Money and monetary policy in the Eurozone: an empirical analysis during crises

Money Macro and Finance Research Group
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This presentation does not necessarily reflect the views of the Bank of Israel

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Layout

- Introduction
  - The question of money
  - New Keynesian models
  - Literature review
- The models
  - Model 1 : Baseline model (Galí, 2008)
  - Model 2 : Non-separable model (Benchimol and Fourçans, 2012)
- Results
  - Methodology
  - Estimations
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- Conclusion
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The question of money

- In the current New Keynesian literature, the role of monetary aggregates is generally **neglected**.
- The main economic variables of this kind of models are: the output gap, inflation and the interest rate.
- Yet it's hard to imagine money completely "passive" to the rest of the system !

Brunner and Meltzer

- As individuals re-allocate their portfolio of assets, the behavior of real money balances induces relative **price adjustments** on financial and real assets. In the process, **aggregate demand** changes, and thus output.
- By affecting aggregate demand, real money balances become part of the transmission mechanism.
- The interest rate alone is thus not sufficient to explain the impact of monetary policy and the role played by credit and financial markets.
- This monetarist transmission process may also imply a specific role to real money balances when dealing with **uncertainty***.

Money and new Keynesian models

- Most of studies about New Keynesian models ignore money because of separable utilities, such as

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} + \frac{\gamma}{1-\vartheta} \left(\frac{M_{t+i}}{P_{t+i}} \right)^{1-\vartheta} - \chi \frac{N_{t+i}^{1+\eta}}{1+\eta} \right]$$

- Solving this problem makes money completely recursive to the rest of the system of equations.
- Yet, real money holdings could affect household's consumption under high uncertainty.
- In other words, real money balances are supposed to affect the marginal utility of consumption.
- We have to assume **non-separable utility** between consumption and real money balances.

Selected papers

- Andrés, López-Salido and Vallés, 2006, **Money in an Estimated Business Cycle Model of the Euro Area**, *Economic Journal* + *JEDC* with Nelson (2009).
- Barthélemy, Clerc, and Marx, 2011, **A two-pillar DSGE monetary policy model for the euro area**, *Economic Modelling*.
- Galí, 2008. **Monetary Policy, Inflation and the business cycle: An introduction to the new Keynesian framework**. Princeton University Press.
- Ireland, 2004, **Money's Role in the Monetary Business Cycle**, *Journal of Money, Credit and Banking*.
- Smets and Wouters, 2003, **An Estimated Dynamic Stochastic General Equilibrium Model for the Euro Area**, *Journal of the European Economic Association*.

Selected similarities and differences

Compared to the literature, we have:

1. Almost the same **utility function**
2. Long run variance decomposition analysis (almost same results)

However, in the literature, we do not have:

3. Micro-founded NKDSGE analysis *à la* Galí (flexible price economy)
4. Money considerations + [3] : **money in flexible-price**.
5. Price-markup shock + [4]
6. **Short sample** analysis + [3]
7. **Rolling window estimations** + [3]
8. Bayesian analysis + [4]
9. **Forecasting accuracy** analysis + [4]
10. **Short run** variance decomposition analysis + [4]

$\sum_{k=1}^{10} [k]$ leads to different results

What do we do ?

- We compare two types of NK models in a DSGE framework.
- We test the models by using Bayesian techniques on Eurozone data (rolling-window estimations).
- Over 3 different crisis periods, we analyze changes in parameters, impulse response functions and variance decompositions.
- We also study the forecasting performances of the two models during these periods.

New Keynesian framework

The models consist of economic agents of 3 types :

- Households: supply labor, purchase goods for consumption, hold money and bonds, and maximize the expected present value of utility.
- Firms: hire labor, produce and sell differentiated products in monopolistically competitive goods markets (Dixit and Stiglitz, 1977), and maximize profits.
- Central bank: controls the nominal rate of interest (ad-hoc rule).

NK features: sticky and flexible-price economies *à la* Galí (2008).

Separable money in the utility

- Preferences of the representative household are defined over a composite consumption good C_t, real money balances $\frac{M_t}{P_t}$, and leisure $1 - N_t$, where N_t is the time devoted to market employment.
- Galí's utility function:

$$U_t = \frac{C_t^{1-\sigma}}{1-\sigma} + \frac{\gamma e^{\varepsilon_t^m}}{1-\vartheta}\left(\frac{M_t}{P_t}\right)^{1-\vartheta} - \frac{\chi N_t^{1+\eta}}{1+\eta}$$

- Budget constraint:

$$P_t C_t + Q_t B_t + M_t \leq B_{t-1} + M_{t-1} + W_t N_t$$

- Production function:

$$Y_t = A_t {N_t}^{1-\alpha}$$

Non-separable money in the utility

- CES utility function:

$$U_t = \frac{1}{1-\sigma}\left(\left(1-b\right)C_t^{1-\nu} + be^{\varepsilon_t^m}\left(\frac{M_t}{P_t}\right)^{1-\nu}\right)^{\frac{1-\sigma}{1-\nu}} - \frac{\chi}{1+\eta}N_t^{1+\eta}$$

- Here real money balances affect the marginal utility of consumption.
- The budget constraint and the production function are the same as in the baseline model.

Solving the models

- By using Lagrangian method in order to optimize the utility function with respect to the budget constraint (and a solvency condition), we obtain three first-order optimal conditions.
- We log-linearize around the steady state these conditions.
- We add an ad-hoc Taylor type rule equation to close our model.
- Structural shocks are assumed to follow a first-order autoregressive process with an *i.i.d.*-normal error term such as $\varepsilon_t^k = \rho_k \varepsilon_{t-1}^k + \omega_{k,t}$ where $\varepsilon_{k,t} \sim N(0; \sigma_k)$ for $k = \{p, m, i, a\}$.
- ε_t^p is the price-markup shock, ε_t^m is the money shock, ε_t^i is the exogenous component of the interest rate and ε_t^a is the technology shock.

$$\hat{y}_t^f = \frac{1+\eta}{\sigma(1-\alpha)+\eta+\alpha}\varepsilon_t^a - \frac{(1-\alpha)\ln\left(\frac{\varepsilon}{\varepsilon-1}\right)}{\sigma(1-\alpha)+\eta+\alpha} \tag{1}$$

$$\hat{\pi}_t = \beta E_t\left[\hat{\pi}_{t+1}\right] + \kappa_{x,t}\left(\hat{y}_t - \hat{y}_t^f\right) \tag{2}$$

$$\hat{y}_t = E_t\left[\hat{y}_{t+1}\right] - \sigma^{-1}\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right]\right) \tag{3}$$

$$\widehat{mp}_t = \frac{\sigma}{\vartheta}\hat{y}_t - \frac{a_2}{\vartheta}\hat{\imath}_t - \frac{\rho_m}{\vartheta} + \frac{1}{\vartheta}\varepsilon_t^m \tag{4}$$

$$\hat{\imath}_t = (1-\lambda_i)\left(\lambda_\pi\left(\hat{\pi}_t - \pi^*\right) + \lambda_x\left(\hat{y}_t - \hat{y}_t^f\right)\right) + \lambda_i\hat{\imath}_{t-1} + \varepsilon_t^i \tag{5}$$

where $\kappa_{x,t} = \frac{(1-\theta)\left(\frac{1}{\theta}-\beta\right)(\sigma(1-\alpha)+\eta+\alpha)(1+(\varepsilon-1)\varepsilon_t^p)}{1+(\varepsilon-1)(\varepsilon_t^p+\alpha)}$ and $a_2 = \frac{1}{e^{\frac{1}{\beta}}-1}$.

$$\hat{y}_t^f = v_a^y \varepsilon_t^a + v_m^y \widehat{mp}_t^f - v_c^y + v_{sm}^y \varepsilon_t^m \tag{6}$$

$$\widehat{mp}_t^f = v_{y+1}^m E_t\left[\hat{y}_{t+1}^f\right] + v_y^m \hat{y}_t^f + \frac{1}{\nu}\varepsilon_t^m \tag{7}$$

$$\hat{\pi}_t = \beta E_t\left[\hat{\pi}_{t+1}\right] + \kappa_{x,t}\left(\hat{y}_t - \hat{y}_t^f\right) + \kappa_{m,t}\left(\widehat{mp}_t - \widehat{mp}_t^f\right) \tag{8}$$

$$\begin{aligned} \hat{y}_t \quad = \quad & E_t\left[\hat{y}_{t+1}\right] - \kappa_r\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right]\right) \\ & + \kappa_{mp} E_t\left[\Delta \widehat{mp}_{t+1}\right] + \kappa_{sm} E_t\left[\Delta \varepsilon_{t+1}^m\right] \end{aligned} \tag{9}$$

$$\widehat{mp}_t = \hat{y}_t - \kappa_i \hat{\imath}_t + \frac{1}{\nu}\varepsilon_t^m \Big|_{\gamma \neq 0} \tag{10}$$

$$\hat{\imath}_t = (1-\lambda_i)\begin{pmatrix} \lambda_\pi\left(\hat{\pi}_t - \pi_c\right) + \lambda_x\left(\hat{y}_t - \hat{y}_t^f\right) \\ + \lambda_m\left(\widehat{mp}_t - \widehat{mp}_t^f\right) \end{pmatrix} + \lambda_i \hat{\imath}_{t-1} + \varepsilon_t^i \tag{11}$$

Micro-founded model

$$v_a^y = \frac{1+\eta}{(\nu-a_1(\nu-\sigma))(1-\alpha)+\eta+\alpha} \qquad \kappa_r = \frac{1}{\nu-a_1(\nu-\sigma)}$$

$$v_m^y = \frac{(1-\alpha)(\nu-\sigma)(1-a_1)}{(\nu-a_1(\nu-\sigma))(1-\alpha)+\eta+\alpha} \qquad \kappa_{mp} = \frac{(\sigma-\nu)(1-a_1)}{\nu-a_1(\nu-\sigma)}$$

$$v_c^y = \frac{(1-\alpha)}{(\nu-a_1(\nu-\sigma))(1-\alpha)+\eta+\alpha}\log\left(\frac{\varepsilon}{\varepsilon-1}\right) \qquad \kappa_i = a_2/\nu$$

$$v_{sm}^y = \frac{(1-\alpha)(\nu-\sigma)(1-a_1)}{((\nu-a_1(\nu-\sigma))(1-\alpha)+\eta+\alpha)(1-\nu)} \qquad \kappa_{sm} = -\frac{(1-a_1)(\nu-\sigma)}{(\nu-a_1(\nu-\sigma))(1-\nu)}$$

$$v_{y+1}^m = -\frac{a_2}{\nu}\left(\nu - a_1\left(\nu-\sigma\right)\right) \qquad a_1 = \frac{1}{1+(b/(1-b))^{1/\nu}(1-\beta)^{(\nu-1)/\nu}}$$

$$v_y^m = 1 + \frac{a_2}{\nu}\left(\nu - a_1\left(\nu-\sigma\right)\right) \qquad a_2 = \frac{1}{\exp(1/\beta)-1}$$

$$\kappa_{m,t} = \left(\sigma-\nu\right)\left(1-a_1\right)\frac{(1-\alpha)\left(\frac{1}{\theta}-\beta\right)(1-\theta)(1+(\varepsilon-1)\varepsilon_t^p)}{1+(\alpha+\varepsilon_t^p)(\varepsilon-1)}$$

$$\kappa_{x,t} = \left(\nu - a_1\left(\nu-\sigma\right) + \frac{\eta+\alpha}{1-\alpha}\right)\frac{(1-\alpha)\left(\frac{1}{\theta}-\beta\right)(1-\theta)(1+(\varepsilon-1)\varepsilon_t^p)}{1+(\alpha+\varepsilon_t^p)(\varepsilon-1)}$$

Methodology

- As in Smets and Wouters (2003), An and Schorfheide (2007) and Barthélemy, Clerc and Marx (2011), we apply **Bayesian techniques** to estimate our DSGE model.
- We use **Eurozone data** like Andrès et *al.* (2006) and Barthélemy et *al.* (2011) from the Euro Area Wide Model database (AWM) of Fagan, Henry and Mestre (2001).
- We use the $M3$ monetary aggregate from the Eurostat database.

Data

- $\hat{\pi}_t$ is the **inflation** rate, measured as the yearly log difference of the GDP deflator from one quarter to the same quarter of the previous year;
- $\hat{y}_t$ is the **output** per capita, measured as the difference between the log of the real GDP per capita and its linear trend;
- $\hat{\imath}_t$ is the short-term (3-month) **nominal interest rate**;
- $\widehat{mp}_t$ is the **real money balances** per capita, measured as the difference between the real money per capita and its linear trend, where real money per capita is measured as the log difference between the money stock per capita and the GDP deflator;
- $\hat{y}_t^f$, the **flexible-price output**, and $\widehat{mp}_t^f$, the **flexible-price real money balances**, are entirely determined by structural shock.

Calibration

- Following standard conventions, we calibrate **beta** distributions for parameters that fall between zero and one, **inverted gamma** distributions for parameters that need to be constrained to be greater than zero, and **normal** distributions in other cases.
- The calibration of the micro parameters is inspired by Rabanal and Rubio-Ramírez (2007), Casares (2007), Galí (2008) and Benchimol and Fourçans (2012).

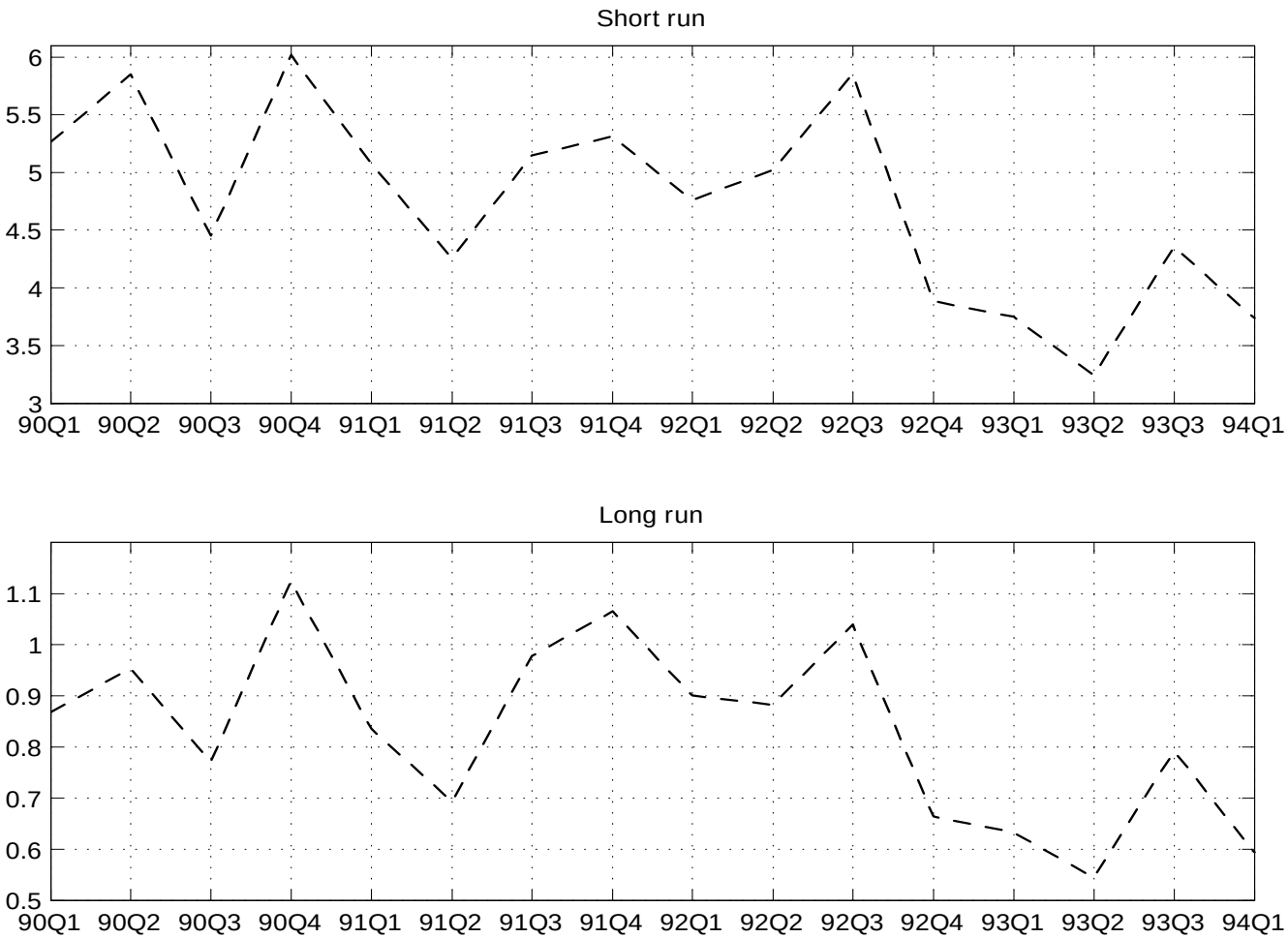
Methodology

- We define three different periods in order to analyze three different crises:
  - **1990Q1** to **1994Q1**, during the speculative attacks on currencies in the European Exchange Rate Mechanism (Black Wednesday crisis);
  - **1999Q1** to **2003Q1**, during the burst of the Dot-com bubble (Dot-com crisis);
  - and **2007Q1** to **2011Q1**, during the Subprime crisis.
- **Rolling window estimations**: for every quarter, we run a Bayesian estimation using the 48 observations before each respective quarter
  - This sample size is validated by Fernandez-Villaverde and Rubio-Ramirez (2004).

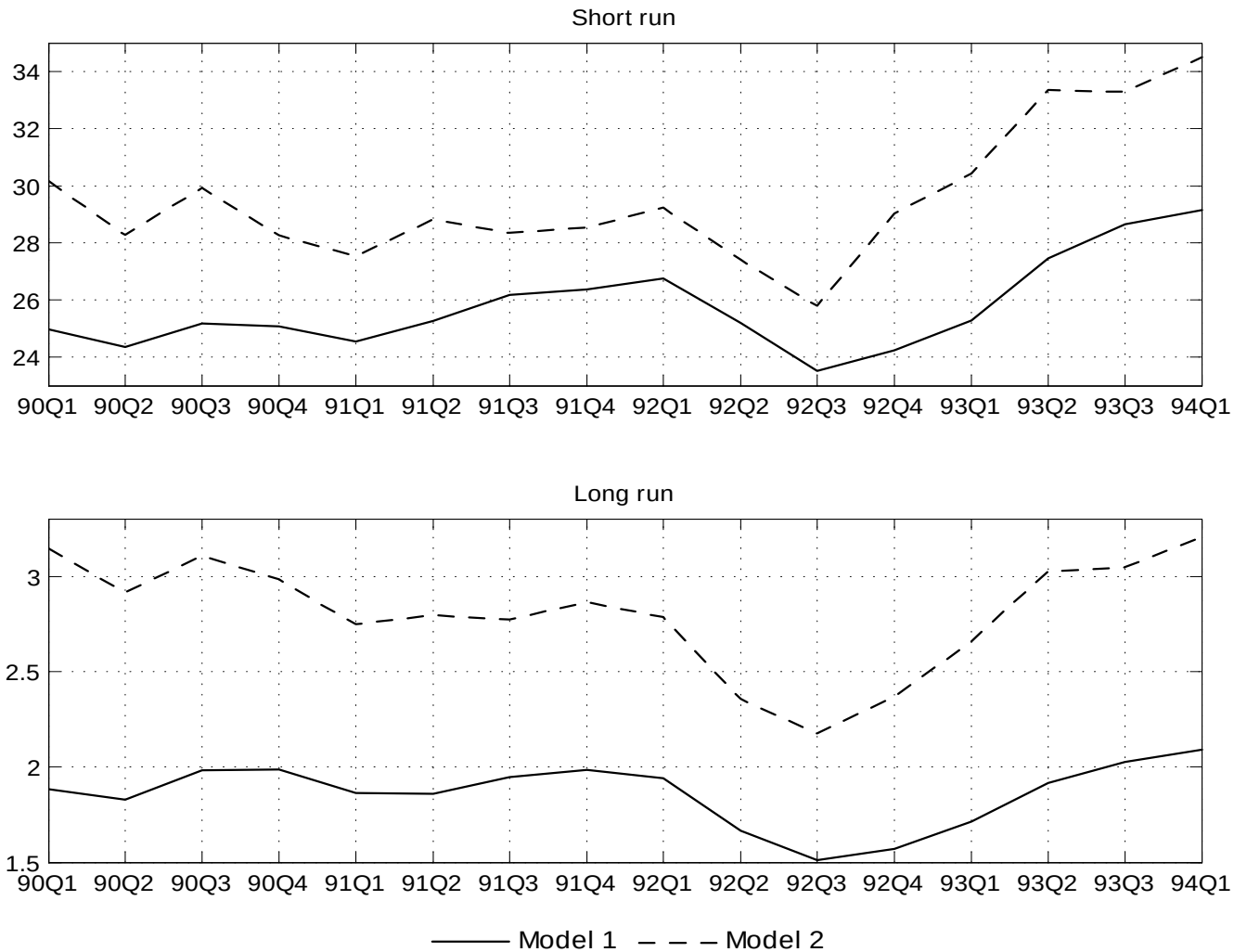
Methodology and results

- These estimates provide the values of micro and macro parameters (explaining the dynamics of the models) **over time**.
- Following Iskrev (2010), all estimated parameters are identified for both models.
- We compute variance decompositions of variables with respect to shocks (technology, price-markup, money, and monetary policy).
- Finally, we run DSGE forecasts **after each estimation** in order to compare the forecasting performances of the two models over four out-of-sample periods (one year).

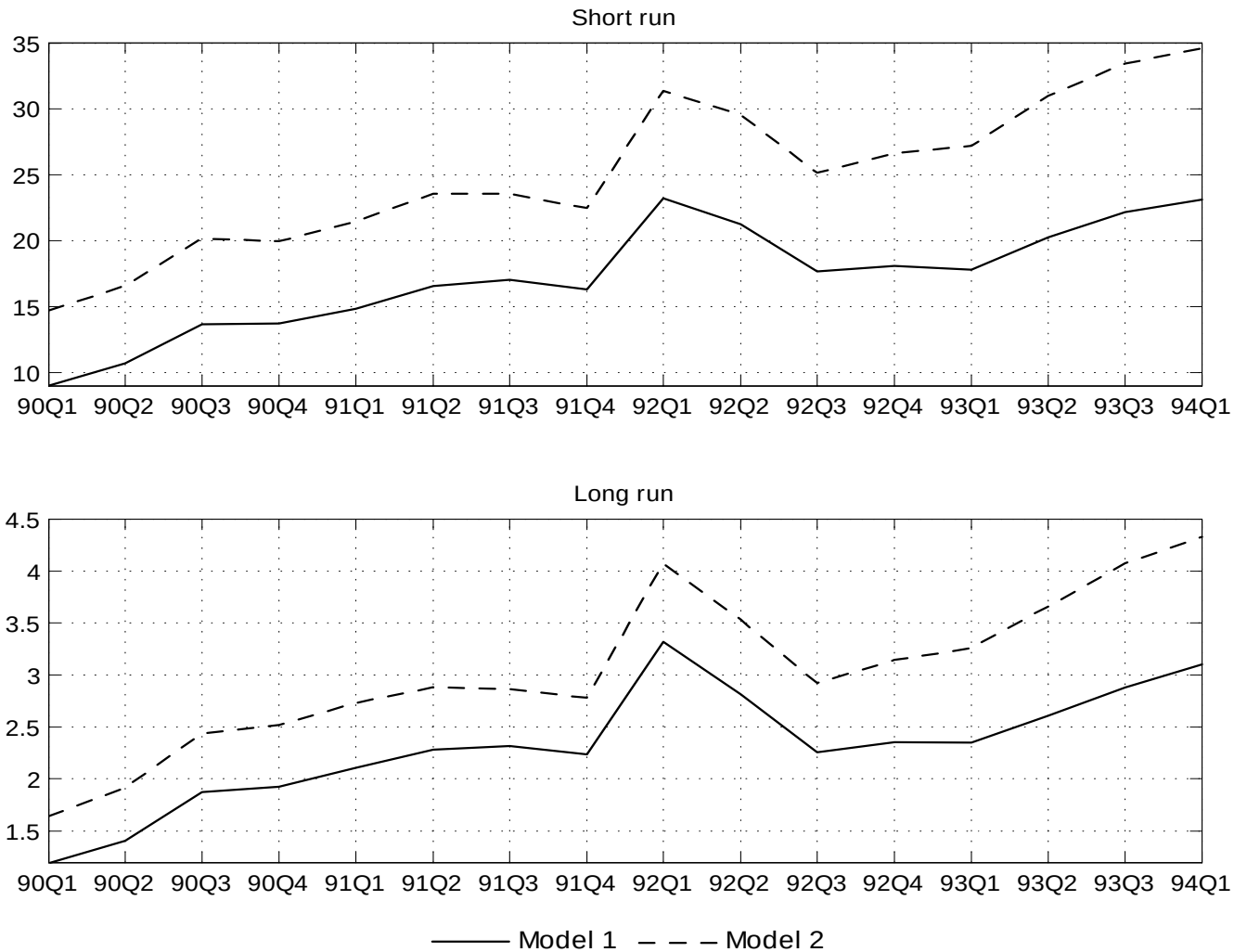
[ERM crisis] Variance decompositions of **output** with respect to the money shock (in percent) from Model 2. Whatever the value of γ, money has no role in Model 1.



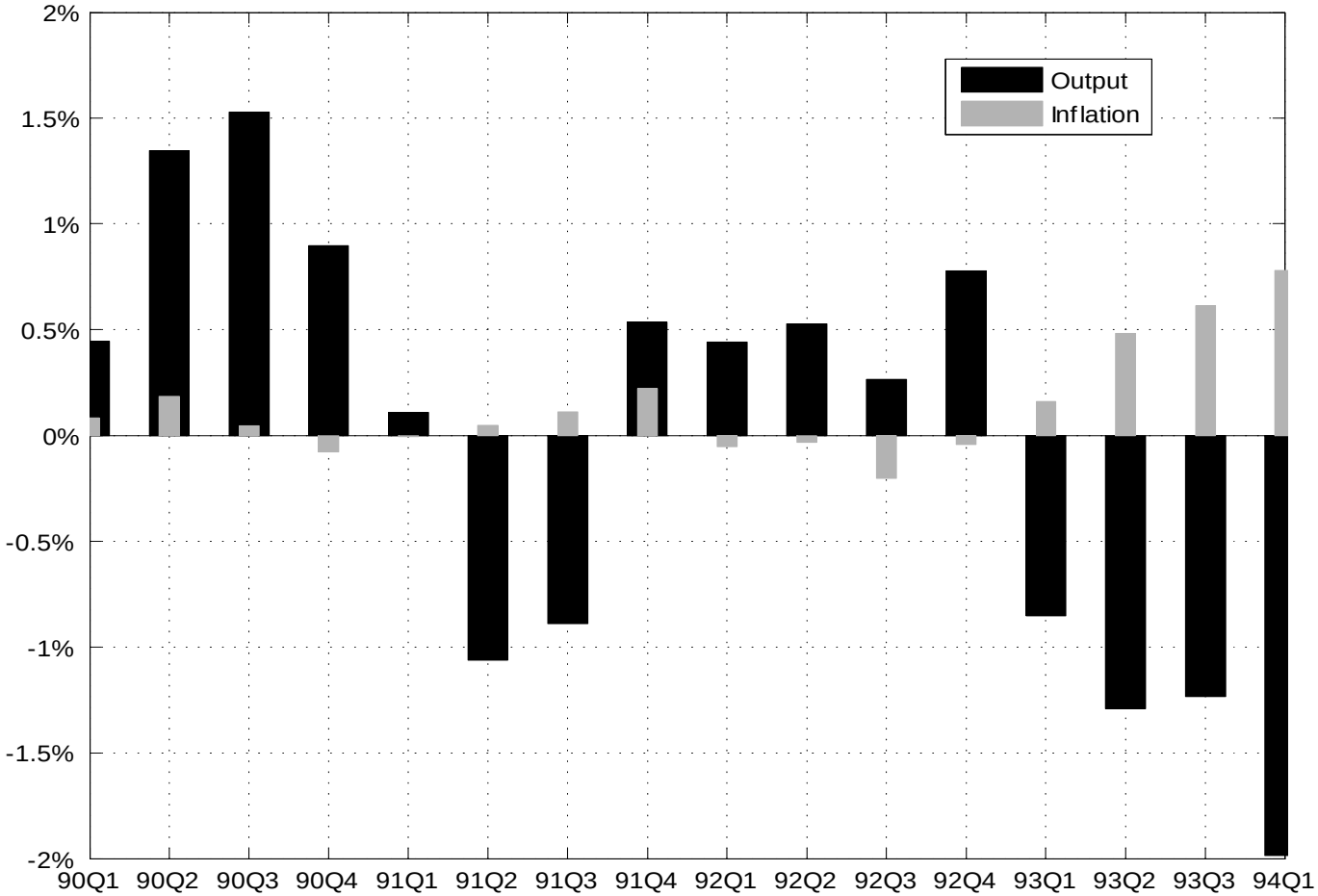
[ERM crisis] Variance decompositions of **output** with respect to the monetary policy shock (in percent) from Model 1 (solid lines) and Model 2 (dashed lines).



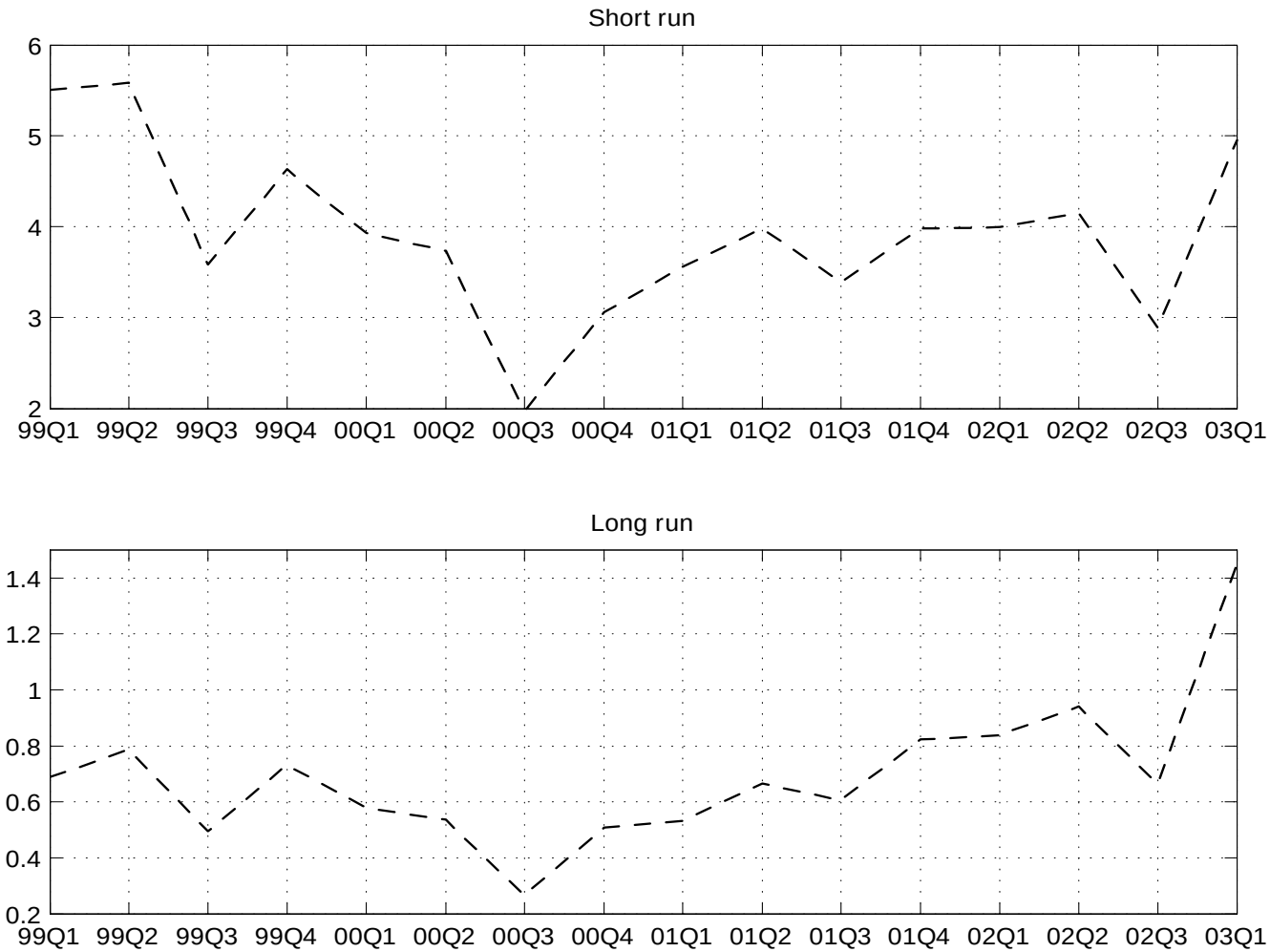
[ERM crisis] Variance decompositions of **inflation** with respect to the monetary policy shock (in percent) from Model 1 (solid lines) and Model 2 (dashed lines).



[ERM crisis] Comparison of output and inflation DSGE forecast errors. Model 2 is better when the bar is positive, Model 1 is better otherwise.



[Dot-com crisis] Variance decompositions of **output** with respect to the money shock (in percent) from Model 2.



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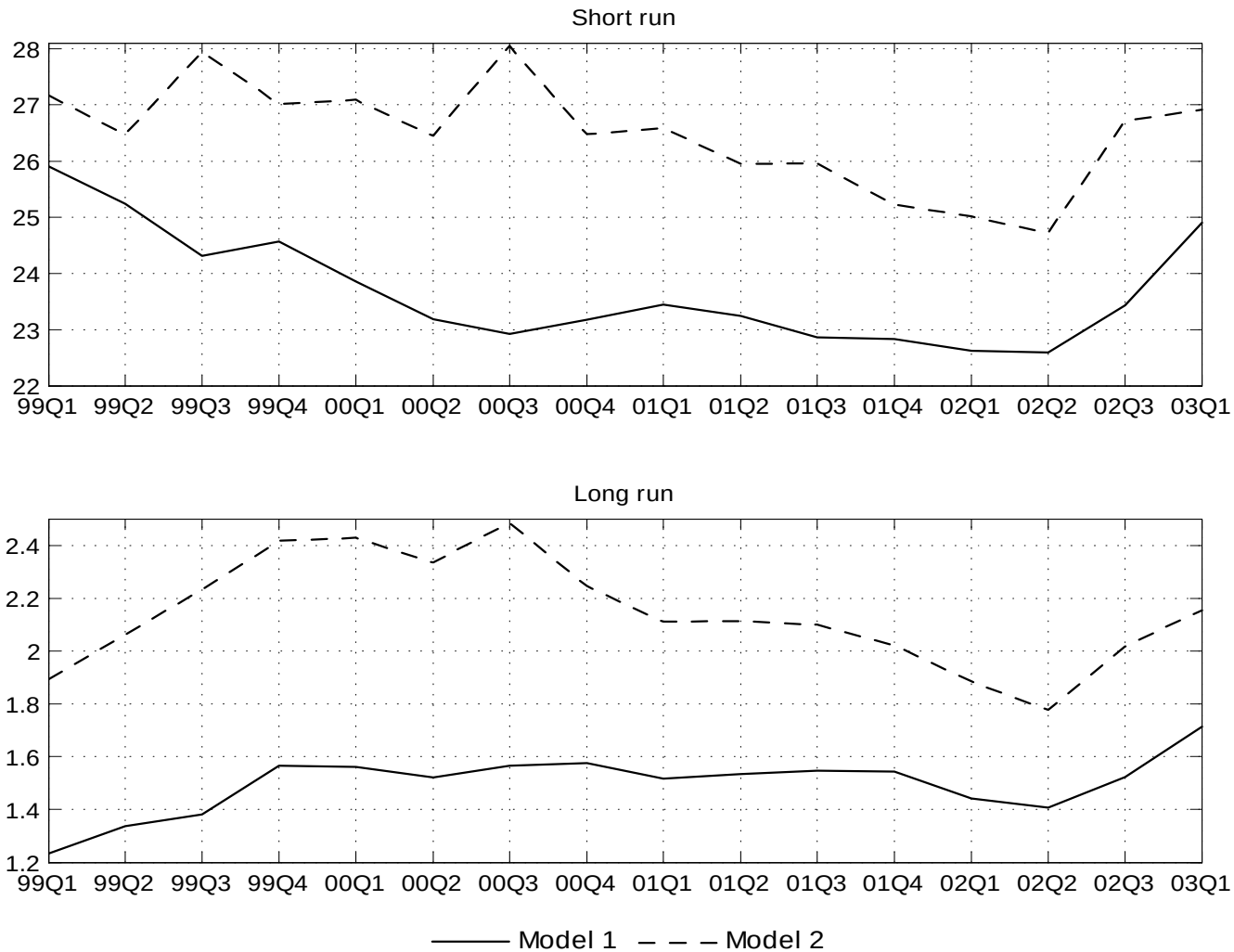

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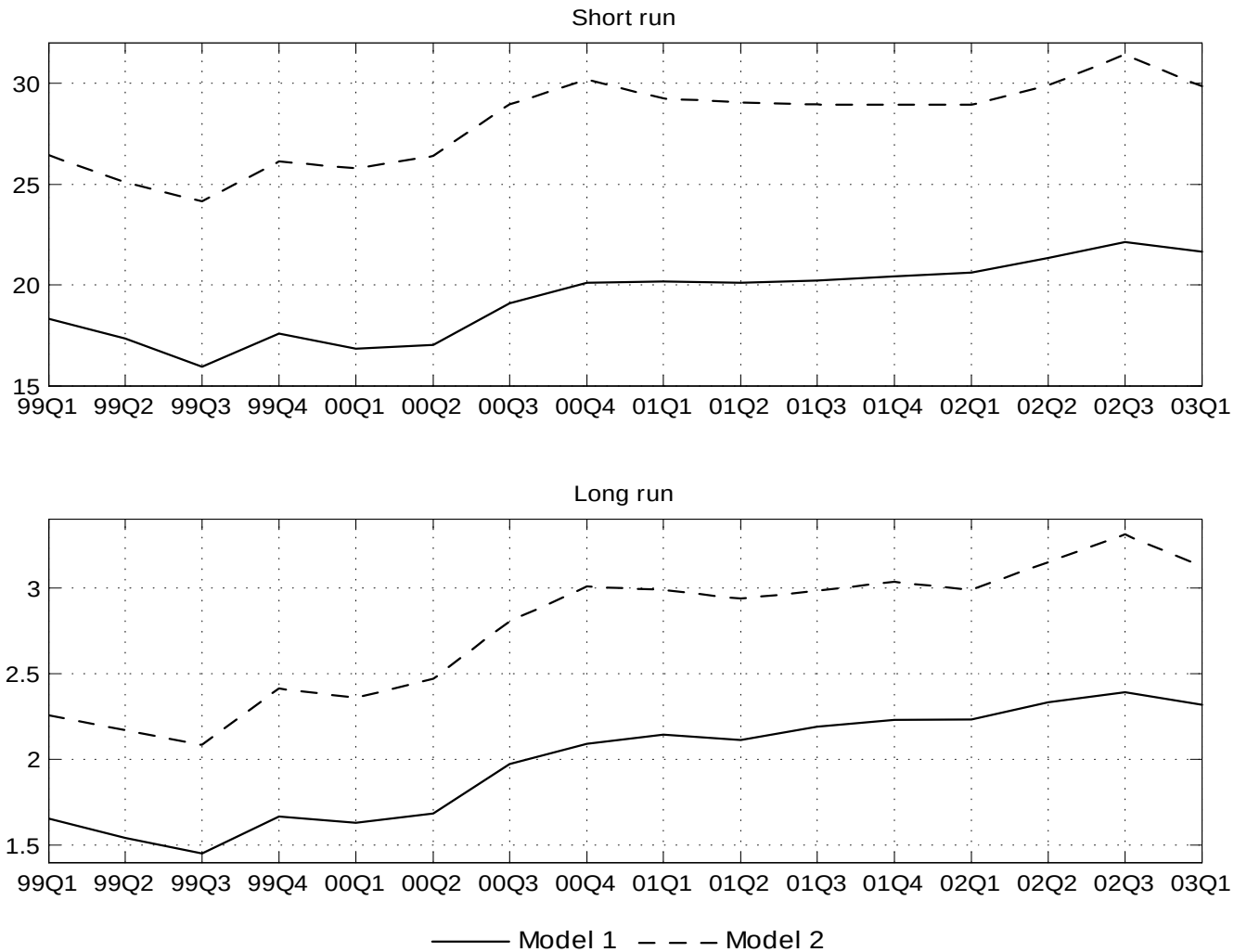

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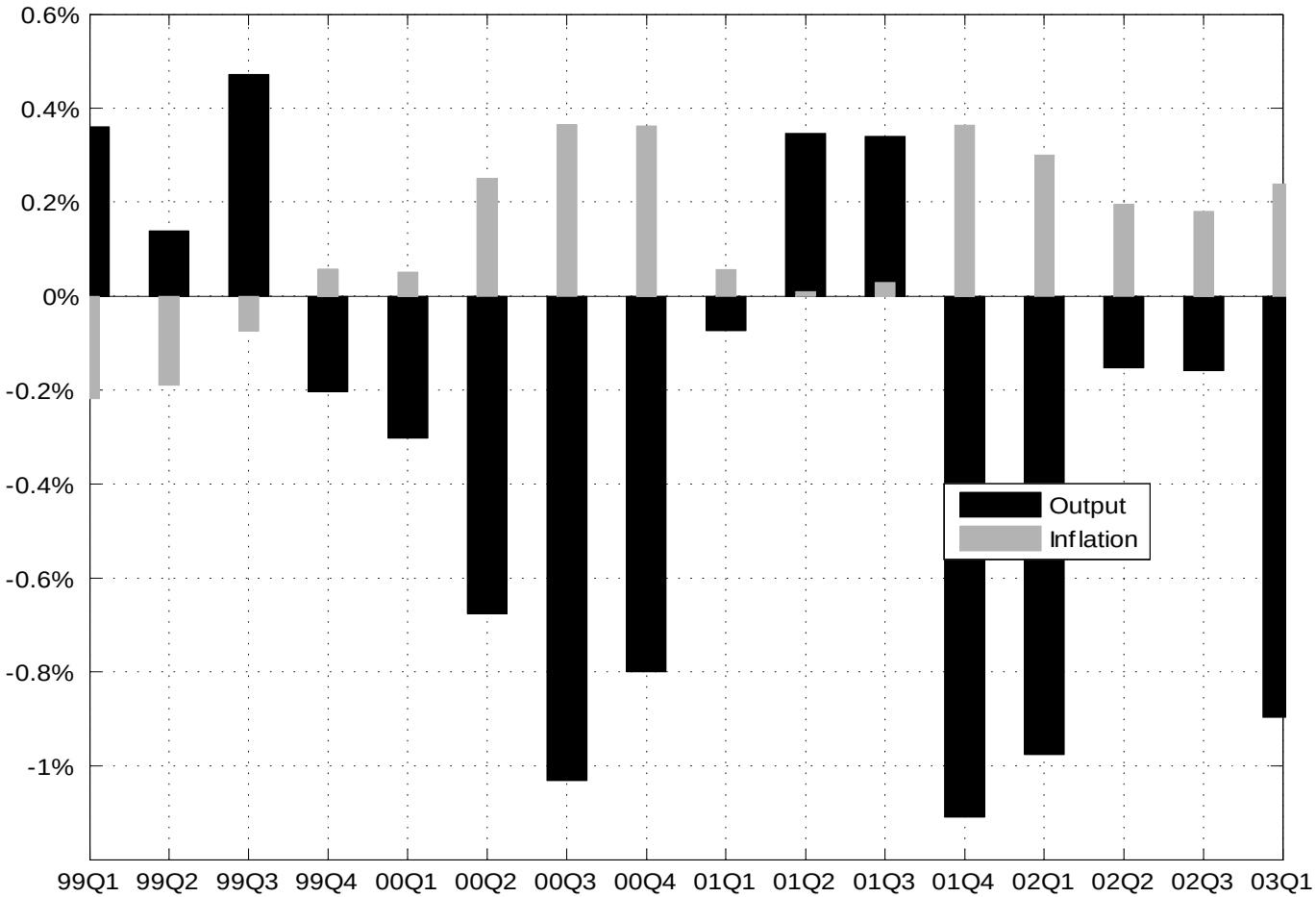
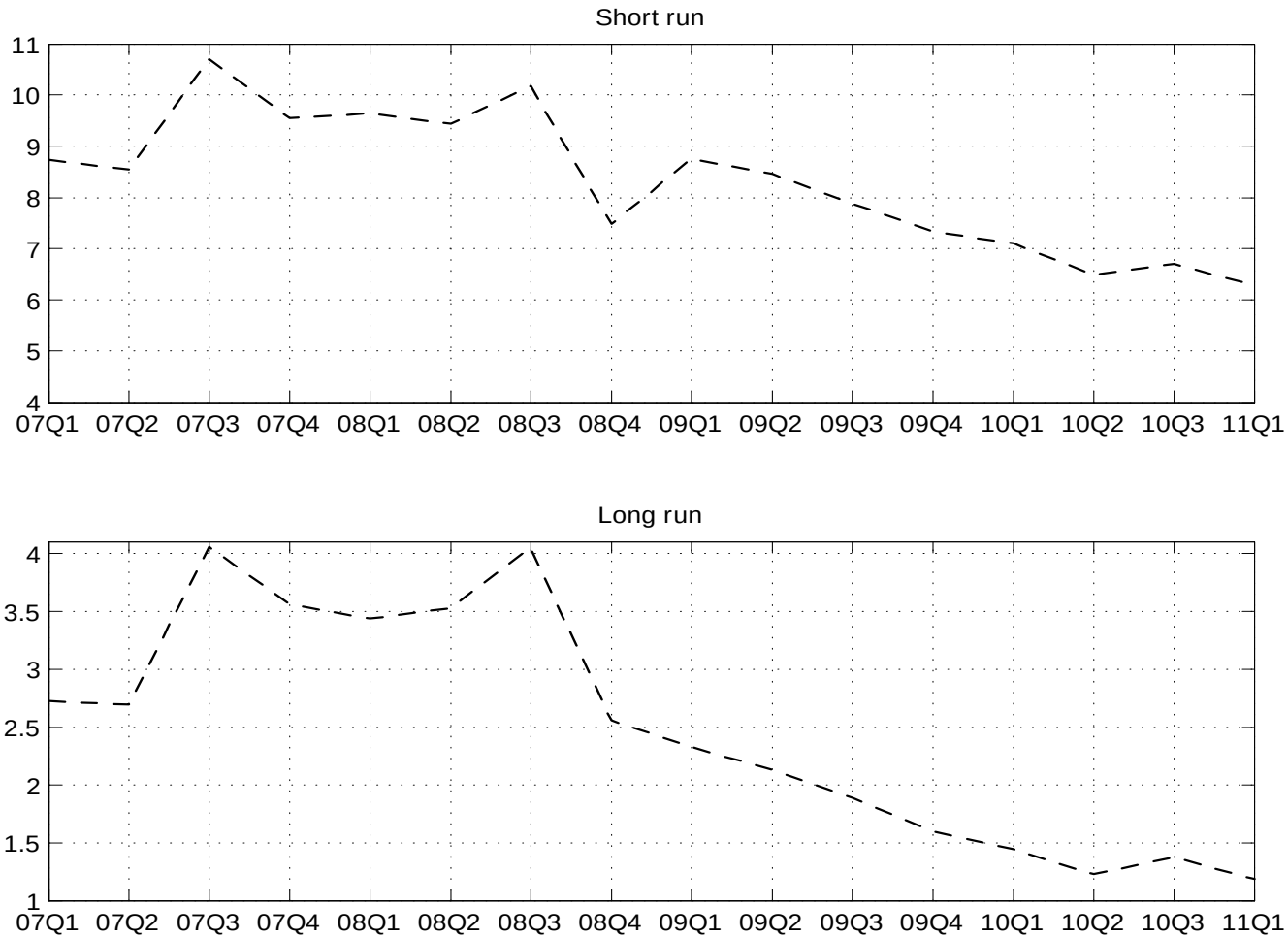


[Subprime crisis] Variance decompositions of **output** with respect to the money shock (in percent) from Model 2.



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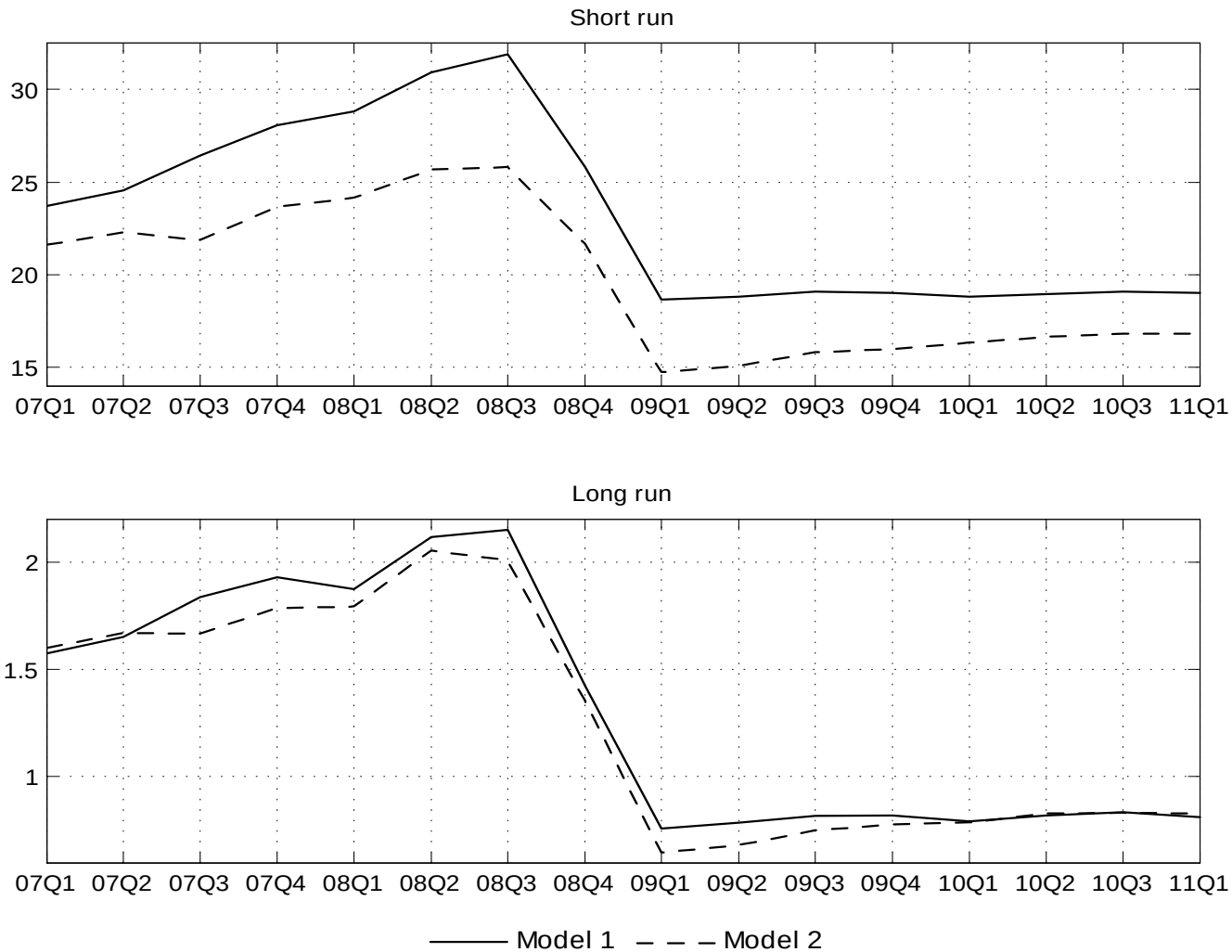

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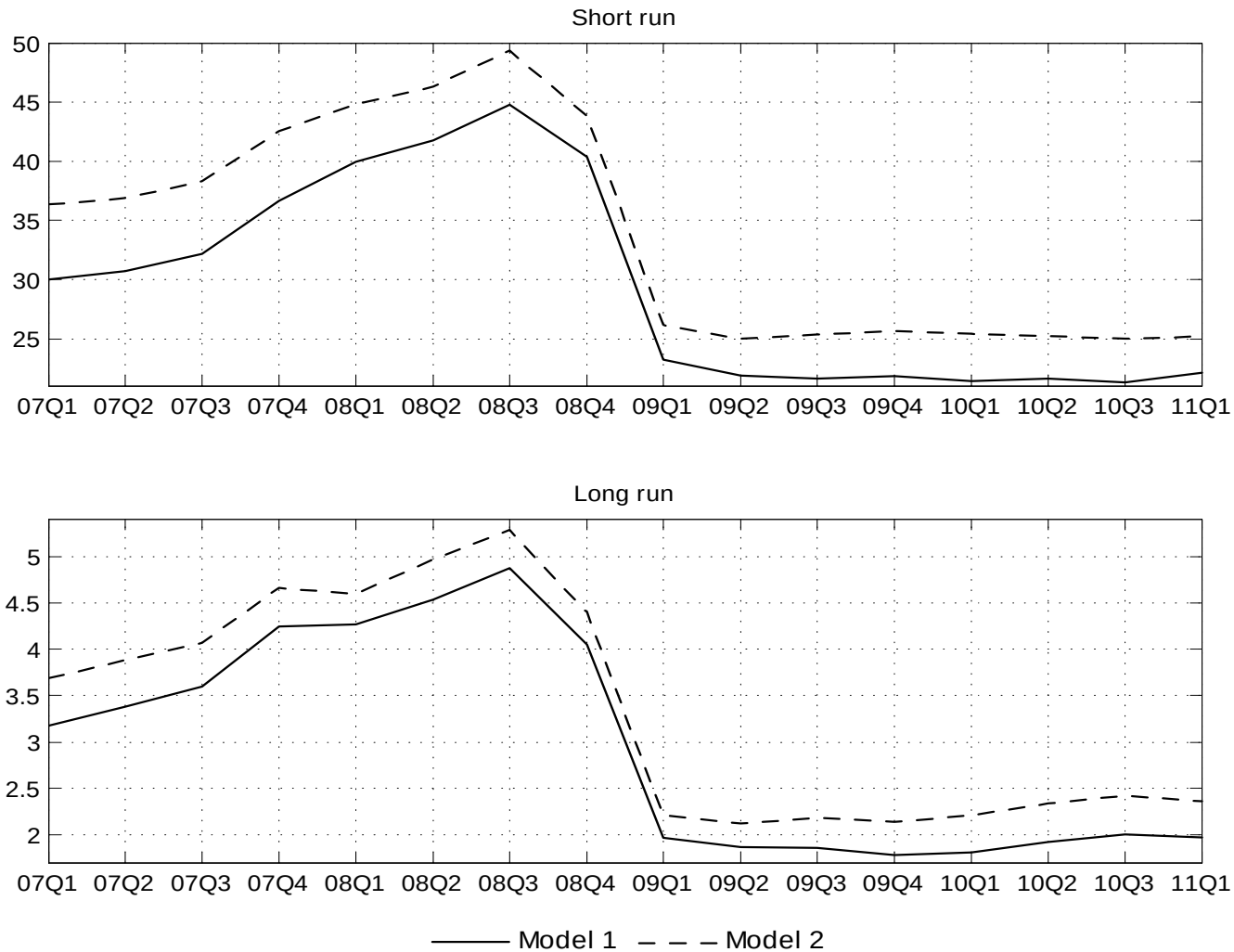
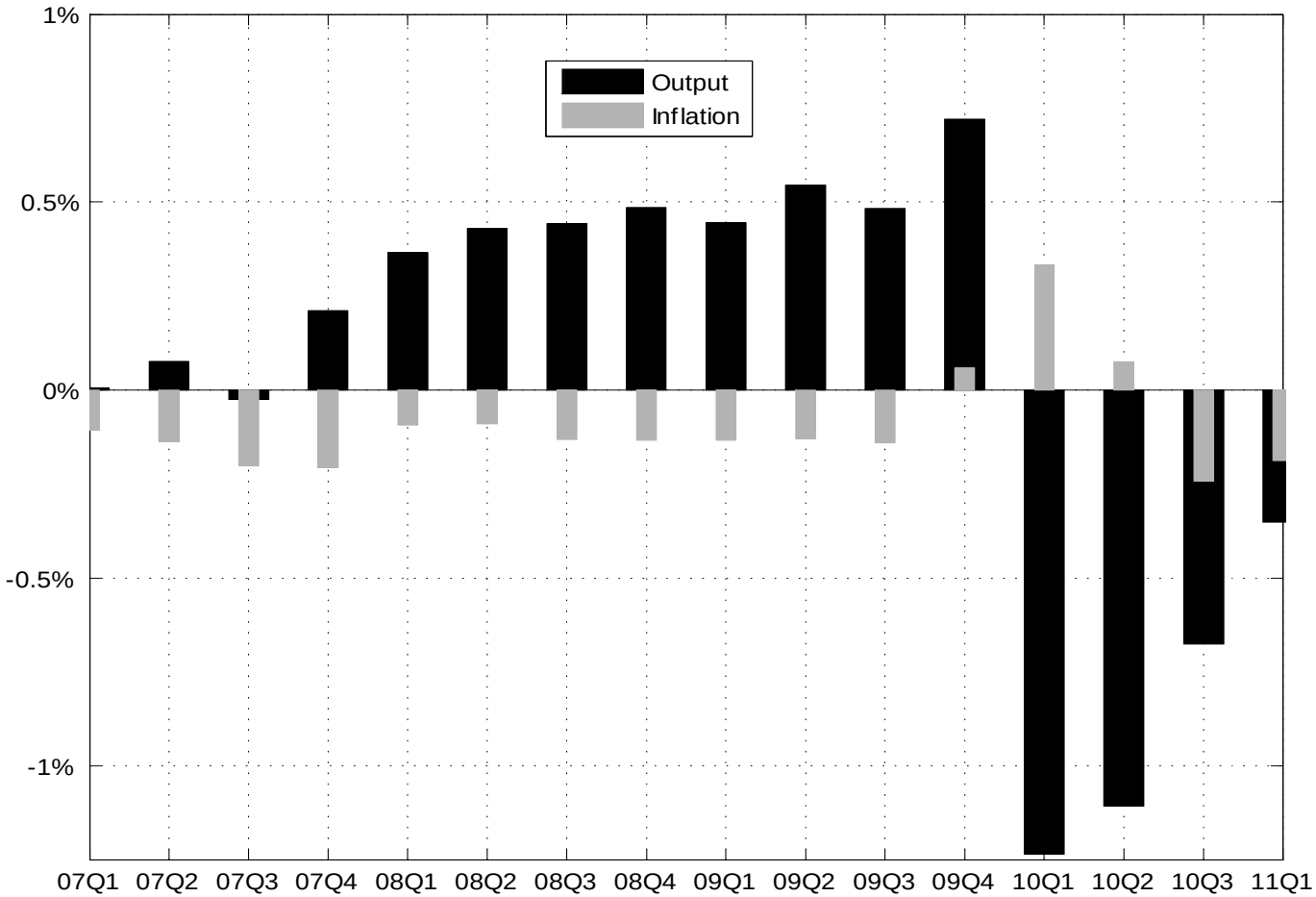


Subprime crisis

Interpretation

- The role of the money shock on output increases in 2007 to reach a peak in 2007Q3 and another in 2008Q3. It explained around 8% of the variance in 2007Q1, reaches 11% in 2007Q3 and goes back to 7% in 2009Q4.
- The impact of money on the flexible price output follows about the same dynamic path.
- Contrary to other studies (Ireland, 2004; Andrès and al., 2006;), this result shows that money had a significant role to play during the financial crisis.
- It is interesting to notice that the role of the monetary policy shock is also in the same vein, but it reaches its peak in 2008Q3 (Lehman Brothers collapse).
- Monetary policy explains most of the inflation variance, but changes along the same lines as above with the crisis.

[Subprime crisis] Comparison of output and inflation DSGE forecast errors. Model 2 is better when the bar is positive, Model 1 is better otherwise.

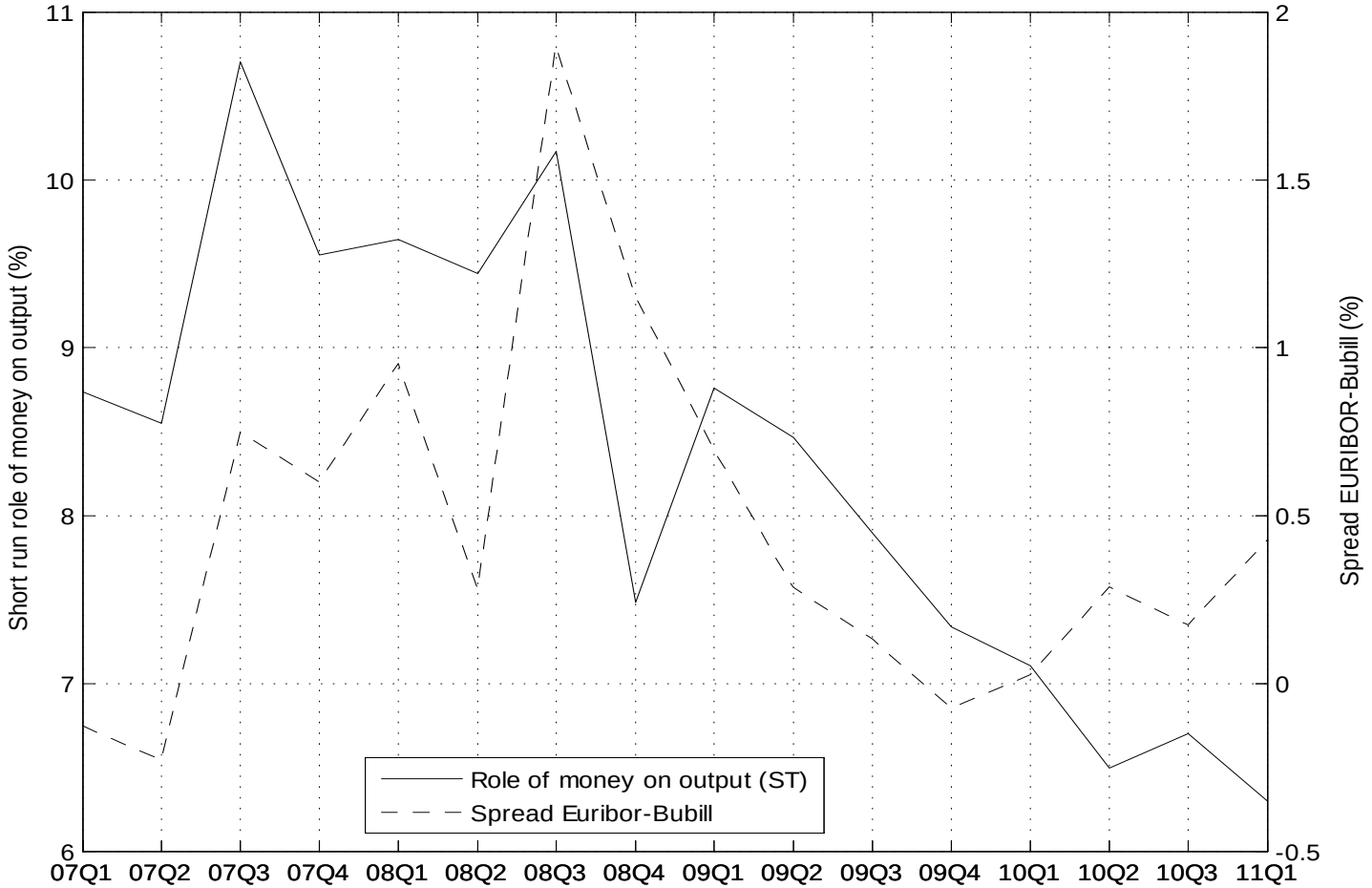


Subprime crisis

Interpretation

- Measurement: the difference in the RMSD of the 2 models with respect to the actual values.
- The non-separable model provides the best forecasting performance for output during the subprime crisis, especially at the top of the financial crisis (2007Q4 to 2009Q4).
- The forecasting performance of the two models is not different as far as inflation is concerned.

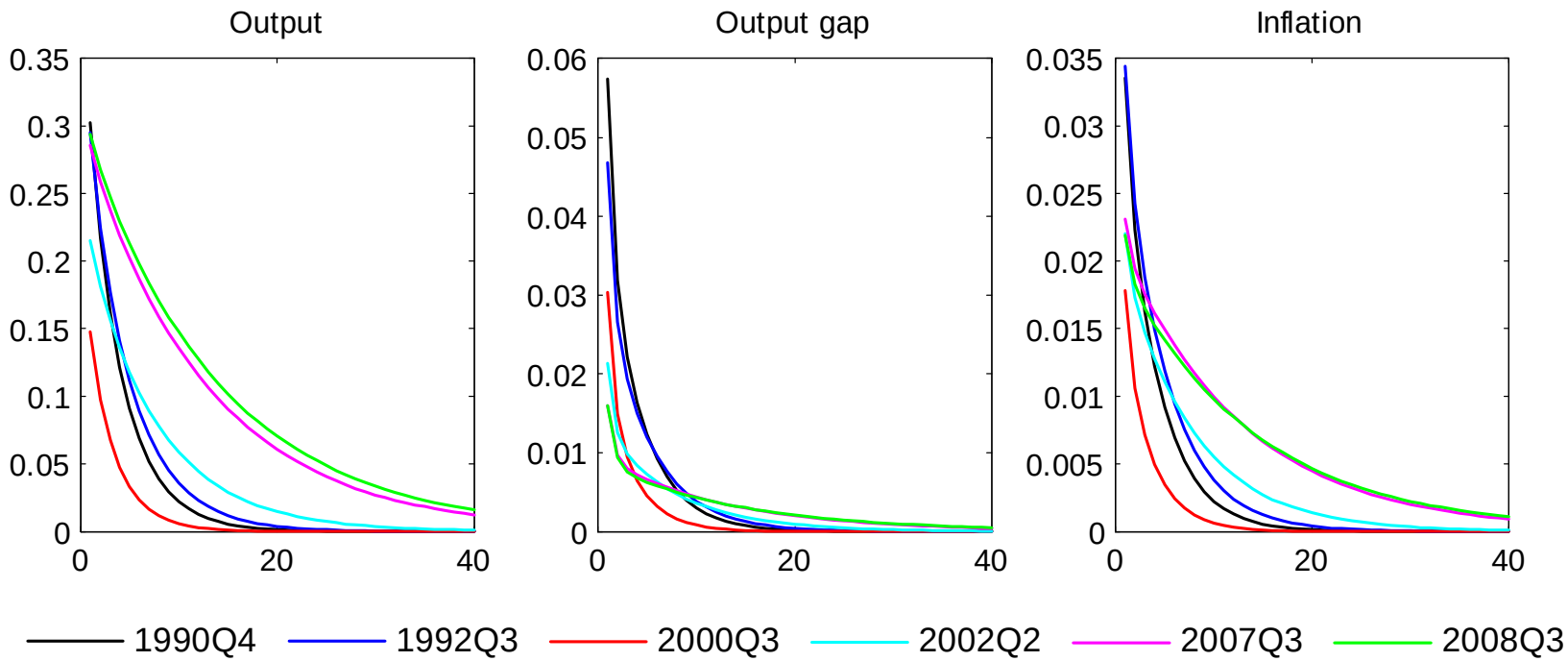
[Subprime crisis] Comparison between the **role of money on output** (short run variance decomposition, Model 2) and the spread Euribor-Bubill



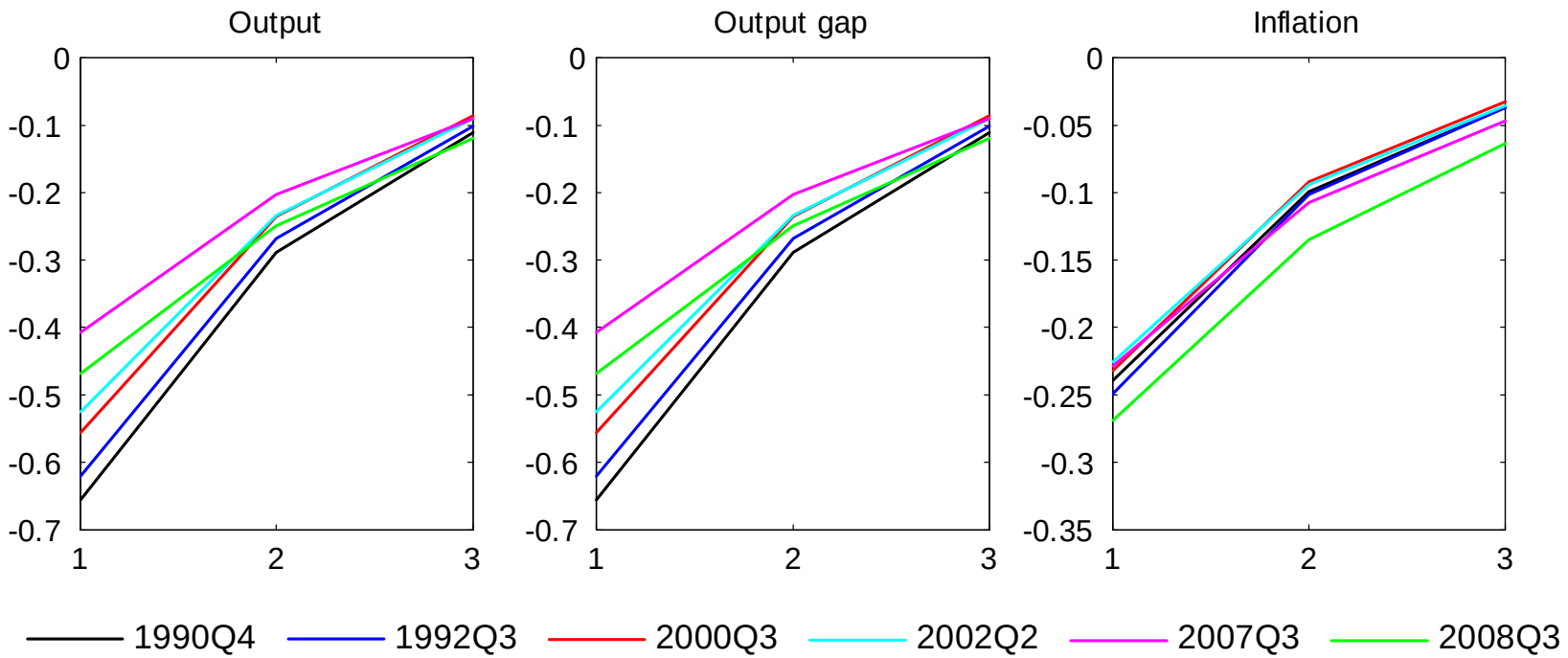
[Subprime crisis] Comparison between the **role of monetary policy on output** (short run variance decomposition, Model 2) and the spread Euribor-Bubill

[Subprime crisis] Comparison between the **role of monetary policy on inflation** (short run variance decomposition, Model 2) and the spread Euribor-Bubill

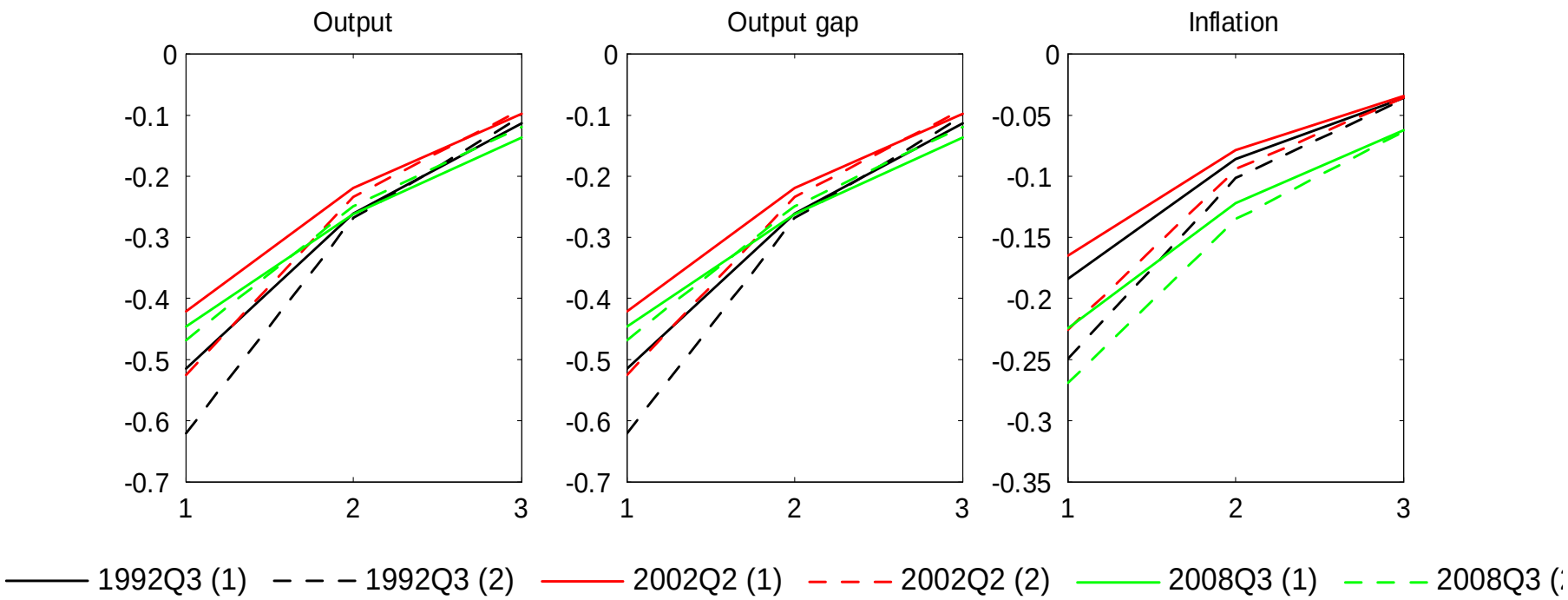
[Money shock] Impulse response function over the three crises



[Monetary policy shock] Impulse response function over the three crises



[Monetary policy shock] Impulse response function over the three crises and the two models



Comments

- We compared 2 DSGE models, one baseline model with **separable preferences** (Galí, 2008) and another with **non-separable preferences** (Benchimol and Fourçans, 2012), during 3 crisis periods: ERM crisis, Dot-com crisis and Subprime crisis.
- We tested the two models by using successive (rolling window) Bayesian estimations, so as to shed light on the evolution of parameters, of variance decompositions and of forecasting performances of the two models over the 3 crises.)

Tests

- This study was also conducted by using:
  - a preference shock instead of a price markup shock,
  - shorter sample sizes (16, 20, 24 obs),
  - model-based detrending methods and measurement equations,
  - Taylor rules without money-related variable,
  - an *ad-hoc* demand shock,
  - other monetary aggregates (M1, M2).
- All these studies lead to similar results.

Reminder (BF, 2012)

- Under a standard risk aversion: money plays a minor role in explaining output variability, as in the literature.
- **Under a higher risk aversion: money plays a non-negligible role in explaining output and flexible-price output fluctuations.**
- The explicit money variable does not appear to have a notable direct role in explaining inflation variability.
- Our results suggest that a nominal or real money growth variable does not improve the estimated ECB monetary policy rule. Yet, a **real money gap** variable significantly improves the estimated Taylor rule.
- One may infer that by **changing economic agents' perception of risks**, the last financial crisis may have increased the **role of money** in the transmission mechanisms and in output changes.

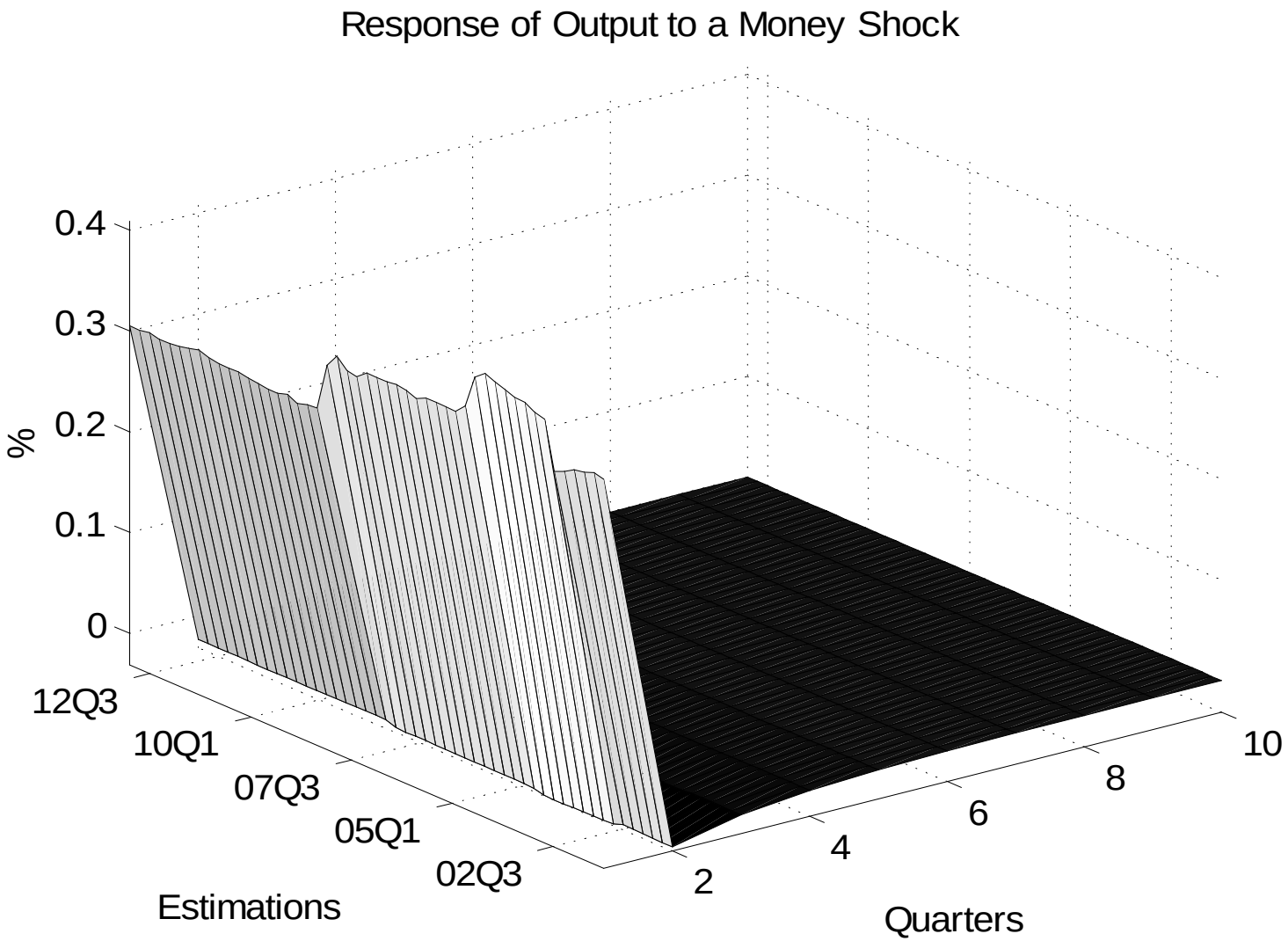
Conclusion

- Our analysis shows that money has a **significant role** to play in explaining output during crises. The role of money related variables increases during these periods.
- Inflation does not seem to be affected directly by money variables. It is mainly explained by monetary policy, but its impact also varies during crises.
- During crisis periods, New Keynesian DSGE models with non-separability between consumption and real money balances should be **preferred** to separable models as far as **macroeconomic forecasting** is concerned.

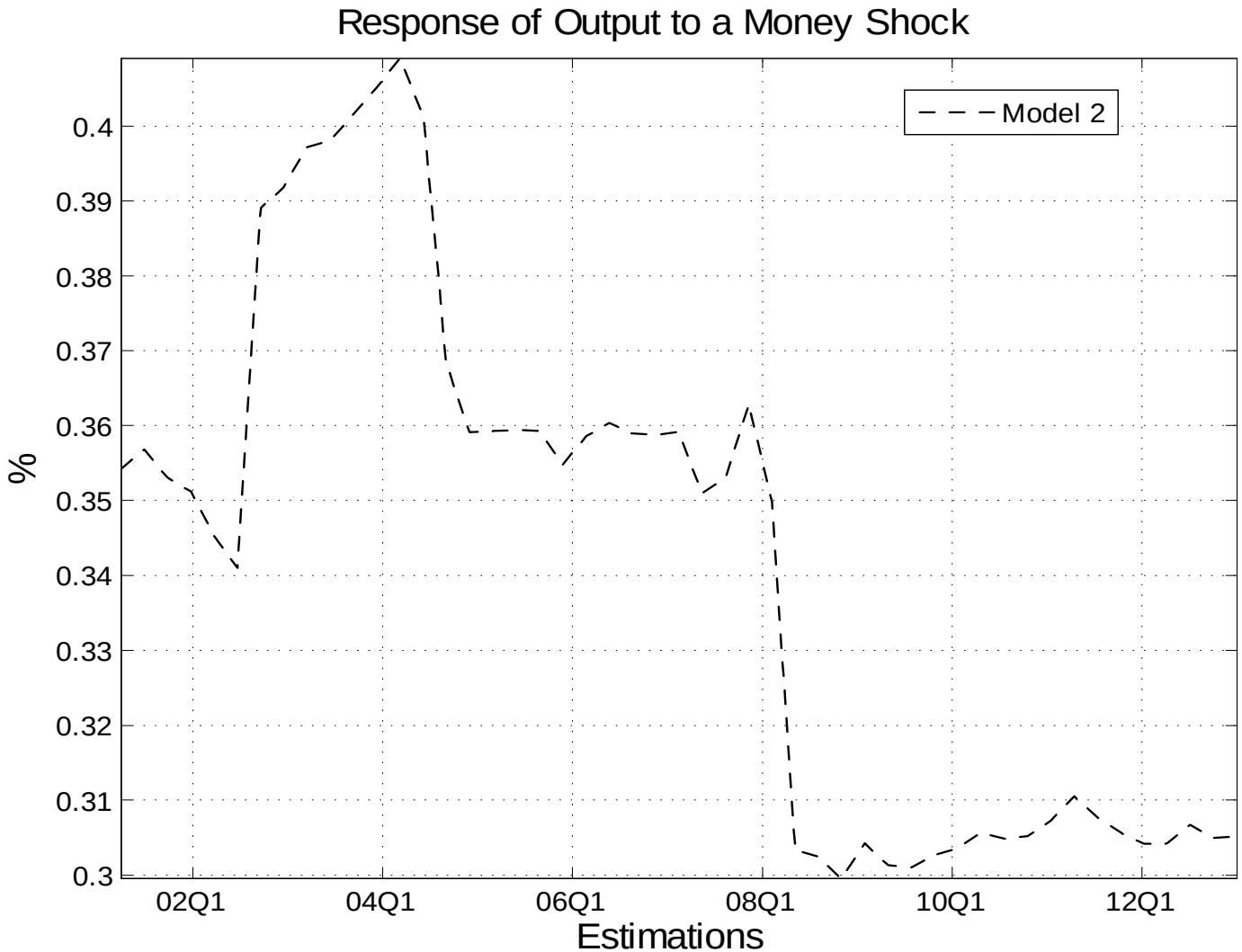
Further research

- Introduce habits (in consumption, money and leisure), capital, investment and government.
- Introduce micro-foundation of the central bank behavior.
- Risk aversion parameter and its implication in the process should be analyzed through a non-linear model and at least through second-order approximation of the overall model.
- Differentiate between risk aversion and uncertainty.
- Use other monetary aggregates measures such as Divisia Monetary Aggregates (Barnett, 1980).
- Just a minute, what about Israel ?

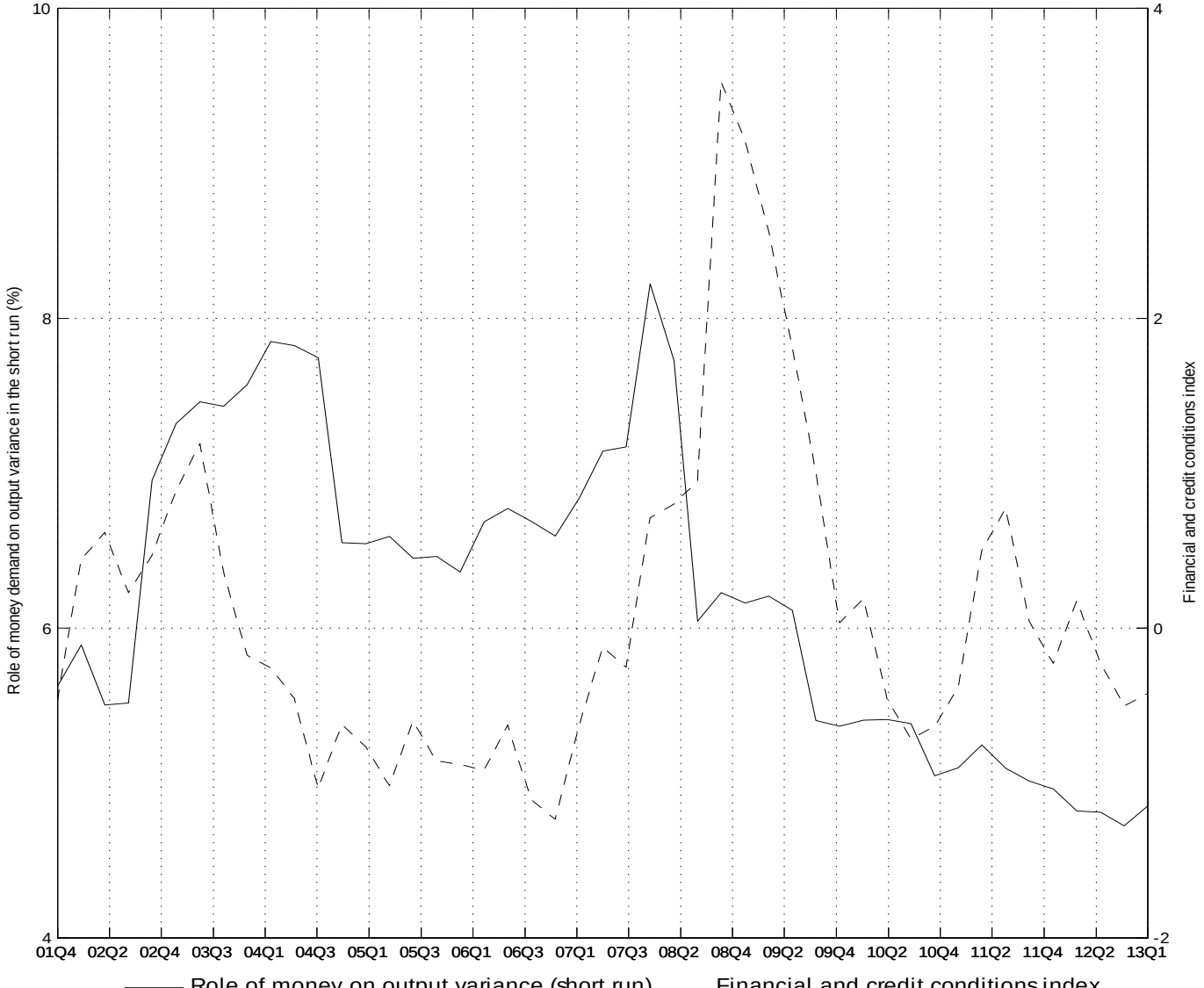
Impulse response function of output with respect to a money shock for Israel



On impact impulse response function of output with respect to a money shock for Israel



Comparison of the role of money on output variance and the financial condition index for Israel (Michelson and Suhoy, 2013).



Distance correlations between the role of money on output and the FCI and its components

	FCI	Bank	Debt	Forex	Equities	Resid.
Money shock's contribution to output variance	0.299	0.425	0.292	0.336	0.263	0.293

- Our indicator, the contribution of a money shock to output variance, is not linearly or non-linearly independent of the FCI or its components.
- Our indicator causes bank and debt components, at 0.89% (F-test: 7.52) and 7.80% (F-test: 3.25), respectively.
- Our indicator is not caused by the FCI or by one of its components.
- Our indicator seems to be a good predictive indicator of bank and debt risks.

Thank you !

- More questions, remarks or ideas to improve this paper, send me an email: **jonathan@benchimol.name**
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