# Putting the New Keynesian DSGE model to the real-time forecasting test

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# Outline













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- Rising transparency among central banks in terms of communicating forecasts to the public (Geraats, 2009)
- Increasing role of DSGE models in forecasting (SIGMA in FED, NAWM in ECB, TOTEM in BOC, BEQM in BOE, SOE-PL in NBP)
- Common practice to adjust model-based forecasts for experts' judgment
- Scarce literature on forecasting performance of DSGE models conditional on expert knowledge

### What do we do?

- Compare real-time point forecasts from the DSGE to SPF and DSGE-VAR
- Analyze different methods of adjusting model-based forecasts for experts' view
- Evaluate absolute forecast errors from the 3 competing methods
- Analyze DSGE model density forecasts

#### Comparison of forecasts: DSGE vs. DSGE-VAR vs. BVAR

General conclusion:	DSGE better in forecasting than BVAR
Christoffel, Coenen, and Warne (2010):	DSGE $\succ$ BVAR (euro area, 1999-2006)
Adolfson, Lindé, and Villani (2007)	$DSGE \succ BVAR$ (euro area, 1994-2002)
Del Negro et al. (2007):	$DSGE-VAR \succ BVAR (US, 1985\text{-}2000)$
Smets and Wouters (2007):	$DSGE \succ BVAR$ (US, 1990-2004)

# Literature review

#### Comparison of forecasts with real-time data: DSGE vs. experts

Wolters (2010):	DSGE $\prec$ staff for inflation and IR DSGE $\succ$ FRB staff for GDP (US, 1980-2000)
Edge and Gurkaynak (2010):	DSGE $\sim$ for inflation and IR DSGE $\sim$ FRB staff for GDP (US, 1992-2004)
Lees, Matheson, and Smith (2011):	DSGE $\prec$ staff for nominal vars. DSGE $\succ$ BBNZ staff for real vars. (NZ 1998-2003)
Edge, Kiley, and Laforte (2010):	DSGE $\prec$ staff for nominal vars. DSGE $\succ$ FRB staff for real vars. (US, 1996-2002)
Rubaszek and Skrzypczynski (2008):	DSGE $\prec$ SPF for inflation and IR DSGE $\succ$ SPF for GDP (US, 1994-2006)

# DSGE model

- Model: Smets and Wouters (2007) DSGE model
- Reason: Benchmark specification for most DSGE models currently used in central banks
- Structure: Households optimizing utility; firms maximizing profits; passive government and central bank following the Taylor rule
- Long-term: Deterministic productivity trend
- Short-term: Stochastic shocks
- Estimation: Bayesian setup
  - Priors: As in Smets and Wouters (2007)

### Survey of Professional Forecasters

- SPF: The oldest quarterly survey of macroeconomic forecasts in US. Launched by the American Statistical Association and NBER in 1968; taken over by the FRB of Philadelphia in 1990
- Coverage: 32 macroeconomic variables, including GDP, GDP price index and 3M TB rate
  - Experts: From 29 to 53 professional forecasters (depending on a quarter, for period 1994-2008)
  - Timing: Forms sent to respondents at the end of the first month of each quarter (after advance release of NA data) and returned in the middle of the next month (before NA data revisions)
  - Horizon: Forecasts for 4 quarters ahead + nowcasts.

# DSGE-VAR model

- DSGE-VAR: DSGE models have a VAR( $\infty$ ) representation. DSGE-VAR: VAR models estimated with  $\lambda T$  artificial observations from the DSGE model (Del Negro and Schorfheide, 2004).
  - DSGE: We use the Smets and Wouters (2007) DSGE model
  - Weight: The prior for  $\lambda$  is U[0, 10]. Joint estimation of  $\lambda$  with other parameters of DSGE-VAR model (Adjemian, Paries, and Moyen, 2008)

### Data

#### Data from Philadelphia FED "Real-Time Data Set for Macroeconomists":

- real GDP (log change)
- real private consumption (log change)
- real private investment (log change)
- hours worked (log)
- GDP deflator (log change)
- 3-month T-bill rate

#### Comparability of forecasts form DSGE and SPF:

- The SPF has information advantage (financial data, monthly data, etc.)
- In retrospective forecasting DSGE benefit from the research on what types of models / priors work well in practice (Edge and Gurkaynak, 2010)

# Data

Forecasting scheme:	Recursive sample starting in 1964:2
Evaluation sample:	1994:1-2008:4 (56 forecasts for each horizon, model and variable)
Forecast horizon:	From nowcast to 4 quarters ahead
Vintage dates:	Middle day of the first quarter of the forecasting period
Actuals:	Latest-available vintage (2009:1)
Point forecasts:	Median of density forecasts

### Estimation results: DSGE model

Compared to Smets and Wouters (2007):

- Average median of 6 structural parameters beyond 90% confidence interval reported by SW
- Slightly different estimates of shock characteristics
- Differences almost entirely due to different sample and definition of variables

Very stable estimates within the recursive sample

### Estimation results: DSGE model, recursive IRFs



### Estimation results: DSGE-VAR, $\lambda$ estimates

#### Recursive estimates of $\lambda$ indicate that:

- The data give from 30.8% to 70.8% probability to the VAR representation of the DSGE model
- DSGE weight  $\lambda$  increases with the maximum lag p (DSGE model is better approximated by a VAR process with high p)
- DSGE weight  $\lambda$  decreases with the sample size T.

Ty DSGE-VAR2( $\hat{\lambda}$ ) ur	ype Mi nif O	n Max	Min	Av.	Max	Min	Âv.	Max
DSG E-VAR2 $(\hat{\lambda})$ ur	nif o	10						
		10	0.44	0.58	0.69	30.8	36.4	40.7
DSGE-VAR4(λ) ur	nif. O	10	0.71	0.91	1.13	41.5	47.6	53.0
DSGE-VAR6 $(\hat{\lambda})$ ur	nif. O	10	1.14	1.41	1.67	53.2	58.3	62.5
DSGE-VAR8 $(\hat{\lambda})$ ur	nif. O	10	1.61	1.99	2.42	61.7	66.4	70.8

### Result 1: Mean forecast errors

h	DSGE	SPF	DSGE-VAR $(\hat{\lambda})$ DSGE-VAR							
			<b>p</b> = 2	<b>p</b> = 4	$\dot{p} = 6$	<b>p</b> = 8	<b>p</b> = 16			
			Output (	growth (real G	DP, QoQ SA.	AR)				
0	-0.57**	0.38	-0.98***	-0.98***	-0.86***	-0.79***	-0.54 *			
1	-0.24	0.17	-1.01***	-0.98***	-0.87**	-0.70**	-0.39			
2	-0.03	0.12	-1.05***	-0.94**	-0.74*	-0.55	-0.31			
3	0.11	0.02	-1.07***	-0.86**	-0.66*	-0.45	-0.28			
4	0.07	-0.19	-1.18***	-0.88**	-0.72*	-0.51	-0.37			
			Inflation	(GDP price in	dex, QoQ SA	AR)				
0	0.15	0.12	0.14	0.16	0.11	0.08	0.18			
1	0.06	0.09	0.05	0.08	0.00	-0.06	0.10			
2	-0.02	0.01	-0.06	-0.01	-0.10	-0.17	0.03			
3	-0.04	-0.01	-0.14	-0.07	-0.18	-0.25	0.01			
4	-0.11	-0.06	-0.26	-0.20	-0.34	-0.40	-0.06			
			interest rate	(three-month	TB rate, per	annum)				
0	-0.11	-0.07***	-0.03	-0.05	-0.12	-0.12	-0.10			
1	-0.25	-0.19**	-0.14	-0.17	-0.30*	-0.29*	-0.21			
2	-0.39	-0.33*	-0.30	-0.36	-0.52**	-0.50**	-0.35			
3	-0.51*	-0.47*	-0.47	-0.55*	-0.75**	-0.72**	-0.48			
4	-0.65*	-0.65*	-0.67*	-0.75**	-0.98 <sup>***</sup>	-0.94***	-0.64			

Notes: A positive value indicates that forecasts are on average below the actual values.

### Result 1: Mean forecast errors

- OSGE-VAR forecasts for output are too high (also nowcasts from DSGE)
- Inflation forecasts are unbiased
- All methods overpredict the future level of TB rates

#### Why DSGE overpredicts the TB rates?

Euler equation implies steady-state gross real risk-free IR:

$$ar{R} = rac{1}{eta} (1 + \Delta C)^{\sigma_{m{c}}},$$

where  $\Delta C$  is per capita consumption growth rate and  $\sigma_c$  is risk aversion.

- Average for US in 1964-2008 ( $\Delta C = 1.9\%$  and  $\bar{R} 1 = 1.5\%$ ) implies unresonable values for  $\beta$  or  $\sigma_c$
- Risk-free interest rate puzzle discussed in the literature (Weil, 1989; Canzoneri, Cumby, and Diba, 2007).

## Result 2: Root mean squared forecast errors

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"	Dage	3PF		D3GE-	VAR(A)		DSGE-VAR(∞)				
			<b>p</b> = 2	<b>p</b> = 4	<b>p</b> = 6	<b>p</b> = 8	<b>p</b> = 16				
			Output gr	owth (real (	GDP, QoQ S.	4AR)					
0	1.95	0.98	1.10	1 17**	1.15	1.16	1.04				
1	1.99	1.07	1.18	1.23**	1.23*	1.23*	1.10				
2	1.83	1.21**	1.23*	1.29**	1.26*	1.25*	1.13*				
3	1.89	1.19**	1.23**	1.23**	1 . 21 *	1.19*	1.14**				
4	2.10	1.16**	1.21**	1.16**	1.17*	1.18*	1.13**				
	Inflation (GDP price index, QoQ SAAR)										
0	0.96	0.91	1.05**	0.96	0.99	0.97	1.02				
1	0.97	0.96	1 07***	0.93*	1.01	1.00	1.02				
2	0.88	1.09	1.09***	0.95	1.03	1.04	1.00				
3	1.03	1.05	1.11***	0.97	1.00	1.01	0.94				
4	1.11	1.02	1.10***	0.96	1.01	1.01	0.96				
		4	nterest rate (	three-montl	n TBrate, pe	er annum)					
0	0.43	0.34***	0.86	0.93	0.94	0.94	0.98				
1	0.80	0.64**	0.91	1.00	1.01	1.02	1.02				
2	1.10	0.79	0.95	1.00	1.03	1.05	1.06				
3	1.32	0.91	1.01	1.05	1.09	1.11	1.11				
4	1.51	1.02	1.07	1.11	1.15	1 16*	1.15*				

Notes: RMSFEs are reported as ratios with respect to DSGE model.

Asterisks \*\*\*, \*\* and \* denote the rejection of the null of the HLN-DM test.

# Result 2: Root mean squared forecast errors

- Output forecasts from DSGE are significantly better than from other methods
- Inflation forecasts are comparable across methods, except for DSGE-VAR(2)
- SPF forecasts for IR are most accurate, especially for nowcasts (information advantage)
- RMSFEs from DSGE tend to be lower than from DSGE-VARs (in contrast to the earlier literature, see Del Negro et al., 2007)

#### Why DSGE $\succ$ DSGE-VAR?

- VAR with small p usually a poor approximation to DSGE model representation VAR(∞) (Chari, Kehoe, and McGrattan, 2008)
- Even DSGE-VAR(16) with  $\lambda = \infty$  performs worse than DSGE
- Gains from relaxing dogmatic DSGE restrictions on VAR more than offset by losses due to lag truncation
- Explanation by Del Negro and Schorfheide (2012): This result might be due to the fact that the 2007-version of the Smets-Wouters model contains a number of features that are designed to boost its forecast performance. Also, the DSGE-VAR specification that they use is in first differences

# Result 3: RMSFE conditional on SPF TB rate nowcasts

h	DSGE	SPF		DSGE	-VAR		DSGE-VAR( $\infty$ )					
			<b>p</b> = 2	<b>p</b> = 4	<b>p</b> = 6	<b>p</b> = 8	p = 16					
		Output growth (real GDP, QoQ SAAR)										
0	2.33	0.82	1.00	1.07	1.07	1.10	1.02					
1	2.05	1.04	1.18	1.23*	1.23**	1.23**	1.11*					
2	1.84	1.20**	1.24*	1.31*	1.28*	1.27*	1.14*					
3	1.89	1.19**	1.23**	1.22*	1.21*	1.19*	1.14**					
4	2.12	1.15**	1.20**	1.15*	1.17*	1.18*	1.11*					
		Inflation (GDP price index, QoQ SAAR)										
0	0.94	0.93	1.06*	0.97	1.01	0.98	1.03					
1	0.96	0.97	1.08*	0.94	1.02	1.00	1.03					
2	0.85	1.12	1.12*	0.97	1.06	1.07	1.03					
3	1.00	1.08	1 14 ***	1.00	1.04	1.04	0.96					
4	1.08	1.05	1.12***	0.98	1.04	1.04	0.98					
			nterest rate (	three-mon	h TBrate,	per annum)						
1	0.60	0.86	0.97	1.02	1.07	1.07	1.07					
2	0.99	0.87	0.96	1.03	1.08	1.09	1.08					
3	1.28	0.94	1.00	1.04	1.09	1.10	1.11					
4	1.50	1.03	1.05	1.08	1.13	1.13	1.15					

# Result 3: RMSFE conditional on SPF TB rate nowcast

Conditioning on SPF TB rate:

- Improves the accuracy of DSGE forecasts for interest rates, which is now comparable to that of the SPF
- e Has no impact on the accuracy of inflation forecasts from DSGE model
- Worsens RMSFE for output nowcast by almost 20% (this is consistent with the finding of Schorfheide, Sill, and Kryshko (2010))

Why conditioning on IR worsens RMSFE for output nowcast from DSGE?

- Nowcasts from DSGE for output and IR tend to be too high
- DSGE model implies a negative comovement between output and IR
- Conditioning on lower level of IR pushes up nowcast for output, which raises RMSFE

# Result 4: RMSFE conditional on SPF nowcast

h	DSGE	SPF		DSGE-VAR $(\hat{\lambda})$					
			<b>p</b> = 2	<b>p</b> = 4	<b>p</b> = 6	<b>p</b> = 8	<b>p</b> = 16		
			Output gr	rowth (real C	GDP, QoQ S.	AAR)			
1	1.93	1.10	1.11	1.18*	1.17*	1.20**	1.08		
2	1.87	1.18*	1.16	1.22*	1.22*	1.23*	1.13*		
3	1.82	1.23***	1.26**	1.29**	1.29**	1.27*	1.20***		
4	2.11	1.16**	1.19**	1.13*	1.16*	1.18*	1.14**		
	Inflation (GDP price index, QoQ SAAR)								
1	0.92	1.01	1.09***	0.97	1.03	1.01	1.02		
2	0.92	1.05	1.07**	0.96	1.02	1.01	0.98		
3	1.01	1.06*	1.09***	0.97	0.98	0.99	0.96		
4	1.11	1.02	1.10***	0.96	0.98	0.98	0.95		
			nterest rate (	three-month	TB rate, pe	er annum)			
1	0.55	0.93	0.96	1.00	1.01	1.01	1.02		
2	0.92	0.94	0.95	0.99	1.02	1.03	1.03		
3	1.21	0.99	0.98	1.02	1.04	1.06	1.07		
4	1.45	1.07	1.02	1.05	1.08	1.09	1.11		

### Result 4: RMSFE conditional on SPF nowcast

- Conditioning on SPF nowcasts improves DSGE forecasts for IR (which are now comparable to those from the SPF)
- 2 The precision of inflation forecasts from SPF and DSGE remains comparable
- The accuracy of output forecasts from DSGE remains significantly higher than that from SPF
- The superior performance of experts in forecasting nominal vars. found in the literature can be attributed to their information advantage
- Including experts' nowcasts in model-based forecasts improves their precision. However, forecasts for the remaining horizons should not be corrected by experts.

### Result 5: Absolute forecast performance



#### Figure : Actuals and four-quarter-ahead forecasts

# Result 5: Absolute forecast performance

The results of the efficiency test:

$$\mathbf{x}_{\tau} = \alpha_{\mathbf{0}} + \alpha_{\mathbf{1}} \mathbf{x}_{\tau}^{\mathbf{F}} + \eta_{\tau}.$$

		D SG				SPF		
h	â	$\hat{\alpha}_1$	R <sup>2</sup>	$\chi^2$	ân	â1	R <sup>2</sup>	$\chi^2$
	( <i>s</i> <sub>â</sub> )	$(s_{\hat{\alpha}_1})$		prob	( <i>s</i> <sub>ĉo</sub> )	$(s_{\hat{\alpha}_1})$		prob
		0	utput gro	wth (rea	IGDP, Qo	Q SAAR)		
0	0.59	0.68	0.17	10.3	1.09	0.74	0.15	3.29
	(0.88)	(0.21)		0.01	(0.61)	(0.19)		0.19
2	0.52	0.82	0.17	0.47	5.03	-0.73	0.05	18.6
	(0.77)	(0.27)		0.79	(1.17)	(0.42)		0.00
4	0.12	0.98	0.11	0.06	5.04	-0.78	0.05	15.2
	(1.14)	(0.43)		0.97	(1.55)	(0.49)		0.00
		Int	flation (G	DP price	index, Qo	Q SAAR)		
0	1.51	0.34	0.08	15.0	1.22	0.47	0.07	4.58
	(0.40)	(0.17)		0.00	(0.57)	(0.26)		0.10
2	1.16	0.47	0.08	5.83	2.43	-0.10	0.00	12.1
	(0.50)	(0.22)		0.05	(0.75)	(0.32)		0.00
4	3.01	-0.36	0.03	27.9	3.91	-0.76	0.10	34.8
	(0.61)	(0.26)		0.00	(0.71)	(0.30)		0.00

Notes:  $\chi^2$  statistics relate to the null of the forecast unbiasedness test ( $\alpha_0 = 0$  and  $\alpha_1 = 1$ ).

# Result 6: Density forecasts

We evaluate density forecasts with Probability Integral Transform (PIT):

$$p_{\tau}=\int_{-\infty}^{x_{\tau}}f(u)du,$$

where f(u) is the ex-ante forecast density and  $x_{\tau}$  is the ex-post realization.

- For well calibrated density forecast  $p_{\tau}$  should be i.i.d. U(0,1)
- Illustration: divide (0,1) into 10 subintervals and check if the fraction of PITs in each of them is close to 1/10

# Result 6: Density forecasts

#### Figure : Density forecasts: PIT histograms for four-quarter-ahead forecasts



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# Result 6: Density forecasts

- GDP growth density forecasts (from DSGE and DSGE-VAR) are too diffuse as too many PITs fall into the middle bins
- The same is true for inflation
- For the interest rate, an unproportional number of PITs fall in the lowest bin, reflecting the fact that both models tend to overpredict its level
- The above results indicate that "fan charts" from DSGE models might be too wide

### Main findings:

- DSGE tends to overpredict the future level of interest rates (risk-free interest rate puzzle)
- DSGE outperforms DSGE-VAR models in forecasting the US economy: Gains from relaxing the dogmatic DSGE restrictions on VAR are more than offset by losses related to the lag truncation bias
- Compared to SPF, DSGE is more accurate in predicting output, but less accurate in predicting IR.
- The above is due to the information advantage of SPF: conditional on SPF nowcasts RMSFEs from DSGE are comparable or smaller than RMSFEs from SPF
- Adding expert corrections (other than nowcasts) to DSGE-based forecasts may deteriorate their quality

# Main findings:

- Conditioning on interest rates only deteriorates DSGE nowcasts for output: Negative co-movement combined with upwardly biased nowcasts for both variables
- The absolute performance of DSGE point forecasts is far from satisfactory: Low correlation of forecasts and realizations
- Onsity forecasts from DSGE model are rather poorly calibrated: Interval forecasts tend to be too wide
- Final remark: results might be dependent on the model choice, estimation technique, evaluation sample, etc...

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