The 9th Biennial Conference of the Czech Economic Society

Forecasting turning points of the business cycle: dynamic logit models for panel data

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Prague, Czech Republic
26.11.2016

The research question

- How to classify the states of the business cycle into the recessionary and expansionary episodes in advance?
  - More importantly, how to predict recessions?
- Useful for macroeconomic forecasting
  - Linear forecasting models tend to perform poorly at the outbreaks of recessions - Chauvet, Potter (2013, Handbook of Ec.Forec.)
  - Nonlinear models may improve the forecasting accuracy at the turning points of the cycle
- Panel data approach is helpful for the countries with short comparable macroeconomic data series
  - European economies due to introduction of the Euro, post-communist economies, ..

Literature review

Recession prediction with discrete dependent variable models

Estrella and Mishkin (1998, REStat); Kauppi and Saikkonen (2008, REStat); Nyberg (2010, JoF); Ng (2012, JMacro), Christiansen at al. (2014, JBF)

- Dynamic models with «classical recession predictors» (government bond term spread, short-term interest rate, stock market index), macroeconomic leading indicators, Ng (2012) and sentiment variables, Christiansen at al. (2014)
- Single country approach, mainly for the US

The determinants of duration of expansions and recessions

Castro (2010, JMacro)

- Panel data of 13 developed countries
- Additional explanatory variables: OECD leading indicators (calculated for the member countries in the unified methodology), the dynamics of private investment and the US business cycle phase

Literature review

Evaluating the classification of business cycle phases

Berge and Jorda (2011, AEJ: Macro)

- Single-indicator analysis. Different indicators of economic activity, different recession definitions
- Receiver operating characteristic (ROC) analysis. Rank models on the entire space of classification «trade-offs»

Dynamic discrete dependent variable models in a panel framework

Candelon et al. (2014, IJF)

- Currency crisis early warning systems (EWS)
- 16 emerging countries, dynamic fixed effects panel model

Contribution

- We generalize single-country time-series approach for recession forecasting for the *panel data* of OECD countries
  - We test classical recession predictors and recently introduced sentiment indicators at the panel of countries
  - We add to the literature by introducing additional "countercyclical" predictors
    - Proxies for macroeconomic imbalances, signals of economy overheating, etc.
  - We test whether one model with large set of predictors for a panel of countries could "beat" its competitor with country-specific OECD leading indicator in recession forecasting. If yes – evidence in favor of panel data model (it fits all countries)

Methodology and data

- **Panel quarterly dataset** on OECD countries (initially 32, finally ~ 20 due to data availability) over the period 1980 – 2013*.
- Dependent variable – state of the economy / business cycle phase (binary)

$$y_{it} = \begin{cases} 1, if\ the\ economy\ i\ is\ in\ a\ recessionary\ state\ at\ time\ t \\ 0, if\ the\ economy\ i\ is\ in\ a\ expansionary\ state\ at\ time\ t \end{cases}$$

- Methodology: *dynamic panel fixed effects logit model*

$$Pr\{y_{it} = 1 | \alpha_i , x_{it-k} , y_{it-k}\} = F(y_{it-k}\,\gamma + x'_{it-k}\beta + \alpha_i)$$

Pr(.) is a conditional probability of recession

F(.) is a logistic distribution function

$x_{it\text{-}k}$ is a set of explanatory variables for country *i* at quarter *(t-k)*

β is a vector of parameters at *x*

γ is a state dependence parameter (inertia)

α_i is a country-specific unobservable heterogeneity component

k is the quarter lag: 1, 2 and 4 quarters ahead models

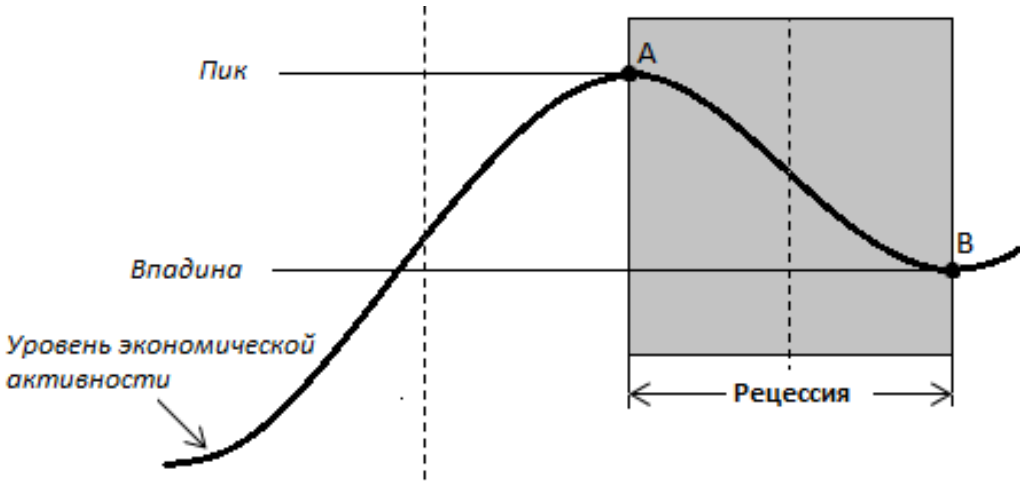
* GDP contraction during transitional period in post socialist countries was removed from the sample

Dating business cycle phases

Classical (business cycle)

Neither international organisation provides business cycle dates for the big set of countries in the same methodology

- NBER - USA
- Economic Cycle Research Institute – 9 European countries+some Asia and America
- CEPR – Euro area



- Harding, Pagan (2002, JME) modified Bry–Boschan (1971) dating algorithm for the quarterly data
- This rule reproduces NBER dates quite closely (Harding, Pagan, 2005, JAE)
- I use BBQForExcel Program written by Adrian Pagan (downloaded from his website) to find turning points in *GDP volume index* (peaks / troughs)
  - Recession = period between peak and trough
  - Expansions = period between trough and peak

Estimation strategy

- Different explanatory variables
  1. Only country OECD leading indicator (OECD CLI)
  2. Classical recession predictors (CLASSICAL): spread between long and short term interest rate (term spread), short-term interest rate, stock market growth
  3. Sentiment indicators (SENTIMENT): OECD consumer and business confidence indicators
  4. State of the world economy (WORLD): OECD US GDP leading indicator
  5. New countercyclical indicators (NEW_COUNTERCYC): country GDP growth, CPI inflation, current account to GDP ratio, REER index, bank credit to GDP ratio
- Dynamic models (inertia in business cycle phases is accounted for)
  - Compared with static
- Different lags
  - One, two, four quarter ahead models

How to interpret countercyclical indicators

- Procyclical leading indicators - reach turning points before the economic activity, move in the same direction
  - Sentiment indicators, interest rates, stock indices, state of the world economy
- Countercyclical leading indicators – at some periods of time go above the «safe» thresholds, meaning that further development is impossible in this way (high inflation and high wages, trade deficit, currency appreciation, financial overheating)

- Missing link in the modern business cycle theory? What drives business cycles, shocks? But shocks are linear combinations of one step ahead forecasting errors (reduced-form innovations).

- Are turning points driven by the exogenous «shocks» or they are (at least partially) explained by domestic economic development?

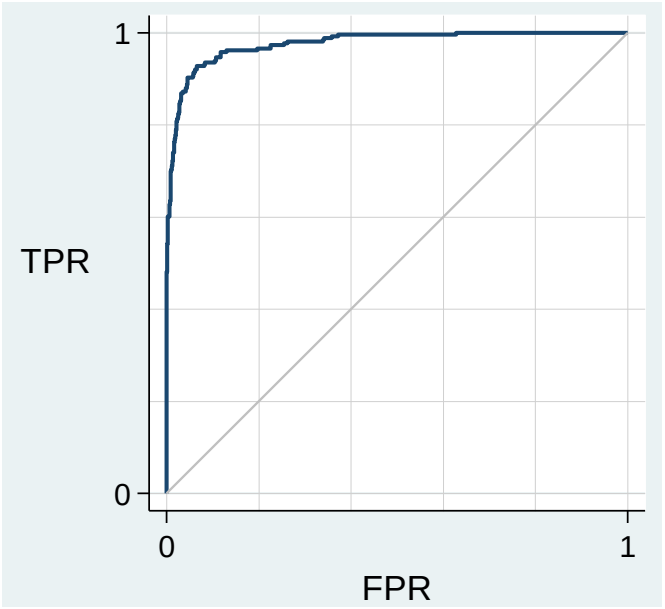
Evaluating the classification of business cycle phases

	True state of the economy	
	$S = 1$ Recession	$S = 0$ Expansion
$Y_t \geq c$ Recession prediction	True positive rate TPR(c)	False positive rate FPR(c)
$Y_t < c$ Expansion prediction	$1 - TPR$	$1 - FPR$

$$ROC(r) = TPR(c)$$

$$r = FPR(c)$$

$$AUROC = \int_0^1 ROC(r)dr$$



Models with different set of predictors, lag=1q

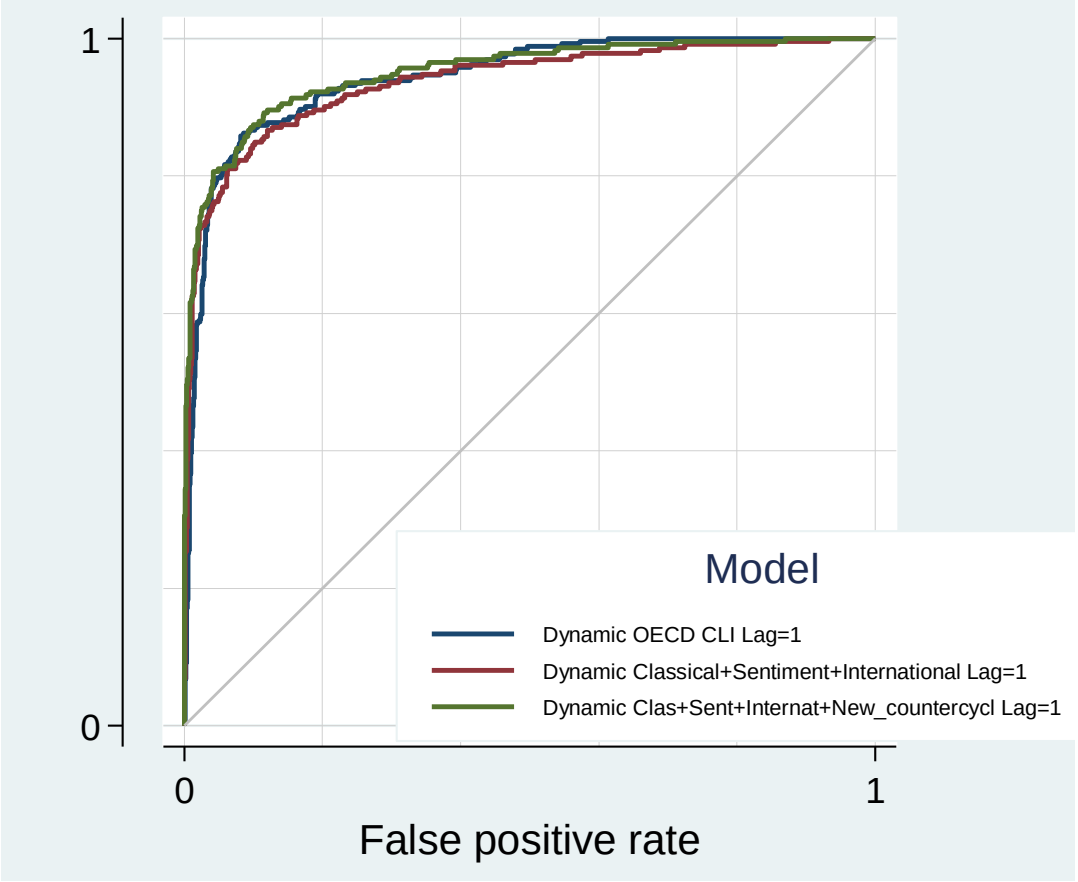
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable: Reces							Dynamic models							Static model
L.Reces	3.017***	4.345***	4.345***	4.438***	4.584***	4.494***	4.369***	4.644***	4.468***	4.588***	4.602***	4.602***	4.587***	
	(11.70)	(19.53)	(19.53)	(18.05)	(17.63)	(17.09)	(15.58)	(13.43)	(13.03)	(13.05)	(12.92)	(12.92)	(13.05)	
L1.oecd_cli	-0.493***													
	(-7.05)													
L1.term_spread		-0.123**	-0.128*	-0.111	-0.076	-0.054	-0.046	-0.037	-0.090	-0.072	-0.083	-0.083	-0.095	-0.103
		(-2.20)	(-1.80)	(-1.50)	(-0.98)	(-0.67)	(-0.58)	(-0.47)	(-1.04)	(-0.87)	(-1.01)	(-1.01)	(-1.10)	(-1.37)
L1.money_market_rate			-0.003	-0.003	-0.005	-0.007	0.001	-0.007	-0.142***	-0.142***	-0.156***	-0.156***	-0.059	-0.058
			(-0.09)	(-0.07)	(-0.13)	(-0.17)	(0.02)	(-0.17)	(-2.64)	(-2.67)	(-2.89)	(-2.89)	(-0.90)	(-1.02)
L1.t_stock_q				-0.100***	-0.080***	-0.072***	-0.068***	-0.067***	-0.063***	-0.064***	-0.065***	-0.065***	-0.064***	-0.046***
				(-8.35)	(-6.18)	(-5.15)	(-4.82)	(-4.65)	(-4.30)	(-4.30)	(-4.25)	(-4.25)	(-4.19)	(-3.74)
L1.t_consum_confid_q					-0.976***	-0.779***	-0.813***	-0.800***	-0.757***	-0.702***	-0.685***	-0.685***	-0.641***	-0.533***
					(-4.51)	(-3.37)	(-3.47)	(-3.40)	(-3.10)	(-2.87)	(-2.81)	(-2.81)	(-2.68)	(-2.58)
L1.t_bus_confid_q						-0.473**	-0.415**	-0.372*	-0.394*	-0.402*	-0.380*	-0.380*	-0.414*	-0.924***
						(-2.43)	(-2.07)	(-1.83)	(-1.87)	(-1.86)	(-1.76)	(-1.76)	(-1.85)	(-4.73)
L1.oecd_cli_usa							-0.082	-0.112	-0.088	-0.064	-0.077	-0.077	-0.043	-0.078
							(-1.21)	(-1.60)	(-1.32)	(-0.96)	(-1.14)	(-1.14)	(-0.64)	(-1.36)
L1.gdp_gr								0.087	0.053	0.075	0.089	0.089	0.090	-0.457***
								(1.43)	(0.86)	(1.20)	(1.39)	(1.39)	(1.48)	(-8.40)
L1.cpi_inflat									0.312***	0.344***	0.360***	0.360***	0.361***	0.493***
									(4.08)	(4.41)	(4.56)	(4.56)	(4.28)	(6.24)
L1.cab_to_gdp_4q										-0.130**	-0.119**	-0.119**	-0.095*	-0.009
										(-2.43)	(-2.22)	(-2.22)	(-1.72)	(-0.23)
L1.reer											0.021	0.021	0.007	0.002
											(1.63)	(1.63)	(0.57)	(0.18)
L1.loans_to_gdp													0.016***	0.017***
													(3.20)	(3.59)
_cons	-1.512	-2.657**	-2.625**	-1.898	-2.059*	-2.057*	-1.987*	-2.049*	-2.659**	-3.231***	-5.453***	-5.453***	-5.023***	-4.248**
	(-1.22)	(-2.35)	(-2.24)	(-1.54)	(-1.72)	(-1.76)	(-1.66)	(-1.69)	(-2.21)	(-2.79)	(-2.80)	(-2.80)	(-2.61)	(-2.50)
N	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430
pseudo R-sq	0.536	0.483	0.483	0.542	0.561	0.566	0.567	0.569	0.579	0.585	0.586	0.586	0.594	0.404
ll	-293.683	-327.234	-327.231	-289.790	-277.319	-274.634	-273.652	-272.791	-266.113	-262.715	-261.774	-261.774	-256.772	-377.166
chi2	336.583	406.171	406.511	387.456	377.226	381.307	366.793	367.221	383.781	374.751	371.854	371.854	386.771	239.962

Classification results, lag=1 quarter

	AUROC
OECD CLI	0.9479
CLASSIC+SENTIMENT+WORLD	0.9437
CLASSIC+SENTIMENT+WORLD+NEW COUNTERCYCL	0.9504

Prob (Areas are equal) = 0.1308

Differencies are minor. All AUROCs are statistically equal



Models with different set of predictors, lag=2q

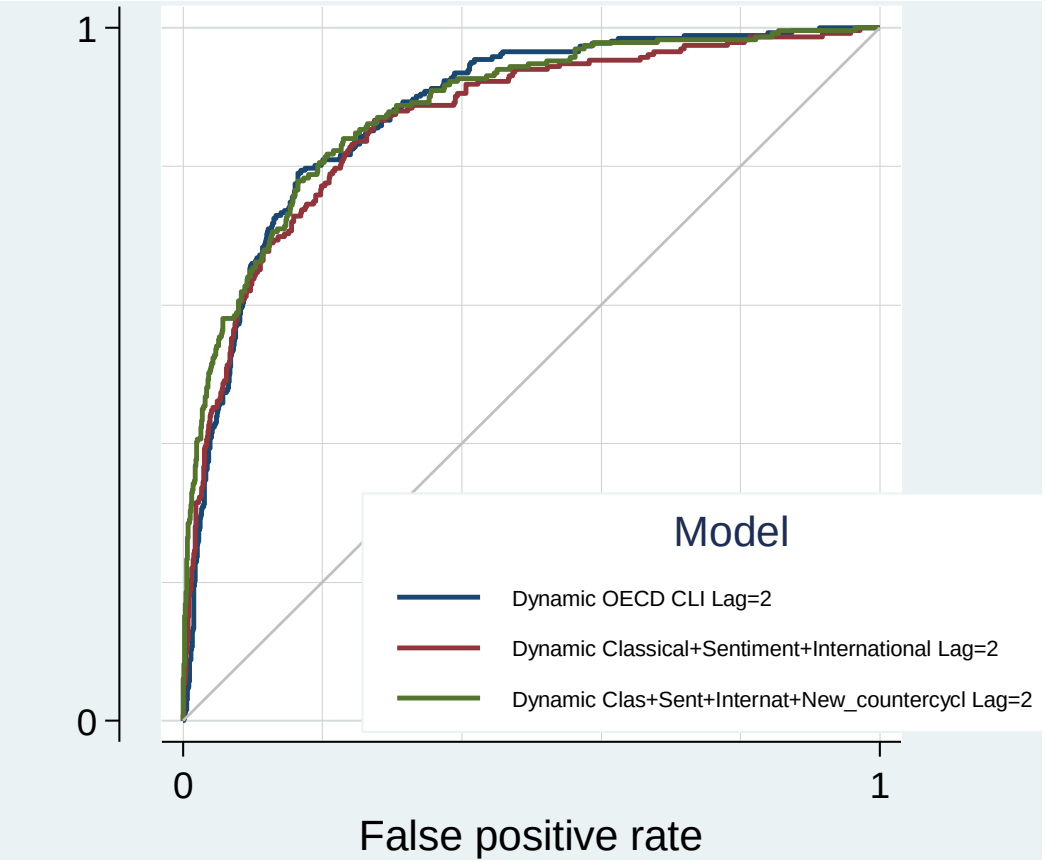
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable: Reces						Dynamic models								Static model
L2.Reces	1.080***	2.480***	2.479***	2.271***	2.272***	2.166***	2.168***	2.507***	2.309***	2.446***	2.456***	2.456***	2.415***	
	(4.50)	(14.06)	(14.03)	(12.14)	(11.74)	(10.75)	(10.15)	(9.35)	(8.63)	(8.97)	(8.93)	(8.93)	(8.61)	
L2.oecd_cli	-0.418***													
	(-7.30)													
L2.term_spread		-0.122**	-0.131*	-0.118*	-0.083	-0.068	-0.068	-0.063	-0.127	-0.110	-0.126	-0.126	-0.144*	-0.120
		(-2.23)	(-1.81)	(-1.73)	(-1.20)	(-0.97)	(-0.98)	(-0.89)	(-1.60)	(-1.41)	(-1.64)	(-1.64)	(-1.87)	(-1.53)
L2.money_market_rate			-0.007	-0.008	-0.005	-0.008	-0.008	-0.022	-0.174***	-0.176***	-0.199***	-0.199***	-0.077	-0.054
			(-0.22)	(-0.25)	(-0.15)	(-0.26)	(-0.26)	(-0.68)	(-4.02)	(-4.15)	(-4.51)	(-4.51)	(-1.49)	(-1.08)
L2.t_stock_q				-0.072***	-0.057***	-0.049***	-0.049***	-0.049***	-0.048***	-0.050***	-0.050***	-0.050***	-0.049***	-0.043***
				(-7.74)	(-5.63)	(-4.58)	(-4.55)	(-4.44)	(-4.25)	(-4.28)	(-4.25)	(-4.25)	(-4.15)	(-3.88)
L2.t_consum_confid_q					-0.736***	-0.595**	-0.595**	-0.577**	-0.557**	-0.518**	-0.512**	-0.512**	-0.444*	-0.437*
					(-3.45)	(-2.49)	(-2.46)	(-2.53)	(-2.37)	(-2.23)	(-2.27)	(-2.27)	(-1.90)	(-1.70)
L2.t_bus_confid_q						-0.381**	-0.382**	-0.338**	-0.351**	-0.355*	-0.324*	-0.324*	-0.389**	-0.636***
						(-2.23)	(-2.12)	(-1.96)	(-1.96)	(-1.92)	(-1.78)	(-1.78)	(-2.00)	(-3.30)
L2.oecd_cli_usa							0.001	-0.033	0.012	0.040	0.025	0.025	0.068	0.024
							(0.03)	(-0.64)	(0.22)	(0.77)	(0.47)	(0.47)	(1.30)	(0.45)
L2.gdp_gr								0.112**	0.073	0.101*	0.119**	0.119**	0.121**	-0.150***
								(2.10)	(1.31)	(1.83)	(2.17)	(2.17)	(2.10)	(-3.21)
L2.cpi_inflat									0.348***	0.394***	0.420***	0.420***	0.413***	0.465***
									(5.52)	(6.39)	(6.63)	(6.63)	(6.17)	(6.71)
L2.cab_to_gdp_4q										-0.157***	-0.140***	-0.140***	-0.109***	-0.061*
										(-3.82)	(-3.38)	(-3.38)	(-2.63)	(-1.65)
L2.reer											0.029***	0.029***	0.012	0.009
											(2.97)	(2.97)	(1.20)	(0.88)
L2.loans_to_gdp													0.021***	0.023***
													(5.09)	(5.20)
_cons	-2.104***	-2.860***	-2.812***	-2.794***	-2.988***	-3.009***	-3.011***	-3.204***	-3.597***	-4.032***	-6.961***	-6.961***	-6.347***	-5.216***
	(-4.60)	(-7.57)	(-6.44)	(-6.25)	(-6.75)	(-6.89)	(-6.70)	(-6.89)	(-7.42)	(-8.01)	(-5.82)	(-5.82)	(-5.13)	(-4.34)
N	1439	1439	1439	1439	1439	1439	1439	1446	1439	1439	1439	1439	1439	1439
pseudo R-sq	0.276	0.210	0.210	0.265	0.283	0.287	0.287	0.291	0.312	0.326	0.331	0.331	0.355	0.288
ll	-457.517	-499.502	-499.480	-465.026	-453.477	-450.566	-450.565	-450.424	-434.745	-426.290	-422.754	-422.754	-408.039	-449.981
chi2	224.707	252.212	253.467	261.518	242.472	242.205	245.722	257.849	291.706	294.305	293.262	293.262	303.529	241.991

Classification results, lag=2 quarters

	AUROC
OECD CLI	0.8705
CLASSIC+SENTIMENT+ WORLD	0.8613
CLASSIC+SENTIMENT+ WORLD+NEW COUNTERCYCL	0.8819

Prob (Areas are equal) = 0.0191

Now differencies in AUROCs are more pronounced and statistically significant



Models with different set of predictors, lag=4q

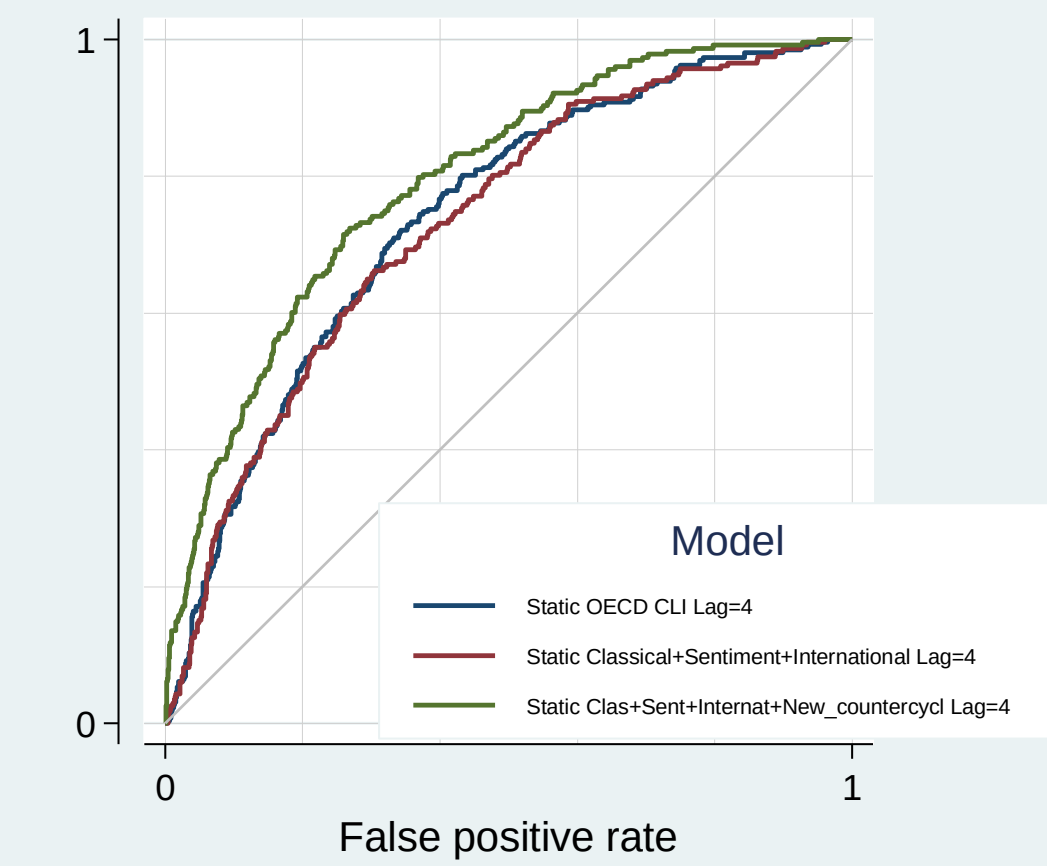
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable: Reces	Dynamic models													Static model
L4.Reces	-0.887***	0.433**	0.417**	0.120	0.026	0.068	0.105	0.323	0.147	0.235	0.214	0.214	0.093	
	(-3.22)	(2.25)	(2.13)	(0.55)	(0.12)	(0.30)	(0.44)	(1.18)	(0.56)	(0.87)	(0.80)	(0.80)	(0.34)	
L4.oecd_cli	-0.316***													
	(-7.46)													
L4.term_spread		-0.104*	-0.186**	-0.177**	-0.133*	-0.139*	-0.145*	-0.147*	-0.211**	-0.183**	-0.194**	-0.194**	-0.188**	-0.186**
		(-1.76)	(-2.17)	(-2.13)	(-1.65)	(-1.68)	(-1.74)	(-1.76)	(-2.25)	(-2.03)	(-2.19)	(-2.19)	(-2.42)	(-2.38)
L4.money_market_rate			-0.052*	-0.053*	-0.046	-0.046	-0.049	-0.058*	-0.187***	-0.180***	-0.205***	-0.205***	-0.051	-0.050
			(-1.66)	(-1.71)	(-1.53)	(-1.50)	(-1.57)	(-1.82)	(-4.58)	(-4.49)	(-4.96)	(-4.96)	(-1.09)	(-1.08)
L4.t_stock_q				-0.043***	-0.031***	-0.033***	-0.034***	-0.035***	-0.034***	-0.036***	-0.035***	-0.035***	-0.034***	-0.034***
				(-5.92)	(-3.90)	(-4.09)	(-4.10)	(-4.20)	(-4.08)	(-4.35)	(-4.26)	(-4.26)	(-3.97)	(-3.97)
L4.t_consum_confid_q					-0.503***	-0.546***	-0.542***	-0.544***	-0.533***	-0.507***	-0.514***	-0.514***	-0.470**	-0.470**
					(-2.79)	(-2.72)	(-2.70)	(-2.94)	(-2.83)	(-2.78)	(-2.84)	(-2.84)	(-2.54)	(-2.52)
L4.t_bus_confid_q						0.111	0.088	0.122	0.129	0.157	0.185	0.185	0.127	0.115
						(0.82)	(0.61)	(0.85)	(0.87)	(1.04)	(1.19)	(1.19)	(0.78)	(0.72)
L4.oecd_cli_usa							0.021	0.003	0.045	0.070	0.059	0.059	0.111**	0.109**
							(0.54)	(0.08)	(1.05)	(1.54)	(1.29)	(1.29)	(2.38)	(2.32)
L4.gdp_gr								0.077*	0.036	0.073	0.088**	0.088**	0.095**	0.087**
								(1.88)	(0.82)	(1.62)	(1.97)	(1.97)	(2.03)	(2.20)
L4.cpi_inflat									0.292***	0.335***	0.371***	0.371***	0.339***	0.341***
									(4.84)	(5.83)	(6.23)	(6.23)	(5.04)	(5.00)
L4.cab_to_gdp_4q										-0.177***	-0.158***	-0.158***	-0.110***	-0.108***
										(-4.88)	(-4.30)	(-4.30)	(-2.98)	(-2.98)
L4.reer											0.033***	0.033***	0.015	0.015
											(3.58)	(3.58)	(1.58)	(1.58)
L4.loans_to_gdp													0.025***	0.025***
													(6.05)	(6.07)
_cons	-1.764***	-2.475***	-2.094***	-2.011***	-2.164***	-2.158***	-2.191***	-2.322***	-2.579***	-3.092***	-6.478***	-6.478***	-6.110***	-6.088***
	(-4.78)	(-6.89)	(-4.70)	(-4.55)	(-4.96)	(-4.93)	(-4.90)	(-5.14)	(-5.68)	(-6.60)	(-5.62)	(-5.62)	(-4.84)	(-4.84)
N	1425	1425	1425	1425	1425	1425	1425	1435	1425	1425	1425	1425	1425	1425
pseudo R-sq	0.102	0.049	0.052	0.077	0.088	0.089	0.089	0.093	0.108	0.130	0.140	0.140	0.180	0.180
ll	-561.054	-594.032	-592.456	-576.753	-569.692	-569.375	-569.255	-572.944	-557.381	-543.715	-537.383	-537.383	-512.195	-512.253
chi2	113.726	76.144	76.036	104.017	97.845	98.657	99.033	107.704	130.878	178.564	182.633	182.633	219.037	219.039

Classification results, lag=4 quarters

	AUROC
OECD CLI	0.7281
CLASSIC+SENTIMENT+ WORLD	0.7255
CLASSIC+SENTIMENT+ WORLD+NEW COUNTERCYCL	0.7923

Prob (Areas are equal) = 0.0000

Differencies in AUROCs are pronounced and statistically significant



For long forecasting horizons we outperform the model with country-specific CLI! Panel data model fits all countries?

Different types of model

Area under ROC

	Lag=1q	Lag=2q	Lag=4q
Static	0.9507	0.8664	0.7923
Dynamic	0.9072	0.8819	0.7923
(Dynamic – Static)	***	**	0

Note:
***/** - difference is statistically significant at 1%/5%

$$Pr\{y_{it} = 1|\alpha_i, x_{it-k}, y_{it-k}\} = F(y_{it-k}\,\gamma + x'_{it-k}\beta + \alpha_i)$$

Static model: γ=0

Dynamic models are more accurate that static at short horizons.
Dynamics is unimportant at 4 quarter lag

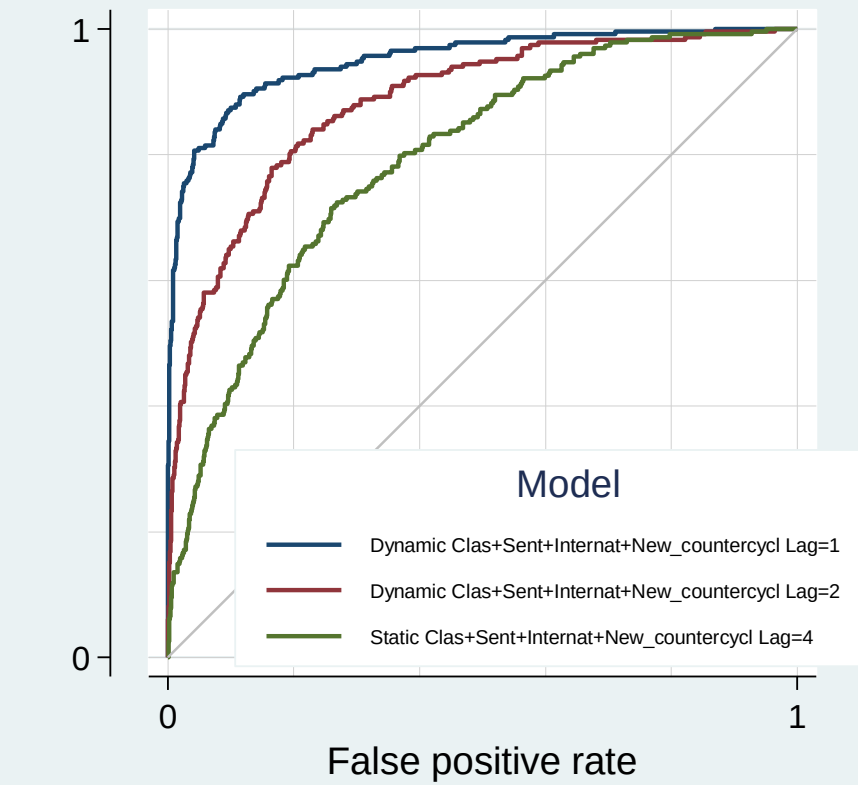
ROC-curves for models with different lags

	AUROC
Lag=1 Q	0.9498
Lag=2 Q	0.8807
Lag=4 Q	0.7926

Prob (Areas are equal) = 0.0000

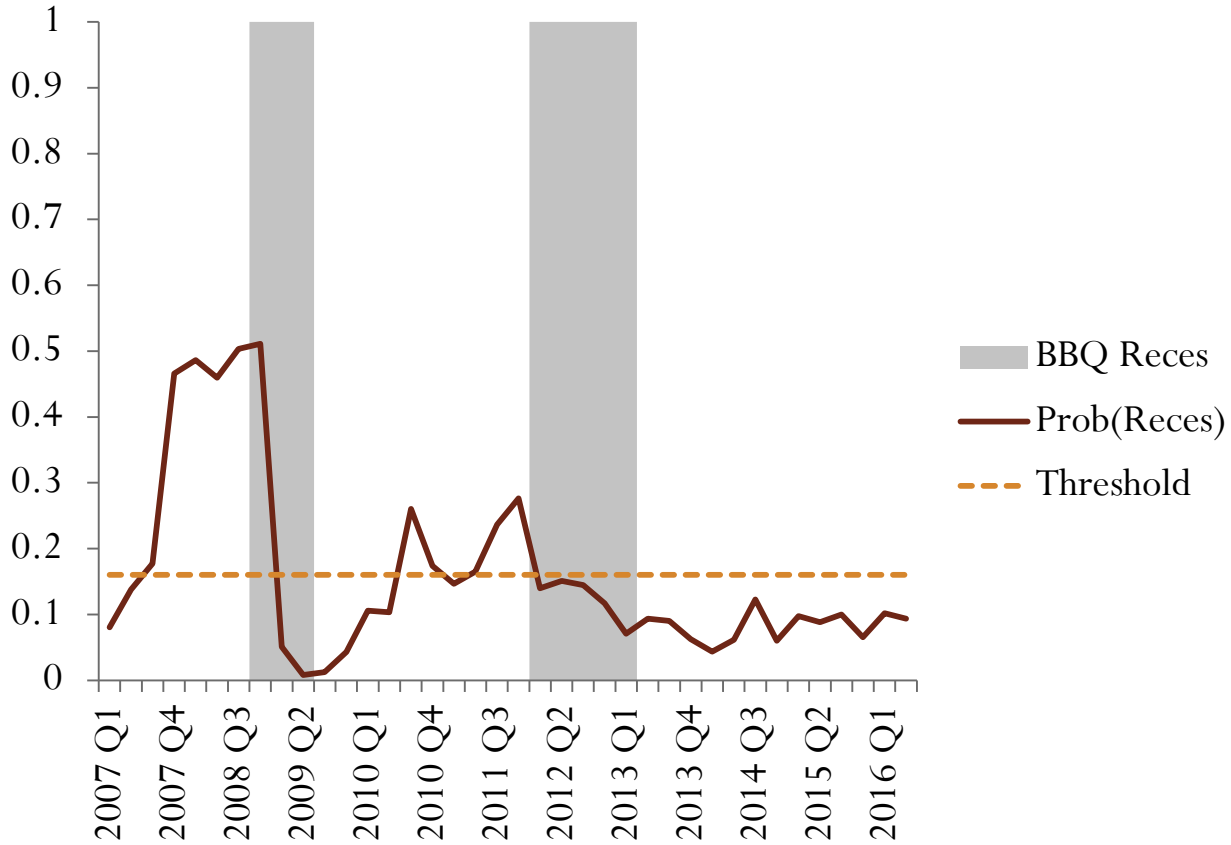
Quality of in-sample fit decreases significantly with lag increase.

Dynamic models with large set of predictors



How this model works for Czech Republic

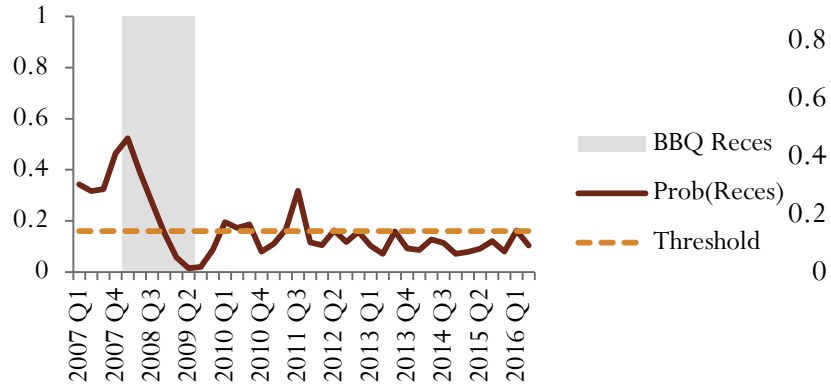
In-sample (up to 2013) and out-of-sample (2014-2015) forecasts of recession probabilities, 4 quarters ahead



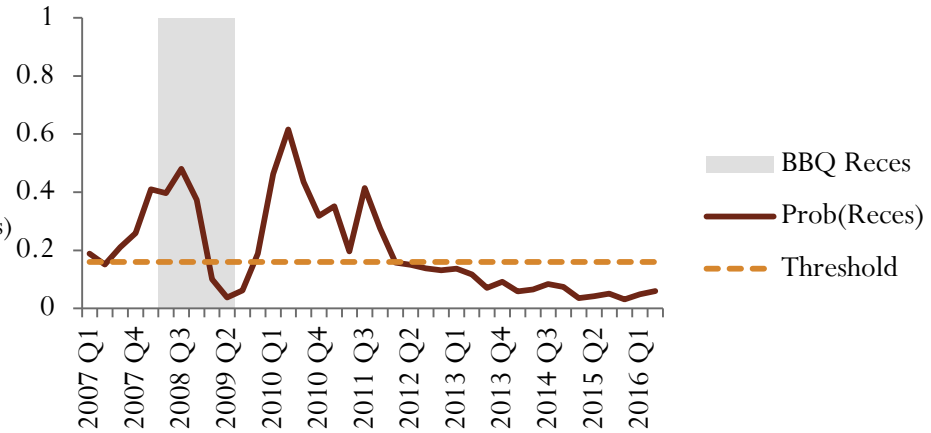
Other countries

In-sample (up to 2013) and out-of-sample (2014-2015) forecasts of recession probabilities, 4 quarters ahead

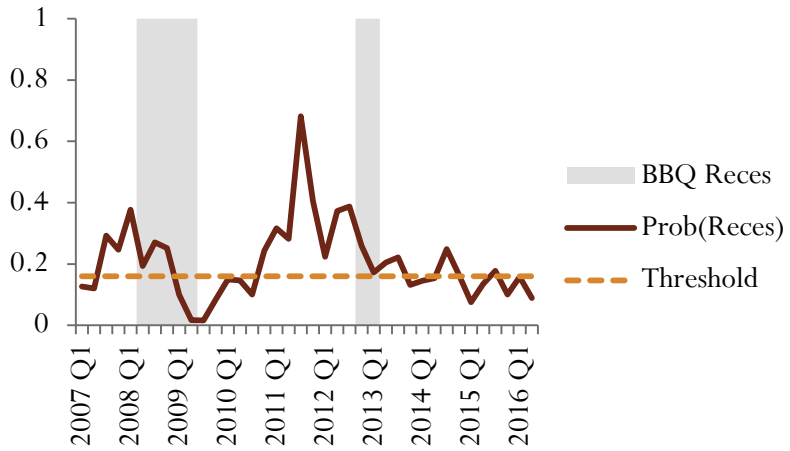
United States



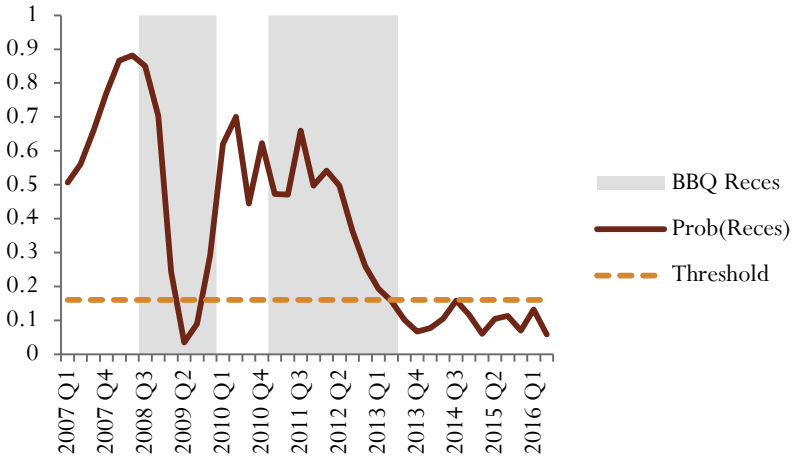
UK



Germany

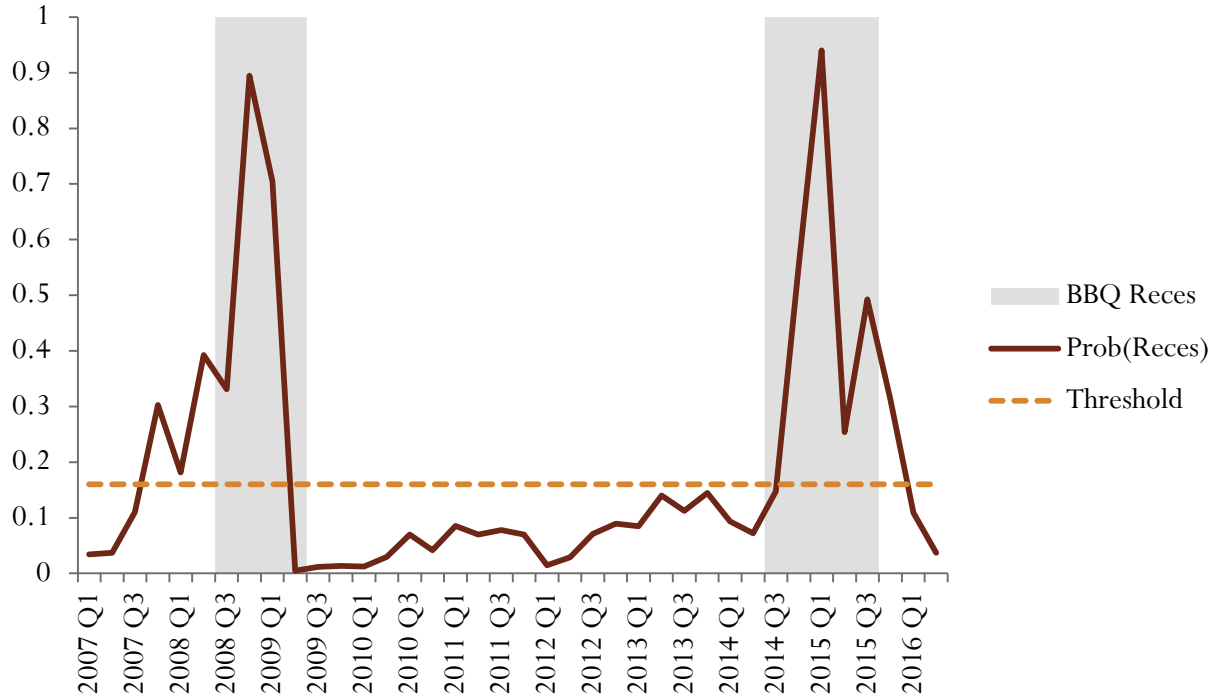


Spain



Russia

In-sample (up to 2013) and out-of-sample (2014-2015) forecasts of recession probabilities, 4 quarters ahead



Main results

- Business cycle turning points *can be predicted on the country panel data set* in a uniform way, and the quality of these predictions is comparable to the analogues for country-specific leading indicator models for short horizons and even outperform them at medium-term horizons
- *Lags of the dependent variable* do matter at short horizons (dynamic mechanism)
- We test classical recession predictors, sentiment indicators and introduced here "countercyclical" (macro imbalances) indicators. We conclude that at different forecasting horizons different list of predictors work
  - Term spread appears to be significant only at medium-term horizon. Stock market is useful at all horizons tested
  - With lag increase the predictive power of business confidence indicators vanishes, while consumer sentiment is significant for up to one year lag (business expectations seem to be less accurate at long horizons).
  - The role of domestic macro and financial imbalances and external trade misalignments, goes up at longer horizons. With these indicators we are able to build acceptable models with a year lag
- Quality of in-sample fit decreases significantly with lag increase.
  - Trade-off between forecasting accuracy and the earliness of the recession signal