

Application of DSGE models at the NBP

Michał Brzoza-Brzezina

Narodowy Bank Polski

Kraków

15.04.2016

Plan of the Presentation

- 1 Introduction
- 2 The RBC model
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 Summary

Plan of the Presentation

- 1 Introduction
- 2 The RBC model
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 Summary

Introduction

- DSGE models are important tools for monetary policy research
- Particularly valuable for applications where empirical evidence is missing or counterfactuals are needed
- Several applied research projects conducted with DSGE models. E.g.:
 - impact of the 2009 credit crunch on the Polish economy (Brzoza-Brzezina, Makarski, 2011, JIMF)
 - forecasting properties of DGSE models (Kolasa, Rubaszek, Skrzypczyński, 2012, JMCB; Kolasa, Rubaszek, 2015, IJCB; Kolasa, Rubaszek, 2015, IJF)
 - **business cycle effects of Poland's (hypothetical) euro area accession** (Brzoza-Brzezina, Makarski, Wesołowski, 2014, EM)
 - preventing boom-bust cycles after euro area accession (Brzoza-Brzezina, Jacquinot, Kolasa, 2014, OER)
 - **benefits of decentralised macroprudential policy in a monetary union** (Brzoza-Brzezina, Kolasa, Makarski, 2015, JIMF)
 - **impact of foreign currency loans on monetary and macroprudential policy** (Brzoza-Brzezina, Kolasa, Makarski, 2014)
 - impact of type and maturity of mortgage loans on the economy (Brzoza-Brzezina, Gelain, Kolasa, 2014)
 - **risk of running into the ZLB** (Brzoza-Brzezina, Kolasa, Szetela, 2015)

What are DSGE models

- Dynamic stochastic general equilibrium
- Popular way of modeling the macroeconomy since the 1980s.
- Early models - real business cycle (RBC) - Kydland & Prescott (1982)
 - response to Lucas (1976) critique of structural economic models
 - based on microeconomic optimization
 - quite successful in explaining many features of business cycles
 - less successful in explaining monetary policy related issues
- Evolution of RBC - New Keynesian models (Clarida, Gali, Gertler 1999, Woodford 2003)
 - take into account nominal rigidities
 - able to explain monetary policy related issues
 - widespread use in academia and central banks
 - critique and further evolution after financial crisis

Plan of the Presentation

- 1 Introduction
- 2 The RBC model**
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 Summary

Households - the problem

- A representative household maximises lifetime utility

$$E_t \sum_{i=0}^{\infty} \beta^{t+i} \left[\frac{c_{t+i}^{1-\sigma}}{1-\sigma} - \frac{l_{t+i}^{1+\varphi}}{1+\varphi} \right]$$

- subject to the budget constraint

$$c_t + i_t = w_t l_t + r_t k_{t-1}$$

and the capital accumulation rule

$$k_t = (1 - \delta)k_{t-1} + i_t$$

- The household rents labour and capital to firms and receives as compensation the real wage w_t and the rental rate r_t .

Lagrangian

- The household chooses c_t , l_t and k_t . Write down the Lagrangian:

$$\mathcal{L}_t = E_t \sum_{i=0}^{\infty} \left[\beta^{t+i} \left(\frac{c_{t+i}^{1-\sigma}}{1-\sigma} - \frac{l_{t+i}^{1+\varphi}}{1+\varphi} \right) - \lambda_{t+i} (c_{t+i} + k_{t+i} - w_{t+i} l_{t+i} - (1 + r_{t+i} - \delta) k_{t-1+i} + Div_t) \right]$$

First order conditions

$$c_t : \frac{\partial \mathcal{L}}{\partial c_t} = \beta^t c_t^{-\sigma} - \lambda_t = 0$$

$$l_t : \frac{\partial \mathcal{L}}{\partial l_t} = -\beta^t l_t^\varphi + \lambda_t w_t = 0$$

$$k_t : \frac{\partial \mathcal{L}}{\partial k_t} = -\lambda_t + E_t \lambda_{t+1} (1 + r_{t+1} - \delta) = 0$$

Firms - the problem

- A representative firm uses capital and labour hired from households to produce a unique good y_t .
- Its objective is to maximise profits:

$$Div_t = y_t - w_t l_t - r_t k_{t-1}$$

- subject to technology

$$y_t = z_t k_{t-1}^\alpha l_t^{1-\alpha}$$

Firms - equilibrium condition for labour

- First order conditions:

$$l_t : \frac{\delta Div_t}{\delta l_t} = (1 - \alpha)z_t k_{t-1}^\alpha l_t^{-\alpha} - w_t = 0$$

$$k_{t-1} : \frac{\delta Div_t}{\delta k} = \alpha z_t k_{t-1}^{\alpha-1} l_t^{1-\alpha} - r_t = 0$$

Productivity and market clearing

- It is assumed that productivity z_t follows an $AR(1)$ process:

$$z_t = \exp(\epsilon_t) z_{t-1}^\rho$$

- where ϵ_t is a productivity shock
- This is the only stochastic process in the basic RBC model
- Together with the internal persistence of the model it generates the business cycle
- The goods market clears:

$$c_t + i_t = y_t$$

What next?

- The RBC is a toy model
- But more complicated models are widely used in applied research
- They can be estimated (Bayesian techniques)
- Possible output:
 - impulse responses
 - historical decompositions
 - counterfactual scenarios
 - forecasting

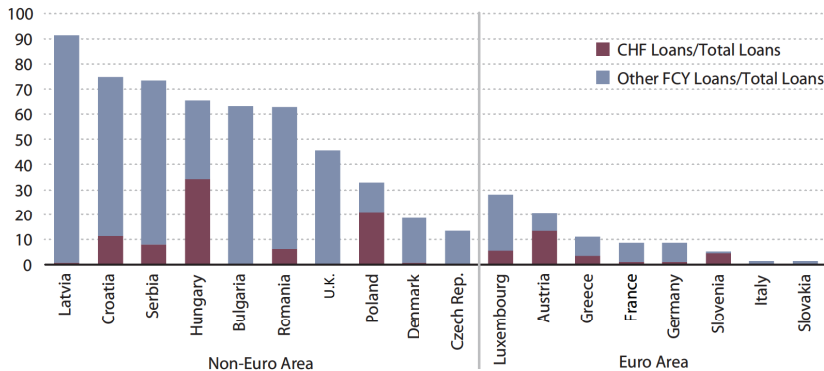
Plan of the Presentation

- 1 Introduction
- 2 The RBC model
- 3 **#1: Monetary and macroprudential policy with foreign currency loans**
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 Summary

Motivation

- Foreign currency lending plays an important role in several countries, especially in CEE
- Affects monetary policy: Egert et al. (2007); Rosenberg and Tirpak (2009); Brzoza-Brzezina et al. (2009); Magud et al. (2011)
- Hence of interest to policymakers: Dubel and Walley (2010); ESRB (2011); Lim et al. (2011); Bakker et al. (2012)
- Analysed from empirical perspective
- No theoretical framework to analyse implications of FCLs

Share of FCLs in loans to non-banking sector (2011:q3)



Source: Yesin (2013)

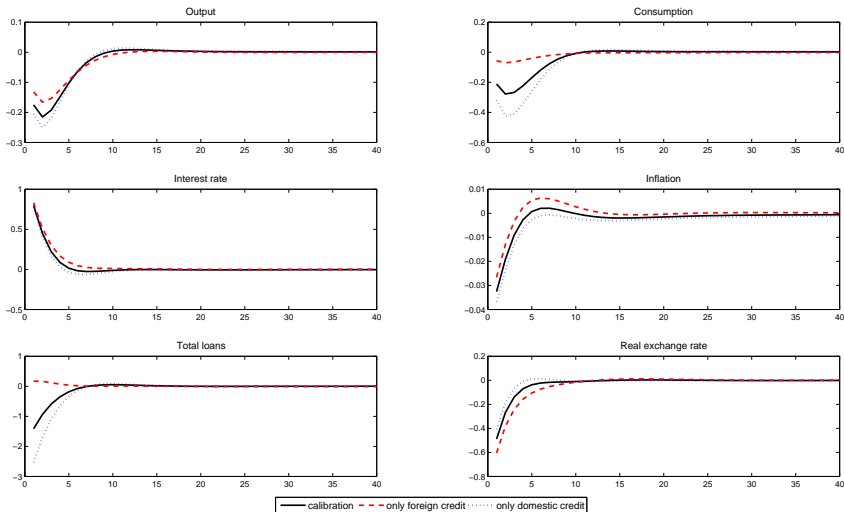
Features of the model

- Medium-sized NK SOE model with housing and standard set of nominal rigidities
- Domestic households can borrow both in domestic and foreign currency
- Financial frictions:
 - collateral constraints drawing on Kiyotaki and Moore (1997) and Iacoviello (2005)
- Policy tools:
 - monetary policy: interest rate
 - macroprudential policy
 - non-discriminatory: loan-to-value ratio (LTV)
 - discriminatory: cap on share of FCLs and tax on FCLs

Calibration

- Structural parameters calibrated to Polish data
- Stochastic parameters: moment matching (Ruge-Murcia, 2012):

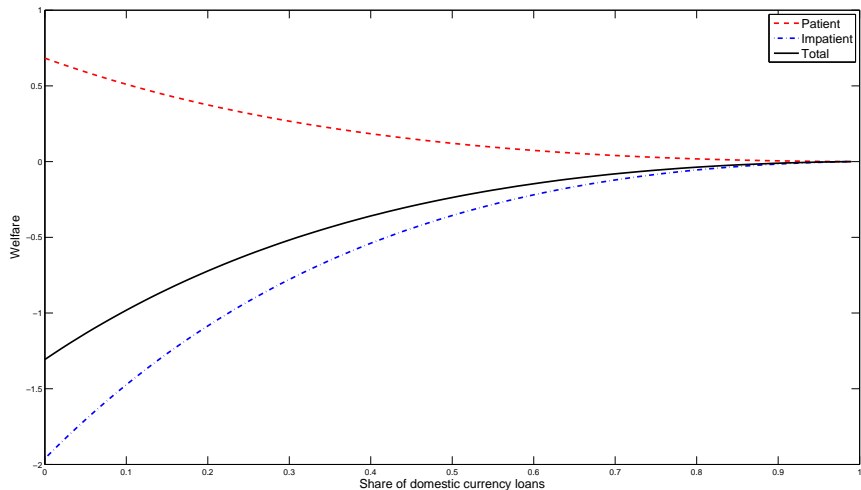
Loan denomination and monetary policy



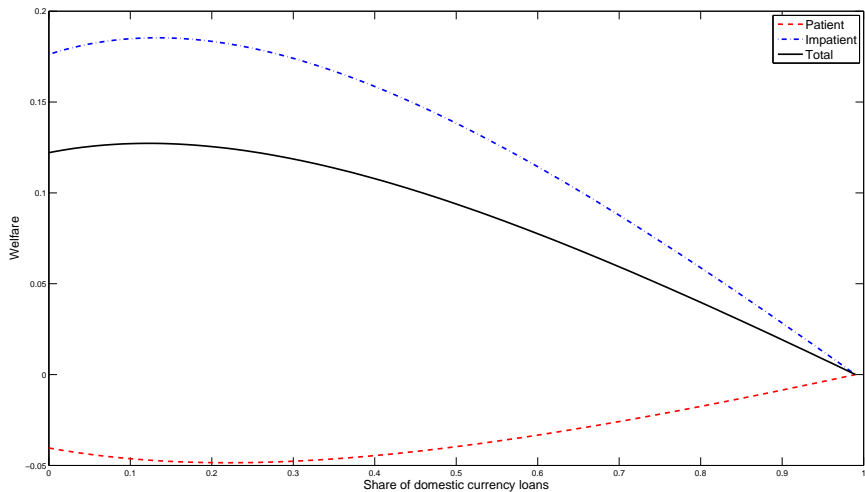
Welfare implications of DCLs and FCLs

- DCLs and FCLs imply different exposition to risk
- FCLs: exchange rate risk + foreign interest rate risk
- DCLs: domestic interest rate risk
- How does welfare change with various sources of risk?

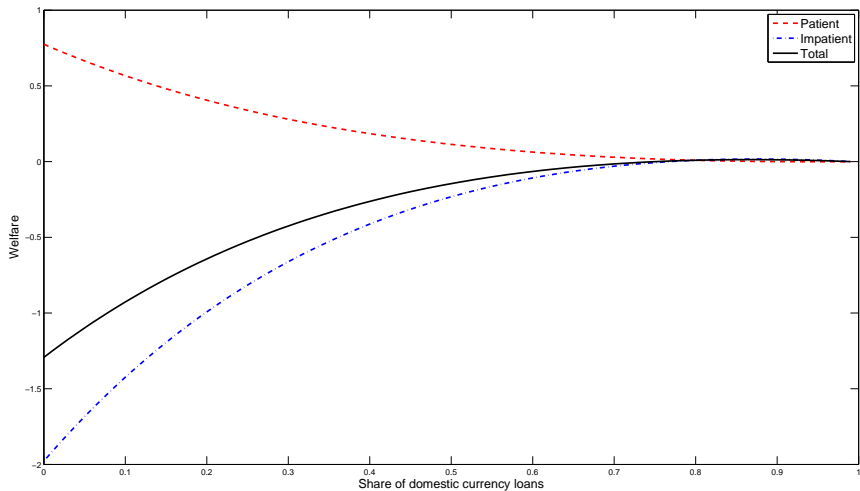
Risk premium shocks



Domestic interest rate shocks



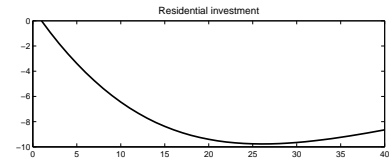
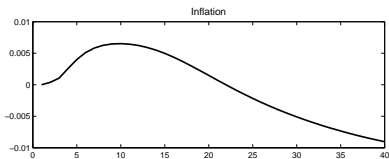
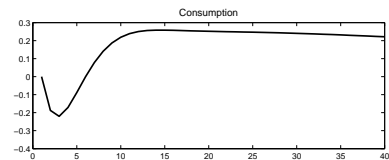
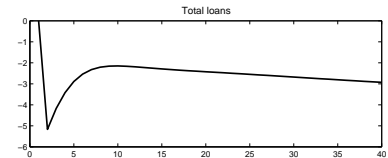
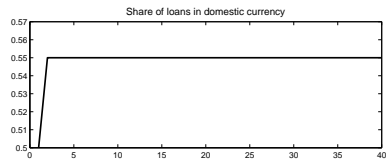
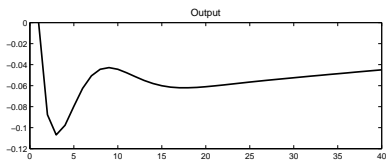
All shocks



FCL discrimination

- Cap on share of FCLs (-5 p.p. on its steady state value)

Cap on FCLs



Takeaways

- Foreign currency loans limit the power of monetary policy
- Decrease welfare
- But removing them can be costly in the short run

Plan of the Presentation

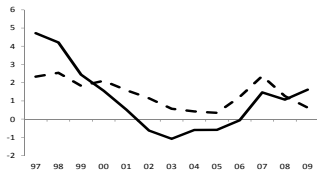
- 1 Introduction
- 2 The RBC model
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area**
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 Summary

Motivation

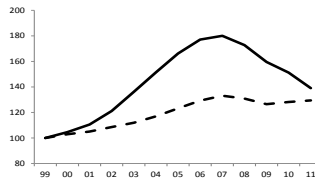
- Large imbalances within the eurozone
- Main culprits:
 - asymmetric interest rate adjustment (Honohan and Leddin, 2006; Blanchard, 2007; Andres et al., 2010),
 - asymmetric housing shocks (in't Veld et al., 2012)
- Common monetary policy struggles with bringing stability in the presence of country specific shocks
- Our goal: examine if macroprudential policy can help

Imbalances within the euro area

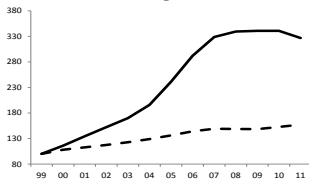
Real interest rate



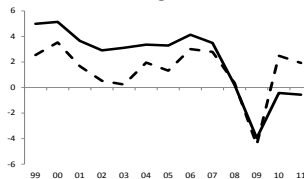
House Prices



Housing loans



GDP growth



Note: Solid line - peripheral members (GR, IE, PT, ES), dashed line - core members (rest of EA).

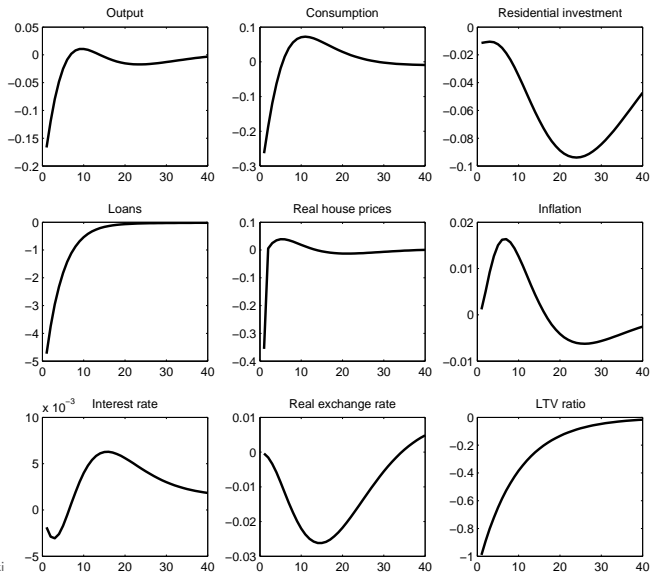
Model features

- Medium-sized two-country New Keynesian model of EA core and periphery with asymmetric shocks and macropru policy
- Build on Kiyotaki and Moore (1997), Iacoviello (2005) and Gerali et. al (2010)
- Financial friction: collateral constraints
- Macroprudential policy tool: loan-to-value ratios (LTV)
- Five types of shocks: productivity, intertemporal preference, housing preference, housing investment specific productivity and monetary policy

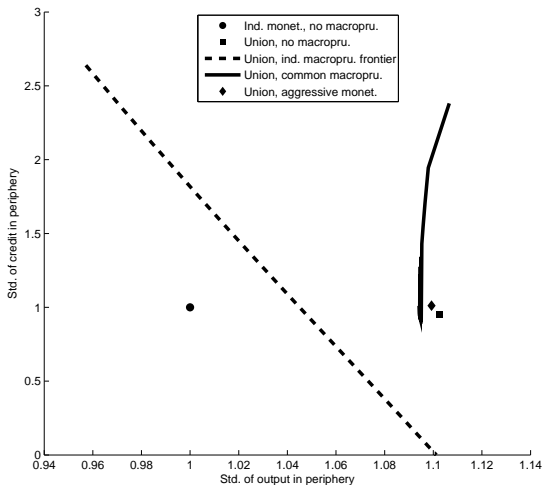
Calibration

- No structural heterogeneity, only in size (periphery = 1%)
- Most parameters (preferences, Calvo, markups, indexation, Taylor etc.) chosen from the literature
- Discount factors $\beta^I = 0.975$, $\beta^P = 0.99$ follow Gerali et. al (2010) and guarantee lending / borrowing of agents near the steady state
- Steady state ratios (e.g. housing/output, resid. inv./output, spreads) to match 1995-2011 averages for the euro area
- Shock properties from the literature or calibrated to match moments of the euro area data
- Shocks are uncorrelated between core and periphery; common monetary shock

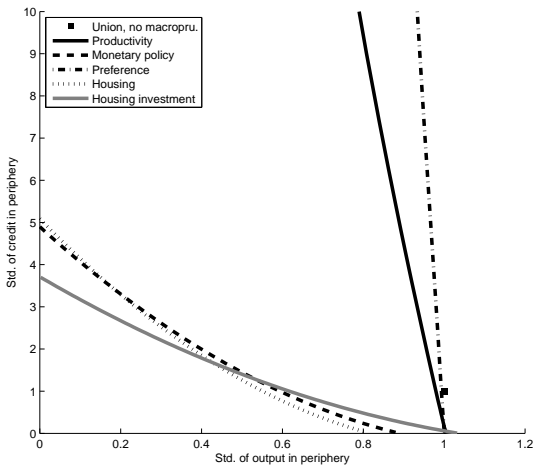
The effects of macroprudential policy



Policy frontiers in periphery (all shocks)



Policy frontier in periphery (shocks separately)



Takeaways

- A heterogenous monetary union does much better when independent macroprudential policy is allowed
- Such policy is particularly efficient in trading off shocks responsible for boom-busts in the EA periphery

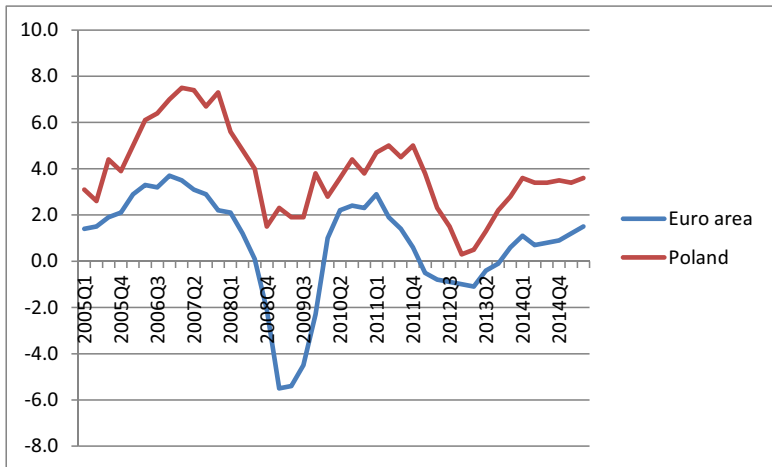
Plan of the Presentation

- 1 Introduction
- 2 The RBC model
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?**
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 Summary

Question

- It is believed that floating exchange rate and independent monetary policy served Poland well during recent financial crisis
- What would have happened if the Polish economy had been deprived of them?

GDP (Y-o-Y)



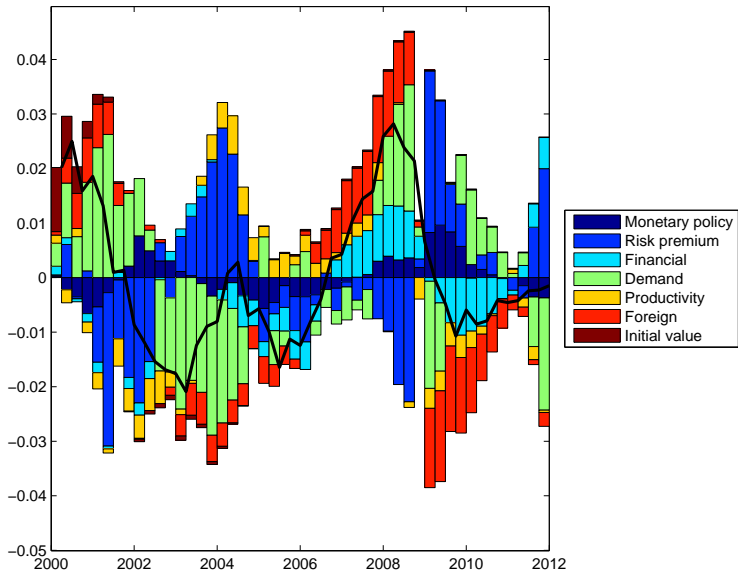
Features of the model

- Standard New Keynesian (NK) model of small open economy with heterogeneous agents, nominal rigidities and Taylor rule.
- Financial frictions in the form of collateral constraints *a la* Kiyotaki and Moore (1997) and Iacoviello (2005) (for households and entrepreneurs)
- Six groups of shocks: monetary policy, risk premium, financial, demand, productivity, foreign.

Data, calibration and estimation

- 13 quarterly series, 10 for Poland, 3 for the euro area (1q2000-4q2011).
- We calibrate the parameters that are well-established in the literature, steady state ratios, and parameters that may be derived from steady state relationships.
- Other parameters are estimated with Bayesian inference.

The role of structural shocks - GDP decomposition



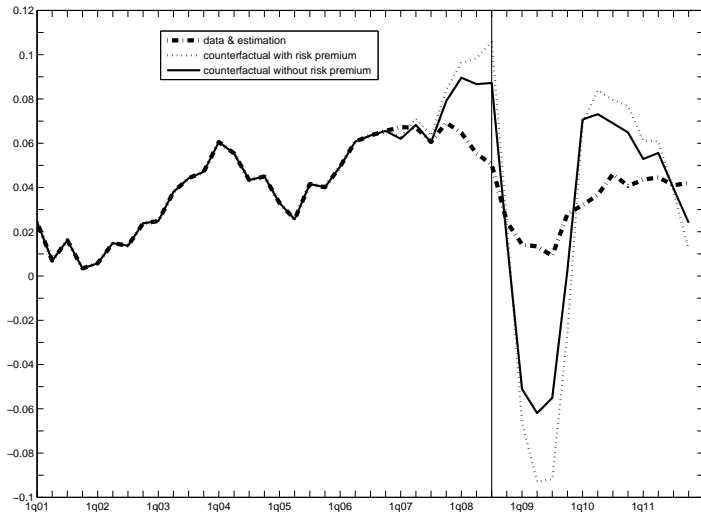
Simulation procedure

- Counterfactual simulations:
- Poland adopted the euro in 1q2007.
- Independent monetary policy is substituted by a rule that fixes the nominal exchange rate of the zloty to the euro:
- As a consequence UIP equation becomes:

$$\hat{R}_t = \hat{R}_t^* + \hat{\rho}_t \quad (1)$$

- Change in domestic monetary policy shock φ_t and the risk premium shock $\varepsilon_{\rho,t}$.
- Two variants of ρ_t

GDP - the euro adoption in 1q2007



Takeaways

- Poland would have been much worse off as part of the eurozone during the 2008-09 crisis
- Main reason - flexible exchange rate (and its depreciation)

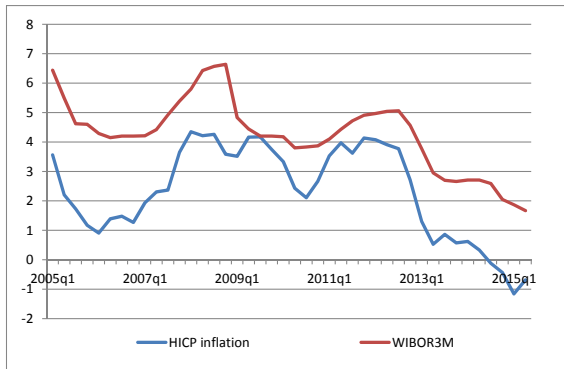
Plan of the Presentation

- 1 Introduction
- 2 The RBC model
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?**
- 7 Summary

Motivation

- Several economies hit recently the ZLB
- This has important consequences for the central bank
- In 1Q2015 Poland faced 1.5% deflation and interest rates o 1.5%
- Several questions emerge:
 - what is the risk of hitting the ZLB?
 - how well does our inflation protect us?
 - what would be the consequences of hitting the ZLB?

Inflation and interest rate



Features of the model

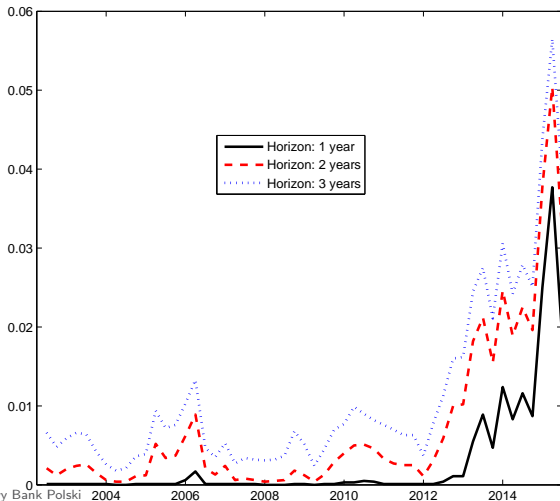
- Medium-sized NK SOE model (Justiniano & Preston with extensions)
- Sticky prices and wages (Calvo)
- Consumption habits, investment adjustment cost
- Local currency pricing
- Monetary policy - Taylor rule with ZLB
- Foreign economy: VAR
- 10 stochastic shocks: technology, government spending, risk premium, monetary, consumption preference, labor supply, investment specific, 3 shocks in foreign VAR

Estimation & solution

- ① Calibration: steady state ratios, some standard parameters (e.g. rate of time preference)
- ② Estimation: remaining parameters
 - ① Bayesian
 - ② Data: 1Q2002-2Q2015
 - ③ PL: GDP, Consumption, Investment, WIBOR3M, Real exchange rate, Real wage, HICP
 - ④ EA: HICP, GDP, Euribor3M
- ③ Solution: piecewise linear solution (Guerrieri & Iacoviello 2015)

Real time ZLB probability (PL)

- Starting every quarter run 10,000 forecasts
 - Calculate ZLB frequency



ZLB episodes conditional on inflation target

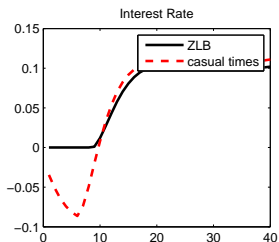
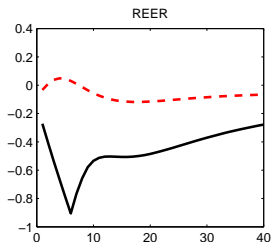
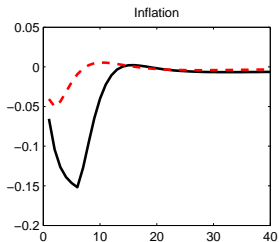
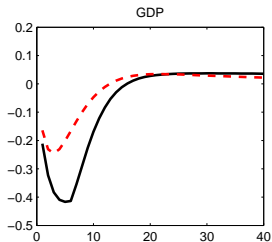
- Stochastic simulations (10,000) initiated at steady state (inflation target for HICP)
- Run until first ZLB episode - calculate distribution of periods until hit

Inflation target	Mean	1st quartile	Median	4th quartile
1,5%	88,7	27	63	122
2,5%	655,8	197	462	903
3,5%	3376,1	983	2331	4672

Modification of impulse responses under the ZLB

- Consider shocks that in normal times would lower the interest rate
- At the ZLB effects of shocks are modified:
 - the exchange rate appreciates
 - GDP and inflation decline by more (increase by less)
- Simulation:
 - long series of negative government spending shocks pushes the economy to the ZLB for 8 periods
 - on this scenario we impose various shocks

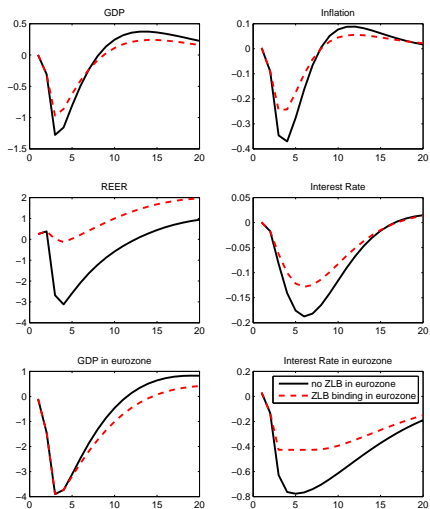
Preference shock



Spillovers from foreign ZLB

- How does the ZLB in the EA affect Poland?
- Simulation: apply shocks identified in EA in 3Q2008-2Q2009
 - ① starting from true state in 3Q2008
 - ② assuming EA interest rate was in steady state in 3Q2008
- First simulation repeats historical experience
- Second leads the EA to the ZLB
- Finding: weaker impact on PL under ZLB in EA
- Reason: exchange rate depreciation outweighs deeper recession in EA

Spillovers from foreign ZLB



Takeaways

- The risk of hitting the ZLB in Poland has been low historically
- Main reasons:
 - high inflation target
 - high natural rate of interest

Plan of the Presentation

- 1 Introduction
- 2 The RBC model
- 3 #1: Monetary and macroprudential policy with foreign currency loans
- 4 #2: Macroprudential policy and imbalances in the euro area
- 5 #3: Would it have paid to be in the eurozone?
- 6 #4: Is Poland at risk of hitting the ZLB?
- 7 **Summary**

Summary

- We use extensively DSGE models for applied research in areas that lack empirical evidence or require strongly counterfactual assumptions
- They provide answers to important policy questions ...
- ... and are publishable ;-)

THANK YOU