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THE INCREASED IMPORTANCE OF ASSET PRICE MISALIGNMENTS
FOR BUSINESS CYCLE DYNAMICS

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The Increased Importance of Asset Price Misalignments for Business Cycle Dynamics¹

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We outline a dynamic stochastic general equilibrium (DSGE) model with trend extrapolation in asset pricing that we fit to quarterly U.S. macroeconomic time series with Bayesian techniques. To be more precise, we modify the DSGE model in Smets and Wouters (2007) by incorporating asset traders who use a mix of fundamental analysis and trend extrapolation in asset pricing. We conclude that trend extrapolation in asset pricing is quantitatively relevant, statistically significant and results in a substantial improvement of the model's fit to the data. We also find that the strength in trend extrapolation is much stronger during the Great Moderation than it was prior to this period. Moreover, allowing for asset mispricing leads to more pronounced hump-shaped dynamics of the asset price and investment. Thus, asset price misalignments should be an important ingredient in DSGE models that aim to understand business cycles dynamics in general and the interaction between the real and financial sectors in particular.

JEL Codes: E32; E44; G01.

Keywords: Asset Price Bubble; Bayesian Technique; Business Cycle; DSGE Model; Fundamental Analysis; Trend Extrapolation.

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1. Introduction

We outline a dynamic stochastic general equilibrium (DSGE) model with trend extrapolation in asset pricing that we fit to quarterly U.S. macroeconomic time series with Bayesian techniques.

To be more precise, we modify the DSGE model in Smets and Wouters (2007) by incorporating asset traders who use a mix of fundamental analysis and trend extrapolation in asset pricing. By doing this modification of their model, we are not only able to quantify to what extent asset prices are misaligned – that is, to what extent asset prices deviate from fundamentals (defined by a conventional present value model) – we are also able to quantify the importance of asset price misalignments for business cycle dynamics.

The main reason why we fit such a DSGE model to the data is the historical evidence that misaligned asset prices have had important consequences for business cycle dynamics. Reinhart and Rogoff (2008b) found in their study of eight centuries of economic crises that a run-up in asset prices is common to most crises. The mispricing of assets also seemed to have played a particularly large role during the Great Recession that started in the U.S. in December 2007 and thereafter was spread to the rest of the world with devastating effects (see Reinhart and Rogoff, 2008a, 2009).

The dominant view in macroeconomic research today is otherwise that asset prices are determined by fundamentals only. This is mostly due to the work of Milton Friedman, but also to Fama's (1965) efficient market hypothesis (see also Samuelson, 1965, for an argument that properly anticipated prices fluctuate randomly). Friedman's (1953) argument was that due to arbitrage at financial markets, sophisticated traders outperform naïve traders and therefore drive them out from the markets. Because of this literature tradition, the effects of asset mispricing have mostly been ignored in business cycle models in general and in DSGE models in particular.

There is, however, empirical evidence suggesting that a significant part of stock price movements cannot be justified by changes in fundamentals. A convincing case was presented by Campbell and Shiller (1987) who found that stock price deviations from fundamentals were quite persistent and also statistically rejected the present value model in stock (and also bond) pricing. Campbell and Shiller (1988), LeRoy and Porter (1981), and Shiller (1981), among others, present similar results. Shiller's (2005) book on irrational exuberance in financial markets should also be mentioned in this context.

Yet another empirical study that has found price deviations from fundamentals in the stock market is Cipriani and Guarino (2010) who looked at transaction data on a New York Stock Exchange stock and found evidence that *"herding often arises and is particularly pervasive on some days"* (p. 1). Brunnermeier and Nagel (2004) made a compelling case that even rational arbitrageurs such as *"hedge funds were riding the technology bubble"* (p. 2014) of the late 1990s and that this did not seem *"to be the result of unaware-*

ness of the bubble" (p. 2013). See also Jegadeesh and Titman (2001) and Korajczyk and Sadka (2004), among others, on profitable momentum strategies in stock trading.

In addition, there is an extensive literature that theoretically demonstrate why Friedman's (1953) claim not necessarily is true (see De Long et al., 1990, and Shleifer and Vishny, 1997, on the limits to arbitrage) and that asset prices can be misaligned despite the presence of rational arbitrageurs (see Abreu and Brunnermeier, 2003, for a model with coordination problems; see Adam et al., 2008, for a learning model; see Angeletos and Werning, 2006, for a model with heterogeneous information; and see Tirole, 1982, for a model with asymmetric information).

Other mechanisms that may cause asset prices to deviate from fundamentals are agency problems (see Allen and Gale, 2000), bounded rationality (see Hong and Stein, 1999), and short-selling constraints (see Gilchrist et al., 2005, and Miller, 1977).

To sum-up, research on asset pricing is increasingly sympathetic to the idea that asset mispricing is not only possible, but also likely. This indicates to us that other asset pricing models, besides the present value model, should be considered in business cycle research.

Alas, despite the key role of misaligned asset prices in several economic recessions, there are few DSGE or DSGE-like models with misaligned asset prices (Bernanke and Gertler, 1999, 2001, De Grauwe, 2011, Kontonikas and Ioannidis, 2005, and Kontonikas and Montagnoli, 2006, belong to the few examples that exist) and no empirical evaluation of its importance (Castelnuovo and Nistico, 2010, find "*a significant role of stock prices in affecting real activity and the business cycle*", p. 1700, but do not consider the possibility of asset mispricing). Thus, to the best of our knowledge, the DSGE model in the present paper is the first model with misaligned asset prices that is fitted to data.

With this paper, we intend to fill this gap in the literature. We therefore incorporate asset traders who use a mix of fundamental analysis and trend extrapolation in asset pricing, resulting in a deviation of the asset price from its fundamental value, into the DSGE model in Smets and Wouters (2007). The data set we use when estimating our DSGE model with Bayesian techniques consists of the same quarterly U.S. macroeconomic time series as in Smets and Wouters (2007), except that we have updated their data set so that it now covers the period between 1966Q1 and 2009Q4.

There are several results we would like to emphasize:

First, trend extrapolation in asset pricing matters. What we find is that the weight attached to trend extrapolation is $2/3$ and that the strength in trend extrapolation is $3/4$. At a first glance, one might argue that the weight attached to fundamental analysis in asset pricing is too small to be a reliable figure. However, the capital in our DSGE model does not only constitute of capital traded at equity markets, but all physical capital in the economy. Thus, our finding that trend extrapolation in asset pricing matters does not have to be at odds with the literature tradition of Eugene Fama.

Second, when we compare the fit of our DSGE model to the data, we obtain very strong evidence in favor of our model over the DSGE model in Smets and Wouters (2007) as well as an alternative specification of their model in which investment expenditures are pre-determined. We can therefore conclude that ‘trend extrapolation in asset pricing’ is not merely a delayed response of investment to the fundamental asset price.

Third, there has been an increased importance of asset price misalignments for business cycle dynamics in recent decades. Specifically, we find that the strength in trend extrapolation in asset pricing is much stronger in the sub-sample that starts in 1984Q1 and ends in 2009Q4, also known as the Great Moderation, than it is in the sub-sample that covers the period between 1966Q1 and 1979Q2.

Fourth, trend extrapolation in asset pricing visibly affects the dynamic responses of the macroeconomic variables in our DSGE model. In particular, it leads to more pronounced hump-shaped responses of the asset price and investment to the different exogenous shocks in the model.

Finally, our DSGE model is better at matching the volatilities in the data than the DSGE model in Smets and Wouters (2007); our DSGE model is more consistent with the decrease in most volatilities during the Great Moderation than the Smets and Wouters (2007) model; and our DSGE model correctly predicts that the volatility in the asset price increased during the Great Moderation, whereas the DSGE model in Smets and Wouters (2007) counterfactually predicts that the same volatility decreased. The last result is especially encouraging since asset pricing plays a key role in our DSGE model.

All these results taken together conclusively support the hypothesis that fluctuations in main U.S. macroeconomic variables are affected by deviations of asset prices from their fundamental values. This also means that asset price misalignments should be an important ingredient in DSGE models that aim to understand business cycles dynamics in general and the interaction between the real and financial sectors in particular.

The rest of the paper is organized as follows: Our linearized DSGE model is presented in the next section, whereas a quantitative analysis of this model and the DSGE model in Smets and Wouters (2007) is performed in Section 3. The paper is thereafter concluded in Section 4 with a discussion of our main findings.

2. The linearized DSGE model

Herein, we outline the linearized DSGE model that we subsequently fit to quarterly U.S. macroeconomic time series. All variables in the model are log-linearized around their steady-state balanced growth path. Apart from the incorporation of asset traders who extrapolate the trend in the asset price, our model is identical to the DSGE model in Smets and Wouters (2007). We therefore follow their notation as closely as possible.

Our choice of the DSGE model in Smets and Wouters (2007) as the baseline model is motivated by its inclusion of a wide variety of real and nominal frictions as well as its good fit to main aggregate U.S. time series (i.e., output, consumption, investment, the real wage, hours worked, the inflation rate, and the interest rate) and, in a slightly different version, to Eurozone data as well (see Smets and Wouters, 2003). Cúrdia and Reis (2010) point out that "*central banks around the world have adopted variants of this model*" (p. 24) and this too fundamented our choice to use it as our main reference.

Since the only modeling change of the Smets and Wouters (2007) model is with respect to asset pricing, we first explain, in Section 2.1, how the asset price is determined in our model. Thereafter, in Sections 2.2 and 2.3, we describe the rest of the model, including the stochastic processes for the exogenous shocks, which coincide with the model in Smets and Wouters (2007).

2.1. Asset pricing in our model

Following the set-up in Bask (2011), among others, we assume that the asset price, q_t , is determined by a weighted average of the asset price according to trend extrapolation, q_t^c , also known as the 'chartist' price (to be defined in (2)), and the asset's fundamental value, q_t^f :

$$(1) \quad q_t = \omega q_t^c + (1 - \omega) q_t^f,$$

where $0 \leq \omega \leq 1$ is the weight attached to trend extrapolation in asset trading. The 'weight' parameter (ω) is estimated when the model is fitted to the data.

The asset price according to trend extrapolation equals the previous asset price plus the previous change in the asset price times a 'strength' parameter in trend extrapolation, $\vartheta > 0$:

$$(2) \quad q_t^c = q_{t-1} + \vartheta(q_{t-1} - q_{t-2}).$$

Thus, if the asset price increased (decreased) between times $t - 2$ and $t - 1$, it is assumed that the asset price continues to increase (decrease) between times $t - 1$ and t . The 'strength' parameter (ϑ) is also estimated when we fit our model to the data.⁴

If $\omega = 1$ in (1), which means that the asset's fundamental value has no impact in asset pricing, (1)-(2) can be written as

$$(3) \quad \Delta q_t = \vartheta \Delta q_{t-1} = \vartheta(\vartheta \Delta q_{t-2}) = \vartheta^2 \Delta q_{t-2} = \dots = \vartheta^t q_{t-t},$$

⁴ Even though we here restrict the 'strength' parameter to positive values, $\vartheta > 0$, our prior distribution when we fit our model to the data is that this parameter is uniformly distributed over the interval $\vartheta \in [-3, 3]$ (see Section 3).

where $\Delta q_t \equiv q_t - q_{t-1}$. Thus, if $\vartheta > 1$, subsequent changes in the asset price will grow exponentially, whereas they will shrink over time if $0 < \vartheta < 1$. We therefore interpret $\vartheta > 1$ as a necessary condition for having an explosive bubble in the asset price. It is not a sufficient condition since the asset price is also determined by its fundamental value when $0 < \omega < 1$. Still, the asset price is misaligned when $q_t \neq q_t^f$, and this is irrespective of the value of ϑ .

One must be careful when interpreting the results in the quantitative analysis since to be able to estimate a DSGE model such as our model, it must have a determinate and stable equilibrium. This means that an explosive asset price bubble is ruled out already in the outset. Nevertheless, whenever $\vartheta > 1$ in the quantitative analysis, this result is emphasized since it is associated with a strong degree of trend extrapolation in asset pricing.

Continuing with the asset's fundamental value, it is determined by the same present value model as in Smets and Wouters (2007). According to this model, the current asset price depends positively on its expected future price and the expected future real rental rate on capital, and negatively on the (ex ante) real interest rate and a risk premium shock:

$$(4) \quad q_t^f = q_1 E_t q_{t+1}^f + (1 - q_1) E_t r_{t+1}^k - (r_t - E_t \pi_{t+1} + \varepsilon_t^b),$$

where r_t^k is the real rental rate on capital, r_t is the nominal interest rate that is controlled by the central bank, π_t is the inflation rate, and ε_t^b is the risk premium shock that represents a wedge between the interest rate controlled by the central bank and the return on assets held by households.

Moreover, $q_1 = \beta \gamma^{-\sigma_c} (1 - \delta)$, where β is the discount factor that is applied by households, γ is the steady-state growth rate in the economy, σ_c is the elasticity of intertemporal substitution, and δ is the depreciation rate of the capital stock.

If $\omega = 0$ in (1), (1) and (4) reduce to the asset pricing equation in Smets and Wouters (2007) (see equation (4) in their paper). In this limiting case, the asset price is determined solely by its fundamental value. If $0 < \omega < 1$, the asset price is only partly determined by its fundamental value and this is because the changes in past asset prices also affect the current asset price. Thus, the asset price is misaligned in this case since, in general, $q_t \neq q_t^f$.

We now describe the remaining equations in our model, which coincide with those found in Smets and Wouters (2007).

2.2. The rest of the model

Besides (1)-(2) and (4) in the previous subsection, there are three more equations that describe the aggregate demand side of the model, nine equations that describe the ag-

gregate supply side of it, and, finally, there is a Taylor rule that describes monetary policy in the model.

Since all equations herein coincide with equations found in Smets and Wouters (2007), we only present them briefly. For details and for derivations of the equations from the agents' (households, firms, etc.) optimization problems, see Smets and Wouters (2007), including the Model Appendix to their paper.

2.2.1. Aggregate demand side of the model

If we begin with the aggregate demand side of the model, the aggregate resource constraint is

$$(5) \quad y_t = c_y c_t + i_y i_t + z_y z_t + \varepsilon_t^g,$$

where y_t is output, c_t is consumption, i_t is investment, z_t is the capital-utilization rate, and ε_t^g is a fiscal shock that represents exogenous spending that also includes net exports. Moreover, $c_y = 1 - g_y - i_y$ and $i_y = (\gamma - 1 + \delta)k_y$ are the steady-state consumption-output ratio and the steady-state investment-output ratio, respectively, where g_y and k_y are the steady-state exogenous spending-output ratio and the steady-state capital-output ratio, respectively. Finally, $z_y = R_*^k k_y$, where R_*^k is the steady-state rental rate on capital.

There are two Euler equations that describe the optimal behavior by households; one equation for consumption behavior and another equation for investment behavior. Specifically, consumption dynamics is given by

$$(6) \quad c_t = c_1 c_{t-1} + (1 - c_1) E_t c_{t+1} + c_2 (l_t - E_t l_{t+1}) - c_3 (r_t - E_t \pi_{t+1} + \varepsilon_t^b),$$

which means that current consumption is determined by a weighted average of past consumption (due to habit formation) and expected future consumption as well as the expected growth in hours worked, the (ex ante) real interest rate, and a risk premium shock. l_t is hours worked. Moreover, $c_1 = \frac{\lambda/\gamma}{1+\lambda/\gamma}$, $c_2 = \frac{(W_*^h L_*/C_*)(\sigma_c - 1)}{(1+\lambda/\gamma)\sigma_c}$, and $c_3 = \frac{1-\lambda/\gamma}{(1+\lambda/\gamma)\sigma_c}$, where λ is the habit parameter in consumption, W_*^h is the steady-state wage rate, L_* is steady-state labor services, and C_* is steady-state consumption.

Further on, investment dynamics is given by⁵

$$(7) \quad i_t = i_1 i_{t-1} + (1 - i_1) E_t i_{t+1} + i_2 q_t + \varepsilon_t^i,$$

⁵ For reasons explained further (see Section 3), we also fit an alternative specification of the model in Smets and Wouters (2007) to the data in which investment expenditures are pre-determined. To be more precise, we replace (7) with an equation in which investment expenditures at time t are determined by investment plans made at time $t - 1$.

which means that current investment is determined by a weighted average of past investment and expected future investment as well as the asset price and an investment-specific technology shock. Moreover, $i_1 = \frac{1}{1+\beta\gamma^{1-\sigma_c}}$ and $i_2 = \frac{1}{(1+\beta\gamma^{1-\sigma_c})\gamma^2\varphi}$, where φ is the steady-state elasticity of the cost of adjusting capital.

As in Christiano et al. (2005), the cost of adjusting capital is a function of the change in investment rather than its level, which better captures the hump-shaped response of investment to various exogenous shocks.

This completes our description of the aggregate demand side of the model.

2.2.2. Aggregate supply side of the model

If we continue with the aggregate supply side of the model, the aggregate production function is

$$(8) \quad y_t = \phi_p(\alpha k_t^S + (1 - \alpha)l_t + \varepsilon_t^a),$$

where k_t^S and l_t are capital and labor services (i.e., hours worked), respectively, and ε_t^a is a total factor productivity shock. Moreover, α is the share of capital in production and ϕ_p equals one plus the share of fixed costs in production.

The capital used in production, in turn, equals capital installed in the previous period plus the capital-utilization rate:

$$(9) \quad k_t^S = k_{t-1} + z_t,$$

where the capital-utilization rate depends on the real rental rate on capital:

$$(10) \quad z_t = z_1 r_t^k.$$

Here, $z_1 = \frac{1-\psi}{\psi}$, where ψ depends positively on the elasticity of the cost of adjusting the capital-utilization rate. Cost minimization by households determines the capital-utilization rate.

The accumulation of installed capital is a weighted average of capital installed in the previous period and current investment as well as the investment-specific technology shock:

$$(11) \quad k_t = k_1 k_{t-1} + (1 - k_1)i_t + k_2 \varepsilon_t^i,$$

where $k_1 = \frac{1-\delta}{\gamma}$ and $k_2 = (1 + \beta\gamma^{1-\sigma_c}) (1 - \frac{1-\delta}{\gamma}) \gamma^2 \varphi$.

If we turn to the monopolistically competitive goods market, the price mark-up, μ_t^p , at the goods market is

$$(12) \quad \mu_t^p = \alpha(k_t^s - l_t) + \varepsilon_t^a - w_t,$$

where the first two terms are the marginal product of labor and the third term is the real wage, w_t . Thus, the marginal product of labor depends on the capital-labor services ratio and the total factor productivity shock.

The Phillips curve follows from profit maximization by firms:

$$(13) \quad \pi_t = \pi_1 \pi_{t-1} + \pi_2 E_t \pi_{t+1} - \pi_3 \mu_t^p + \varepsilon_t^p,$$

which means that the current inflation rate depends on the past inflation rate, the expected future inflation rate, the price mark-up, and a price mark-up shock, ε_t^p . Moreover,

$\pi_1 = \frac{\iota_p}{1+\beta\gamma^{1-\sigma_c}\iota_p}$, $\pi_2 = \frac{\beta\gamma^{1-\sigma_c}}{1+\beta\gamma^{1-\sigma_c}\iota_p}$, and $\pi_3 = \frac{1}{1+\beta\gamma^{1-\sigma_c}\iota_p} \cdot \frac{(1-\beta\gamma^{1-\sigma_c}\xi_p)(1-\xi_p)}{(1+\varepsilon_p(\phi_p-1))\xi_p}$, where ι_p is the degree of indexation to past inflation rates, ξ_p is the degree of price stickiness (cf., Calvo, 1983), and ε_p is the curvature of the Kimball (1995) goods market aggregator.

Cost minimization by firms means that the real rental rate on capital is

$$(14) \quad r_t^k = -(k_t - l_t) + w_t,$$

which means that the real rental rate on capital depends negatively on the capital-labor ratio and positively on the real wage.

If we turn to the monopolistically competitive labor market, the wage mark-up, μ_t^w , at the labor market is

$$(15) \quad \mu_t^w = w_t - \left(\sigma_l l_t + \frac{1}{1-\lambda/\gamma} \cdot \left(c_t - \frac{\lambda}{\gamma} \cdot c_{t-1} \right) \right),$$

where σ_l is the elasticity of labor supply with respect to the real wage.

Similarly, as with the Phillips curve (see (13)), the real wage is affected by partial indexation to past inflation rates and to nominal wage stickiness (cf., Calvo, 1983):

$$(16) \quad w_t = w_1 w_{t-1} + (1 - w_1)(E_t w_{t+1} + E_t \pi_{t+1}) - w_2 \pi_t + w_3 \pi_{t-1} - w_4 \mu_t^w + \varepsilon_t^w,$$

where ε_t^w is a wage mark-up shock. Moreover, $w_1 = \frac{1}{1+\beta\gamma^{1-\sigma_c}}$, $w_2 = \frac{1+\beta\gamma^{1-\sigma_c}\iota_w}{1+\beta\gamma^{1-\sigma_c}}$, $w_3 = \frac{\iota_w}{1+\beta\gamma^{1-\sigma_c}}$,

and $w_4 = \frac{1}{1+\beta\gamma^{1-\sigma_c}} \cdot \frac{(1-\beta\gamma^{1-\sigma_c}\xi_w)(1-\xi_w)}{(1+\varepsilon_w(\phi_w-1))\xi_w}$, where ι_w is the degree of indexation to past nominal wages, ξ_w is the degree of nominal wage stickiness, ε_w is the curvature of the Kimball (1995) labor market aggregator, and ϕ_w equals one plus the steady-state wage mark-up.

This completes our description of the aggregate supply side of the model.

2.2.3. Monetary policy in the model

Last but not least, the central bank sets the nominal interest rate according to the following Taylor rule (see Taylor, 1993, for the origin of this rule):

$$(17) \quad r_t = \rho r_{t-1} + (1 - \rho) (r_\pi \pi_t + r_y (y_t - y_t^p)) + r_{\Delta y} (y_t - y_t^p - (y_{t-1} - y_{t-1}^p)) + \varepsilon_t^r,$$

where y_t^p is potential output, which means that the difference between actual and potential output, $y_t - y_t^p$, is the output gap, and ε_t^r is a monetary policy shock. Moreover, ρ is the degree of interest rate inertia in monetary policy, r_π is the response in monetary policy to the inflation rate, r_y is the response in monetary policy to the output gap, and $r_{\Delta y}$ is the response in monetary policy to the change in output gap.

2.3. Shocks in the model

After we have presented the equations that determine the endogenous variables in the model, it is time to specify the stochastic processes for the exogenous shocks. Specifically, there are seven stochastic processes in the model that also coincide with the stochastic processes in Smets and Wouters (2007): (i) the risk premium shock:

$$(18) \quad \varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \eta_t^b;$$

(ii) the fiscal shock:

$$(19) \quad \varepsilon_t^g = \rho_g \varepsilon_{t-1}^g + \eta_t^g + \rho_{ga} \eta_t^a,$$

where the total factor productivity shock also affects the fiscal shock, and this is because net exports are included in exogenous spending that are affected by domestic productivity; (iii) the investment-specific technology shock:

$$(20) \quad \varepsilon_t^i = \rho_i \varepsilon_{t-1}^i + \eta_t^i;$$

(iv) the total factor productivity shock:

$$(21) \quad \varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a;$$

(v) the price mark-up shock:

$$(22) \quad \varepsilon_t^p = \rho_p \varepsilon_{t-1}^p + \eta_t^p - \mu_p \eta_{t-1}^p;$$

(vi) the wage mark-up shock:

$$(23) \quad \varepsilon_t^w = \rho_w \varepsilon_{t-1}^w + \eta_t^w - \mu_w \eta_{t-1}^w;$$

and (vii) the monetary policy shock:

$$(24) \quad \varepsilon_t^r = \rho_r \varepsilon_{t-1}^r + \eta_t^r.$$

Finally, $\eta_t^b, \eta_t^g, \eta_t^a, \eta_t^i, \eta_t^p, \eta_t^w$, and η_t^r are IID-Normal error terms with standard deviations $\sigma_t^b, \sigma_t^g, \sigma_t^a, \sigma_t^i, \sigma_t^p, \sigma_t^w$, and σ_t^r , respectively.

This completes the description of our linearized DSGE model.

3. Quantitative analysis

Herein, we fit our linearized DSGE model and the DSGE model in Smets and Wouters (2007) to quarterly U.S. macroeconomic time series and ask ourselves: *‘Does trend extrapolation in asset pricing matter?’*, *‘How well does our model fit the data?’*, and *‘Has there been an increased importance of asset price misalignments for business cycle dynamics?’*.

We also fit an alternative specification of the DSGE model in Smets and Wouters (2007) to the data in which investment expenditures are pre-determined. To be more precise, we replace (7) with an equation in which investment expenditures at time t are determined by investment plans made at time $t - 1$.

We simulate the DSGE models under scrutiny and evaluate the dynamic responses to various shocks via impulse-response functions for key macroeconomic variables. The volatilities of these variables are thereafter compared with the respective volatilities in the data, including a study of how the volatilities have changed between the two sub-samples in the data set.

The data set is described in Section 3.1, whereas the DSGE models are estimated and simulated in Sections 3.2 and 3.3, respectively.

3.1. Data set

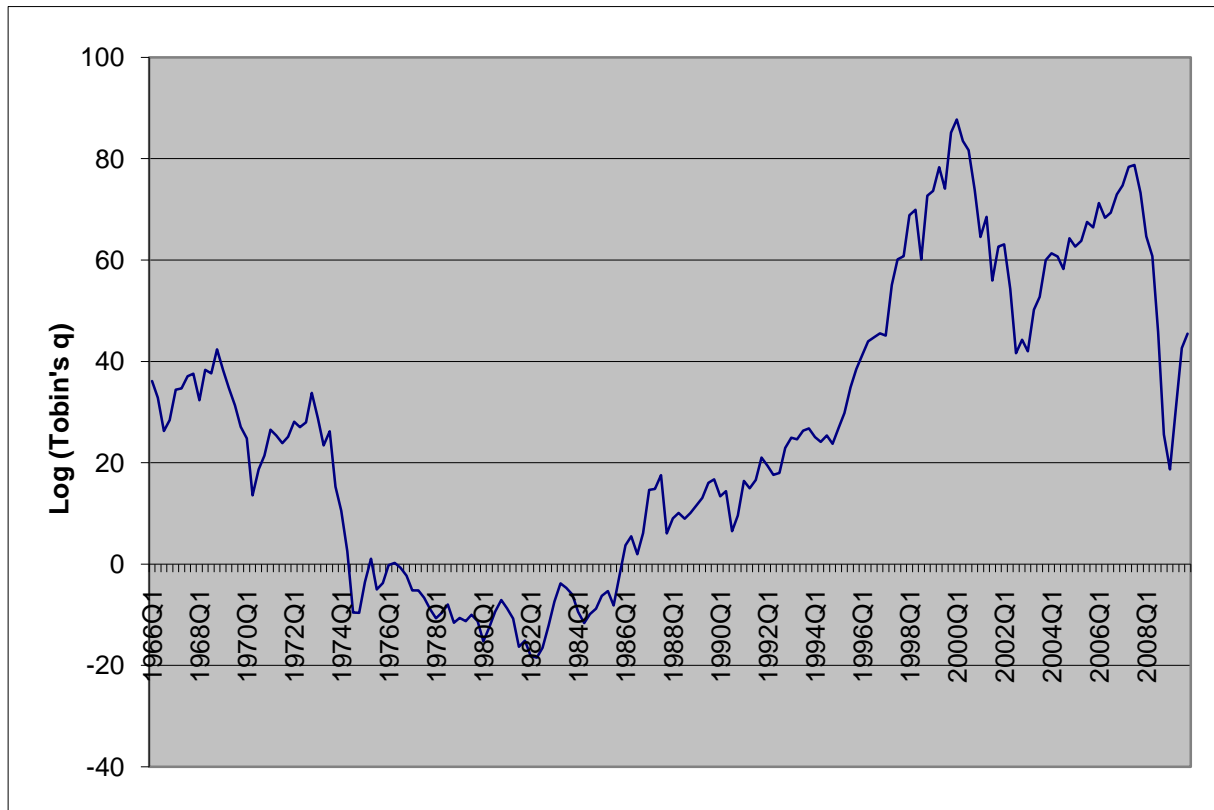
Our data set consists of the same seven quarterly U.S. macroeconomic time series as in Smets and Wouters (2007), except that we have updated their data set with five more years of data. Our data set therefore starts in 1966Q1 and ends in 2009Q4, whereas the data set in Smets and Wouters (2007) covers the period between 1966Q1 and 2004Q4.

We do not only estimate the DSGE models using the full sample. We also divide the data set into two sub-samples in order to investigate the stability of the full-sample estimates. What we specifically have in mind is whether trend extrapolation in asset pricing has become more important over time.

The first sub-sample covers a period of high inflation rates; it starts in 1966Q1 and it ends in 1979Q2 with the appointment of Paul Volcker as the Federal Reserve’s chairman. The second sub-sample covers a period known as the Great Moderation; it starts in

1984Q1 and it ends in 2009Q4. This period was not only a period of low inflation rates and low business cycle volatility (cf., McConnell and Perez-Quiros, 2000) but also, as can be seen in Figure 1, a period that saw a large increase in the market value of capital relative to its replacement cost (i.e., Tobin's q).⁶

Figure 1 The market value of capital relative to its replacement cost (i.e., Tobin's q).



The data set includes the following seven time series: (i) the log-difference of real gross domestic product (GDP); (ii) the log-difference of real consumption; (iii) the log-difference of real investment; (iv) the log-difference of the real wage; (v) log hours worked; (vi) the log-difference of the GDP deflator; and (vii) the federal funds rate.

⁶ Following Laitner and Stolyarov (2003), we computed Tobin's q as the aggregate market value of U.S. businesses divided by the replacement cost of their capital stock. In doing this, we made use of the same variables as Laitner and Stolyarov (2003) but obtained at a quarterly frequency. We obtained a time series for the stock of reproducible capital by adding business inventories and private non-residential fixed assets. (Private non-residential fixed assets is the only time series that was not available at a quarterly frequency. We therefore converted an annual time series into a quarterly time series by means of linear interpolation.) The market value of businesses was obtained by using the data from the Z.1 Release of the Flow of Funds Accounts of the United States provided by the Federal Reserve. Details are available on request from the authors.

3.2. Estimation of the DSGE models

After we have outlined the methodology in the estimation of the DSGE models, we ask ourselves: ‘Does trend extrapolation in asset pricing matter?’, ‘How well does our model fit the data?’, and ‘Has there been an increased importance of asset price misalignments for business cycle dynamics?’.

3.2.1. Methodology

All DSGE models are fitted to the data set described in Section 3.1 with Bayesian techniques (see An and Schorfheide, 2007, for an overview of these techniques in DSGE modeling).⁷

First, the mode and the standard deviation of the posterior distribution are estimated by maximizing the log-posterior function that combines the prior information on the parameters with the likelihood of the data.

Second, the Metropolis-Hastings algorithm is used to obtain a more complete picture of the posterior distribution and to evaluate the marginal likelihood of a model. As in Smets and Wouters (2007), a sample of 250 000 draws was created for each model, neglecting the first 50 000 draws, where the Markov Chain Monte Carlo univariate and multivariate diagnostics indicated convergence and stability in the parameter moments.

If we turn to the priors in the estimations, they coincide with the priors in Smets and Wouters (2007). We therefore refer to their paper for a discussion of the chosen priors. There are, of course, two parameters in our model that are not part of the Smets and Wouters (2007) model: (i) the weight attached to trend extrapolation in asset trade, ω (see (1)); and (ii) the ‘strength’ parameter in trend extrapolation, ϑ (see (2)).

The first parameter, ω , is assumed to be uniformly distributed over the interval $\omega \in [0,1]$, and the second parameter, ϑ , is assumed to be uniformly distributed over the interval $\vartheta \in [-3,3]$. Thus, the interval for the latter parameter is not only wide, it also includes non-positive values, even though we have restricted this parameter on theoretical grounds to positive values, $\vartheta > 0$.

Five parameters are fixed in the estimations. It is the same parameters as in Smets and Wouters (2007) and they are also fixed at the same values. Specifically, the depreciation rate of the capital stock (δ) is fixed at 0.025, the steady-state exogenous spending-output ratio (g_y) is fixed at 0.18, the steady-state wage mark-up ($\phi_w - 1$) is fixed at 1.5, and the curvatures of the Kimball (1995) goods and labor markets aggregators are fixed at 10.

⁷ We have used Dynare when estimating and simulating the DSGE models, which is a software freely available at www.dynare.org.

Last but not least, the measurement equations in the quantitative analysis are

$$(25) \quad \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ FEDFUNDS_t \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{l} \\ \bar{\pi} \\ \bar{r} \end{bmatrix} + \begin{bmatrix} \Delta y_t \\ \Delta c_t \\ \Delta i_t \\ \Delta w_t \\ l_t \\ \pi_t \\ r_t \end{bmatrix},$$

where l and dl denote log and log-difference, respectively. Furthermore, $\bar{\gamma} = 100 \cdot (\gamma - 1)$ is the common quarterly trend growth rate in real GDP, real consumption, real investment, and the real wage. \bar{l} is hours worked in steady-state, which is normalized to zero, $\bar{\pi} = 100 \cdot (\Pi_* - 1)$ is the quarterly steady-state inflation rate, $\bar{r} = 100 \cdot \left(\frac{\Pi_* \gamma^{\sigma c}}{\beta} - 1\right)$ is the quarterly steady-state nominal interest rate, and Π_* is the steady-state inflation rate.

3.2.2. Does trend extrapolation in asset pricing matter?

In Table 1A, we find the prior and posterior distributions of the structural parameters in our model, whereas the prior and posterior distributions of the shock processes can be found in Table 1B. As is clear from the tables, all parameter estimates are statistically significant and in accordance with theory. Recall that \bar{l} is normalized to zero.

Table 1A Estimation results of structural parameters for our model.

<i>Parameter</i>	<i>Prior distribution</i>			<i>Posterior distribution</i>				
	<i>Type of distribution</i>	<i>Mean</i>	<i>Standard deviation</i>	<i>Mode</i>	<i>Standard deviation</i>	<i>Mean</i>	<i>5 %</i>	<i>95 %</i>
ω	Uniform [0,1]	-	-	0.76	0.05	0.67	0.48	0.85
ϑ	Uniform [-3,3]	-	-	0.91	0.12	0.75	0.34	1.11
$\frac{100 \cdot (1-\beta)}{\beta}$	Gamma	0.250	0.100	0.14	0.06	0.17	0.07	0.26
σ_c	Normal	1.500	0.375	1.26	0.15	1.27	1.03	1.48
λ	Beta	0.700	0.100	0.62	0.08	0.67	0.56	0.78
φ	Normal	4.000	1.500	2.51	0.71	3.29	1.79	4.70
α	Normal	0.300	0.050	0.17	0.02	0.18	0.15	0.20
ϕ_p	Normal	1.250	0.125	1.52	0.08	1.54	1.41	1.67
ψ	Beta	0.500	0.150	0.69	0.11	0.67	0.50	0.85
l_p	Beta	0.500	0.150	0.25	0.09	0.27	0.12	0.40
ξ_p	Beta	0.500	0.100	0.75	0.04	0.74	0.68	0.80
σ_l	Normal	2.000	0.750	2.02	0.59	1.99	1.05	3.06
l_w	Beta	0.500	0.150	0.59	0.13	0.60	0.41	0.83
ξ_w	Beta	0.500	0.100	0.83	0.05	0.83	0.75	0.95
ρ	Beta	0.750	0.100	0.81	0.03	0.81	0.76	0.86
r_π	Normal	1.500	0.250	1.79	0.19	1.79	1.48	2.08
r_y	Normal	0.125	0.050	0.07	0.03	0.06	0.02	0.10
$r_{\Delta y}$	Normal	0.125	0.050	0.22	0.03	0.22	0.18	0.27
\bar{y}	Normal	0.400	0.100	0.41	0.02	0.41	0.37	0.44
\bar{l}	Normal	0.000	2.000	-0.79	1.00	-0.76	-2.53	0.98
$\bar{\pi}$	Gamma	0.625	0.100	0.78	0.10	0.79	0.64	0.95

Table 1B Estimation results of shock processes for our model.

<i>Parameter</i>	<i>Prior distribution</i>			<i>Posterior distribution</i>				
	<i>Type of distribution</i>	<i>Mean</i>	<i>Standard deviation</i>	<i>Mode</i>	<i>Standard deviation</i>	<i>Mean</i>	<i>5 %</i>	<i>95 %</i>
ρ_b	Beta	0.500	0.200	0.63	0.13	0.54	0.33	0.75
ρ_g	Beta	0.500	0.200	0.98	0.01	0.98	0.96	0.99
ρ_i	Beta	0.500	0.200	0.95	0.05	0.91	0.83	0.99
ρ_a	Beta	0.500	0.200	0.97	0.01	0.97	0.95	0.99
ρ_p	Beta	0.500	0.200	0.90	0.04	0.88	0.81	0.96
ρ_w	Beta	0.500	0.200	0.94	0.03	0.88	0.52	0.99
ρ_r	Beta	0.500	0.200	0.17	0.07	0.20	0.08	0.31
ρ_{ga}	Beta	0.500	0.200	0.53	0.08	0.52	0.39	0.65
μ_p	Beta	0.500	0.200	0.80	0.07	0.77	0.65	0.90
μ_w	Beta	0.500	0.200	0.89	0.05	0.81	0.33	0.96
σ_b	Inv. Gamma	0.100	2.000	0.16	0.03	0.18	0.12	0.23
σ_g	Inv. Gamma	0.100	2.000	0.49	0.03	0.50	0.46	0.55
σ_i	Inv. Gamma	0.100	2.000	0.36	0.06	0.36	0.29	0.44
σ_a	Inv. Gamma	0.100	2.000	0.48	0.03	0.48	0.43	0.53
σ_p	Inv. Gamma	0.100	2.000	0.16	0.02	0.16	0.13	0.18
σ_w	Inv. Gamma	0.100	2.000	0.27	0.02	0.26	0.22	0.30
σ_r	Inv. Gamma	0.100	2.000	0.24	0.01	0.24	0.22	0.26

Marginal likelihood of the model: -1062.75

If we turn to the parameters that distinguish our model from the model in Smets and Wouters (2007), ω and ϑ , both parameters are quantitatively large, besides being statistically significant. The estimated mode of ω is 0.76, while the estimated mean is 0.67. Moreover, the 5 and 95 percentiles of the posterior distribution are 0.48 and 0.85, respectively. Further on, the estimated mode of ϑ is 0.91, while the estimated mean is 0.75, and the 5 and 95 percentiles of the posterior distribution are 0.34 and 1.11, respectively.

Thus, the weight attached to trend extrapolation in asset pricing, ω , is not only 2/3, the strength in trend extrapolation, ϑ , is 3/4. These findings suggest that asset price misalignments are important to the understanding of business cycle dynamics.

3.2.3. Other findings

The remaining parameters in our model are common to the baseline model, which is the Smets and Wouters (2007) model, and the alternative baseline model in which investment expenditures are pre-determined. See Tables 2A and 2B for estimation results of the structural parameters and the shock processes, respectively, for the baseline model and the alternative baseline model.

Table 2A Estimation results of structural parameters for the baseline models.

<i>Parameter</i>	<i>Baseline model</i>			<i>Alternative baseline model</i>		
	<i>Mode</i>	<i>Standard deviation</i>	<i>Mean</i>	<i>Mode</i>	<i>Standard deviation</i>	<i>Mean</i>
ω	-	-	-	-	-	-
ϑ	-	-	-	-	-	-
$\frac{100 \cdot (1-\beta)}{\beta}$	0.14	0.06	0.17	0.12	0.05	0.14
σ_c	1.28	0.26	1.25	1.53	0.15	1.50
λ	0.62	0.08	0.64	0.64	0.05	0.65
φ	4.32	1.24	4.80	6.19	1.09	6.39
α	0.17	0.02	0.17	0.18	0.01	0.18
ϕ_p	1.52	0.10	1.52	1.58	0.07	1.57
ψ	0.65	0.12	0.64	0.63	0.11	0.63
l_p	0.24	0.09	0.27	0.23	0.09	0.26
ξ_p	0.76	0.05	0.76	0.75	0.04	0.74
σ_l	1.73	0.60	1.74	1.53	0.61	1.50
l_w	0.58	0.13	0.57	0.61	0.13	0.60
ξ_w	0.83	0.05	0.80	0.81	0.06	0.76
ρ	0.81	0.04	0.81	0.81	0.03	0.81
r_π	1.74	0.24	1.81	1.69	0.17	1.78
r_y	0.06	0.03	0.06	0.05	0.02	0.06
$r_{\Delta y}$	0.24	0.03	0.24	0.22	0.03	0.22
\bar{y}	0.42	0.02	0.41	0.42	0.01	0.42
\bar{l}	-0.52	1.19	-0.49	-0.15	1.24	-0.14
$\bar{\pi}$	0.77	0.10	0.78	0.79	0.10	0.79

Table 2B Estimation results of shock processes for the baseline models.

<i>Parameter</i>	<i>Baseline model</i>			<i>Alternative baseline model</i>		
	<i>Mode</i>	<i>Standard deviation</i>	<i>Mean</i>	<i>Mode</i>	<i>Standard deviation</i>	<i>Mean</i>
ρ_b	0.62	0.28	0.62	0.37	0.10	0.42
ρ_g	0.98	0.01	0.98	0.99	0.01	0.98
ρ_i	0.81	0.06	0.81	0.79	0.05	0.79
ρ_a	0.97	0.02	0.97	0.96	0.01	0.96
ρ_p	0.90	0.04	0.88	0.90	0.04	0.88
ρ_w	0.97	0.02	0.95	0.96	0.02	0.95
ρ_r	0.17	0.08	0.18	0.22	0.07	0.23
ρ_{ga}	0.52	0.08	0.51	0.52	0.08	0.52
μ_p	0.80	0.07	0.77	0.79	0.07	0.76
μ_w	0.94	0.03	0.90	0.92	0.04	0.88
σ_b	0.15	0.06	0.16	0.21	0.03	0.20
σ_g	0.50	0.03	0.50	0.50	0.03	0.51
σ_i	0.39	0.05	0.39	0.42	0.04	0.42
σ_a	0.48	0.03	0.49	0.47	0.03	0.48
σ_p	0.16	0.02	0.16	0.15	0.02	0.15
σ_w	0.28	0.02	0.27	0.27	0.02	0.27
σ_r	0.24	0.01	0.24	0.23	0.01	0.23

Marginal likelihood of the baseline model: -1068.16

Marginal likelihood of the alternative baseline model: -1076.17

Since the estimates for most of the parameters are quite close to those obtained in Smets and Wouters (2007), we focus on those parameters whose values are significantly altered by the introduction of trend extrapolation in asset pricing.

Among the structural parameters, it is only the steady-state elasticity of the cost of adjusting capital, φ , that is significantly altered. In our model, the estimated mode is 2.51, while the estimated mean is 3.29, whereas the estimated mode and mean are 4.32 and 4.80, respectively, in the baseline model. Further on, in the alternative baseline model, the estimated mode and mean are 6.19 and 6.39, respectively. Thus, since i_2 in (7) depends inversely on φ , investment is much more responsive to changes in the asset price in our model.

Among the shock processes, there are two processes that are significantly altered. First, the mean of ρ_i in the investment-specific technology shock is 0.91 in our model (the mode is 0.95), whereas the mean (and also the mode) is 0.81 and 0.79 in the baseline model and the alternative baseline model, respectively. Thus, the investment-specific technology shock is more persistent in our model.

Second, the process for the wage mark-up shock is significantly altered. Specifically, the mean of ρ_w in the AR term in this process is 0.88 in our model (the mode is 0.94), whereas the mean is 0.95 in the other two models (the mode is 0.97 and 0.96, respectively). Moreover, the mean of μ_w in the MA term in this process is 0.81 in our model (the mode is 0.89), whereas the mean is 0.90 and 0.88 in the other two models, respectively (the mode is 0.94 and 0.92, respectively). Thus, the wage mark-up shock is less persistent in our model.

3.2.4. How well does our model fit the data?

Since the marginal likelihood of a model gives an indication of the model's out-of-sample prediction performance, it forms a natural benchmark for comparing different models.

We have therefore computed the marginal likelihood by modified harmonic mean estimation for all three models; our model, the baseline model in Smets and Wouters (2007), and the alternative version of the baseline model in which investment expenditures are pre-determined. We have also computed the marginal likelihood by Laplace approximation and the values obtained were nearly identical to those obtained by modified harmonic mean estimation. It is the modified harmonic mean estimates that we report below.

The marginal likelihood of our model is -1062.75, whereas the marginal likelihood of the baseline model is -1068.16. However, one might argue that the reason why our model is the preferred model is that 'trend extrapolation in asset pricing' instead captures a delayed response of investment to the fundamental asset price. But this does not appear to be the case since the marginal likelihood of the model with pre-determined investment expenditures is -1076.17, which is the lowest value among all three models.

This suggests that the incorporation of trend extrapolation in asset pricing into the Smets and Wouters (2007) model improves the fit of the model to the data. But how substantial is this improvement? To answer this question, we computed the Bayes factor (BF) for our model against the baseline model in Smets and Wouters (2007) as well as the alternative version of the baseline model in which investment expenditures are pre-determined.

Kass and Raftery (1995) put forward that values of $2\log\text{BF}$ above 10 can be considered as very strong evidence in favor of the tested model (i.e., our model in this case). Further on, values between 6 and 10 represent strong evidence, values between 2 and 6

represent positive evidence, while values below 2 are “*not worth more than a bare mention*” (see p. 777 in Kass and Raftery, 1995). From now on, we refer to this statistic as the KR statistic.

When we consider our model against the baseline model in Smets and Wouters (2007), we obtain 10.82 as the value of the KR statistic. Moreover, when we compare our model against the alternative version of the baseline model in which investment expenditures are pre-determined, the value of the KR statistic is 26.84. These results therefore conclusively support the hypothesis that fluctuations in main U.S. macroeconomic variables are affected by deviations of asset prices from their fundamental values.

Since our model and the baseline model in Smets and Wouters (2007) outperform the alternative specification of the latter model in which investment expenditures are pre-determined, we hereafter concentrate on the first two models.

3.2.5. Has there been an increased importance of asset price misalignments for business cycle dynamics?

To investigate whether there has been an increased importance of asset price misalignments for business cycle dynamics, we divided the full sample into two sub-samples. The first sub-sample corresponds to a period of high inflation rates and starts in 1966Q1 and ends in 1979Q2. The second sub-sample, which starts in 1984Q1 and ends in 2009Q4, corresponds to a period of low inflation rates, low business cycle volatility, and a large increase in Tobin’s q .

See Table 3 for the estimation results for our model and the Smets and Wouters (2007) model using these two sub-samples of the data set, where we only present the mean of the posterior distribution of the respective structural parameters to conserve space.

Table 3 Estimation results for our model (BM) and the baseline model (SW).

<i>Parameter</i>	<i>1966Q1-1979Q2</i>		<i>1984Q1-2009Q4</i>	
	<i>BM</i>	<i>SW</i>	<i>BM</i>	<i>SW</i>
ω	0.57	-	0.52	-
ϑ	0.39	-	1.07	-
$\frac{100 \cdot (1-\beta)}{\beta}$	0.18	0.18	0.20	0.20
σ_c	1.38	1.36	1.03	1.00
λ	0.66	0.63	0.60	0.60
φ	3.12	4.04	4.93	5.66
α	0.19	0.19	0.15	0.15
ϕ_p	1.46	1.45	1.39	1.38
ψ	0.38	0.39	0.75	0.73
ι_p	0.57	0.57	0.29	0.26
ξ_p	0.59	0.58	0.83	0.84
σ_l	1.53	1.51	1.77	1.75
ι_w	0.58	0.60	0.43	0.43
ξ_w	0.70	0.70	0.83	0.82
ρ	0.79	0.79	0.86	0.86
r_π	1.53	1.54	1.67	1.67
r_y	0.18	0.17	0.08	0.08
$r_{\Delta y}$	0.20	0.21	0.17	0.17
$\bar{\gamma}$	0.31	0.33	0.46	0.47
\bar{l}	0.44	0.40	0.02	-0.06
$\bar{\pi}$	0.68	0.68	0.63	0.63
Marginal likelihood of BM for 1966Q1-1979Q2:				-369.65
Marginal likelihood of SW for 1966Q1-1979Q2:				-370.83
Marginal likelihood of BM for 1984Q1-2009Q4:				-506.96
Marginal likelihood of SW for 1984Q1-2009Q4:				-509.55

We have three important comments to make to these results. First, when we compare how well our model fits the data compared to the Smets and Wouters (2007) model, the value of the KR statistic is 2.36 for the first sub-sample, whereas we obtain 5.18 as the value of the KR statistic for the second sub-sample. Thus, we have positive evidence in favor of our model (since the values of the KR statistic are between 2 and 6).

Second, the weight attached to trend extrapolation in asset pricing, ω , is relatively stable since the mean is 0.57 and 0.52, respectively, in the two sub-samples.

Third, the strength in trend extrapolation, ϑ , differs significantly between the two sub-samples. In the first sub-sample, the mean value of the ‘strength’ parameter is 0.39, which is well below 1, but when it comes to the second sub-sample, the mean value of the same parameter is 1.07. Thus, the strength in trend extrapolation is much stronger during the Great Moderation, which is a period characterized by a large increase in Tobin’s q , than it was prior to this period.

3.3. Simulation of the DSGE models

To more deeply scrutinize the properties of the Smets and Wouters (2007) model and our modification of their model, we simulate the two DSGE models under the respective means of their posterior distributions. We first evaluate the dynamic responses to various exogenous shocks via impulse-response functions for key macroeconomic variables. Thereafter, we compare the volatilities of the same variables with the respective volatilities in the data, including how the volatilities changed between the two sub-samples of the data set.

3.3.1. Impulse-response functions

Figures 2-8 display impulse-response functions for key macroeconomic variables in both models (i.e., the asset price, output, consumption, investment, the real wage, hours worked, the inflation rate, and the interest rate), where the shocks in the models are a risk premium shock, a fiscal shock, an investment-specific technology shock, a total factor productivity shock, a price mark-up shock, a wage mark-up shock, and a monetary policy shock.

Figure 2 Impulse-response functions when there is a risk premium shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.

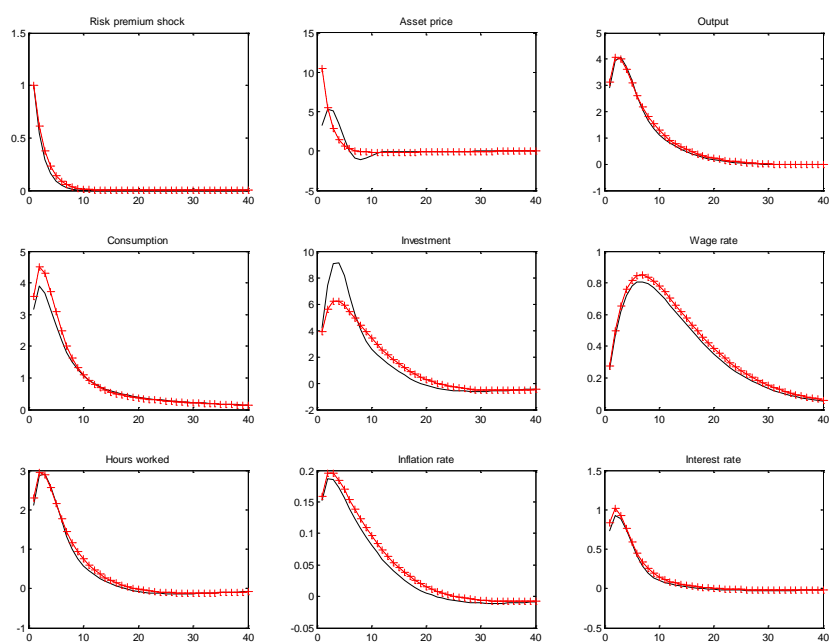


Figure 3 Impulse-response functions when there is a fiscal shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.

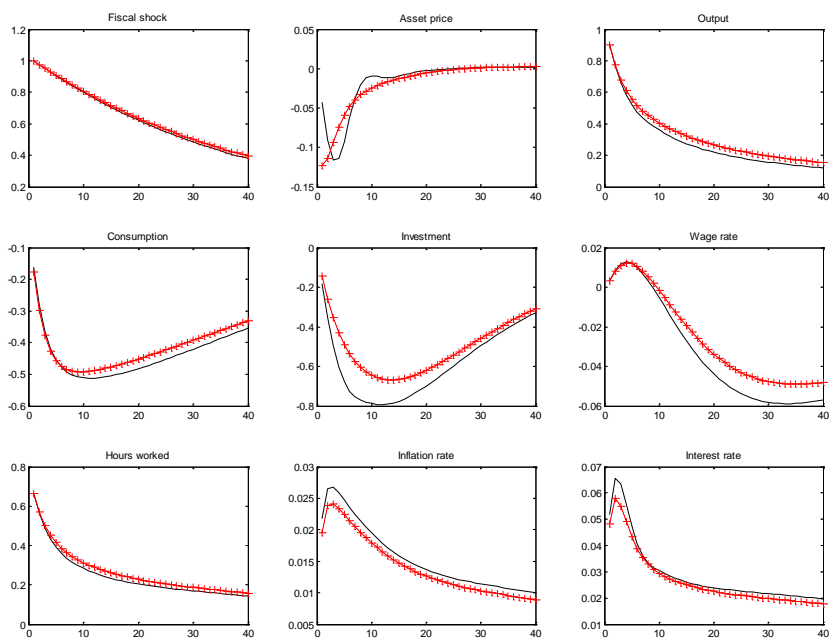


Figure 4 Impulse-response functions when there is an investment-specific technology shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.

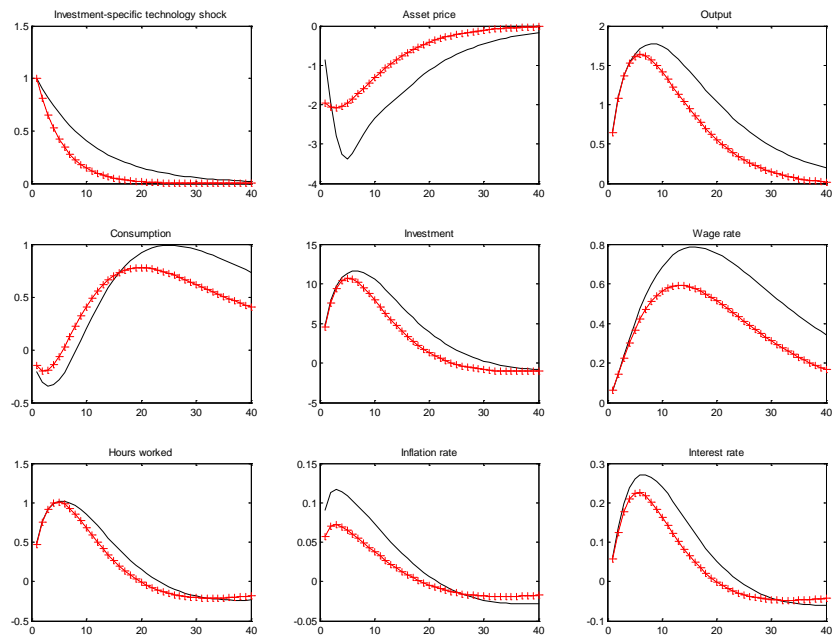


Figure 5 Impulse-response functions when there is a total factor productivity shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.

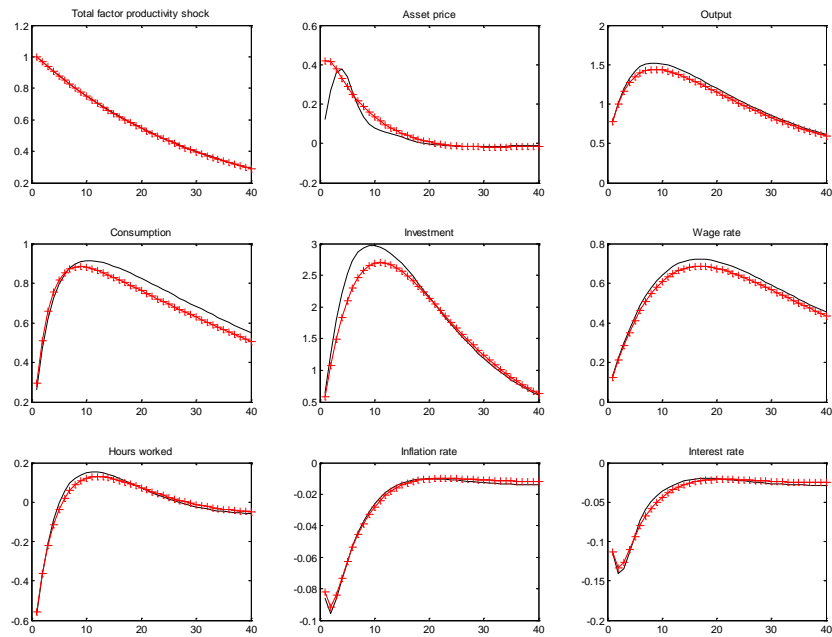


Figure 6 Impulse-response functions when there is a price mark-up shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.

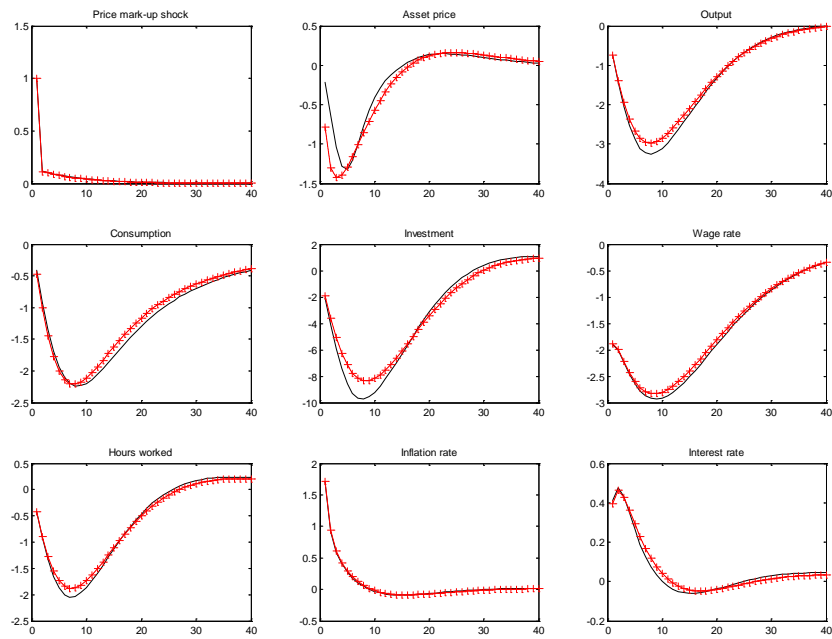


Figure 7 Impulse-response functions when there is a wage mark-up shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.

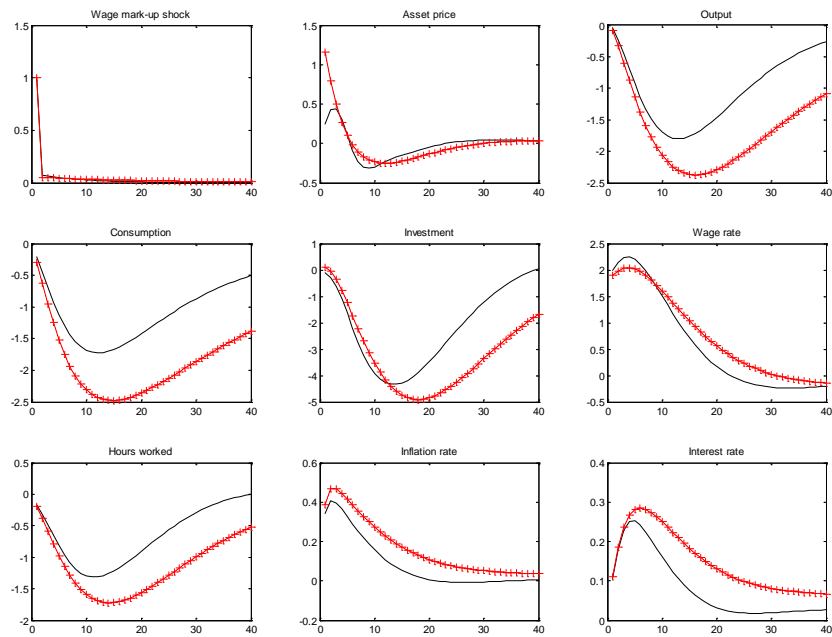
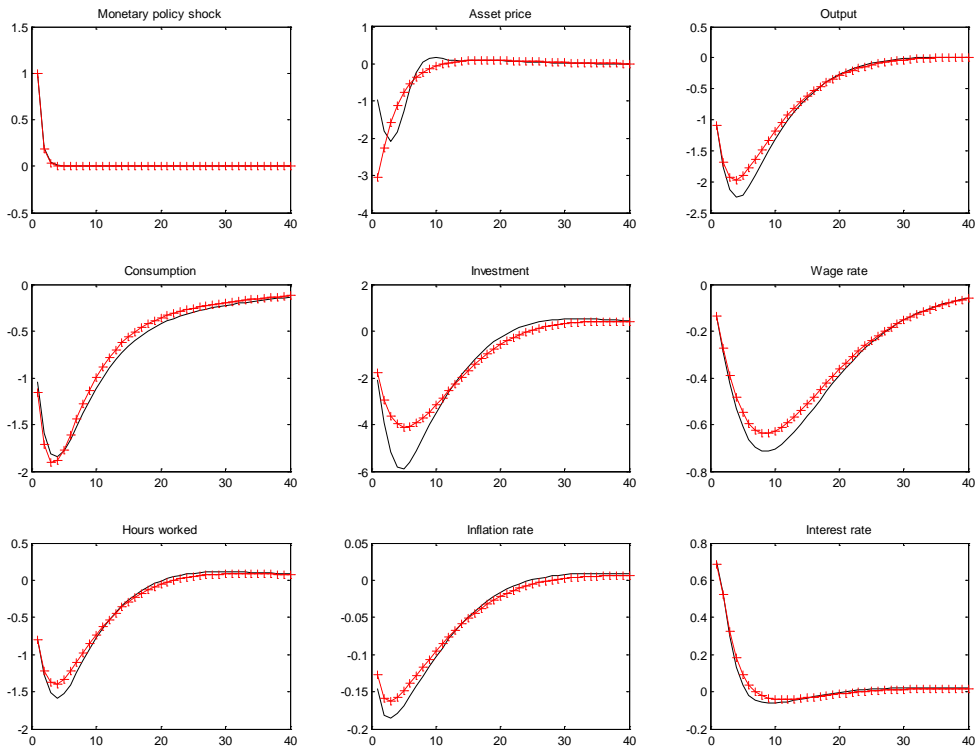


Figure 8 Impulse-response functions when there is a monetary policy shock. Note: - refers to our model and +- refers to the Smets and Wouters (2007) model.



For most shocks, only the responses of the asset price and investment are significantly affected after allowing for trend extrapolation in asset pricing. In our model, the asset price and investment exhibit a more pronounced hump-shaped response to the different shocks.

When it comes to the remaining macroeconomic variables in the models, large differences are only observed for the investment-specific technology shock and the wage mark-up shock. This is not surprising since the estimated values of the shock parameters were only significantly altered for these two shocks. The more persistent investment-specific technology shock results in larger and more prolonged responses of all variables, whereas the opposite happens for the less persistent wage mark-up shock.

3.3.2. Macroeconomic volatilities

Tables 4A and 4B display the volatilities and the changes in volatilities, respectively, of key macroeconomic variables in both models and in U.S. data.

Table 4A Volatilities in U.S. data, our model (BM) and the baseline model (SW).

<i>Variable</i>	1966Q1-1979Q2			1984Q1-2009Q4		
	<i>U.S. data</i>	<i>BM</i>	<i>SW</i>	<i>U.S. data</i>	<i>BM</i>	<i>SW</i>
lQ_t	18.14	1.96	2.79	27.49	2.31	2.22
$dlGDP_t$	1.03	1.17	1.27	0.64	0.81	0.79
$dlCONS_t$	0.75	0.79	0.91	0.61	0.67	0.67
$dlINV_t$	2.50	2.36	2.18	2.21	2.37	2.34
$dlWAG_t$	0.51	0.55	0.88	0.70	0.71	0.72
$lHOURS_t$	2.85	2.34	2.87	2.70	2.31	2.26
dlP_t	0.55	0.93	1.44	0.28	0.32	0.33
$FEDFUNDS_t$	0.54	0.85	1.02	0.64	0.44	0.44

Table 4B Volatility changes in U.S. data, our model (BM) and the baseline model (SW).

<i>Variable</i>	Between 1966Q1-1979Q2 and 1984Q1-2009Q4		
	<i>U.S. data</i>	<i>BM</i>	<i>SW</i>
lQ_t	0.52	0.18	-0.20
$dlGDP_t$	-0.38	-0.31	-0.38
$dlCONS_t$	-0.19	-0.15	-0.26
$dlINV_t$	-0.12	0.00	0.07
$dlWAG_t$	0.37	0.29	-0.18
$lHOURS_t$	-0.05	-0.01	-0.21
dlP_t	-0.49	-0.66	-0.77
$FEDFUNDS_t$	0.19	-0.48	-0.57

First, none of the models are able to generate the volatility in asset prices that we observe in the data. This, however, is a shortcoming that the models share with the rest of the literature.

Second, our model matches much better the volatilities in the data than the model in Smets and Wouters (2007). Specifically, in the first sub-sample, our model outperforms the model in Smets and Wouters (2007) in six of eight variables, whereas our model

does a better job in four of eight variables in the second sub-sample. There is also a tie in two variables in the latter sub-sample.

Third, the Great Moderation is visible in Table 4B (since the volatility decreased in almost all variables) and our model is also better at matching the changes in volatilities between the two sub-samples than the model in Smets and Wouters (2007).

Fourth, our model correctly predicts that the volatility in asset prices increased during the Great Moderation, whereas the Smets and Wouters (2007) model counterfactually predicts that the same volatility decreased. This result is especially encouraging since asset pricing plays a key role in our model.

4. Discussion

The apparent key role of asset mispricing in many economic recessions highlights the need to understand better how it affects aggregate economic variables, including an quantitative evaluation of its importance. To address this issue, we introduced asset traders who use a mix of fundamental analysis and trend extrapolation in asset pricing, resulting in a deviation of the asset price from its fundamental value, into the standard New Keynesian framework. Our approach allowed us to analyze the impact of asset mispricing on business cycle dynamics from both a qualitative and quantitative standpoint.

We estimated our model with Bayesian techniques and found that the weight attached to trend extrapolation in asset pricing to be statistically significant and quantitatively large. We also found that allowing for asset mispricing resulted in a substantial improvement of our model's fit to main U.S. macroeconomic time series. We presented evidence that it improves the predictions of the model with respect to movements in asset prices. In particular, our model unlike the standard model in Smets and Wouters (2007) is consistent with the increased volatility in asset prices during the Great Moderation.

Our analysis contributed to greater insights on the effects of trend extrapolation in asset pricing on the dynamic responses of macroeconomic variables to various shocks as well. Specifically, its introduction was found to lead to more pronounced hump-shaped responses of the asset price and investment.

This paper intends to be informative to researchers working on the issue of how monetary policy should respond to asset price misalignments since we have provided empirical support that these are relevant for aggregate economic fluctuations. Our parameter estimates could therefore be used to inform the calibration of new studies on this topic. Interesting examples of work in this area include Bask (2011), Bean (2004), Bernanke and Gertler (1999, 2001), Bordo and Jeanne (2002), Bullard and Schaling (2002), Cecchetti (2006), Kontonikas and Ioannidis (2005), and Kontonikas and Montagnoli (2006).

We focused on a single issue. As a result, we left out many possible extensions and avenues for further explorations. In future research, we intend to build on the work of Iacoviello (2005) and study how the introduction of trend extrapolation in housing prices (as these often appear to be associated to mispricing as observed by Allen and Gale, 2000) would affect business cycle dynamics in his model. Another avenue we consider worth pursuing is to study how trend extrapolation in asset pricing would affect credit restrictions models like those of Bernanke et al. (1999) and Kiyotaki and Moore (1997).

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