# Pervasive inattentiveness☆

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**Abstract**

In this paper we analyze how inattentiveness in capital investment decisions shapes business cycle dynamics in a dynamic stochastic general equilibrium (DSGE) model with inattentiveness. We find that the model with pervasive inattentiveness matches several business cycle moments much better than an otherwise identical model without informational frictions in investment. These findings reinforce the need for pervasive stickiness to mimic the inertia found in macroeconomic data.

*Keywords:* inattentiveness, DSGE, business cycle dynamics *JEL classification*: E10, E22, E32

## 1. Introduction

Economic models have to include stickiness if they are to match the data (Sims, 1998). Stickiness is usually included by assuming sticky actions – staggered price and wage setting with partial indexation, habit persistence in consumption and investment adjustment costs (see *e.g.* Christiano et al., 2005). Recently, Mankiw and Reis (2002) introduce stickiness in form of sticky information (or inattentiveness). The idea is that information disseminates slowly through the population because it is costly for agents to collect and process information and to make decisions based on that information (Reis, 2006a, 2006b and Verona, 2014). Faced with such costs, agents are inattentive and so react only with a delay to shocks.

Mankiw and Reis (2006) develop the first DSGE model in which sticky information is the only rigidity.[1] They show that pervasive information stickiness is necessary to explain business cycle dynamics in sticky

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[1] See also Mankiw and Reis (2007) and Reis (2009a, 2009b).

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information models. One missing feature of the Mankiw and Reis (2006) model is investment and capital accumulation. Verona (2011) takes a step toward improving the Mankiw and Reis (2006) model by augmenting it with a set of firms that make capital investment decisions inattentively, as micro-founded in Verona (2014). In Verona (2011), inattentiveness is the only friction, and it affects all decisions: consumption, wages, prices and capital investment decisions are all based on somewhat outdated information.

In this paper, we use the Verona (2011) model to analyse how and to what extent inattentiveness in the capital investment decision shapes business cycle dynamics. We also examine whether the capital-augmented version of the Mankiw and Reis (2006) sticky information DSGE model matches the business cycle moments presented in Mankiw and Reis (2006).

The paper is organized as follows. Section 2 gives an overview of the model and presents the key equations. Section 3 analyses the implications of inattentiveness for aggregate dynamics, and section 4 concludes.

## 2. The model

### *2.1. An overview of the model*

There are three sets of agents: firms, households and the central bank. Within the firms sector, there are two types of firms, intermediate- and final-good firms. Monopolistically competitive firms produce a continuum of intermediate goods by hiring labor varieties, and set the prices for their goods. A continuum of perfectly competitive final-good firms produce the final good by combining their optimally chosen firm-specific capitals with a Dixit-Stiglitz aggregator of varieties of intermediate goods. The final output is divided into consumption and investment goods. Households include consumers and workers. Consumers consume, save and borrow, while each monopolistic worker provides differentiated labor services to intermediate-good firms. Finally, the central bank sets the nominal interest rate according to a Taylor-type rule.

The only rigidity in the model is sticky information. There are four agents making decisions: consumers, workers, intermediate-good firms and final-good firms. We assume that, at any date, only a fraction $\delta$ of consumers, $\omega$ of workers, $\lambda$ of price-setting firms and $\eta$ of capital-investing firms update their information and make plans for, respectively, consumption, wages, prices and capital adjustments for the future.

*2.2. The sticky information equilibrium*

A detailed presentation of the model log-linearisation is presented in Verona (2011, appendix A). Here we discuss the key reduced-form relations.[2]

Aggregate investment ($inv_t$) develops according to

$$inv_t = \frac{1}{\rho} k_t - \frac{1-\rho}{\rho} k_{t-1} \ , \tag{1}$$

where $\rho$ denotes the depreciation rate and $k_t$ the aggregate capital stock given by

$$k_t = \eta \sum_{\tau=0}^{\infty} (1-\eta)^{\tau} E_{t-\tau} \left[ \frac{1}{1-\alpha} y_{t+1}^{FIN} - \frac{\alpha}{1-\alpha} k_t - \frac{r}{(r+\rho)(1-\alpha)} r_t \right] \ . \tag{2}$$

There are three determinants of the stock of capital: (i) higher expected future output ($y_{t+1}^{FIN}$) increases the current stock of capital, (ii) the higher the current capital stock, the lower the current accumulated capital stock (due to decreasing returns to scale in production, $\alpha < 1$), (iii) the lower the real interest rate ($r_t$), the lower the opportunity cost of holding capital and thus the greater the incentive to increase the capital stock. If many firms are informed ($\eta$ is high), capital is highly responsive to changes in these determinants; otherwise, capital adjusts slowly over time.

The Phillips curve is given by

$$p_t = \lambda \sum_{\tau=0}^{\infty} (1-\lambda)^{\tau} E_{t-\tau} \left[ p_t + \frac{\beta (w_t - p_t) + (1-\beta) y_t - a_t}{\beta + v(1-\beta)} \right] \ . \tag{3}$$

The price level ($p_t$) depends on past expectations of its current value and real marginal costs.[3] Real marginal costs are the higher (i) the higher the real wages paid to workers ($w_t - p_t$), (ii) the greater the output ($y_t$) due to decreasing returns to scale ($\beta < 1$), and (iii) the lower the productivity ($a_t$). Productivity follows a random walk with standard deviation $\sigma_a$. The higher the value of $\lambda$, the larger the number of informed price-setting firms that respond immediately to shocks.

[2] Variables with a $t$ subscript refer to log-linearized values around their non-stochastic steady state. Letters with no subscript denote parameters or steady-state values.

[3] $v$ is the elasticity of substitution across goods varieties.

The IS curve is given by

$$c_t = \delta \sum_{\tau=0}^{\infty} (1-\delta)^{\tau} E_{t-\tau} (c_t^n - R_t) \quad , \tag{4}$$

where $c_t^n = \lim_{T\to\infty} E_t c_{t+T}$ is a measure of consumers' wealth and $R_t = \sum_{T=0}^{\infty} (r_{t+T})$ is the long-term real interest rate. Higher expected future wealth encourages current consumption ($c_t$), while higher expected interest rates encourage savings and cause postponement of consumption. Unexpected shocks only raise current consumption by $\delta$ because only this fraction of consumers is aware of the news.

The wage curve is:

$$w_t = \omega \sum_{\tau=0}^{\infty} (1-\omega)^{\tau} E_{t-\tau} \left[ p_t + \frac{\gamma}{\gamma+\psi} (w_t - p_t) + \frac{l_t}{\gamma+\psi} + \frac{\psi}{\gamma+\psi} (c_t^n - R_t) \right] \quad . \tag{5}$$

Current wages ($w_t$) are the higher (i) the higher the price level (since workers care about real wages), (ii) the higher the real wages in the economy (as these increase the demand for a particular labor variety via substitution), (iii) the higher the level of employment ($l_t$) (because of increasing marginal disutility of working), (iv) the greater the wealth (because of the income effect), and (v) the lower the interest rates (since the return on savings is lower and the incentive to work in order to save is also lower).[4] Wages become more responsive to shocks as $\omega$ increases, because many workers are informed

The aggregate resource constraint is

$$y_t^{FIN} = \alpha_c c_t + \alpha_i inv_t \quad , \tag{6}$$

where $\alpha_c = c/(c+inv)$ and $\alpha_i = inv/(c+inv)$.

Intermediate output and labor are respectively given by

$$y_t = \frac{y_t^{FIN} - \alpha k_{t-1}}{1-\alpha} \tag{7}$$

and

$$l_t = \frac{y_t - a_t}{\beta} \quad . \tag{8}$$

[4] $\gamma$ is the elasticity of substitution across labor varieties, and $\psi$ is the Frisch elasticity of labor supply.

The central bank sets the nominal interest rate $i_t$ according to

$$i_t = \phi_\pi \Delta p_t + \phi_y \left( y_t^{FIN} - y_t^{FIN,n} \right) - \varepsilon_t \ \ , \tag{9}$$

where $y_t^{FIN,n} = \lim_{T \to \infty} E_t y_{t+T}^{FIN}$ and $\varepsilon_t$ is a policy shock that follows an $AR(1)$ process with the persistence parameter $\rho_\varepsilon$ and standard deviation of the innovation $\sigma_\varepsilon$. Finally, the Fisher equation holds:

$$r_t = i_t - E_t \left( \Delta p_{t+1} \right) \ \ . \tag{10}$$

Equations (1) to (10) characterise the equilibrium for ($y_t^{FIN}$, $c_t$, $w_t$, $p_t$, $inv_t$, $k_t$, $r_t$, $i_t$, $y_t$, $l_t$) given exogenous shocks to ($\varepsilon_t$, $a_t$). Having presented the model's key relations, we proceed to compare the model's predictions with some second-order moments characterising the US economy.

## 3. Business cycle dynamics under inattentiveness

To compute the model's predictions, we use the following baseline set of parameters (the time period is one quarter). The share of consumption in total output $\alpha_c$ is assumed to be 0.85 and, accordingly, the share of investment $\alpha_i$ is 0.15. The steady-state real depreciation rate and real interest rate, $\rho$ and $r$, are set at 0.035 and 0.01, respectively. The capital share in the final-good firms' production function $\alpha$ is set at 0.33. The parameter $\eta$, which determines the degree of inattentiveness in capital decisions, is assumed to be 0.07. This value, which lies within the empirically plausible range indicated by Sveen and Weinke (2007), implies that final-goods firms are inattentive, on average, for about three and a half years. The remaining parameters are from Mankiw and Reis (2006). Consumers, workers and price-setting firms update their plans with the same frequency: $\delta = \omega = \lambda = 0.25$. The Frisch elasticity of labor supply $\psi$ is set at 4. The elasticity of substitution across goods and labor varieties are, respectively, $v = 20$ and $\gamma = 10$. The return to scale in intermediate-good firms' production function $\beta$ is 2/3. The Taylor rule parameters, which are taken from Rudebusch (2002), are: $\phi_\pi = 1.24$, $\phi_y = 0.33$, $\rho_\varepsilon = 0.92$ and $\sigma_\varepsilon = 0.36$. Finally, $\sigma_a = 0.85$.

Table 1 displays the business cycle statistics for output, investment, consumption and hours for the US economy, as well as the model's predictions for different values of the parameter $\eta$.[5,6] Investment is about 3 times as volatile as output, consumption is less volatile than output, and hours are nearly as volatile as output. All series are strongly persistent, with first order serial correlations exceeding 0.9. Investment, consumption and hours are procyclical. As panels A and B show, in the model with frictionless investment ($\eta = 1$), both output and investment are more than twice as volatile as they are in the data, and far less persistent. This model can only match the correlation of investment with output. Sticky information on the part of capital-investing firms ($\eta = 0.07$) brings the model more in line with observed data on output and investment. In fact, the model with inattentive capital-investing firms improves promisingly as regards the fitting of output and investment volatilities and persistences, despite the fact that it predicts a low correlation of investment with output. To check for robustness, the last rows in each panel report the model's predictions for different empirically plausible values of $\eta$, ranging from 0.06 to 0.12 (see Sveen and Weinke, 2007). As one would expect, as $\eta$ increases, more firms are attentive and respond to shocks, so investment becomes more volatile and less persistent. Table 1 nevertheless shows that the second moments are much more closer to the data in the model where firms are inattentive. Panels C and D of table 1 further confirm this finding. In fact, the model with pervasive inattentiveness also matches well the persistence of consumption and hours as well as their correlations with output, even though it overestimates their volatilities.

We now see whether the capital-augmented version of the Mankiw and Reis (2006) model is also able to match the business cycle moments presented in Mankiw and Reis (2006). They focus on three key facts describing short-run economic fluctuations: (i) inflation rises in expansions and falls in recessions, (ii) the real wage is smooth relative to labor productivity, and (iii) the dynamic response of output to shocks typically shows a hump-shaped response. To see whether their model matches these facts, they compute (i) the correlation between changes in inflation and detrended output, (ii) the ratio between the standard deviation of the change in real wage and the standard deviation of the change in output per hour, and (iii) the ratio between

[5] We use quarterly data from 1954Q3 to 2005-Q3. All data are from the Bureau of Economic Analysis. Output is measured by real gross domestic product, investment is measured by real gross private nonresidential domestic investment, consumption is measured by personal consumption expenditures, and hours as total hours in the non-farm business sector. The cyclical components of each series were obtained by applying the Baxter-King bandpass filter to the logarithm of the original series, with a band of 6 to 32 quarters.

[6] All simulations were conducted with Dynare version 4.3.3, using the procedure described in Verona and Wolters (2014), and considering 32 lags in equations (2)-(5) (adding more lags does not affect the results). We also choose $T = 200$ to approximate for $y_t^{FIN,n}$ and $c_t^n$.

Table 1: Business cycle moments, US data (1954Q3-2005Q3) and model

| | **standard deviation**[a] | **autocorrelation coefficients** 1 | 2 | **correlation with output** |
|---|---|---|---|---|
| ***Panel A: output*** | | | | |
| **data** | **1.47** | **0.91** | **0.69** | |
| model ($\eta = 1$) | 3.56 | 0.27 | 0.21 | |
| model ($\eta = 0.07$) | 1.71 | 0.92 | 0.83 | |
| model ($\eta = 0.06/0.12$) | 1.69 / 1.84 | 0.92 / 0.90 | 0.83 / 0.80 | |
| ***Panel B: investment*** | | | | |
| **data** | **2.92** | **0.93** | **0.75** | **0.80** |
| model ($\eta = 1$) | 6.87 | 0.11 | 0.03 | 0.87 |
| model ($\eta = 0.07$) | 2.75 | 0.86 | 0.70 | 0.32 |
| model ($\eta = 0.06/0.12$) | 2.42 / 4.14 | 0.88 / 0.75 | 0.73 / 0.56 | 0.32 / 0.42 |
| ***Panel C: consumption*** | | | | |
| **data** | **0.81** | **0.93** | **0.74** | **0.90** |
| model ($\eta = 1$) | 0.61 | 0.89 | 0.81 | 0.20 |
| model ($\eta = 0.07$) | 1.12 | 0.93 | 0.86 | 0.91 |
| model ($\eta = 0.06/0.12$) | 1.12 / 1.10 | 0.93 / 0.93 | 0.86 / 0.85 | 0.93 / 0.80 |
| ***Panel D: hours*** | | | | |
| **data** | **1.17** | **0.93** | **0.74** | **0.87** |
| model ($\eta = 1$) | 2.25 | 0.17 | 0.11 | 0.99 |
| model ($\eta = 0.07$) | 2.05 | 0.93 | 0.83 | 0.93 |
| model ($\eta = 0.06/0.12$) | 2.05 / 2.06 | 0.93 / 0.87 | 0.84 / 0.85 | 0.93 / 0.95 |

[a] The standard deviations of investment, consumption and hours are relative to the standard deviation of output.

Table 2: Other business cycle moments, US data (1954Q3-2005Q3) and model

| | $\rho\begin{pmatrix} \Delta p_{t+2} - \Delta p_{t-2}\,; \\ y_t^{FIN} - y_t^{FIN,n} \end{pmatrix}$ | $\frac{\sigma[\Delta(w-p)]}{\sigma[\Delta(y-l)]}$ | $\frac{\sigma\left(y_t^{FIN}-y_{t-1}^{FIN}\right)}{1/2\,\sigma\left(y_t^{FIN}-y_{t-4}^{FIN}\right)}$ |
|---|---|---|---|
| **data**[a] | **0.47** | **0.69** | **0.79** |
| model ($\eta = 1$) | 0.27 | 0.11 | 1.84 |
| model ($\eta = 0.07$) | 0.77 | 0.32 | 0.82 |
| model ($\eta = 0.06/0.12$) | 0.76 / 0.75 | 0.32 / 0.35 | 0.79 / 0.98 |

[a] Source: Mankiw and Reis (2006)

the standard deviation of quarterly changes in output and one-half of the standard deviation of four-quarter changes in output. Mankiw and Reis (2006) find that the model with pervasive stickiness is better at matching these moments than the model with only a subset of informational frictions. Table 2 reports these moments for the US economy, as well as the model's predictions.[7] The results in table 2 confirm the Mankiw-Reis results, as the model with pervasive inattentiveness matches these business cycle moments better than the model with frictionless investment.

## 4. Conclusion

In this paper we analyse how inattentiveness in capital investment decisions affects business cycle dynamics. We find that a model with pervasive stickiness – in the form of sticky information – is better at matching business cycle moments than an otherwise identical model with frictionless investment. These findings confirm the results of Mankiw and Reis (2006), and thus reinforce the need to include pervasive stickiness in order to mimic the inertia found in macroeconomic data.

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[7] The model's moments are similar to those in Mankiw and Reis (2006).

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