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Unemployment Fluctuations and Nominal GDP Targeting*

Roberto M. Billi

Sveriges Riksbank Working Paper Series

No. 385

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Abstract

I evaluate the welfare performance of a target for the *level* of nominal GDP in a New Keynesian model with unemployment, accounting for a zero lower bound (ZLB) constraint on the nominal interest rate. Nominal GDP targeting is compared to employment targeting, a conventional Taylor rule, and the optimal monetary policy with commitment. I find that employment targeting is optimal when supply shocks are the source of fluctuations; however, facing demand shocks and the ZLB constraint, nominal GDP targeting can outperform substantially employment targeting.

Keywords: employment targeting, optimal monetary policy, Taylor rule, ZLB

JEL: E24, E32, E52

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1 Introduction

The standard New Keynesian model with staggered price and wage setting allows for unemployment to play a role in the design of monetary policy, while taking into account a zero lower bound (ZLB) constraint on the nominal interest rate.¹ Facing the ZLB, a target for the *level* of nominal GDP is conceptually appealing, as argued by Woodford (2012) and others, because it requires monetary policy to make up for any past shortfalls from the target, which ensures greater policy stimulus during ZLB episodes. Disregarding the ZLB constraint, however, another perspective, since Erceg et al. (2000), is that central banks could seek to stabilize the output *gap* in order to promote stability in price and wage inflation, and contribute to greater social welfare.

In light of such views, I compare the welfare performance of nominal GDP targeting relative to employment targeting, as well as to a conventional Taylor rule (used to calibrate the model) and the optimal monetary policy with commitment (representing an ideal benchmark). This policy evaluation provides two main results, related to whether demand or technology shocks are the source of fluctuations in the economy. First, if supply shocks drive fluctuations, employment targeting improves welfare relative to nominal GDP targeting, and achieves the same welfare as the optimal policy with commitment. This finding complements related analysis, for example Garín et al. (2016), which does not account for the ZLB constraint.² As a second result, conditional on demand shocks driving fluctuations and facing the ZLB, nominal GDP targeting outperforms substantially employment targeting and the Taylor rule, in particular when prices are sticky relative to wages. This insight is novel relative to the existing literature.

Next, Section 2 describes the model environment, and Section 3 presents the policy evaluation.

2 The Model

The analysis uses a version of the New Keynesian model with staggered price and wage setting à la Calvo, and with unemployment fluctuations, as proposed in Galí (2011, 2015). The model is augmented with a ZLB constraint on the short-term nominal interest rate, and four monetary-policy

¹I adopt the standard practice of referring to a zero lower bound on nominal interest rates. The recent experience with negative nominal interest rates in Denmark, Japan, Sweden, Switzerland, and the eurozone suggests the effective lower bound is somewhat below zero. See Svensson (2010) for a discussion.

²Erceg et al. (2000) and Garín et al. (2016) discuss the notion of output *gap* targeting. In this model, however, the output *gap* is proportional to the employment *gap* (Section 2.1) and, therefore, whether the central bank seeks to stabilize one or the other variable does not affect the results presented.

frameworks are considered. The calibration of the model is standard.

2.1 Private Sector

The behavior of the private sector is described by a set of equilibrium conditions, which correspond to a closed economy version of the New Keynesian model with staggered price and wage setting, without capital accumulation or a fiscal sector.³

The supply side of the economy is described by the following equations representing the dynamics of price and wage inflation, π_t^p and π_t^w , and the labor market conditions:

$$\pi_t^p = \beta E_t \{ \pi_{t+1}^p \} + \varkappa_p \tilde{y}_t + \lambda_p \tilde{\omega}_t \quad (1)$$

$$\pi_t^w = \beta E_t \{ \pi_{t+1}^w \} + \varkappa_w \tilde{y}_t - \lambda_w \tilde{\omega}_t \quad (2)$$

$$\tilde{\omega}_t \equiv \tilde{\omega}_{t-1} + \pi_t^w - \pi_t^p - \Delta \omega_t^n \quad (3)$$

$$n_t = \frac{1}{1-\alpha} (y_t - a_t) \quad (4)$$

$$\hat{u}_t \equiv \frac{1}{\varphi} \left(\tilde{\omega}_t - \left(\sigma + \frac{\varphi}{1-\alpha} \right) \tilde{y}_t \right), \quad (5)$$

where $\tilde{y}_t \equiv y_t - y_t^n$ and $\tilde{\omega}_t \equiv \omega_t - \omega_t^n$ denote respectively the output and wage *gaps*, with $y_t^n \equiv \psi_{ya} a$ and $\omega_t^n \equiv \psi_{\omega a} a_t$ representing the (log) *natural* output and (log) *natural* wage (i.e. their equilibrium values in the absence of nominal rigidities) ignoring constant terms. a_t is an exogenous technology shifter which follows an $AR(1)$ process with autoregressive coefficient ρ_a . n_t denotes employment. The employment *gap* is then given by $\tilde{n}_t \equiv n_t - n_t^n = \frac{1}{1-\alpha} \tilde{y}_t$ and is proportional to the output *gap*. $\hat{u}_t \equiv u_t - u^n$ denotes the unemployment *gap*, with $u^n \equiv \frac{1}{\varphi} \log \left(\frac{\epsilon_w}{\epsilon_w - 1} \right)$ representing the *natural* rate of unemployment which is constant due to the assumption of a constant desired wage markup.

In addition, $\varkappa_p \equiv \frac{\alpha \lambda_p}{1-\alpha}$, $\varkappa_w \equiv \lambda_w \left(\sigma + \frac{\varphi}{1-\alpha} \right)$, $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p} \frac{1-\alpha}{1-\alpha+\alpha\epsilon_p}$, $\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$, $\psi_{ya} \equiv \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$ and $\psi_{\omega a} \equiv \frac{1-\alpha\psi_{ya}}{1-a}$, where $\theta_p \in [0, 1)$ and $\theta_w \in [0, 1)$ are the Calvo indexes of price and wage rigidities, and $\epsilon_p > 1$ and $\epsilon_w > 1$ denote the elasticities of substitution among varieties of goods and labor services, respectively. Parameters σ , φ and β denote the household's coefficient of

³All the equations are log-linearized around a steady state with zero price and wage inflation, and with a wage subsidy that exactly offsets the distortions resulting from price and wage markups. In particular, equations (4) and (5) result from a reinterpretation of the labor market in the model with staggered wage setting, where employment is demand determined, labor demand is given by the inverse production function, and unemployment fluctuation are associated with variation in the average wage markup. Galí (2015) provides the detailed derivations of these equations, as well as a complete analysis of the model in the absence of the ZLB constraint.

relative risk aversion, the curvature of labor disutility and the discount factor, respectively. Parameter α denotes the degree of decreasing returns to labor in production.

The demand side of the economy is described by a dynamic IS equation:

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{1}{\sigma} (i_t - E_t\{\pi_{t+1}^p\} - r_t^n), \quad (6)$$

where i_t is the nominal interest rate, and r_t^n represents the *natural* rate of interest. Under the assumptions made and ignoring constant terms $r_t^n \equiv \rho - \sigma(1 - \rho_a)\psi_{y_a}a_t + (1 - \rho_z)z_t$, where $\rho \equiv -\log \beta$ is the discount rate. z_t is an exogenous preference shifter (or demand shock) which follows an *AR*(1) process with autoregressive coefficient ρ_z .

2.2 Monetary Policy

The analysis considers four monetary-policy frameworks, subject to a ZLB constraint on the nominal interest rate. The first framework is a "truncated" Taylor rule given by:

$$i_t = \max[0, i_t^*],$$

where

$$i_t^* = \phi_i i_{t-1}^* + (1 - \phi_i) (\rho + \phi_p \pi_t^p - \phi_u \hat{u}_t).$$

This rule, which incorporates explicitly the ZLB, can be viewed as capturing in a parsimonious way the behavior of central banks in many advanced economies. i_t^* can be interpreted as a *shadow* interest rate in that context.⁴

The second framework is a target for the employment *gap*:

$$\tilde{n}_t i_t = 0 \quad \text{subject to} \quad \tilde{n}_t \leq 0 \text{ and } i_t \geq 0,$$

where the central bank seeks to stabilize the employment *gap* (or the output *gap*, equivalently), while employment can fall below its *natural* rate when the ZLB constraint is binding.

⁴This specification of the rule for the shadow rate, which makes the latter a function of its own lag (as opposed to the lag of the actual policy rate) implies a kind of "forward guidance" that may compensate partly for the lost monetary stimulus due to the presence of a ZLB constraint.

The third framework is a target for the nominal GDP *level*:

$$h_t i_t = 0 \quad \text{subject to} \quad h_t \leq 0 \text{ and } i_t \geq 0,$$

where $h_t \equiv p_t + y_t$ denotes the (log) *level* of nominal GDP, and $p_t \equiv p_{t-1} + \pi_t^p$ is the (log) price level. Thus, the nominal GDP *level* can fall below its target (or *trend*) if the ZLB binds.

The fourth framework is the optimal policy under commitment with a ZLB constraint. It is a state-contingent plan that maximizes the representative household's welfare, subject to an infinite sequence of private-sector constraints given by (1) through (6), and $i_t \geq 0$, for $t = 0, 1, 2, \dots$. This problem is shown formally in the Appendix and gives rise to a set of difference equations which, together with (1) to (6), describe the equilibrium under the optimal policy.

2.3 Calibration

The model's calibration is conventional and largely follows Galí (2015). The discount factor β is set to 0.995 so the steady-state real interest rate is 2 percent annual. I set $\sigma = 1$, $\varphi = 5$ and $\alpha = 0.25$. Elasticity of substitution parameters ϵ_p and ϵ_w are set respectively to 9 and 4.5.⁵ I set $\theta_p = \theta_w = 0.75$, consistent with an average duration of price and wage spells of one year. I use the Taylor rule coefficients in Galí (2015), i.e. $\phi_p = 1.5$ and $\phi_u = 0.5$. The smoothing coefficient ϕ_i is set to 0.8, close to the estimates in Galí et al. (2011) and others.

In addition, the autoregressive coefficient of the shocks ρ_a and ρ_z are set respectively to 0.97 and 0.8, close to the values in Garín et al. (2016). The standard deviation of the shocks σ_a and σ_z are set respectively to 0.017 and 0.048 so that, conditional on only technology or demand shocks being the source of fluctuations, the Taylor rule with ZLB imposed generates a standard deviation of (log) output of 1.6 percent. The latter value matches the volatility of HP-detrended (log) real GDP in postwar U.S. data.⁶

3 The Policy Evaluation

I now present the predictions of the model regarding the performance of the four monetary-policy frameworks, with or without the ZLB constraint imposed. I first show the dynamics arising from

⁵This calibration is consistent with an average unemployment rate of 5 percent as in Galí (2015).

⁶Data source <https://fred.stlouisfed.org/series/GDPC1>.

shifts in either technology or preferences, and then provide a welfare analysis conditional on each type of shock.⁷

3.1 Response to Shocks and the ZLB Constraint

Shown are the impulse responses of the unemployment and output *gaps*, price inflation, and nominal interest rate, all in deviation from steady state.⁸ Figure 1 displays the responses to a *positive* technology shock, with a size of one standard deviation. When productivity increases, inflation falls in all the frameworks considered, whereas the response of unemployment depends on the framework in place. The unemployment *gap* is fully stabilized under the employment target and the optimal policy, but falls under the Taylor rule because the central bank leans against the deflationary pressure. The unemployment and output *gaps* generally move in opposite directions. The nominal interest rate stays fixed under the nominal GDP target, because such a framework requires that after a technology shock the price level and output move in opposite directions by the same amount.⁹ The nominal interest rate falls the most under the Taylor rule, nevertheless the ZLB is not reached facing the technology shock.

Figures 2 and 3 display the responses to a *negative* demand shock, respectively without or with the ZLB imposed. The size of the shock is one standard deviation, and on impact it raises unemployment by 5 percent above its *natural* rate under the Taylor rule with the ZLB. As Figure 2 shows, if the ZLB is absent, unemployment rises and inflation falls under the Taylor rule. By contrast, unemployment and inflation are fully stabilized under the employment target, nominal GDP target, and optimal policy. However, to achieve full stability in such frameworks, the nominal interest rate has to fall below the ZLB. As Figure 3 shows, with the ZLB imposed, unemployment rises and inflation falls on impact in all the frameworks considered. Furthermore, with the optimal policy, unemployment undershoots and inflation overshoots during the recovery, because the nominal interest rate stays longer at the ZLB, relative to the other frameworks considered.

⁷The model outcomes are obtained with Dynare using an extended-path method. Replication files are available from the author upon request.

⁸In the figures, the unemployment and output *gaps* are shown in percentage points (pp) while the inflation rate and nominal interest rate are shown in percent annualized (pa).

⁹Furthermore the parameter σ is set to 1, which implies a slope of unity in the dynamic IS equation.

3.2 Nominal Rigidities, the ZLB Constraint, and Welfare

I use as a welfare metric the second-order approximation of the average welfare loss experienced by the representative household as a result of fluctuations around an efficient, zero-inflation steady state, expressed as a fraction of steady-state consumption. Such a welfare loss function can be written as:

$$\mathbb{L} = \frac{1}{2} \left[\left(\sigma + \frac{\varphi + \alpha}{1 - \alpha} \right) var(\tilde{y}_t) + \frac{\epsilon_p}{\lambda_p} var(\pi_t^p) + \frac{\epsilon_w(1 - \alpha)}{\lambda_w} var(\pi_t^w) \right],$$

where the welfare loss has three components, respectively associated with the volatilities in the output *gap*, price inflation, and wage inflation.¹⁰ Tables 1 and 2 illustrate the effects of price and wage rigidities on the (total) welfare loss, \mathbb{L} , conditional on either technology or demand shocks driving fluctuations. Each table reports the outcomes with or without the ZLB imposed, respectively in the top and bottom panels.

Table 1 shows the welfare loss conditional on only technology shocks. Facing such shocks, the ZLB does not bind in any of the frameworks considered.¹¹ If prices and wages are rigid (first column), the nominal GDP target is the least effective framework in terms of welfare, because as explained earlier the nominal interest rate stays fixed in response to technology shocks. However, the employment target achieves the same welfare as the optimal policy. What if either prices or wages are fully flexible in the model? If prices are flexible (second column), all the frameworks considered become more effective in welfare terms, and only the Taylor rule does not fully stabilize the economy. But if wages are flexible (third column), the nominal GDP target is the only framework considered that becomes less effective in welfare terms. The reason is that, when the nominal interest rate stays fixed, wage flexibility causes greater variation in price inflation (not shown) in the face of technology shocks. Overall, regarding technology shocks, these results are consistent with Garín et al. (2016).

Next, Table 2 reports the welfare loss conditional on only demand shocks. Facing demand shocks, with or without the ZLB, the Taylor rule is the least effective framework in welfare terms. Absent the ZLB (bottom panel), and regardless of whether prices or wages are flexible, the economy is fully stabilized under the employment target, nominal GDP target, and optimal policy. However, with the ZLB imposed (top panel), all the frameworks considered become less effective in welfare terms because the ZLB binds. Facing the ZLB, what do the nominal rigidities imply for the performance of

¹⁰See Galí (2015) for the derivation. Parameters θ_p and θ_w enter the welfare loss function respectively through λ_p and λ_w , to which they are inversely related. Thus, if price are fully flexible then $var(\pi_t^p)$ is irrelevant for welfare, whereas if wages are fully flexible then $var(\pi_t^w)$ is irrelevant for welfare.

¹¹Thus, the top and bottom panels of this table display identical outcomes.

the frameworks? If prices and wages are rigid (first column), the nominal GDP target outperforms the employment target in welfare terms. If prices are flexible (second column), all the frameworks considered become more effective in welfare terms, and the nominal GDP target achieves the same welfare as the optimal policy. But if wages are flexible (third column), all the frameworks become less effective in welfare terms. The reason is that, facing demand shocks and the ZLB, wage flexibility causes greater variation in price inflation (not shown). Furthermore, the deterioration in welfare from wage flexibility is substantially larger under the employment target and the Taylor rule. In summary, after taking into account the ZLB constraint, the nominal GDP target outperforms substantially the employment target and the Taylor rule, in particular when prices are sticky relative to wages.

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APPENDIX: Optimal Policy under Commitment with a ZLB Constraint

The problem of optimal policy with commitment is given by

$$\min \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\sigma + \frac{\varphi + \alpha}{1 - \alpha} \right) \tilde{y}_t^2 + \frac{\epsilon_p}{\lambda_p} (\pi_t^p)^2 + \frac{\epsilon_w(1 - \alpha)}{\lambda_w} (\pi_t^w)^2 \right],$$

subject to (1)-(6) and $i_t \geq 0$.

Write the period Lagrangian

$$\begin{aligned} L_t = & \frac{1}{2} \left[\left(\sigma + \frac{\varphi + \alpha}{1 - \alpha} \right) \tilde{y}_t^2 + \frac{\epsilon_p}{\lambda_p} (\pi_t^p)^2 + \frac{\epsilon_w(1 - \alpha)}{\lambda_w} (\pi_t^w)^2 \right] + \beta E_t V_{t+1} \\ & + m_{1t} \left[y_t + \frac{1}{\sigma} (i_t - \rho - (1 - \rho_z) z_t) \right] - \frac{1}{\beta} m_{1t-1} \left(y_t + \frac{1}{\sigma} \pi_t^p \right) \\ & + m_{2t} (\pi_t^p - \varkappa_p \tilde{y}_t - \lambda_p \tilde{\omega}_t) - m_{2t-1} \pi_t^p \\ & + m_{3t} (\pi_t^w - \varkappa_w \tilde{y}_t + \lambda_w \tilde{\omega}_t) - m_{3t-1} \pi_t^w \\ & + m_{4t} (\omega_t - \omega_{t-1} - \pi_t^w + \pi_t^p). \end{aligned}$$

The Kuhn-Tucker conditions are

$$0 = \frac{\partial L_t}{\partial y_t} = \left(\sigma + \frac{\varphi + \alpha}{1 - \alpha} \right) \tilde{y}_t + m_{1t} - \frac{1}{\beta} m_{1t-1} - \varkappa_p m_{2t} - \varkappa_w m_{3t} \quad (7)$$

$$0 = \frac{\partial L_t}{\partial \pi_t^p} = \frac{\epsilon_p}{\lambda_p} \pi_t^p - \frac{1}{\beta \sigma} m_{1t-1} + m_{2t} - m_{2t-1} + m_{4t} \quad (8)$$

$$0 = \frac{\partial L_t}{\partial \pi_t^w} = \frac{\epsilon_w(1 - \alpha)}{\lambda_w} \pi_t^w + m_{3t} - m_{3t-1} - m_{4t} \quad (9)$$

$$0 = \frac{\partial L_t}{\partial \omega_t} = \frac{\partial \beta E_t V_{t+1}}{\partial \omega_t} - \lambda_p m_{2t} + \lambda_w m_{3t} + m_{4t} \quad (10)$$

$$0 = \frac{\partial L_t}{\partial i_t} i_t = \frac{1}{\sigma} m_{1t} i_t, \quad m_{1t} \geq 0 \text{ and } i_t \geq 0, \quad (11)$$

whereas the envelope condition gives

$$\frac{\partial \beta E_t V_{t+1}}{\partial \omega_t} = -\beta E_t m_{4t+1}.$$

The equilibrium conditions under the optimal policy are then given by (1)-(11).

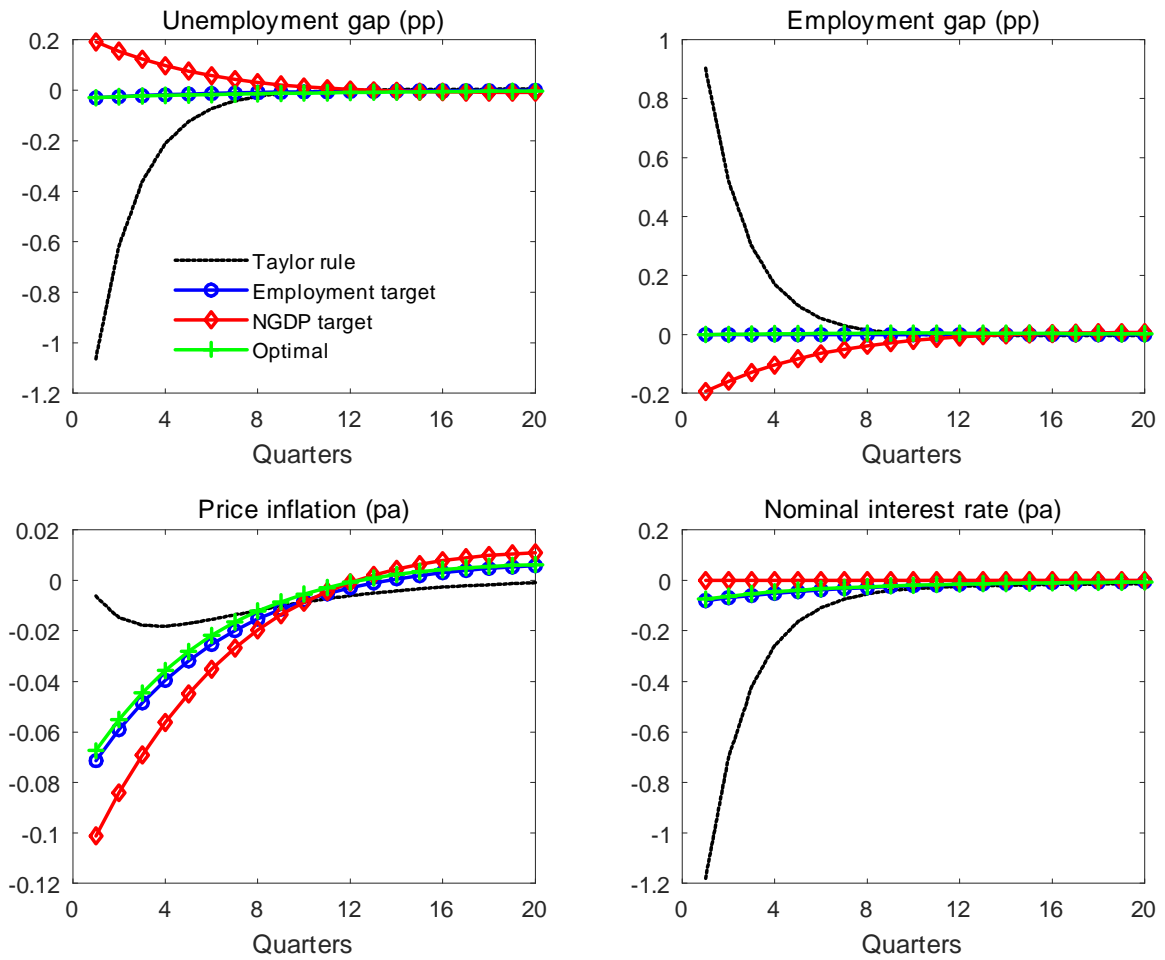


Figure 1: Responses to technology shock, ZLB not reached.

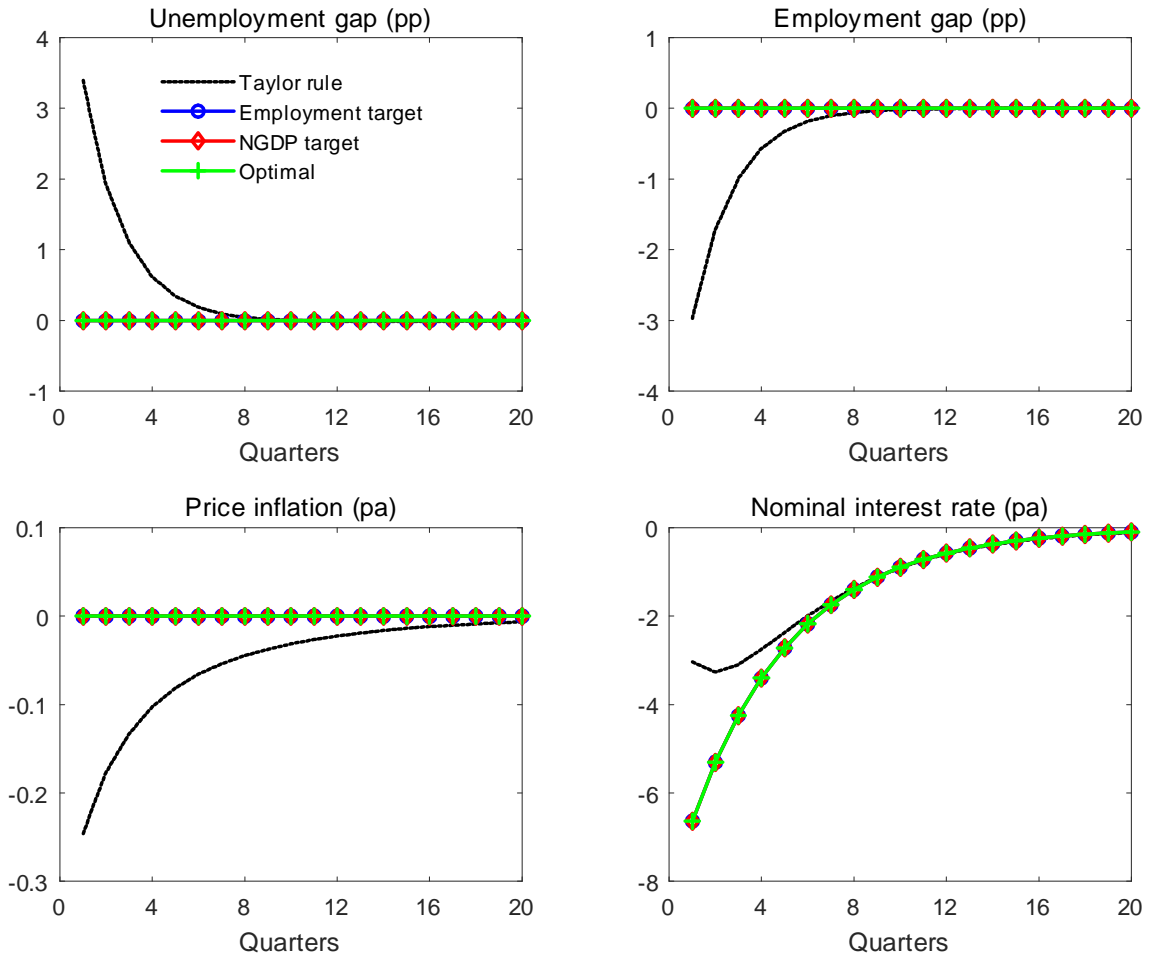


Figure 2: Responses to demand shock if ZLB absent.

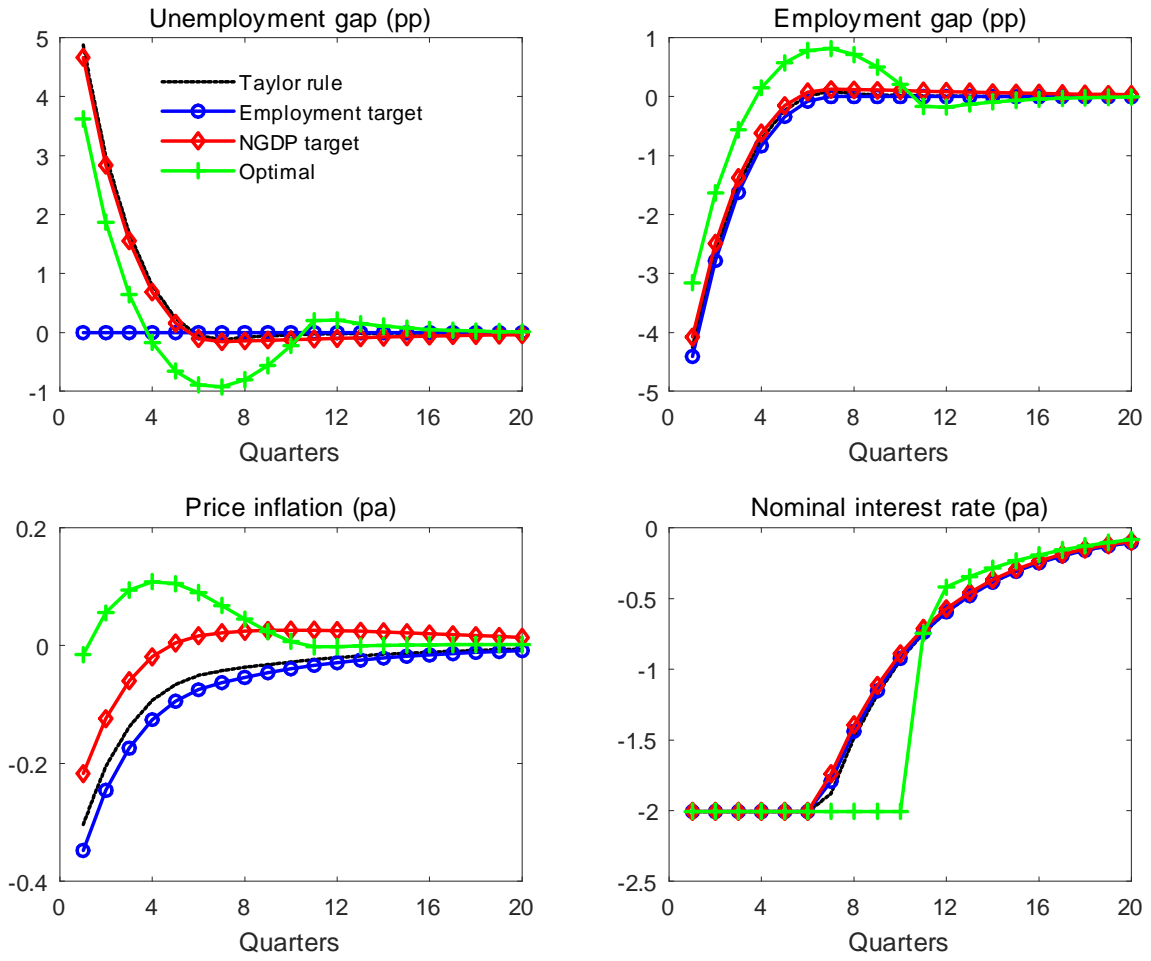


Figure 3: Responses to demand shock during ZLB episode.

Table 1: Welfare loss if technology shocks.

	$\theta_p = 0.75$	$\theta_p \approx 0$	$\theta_p = 0.75$
	$\theta_w = 0.75$	$\theta_w = 0.75$	$\theta_w \approx 0$
ZLB			
Taylor rule	0.03	0.01	0.02
Employment target	0.01	0.00	0.00
NGDP target	0.05	0.00	0.07
Optimal	0.01	0.00	0.00
No ZLB			
Taylor rule	0.03	0.01	0.02
Employment target	0.01	0.00	0.00
NGDP target	0.05	0.00	0.07
Optimal	0.01	0.00	0.00

Note: Shown is the permanent consumption loss in percentage points.

Table 2: Welfare loss if demand shocks.

	$\theta_p = 0.75$	$\theta_p \approx 0$	$\theta_p = 0.75$
	$\theta_w = 0.75$	$\theta_w = 0.75$	$\theta_w \approx 0$
ZLB			
Taylor rule	0.15	0.10	1.68
Employment target	0.11	0.05	1.26
NGDP target	0.06	0.03	0.09
Optimal	0.05	0.03	0.07
No ZLB			
Taylor rule	0.09	0.07	1.27
Employment target	0.00	0.00	0.00
NGDP target	0.00	0.00	0.00
Optimal	0.00	0.00	0.00

Note: Shown is the permanent consumption loss in percentage points.

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Monetary Policy and Staggered Wage Bargaining when Prices are Sticky <i>by Mikael Carlsson and Andreas Westermark</i>	2006:199
The Swedish External Position and the Krona <i>by Philip R. Lane</i>	2006:200

Price Setting Transactions and the Role of Denominating Currency in FX Markets <i>by Richard Friberg and Fredrik Wilander</i>	2007:201
The geography of asset holdings: Evidence from Sweden <i>by Nicolas Coeurdacier and Philippe Martin</i>	2007:202
Evaluating An Estimated New Keynesian Small Open Economy Model <i>by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani</i>	2007:203
The Use of Cash and the Size of the Shadow Economy in Sweden <i>by Gabriela Guibourg and Björn Segendorf</i>	2007:204
Bank supervision Russian style: Evidence of conflicts between micro- and macro-prudential concerns <i>by Sophie Claeys and Koen Schoors</i>	2007:205
Optimal Monetary Policy under Downward Nominal Wage Rigidity <i>by Mikael Carlsson and Andreas Westermark</i>	2007:206
Financial Structure, Managerial Compensation and Monitoring <i>by Vittoria Cerasi and Sonja Daltung</i>	2007:207
Financial Frictions, Investment and Tobin's q <i>by Guido Lorenzoni and Karl Walentin</i>	2007:208
Sticky Information vs Sticky Prices: A Horse Race in a DSGE Framework <i>by Mathias Trabandt</i>	2007:209
Acquisition versus greenfield: The impact of the mode of foreign bank entry on information and bank lending rates <i>by Sophie Claeys and Christa Hainz</i>	2007:210
Nonparametric Regression Density Estimation Using Smoothly Varying Normal Mixtures <i>by Mattias Villani, Robert Kohn and Paolo Giordani</i>	2007:211
The Costs of Paying – Private and Social Costs of Cash and Card <i>by Mats Bergman, Gabriella Guibourg and Björn Segendorf</i>	2007:212
Using a New Open Economy Macroeconomics model to make real nominal exchange rate forecasts <i>by Peter Sellin</i>	2007:213
Introducing Financial Frictions and Unemployment into a Small Open Economy Model <i>by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin</i>	2007:214
Earnings Inequality and the Equity Premium <i>by Karl Walentin</i>	2007:215
Bayesian forecast combination for VAR models <i>by Michael K. Andersson and Sune Karlsson</i>	2007:216
Do Central Banks React to House Prices? <i>by Daria Finocchiaro and Virginia Queijo von Heideken</i>	2007:217
The Riksbank's Forecasting Performance <i>by Michael K. Andersson, Gustav Karlsson and Josef Svensson</i>	2007:218
Macroeconomic Impact on Expected Default Frequency <i>by Per Åsberg and Hovick Shahnazarian</i>	2008:219
Monetary Policy Regimes and the Volatility of Long-Term Interest Rates <i>by Virginia Queijo von Heideken</i>	2008:220
Governing the Governors: A Clinical Study of Central Banks <i>by Lars Frisell, Kasper Roszbach and Giancarlo Spagnolo</i>	2008:221
The Monetary Policy Decision-Making Process and the Term Structure of Interest Rates <i>by Hans Dillén</i>	2008:222
How Important are Financial Frictions in the U S and the Euro Area <i>by Virginia Queijo von Heideken</i>	2008:223
Block Kalman filtering for large-scale DSGE models <i>by Ingvar Strid and Karl Walentin</i>	2008:224
Optimal Monetary Policy in an Operational Medium-Sized DSGE Model <i>by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson</i>	2008:225
Firm Default and Aggregate Fluctuations <i>by Tor Jacobson, Rikard Kindell, Jesper Lindé and Kasper Roszbach</i>	2008:226
Re-Evaluating Swedish Membership in EMU: Evidence from an Estimated Model <i>by Ulf Söderström</i>	2008:227

The Effect of Cash Flow on Investment: An Empirical Test of the Balance Sheet Channel <i>by Ola Melander</i>	2009:228
Expectation Driven Business Cycles with Limited Enforcement <i>by Karl Walentin</i>	2009:229
Effects of Organizational Change on Firm Productivity <i>by Christina Håkanson</i>	2009:230
Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost <i>by Mikael Carlsson and Oskar Nordström Skans</i>	2009:231
Monetary Policy Trade-Offs in an Estimated Open-Economy DSGE Model <i>by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson</i>	2009:232
Flexible Modeling of Conditional Distributions Using Smooth Mixtures of Asymmetric Student T Densities <i>by Feng Li, Mattias Villani and Robert Kohn</i>	2009:233
Forecasting Macroeconomic Time Series with Locally Adaptive Signal Extraction <i>by Paolo Giordani and Mattias Villani</i>	2009:234
Evaluating Monetary Policy <i>by Lars E. O. Svensson</i>	2009:235
Risk Premiums and Macroeconomic Dynamics in a Heterogeneous Agent Model <i>by Ferre De Graeve, Maarten Dossche, Marina Emiris, Henri Sneessens and Raf Wouters</i>	2010:236
Picking the Brains of MPC Members <i>by Mikael Apel, Carl Andreas Claussen and Petra Lennartsdotter</i>	2010:237
Involuntary Unemployment and the Business Cycle <i>by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin</i>	2010:238
Housing collateral and the monetary transmission mechanism <i>by Karl Walentin and Peter Sellin</i>	2010:239
The Discursive Dilemma in Monetary Policy <i>by Carl Andreas Claussen and Øistein Røisland</i>	2010:240
Monetary Regime Change and Business Cycles <i>by Vasco Cúrdia and Daria Finocchiaro</i>	2010:241
Bayesian Inference in Structural Second-Price common Value Auctions <i>by Bertil Wegmann and Mattias Villani</i>	2010:242
Equilibrium asset prices and the wealth distribution with inattentive consumers <i>by Daria Finocchiaro</i>	2010:243
Identifying VARs through Heterogeneity: An Application to Bank Runs <i>by Ferre De Graeve and Alexei Karas</i>	2010:244
Modeling Conditional Densities Using Finite Smooth Mixtures <i>by Feng Li, Mattias Villani and Robert Kohn</i>	2010:245
The Output Gap, the Labor Wedge, and the Dynamic Behavior of Hours <i>by Luca Sala, Ulf Söderström and Antonella Trigari</i>	2010:246
Density-Conditional Forecasts in Dynamic Multivariate Models <i>by Michael K. Andersson, Stefan Palmqvist and Daniel F. Waggoner</i>	2010:247
Anticipated Alternative Policy-Rate Paths in Policy Simulations <i>by Stefan Laséen and Lars E. O. Svensson</i>	2010:248
MOSES: Model of Swedish Economic Studies <i>by Gunnar Bårdsen, Ard den Reijer, Patrik Jonasson and Ragnar Nymoén</i>	2011:249
The Effects of Endogenous Firm Exit on Business Cycle Dynamics and Optimal Fiscal Policy <i>by Lauri Vilmi</i>	2011:250
Parameter Identification in a Estimated New Keynesian Open Economy Model <i>by Malin Adolfson and Jesper Lindé</i>	2011:251
Up for count? Central bank words and financial stress <i>by Marianna Blix Grimaldi</i>	2011:252
Wage Adjustment and Productivity Shocks <i>by Mikael Carlsson, Julián Messina and Oskar Nordström Skans</i>	2011:253

Stylized (Arte) Facts on Sectoral Inflation <i>by Ferre De Graeve and Karl Walentin</i>	2011:254
Hedging Labor Income Risk <i>by Sebastien Betermier, Thomas Jansson, Christine A. Parlour and Johan Walden</i>	2011:255
Taking the Twists into Account: Predicting Firm Bankruptcy Risk with Splines of Financial Ratios <i>by Paolo Giordani, Tor Jacobson, Erik von Schedvin and Mattias Villani</i>	2011:256
Collateralization, Bank Loan Rates and Monitoring: Evidence from a Natural Experiment <i>by Geraldo Cerqueiro, Steven Ongena and Kasper Roszbach</i>	2012:257
On the Non-Exclusivity of Loan Contracts: An Empirical Investigation <i>by Hans Degryse, Vasso Ioannidou and Erik von Schedvin</i>	2012:258
Labor-Market Frictions and Optimal Inflation <i>by Mikael Carlsson and Andreas Westermark</i>	2012:259
Output Gaps and Robust Monetary Policy Rules <i>by Roberto M. Billi</i>	2012:260
The Information Content of Central Bank Minutes <i>by Mikael Apel and Marianna Blix Grimaldi</i>	2012:261
The Cost of Consumer Payments in Sweden <i>by Björn Segendorf and Thomas Jansson</i>	2012:262
Trade Credit and the Propagation of Corporate Failure: An Empirical Analysis <i>by Tor Jacobson and Erik von Schedvin</i>	2012:263
Structural and Cyclical Forces in the Labor Market During the Great Recession: Cross-Country Evidence <i>by Luca Sala, Ulf Söderström and Antonella Trigari</i>	2012:264
Pension Wealth and Household Savings in Europe: Evidence from SHARELIFE <i>by Rob Alessie, Viola Angelini and Peter van Santen</i>	2013:265
Long-Term Relationship Bargaining <i>by Andreas Westermark</i>	2013:266
Using Financial Markets To Estimate the Macro Effects of Monetary Policy: An Impact-Identified FAVAR* <i>by Stefan Pitschner</i>	2013:267
DYNAMIC MIXTURE-OF-EXPERTS MODELS FOR LONGITUDINAL AND DISCRETE-TIME SURVIVAL DATA <i>by Matias Quiroz and Mattias Villani</i>	2013:268
Conditional euro area sovereign default risk <i>by André Lucas, Bernd Schwaab and Xin Zhang</i>	2013:269
Nominal GDP Targeting and the Zero Lower Bound: Should We Abandon Inflation Targeting?*	2013:270
<i>by Roberto M. Billi</i>	
Un-truncating VARs* <i>by Ferre De Graeve and Andreas Westermark</i>	2013:271
Housing Choices and Labor Income Risk <i>by Thomas Jansson</i>	2013:272
Identifying Fiscal Inflation* <i>by Ferre De Graeve and Virginia Queijo von Heideken</i>	2013:273
On the Redistributive Effects of Inflation: an International Perspective* <i>by Paola Boel</i>	2013:274
Business Cycle Implications of Mortgage Spreads* <i>by Karl Walentin</i>	2013:275
Approximate dynamic programming with post-decision states as a solution method for dynamic economic models <i>by Isaiah Hull</i>	2013:276
A detrimental feedback loop: deleveraging and adverse selection <i>by Christoph Bertsch</i>	2013:277
Distortionary Fiscal Policy and Monetary Policy Goals <i>by Klaus Adam and Roberto M. Billi</i>	2013:278
Predicting the Spread of Financial Innovations: An Epidemiological Approach <i>by Isaiah Hull</i>	2013:279
Firm-Level Evidence of Shifts in the Supply of Credit <i>by Karolina Holmberg</i>	2013:280

Lines of Credit and Investment: Firm-Level Evidence of Real Effects of the Financial Crisis <i>by Karolina Holmberg</i>	2013:281
A wake-up call: information contagion and strategic uncertainty <i>by Toni Ahnert and Christoph Bertsch</i>	2013:282
Debt Dynamics and Monetary Policy: A Note <i>by Stefan Laséen and Ingvar Strid</i>	2013:283
Optimal taxation with home production <i>by Conny Olovsson</i>	2014:284
Incompatible European Partners? Cultural Predispositions and Household Financial Behavior <i>by Michael Haliassos, Thomas Jansson and Yigitcan Karabulut</i>	2014:285
How Subprime Borrowers and Mortgage Brokers Shared the Piecial Behavior <i>by Antje Berndt, Burton Hollifield and Patrik Sandås</i>	2014:286
The Macro-Financial Implications of House Price-Indexed Mortgage Contracts <i>by Isaiah Hull</i>	2014:287
Does Trading Anonymously Enhance Liquidity? <i>by Patrick J. Dennis and Patrik Sandås</i>	2014:288
Systematic bailout guarantees and tacit coordination <i>by Christoph Bertsch, Claudio Calcagno and Mark Le Quement</i>	2014:289
Selection Effects in Producer-Price Setting <i>by Mikael Carlsson</i>	2014:290
Dynamic Demand Adjustment and Exchange Rate Volatility <i>by Vesna Corbo</i>	2014:291
Forward Guidance and Long Term Interest Rates: Inspecting the Mechanism <i>by Ferre De Graeve, Pelin Ilbas & Raf Wouters</i>	2014:292
Firm-Level Shocks and Labor Adjustments <i>by Mikael Carlsson, Julián Messina and Oskar Nordström Skans</i>	2014:293
A wake-up call theory of contagion <i>by Toni Ahnert and Christoph Bertsch</i>	2015:294
Risks in macroeconomic fundamentals and excess bond returns predictability <i>by Rafael B. De Rezende</i>	2015:295
The Importance of Reallocation for Productivity Growth: Evidence from European and US Banking <i>by Jaap W.B. Bos and Peter C. van Santen</i>	2015:296
SPEEDING UP MCMC BY EFFICIENT DATA SUBSAMPLING <i>by Matias Quiroz, Mattias Villani and Robert Kohn</i>	2015:297
Amortization Requirements and Household Indebtedness: An Application to Swedish-Style Mortgages <i>by Isaiah Hull</i>	2015:298
Fuel for Economic Growth? <i>by Johan Gars and Conny Olovsson</i>	2015:299
Searching for Information <i>by Jungsuk Han and Francesco Sangiorgi</i>	2015:300
What Broke First? Characterizing Sources of Structural Change Prior to the Great Recession <i>by Isaiah Hull</i>	2015:301
Price Level Targeting and Risk Management <i>by Roberto Billi</i>	2015:302
Central bank policy paths and market forward rates: A simple model <i>by Ferre De Graeve and Jens Iversen</i>	2015:303
Jump-Starting the Euro Area Recovery: Would a Rise in Core Fiscal Spending Help the Periphery? <i>by Olivier Blanchard, Christopher J. Erceg and Jesper Lindé</i>	2015:304
Bringing Financial Stability into Monetary Policy* <i>by Eric M. Leeper and James M. Nason</i>	2015:305
SCALABLE MCMC FOR LARGE DATA PROBLEMS USING DATA SUBSAMPLING AND THE DIFFERENCE ESTIMATOR <i>by MATIAS QUIROZ, MATTIAS VILLANI AND ROBERT KOHN</i>	2015:306

SPEEDING UP MCMC BY DELAYED ACCEPTANCE AND DATA SUBSAMPLING <i>by MATIAS QUIROZ</i>	2015:307
Modeling financial sector joint tail risk in the euro area <i>by André Lucas, Bernd Schwaab and Xin Zhang</i>	2015:308
Score Driven Exponentially Weighted Moving Averages and Value-at-Risk Forecasting <i>by André Lucas and Xin Zhang</i>	2015:309
On the Theoretical Efficacy of Quantitative Easing at the Zero Lower Bound <i>by Paola Boel and Christopher J. Waller</i>	2015:310
Optimal Inflation with Corporate Taxation and Financial Constraints <i>by Daria Finocchiaro, Giovanni Lombardo, Caterina Mendicino and Philippe Weil</i>	2015:311
Fire Sale Bank Recapitalizations <i>by Christoph Bertsch and Mike Mariathasan</i>	2015:312
Since you're so rich, you must be really smart: Talent and the Finance Wage Premium <i>by Michael Böhm, Daniel Metzger and Per Strömberg</i>	2015:313
Debt, equity and the equity price puzzle <i>by Daria Finocchiaro and Caterina Mendicino</i>	2015:314
Trade Credit: Contract-Level Evidence Contradicts Current Theories <i>by Tore Ellingsen, Tor Jacobson and Erik von Schedvin</i>	2016:315
Double Liability in a Branch Banking System: Historical Evidence from Canada <i>by Anna Grodecka and Antonis Kotidis</i>	2016:316
Subprime Borrowers, Securitization and the Transmission of Business Cycles <i>by Anna Grodecka</i>	2016:317
Real-Time Forecasting for Monetary Policy Analysis: The Case of Sveriges Riksbank <i>by Jens Iversen, Stefan Laséen, Henrik Lundvall and Ulf Söderström</i>	2016:318
Fed Liftoff and Subprime Loan Interest Rates: Evidence from the Peer-to-Peer Lending <i>by Christoph Bertsch, Isaiah Hull and Xin Zhang</i>	2016:319
Curbing Shocks to Corporate Liquidity: The Role of Trade Credit <i>by Niklas Amberg, Tor Jacobson, Erik von Schedvin and Robert Townsend</i>	2016:320
Firms' Strategic Choice of Loan Delinquencies <i>by Paola Morales-Acevedo</i>	2016:321
Fiscal Consolidation Under Imperfect Credibility <i>by Matthieu Lemoine and Jesper Lindé</i>	2016:322
Challenges for Central Banks' Macro Models <i>by Jesper Lindé, Frank Smets and Rafael Wouters</i>	2016:323
The interest rate effects of government bond purchases away from the lower bound <i>by Rafael B. De Rezende</i>	2016:324
COVENANT-LIGHT CONTRACTS AND CREDITOR COORDINATION <i>by Bo Becker and Victoria Ivashina</i>	2016:325
Endogenous Separations, Wage Rigidities and Employment Volatility <i>by Mikael Carlsson and Andreas Westermark</i>	2016:326
Renovatio Monetae: Gesell Taxes in Practice <i>by Roger Svensson and Andreas Westermark</i>	2016:327
Adjusting for Information Content when Comparing Forecast Performance <i>by Michael K. Andersson, Ted Aranki and André Reslow</i>	2016:328
Economic Scarcity and Consumers' Credit Choice <i>by Marieke Bos, Chloé Le Coq and Peter van Santen</i>	2016:329
Uncertain pension income and household saving <i>by Peter van Santen</i>	2016:330
Money, Credit and Banking and the Cost of Financial Activity <i>by Paola Boel and Gabriele Camera</i>	2016:331
Oil prices in a real-business-cycle model with precautionary demand for oil <i>by Conny Olovsson</i>	2016:332
Financial Literacy Externalities <i>by Michael Haliasso, Thomas Jansson and Yigitcan Karabulut</i>	2016:333

The timing of uncertainty shocks in a small open economy <i>by Hanna Armelius, Isaiah Hull and Hanna Stenbacka Köhler</i>	2016:334
Quantitative easing and the price-liquidity trade-off <i>by Marien Ferdinandusse, Maximilian Freier and Annukka Ristiniemi</i>	2017:335
What Broker Charges Reveal about Mortgage Credit Risk <i>by Antje Berndt, Burton Hollifield and Patrik Sandås</i>	2017:336
Asymmetric Macro-Financial Spillovers <i>by Kristina Bluwstein</i>	2017:337
Latency Arbitrage When Markets Become Faster <i>by Burton Hollifield, Patrik Sandås and Andrew Todd</i>	2017:338
How big is the toolbox of a central banker? Managing expectations with policy-rate forecasts: Evidence from Sweden <i>by Magnus Åhl</i>	2017:339
International business cycles: quantifying the effects of a world market for oil <i>by Johan Gars and Conny Olovsson I</i>	2017:340
Systemic Risk: A New Trade-Off for Monetary Policy? <i>by Stefan Laséen, Andrea Pescatori and Jarkko Turunen</i>	2017:341
Household Debt and Monetary Policy: Revealing the Cash-Flow Channel <i>by Martin Flodén, Matilda Kilström, Jósef Sigurdsson and Roine Vestman</i>	2017:342
House Prices, Home Equity, and Personal Debt Composition <i>by Jieying Li and Xin Zhang</i>	2017:343
Identification and Estimation issues in Exponential Smooth Transition Autoregressive Models <i>by Daniel Buncic</i>	2017:344
Domestic and External Sovereign Debt <i>by Paola Di Casola and Spyridon Sichelmiris</i>	2017:345
The Role of Trust in Online Lending <i>by Christoph Bertsch, Isaiah Hull, Yingjie Qi and Xin Zhang</i>	2017:346
On the effectiveness of loan-to-value regulation in a multiconstraint framework <i>by Anna Grodecka</i>	2017:347
Shock Propagation and Banking Structure <i>by Mariassunta Giannetti and Farzad Saidi</i>	2017:348
The Granular Origins of House Price Volatility <i>by Isaiah Hull, Conny Olovsson, Karl Walentin and Andreas Westermark</i>	2017:349
Should We Use Linearized Models To Calculate Fiscal Multipliers? <i>by Jesper Lindé and Mathias Trabandt</i>	2017:350
The impact of monetary policy on household borrowing – a high-frequency IV identification <i>by Maria Sandström</i>	2018:351
Conditional exchange rate pass-through: evidence from Sweden <i>by Vesna Corbo and Paola Di Casola</i>	2018:352
Learning on the Job and the Cost of Business Cycles <i>by Karl Walentin and Andreas Westermark</i>	2018:353
Trade Credit and Pricing: An Empirical Evaluation <i>by Niklas Amberg, Tor Jacobson and Erik von Schedvin</i>	2018:354
A shadow rate without a lower bound constraint <i>by Rafael B. De Rezende and Annukka Ristiniemi</i>	2018:355
Reduced "Border Effects", FTAs and International Trade <i>by Sebastian Franco and Erik Frohm</i>	2018:356
Spread the Word: International Spillovers from Central Bank Communication <i>by Hanna Armelius, Christoph Bertsch, Isaiah Hull and Xin Zhang</i>	2018:357
Predictors of Bank Distress: The 1907 Crisis in Sweden <i>by Anna Grodecka, Seán Kenny and Anders Ögren</i>	2018:358

Diversification Advantages During the Global Financial Crisis <i>by Mats Levander</i>	2018:359
Towards Technology-News-Driven Business Cycles <i>by Paola Di Casola and Spyridon Sichliridis</i>	2018:360
The Housing Wealth Effect: Quasi-Experimental Evidence <i>by Dany Kessel, Björn Tyrefors and Roine</i>	2018:361
Identification Versus Misspecification in New Keynesian Monetary Policy Models <i>by Malin Adolfson, Stefan Laseén, Jesper Lindé and Marco Ratto</i>	2018:362
The Macroeconomic Effects of Trade Tariffs: Revisiting the Lerner Symmetry Result <i>by Jesper Lindé and Andrea Pescatori</i>	2019:363
Biased Forecasts to Affect Voting Decisions? The Brexit Case <i>by Davide Cipullo and André Reslow</i>	2019:364
The Interaction Between Fiscal and Monetary Policies: Evidence from Sweden <i>by Sebastian Ankargren and Hovick Shahnazarian</i>	2019:365
Designing a Simple Loss Function for Central Banks: Does a Dual Mandate Make Sense? <i>by Davide Debortoli, Jinill Kim and Jesper Lindé</i>	2019:366
Gains from Wage Flexibility and the Zero Lower Bound <i>by Roberto M. Billi and Jordi Galí</i>	2019:367
Fixed Wage Contracts and Monetary Non-Neutrality <i>by Maria Björklund, Mikael Carlsson and Oskar Nordström Skans</i>	2019:368
The Consequences of Uncertainty: Climate Sensitivity and Economic Sensitivity to the Climate <i>by John Hassler, Per Krusell and Conny Olovsson</i>	2019:369
Does Inflation Targeting Reduce the Dispersion of Price Setters' Inflation Expectations? <i>by Charlotte Paulie</i>	2019:370
Subsampling Sequential Monte Carlo for Static Bayesian Models <i>by David Gunawan, Khue-Dung Dang, Matias Quiroz, Robert Kohn and Minh-Ngoc Tran</i>	2019:371
Hamiltonian Monte Carlo with Energy Conserving Subsampling <i>by Khue-Dung Dang, Matias Quiroz, Robert Kohn, Minh-Ngoc Tran and Mattias Villani</i>	2019:372
Institutional Investors and Corporate Investment <i>by Cristina Cella</i>	2019:373
The Impact of Local Taxes and Public Services on Property Values <i>by Anna Grodecka and Isaiah Hull</i>	2019:374
Directed technical change as a response to natural-resource scarcity <i>by John Hassler, Per Krusell and Conny Olovsson</i>	2019:375
A Tale of Two Countries: Cash Demand in Canada and Sweden <i>by Walter Engert, Ben Fung and Björn Segendorf</i>	2019:376
Tax and spending shocks in the open economy: are the deficits twins? <i>by Mathias Klein and Ludger Linnemann</i>	2019:377
Mind the gap! Stylized dynamic facts and structural models <i>by Fabio Canova and Filippo Ferroni</i>	2019:378
Financial Buffers, Unemployment Duration and Replacement Labor Income <i>by Mats Levander</i>	2019:379
Inefficient Use of Competitors' Forecasts? <i>by André Reslow</i>	2019:380
How Much Information Do Monetary Policy Committees Disclose? Evidence from the FOMC's Minutes and Transcripts <i>by Mikael Apel, Marianna Blix Grimaldi and Isaiah Hull</i>	2019:381
Risk endogeneity at the lender/investor-of-last-resort <i>by Diego Caballero, André Lucas, Bernd Schwaab and Xin Zhang</i>	2019:382
Heterogeneity in Households' Expectations of Housing Prices – Evidence from Micro Data <i>by Erik Hjalmarsson and Pär Österholm</i>	2019:383
Big Broad Banks: How Does Cross-Selling A Affect Lending? <i>by Yingjie Qi</i>	2020:384



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