \left\{y_t - y_t^*\right\}\right)$	1.958***/(1.11e-06)	7.743***/(2.83e-07)
$Adj.R^2$	0.642	0.783
$s_1 \left(E_t \left\{\pi_{t+2} - \pi^*\right\}\right)$	1.000***/(0.00486)	1.000***/(0.00432)
$s_2 \left(E_t \left\{y_t - y_t^*\right\}\right)$	2.788***/(4.57e-07)	7.620***/(1.18e-06)
$Adj.R^2$	0.660	0.786
$s_1 \left(E_t \left\{\pi_{t+3} - \pi^*\right\}\right)$	1.000***/(0.00271)	1.000***/(2.1e-05)
$s_2 \left(E_t \left\{y_t - y_t^*\right\}\right)$	3.212***/(9.8e-08)	2.319***/(0.000261)
$Adj.R^2$	0.677	0.712
$s_1 \left(E_t \left\{\pi_{t+4} - \pi^*\right\}\right)$	1.000***/(0.000465)	1.000***/(3.44e-05)
$s_2 \left(E_t \left\{y_t - y_t^*\right\}\right)$	2.963***/(2.65e-06)	7.833***/(1.22e-08)
$Adj.R^2$	0.694	0.805
Observations	48	48

Note: Estimated degrees of freedom of the splines in the GAM Taylor rules, P-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Univariate Taylor rules augmented with a nominal effective appreciation

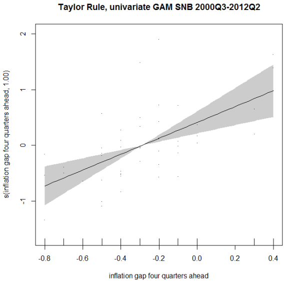
$$i_t = c + s_1\left(E_t\left\{\pi_{t+k} - \pi^*\right\}\right) + s_2\left(E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + s_3\left(\Delta e_{nom,t}\right) + \epsilon_t$$

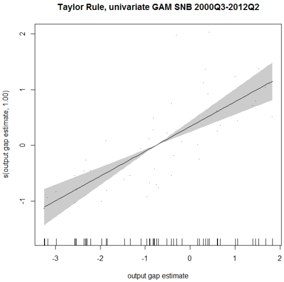
	SNB data	CEF data
$s_1\left(E_t\left\{\pi_{t+1} - \pi^*\right\}\right)$	1.000***/(0.00269)	1.000***/(0.000319)
$s_2\left(E_t\left\{y_t - y^*_t\right\}\right)$	1.000***/(5.45e-08)	6.863***/(1.17e-07)
$s_3\left(\Delta e_{nom,t}\right)$	1.000***/(0.00695)	1.000***/(3.42e-06)
$Adj.R^2$	0.673	0.811
$s_1\left(E_t\left\{\pi_{t+2} - \pi^*\right\}\right)$	1.000***/(0.0048)	1.000***/(0.00712)
$s_2\left(E_t\left\{y_t - y^*_t\right\}\right)$	1.000***/(1.96e-08)	6.425***/(5.35e-07)
$s_3\left(\Delta e_{nom,t}\right)$	1.000**/(0.0144)	2.879***/(0.00928)
$Adj.R^2$	0.665	0.817
$s_1\left(E_t\left\{\pi_{t+3} - \pi^*\right\}\right)$	1.000***/(0.00914)	1.000***/(0.000151)
$s_2\left(E_t\left\{y_t - y^*_t\right\}\right)$	1.000***/(3.77e-09)	5.383***/(2.04e-06)
$s_3\left(\Delta e_{nom,t}\right)$	2.688*/(0.05787)	3.364***/(0.003217)
$Adj.R^2$	0.681	0.837
$s_1\left(E_t\left\{\pi_{t+4} - \pi^*\right\}\right)$	1.000***/(0.000144)	1.593***/(9.05e-05)
$s_2\left(E_t\left\{y_t - y^*_t\right\}\right)$	1.000***/(2.32e-08)	2.413***/(3.35e-07)
$s_3\left(\Delta e_{nom,t}\right)$	3.012**/(0.013603)	3.476***/(1.70e-05)
$Adj.R^2$	0.738	0.817
Observations	48	48

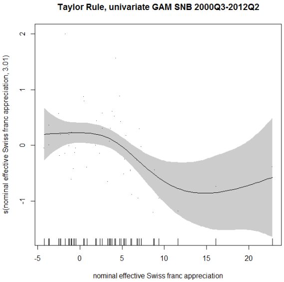
Note: Estimated degrees of freedom of the splines in the GAM Taylor rules, P-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Univariate Taylor rules, SNB data

$$i_t = c + s_1\left(E_t\left\{\pi_{t+4} - \pi^*\right\}\right) + s_2\left(E_t\left\{y_t - y_t^*\right\}\right) + s_3\left(\Delta e_{nom,t}\right) + \epsilon_t$$

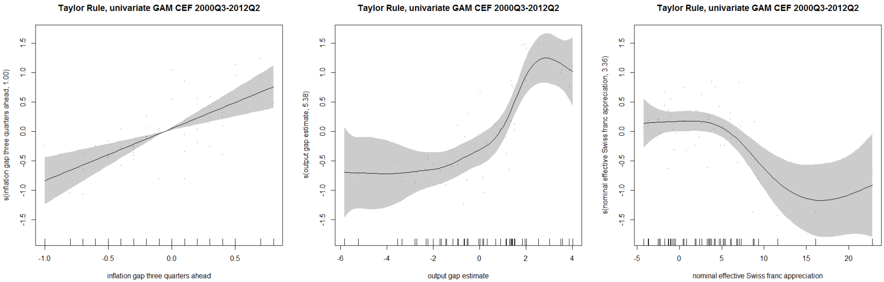






Univariate Taylor rules, CEF data

$$i_t = c + s_1\left(E_t\left\{\pi_{t+3} - \pi^*\right\}\right) + s_2\left(E_t\left\{y_t - y_t^*\right\}\right) + s_3\left(\Delta e_{nom,t}\right) + \epsilon_t$$



Bivariate Taylor rules

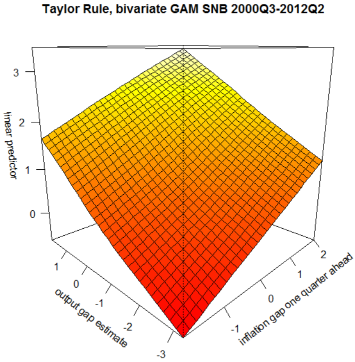
$$i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}, E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$$

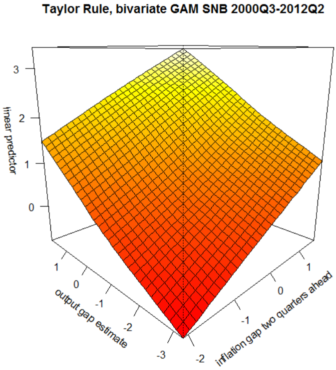
	SNB data	**CEF data**
$s\left(E_t\left\{\pi_{t+1} - \pi^*\right\}, E_t\left\{y_t - y^*_t\right\}\right)$	2.886***/(5.86e-10)	5.173***/(7.69e-09)
$Adj.R^2$	0.638	0.665
$s\left(E_t\left\{\pi_{t+2} - \pi^*\right\}, E_t\left\{y_t - y^*_t\right\}\right)$	3.006***/(5.86e-10)	6.013***/(1.61e-09)
$Adj.R^2$	0.642	0.706
$s\left(E_t\left\{\pi_{t+3} - \pi^*\right\}, E_t\left\{y_t - y^*_t\right\}\right)$	3.573***/(8.7e-10)	5.686***/(3.13e-11)
$Adj.R^2$	0.657	0.750
$s\left(E_t\left\{\pi_{t+4} - \pi^*\right\}, E_t\left\{y_t - y^*_t\right\}\right)$	3.651***/(8.67e-11)	8.929***/(3.82e-10)
$Adj.R^2$	0.692	0.772
Observations	48	48

Note: Estimated degrees of freedom of the splines in the GAM Taylor rules, P-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Bivariate Taylor rules, SNB data

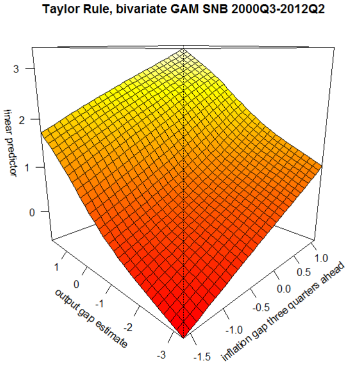
$$i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}, E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$$

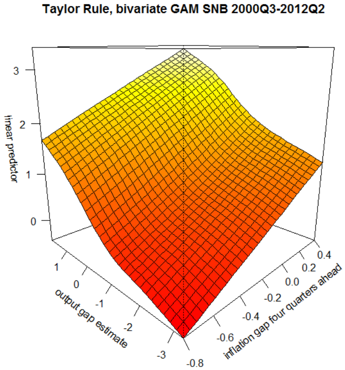




Bivariate Taylor rules, SNB data

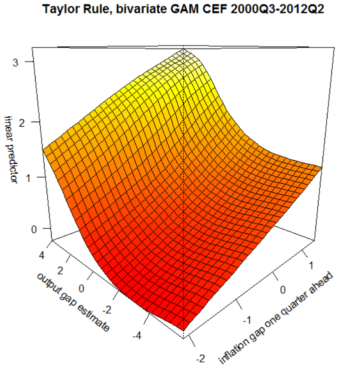
$$i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}, E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$$

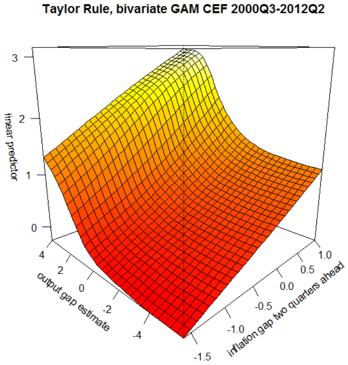




Bivariate Taylor rules, CEF data

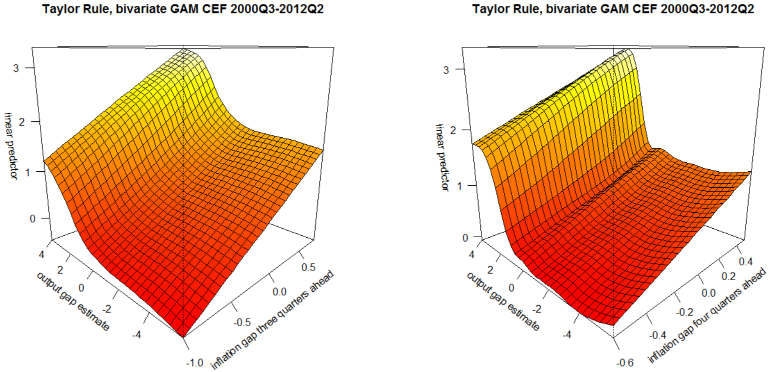
$$i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}, E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$$





Bivariate Taylor rules, CEF data

$$i_t = c + s\left(E_t\left\{\pi_{t+k} - \pi^*\right\}, E_t\left\{y_{t+q} - y^*_{t+q}\right\}\right) + \epsilon_t$$



Semi-parametric regressions results

- Evidence for nonlinearity in the univariate and bivariate Taylor rules.
- Increasing nonlinearity of the policy rules along the inflation forecast horizon.
- Overall linear reaction to inflation and nonlinear response to the output gap and the exchange rate, particularly with the CEF data.
- The SNB reacts more strongly to a Swiss franc appreciation above 5%.
- The market participants perceive a stronger SNB's reaction to positive output gaps.

Concluding comments

- Better performance of forward-looking policy rules than backward-looking specifications.
- The market participants seem to understand well the SNB's price stability commitment.
- Better fit of the Libor rate with the semi-parametric than parametric policy rules.
- Evidence for a perceived higher nonlinearity of the Taylor rules.
- The market participants may not understand well the weights assigned to the stabilization of the economic outlook and the exchange rate relative to inflation.

Future research

- Out-of-sample forecast evaluation of the semi-parametric and parametric Taylor rules.
- Better forecast performance of the semi-parametric specifications compared to the parametric policy rules for the period 2006 Q4-2012 Q2.
- Financial stability considerations in the policy reaction functions.
- Optimal Taylor rules within a general equilibrium framework.