Central bank losses and monetary policy rules: a DSGE investigation

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This presentation does not necessarily reflect the views of the Bank of Israel

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The issues

- Rules vs discretion in monetary policy. Rules for academics, uncertain for policy makers.
- Debates held during the 70s-80s put forward more or less nominal income targeting concepts, even if they were not presented as such.[3]
- The consensus with respect to Taylor (1993) rules increased during the last two decades.[4]
- Criticism towards such Taylor-type rules also increased,[5] especially over the GFC.[6]
- Could nominal income targeting be a better way to achieve the central banks' objectives ?

[3] Friedman, 1971; Meade, 1978; McCallum, 1973, 1987.

[4] Bernanke & Mishkin, 1997; Svensson, 1999; Taylor, 1999.

[5] Hall & Mankiw, 1994; Frankel & Chinn, 1995; McCallum and Nelson, 1999.

[6] Hendrickson, 2012; Woodford, 2012; Frankel, 2014; Sumner, 2014, 2015; McCallum, 2015.

Research Issues

In it's post "MacroMania on Nominal GDP Targeting and the Taylor Rule", John Taylor suggested that:[7]

- different monetary proposals and rules "should be compared and evaluated".
- to simulate them in macro models "hopefully dynamic stochastic models" is "a good way to compare and evaluate different monetary proposals and rules".
- "the dynamics are so important and so hard to work through intuitively, empirical models can help a lot".
- "more policy evaluation research on the new and different proposals is needed to inform the policy discussion, and it is certainly welcome in my view".

[7] EconomicsOne.com, Sept. 8, 2013.

Literature review

- Meade, 1978. **The meaning of internal balance**. Economic Journal.
- Taylor, 1993. **Discretion versus policy rules in practice**. Carnegie-Rochester Conference Series on Public Policy.
- Frankel and Chinn, 1995. **The stabilizing properties of a nominal GNP rule**. Journal of Money, Credit and Banking.
- Rudebusch, 2002. **Assessing nominal income rules for monetary policy with model and data uncertainty**. Economic Journal.
- Smets and Wouters, 2007. **Shocks and frictions in US business cycles: a Bayesian DSGE approach**. American Economic Review.
- Galí, 2015. **Monetary policy, inflation and the business cycle: an introduction to the New Keynesian framework**. Princeton University Press.

What do we do ?

- Evaluate various monetary rules and their consequences in terms of CBs' objectives.
  - Use of canonical SW2007 New-Keynesian DSGE model fitted to the US.
  - Empirical analysis of 12 rules (4 Taylor type, 4 NGDP growth type, 4 NGDP level type).
- Bayesian estimations over 1955-2017 and various subsamples.
- 3 subsamples with different environments and monetary policy styles:
  - 1955-1985;
  - 1985-2007;
  - 2007-2017.
- Estimations and analysis of models leading to:
  - monetary rules parameters;
  - in-sample fits;
  - CB's loss function (current and forecasted).

Research questions

- Which monetary policy rule best:
  - fits US historical data ?
  - in terms of Fed's loss function ?
  - in terms of forecasted Fed's loss function ?
- May one single rule fit all these requirements ?
- And when ?

Smets and Wouters (2007) in a nutshell

- Sticky and flexible-price economy.
- Households, firms, and central bank blocks.
- sticky-prices and wages.
- Capital and investment features.
- Rich stochastic structure: technology, monetary policy, markups (wages and prices), risk premium, investment, and government spending.
- **One ad-hoc monetary policy rule**.

Models	Sources
1	Smets and Wouters (2007)
2	Taylor (1993)
3	Gali (2015)
4	Garin,Lester, and Sims (2016)
5	Adapted NGDP Growth Targeting
6	NGDP Growth + FPC Targeting
7	NGDP Growth + NIR Targeting
8	NGDP Growth Targeting
9	Adapted NGDP Level Targeting
10	NGDP Level + FPC Targeting
11	NGDP Level + NIR Targeting
12	NGDP Level Targeting

1: $r_t = \rho r_{t-1} + (1-\rho)\left[r_\pi \pi_t + r_y\left(y_t - y_t^p\right)\right] + r_{\triangle y}\left(\triangle y_t - \triangle y_t^p\right) + \varepsilon_t^r$
2: $r_t = \rho r_{t-1} + (1-\rho)\left[r_\pi \pi_t + r_y\left(y_t - y_t^p\right)\right] + \varepsilon_t^r$
3: $r_t = \rho r_{t-1} + (1-\rho)\left[r_t^* + r_\pi \pi_t + r_y\left(y_t - y_t^p\right)\right] + \varepsilon_t^r$
4: $r_t = \rho r_{t-1} + (1-\rho)\left[r_\pi \pi_t + r_y \triangle y_t\right] + \varepsilon_t^r$

5: $r_t = \rho r_{t-1} + (1-\rho)\left[r_n\left(\pi_t + \triangle y_t - \triangle y_t^p\right)\right] + r_{\triangle y}\left(\triangle y_t - \triangle y_t^p\right) + \varepsilon_t^r$
6: $r_t = \rho r_{t-1} + (1-\rho)\left[r_n\left(\pi_t + \triangle y_t - \triangle y_t^p\right)\right] + \varepsilon_t^r$
7: $r_t = \rho r_{t-1} + (1-\rho)\left[r_t^* + r_n\left(\pi_t + \triangle y_t - \triangle y_t^p\right)\right] + \varepsilon_t^r$
8: $r_t = \rho r_{t-1} + (1-\rho)\left[r_n\left(\pi_t + \triangle y_t\right)\right] + \varepsilon_t^r$

9: $r_t = \rho r_{t-1} + (1-\rho)\left[r_n\left(p_t + y_t - y_t^p\right)\right] + r_{\triangle y}\left(\triangle y_t - \triangle y_t^p\right) + \varepsilon_t^r$
10: $r_t = \rho r_{t-1} + (1-\rho)\left[r_n\left(p_t + y_t - y_t^p\right)\right] + \varepsilon_t^r$
11: $r_t = \rho r_{t-1} + (1-\rho)\left[r_t^* + r_n\left(p_t + y_t - y_t^p\right)\right] + \varepsilon_t^r$
12: $r_t = \rho r_{t-1} + (1-\rho)\left[r_n\left(p_t + y_t\right)\right] + \varepsilon_t^r$

Why these rules?

- Our Taylor-type rules are based on:
  - Rule 1: Rule 2 + output-gap growth component $\left(\triangle y_t - \triangle y_t^p\right)$.
  - Rule 2: Taylor (1993) with a microfounded output gap $\left(y_t - y_t^p\right)$.
  - Rule 3: Rule 2 with a natural interest rate component (r_t^*).
  - Rule 4: a GDP growth targeting without flexible-price economy unknowns (NIR and FPC).
- Our NGDP Growth rules replace the core functions of the previous rules with a NGDP growth targeting function (rules 5 to 8).
- Our NGDP Level rules replace the core functions of the previous rules with a NGDP level targeting function (rules 9 to 12).

Data

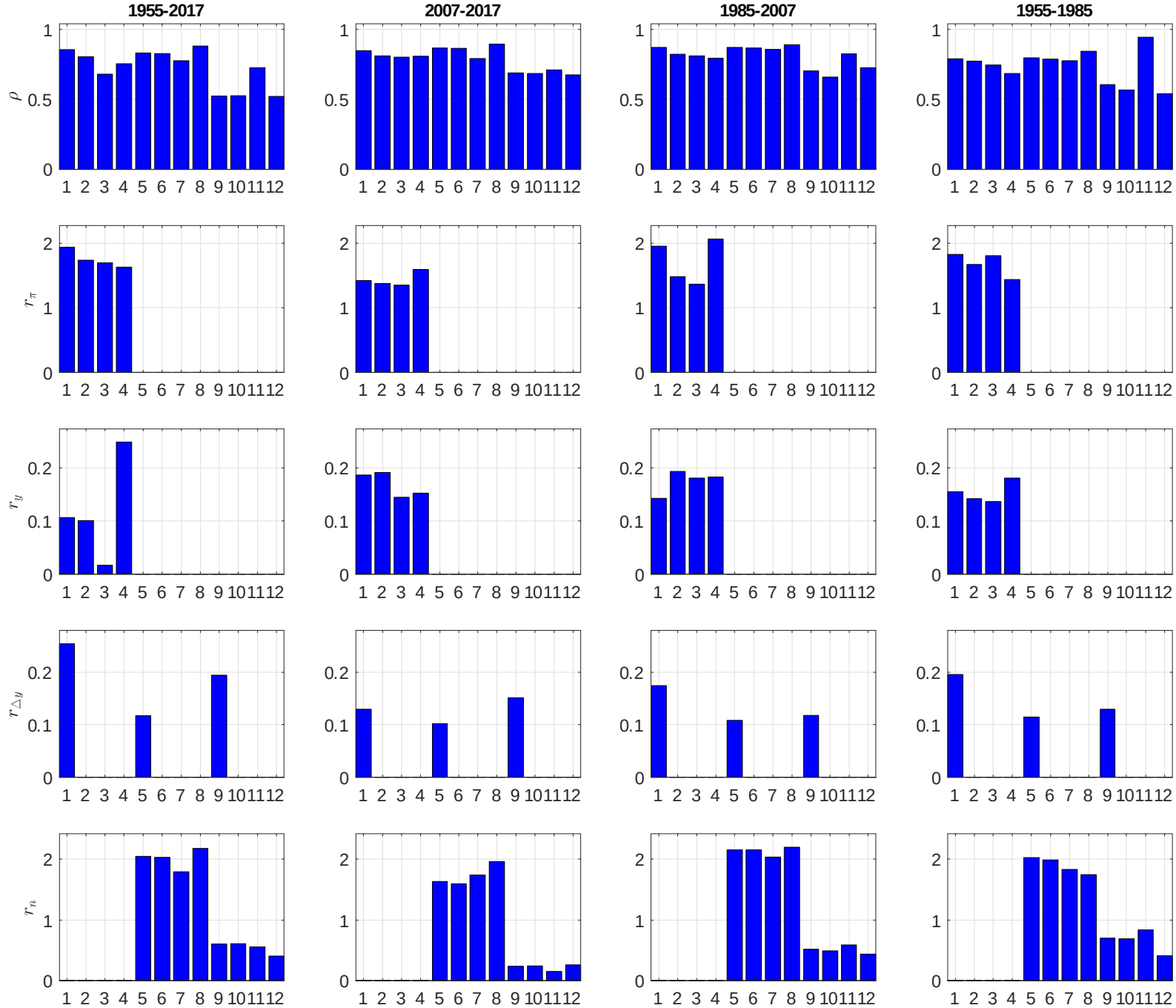
- As in Smets-Wouters (2007), we use the following time series extracted from FRED®:
  - Real Gross Domestic Product.
  - Implicit Price Deflator.
  - Personal Consumption Expenditures.
  - Fixed Private Investment.
  - Civilian Employment.
  - Civilian Non institutional Population.
  - Average Weekly Hours from Nonfarm Business Sector.
  - Compensation Per Hour from Nonfarm Business Sector.
  - Effective Federal Funds Rate.
- Wu-Xia (2016) shadow rate from 2009Q2 to 2015Q4; Fed funds otherwise.
- For each sample, we use the same data-transformations as in Smets-Wouters (2007).

Samples

For each model, estimations are done over 4 different periods:

- Full sample: 1955 – 2017.
- GFC/ZLB era: 2007 – 2017.
- Discretionary era: 1955 – 1985.
- GM era: 1985 – 2007.

Our estimation procedures are in line with the DSGE-Bayesian estimation literature (Smets and Wouters, 2007; An and Schorfheide, 2007).



Monetary policy rule parameter values for each model (1 to 12).

Rules parameter values

- In line with literature when exists.
- Values vary through time and rules.
- Comparison GFC/ZLB with GM: less emphasis on inflation, a bit more emphasis on output. But not clear.

In-sample fit

Sample	Rule											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1955-2017	-1491	-1515	-1512	-1510	**-1464***	-1481	-1488	-1514	-1563	-1602	-1556	-1548
2007-2017	-269	-270	-285	-285	-307	-308	-283	-302	-258	-262	-278	**-254***
1985-2007	-386	-428	-408	-406	-406	-404	-396	-410	-393	-395	-405	**-383***
1955-1985	**-817***	-824	-835	-840	-840	-855	-837	-842	-844	-846	-863	-853

Table: Log marginal data densities for each model and each period (Laplace approximation). * indicates the best value for each period.

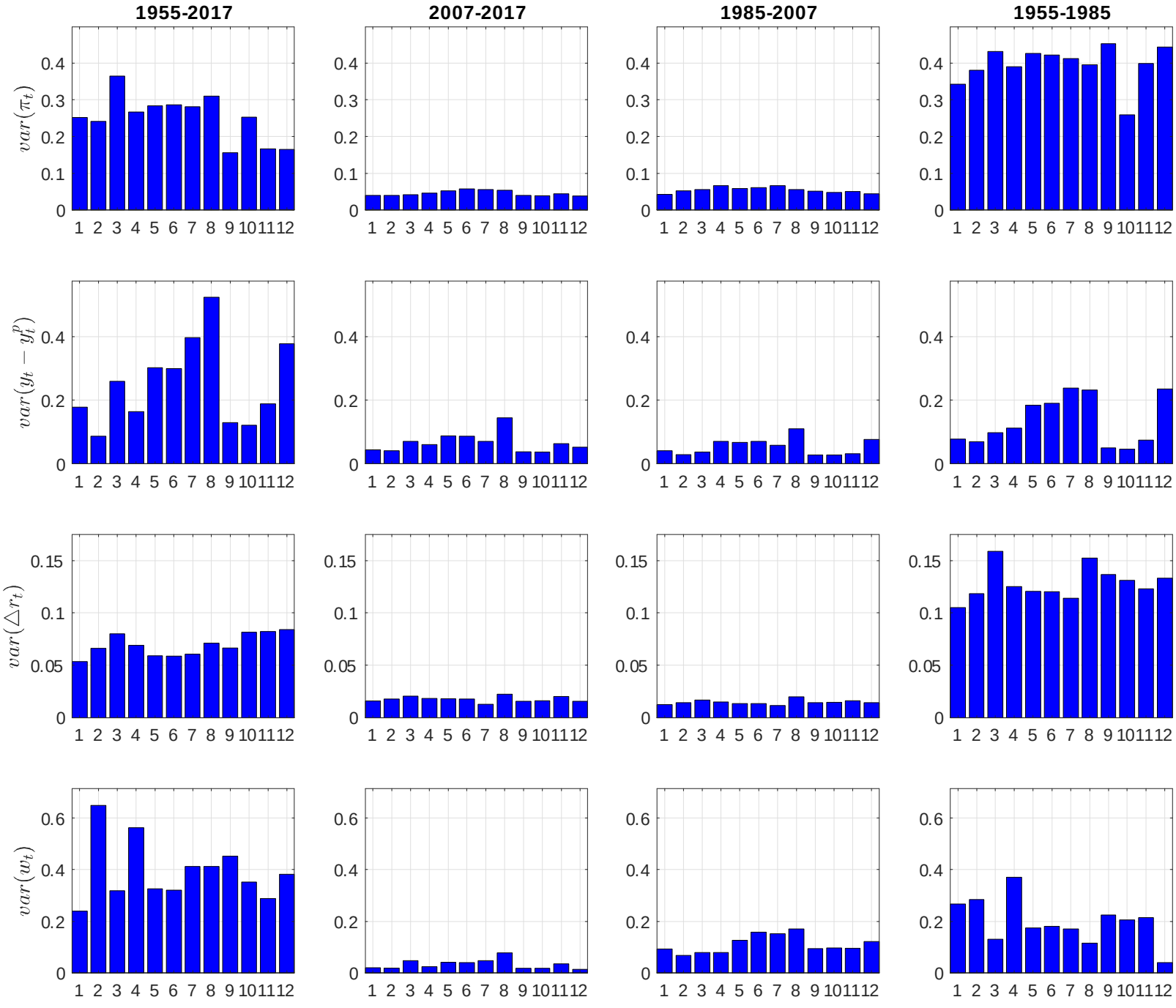
- For each period a different rule, but rule 12 twice.
- Suggests that the Fed may have changed strategy during the GM compared to before 1985, from Taylor type to NGDP level targeting.

Central bank's loss

- Our general central bank loss function is defined such as

$$L_t = var\left(\pi_t\right) + \lambda_y var\left(y_t - y_t^p\right) + \lambda_r var\left(\Delta r_t\right) + \lambda_w var\left(w_t\right)$$

  where $var\left(.\right)$ is the variance operator, and $\forall k = \{y, r, w\}$, λ_k represents the weight on the respective variance.
- π_t is price-inflation, $y_t - y_t^p$ the output-gap, Δr_t nominal interest rate differential, and w_t wage-inflation.



Estimated variances for each period and each rule.

Specific variances

- All variances smaller during GM and GFC/ZLB.
- Note: low level of output gap volatility during GCF/ZLB and GM.

	1	2	3	4	5	6	7	8	9	10	11	12
λ_y=0.0 λ_r=0.0 λ_w=0.0	25.1	24.1	36.4	26.7	28.3	28.6	28.1	31.0	15.6	25.3	16.6	16.5
λ_y=0.5 λ_r=0.0 λ_w=0.0	34.1	28.4	49.4	34.8	43.5	43.6	47.9	57.2	22.1	31.3	26.1	35.4
λ_y=1.0 λ_r=0.0 λ_w=0.0	43.0	32.7	62.4	43.0	58.6	58.5	67.8	83.4	28.5	37.3	35.5	54.3
λ_y=0.0 λ_r=0.5 λ_w=0.0	27.8	27.4	40.4	30.1	31.3	31.5	31.1	34.5	19.0	29.4	20.8	20.7
λ_y=0.5 λ_r=0.5 λ_w=0.0	36.7	31.7	53.4	38.3	46.4	46.5	50.9	60.7	25.4	35.4	30.2	39.6
λ_y=1.0 λ_r=0.5 λ_w=0.0	45.6	36.0	66.4	46.4	61.5	61.5	70.8	86.9	31.8	41.4	39.6	58.5
λ_y=0.0 λ_r=1.0 λ_w=0.0	30.5	30.7	44.4	33.5	34.2	34.4	34.1	38.1	22.3	33.4	24.9	24.9
λ_y=0.5 λ_r=1.0 λ_w=0.0	39.4	35.0	57.4	41.7	49.4	49.4	54.0	64.3	28.7	39.5	34.3	43.8
λ_y=1.0 λ_r=1.0 λ_w=0.0	48.3	39.3	70.4	49.9	64.5	64.4	73.8	90.5	35.2	45.5	43.7	62.7
λ_y=0.0 λ_r=0.0 λ_w=0.5	37.1	56.6	52.3	54.8	44.6	44.6	48.6	51.6	38.2	42.8	31.1	35.6
λ_y=0.5 λ_r=0.0 λ_w=0.5	46.0	60.9	65.3	62.9	59.7	59.6	68.5	77.7	44.6	48.9	40.5	54.5
λ_y=1.0 λ_r=0.0 λ_w=0.5	54.9	65.2	78.3	71.1	74.8	74.6	88.4	103.9	51.1	54.9	49.9	73.4
λ_y=0.0 λ_r=0.5 λ_w=0.5	39.8	59.9	56.3	58.2	47.5	47.6	51.7	55.1	41.5	46.9	35.2	39.8
λ_y=0.5 λ_r=0.5 λ_w=0.5	48.7	64.2	69.3	66.4	62.7	62.5	71.5	81.3	48.0	53.0	44.6	58.7
λ_y=1.0 λ_r=0.5 λ_w=0.5	57.6	68.5	82.3	74.5	77.8	77.5	91.4	107.5	54.4	59.0	54.0	77.6
λ_y=0.0 λ_r=1.0 λ_w=0.5	42.5	63.2	60.3	61.6	50.5	50.5	54.7	58.7	44.8	51.0	39.3	44.0
λ_y=0.5 λ_r=1.0 λ_w=0.5	51.4	67.5	73.3	69.8	65.6	65.5	74.6	84.8	51.3	57.0	48.7	62.9
λ_y=1.0 λ_r=1.0 λ_w=0.5	60.3	71.8	86.3	78.0	80.7	80.5	94.4	111.0	57.7	63.1	58.1	81.8
λ_y=0.0 λ_r=0.0 λ_w=1.0	49.1	89.0	68.2	82.8	60.8	60.7	69.2	72.1	60.7	60.4	45.5	54.7
λ_y=0.5 λ_r=0.0 λ_w=1.0	58.0	93.3	81.2	91.0	76.0	75.7	89.1	98.3	67.2	66.4	54.9	73.6
λ_y=1.0 λ_r=0.0 λ_w=1.0	66.9	97.6	94.2	99.2	91.1	90.7	108.9	124.5	73.6	72.5	64.3	92.5
λ_y=0.0 λ_r=0.5 λ_w=1.0	51.7	92.3	72.3	86.3	63.8	63.6	72.3	75.7	64.1	64.5	49.6	58.9
λ_y=0.5 λ_r=0.5 λ_w=1.0	60.6	96.6	85.2	94.4	78.9	78.6	92.1	101.9	70.5	70.5	59.0	77.8
λ_y=1.0 λ_r=0.5 λ_w=1.0	69.5	100.9	98.2	102.6	94.0	93.6	112.0	128.1	77.0	76.5	68.5	96.7
λ_y=0.0 λ_r=1.0 λ_w=1.0	54.4	95.6	76.3	89.7	66.7	66.6	75.3	79.2	67.4	68.6	53.7	63.1
λ_y=0.5 λ_r=1.0 λ_w=1.0	63.3	99.9	89.3	97.9	81.9	81.5	95.1	105.4	73.8	74.6	63.2	82.0
λ_y=1.0 λ_r=1.0 λ_w=1.0	72.2	104.2	102.3	106.0	97.0	96.5	115.0	131.6	80.3	80.6	72.6	100.9

CB losses, for each rule, between 1955 and 2017. The shading scheme is defined separately in relation to each line. The lighter the shading is, the smaller the loss.

	1	2	3	4	5	6	7	8	9	10	11	12
λ_y=0.0 λ_r=0.0 λ_w=0.0	3.9	3.9	4.1	4.5	5.1	5.7	5.5	5.3	3.9	3.8	4.4	3.8
λ_y=0.5 λ_r=0.0 λ_w=0.0	6.1	5.9	7.6	7.5	9.5	10.0	9.0	12.5	5.8	5.7	7.6	6.4
λ_y=1.0 λ_r=0.0 λ_w=0.0	8.2	7.9	11.1	10.5	13.8	14.3	12.5	19.7	7.6	7.5	10.7	9.0
λ_y=0.0 λ_r=0.5 λ_w=0.0	4.7	4.8	5.1	5.4	6.0	6.6	6.1	6.4	4.7	4.6	5.4	4.5
λ_y=0.5 λ_r=0.5 λ_w=0.0	6.8	6.8	8.6	8.4	10.4	10.9	9.6	13.6	6.5	6.5	8.6	7.1
λ_y=1.0 λ_r=0.5 λ_w=0.0	9.0	8.8	12.1	11.4	14.8	15.2	13.1	20.8	8.4	8.3	11.8	9.7
λ_y=0.0 λ_r=1.0 λ_w=0.0	5.5	5.7	6.2	6.3	6.9	7.5	6.8	7.5	5.5	5.5	6.4	5.3
λ_y=0.5 λ_r=1.0 λ_w=0.0	7.6	7.7	9.7	9.3	11.3	11.8	10.3	14.7	7.3	7.3	9.6	7.9
λ_y=1.0 λ_r=1.0 λ_w=0.0	9.8	9.7	13.2	12.3	15.7	16.1	13.8	22.0	9.2	9.1	12.8	10.5
λ_y=0.0 λ_r=0.0 λ_w=0.5	4.9	4.8	6.4	5.6	7.2	7.7	7.8	9.1	4.7	4.7	6.1	4.4
λ_y=0.5 λ_r=0.0 λ_w=0.5	7.1	6.8	9.9	8.6	11.5	12.0	11.3	16.4	6.6	6.5	9.3	7.0
λ_y=1.0 λ_r=0.0 λ_w=0.5	9.2	8.9	13.4	11.6	15.9	16.3	14.8	23.6	8.5	8.4	12.5	9.6
λ_y=0.0 λ_r=0.5 λ_w=0.5	5.7	5.7	7.5	6.6	8.1	8.6	8.5	10.3	5.5	5.5	7.1	5.2
λ_y=0.5 λ_r=0.5 λ_w=0.5	7.9	7.7	11.0	9.6	12.4	12.9	11.9	17.5	7.4	7.3	10.3	7.8
λ_y=1.0 λ_r=0.5 λ_w=0.5	10.0	9.7	14.5	12.5	16.8	17.2	15.4	24.7	9.3	9.2	13.5	10.4
λ_y=0.0 λ_r=1.0 λ_w=0.5	6.5	6.6	8.5	7.5	9.0	9.5	9.1	11.4	6.3	6.3	8.1	6.0
λ_y=0.5 λ_r=1.0 λ_w=0.5	8.6	8.6	12.0	10.5	13.3	13.8	12.6	18.6	8.2	8.1	11.3	8.6
λ_y=1.0 λ_r=1.0 λ_w=0.5	10.8	10.6	15.5	13.5	17.7	18.1	16.1	25.8	10.0	10.0	14.5	11.2
λ_y=0.0 λ_r=0.0 λ_w=1.0	5.9	5.7	8.8	6.8	9.2	9.7	10.1	13.0	5.6	5.5	7.9	5.1
λ_y=0.5 λ_r=0.0 λ_w=1.0	8.1	7.7	12.3	9.8	13.6	14.0	13.6	20.2	7.5	7.3	11.0	7.7
λ_y=1.0 λ_r=0.0 λ_w=1.0	10.2	9.8	15.8	12.8	17.9	18.3	17.1	27.4	9.3	9.2	14.2	10.3
λ_y=0.0 λ_r=0.5 λ_w=1.0	6.7	6.6	9.8	7.7	10.1	10.6	10.8	14.1	6.4	6.3	8.9	5.9
λ_y=0.5 λ_r=0.5 λ_w=1.0	8.9	8.6	13.3	10.7	14.5	14.9	14.3	21.3	8.2	8.2	12.0	8.5
λ_y=1.0 λ_r=0.5 λ_w=1.0	11.0	10.7	16.8	13.7	18.8	19.2	17.8	28.5	10.1	10.0	15.2	11.1
λ_y=0.0 λ_r=1.0 λ_w=1.0	7.5	7.5	10.8	8.6	11.0	11.5	11.4	15.2	7.1	7.1	9.9	6.7
λ_y=0.5 λ_r=1.0 λ_w=1.0	9.7	9.5	14.3	11.6	15.4	15.8	14.9	22.4	9.0	9.0	13.1	9.3
λ_y=1.0 λ_r=1.0 λ_w=1.0	11.8	11.5	17.8	14.6	19.7	20.1	18.4	29.6	10.9	10.8	16.2	11.9

CB losses, for each rule, between 2007 and 2017. The shading scheme is defined separately in relation to each line. The lighter the shading is, the smaller the loss.

	1	2	3	4	5	6	7	8	9	10	11	12
λ_y=0.0 λ_r=0.0 λ_w=0.0	4.2	5.2	5.5	6.6	5.8	6.0	6.5	5.5	5.0	4.7	5.0	4.3
λ_y=0.5 λ_r=0.0 λ_w=0.0	6.2	6.6	7.3	10.1	9.1	9.5	9.4	11.0	6.4	6.1	6.6	8.2
λ_y=1.0 λ_r=0.0 λ_w=0.0	8.2	8.0	9.2	13.6	12.5	13.1	12.3	16.5	7.8	7.4	8.1	12.0
λ_y=0.0 λ_r=0.5 λ_w=0.0	4.8	5.9	6.3	7.3	6.5	6.7	7.1	6.5	5.7	5.5	5.8	5.1
λ_y=0.5 λ_r=0.5 λ_w=0.0	6.8	7.3	8.2	10.8	9.8	10.2	10.0	12.0	7.1	6.8	7.4	8.9
λ_y=1.0 λ_r=0.5 λ_w=0.0	8.8	8.7	10.0	14.3	13.2	13.7	12.9	17.5	8.5	8.2	9.0	12.7
λ_y=0.0 λ_r=1.0 λ_w=0.0	5.4	6.6	7.2	8.1	7.1	7.3	7.7	7.5	6.4	6.2	6.6	5.8
λ_y=0.5 λ_r=1.0 λ_w=0.0	7.4	8.0	9.0	11.6	10.5	10.9	10.6	13.0	7.8	7.5	8.2	9.6
λ_y=1.0 λ_r=1.0 λ_w=0.0	9.5	9.4	10.8	15.1	13.8	14.4	13.5	18.5	9.2	8.9	9.8	13.4
λ_y=0.0 λ_r=0.0 λ_w=0.5	8.8	8.5	9.4	10.5	12.1	13.9	14.2	14.1	9.7	9.5	9.7	10.4
λ_y=0.5 λ_r=0.0 λ_w=0.5	10.8	9.9	11.2	14.0	15.5	17.4	17.1	19.5	11.1	10.9	11.3	14.2
λ_y=1.0 λ_r=0.0 λ_w=0.5	12.8	11.3	13.0	17.5	18.8	21.0	19.9	25.0	12.4	12.2	12.9	18.1
λ_y=0.0 λ_r=0.5 λ_w=0.5	9.4	9.3	10.2	11.2	12.8	14.6	14.7	15.0	10.4	10.2	10.6	11.1
λ_y=0.5 λ_r=0.5 λ_w=0.5	11.4	10.7	12.1	14.7	16.1	18.1	17.6	20.5	11.8	11.6	12.1	14.9
λ_y=1.0 λ_r=0.5 λ_w=0.5	13.5	12.1	13.9	18.2	19.5	21.6	20.5	26.0	13.2	13.0	13.7	18.8
λ_y=0.0 λ_r=1.0 λ_w=0.5	10.0	10.0	11.1	12.0	13.4	15.2	15.3	16.0	11.1	11.0	11.4	11.8
λ_y=0.5 λ_r=1.0 λ_w=0.5	12.0	11.4	12.9	15.5	16.8	18.8	18.2	21.5	12.5	12.3	12.9	15.7
λ_y=1.0 λ_r=1.0 λ_w=0.5	14.1	12.8	14.7	19.0	20.2	22.3	21.1	27.0	13.9	13.7	14.5	19.5
λ_y=0.0 λ_r=0.0 λ_w=1.0	13.4	11.9	13.3	14.4	18.4	21.8	21.8	22.6	14.3	14.3	14.5	16.5
λ_y=0.5 λ_r=0.0 λ_w=1.0	15.4	13.3	15.1	17.9	21.8	25.3	24.7	28.1	15.7	15.7	16.1	20.3
λ_y=1.0 λ_r=0.0 λ_w=1.0	17.4	14.7	16.9	21.4	25.1	28.9	27.6	33.5	17.1	17.0	17.6	24.1
λ_y=0.0 λ_r=0.5 λ_w=1.0	14.0	12.6	14.1	15.1	19.1	22.5	22.4	23.6	15.1	15.0	15.3	17.2
λ_y=0.5 λ_r=0.5 λ_w=1.0	16.0	14.0	15.9	18.6	22.4	26.0	25.3	29.0	16.4	16.4	16.9	21.0
λ_y=1.0 λ_r=0.5 λ_w=1.0	18.1	15.4	17.8	22.1	25.8	29.5	28.1	34.5	17.8	17.8	18.4	24.8
λ_y=0.0 λ_r=1.0 λ_w=1.0	14.6	13.3	15.0	15.9	19.8	23.2	22.9	24.6	15.8	15.8	16.1	17.9
λ_y=0.5 λ_r=1.0 λ_w=1.0	16.7	14.7	16.8	19.4	23.1	26.7	25.8	30.0	17.2	17.1	17.7	21.7
λ_y=1.0 λ_r=1.0 λ_w=1.0	18.7	16.1	18.6	22.9	26.5	30.2	28.7	35.5	18.5	18.5	19.2	25.6

CB losses, for each rule, between 1985 and 2007. The shading scheme is defined separately in relation to each line. The lighter the shading is, the smaller the loss.

	1	2	3	4	5	6	7	8	9	10	11	12
λ_y=0.0 λ_r=0.0 λ_w=0.0	34.2	37.9	43.2	38.9	42.6	42.2	41.2	39.6	45.3	25.8	39.9	44.4
λ_y=0.5 λ_r=0.0 λ_w=0.0	38.0	41.4	48.1	44.5	51.8	51.7	53.2	51.2	47.8	28.1	43.6	56.2
λ_y=1.0 λ_r=0.0 λ_w=0.0	41.9	44.8	53.0	50.1	61.1	61.2	65.1	62.8	50.2	30.4	47.3	68.0
λ_y=0.0 λ_r=0.5 λ_w=0.0	39.4	43.9	51.1	45.2	48.7	48.2	46.9	47.2	52.1	32.4	46.1	51.1
λ_y=0.5 λ_r=0.5 λ_w=0.0	43.3	47.3	56.0	50.8	57.9	57.7	58.9	58.9	54.6	34.7	49.8	62.9
λ_y=1.0 λ_r=0.5 λ_w=0.0	47.1	50.8	60.9	56.4	67.1	67.2	70.8	70.5	57.1	37.0	53.5	74.7
λ_y=0.0 λ_r=1.0 λ_w=0.0	44.7	49.8	59.1	51.5	54.7	54.2	52.6	54.9	59.0	38.9	52.2	57.7
λ_y=0.5 λ_r=1.0 λ_w=0.0	48.6	53.3	64.0	57.1	63.9	63.7	64.6	66.5	61.4	41.3	55.9	69.5
λ_y=1.0 λ_r=1.0 λ_w=0.0	52.4	56.7	68.9	62.7	73.1	73.2	76.5	78.1	63.9	43.6	59.6	81.3
λ_y=0.0 λ_r=0.0 λ_w=0.5	47.5	52.2	49.7	57.5	51.4	51.2	49.7	45.3	56.5	36.1	50.7	46.4
λ_y=0.5 λ_r=0.0 λ_w=0.5	51.3	55.6	54.6	63.1	60.6	60.7	61.7	56.9	59.0	38.4	54.4	58.2
λ_y=1.0 λ_r=0.0 λ_w=0.5	55.2	59.1	59.5	68.7	69.8	70.2	73.6	68.5	61.5	40.7	58.1	70.0
λ_y=0.0 λ_r=0.5 λ_w=0.5	52.8	58.1	57.6	63.7	57.4	57.2	55.5	52.9	63.4	42.6	56.8	53.0
λ_y=0.5 λ_r=0.5 λ_w=0.5	56.6	61.6	62.5	69.3	66.6	66.7	67.4	64.6	65.8	45.0	60.5	64.8
λ_y=1.0 λ_r=0.5 λ_w=0.5	60.5	65.0	67.4	74.9	75.8	76.2	79.3	76.2	68.3	47.3	64.2	76.6
λ_y=0.0 λ_r=1.0 λ_w=0.5	58.0	64.1	65.6	70.0	63.4	63.3	61.2	60.6	70.2	49.2	63.0	59.7
λ_y=0.5 λ_r=1.0 λ_w=0.5	61.9	67.5	70.5	75.6	72.7	72.8	73.1	72.2	72.7	51.5	66.7	71.5
λ_y=1.0 λ_r=1.0 λ_w=0.5	65.7	70.9	75.4	81.2	81.9	82.3	85.1	83.8	75.1	53.8	70.4	83.3
λ_y=0.0 λ_r=0.0 λ_w=1.0	60.8	66.4	56.2	76.0	60.1	60.3	58.3	51.0	67.7	46.3	61.4	48.3
λ_y=0.5 λ_r=0.0 λ_w=1.0	64.7	69.9	61.1	81.6	69.3	69.8	70.2	62.6	70.2	48.7	65.1	60.1
λ_y=1.0 λ_r=0.0 λ_w=1.0	68.5	73.3	66.0	87.2	78.5	79.3	82.2	74.2	72.7	51.0	68.8	71.9
λ_y=0.0 λ_r=0.5 λ_w=1.0	66.1	72.4	64.1	82.3	66.1	66.3	64.0	58.6	74.6	52.9	67.6	55.0
λ_y=0.5 λ_r=0.5 λ_w=1.0	69.9	75.8	69.0	87.9	75.4	75.8	75.9	70.3	77.1	55.2	71.3	66.8
λ_y=1.0 λ_r=0.5 λ_w=1.0	73.8	79.2	73.9	93.5	84.6	85.3	87.9	81.9	79.5	57.5	75.0	78.6
λ_y=0.0 λ_r=1.0 λ_w=1.0	71.4	78.3	72.1	88.6	72.2	72.3	69.7	66.3	81.4	59.5	73.7	61.7
λ_y=0.5 λ_r=1.0 λ_w=1.0	75.2	81.7	77.0	94.2	81.4	81.8	81.7	77.9	83.9	61.8	77.4	73.5
λ_y=1.0 λ_r=1.0 λ_w=1.0	79.0	85.2	81.9	99.8	90.6	91.3	93.6	89.5	86.4	64.1	81.1	85.3

CB losses, for each rule, between 1955 and 1985. The shading scheme is defined separately in relation to each line. The lighter the shading is, the smaller the loss.

Current loss functions

- Ranking of rules:
  - Follows values of L function given by each line.
  - Changes with weighting scheme (from CB's preferences).
- During GFC/ZLB Fed would have minimized losses via NGDP rules in level but difference of loss minimal with some Taylor type rules.

Forecasted loss functions (not presented)

- Out out of sample forecasted losses over 3-year out of sample period.
- To be noted: whatever the period, NGDP in level rules dominate (rule 10 closely followed by 9 and 12)

Summary

	1955-2017	2007-2017	1985-2007	1955-1985
Fitting				
Marginal density	5	12	12	1
Central bank loss				
Current	9,11	9,10 (1,2,12)	2,10 (1,9)	10
Forecasted	9,12	9,12 (10)	10 (11)	10 (12)

Table: Summary of the best rule(s) for each criterion. Rules close to the best one(s) are in parentheses.

- Fitting:
  - a different rule for each period, but 12 twice.
  - Fed may have changed strategy during GM.
- Losses:
  - some NGDP in level rules best most of the time (some Taylor type close) but not one that dominates whatever the period.

Policy implications

- Irrespective of the period in question, central bank's objectives are not achieved by one single rule.
  - For each type of period (more or less stable, crisis, recovery), a given central bank reaction function performs better than others.
  - Parameter estimates change with period for any monetary rule.
- Yet current and forecasted losses indicate superiority of NGDP rules in level except during the GM where the Taylor rule is better with current losses (but NGDP in level is close).
- In fine:
  - NGDP in level rules most frequently indicated, especially during crisis.
  - But some Taylor type rules also perform well, especially during more stable periods.
  - Necessary to regularly re-estimate the models, thus the parameters, to better fit the dynamics of the economy.

Conclusion

- CBs' objectives not achieved by one single empirical rule with same weight to each variable entering the rule. For each type of period (more or less stable, crisis, recovery) a specific reaction function performs better than others.
- CBs which base their forecast and policy on such models and rules should refresh their estimates regularly.
- Policy makers should estimate CB losses (current or forecasted) via several empirical monetary rules and models to better assess their interest rate decisions.