Rationalizing the Irrational: How relevant are beliefs?

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Motivation

Following the financial crisis of 2008, a number of initial studies suggested that the interaction between the supply side and the financial sector was at the core of the contraction in GDP during the Great Recession. Although the original negative shocks were generated in the financial sector, a sharp drop in aggregate supply is observed.

10 years after the crisis, authors have started to talk about a long-term (*secular*) slowdown in income and GDP. Many of the causal factors suggested are related to the supply side, with important consequences for the financial-and monetary sectors.

Most existing macroeconomic models are not capable of replicating such a slowdown, even less to explain it. The transmission channels are simply not powerful enough to alter the steady state to a lower level. The only way is to include highly persistent permanent shocks that jointly hit the economy. Yet shocks, being generated elsewhere, do not explain anything.

In this paper, we propose a powerful joint propoagation mechanism including expectations-augmented asset prices, financial frictions, nominal rigidities, and supply-side imperfections that can explain a phenomenon of this type.

Yet, *a priori* it is not clear whether rational expectations can generate such dynamics. Moreover, how do expectations adjust when agents anticipate such a regime? Many have claimed that this hypothesis needs to be relaxed in order to generate that particular equilibrium. Moreover, it is not evident that (quasi) linear models are capable of encompassing such a scenario.

We integrate the new literature on bounded rationality (or heterogeneous expectations) in aggregate models in our analysis of this matter. We include this joint mechanism in a behavioural macro model as well as in a standard DSGE model. We evaluate their capacity to reproduce stylized empirical facts, as well as compare their cross-model performance.

- Some empirical facts
- What are we interested in?
- How do we model these facts?
- Results in the DSGE model
- Results in the behavioural model
- Model comparisons

Some empirical facts

DO CYCLICAL OR STRUCTURAL FACTORS LIE BEHIND THE GREAT RECESSION?

HOW PROFOUND HAVE THE EFFECTS BEEN ON MACRO-FINANCIAL LINKAGES, ECONOMIC PERFORMANCE, AND MACROECONOMIC STABILITY?

HAVE CYCLICAL AND STRUCTURAL EVENTS COINCIDED, DID CYCLICAL PROBLEMS BECOME STRUCTURAL, OR IS IT SIMPLY A QUESTION OF A COGNITIVE LIMITATION OF THE SCIENTIST?

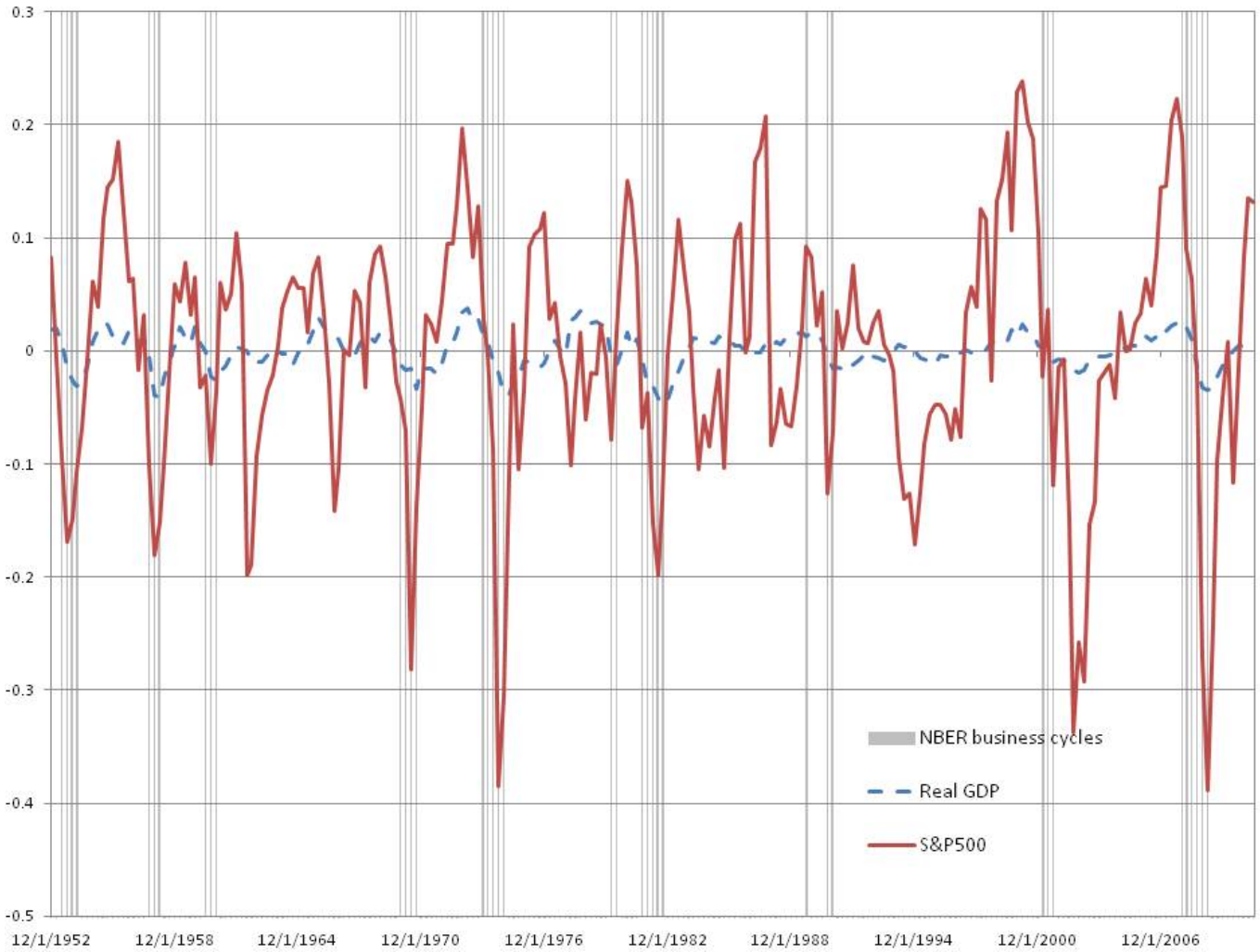
Real wages in most advanced economies have fallen since the start of the Great Recession. For many, this trend started much earlier.

At the same time, the level of indebtedness has increased over the past 2 decades. Meanwhile, the rate at which liquidity 'is produced' is at a historical high, but also prone to heavy swings (compare liquidity, credit supply, cost of financing, risk premia).

Asset price swings have also increased during the past 20 years (see S&P500 index). Moreover, Bank of England (2011, 2012) showed that price-to-book ratios for banks had remained below 1 for years.

Some empirical factsl
Asset prices in the US 1952-2012

Cyclical swings in S&P500



Real interest rates are at historically lowest levels. Some suggest (Summers, 2014) that the new natural rate of interest is close to zero (or negative). But inflation remains 'stubbornly' low, well below the rate at which it should be after all the unconventional policies.

There are important implications for asset prices. Their natural level may be lower, and remain low for long periods of time.

In this new regime, GDP is expected to grow at a lower rate. TFP growth is also expected to be small and decrease, while capital is having a more prominent role. The capital per worker ratio is therefore expected to explode. *(For more details see Eddie Gerba (2018) input to the Monetary Dialogue on 26 November regarding monetary policy effects of secular stagnation)*

Chadha and Warren (2012) estimate a business cycle accounting (BCA) model to find that the main cause of the output variation during the Great Recession to be the variation in the efficiency wedge of production, rather than any of the other factors, such as the labour supply, investment or total expenditure wedge.

In a BCA decomposition on a version of the BGG model that includes a dominant asset price, they find that the asset price shock show up in wedges other than the consumption or investment, and that the shocks transmitted via the supply-side may be generated elsewhere. Hence, the role of asset prices for the wider economy must be considered more broadly, as their impacts in general equilibrium may be to shift labour supply, or even to shift the ratio of outputs to inputs.

Manasse (2013) argues that the cause for the most recent recession in Italy is a weak and anemic supply side. A lack of reform in the product, labor and credit markets has resulted in weak (if not zero) innovation, competitiveness and productivity performance for more than a decade.

This empirical regularity applies to several other Eurozone countries, such as Spain, Portugal, Greece, and to some extent France.

Our approach

What are we interested in?
Supply-side matters a lot

Whether it is cyclical or structural, production-side of the economy matters. Not only for economic growth *per se*, but as potential powerful propagator, a kind of **financial amplifier**. Thus the question is:

In what way and under what conditions does the supply side work as a propagator of shocks generated in the financial sector, or more generally of financial shocks?

We propose to examine how imperfect credit and stock markets affect the allocations on the production side of the economy, and specifically the effects it has on the supply of capital and credit, demand for labour and technology. We perform a qualitative and quantitative study, and examine the ability that this joint has to explain recent phenomena.

But we do this in two frameworks:

Framework 1: RE-DSGE model with nominal rigidities. Linearized around a steady state.

Framework 2: Behavioural-macro model with nominal rigidities. Linearized around a stochastic steady state driven by learning.

In other words, we examine and quantify the role of beliefs for replicating stylized facts.

Models

Model 1

We start-off with a financial accelerator (BGG) model extended to include a stock market mechanism as in Gerba (2016) (not Bernanke and Gertler, 2000), and incorporate the following:

- We connect a corporate's purchasing power in the input markets to its external financing position/condition.
- We link a firm's marginal costs to the stock market performance of its equity.
- We introduce costs in the utilization of capital.

We connect a corporate's purchasing power in the input markets to its external financing position/condition.

$$E_t[S_{t+1}]K_{t+1} \leq \vartheta_t B_t \equiv \vartheta_t \left[\frac{E_t[S_{t+1}]K_{t+1}}{N_t}\right] \tag{1}$$

We link a firm's marginal costs to the stock market performance of its equity.

$$S(Y) = \min_{k,l}[R^s_{t+1}K_t + w_t L_t] \tag{2}$$

$$E_t[R^s_{t+1}] = E_t[\frac{(\frac{1}{X_{t+1}})(\frac{\alpha Y_{t+1}}{K_{t+1}}) + (1-\delta)S_{t+1}}{S_t}] \tag{3}$$

$$S_t = Q_t \sum_{\tau=1}^{\infty} R^{-\tau} E_t[X^{re}_{t+i}] = Q_t E_t[X^{re}_{t+\tau}/R^{\tau}] \tag{4}$$

$$X^{re}_t = \rho_x X^{re}_{t-1} + (\chi)(E_t[y_{t+1}] + n_t - E_t[r_{t+1}]) \tag{5}$$

We introduce costs in the utilization of capital.
V=max $E_0 \sum_{k=0}^{\infty}[(1-\mu)\int_0^{\varpi} \omega dF\omega U^{rk}_{t+1}]E_t(R^{ks}_{t+1})S_t\psi(u_t)K_{t+1} - R_{t+1}$
$S_t K_{t+1} - N_{t+1}$

Model 2

We start-off with a financial accelerator behavioural NK-model augmented with stock markets (De Grauwe and Macchiarelli, 2016) and incorporate the following:

The same mechanisms as outlined for Model 1. But because the RE hypothesis does not hold, stock prices are driven by **sentiments**, that not necessarily are rational (see De Grauwe and Gerba, 2018).

In **Behavioural** model:

- Agents are rationally 'bounded'. Understanding the full structure of the economy is excessively costly and cognitively difficult. Therefore agents *imperfectly* forecast output and inflation.
- They forecast using time-consistent rules and are (intrinsically) rational insofar that they learn from the past. Thus the memory parameter is different from 0.
- Stock markets are based on *imperfect* beliefs (of output and inflation in Gordon's dividend model) which can, at times, result in (myopic) sentiment-driven market dynamics.
- Model solved using recursive methods and Brock and Hommes (1998) learning algorithm.
- The model is highly non-linear and asymmetric over the business cycle.

Agent learning structure:

- Agents do not 'understand' the structure of the entire economy and therefore forecast output and inflation under limited cognitive ability.
- Following Brock and Hommes (1997,1998) and other similar, they forecast using two alternative rules:
- *Fundamentalist*: The steady state (or target) ratio is the best forecast of the future (Frankel and Froot, 1990):

$$\tilde{E}_t^f i_{t+1} = i^* \tag{6}$$

- *Extrapolative:* Last available observation is the best predictor of the future (Cogley (2002), Cogley and Sargent (2007) and Cornea, Hommes and Massaro (2013)). This is nested within the adaptive learning framework.

$$\tilde{E}_t^e i_{t+1} = \theta i_{t-1} \tag{7}$$

- All variables are expressed in gaps.

The switching between rules takes the following form:

- The market forecast is:

$$\tilde{E}_t i_{t+1} = \alpha_t^f \tilde{E}_t^f i_{t+1} + \alpha_t^e \tilde{E}_t^e i_{t+1} \tag{8}$$

- where for *fundamentalists* the share α_t^f is:

$$\alpha_{i,t}^f = \frac{exp(\gamma U_{i,t}^f)}{exp(\gamma U_{i,t}^f) + exp(\gamma U_{i,t}^e)} \tag{9}$$

- and the utility of one rule is:

$$U_{i,t}^f = -\sum_{k=0}^{\infty} w_k [i_{t-k-1} - \tilde{E}_{t-k-2}^f i_{t-k-1}]^2 \tag{10}$$

- and the gemoetrically declining weights adopted to include degree of forgetfulness is:

$$w_k = (\rho^k (1-\rho)) \tag{11}$$

An alternative way to view this exercise is through the lense of the method we employ:

- In one state of the world, agents are RATIONAL, growth results in NEW STEADY STATE, but otherwise the economy is LINEAR, and SYMMETRIC with respect to booms and busts. There is only inter-agent HETEROGENEITY.
- In the other state of the world, agents are CONSTRAINED in their EXTENSIVE rationality, but INTRINSICALLY rational, growth is endogenous, and the economy is highly NON-LINEAR and ASYMMETRIC with respect to booms and busts. There is BOTH inter-agent and intra-agent HETEROGENEITY.

In other words, we are comparing '*two extreme*' versions of macroeconomic models to test if any is superior in terms of empirical fit, and if future models should converge towards the first or the second. **Is non-linear necessarily better?**

Results

Quantitative results
How do we evaluate model performances?

DSGE:

- Moment matching: correlation and variance
- Impulse response analysis to supply and demand shocks

Behavioural:

- Analysis in frequency domain
- Impulse response analysis to supply and demand shocks

Cross-model:

- Moment matching: correlation and variance
- Impulse response analysis to supply and demand shocks (
- Asymmetries along the cycle)

DSGE

The supply-side and demand-side relation are correctly matched, and the autocorrelations are much closer to the data than in many other financial friction models.

- Autocorrelations of output, capital, inflation.
- Correlations of investment, consumption, stock prices, residual earnings, book value to the business cycle
- Many supply side relations are also captured such as capital-output, marginal costs-output, labour-output, capital-interest rate, and capital-marginal costs.

It does less well in capturing:

- Autocorrelation of the spread
- Correlations of output-inflation, inflation-interest rate, net worth of firms and banks to the general business cycle.

A significant number of second moments in the US data are captured:

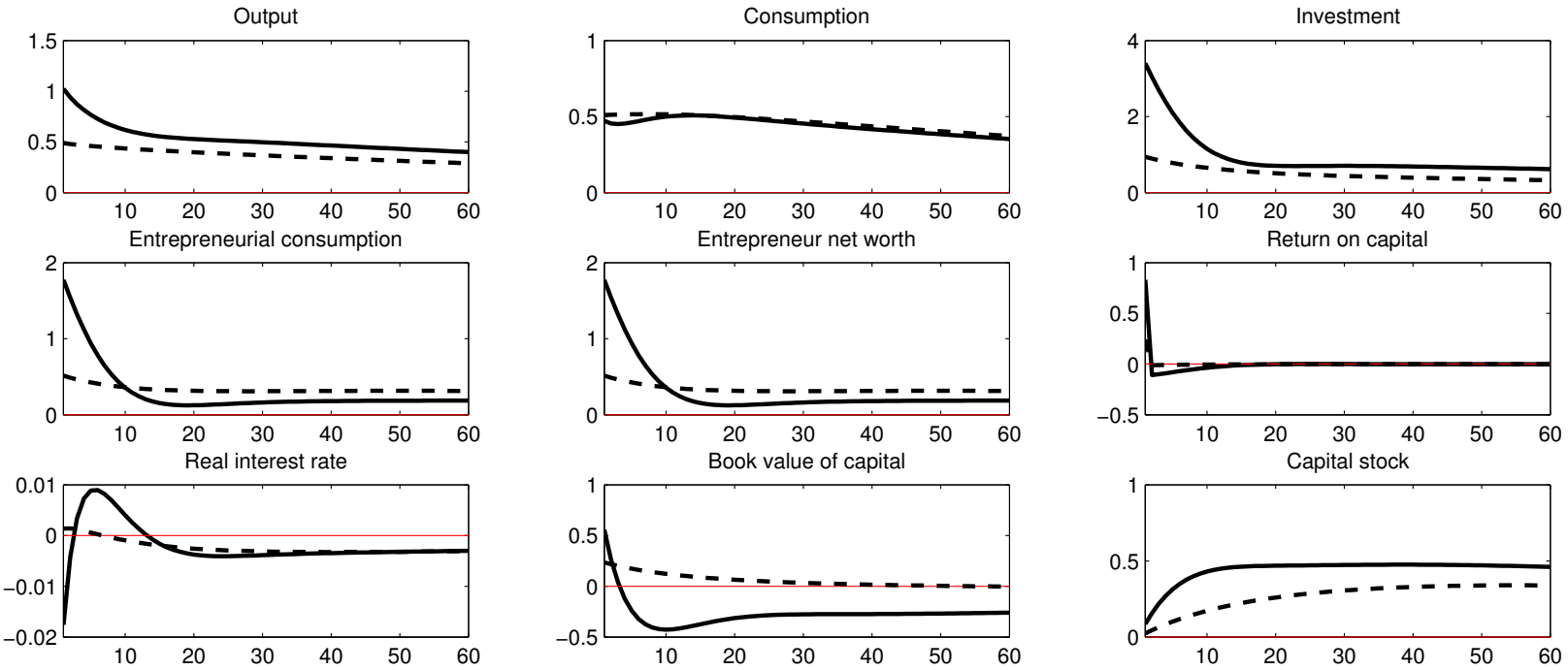
- Inflation, investment, labour supply, and net worth of firms.

It does less well in capturing:

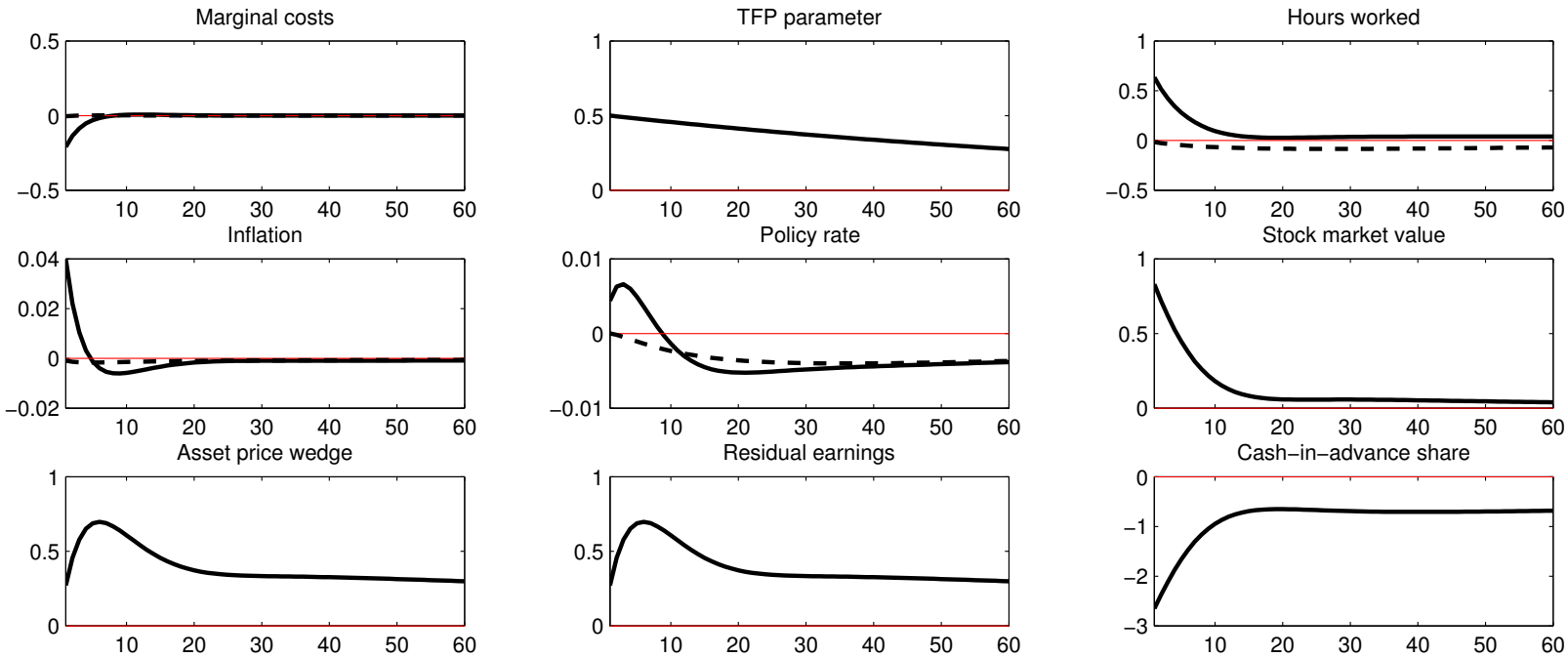
- Capital, residual earnings, and book value.

For the rest, it gets it right qualitatively, but not quantitatively (magnitudes).

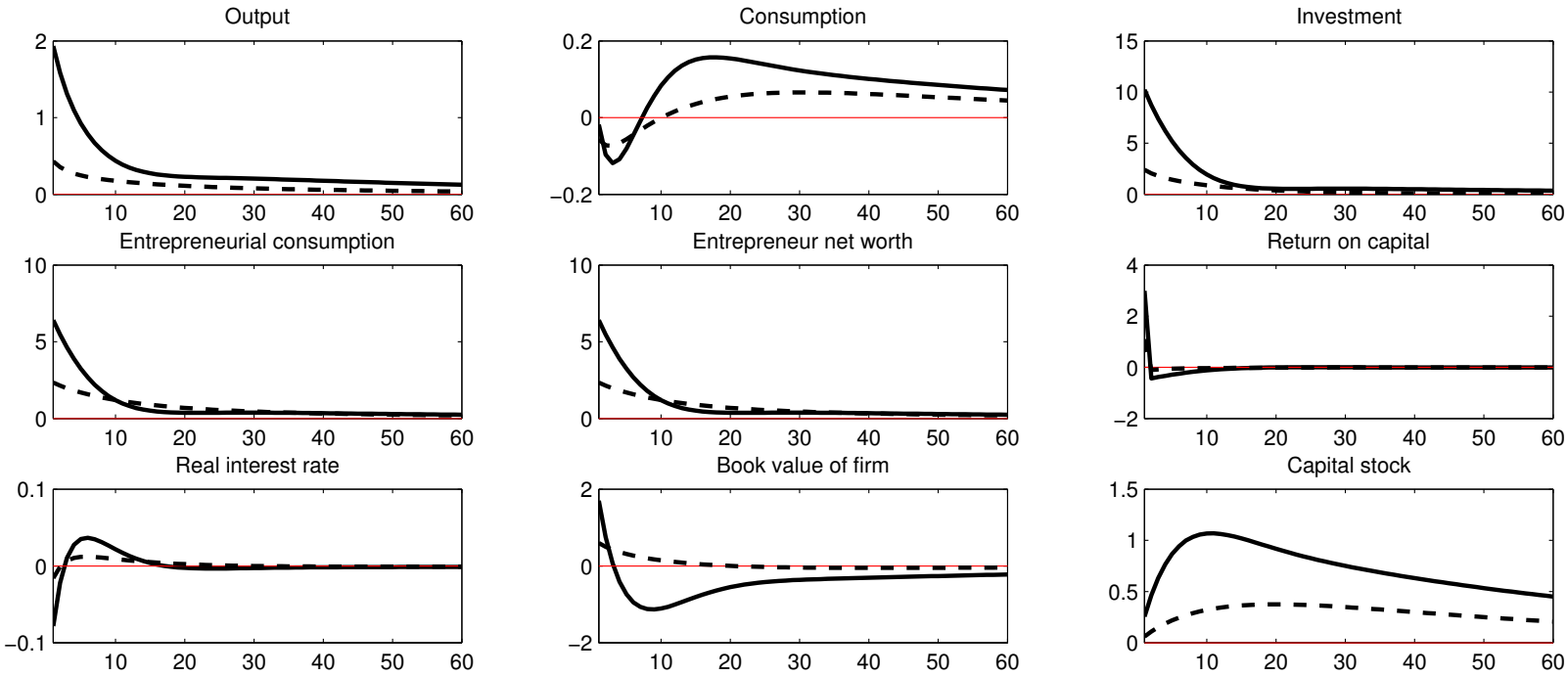
Responses to a (positive) TFP shock



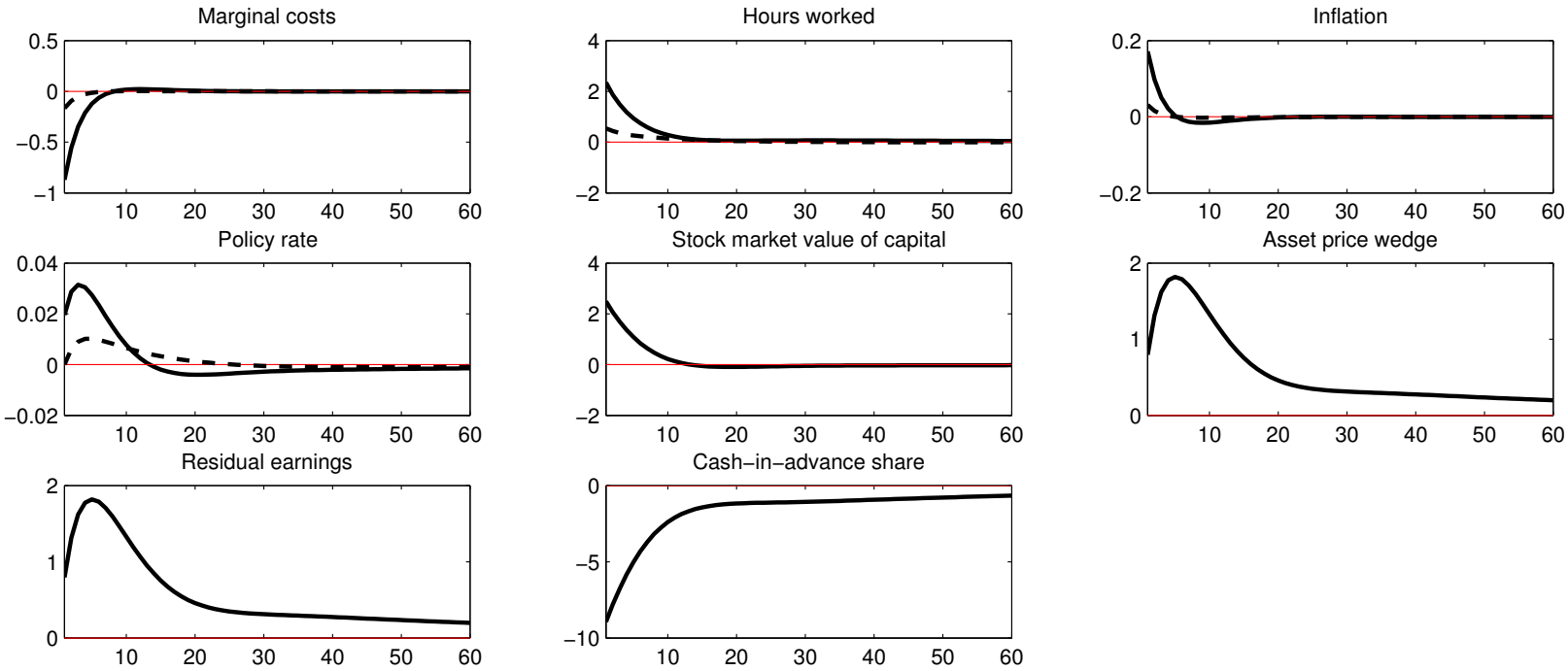
Responses to a (positive) TFP shock



Responses to a (positive) financial shock



Responses to a (positive) financial shock

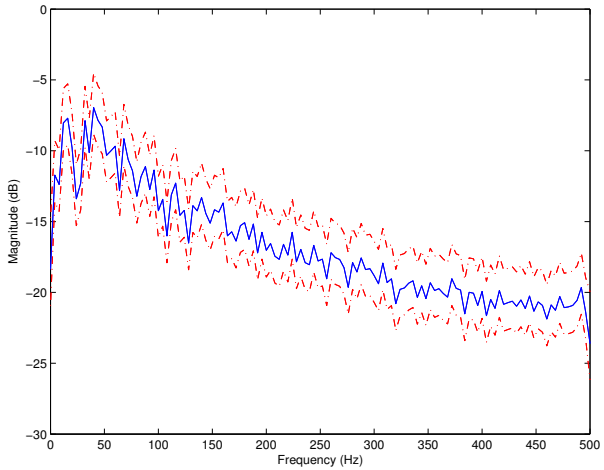


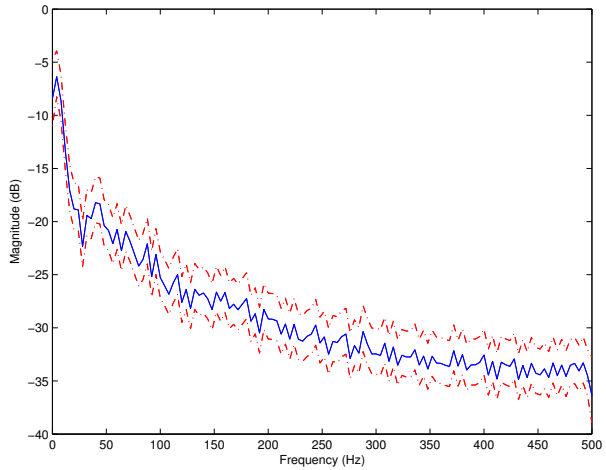
Behavioural

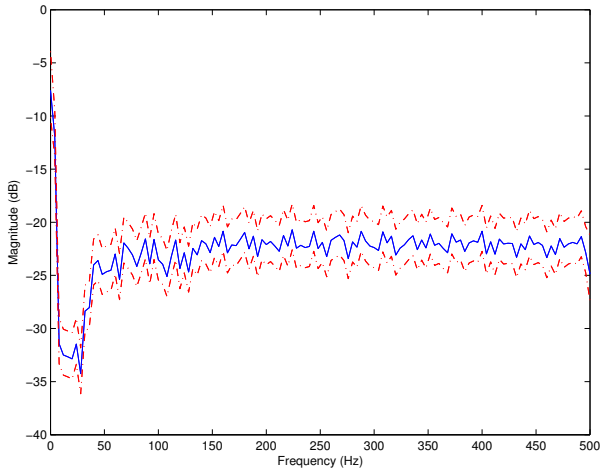
Quantitative results in the behavioural model

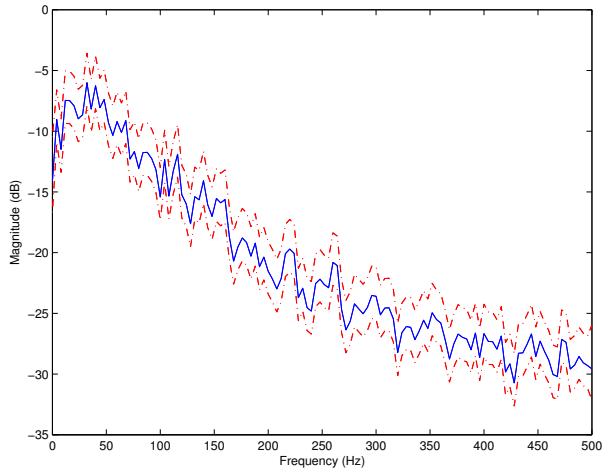
Frequency domain for real variables

Above: Output, capital; *Below*: Consumption, interest rate





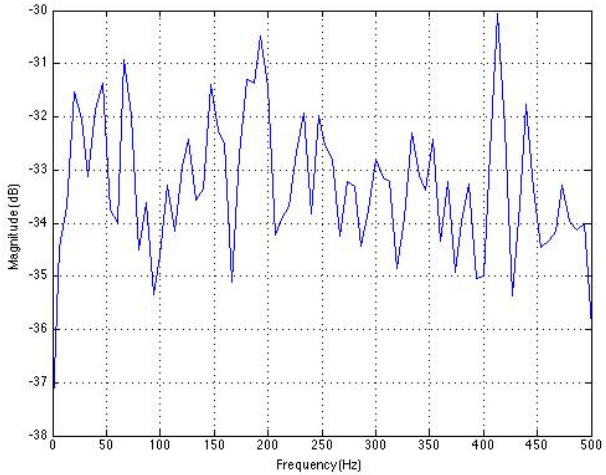


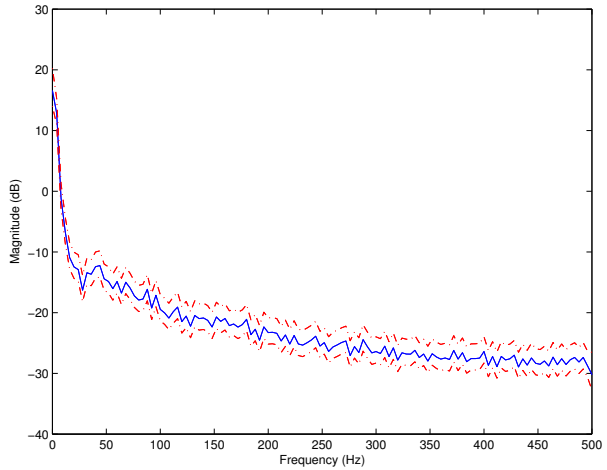


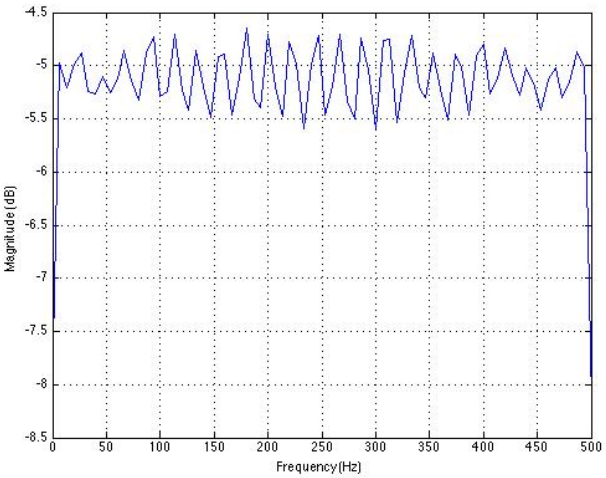
Quantitative results in the behavioural model

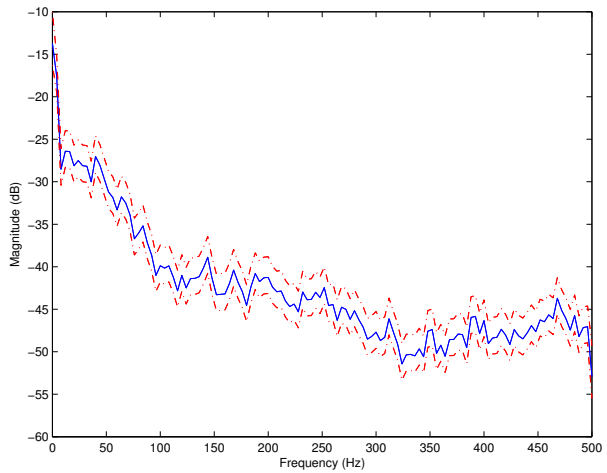
Frequency domain for financial/supply variables

Above: Utilization costs, loan supply; *Below*: Stock prices, sentiments



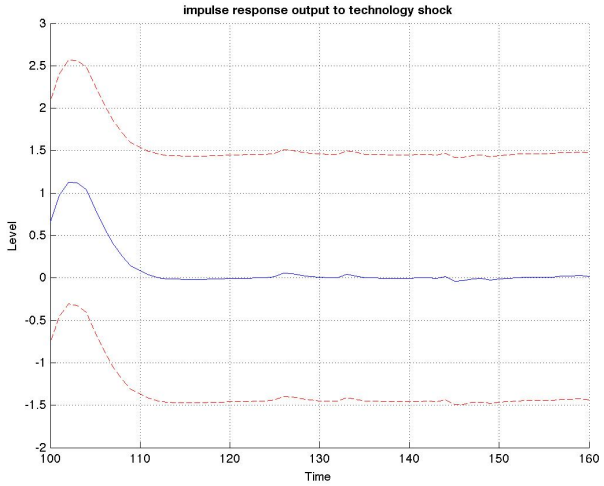


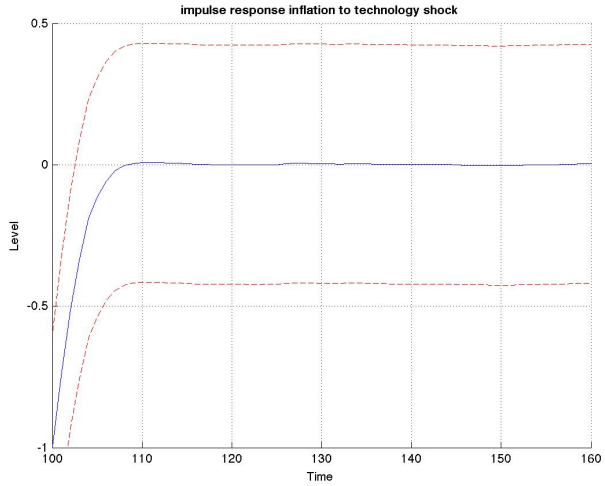


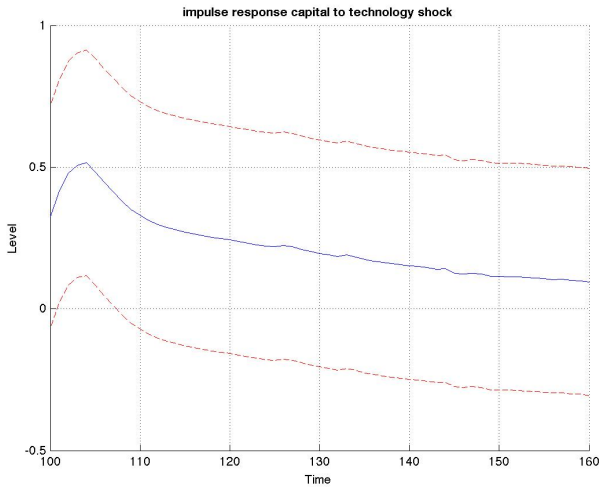


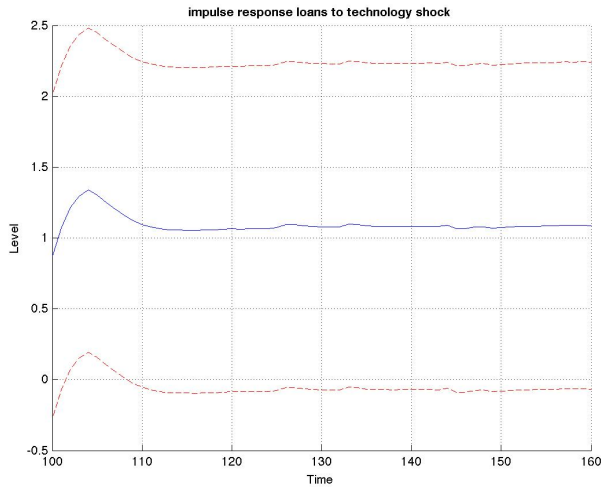
Quantitative results in the behavioural model
Technology shock

Responses to a (positive) TFP shock with 95% confidence interval



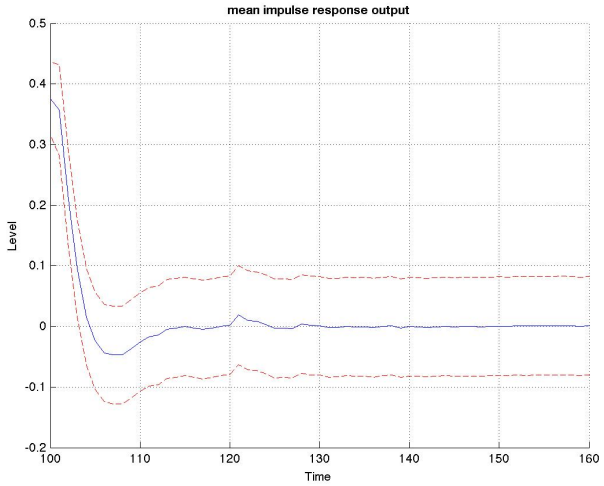


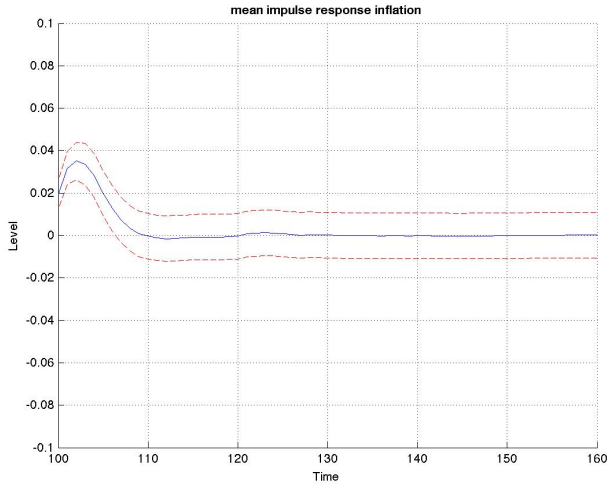


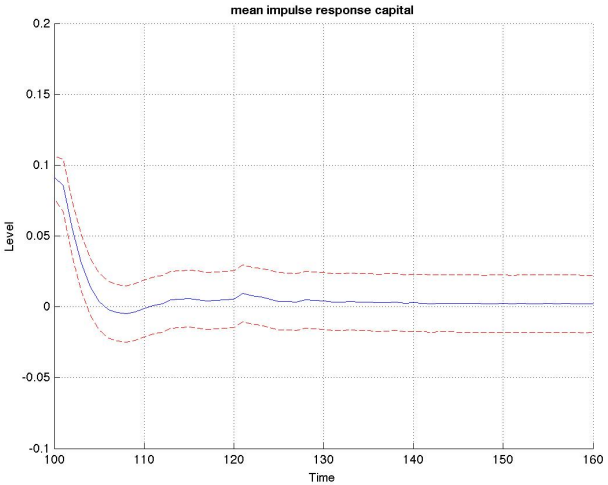


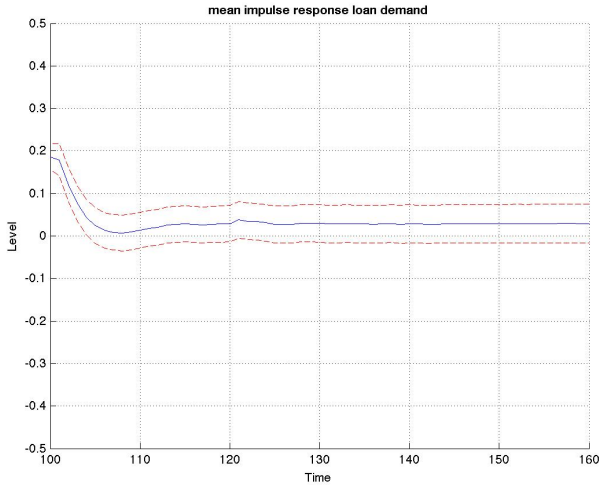
Quantitative results in the behavioural model
Financial shock

Responses to a (positive) financial shock with 95% confidence interval









Model comparisons

- Both models do a good job in capturing many (if not most) of the correlations. However, behavioural is even more successful as it matches 13 correlations better than the DSGE model (the opposite is only 4).
- Behavioural model better in matching: autocorrelations, stock market cycle, prices and many of the suplly-side relations.
- DSGE model better in matching: capital series and some demand-side variables.

- Similar pattern as for correlations.
- Behavioural model matches: 8 variables better than DSGE: prices, some financial accelerator variables (loan supply, net worth of banks, net worth of firms)
- DSGE model matches: 5 variables better than behavioural: supply side variables and some demand-side variables (investment, consumption, book value)

- In general, a starker transmission and higher responses to supply shocks in the behavioural model, but to financial/monetary shocks in the DSGE model.
- For supply shocks, the responses in the behavioural model are significantly higher, in particular for investment and inflation (AR term included in the shock for the DSGE model)
- For financial shocks, the IRFs in the DSGE model are between **5** and **10** times higher (no AR term in the shock has been included in either of the models)
- The supply channel (more than cognitive limitation of agents) plays a larger role in the propagation of financial shocks

- Output, consumption, investment and capital are almost symmetric over the business cycle (weakly skewed and highly platykurtic). This is much easier to capture in a linearized DSGE model than in the behavioural.
- However, most of the other variables are highly asymmetric (and non-linear) over the cycle (highly skewed and leptokurtic). Much better captured in the behavioural model.
- Financial variables (loan supply, deposits, interest rate, net worth of firms, net worth of banks), prices (inflation, stock market prices and animal spirits) and marginal costs are closely replicated in the behavioural model (if anything the asymmetry or kurtosis is even higher in the model compared to the data).

- Bear in mind that asymmetries in the behavioural model are endogenously created.
- Interaction between market frictions and learning leads to powerful propagation of shocks.
- In the RE-DSGE model, on the other hand, the propagation is achieved via the interaction between market frictions and highly persistent shocks.
- To conclude, tractability is compromised for complexity in the behavioural model: The tractability of the model solution in the DSGE model is clearer and more straight-forward.

Annex

- We introduce Capital Good Producers who produce primary goods and sell them to Entrepreneurs. CGP face investment adjustment costs in their production (see Christiano et al, 2005).

$$\max_{K_t, I_t} E_0 \Sigma_{t=0}^{\infty} \Lambda_{0,t} [Q_t [K_t - (1-\delta) K_{t-1}] - I_t] \tag{12}$$

$$K_t = (1-\delta) K_{t-1} + [1 - \frac{\kappa_i}{2} [\frac{I_t}{I_{t-1}} - 1]^2] I_t \tag{13}$$

- The purchasing power of Entrepreneurs in the input market is directly conditional on its access to liquidity in the financial market.

$$\vartheta E_t[S_{t+1}] K_{t+1} + w_t L_t + \psi(u_t) K_t + R_t [S_t K_t - N_t] + (1-\vartheta) S_t K_t = \frac{Y_t}{X_t} + [E_t[S_{t+1}] K_{t+1} - N_{t+1}] + E_t[S_t](1-\delta) K_{t-1} \tag{14}$$

- We introduce a pay-in-advance constraint for entrepreneurs (a share of their external credit) as a pre-payment insurance to CGP.

$$E_t[S_{t+1}]K_{t+1} \leq \vartheta_t B_t \equiv \vartheta_t[E_t[S_{t+1}]K_{t+1} - N_t] \tag{15}$$

- Entrepreneurs face (capital) utilization costs in the production of wholesale goods.

$$Y_t = A_t[\psi(u_t)K_t]^{\alpha} L^{1-\alpha} \tag{16}$$

$$\psi(u_t) = \xi_0 + \xi_1(u_t - 1) + \frac{\xi_2}{2}(u_t - 1)^2 \tag{17}$$

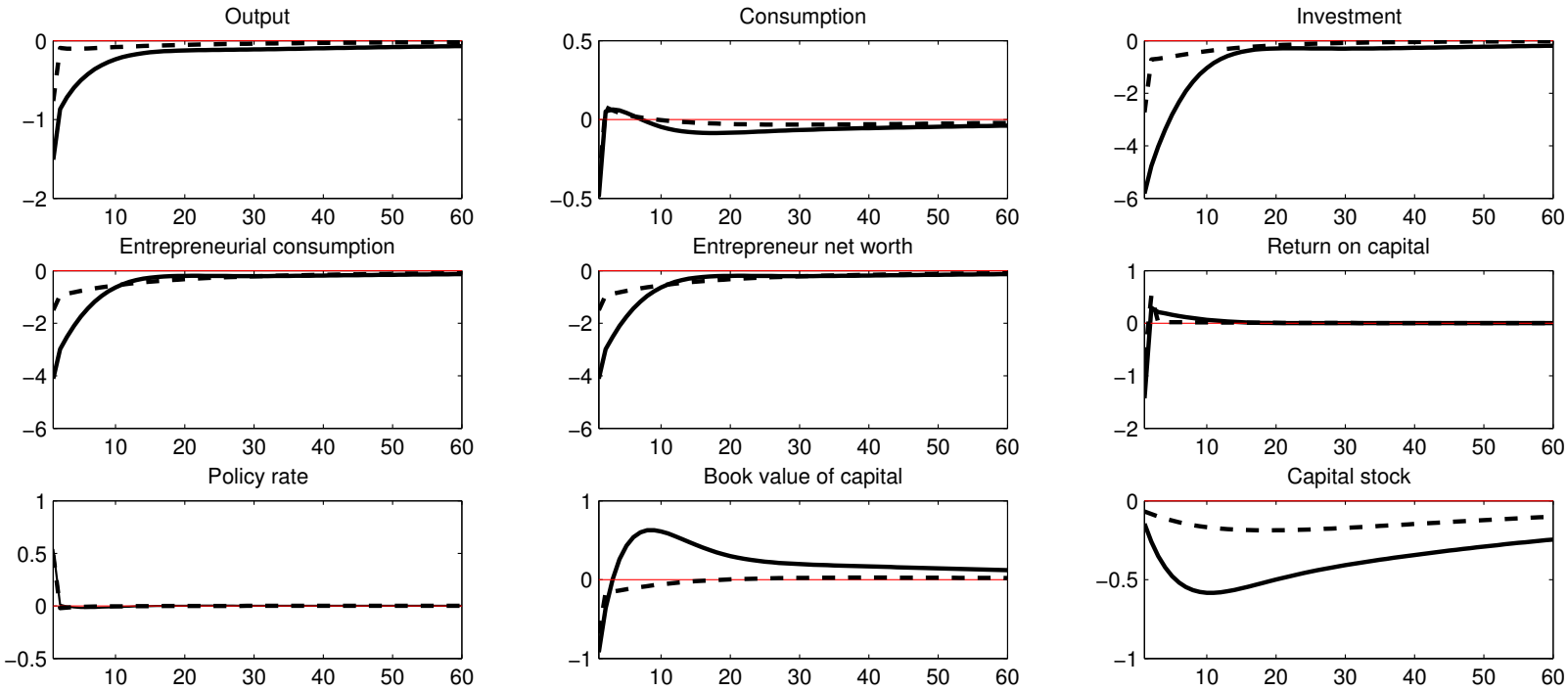
We have introduced the same type of supply-side and financial friction in the behavioural De Grauwe and Macchiarelli (2016) model. Moreover:

- We have introduced stock market prices based on the Gordon dividend model. De Grauwe and Macchiarelli (2016) assume that the pay-out share of the nominal GDP is constant over time. We use here the same assumption.

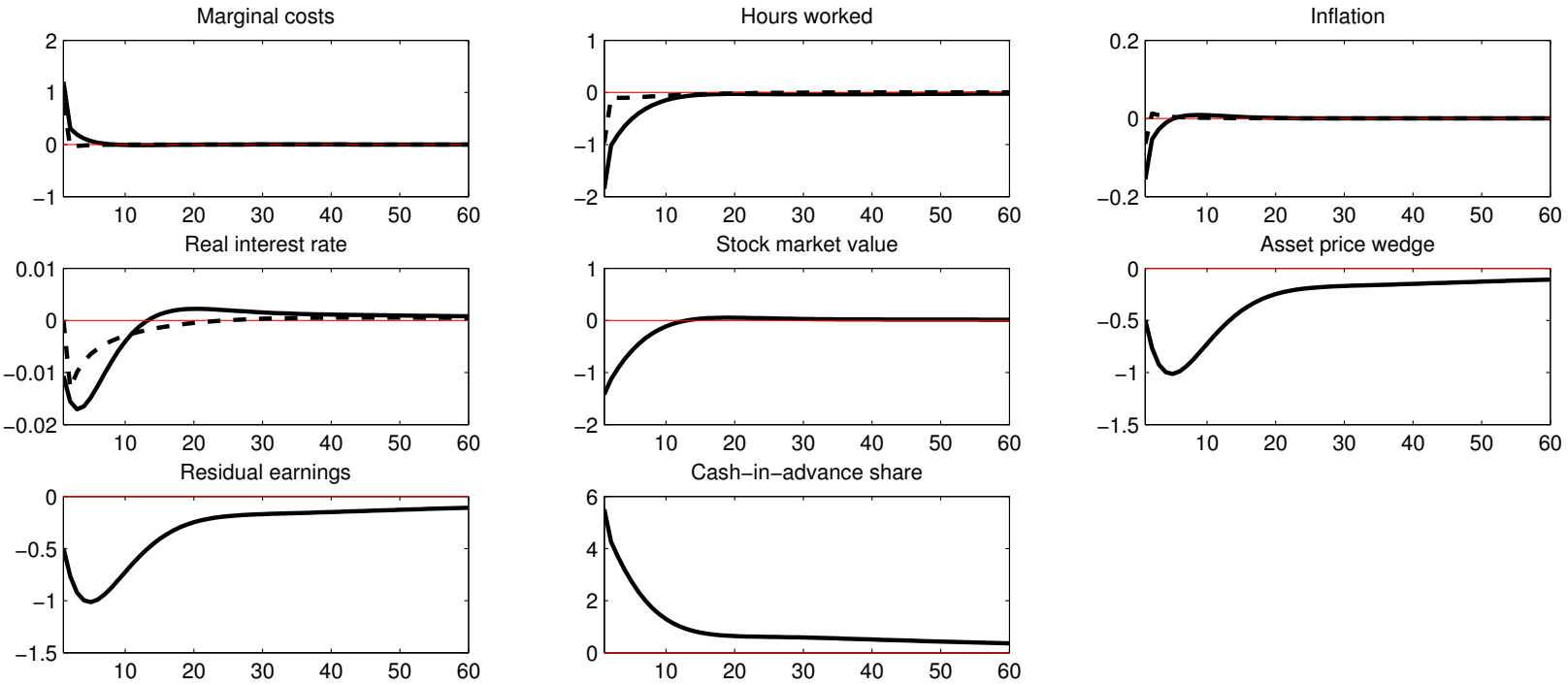
$$S_t = \frac{E_t[\bar{\Lambda}_{t+1}]}{R_t^s} \tag{18}$$

- Agents in this set-up assume that the 1-period ahead forecast of dividends is a fraction f of the nominal GDP one period ahead, and constant thereafter in $t+1$, $t+2$, etc. Since nominal GDP consists of a real and inflation component, agents make forecast of future output gap and inflation. This forecast is reevaluated in each period

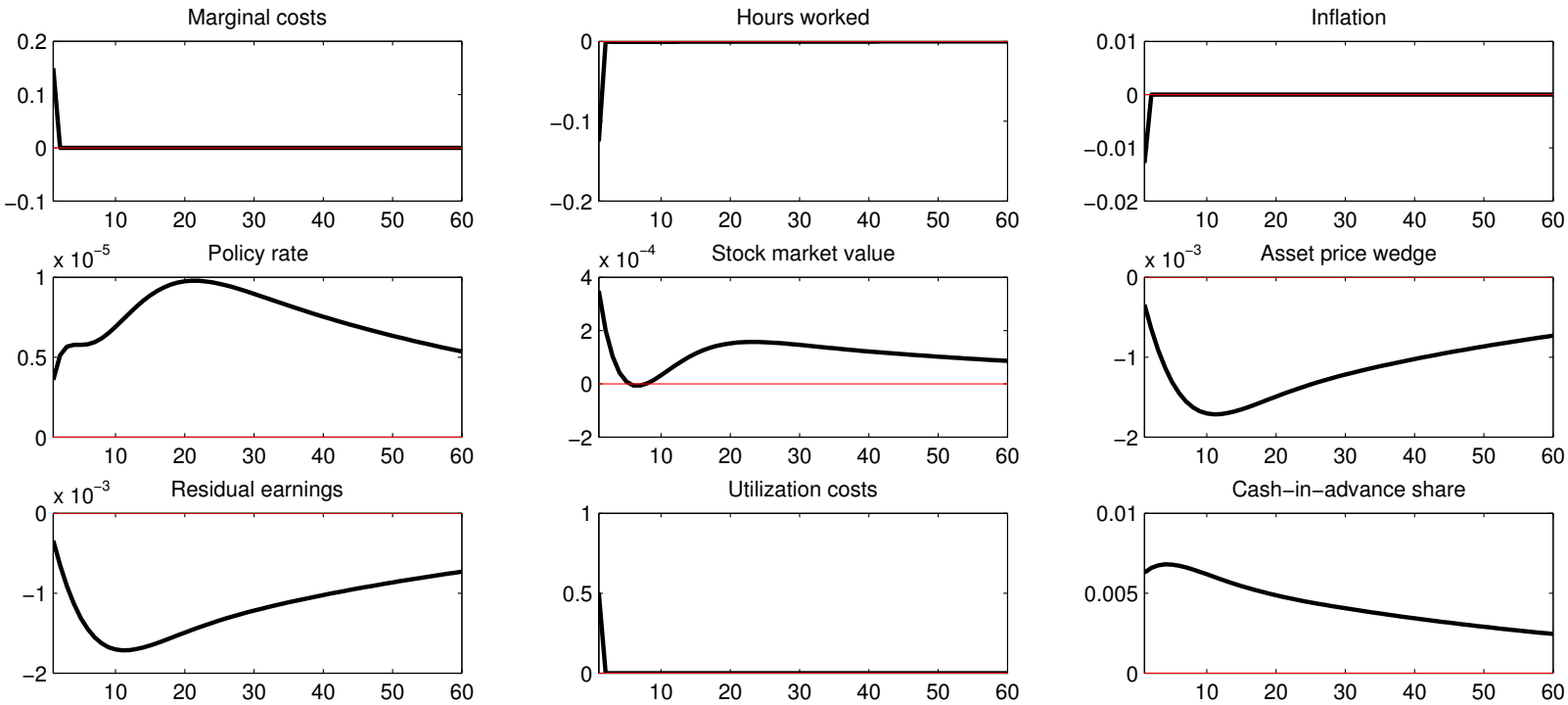
Responses to a (contractionary) monetary policy shock



Responses to a (contractionary) monetary policy shock



Responses to a (positive) shock ot utilization costs



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