Microfounding the Investment Wedge

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Abstract

Motivated by behavioral evidence, we develop a tractable method for incorporating competition neglect, the systematic underestimation of competitors' actions, into dynamic general equilibrium models. We show that competition neglect acts like an investment wedge that causes firms to over-invest at first and under-invest later relative to a frictionless benchmark after an expansionary shock. In contrast to a prototype model with exogenous wedges, however, these dynamics are accompanied by variation in equity premia, as investment booms predict periods of low stock market excess returns. When we introduce competition neglect into a canonical RBC model, the model can generate realistic comovement of real and financial variables.

Keywords: Animal spirits, boom-bust cycles, stock return predictability, Q theory of investment, behavioral macro-finance.

JEL codes: E22, E32, D21, D91.

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1 Introduction

Despite Keynes' influential idea that animal spirits and investment-driven business cycles are crucial to understanding major macroeconomic events such as the Great Depression, modeling these dynamics in standard DSGE frameworks has remained a challenging exercise. To this day, the concept of investment-driven fluctuations remains elusive and difficult to operationalize in modern macroeconomic models. Efforts to study the effects of exogenous investment shocks, which generate so-called investment wedges (Chari, Kehoe, and McGrattan 2007), such as those by Justiniano, Primiceri, and Tambalotti (2010), have been influential and have successfully replicated business cycles in quantitative models, but with significant shortcomings. These models fail to generate realistic comovement across macroeconomic and financial aggregates.

This paper develops a framework to microfound the sources of investment wedges based on competition neglect, whereby firms systematically neglect their competitors' strategic investment decisions, which causes distortions in firms' expectations about their own returns to investment. We explore the implications of these distortions in general equilibrium economies. In its effects on macroeconomic variables, we show that competition neglect acts like an *endogenous* investment wedge in a frictionless prototype model that, in response to a productivity shock, displays boom-bust dynamics. After a positive productivity shock, the investment wedge is initially negative, acting like an investment subsidy, and then positive, acting like an investment tax. Accordingly, relative to the frictionless benchmark, the model produces over-investment initially followed by under-investment. Furthermore, when we turn to financial variables, competition neglect is able to produce realistic stock price dynamics, unlike the prototype model with wedges. Specifically, because it associates with distortions to the perceived returns to investment, the investment boom is followed by predictably negative first, positive later excess stock returns; the model can therefore produce time variation in equity premia.

The cornerstone of our approach is a behavioral friction known as *competition neglect* (CN), which was introduced by Greenwood and Hanson (2015). They study a Q-theory investment model where firms neglect the competitive investment responses of other firms. This neglect causes firms to overinvest following a positive shock, because they overestimate the returns of investment. These returns are a negative function of aggregate investment, driven by other firms' investment, which is *underestimated* by firms. In this paper, we introduce

this insight into a fully-fledged DSGE framework. We derive a solution method that operationalizes the concept of CN in nonlinear, general equilibrium settings. By doing so, we derive an explicit form for the investment wedge and demonstrate its quantitative implications for macroeconomic fluctuations.

The psychological foundation of competition neglect (CN) is rooted in well-documented cognitive biases. Camerer and Lovallo (1999) demonstrate that overconfidence leads individuals to overestimate their relative abilities, resulting in excessive market entry, a phenomenon closely related to firms' overinvestment. These biases align with broader evidence from social psychology, where individuals consistently exhibit overconfidence in various domains, such as the well-documented "better-than-average" effect (Svenson 1981).[1] Kahneman (2011) further emphasizes that CN is exacerbated by delayed feedback, reinforcing firms' systematic errors in forecasting investment returns. Similarly, the findings of Greenwood and Hanson (2015) emphasize that CN can interact with extrapolation (Gabaix 2019) to generate powerful amplification. By incorporating these psychological insights into macroeconomic models, we can better understand their impact on investment distortions and cyclical fluctuations.

As a first step, we develop a tractable solution method that allows for the incorporation of CN into general equilibrium models. We write down the problem of the behavioral firm, making explicit the bounds on rationality that the firm faces, and letting the firm optimally choose the degree of awareness of its competitors' actions. Unlike standard approaches that rely on ad hoc behavioral assumptions, our framework reinterprets CN as a constrained optimization problem where firms balance the costs of awareness against the benefits of better investment forecasting. This method circumvents common issues in behavioral macroeconomics, such as the challenge of modeling higher-order beliefs about other agents' expectations. When doing this, we suitably split the firm, thereby carefully isolating the friction to the branch of the firm that chooses capital investment, to align with the evidence used by (Greenwood and Hanson 2015). As a result, our approach provides a bounded rationality equivalence to the behavioral friction, making it both analytically convenient and broadly applicable to a range of macroeconomic settings.

Conventional real business cycle (RBC) and dynamic stochastic general equilibrium (DSGE) models typically assume that firms make investment decisions under rational expectations (RE). This means, in particular, that they under-

[1]This classic study in social psychology shows that a majority of drivers regard themselves as more skillful and less risky than the average driver in each respective group, which is statistically impossible.

stand the competitive responses of other firms in the market when evaluating the returns to investment. By changing this assumption to the more realistic CN assumption, we obtain the following qualitative and quantitative results.

Qualitatively, we obtain a closed form solution for the wedges implied by the behavioral friction in a benchmark RBC setting, connecting CN to the broader literature on business cycle accounting. Interestingly, CN drives only an investment wedge, with the efficiency, labor and government spending wedge at zero. We show that the investment wedge introduced by CN does not lead to simple mean-reverting dynamics. Instead, it generates endogenous investment booms and busts, even in response to standard AR(1) productivity shocks. In particular, firms' misperceptions cause them to overinvest following positive shocks, which leads to an overaccumulation of capital. As these misperceptions are later corrected, investment falls below its efficient level, generating a bust phase. This mechanism provides a novel explanation for observed patterns of investment economic shocks, and add significant structure to Keynes' idea of animal spirits.

The financial implications of CN are also examined through its impact on stock prices, earnings, and asset returns. The model predicts that stock prices initially surge due to excessive investment, but later decline as firms adjust their expectations. This dynamic leads to predictable excess returns, where high valuations are followed by lower-than-expected stock returns, a pattern consistent with empirical findings on return predictability. The study contrasts these results with an alternative model featuring exogenous investment wedge shocks, demonstrating that such a specification fails to generate the sign-switching behavior of the investment wedge observed under CN. By endogenizing the investment wedge through competition neglect, the paper provides a novel explanation for cyclical investment patterns and excess return predictability.

1.1 Related Literature

This paper relates to a literature in behavioral macroeconomics that uses behavioral distortions to explain the comovement between macroeconomic and financial variables, such as Barberis, Greenwood, Jin, and Shleifer (2015) and Bordalo, Gennaioli, Porta, OBrien, and Shleifer (2024). More broadly, our work relates to the behavioral macroeconomics literature that studies emphasizing departures from rational expectations due to bounded rationality and informational frictions. Farhi and Werning (2019) and Gabaix (2020) intro-

duce behavioral frictions into New Keynesian models, demonstrating how cognitive limitations and myopia alter macroeconomic dynamics. In related work, Bianchi-Vimercati, Eichenbaum, and Guerreiro (2024) explore level-k agents and the effects of fiscal spending. Garcia-Schmidt and Woodford (2019) explore the related notion of reflective equilibrium.

In landmark work, Angeletos, Huo, and Sastry (2021) organize systematic biases in forecasts around alternative notions of imperfect information and extrapolation. In closely related work, Angeletos and Lian (2023) provide a comprehensive analysis of "dampened GE", a close cousin of the workings of CN in GE models. However, they limit their analysis to simplified loglinear settings without endogenous states. Ilut and Valchev (2022) study the effects of bounded rationality at the level of problem solving, a notion that is related to the bounded rationality on the perception of the firms' competitors actions. Flynn and Sastry (2024a) explore how limited attention by firms generates cycles (see also Flynn and Sastry (2024b)). By embedding competition neglect into a general equilibrium framework, our paper contributes to this growing literature on how behavioral frictions shape macroeconomic fluctuations.

GH emphasize the interaction of CN interacts with extrapolative expectations for additional amplification. We clarify how our mechanism relates with the broader literature with such behavioral distortions (Gabaix 2019) as well as with diagnostic expectations (Bordalo, Gennaioli, and Shleifer 2018). See also, Bianchi, Ilut, and Saijo (2024), L'Huillier, Singh, and Yoo (2023) and Maxted (2023), who study diagnostic expectation in general equilibrium.

1.2 Organization

The paper is organized as follows. Section 2 presents our solution method for embedding CN into DSGE models and discusses its advantages over existing approaches. Section 3 develops a real business cycle model with CN and characterizes the investment wedge analytically. Section 4 provides a quantitative analysis, exploring the empirical relevance of the investment wedge and its implications for macroeconomic moments. Section 5 concludes.

2 Solution Method: Competition Neglect in General Equilibrium

We develop a method for introducing CN (Greenwood and Hanson 2015, henceforth, GH) into a general class of DSGE models. The method rests on finding an approach to apply these ideas to non-linear models. Our approach on a cost-function approach, whereby agents biased by CN need to optimally choose, under RE, an 'awareness cost' to correctly anticipate the equilibrium actions of their competitors. The size of this cost parametrizes the amount of CN, and agents optimally tradeoff the costs of awareness and economic objectives. The key methodological contribution is to show that writing the problem with this approach delivers clarity when embedding CN into nonlinear, GE, problems.

The reason our cost-function approach delivers tractability is that it solves a technical challenge with computing general equilibrium in nonlinear models under CN. Different from the canonical GH linear investment setting, in a benchmark RBC model, for instance, and any other more complex DSGE, the returns to investment as nonlinear functions of aggregate capital, which is misperceived by the behavioral firm. We show how to make progress on this issue by writing the problem in general form. Another issue that needs to be dealt with is that in GH, the interest rate is fixed. General equilibrium, instead, requires the interest rate to adjust to clear the aggregate capital market. It is not clear how to solve for this under the CN operator presented in GH. Since our cost-function approach allows to solve the problem under the RE operator, this issue is de facto taken care off. The approach is general and can be introduced in DSGE models of any scale, offering elegance and broad applicability.

2.1 Illustration: Linear, Partial Equilibrium, Setting: Greenwood and Hanson (2015)

The seminal paper by GH considers the partial equilibrium problem of a representative firm subject to CN. The problem leads to *linear* first-order conditions, where the notion of competition neglect can be introduced in a straightforward way. We start by illustrating the steps taken by our solution method in the original GH problem.

2.1.1 Original Problem

Consider the following model of the shipping industry. A unit mass of firms, each indexed by i, chooses a sequence of net investments (ships) to maximize profits. These profits are mainly determined by a ships rental rate expression, which in GH is postulated to be a linear function of the industry-wide stock of ships.

More specifically, firm i chooses the sequence of net investments $\{I_{it}\}_{t\geq 0}$ to maximize

$$E_0^\theta \sum_{t=0}^{\infty} \beta^t \left\{ H_t K_{it} - I_{it} - \delta K_{it} - \frac{\phi}{2} I_{it}^2 \right\} \tag{1}$$

where β is the firm's discount factor, K_{it} is the firm's stock of capital (ships), δ is the depreciation rate and ϕ is an investment adjustment costs parameter. Firms take the ship rental rate

$$H_t = A_t - BK_t \tag{2}$$

which pins down the return to investment, as given. These returns depend on an exogenous law of motion $A_t = (1-\rho_a)\bar{A} + \rho_a A_{t-1} + \varepsilon_t$, $\varepsilon_t \sim N(0, \sigma^2)$. The aggregate law of motion of capital is

$$K_{t+1} = K_t + I_t$$

The operator E_t^θ is the CN operator to degree θ, $0 \leq \theta < 1$. It signifies that, when evaluating current and future returns H_t, $t \geq 0$, firms neglect the competitive action of their competitors. Firm i neglects the fact that other firms will also choose their investment to take advantage of the returns, increasing the total stock of ships K_t, thereby *lowering* returns. When a positive shock ε_t impacts the industry, firms will be overconfident and overinvest.[2] Mathematically, whenever aggregate investment at a date $t+\tau$, that is $I_{t+\tau}$, $\tau \geq 0$, appears in the argument, individual firms replace it with $\theta I_{it+\tau}$.[3]

This problem is subject to firm's i law of motion for capital

$$K_{it+1} = K_{it} + I_{it} \tag{3}$$

Notice then that firms do not suffer behavioral distortions when evaluating their

[2]Here briefly provide similar justification as in GH and discuss evidence in psychology.
[3]As in GH, note that firms do not internalize this dependence when they optimize.

own capital law of motion.

Optimality implies:

$$I_{it} = \beta \frac{E_t^{\theta} \left[A_{t+1} - BK_{t+1} + 1 - \delta + I_{it+1} \right]}{\phi} - 1$$

Thanks to linearity in the aggregate capital next period, K_{t+1}, CN leads to the distorted optimality condition

$$I_{it} = \beta \frac{E_t \left[A_{t+1} \right] - B(K_t + \theta I_{it}) + 1 - \delta + E_t \left[I_{it+1} \right]}{\phi} - 1$$

Because $\theta < 1$, overestimation of the returns to investment leads the firm to overinvest.[4]

2.1.2 Neglect Expressed as a Costly Computation Problem

We prove equivalence to the original GH problem of the following 'as if' problem. A behavioral firm has rational competition awareness, whereby it is biased towards a natural awareness level θ_n of their competitors actions, but can incur a cost to change its awareness level. The firm optimally tradeoffs these costs to the implied increase in expected returns that more awareness delivers. This problem leads to the same GH solution, but it has the advantage of being expressed as a forward looking problem using the rational expectations (RE) operator. This property is crucial when generalizing the CN distortion to non-linear, GE, models.

This bounded rationality problem is written as follows. Denote by $I_{t+\tau|t}^{\theta}$ perceived aggregate date-$t+\tau$ investment from the point of view of date t, $\tau \geq 0$, given by

$$I_{t+\tau|t}^{\theta} \equiv \theta_{it} E_t \left[I_{t+\tau} \right] + (1 - \theta_{it}) I \tag{4}$$

where I is steady state investment. Hence, the behavioral firm has a tendency to underestimate how much aggregate investment will deviate from its steady state value.

The variable θ_{it} is the firm's optimal awareness decision, which is subject to

[4] Iterating forward, one can show that the solution is given by $I_{it} = xK_t + yA_t$, with $x = \frac{B\theta + r\phi}{2\phi\theta} - \sqrt{\left(\frac{B\theta + r\phi}{2\phi\theta} \right)^2 + \frac{B}{\phi\theta}}$ and $y = \frac{\rho_a}{\phi(1-\rho_a) - \phi\theta h_{I_i x} + B\theta + r\phi} = \frac{\rho_a}{\phi(1-\rho_a) - \frac{B}{h_{I_i x}}}$ if $\theta > 0$, or $x = -\frac{B}{r\phi}$ and $y = \frac{\rho_a}{\phi(1-\rho_a) + r\phi}$ if $\theta = 0$.

a cost

$$\frac{\kappa}{2}\left(\theta_{it}-\theta_n\right)^2, \quad 0 \leq \theta_n < 1 \tag{5}$$

At time t,

$$I^{\theta}_{t|t} = \theta_{it} I_t + (1-\theta_{it}) I$$

By implication, perceived aggregate capital next period $t+1$ is given by

$$K^{\theta}_{t+1|t} \equiv K_t + I^{\theta}_{t|t} \tag{6}$$

Firm i chooses the sequence of attention levels $\{\theta_{it}\}_{t\geq 0}$ and investments $\{I_{it}\}_{t\geq 0}$ to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ H_t K_{it} - I_{it} - \delta K_{it} - \frac{\phi}{2} I_{it}^2 - \frac{\kappa}{2}\left(\theta_{it}-\theta_n\right)^2 \right\} \tag{7}$$

subject to the perceived aggregate investment equation (4), equation (6), and the firm's law of motion of capital

$$K_{it+1} = K_{it} + I_{it} \tag{8}$$

We obtain the following equivalence result.

Proposition 1 *When $\theta = \theta_n$, the rational competition awareness problem of the boundedly rational firm (7)-(8) and (4) has, to first order, the same solution as the original GH problem (1)-(3).*

The proof is presented in the appendix. The intuition for this result is that, in the first-order approximation to the solution of the rational competition awareness problem, the firm chooses awareness $\theta_{it} = \theta_n$. If this natural attention level θ_n is equal to the CN parameter in the GH model θ, then both solutions coincide (to first order).

2.2 Generalization to Nonlinear Models

As a first step towards general equilibrium, we demonstrate how to introduce CN into a general class of nonlinear production models. We employ the rational awareness cost-function approach illustrated above, which allows to isolate the behavioral friction to a single perceived investment equation, while the rest of the problem is written based on the RE operator. This circumvents a num-

ber of issues that may arise when mixing different expectation operators while attempting to find a general equilibrium. In other words, the resulting set of equilibrium equations can then be readily embedded into DSGEs.[5]

The representative firm is split into two sectors: final good producers and capital good producers. Final good producers hire labor, rent capital from capital-good producers and produce final output. Capital good producers accumulate capital by investing units of the final output, and rent it to final good producers. Following GH, we model competition neglect among capital producers. To do this, as above, we assume that capital producers are boundedly rational, and that they optimally decide how much awareness to exert when considering their competitors' investment.

2.2.1 Final Good Producers

A continuum of competitive firms, indexed by i, produces an undifferentiated good using labor and physical capital. The ith firm chooses labor demand N_{it}^d and capital demand K_{it}^d to maximize

$$\max_{\{N_{it},K_{it}\}} E_0 \sum_{t=0}^{\infty} M_{0,t} \left(Y_{it} - W_t N_{it} - H_t K_{it}\right)$$

where $M_{0,t} \equiv \prod_{s=1}^{t} M_s$ is the stochastic discount factor, Y_{it} is output, W_t is the wage, and H_t is the capital rental rate. Profit maximization is subject to the production function

$$Y_{it} = \left(A_t N_{it}\right)^{1-\alpha} \left(K_{it}\right)^{\alpha}$$

Note that the problem is static. Optimality at each date t implies:

$$W_t = (1-\alpha)\frac{Y_{it}}{N_{it}}$$
$$H_t = \alpha \frac{Y_{it}}{K_{it}}$$

Exploiting symmetry, we obtain the following expression for the rental rate:

$$H_t = \alpha \left(\frac{A_t N_t}{K_t}\right)^{1-\alpha} \tag{9}$$

[5]We consider the problem of a competitive representative firm, but nothing prevents from considering other production structures, such as monopolistic competition, or to incorporate other frictions, such as price stickiness, for instance.

(This rental rate is the analogue of GH's linear function (2).)

2.2.2 Capital Good Producers

A continuum of competitive firms, indexed by i, accumulate capital by investing units of the undifferentiated final good. Capital good producers have bounded rationality in the same sense as in 2.1.2 above. They understand the dynamics of their own capital stock, but they have limited awareness of their competitors actions, and therefore distort their perception of aggregate investment by equation (4), with implication for their perception of future stock of capital. Similar to the linear problem above, these agents incur cost (5) to optimally modify their awareness away from the natural level θ_n. This behavioral friction ultimately impacts their perception of expected returns.

Each firm starts from a common initial condition of own's capital, $K_{i0} = K_0$. We assume that the firm receives information directly relevant to solve their intertemporal optimization program from their 'close contacts'. This is motivated by evidence (Gormsen and Huber 2024a; Gormsen and Huber 2024b) that, in contrast to standard theory, firms maximize profits using nominal discount factors that are discussed in conference calls with shareholders. Consistent with this evidence, our firms receive discount rates from shareholders (consumers), and capital market rental rates from final good producers. Both of these are given in the form of functions of perceived aggregate capital, as specified below.

The ith firm chooses a path of attention levels and individual investment choices to maximize profits, given perceived aggregate investment (4) and perceived aggregate capital (6), and given the information received from their close contacts about discount factors, denoted $\beta M_{0,t}(K^{\theta}_{t|0})$, and about rental rates $H_t(K^{\theta}_{t|0})$. Denoting by $\Phi(K_{it}, I_{it})$ the adjustment costs function, the problem is:

$$\max_{\{\theta_{it}, I_{it}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t M_{0,t}(K^{\theta}_{t|0}) \left\{ H_t(K^{\theta}_{t|0}) K_{it} - I_{it} - \delta K_{it} - \Phi(K_{it}, I_{it}) - \frac{\kappa}{2}(\theta_{it} - \theta_d)^2 \right\} \tag{10}$$

When solving the problem, the firm plugs in its perceived path of aggregate capital $K^{\theta}_{t|0}$ to obtain discout factors and rental rates. The maximization is subject to the individual capital accumulation equation

$$K_{it+1} = K_{it} + I_{it}$$

As in GH, we assume that at the beginning of every period t, every firm observes the realization of aggregate capital in that period (which depends on past investment I_{t-1}), K_t before deciding investment I_{it}. This assumption preserves the recursivity of the firm's problem.

2.3 General Equilibrium

An advantage of expressing the behavioral firm's problem as an if distorted problem that uses the RE operator is that it can be readily combined with other the optimality conditions of other agents under RE to obtain general equilibrium. Here we describe these steps. The main novelty is a requirement is that the information received by the boundedly rational firm from its close contacts is consistent with equilibrium, which established formally in the definition below.

We obtain equilibrium mappings from the aggregate state into equilibrium objects from other agents' problems. For instance, the consumer problem delivers a mapping of the aggregate state into consumption C_t. We denote equilibrium mappings from the aggregate state $\{K_t, A_t\}$ using curly capital letters. For instance, for aggregate consumption C_t,

$$C_t = \mathcal{C}(K_t, A_t)$$

and other endogenous variables. In a standard RBC model, these take the form of labor N_t, the interest rate R_t, and wages W_t.

It is useful to record the following lemma, characterizing the rational choice of awareness level by the boundedly rational firm.

Lemma 1 *In the first order approximation we have $\theta_{it} = \theta_n$.*

Hence, we can set θ_n equal to the GH CN parameter θ in order to obtain the equilibrium conditions under CN (to a first order).

We can now define a general equilibrium.

Definition 1 *A general equilibrium is given by choices by capital-goods firms $\{\theta_{it}, I_{it}\}$ and states $\{K_{it}\}$, choices by consumers and final-goods producing firms N_t, C_t, and prices R_t, W_t, such that,*

1. *the information that the firm receives from close contacts, used in maximization (10) above, is consistent with the optimality conditions and con-*

straints of other agents, that is we have two conditions hold:

$$\begin{aligned} M_{0,t}(K_t) &= \mathcal{M}_{0,t}(K_t, A_t) \\ H_t(K_t) &= \mathcal{H}(K_t, A_t) \end{aligned}$$

2. *agent's optimality constraints are satisfied,*
3. *and markets clear.*

3 A Real Business Cycle Model with Competition Neglect

In this section, we derive a real business cycle model augmented with competition neglect in the investment sector. In the spirit of business cycle accounting, a frictionless benchmark is used to isolate the endogenous investment wedge generated by the novel competition neglect friction, and we find that even productivity shocks, which are efficient in the frictionless benchmark, lead to an investment wedge as well as create boom bust dynamics in investment.

3.1 Model

Time is discrete and runs forever. There are four sets of agents in the economy: households, final good producing firms, capital good producing firms, and the government. Except for the behavioral friction in the capital goods sector, other model ingredients are standard. We begin by describing each block.

3.1.1 Households

At each time t, a representative household chooses consumption (C_t), hours (N_t)to supply, and savings in the form of real government bonds (B_{t+1}) to maximize the following lifetime utility:

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma} - 1}{1-\gamma} - \chi \frac{N_t^{1+\varphi}}{1+\varphi} \right) \right] \tag{11}$$

subject to a per-period budget constraint

$$C_t + \frac{1}{1+r_t} B_{t+1} = B_t + W_t N_t + D_t + T_t$$

where β is the discount factor satisfying $0 < \beta < 1$, γ is the inverse of the intertemporal elasticity of substitution, χ is a parameter that pins down the steady-state level of hours, φ is the inverse of the Frisch elasticity of labor supply, W_t is the real wage, D_t denotes dividends from the ownership of investment and goods producing firms, and T_t denotes lump-sum government transfers. Government bonds pay off $1 + r_t$ interest rate in the following period.

3.1.2 Final good producing sector

The final good is produced by a chain of perfectly competitive producers. At each time t, identical firms produce the final good Y_t combining labor N_t and physical capital K_t, according to the technology: $Y_t = (A_t N_t)^{1-\alpha} K_t^{\alpha}$, where $0 < \alpha < 1$ is a Cobb-Douglas parameter. Firms hire labor and capital at wage rate W_t and rental rate H_t respectively.

3.1.3 Capital good producing sector

A continuum of competitive firms, indexed by i, accumulate capital goods by investing units of the undifferentiated final good. They are subject to bounded rationality in that they understand the dynamics of their own capital stock but have limited awareness of their competitors' actions, and therefore their perceived aggregate net investment is distorted. Their problem is similar to what was described in Section 2. To avoid repetition, we refer the reader to Section 2 for detailed discussion, and only provide an outline here.

At each period t, these firms rent out their capital stock K_{it} at perceived market rental rate H_t^f which they take as given. They spend δK_{it} of final good towards repairing depreciating capital. Changes in net investment I_{it} are subject to investment adjustment costs $\Phi(K_{it}, I_{it})$ where the function $\Phi(\cdot, \cdot)$ is assumed such that in the steady state $\Phi(\bar{K}, \bar{I}) = \Phi_1(\bar{K}, \bar{I}) = \Phi_2(\bar{K}, \bar{I}) = 0$, and $\Phi_{22}(\bar{K}, \bar{I}) < 0$. In this section, for analytical tractability, we assume quadratic adjustment costs $\Phi(\cdot, \cdot) = \frac{\phi}{2} I_{it}^2$. In Section 4, we present quantitative results with a more general adjustment cost function.

Each firm chose path of attention levels θ_{it} and individual investment to solve the problem described in Section 2. The stock of capital for each firm evolves according to Section 2.

3.1.4 Government

The government runs balanced budget every period, spending G_t of final good, and raising net taxes $-T_t$. We assume government bonds are in zero net supply.

3.1.5 Aggregate Resource Constraints

The final good in the economy is used towards consumption, net investment, depreciation, investment adjustment costs, and government spending. Final goods' market clearing is given by:

$$Y_t = C_t + I_t - \delta K_t - \frac{\phi}{2} I_t^2 + G_t \tag{12}$$

We will assume government spending is zero: $G_t = 0$.
Aggregate capital stock, K_t, follows the following law of motion:

$$K_{t+1} = K_t + I_t \tag{13}$$

3.2 Equilibrium

The appendix presents the equilibrium conditions. There, we also goes over the log-linear approximation in detail. Given the log-linearized equilibrium conditions, the general equilibrium is obtained as follows. In equilibrium, the solution to firm level investment is exactly equal to aggregate investment since all firms are identical. The following equations then form the equilibrium of the model for endogenous aggregate variables $\{n_t, k_{t+1}, \hat{I}_t, c_t, r_t\}$:

$$(1-\alpha)(a_t + n_t) + \alpha k_t = \frac{C}{Y} c_t + \frac{1}{Y} \hat{I}_t + \frac{\delta K}{Y} k_t \tag{14}$$

$$k_{t+1} = k_t + \frac{1}{K} \hat{I}_t \tag{15}$$

$$c_t = E_t c_{t+1} - \frac{1}{\gamma} r_t \tag{16}$$

$$(1-\alpha) a_t + \alpha k_t = \gamma c_t + (\alpha + \varphi) n_t \tag{17}$$

$$\phi \hat{I}_t = -\gamma (E_t^f c_{t+1} - c_t) + (1-\alpha)[1 - \beta(1-\delta)] \tilde{E}_t^f \left[a_{t+1} + n_{t+1} - k_{t+1} \right] + \beta \phi \tilde{E}_t^f \hat{I}_{t+1} \tag{18}$$

where the firm's expectations operator $\tilde{E}_t^f[\cdot]$ implies that the policy function for those variables is formed over perceived capital stock instead of actual capital

stock. The perceived capital stock follows the law of motion

$$\tilde{E}_t^f[k_{t+1}] = k_{t+1|t}^{\theta} = k_t + \theta_d \hat{I}_t \tag{19}$$

The exogenous AR(1) process for a_t is given by :

$$a_t = \rho_a a_{t-1} + \epsilon_{at} \tag{20}$$

where the lower case letters denote the corresponding log-linearized objects.

The model is solved using a minimum state variable solution. Linear policy functions for each of the variables are postulated as functions of state variables $\{k_t, a_t, g_t\}$, and solution can be obtained using a guess and verify method. We present the solution in the appendix.

Proposition 2 *Solution to the real business cycle competition neglect take the form of policy functions for aggregate endogenous variables* $\{n_t, k_{t+1}, \hat{I}_t, c_t, r_t\}$*:*

$$x_t = \psi_{xk} k_t + \psi_{xa} a_t \tag{21}$$

The perceived aggregate capital stock is given by the following law of motion:

$$k_{t+s+1|t}^{\theta} = (1 + \theta_d \psi_{Ik}) k_{t+s|t}^{\theta} + \theta_d \psi_{Ia} E_t a_{t+s} \tag{22}$$

where $k_{t|t}^{\theta} = k_t$ *is given at each time* t*.*

3.3 Endogenous Investment Wedge

Consider a prototype frictionless model with four wedges: labor wedge τ_{nt} (tax on household's labor income), efficiency wedge τ_{at}, investment wedge τ_{it} (tax on net investment), and government spending wedge τ_{gt}. The model is same as the real business cycle model except the investment goods sector has full information rational expectations.

In the appendix, we write down the non-linear equilibrium conditions and show that the assumed competition neglect friction does not alter the steady state relative to the prototype model. We list the log-linearized equilibrium of the prototype model, where the variables with asterisks denote the corresponding variables under the prototype model.

Definition 2 (Equilibrium in the protoype model)

$$(1-\alpha)(a_t + n_t^*) + \alpha k_t^* = \frac{C}{Y}c_t^* + \frac{1}{Y}\hat{I}_t^* + \frac{\delta K}{Y}k_t^* + \tau_{gt} \tag{23}$$

$$k_{t+1}^* = k_t^* + \frac{1}{K}\hat{I}_t^* \tag{24}$$

$$c_t^* = E_t c_{t+1}^* - \frac{1}{\gamma}r_t^* \tag{25}$$

$$(1-\alpha)(a_t + \tau_{at}) + \alpha k_t^* = \gamma c_t^* + (\alpha+\varphi)n_t^* + \tau_{nt} \tag{26}$$

$$\tau_{it} + \phi\hat{I}_t^* = -\gamma(E_t c_{t+1}^* - c_t^*) + (1-\alpha)[1-\beta(1-\delta)]E_t(a_{t+1} + n_{t+1}^* - k_{t+1}^*) + \beta\phi E_t\hat{I}_{t+1}^* + \beta E_t\tau_{it+1} \tag{27}$$

Equation (27) recursively defines the investment wedge as function of observed variables in the prototype model. We recover the wedges such that the prototype model with the wedges is observationally equivalent to the competition neglect model.

Proposition 3 (Business Cycle Accounting) *The dynamics of output, consumption, investment, capital stock, real interest rate in the prototype model with wedges are observationally equivalent to that of competition neglect when*

1. *labor wedge, efficiency wedge, and government wedge are set to zero in all periods, and*
2. *the investment wedge is given by:*

$$\tau_{it} = \nu_k K k_t + \nu_a K a_t \tag{28}$$

where the coefficients are given by

$$\nu_k = (1-\theta_d)\left(-\gamma\frac{\psi_{ck}}{K} - \beta B(1-\psi_{nk}) + \beta\phi\psi_{Ik}\right)\frac{\psi_{Ik}}{1-\beta(1+\psi_{Ik})} \tag{29}$$

$$\nu_a = (1-\theta_d)\left(-\gamma\frac{\psi_{ck}}{K} - \beta B(1-\psi_{nk}) + \beta\phi\psi_{Ik}\right)\frac{1-\beta}{1-\beta(1+\psi_{Ik})}\frac{\psi_{Ia}}{1-\beta\rho_a} \tag{30}$$

$B \equiv (1-\alpha)[1-\beta(1-\delta)]/\beta K$, K is the steady state level of capital stock, and the coefficients ψ_{xy} for $x = \{c, n, I\}$ and $y = \{a, k\}$ are defined in Proposition 2.

Notice that the investment wedge given in Equation (28) is zero when $\theta_d = 1$, i.e. when there is no competition neglect. In the presence of competition neglect

$0 \leq \theta_d < 1$, a shock to productivity gives rise to an investment wedge.

Corollary 1 (ARMA (2,1) representation of the Investment Wedge) *The investment wedge can be re-written as the following ARMA(2,1) process:*

$$\tau_{it} = (1 + \psi_{Ik} + \rho_a)\tau_{it-1} - (1 + \psi_{Ik})\rho_a\tau_{it-2} + \nu_a K\epsilon_t + [\nu_k\tilde{\psi}_{Ia} - \nu_a(1 + \tilde{\psi}_{Ik})]K\epsilon_{t-1} \tag{31}$$

Proposition 4 (Special Case: boom-bust dynamics in investment wedge) *Assume full competition neglect $\theta_d = 0$, linear utility in consumption ($\gamma = 0$) and inelastic labor supply $\chi = 0$, the coefficients on the investment wedge derived in equation 28 are now given by*

$$\nu_k = (-\beta B + \beta\phi\psi_{Ik})\frac{\psi_{Ik}}{1 - \beta(1 + \psi_{Ik})} > 0 \tag{32}$$

$$\nu_a = (-\beta B + \beta\phi\psi_{Ik})\frac{1 - \beta}{1 - \beta(1 + \psi_{Ik})}\frac{\psi_{Ia}}{1 - \beta\rho_a} < 0 \tag{33}$$

where $\psi_{Ik} = -\frac{B}{r\phi} < 0$ and $\psi_{Ia} = \frac{B\rho_a}{\phi(1-\rho_a)+r\phi} \geq 0$.

After an unanticipated positive TFP shock at date t, the investment firms misperceive expected return on capital in the following period. This is because they underestimate the amount of total investment at date t, and hence underestimate the total stock of capital available for production in the subsequent period. Under a business cycle accounting, this misperception shows up as a negative investment wedge implying an as-if subsidy to capital investment. The coefficient on capital stock in the investment wedge (at $\theta_d = 0$) is unambiguously positive. As the shock abates, the dynamics are driven by the first component in equation 28 which implies the wedge eventually becomes positive and the behavioral friction gives rise to an as-if tax on capital investment relative to the frictionless prototype model.

4 Quantitative Analysis

4.1 Parameterization

Table 1 reports the parameters of the model. We choose a standard rate of time preference $\beta = 0.99$ that implies a risk-free rate of around 1 percent p.a. The inverse elasticity of intertemporal substitution is set to 2, to produce a realistic

amount of excess return predictability, as discussed below. We choose a labor disutility parameter $\chi = 1.03$ to imply steady state hours of 0.5, so half of the available time endowment is devoted to production, and the curvature of leisure in the utility function $\varphi = 1$ to imply a Frisch's elasticity of one.

The economy grows deterministically along a balanced growth path with average growth μ of 2 percent p.a. Capital depreciates at a standard value of 10 percent p.a. and the capital share in value added has a standard value of $\alpha = 1/3$. We choose a capital adjustment cost parameter of 20. The exogenous process for productivity is a persistent $AR(1)$ process with an annualized autoregressive coefficient of 0.95 and an annualized standard deviation for its shocks of 0.01.

Finally, we set the competition awareness parameter to $\theta = 0.1$—when considering the aggregate investment policy, individual firms place a weight of 10 percent on the true response and of 90 percent on the default response along the balanced-growth path.

Parameter		Value
β	Time preference	0.99
γ	Inverse EIS $= 1/\gamma$	2
χ	Labor disutility parameter	1.0324
φ	Inverse Frisch elasticity $= (1-N)/N/\varphi$	1
μ	Mean growth rate	0.02/4
δ	Capital depreciation rate	.025
α	Capital share in value added	1/3
ϕ	Capital adjustment costs	20
ρ_a	Serial correlation productivity shock	$0.95^{1/4}$
σ_a	Volatility productivity shock	$0.01/\sqrt{4}$
θ	Steady-state awareness	0.1

Table 1: Parameter Values (quarterly frequency)

We solve the model by a first-order approximation around the steady state, as described above.

4.2 Impulse responses: Real variables

We begin by examining how the economy responds to a positive productivity shock in our model. Figure 1 shows the dynamic responses of the main real variables to a one-standard-deviation productivity shock under two versions of the model—the frictionless benchmark (blue dashed lines) and the version with competition neglect (red solid lines).

Several notable patterns emerge. Net investment rises strongly on impact in the frictional model, overshooting the frictionless benchmark. Over time, net investment converges back to steady state and even falls below the frictionless path for a period—what we term underinvestment.

Accordingly, capital grows more quickly at first under frictions, peaking above the frictionless level. Output similarly exhibits a stronger near-term expansion. Eventually both begin reverting toward their balanced-growth path. Similarly, in contrast with the negative response of hours in the frictionless model, hours worked increase at the outset under frictions, then undershoot the frictionless path before returning to steady state. Consumption also exhibits a modest hump-shaped pattern, with a higher peak under frictions, driven partly by the stronger initial rise in output.

To understand the mechanism, it is useful to interpret the results under the lens of the observationally-equivalent prototype model with wedges described above. Here, the endogenous investment wedge produced by competition neglect responds nontrivially and changes sign after the productivity shock, acting like an investment subsidy at first and like an investment tax later. Indeed, the response of investment reflects the subsidy-like effect of the endogenous investment wedge when productivity first improves, with firms overinvesting relative to the frictionless case, and the tax-like effect later.

Overall, these results illustrate how a single positive productivity shock, mediated by behavioral frictions, can generate a short-lived boom-bust response relative to the frictionless model.

4.3 Impulse responses: Financial variables

We now introduce stock prices, dividends, and returns into the picture. Let V_{it} denote the cum-dividend value of firm i and D_{it} its dividend flow. We define these variables in the model as

$$V_{it} = D_{it} + E_t M_{t+1|t} V_{it+1}, \quad D_{it} = H_t K_{it} - I_{it} - \delta K_{it} - \frac{\phi}{2}\left(\frac{I_{it}}{K_{it}} - \frac{I}{K}\right)^2 K_{it} - \frac{\kappa_t}{2}[\theta_{it} - \theta_d]^2$$

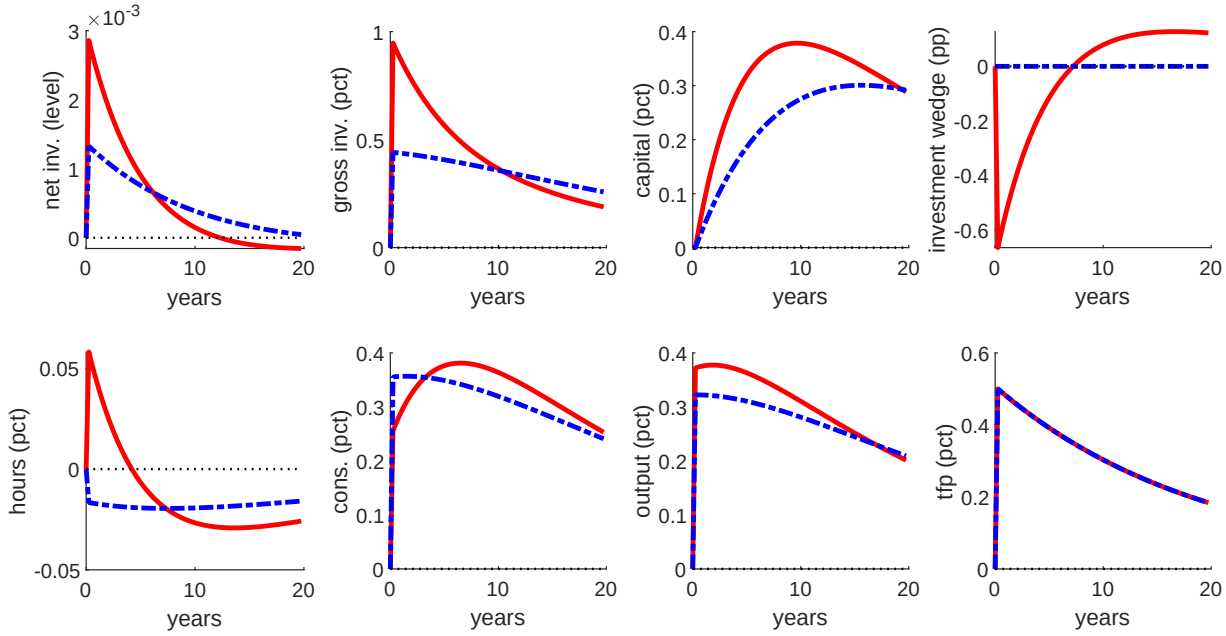


Figure 1: Impulse responses of real variables to a +1 s.d. productivity shock. Red (solid): with competition neglect. Blue (dashed): frictionless model. Deviations from balanced-growth path.

where $M_{t+1|t}$ is the one-period stochastic discount factor used by capital good producers.[6] Accordingly, we define the stock return as

$$R_{i,st+1} = \frac{V_{it+1}}{V_{it} - D_{it}} \tag{34}$$

As we show in the Appendix, average Tobin's Q equals marginal Tobin's Q plus a term related to the awareness costs, which are trivial to a first-order approximation around the steady state. As a result, the equity return, $R_{i,st+1}$, is approximately equal to the firm's investment return, $R_{i,kt+1}$, reflected in the optimal investment condition, or

$$R_{i,st+1} \approx R_{i,kt+1} = \frac{H_{t+1} - \delta + \phi\left(\frac{I_{it+1}}{K_{it+1}} - \frac{I}{K}\right)\frac{I_{it+1}}{K_{it+1}} - \frac{\phi}{2}\left(\frac{I_{it+1}}{K_{it+1}} - \frac{I}{K}\right)^2 + Q_{it+1}}{Q_{it}}$$

In this context, we can construct the risk-free rate $r_{ft} = -\log E_t M_{t+1}$ and the equity premium $E_t(r_{st+1} - r_{ft})$. Here, expectations are computed not from the perspective of the capital good producers, but rather from the perspective of the household, who is not affected by behavioral distortions, or, equivalently,

[6]Note that, because final good producers realize no profits, the aggregate stock market value and dividend can be defined by aggregating the prices and dividends of capital good producers.

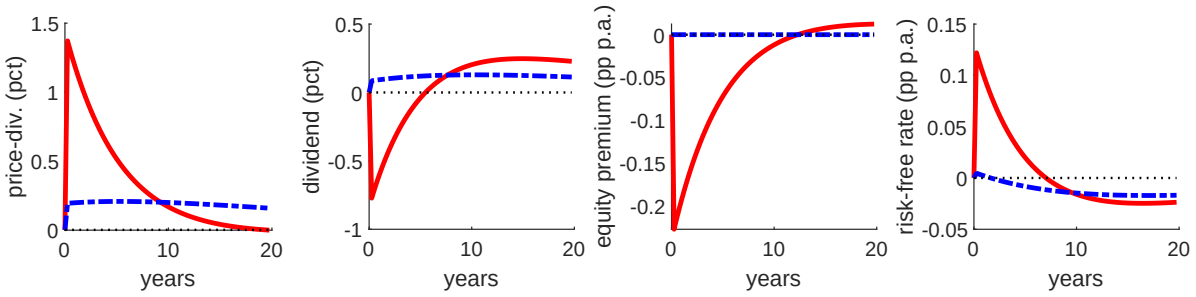


Figure 2: Impulse responses of financial variables to a +1 s.d. productivity shock. Red (solid): with competition neglect. Blue (dashed): frictionless model. Deviations from balanced-growth path.

from the perspective of an econometrician that regresses realized returns and discount rates on the current observed states.

Figure 2 displays the impulse responses for several financial variables to the same productivity shock displayed in Figure 1—namely, for aggregate stock price-dividend ratios $(V_t - D_t)/D_t$, dividends, the equity premium, and the risk-free rate. Aggregate stock price-dividend ratios exhibit an initial jump that overshoots at first, but the undershoots the frictionless ratio. Associated with this movement in price-dividend ratios is a dip in dividends on impact caused by the initial investment surge, which then recover as overinvestment turns into underinvestment, an increase in the risk-free rate on impact, as incentives to shift resources to the future decrease in favor of current investment, and, importantly, a negative equity premium.

Indeed, the model's core mechanism, overinvestment followed by underinvestment, translates naturally into predictable movements in excess stock returns. In the frictionless model, the increases in investments are such that the expected return on investment equals the risk-free rate, which increases as incentives to save decrease as a consequence of the transitorily higher productivity. In contrast, with competition neglect firms fail to internalize the strategic response of other firms. As a consequence, they invest until their individual expected return on investment equals the risk-free rate, but their evaluation of such future returns are distorted. Indeed, the resulting overinvestment pushes the true expected returns below the risk-free rate. Therefore, high valuations predict negative future excess returns on investment.

To understand the mechanism, we can once again turn to the interpretation of our mechanism as an endogenous investment wedge within a prototype RBC

model. In the Appendix we show that linearizing the firm's optimal-investment and valuation conditions around the steady state implies

$$E_t[r_{st+1} - r_{ft}] = \tau_{xt} - \beta E_t[\tau_{xt+1}] \tag{35}$$

Thus, the endogenous movements of the investment wedge are tightly linked to excess return predictability. Intuitively, when the investment wedge subsidizes investment, the resulting overinvestment phase leads to negative future excess returns, and vice versa.

Overall, the model highlights how our behavioral distortion can give rise to cyclical investment behavior—a boom then a bust investment relative to the frictionless economy—and time-varying equity premia—as high valuations are followed by disappointing returns rather than high earnings.

4.4 Return predictability

An implication of our model is the predictability of excess stock returns after a productivity shock. Investment booms are followed by predictably negative stock returns. To gauge quantitatively whether our setup can produce a realistic amount of return predictability, we turn to a standard Campbell-Shiller decomposition of the variance of stock valuations. Namely, using the approximate definition of stock returns,

$$r_{st+1} = -\log(\beta e^{(1-\gamma)\mu}) + \Delta d_{t+1} + \beta e^{(1-\gamma)\mu}(pd_{t+1} - pd) - (pd_t - pd)$$

it follows that variation in log price-dividend ratios, pd, must correspond to either variation in future dividend growth or variation in future returns, or

$$1 = \frac{cov(\sum_{j=1}^{\infty}(\beta e^{(1-\gamma)\mu})^j \Delta \tilde{d}_{t+j}, pd_t)}{var(pd_t)} - \frac{cov(\sum_{j=1}^{\infty}(\beta e^{(1-\gamma)\mu})^j r_{st+j}, pd_t)}{var(pd_t)}$$

Empirical estimates of such decompositions differ, depending on the construction of the equity payouts—see Larrain and Yogo (2008) and Cochrane (2011). Overall, a decomposition that attributes half of the variation in price-dividend ratios to covariance with future dividend growth and half to covariance with future returns seems a reasonable empirical target. In this context, our baseline parameterization attributes 52 percent of the volatility of price-dividend ratios to covariance with future dividends, and 48 percent to covari-

ance with future returns.

Overall, the amount of return predictability produced by the model appears empirically reasonable.

4.5 Exogenous investment shocks

It can be useful to compare the dynamics of our endogenous investment wedge with the response of the economy to an exogenous autoregressive shock to the investment wedge. A model with an exogenous investment wedge shock that follows that typical autoregressive dynamics would not be able to produce an investment wedge that switches sign.

Figure 3 plots the response of the same variables in the frictionless prototype model to a negative exogenous investment shock, $s_{xt} \sim AR(1)$, that scales the investment expenditures of capital-good producers, which becomes $(1 + s_{xt})I_t$. Such exogenous autoregressive movements in the investment wedge associate with persistently positive investment dynamics, as the shocks acts throughout the horizon exclusively like an investment subsidy, thereby missing the underinvestment phase generated by the movements in the endogenous wedge of Figure 1.

Furthermore, no combination of such shocks can ever be observationally equivalent to our model in its implications for stock prices, as they will never be able to generate excess return predictability.

5 Conclusion

This paper contributes to the understanding of how firm expectations interact with aggregate investment outcomes. While much of the literature on bounded rationality focuses on household decision-making, our model highlights the broader implications of firm-level biases on macroeconomic variables. This approach suggests that firms' decision-making processes, particularly their forecasting of market conditions, may be just as important as traditional drivers of aggregate demand, such as preference shocks or news shocks. By explicitly modeling this behavioral friction, our framework connects the macroeconomic literature on firm investment and the behavioral economics literature on bounded rationality.

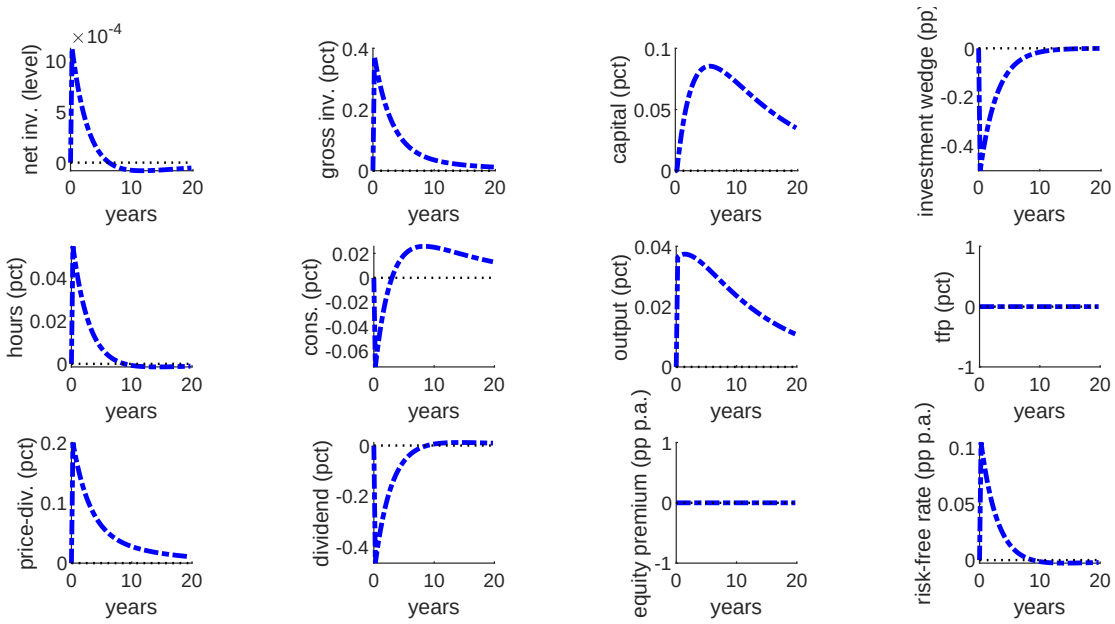


Figure 3: Impulse responses of real variables to an exogenous investment-wedge shock in the frictionless model. Deviations from balanced-growth path.

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