Dividends: Relevance, Rigidity, and Signaling*

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March 15, 2012

Abstract

This paper uses a dynamic stochastic general equilibrium model to explain a puzzle of dividend smoothing and to study several other stylized facts about payout policy. The model is derived from microeconomic principles (i.e. utility maximization) and describes the behavior of the firm as a whole by analyzing the interaction of firm’s investment, financing, and production decisions. The model replicates the simplified behavior of a real profit-seeking firm. Its manager acts in the best interest of current shareholders. In each period, to respond to the changes in the environment (i.e. exogenous shocks), the manager needs to make decisions regarding investment, production, debt level, and share issues/repurchases. I assume that dividends per share are the weighted sum of constant amount of cash and net income per share.

In contrast to the Modigliani-Miller theory, I show that firm value depends on payout policy. The analysis implies that firms with more stable dividend

*I would like to thank Fan Yu and seminar participants at the University of Adelaide for their helpful comments and suggestions.

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policy are more valuable. This explains why dividends are rigid over time. The result is consistent with the opinion of managers that “the market puts a premium on stability” (Lintner 1956). I show that permanent or even temporal increases in the constant part of dividends, keeping the amount of total dividends the same, lead to higher share prices. Firms use share repurchases and special dividends, in addition to constant regular cash dividends, in order to reduce the likelihood of dividend cuts in bad times while keeping the same historical average payout. However, I do not find support for dividend signaling theory; rather, results depend on a firm’s performance measure and the environment in which a firm operates (autocorrelation coefficients of the shocks). This suggests that dividends cannot be used to predict a firm’s future performance and is in contrast to a large body of literature on dividend signaling.

Key words: Payout Policy; Dividends; General Equilibrium Model

JEL classifications: G35; D21; D58
1 Introduction

Approximately 90% of CFOs agree or strongly agree that they smooth dividends from year to year and try to avoid reducing dividends (Brav et al., 2005). Dividend smoothing behavior was also recorded by other surveys (Baker and Powell, 1999; Bernheim, 1991; Lintner, 1956). According to the survey, managers believed that “the market puts a premium on stability or gradual growth in rate” (Lintner, 1956). In addition, empirical studies document dividend smoothing behavior. In approximately 80% of cases, firms do not change their quarterly dividends (see Aharony and Swary, 1980; Loderer and Mauer, 1992; Nissim and Ziv, 2001). The number reduces to 25% for annual dividend per-share changes from 1966 to 2005 for all Compustat firms (Guttman, Kadan, and Kandel, 2010).

There were several attempts to explain the puzzle of rigid dividends. One stream of literature argues that firms use dividends as a costly signal regarding future earnings prospects (Bernheim, 1991; Bhattacharya, 1979; John and Williams, 1985). Thus, firms tend not to decrease dividends as it would be a bad signal. However, these studies fail to explain why firms use dividends but not share repurchases to signal and why firms smooth dividends.

Allen, Bernardo, and Welch (2000) find that some firms prefer to pay dividends rather than repurchase shares due to clientele effect. When institutional investors are relatively less taxed than individual investors, firms paying dividends attract more institutions. Allen, Bernardo, and Welch (2000) argue that their static model is able to explain dividend smoothing; however, they do not show this in a dynamic framework. The model in Kumar (1988) shows that small changes in productivity do not lead to dividend changes. Similarly, Garrett and Priestley (2000) assume managers minimize the costs of adjusting dividends toward the target dividend and
find that for an unexpected increase in permanent earnings, dividends will increase by less than one third of the increase in permanent earnings. Thus, the findings of Garrett and Priestley (2000) and Kumar (1988) are consistent with rigid dividends but these studies cannot explain this phenomenon. Guttman, Kadan, and Kandel (2010) argue that managers use a partially pooling dividend policy according to which the same dividend is paid for a range of different earnings realizations. However, Guttman, Kadan, and Kandel (2010) use the two-period model and do not distinguish between dividends and share repurchases.

This paper provides an alternative explanation for why dividends tend to be constant from year to year. Besides dividend smoothing, I explain several other stylized facts about dividends and payout policy. Specifically, the goal of this paper is: a) to test whether firm value depends on payout policy; b) to explain the puzzle of dividend smoothing; c) to analyze dividend information content.

The main methodological tool employed in the analysis is a dynamic stochastic general equilibrium model. The model is derived from microeconomic principles (i.e. utility maximization) and describes the behavior of the firm as a whole by analyzing the interaction of several firm’s decisions. The model replicates the simplified behavior of a real profit-seeking firm. I consider an infinitely lived firm in discrete time. The model assumes that the firm’s manager acts in the best interest of current shareholders. A manager maximizes a certain objective function that positively depends on equity value subject to the evolution of shareholder value and asset composition of a firm. The model incorporates the main items of balance sheet and income statement. Those items are endogenous variables. The model includes also nine stochastic processes (shocks or exogenous variables), such as technology,

\footnote{Similar models are extensively used in macroeconomics; however, to my best knowledge, there have been no attempts to adopt them in corporate finance.}
interest rate, or corporate income tax rate. In each period, to respond to the changes in the environment (i.e. shocks), the manager needs to make several decisions regarding production volume and price, investment, the amount of raw materials used in production, debt level, and share issues/repurchases. The optimal choices of the manager are expressed by first-order conditions. Thus, the model consists of the evolution of shareholder value, asset composition constraint, first-order conditions, several variable definitions, and exogenous processes. The relationship among all endogenous variables and their dynamics are jointly determined in equilibrium. The solution of the model is a unique stable rational expectations equilibrium. The dynamics of endogenous variables are expressed by the policy functions that are linearized functions that depends on magnitude of shocks and past values of endogenous state variables that are those endogenous variables which appear at the previous period. The model is calibrated assuming that the variables are measured quarterly.

Such a model is superior to traditional methods used in the empirical and theoretical corporate finance research. First of all, the model is constructed in such a way that it reflects the behavior of a real firm which manager maximizes shareholder value and each period makes operating, financial, and investment decisions. The dynamic of endogenous variables reflects the optimal managerial decisions that are consistent with the shareholder wealth maximization. Secondly, the model is dynamic. In contrast, many theoretical models used in corporate finance research are either static or two-period. The dynamic models allow to analyze the behavior of firms during the long time period. More importantly, the dynamic models are

2The model takes into account endogeneity issue. The dynamic of endogenous variables is explained by the exogenous processes and past values of endogenous state variables. From the perspective of instrumental variable approach widely used in corporate finance research, those endogenous variables, which appear in the model at the previous period, can be viewed as instrumental variables.
superior in most cases as the impact of a shock on an endogenous variable could be
different in the short-term and in the long-term. Thirdly, the model does not suffer
from endogeneity problem. Thus, the generated results are reliable. Fourthly, the
manager is assumed to have rational expectations about the future; therefore, the
solution of the model is a rational expectations equilibrium. Finally, the equilib-
rium relationship between any two endogenous variables is determined by structural
parameters that are policy-invariant. The dynamic of the variables depends on the
shock pattern over certain time period. If shocks are different enough during two
time periods, it possible that the correlation coefficient, that reflects the dynamic
relationship, between two endogenous variables, for example, dividends and lever-
age, will be positive in one period and negative in the other period. This could help
explain why the relationship between endogenous variables changes over time.

The model allows us to examine the impact of payout policy on firm value within
the dynamic framework. I assume that dividends per share are the weighted sum
of constant amount of cash and net income per share. This implies that dividends
consist of constant and variable parts. [Lintner (1956)] reports that current earnings
are the most important factor of a firm’s decision to alter existing dividend yield.
Thus, I assume that the variable part of dividends per share is net income per share
multiplied by its weight. One can interpret the latter part of dividends as special
dividends and share repurchase that is followed by the respective stock split (in
order to keep the number of shares outstanding unchanged).

The definition of dividends and the functions defining the manager’s optimal
decisions imply that share price is equal to the discounted sum of constant parts of
dividends and is not impacted by the variable part. Thus, firm value depends on
payout policy. The result is in contrast to the Modigliani-Miller theory [Miller and
Modigliani [1961]] but is consistent with [DeAngelo and DeAngelo [2006]]. This result
helps explain why dividend-paying firms tend to keep their dividends constant. The board of directors chooses dividend policy that maximizes firm value. Since equity value only depends on constant part of dividends, firms tend to smooth dividends (that is to set the weight of constant part of dividends to a value close to one keeping the dividend-to-price ratio constant) in order to maximize share price. The result that dividend-smoothing firms are more valuable is consistent with the survey conducted by Lintner (1956).

Despite share price is equal to the discounted sum of constant parts of dividends, it does not mean that if a firm increases dividends, it’s stock price would increase as well. I show that share price and so value of the firm depend on firm’s net income which is determined by several other factors, such as productivity. Thus, to improve firm value, the manager should maximize firm’s intertemporal earnings rather than increase dividends.

Further, I analyze why firms use special dividends and share repurchase in addition to rigid cash dividends. If a firm chooses not to use special dividends and share repurchases, then, according to the definition of the model, a firm commits to pay a constant stream of cash dividends in both good times and bad times. There could be a hypothetical long period of time with adverse environment and continuous losses. And if a firm continues to pay dividends, it increases its default likelihood. Thus, it is more likely that a firm will cease paying dividends or will at least cut them. I use simulated dataset and show that greater weight of constant amount of cash (or lower weight of variable dividend part) leads to higher default probability. It is more realistically that a firm would cut dividends rather than default. The model implies that dividend cuts result in lower share prices. Thus, firms use alternative payout mechanisms besides constant regular cash dividends to avoid dividend omissions/cuts or to reduce their bankruptcy risk while keeping the same historical average
dividend yield. Thus, firms with more stable dividends are riskier. I show that permanent or even temporal increases in the constant part of dividends, keeping the amount of total dividends the same, lead to higher share prices. Previously, I find that firms with more stable dividend stream are more valuable. Thus, a positive risk-return trade-off exists.

Finally, I analyze dividend information content. I compute asymptotic autocorrelation coefficients between firm performance, proxied by either net income or share price, and dividends up to 12th lead for different values of autocorrelation coefficients of all shocks. I find that in most cases the asymptotic autocorrelation coefficients are negative implying that increase in dividends leads to poorer firm performance. Thus, I do not find support for dividend signaling theory. The results depend on whether share price or net income are used as a firm’s performance measure, as well as the environment in which a firm operates (autocorrelation coefficients of the shocks). This suggests that dividends cannot be used to predict a firm’s future performance and is in contrast to a large body of literature on dividend signaling.

One possible reason why no support for dividend signaling theory is found is the structure of the model. It is assumed that dividends depend on the current but not expected future net income. In the model, the manager does not purposely do any signaling to investors and does not derive any utility from using dividends as a signaling device. Thus, this could be a reason why we do not observe a positive correlation between dividends and future firm performance. The results above means that if we do not assume that managers signal the market using dividends, the relationship between dividends and future firm performance is unlikely to be positive as larger dividends suppress future growth opportunities and so negatively impact future share price and profit.
The rest of the paper is structured as follows. Section 2 develops a dynamic stochastic general equilibrium model. Obtained results are detailed in Section 3. Finally, Section 4 concludes.

2 The model

In this section, I develop a dynamic stochastic general equilibrium model for a firm. The model tries to replicate the life and behavior of a representative firm in a dynamic world with a changing environment. I consider an infinitely lived firm in discrete time. It is assumed that a firm’s manager has rational expectations about the future and acts completely in the best interest of shareholders. In each time period, the firm’s manager has to choose how much to raise capital in the external equity and debt markets, how much to produce, and how much to invest in capital stock (i.e. fixed assets used in production). The decisions are made with respect to the changes in the environment that are defined by several shocks such as productivity or interest rate shocks. The firm’s manager does not know when the future shocks will occur but knows their distribution. Thus, the decisions of the manager are made knowing that the future value of innovations are random but will have zero mean. A firm produces a single tradable final good that is sold in a competitive market.

2.1 A firm

I assume that the firm’s manager acts in the best interest of current shareholders and maximizes a certain objective function that depends positively on shareholder
An intertemporal objective function of the firm’s manager is given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U_t,$$

where $\beta$ is the subjective discount factor. The instantaneous objective function, $U_t$, is

$$U_t = \exp \left( \zeta_t \frac{\left( P^b_t N_t \right)^{1-\sigma}}{1-\sigma} \right),$$

where $P^b_t$ is book value of equity per share at time $t$ and $N_t$ is the number of shares outstanding. It is assumed that the book value of equity per share is a proxy for fair share price. $\sigma$ is the coefficient of constant relative risk aversion (the inverse of elasticity of substitution). $\zeta_t$ is the preference shock and is assumed to follow an independent first-order autoregressive (AR(1)) process:

$$\zeta_t = \rho \zeta_{t-1} + \eta_t,$$

where $\eta_t \sim \mathcal{N}(0, \sigma^2)$.  

The firm’s manager maximizes the objective function subject to the evolution of book value of equity and asset composition of the firm:

$$P_t^b N_t = P_{t-1}^b N_{t-1} + P_{t-1}^m N_t - P_{t-1}^m N_{t-1} - \Phi_N \frac{(N_t - N_{t-1})^2}{N_{t-1}} - d_t N_{t-1} + \pi_t$$

$$- \Phi_D \frac{(D_t - D_{t-1})^2}{D_{t-1}} - \Phi_K \frac{(K_t - K_{t-1})^2}{K_{t-1}},$$

$$K_t = \bar{\kappa} \exp(\kappa_t)(D_t + P_t^b N_t).$$

The left hand side of Equation (4) is the book value of equity. $P_t^m$ is the market value of equity per share. Therefore, $(P_{t-1}^m N_t - P_{t-1}^m N_{t-1})$ is the proceeds from issuance.
of common stock. The relationship between market value and book value of equity is given by:

\[ P_t^m = P_t^b \bar{q} \exp(q_t). \] (6)

where \( \bar{q} \) is market-to-book value in steady state and \( q_t \) is shock to market-to-book value and follows the AR(1) process:

\[ q_t = \rho q_{t-1} + \eta^q_t, \quad \text{where } \eta^q_t \sim \mathcal{N}(0, \sigma^2_q). \] (7)

Positive \( q_t \) means that stock is overvalued, and vice versa. Dividends at time \( t \), \( d_t \), are paid to those who owned shares at time \((t - 1)\). Thus, investors who purchase shares at time \( t \) are not entitled to receive dividends in this period. \( \pi_t \) represents net income. \( D_{t-1} \) is debt a firm pays back in period \( t \); thus, \( D_t \) is new borrowing. For simplicity, it is assumed that debt consists of one-period securities. \( K_t \) is capital stock at time \( t \). The quadratic number of shares outstanding, debt, and capital adjustment costs, \( \Phi_N \frac{(N_t - N_{t-1})^2}{N_{t-1}}, \Phi_D \frac{(D_t - D_{t-1})^2}{D_{t-1}}, \) and \( \Phi_K \frac{(K_t - K_{t-1})^2}{K_{t-1}} \), are assumed in order to reduce volatility of the number of shares outstanding, \( N_t \), debt, \( D_t \), and capital stock, \( K_t \). \( \Phi_N \geq 0, \Phi_D \geq 0, \) and \( \Phi_K \geq 0 \) are the number of shares outstanding, debt, and capital adjustment cost parameters. Due to quadratic debt adjustment costs, short-term debt becomes equivalent to long-term debt with variable interest rates.

Equation (5) implies that a firm can invest only the \( \bar{\kappa} \exp(\kappa_t) \) fraction of its

\[ \frac{(P_{t-1}^m N_t - P_{t-1}^m N_{t-1})}{P_{t-1}^m N_{t-1}} \]

is equal to the funds spent to repurchase shares and will not be counted as a part of a firm’s payout. This term controls for market timing activities. For example, if the share price falls below its fair value, a firm might decide to repurchase some shares as it would be in line with the interests of shareholders. This should not affect the inferences of this paper.

Throughout this paper, variables with bars denote steady-state values and the term “steady state” refers to the deterministic steady state.
financial assets into capital stock. $\bar{\kappa}$ is a constant, and $\kappa_t$ is the AR(1) process:

$$\kappa_t = \rho \kappa_{t-1} + \eta_t^\kappa, \text{ where } \eta_t^\kappa \sim \mathcal{N}(0, \sigma^2_{\kappa}).$$ (8)

If the shock is positive ($\kappa_t > 0$), a firm invests a larger portion of its financial resources into capital stock, and vice versa.

The capital accumulation evolves subject to quadratic capital adjustment costs:

$$K_t = (1 - \delta)K_{t-1} + I_t,$$ (9)

where $\delta$ is the capital depreciation rate. $I_t$ stands for investment. Equation (9) implies that it is costly for a firm to increase or decrease its capital stock. Capital adjustment costs are included in the process of capital accumulation as it is likely that any change in capital stock will cause certain costs that cannot be amortized (for example, management time).

Firm’s net income is given by:

$$\pi_t = [S_t - \exp(c_t)C_t - \delta K_t - D_{t-1}r_{t-1}] \times [1 - \bar{\tau} \exp(\tau_t)],$$ (10)

where $S_t$ is sales revenue. $C_t$ is an amount of production input (for example, labor and raw materials). It is assumed that the unit cost of $C_t$ is one. $c_t$ is the shock to the input price:

$$c_t = \rho_c c_{t-1} + \eta_t^c, \text{ where } \eta_t^c \sim \mathcal{N}(0, \sigma^2_c).$$ (11)

$\bar{\tau}$ is corporate income tax in steady state. $\tau_t$ is shock to corporate income tax.
that follows the AR(1) process:

$$\tau_t = \rho \tau_{t-1} + \eta^\tau_t, \text{ where } \eta^\tau_t \sim \mathcal{N}(0, \sigma^2_{\tau}). \quad (12)$$

$r_t$ is the interest rate for a debt obtained in time $t$, $D_t$. The interest rate at which a firm can borrow funds evolves according to the following equation:

$$r_t = \bar{r}^* \exp(r^*_t) \left( 1 + \Phi, \frac{D_t}{D_t + P_t N_t} \right), \quad (13)$$

where $\bar{r}^*$ is the hypothetical interest rate on corporate bonds for firms with zero leverage in the steady state. $r^*_t$ is shock to the interest rate on long-term corporate bonds and follows the AR(1) process:

$$r^*_t = \rho r^*_{t-1} + \eta^*_{r^*_t}, \text{ where } \eta^*_{r^*_t} \sim \mathcal{N}(0, \sigma^2_{r^*}). \quad (14)$$

The last term in Equation (13) is the risk premium related to a firm’s financial leverage. $\Phi_r > 0$ is the parameter of risk premium. The definition of interest rate implies that it is an increasing function of a firm’s financial leverage.

Sales revenue, $S_t$, is the product of output volume, $Y_t$, and the price per output unit, $p_t$:

$$S_t = Y_t p_t. \quad (15)$$

The price per output unit depends on demand for a firm’s products and is given by the following equation:

$$p_t = \exp(\gamma_t)\bar{p} \left( \frac{\bar{Y}}{\bar{Y}_t} \right)^\eta, \quad (16)$$

where $\bar{Y}$ and $\bar{p}$ are respectively the demand for a firm’s products and market price
in the steady state. $\gamma_t$ is the demand shock that affects product price:

$$\gamma_t = \rho_\gamma \gamma_{t-1} + \eta_\gamma t, \text{ where } \eta_\gamma t \sim \mathcal{N}(0, \sigma_\gamma^2).$$

(17)

Parameter $\eta$ is price elasticity of demand.

To produce a single tradable good, a firm uses the following Cobb-Douglas technology:

$$Y_t = \bar{A} \exp(A_t) K_t^\alpha C_t^{1-\alpha},$$

(18)

where $\bar{A}$ is the total factor of productivity. $A_t$ is the productivity shock that follows the AR(1) process:

$$A_t = \rho_a A_{t-1} + \eta_a t, \text{ where } \eta_a t \sim \mathcal{N}(0, \sigma_a^2).$$

(19)

$\alpha$ is capital share. Equation (18) implies that production output is the increasing function of capital stock and other production inputs.

To analyze the rigidity of dividends, I assume that dividends, $d_t$, consist of constant and variable parts. The constant part is equal to the steady state dividends, $\bar{d}$, multiplied by $\bar{\psi} \exp(\psi_t)$. It is equivalent to a certain amount of cash per share distributed to shareholders at the end of each period. [Lintner (1956)] argues that current earnings are the most important determinant of a firm’s decision to change existing dividend yield. Thus, I assume that the variable part of dividends per share is net income per share multiplied by its weight, $[1 - \bar{\psi} \exp(\psi_t)]$:

$$d_t = \bar{\psi} \exp(\psi_t) \bar{d} \left[1 - \bar{\psi} \exp(\psi_t)\right] \frac{\pi_t}{N_{t-1}},$$

(20)
where $\bar{\psi}$ is the weighting parameter and $\exp(\psi_t)$ is its shock:

$$\psi_t = \rho_{\psi} \psi_{t-1} + \eta_{t}^{\psi}, \text{ where } \eta_{t}^{\psi} \sim N(0, \sigma_{\psi}^2).$$

(21)

One can interpret the constant part of dividends as normal cash dividends. The variable part of dividends consists of special dividends and share repurchase that is followed by the respective stock split (in order to keep the number of shares outstanding unchanged). The definition of dividends implies that dividends per share are the weighted sum of constant amount of cash and net income per share. It is assumed that the magnitude of weighting parameter is chosen by the board of directors and the manager does not participate in choosing the value of $\bar{\psi}$ but takes it as given.

In each period, the manager chooses strategy $\{C_t, K_t, N_t, D_t\}_{t=0}^{\infty}$ to maximize her expected lifetime utility subject to constraints (Equations (4) and (5)) and initial values of debt, capital stock, share price, and the number of shares outstanding.

Maximization of objective function (Equation 1) subject to the evolution of shareholder value and asset composition of a firm (Equations (4) and (5)) yields the following first-order conditions:
\[ \frac{\partial}{\partial \partial C_t} : \exp(\zeta_t)C_t = (1 - \alpha)(1 - \eta)S_t, \tag{22} \]

\[ \frac{\partial}{\partial \partial K_t} : \exp(\zeta_t) \left[ \frac{K_t}{K \exp(K_t)} - D_t \right]^{-\sigma} + \lambda_t \left[ -\frac{1}{K \exp(K_t)} - 2\Phi_K \left( \frac{K_t}{K_{t-1}} - 1 \right) \right] \]

\[ + \beta \mathbb{E}_t \left\{ \lambda_{t+1} \left[ \frac{1}{K \exp(K_t)} + \bar{q} \exp(q_t) \left( \frac{N_{t+1}}{N_t} - 1 \right) + \Phi_K \left( \frac{K_{t+1}}{K_t} \right)^2 \right] - \Phi_K + \bar{\psi} \exp(\psi_{t+1}) (1 - \bar{\tau} \exp(\tau_{t+1})) \right\} \right\} = 0, \tag{23} \]

\[ \frac{\partial}{\partial \partial N_t} : \lambda_t \left[ \bar{q} \exp(q_{t-1}) \left( \frac{K_{t-1}}{K \exp(K_{t-1})} - D_{t-1} \right) - 2\Phi_N \left( \frac{N_t}{N_{t-1}} - 1 \right) \right] \]

\[ = \beta \mathbb{E}_t \left\{ \lambda_{t+1} \left[ \bar{q} \exp(q_t) \left( \frac{N_{t+1}}{N_t} \right)^2 \left( \frac{K_t}{K \exp(K_t)} - D_t \right) - \Phi_N \left( \frac{N_{t+1}}{N_t} \right)^2 + \Phi_N + \bar{\psi} \exp(\psi_{t+1}) \bar{d} \right] \right\}, \tag{24} \]

\[ \frac{\partial}{\partial \partial D_t} : -\exp(\zeta_t) \left[ \frac{K_t}{K \exp(K_t)} - D_t \right]^{-\sigma} + \lambda_t \left[ 1 - 2\Phi_D \left( \frac{D_t}{D_{t-1}} - 1 \right) \right] \]

\[ = \beta \mathbb{E}_t \left\{ \lambda_{t+1} \left[ 1 + \bar{q} \exp(q_t) \left( \frac{N_{t+1}}{N_t} - 1 \right) - \Phi_D \left( \frac{D_{t+1}}{D_t} \right)^2 - 1 \right] \right\} \]

\[ + \bar{\psi} \exp(\psi_{t+1}) \left( 1 - \bar{\tau} \exp(\tau_{t+1}) \right) \bar{r}^* \exp(r_t^*) \left[ 1 + 2\Phi_r \exp(K_t) \left( \frac{D_t}{K_t} \right) \right] \right\}, \tag{25} \]

where \( \lambda_t \) is a Lagrange multiplier. Equation (22) defines the optimal level of production input, \( C_t \), and Equations (23)-(25) are Euler conditions.

The equilibrium of the model is defined by the evolution of shareholder value, asset composition constraint, first-order conditions, several variable definitions (in
total 14 equations) and nine shocks. The number of endogenous variables is equal to the number of equations; thus, the model can be solved. First of all, I analyze the properties of the model assuming a non-stochastic environment. It would help to understand long-term equilibrium relationships among the model’s variables. To do so, I solve for the non-stochastic steady state of the model by using the following procedure: all shocks are set to zero, the time subscripts are dropped, and the steady-state values of each endogenous variable are expressed in terms of parameters.

When all shocks are set to zero and the time subscripts are dropped, the model reduces to 12 equations: Equation (16) cancels out and the steady-state expressions of Equations (4) and (20) are identical. To express the steady-state values of each endogenous variable in terms of parameters and constants, the number of endogenous variables must be equal to the number of equations. Thus, I assume that steady-state values of the number of shares outstanding, $\bar{N}$, and dividends, $\bar{d}$, are known.

### 2.2 Calibration

The model is calibrated assuming that the variables are measured quarterly. The calibration of the model is summarized in Panel A of Table I. I assume that steady-state values for the number of shares outstanding, $\bar{N}$, and dividends, $\bar{d}$, are equal to one. The steady-state market-to-book value, $\bar{q}$, is 1.1.

Quarterly discount factor, $\beta$, is set to 0.97. It corresponds to a 12% annual discount rate or the approximate long-term average return on equity. The coefficient of manager’s risk aversion, $\sigma$, is three. I assume that $\bar{\psi}$ is 0.75. It implies that the weight of constant dividend is 0.75. Following macroeconomic literature, quarterly

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5Specifically, the equilibrium of the model is defined by Equations (4)-(6), (9), (10), (13), (15), (16), (18), (20), (22)-(25) and nine exogenous processes: Equations (3), (7), (8), (11), (12), (14), (17), (19), and (21).
Table 1: Calibration of the parameters

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Panel A</th>
<th>Coefficient</th>
<th>Panel B</th>
<th>Coefficient</th>
<th>Panel C</th>
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<td>Value</td>
<td>Value</td>
<td>Value</td>
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<td>( \bar{N} )</td>
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<td>( \rho_\zeta )</td>
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<td>( \sigma_\zeta )</td>
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<tr>
<td>( \bar{d} )</td>
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<td>( \rho_\eta )</td>
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<td>( \sigma_\eta )</td>
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<td>( \rho_\kappa )</td>
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<td>( \sigma_\kappa )</td>
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Capital depreciation rate, \( \delta \), is set to 0.025. The total factor of productivity, \( \bar{A} \), is one. Capital share in the production function, \( \alpha \), is equal to 0.3. Further, I assume that a firm can invest only 20% of its financial resources in the productive capital \( (\bar{\kappa} = 0.2) \).

The steady-state quarterly interest rate on corporate bonds, \( \bar{r^*} \), is set to 0.02. It implies that the hypothetical annual interest rate for firms without debt is 8%. Thus, debt financing is cheaper than equity financing. The corporate income tax rate, \( \bar{\tau} \), is 0.3. I assume that price elasticity of demand, \( \eta \), is 0.2. It implies that if the production supply increases by 10%, the sale price decreases by 2%, and vice versa. The parameter of risk premium, \( \Phi_r \), is set to four. It implies that if a firm’s leverage increases by one percentage point, the interest rate will increase by 8 basis points.
points if \( \bar{r}^* \) is 0.02. To introduce some persistence in the artificially generated time series, I calibrate debt and capital adjustment cost parameters, \( \Phi_D \) and \( \Phi_K \), to two and four, respectively. In unreported simulations, I found that the number of shares outstanding tend to be quite volatile in contrast to empirical data. Thus, \( \Phi_N \) is set to 8.

The calibrated parameter values imply quite reasonable firm characteristics in the steady state. Book (market) leverage is 0.20 (0.11). Dividend yield is 0.04. Net margin (net income, \( \bar{\pi} \), over sales, \( \bar{S} \)) is equal to 0.25. The steady-state value of tangibility (fixed assets, \( \bar{K} \), over assets, \( (\bar{D} + \bar{P}^bN) \)) is 0.2\(^6\)

3 Results

In this section, I analyze several stylized facts about dividends and payout policy. First of all, I study the relevance of payout policy, in particular the constant part of dividends, and whether firm value is impacted by dividends. Secondly, I analyze why firms use share repurchases and special dividends besides constant cash dividends. Finally, I analyze the dividend information content.

3.1 Why are dividends rigid?

I re-arrange steady-state expressions of Equations (5) and (24) and get that book and market values of equity per share in the steady state are as follows\(^7\)

\(^6\)Table 5 in Appendix A presents the steady-state values of all variables.
\(^7\)See Appendix B for more details.
\[ \bar{P}^b = \frac{\beta \bar{\psi} \bar{d}}{q(1 - \beta)}, \quad (26) \]
\[ \bar{P}^m = \frac{\beta \bar{\psi} \bar{d}}{1 - \beta}, \quad (27) \]

\( \beta \) is the subjective discount factor; thus, \((1 - \beta)\) is a discount rate. Equations (26) and (27) imply that steady-state share price is the sum of discounted constant parts of dividends. There is a coefficient \( \beta \) in the numerator because it is assumed that new shareholders start receiving dividends only in the next period. If this assumption is relaxed then market value of equity per share, \( \tilde{P}^m \), is as follows:

\[ \tilde{P}^m = \frac{\beta \bar{\psi} \bar{d}}{1 - \beta} + \bar{\psi} \bar{d} = \frac{\bar{\psi} \bar{d}}{1 - \beta}. \quad (28) \]

Equation (28) implies that share price is equal to the sum of discounted future dividends. Equation (28) is similar to zero growth dividend discount model except that the latter considers whole dividends: constant and variable parts.

Firms with a more stable dividend policy (with greater \( \bar{\psi} \)) have higher share price:

\[ \frac{\partial \bar{P}^b}{\partial \bar{\psi}} = 1 > 0, \quad (29) \]
\[ \frac{\partial \bar{P}^m}{\partial \bar{\psi}} = 1 > 0. \quad (30) \]

A firm that pays constant dividends each period is less risky for investors than a comparable firm which pays volatile dividends when the expected or average dividend is the same. Thus, such stocks are preferred by investors. The result is consistent with the survey conducted by (Lintner 1956).
Equations (26) and (27) do not mean that if a firm increases dividends, its share price will also increase. Firm’s net income in the steady state is $\bar{\pi} = \bar{N}\bar{d}$. Thus, $\bar{d} = \frac{\bar{\pi}}{\bar{N}}$ and the equations can be rewritten as:

$$P^b = \frac{\beta \bar{\psi} \frac{\bar{\pi}}{\bar{N}}}{\bar{q}(1 - \beta)}, \quad (31)$$

$$P^m = \frac{\beta \bar{\psi} \frac{\bar{\pi}}{\bar{N}}}{1 - \beta}. \quad (32)$$

Equations (31) and (32) show that share price and so value of the firm depend on firm’s net income which is determined by several other factors, such as productivity. Thus, if managers would like to improve firm value, they should focus on profit maximization rather than just increase dividends.8

Equations (26) and (27) have several important implications. First of all, they show that dividends are not irrelevant as argued by Miller and Modigliani (1961). Thus, dividends matter.9 Second, firm value depends on their stability of expected dividends or how dividends are paid. This outcome is able to explain why dividend-paying firms tend to keep their dividends constant. The board of directors chooses dividend policy that maximizes firm value. In most cases, it implies that the value of the coefficient of dividend rigidity, $\bar{\psi}$, will be high. Third, firm value is not impacted by the variable part of dividends. Combining the evolution of book value of equity (Equation (4) and the definition of dividends (Equation (20)) results in the following

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8The impact of dividends on share price is discussed in Section 3.3.

9The result is different from the one in Miller and Modigliani (1961) possibly due to different assumptions regarding the dividends. Miller and Modigliani (1961) assume 100% free cash flow payout in every period whereas in this paper, dividends consist of constant part and variable part.
representation of the evolution of book value of equity:

\[
P^b_t N_t = P^b_{t-1} N_{t-1} + P^{m}_{t-1} N_t - P^{m}_{t-1} N_{t-1} - \Phi_N \frac{(N_t - N_{t-1})^2}{N_{t-1}} - \bar{\psi} \exp(\psi_t) dN_{t-1} + \\
\bar{\psi} \exp(\psi_t) \pi_t - \Phi_D \frac{(D_t - D_{t-1})^2}{D_{t-1}} - \Phi_K \frac{(K_t - K_{t-1})^2}{K_{t-1}}.
\]

(33)

According to Equation (33), if an investor purchases one share at time \( t \) (for \( P^m_t \)), the value of investment will be \( (\bar{\psi} \exp(\psi_t) \bar{d} + P^m_{t+1}) \) in the next period. Assuming that \( \beta \) is the effective discount factor, the present value of the investment’s expected future value is \( \beta(\bar{\psi} \bar{d} + P^m_{t+1}) \)\(^{10}\). Further, the value of \( P^m_{t+1} \) in the next period \((t + 2)\) will be \( (\bar{\psi} \exp(\psi_t) \bar{d} + P^m_{t+2}) \); thus, the present value of the investment’s expected future value is \( \beta \bar{\psi} \bar{d} + \beta^2(\bar{\psi} \bar{d} + P^m_{t+2}) \). If we continue this process, we will get that the present value of the investment’s expected future value is equal to \( \sum_{t=1}^{\infty} \beta^t \bar{\psi} \bar{d} \) or \( \frac{\bar{\psi} \bar{d}}{1 - \beta} \). This would suggest that the variable part of dividends could be considered as a waste; however, it increases payout-to-price ratio. The fourth implication is that firm value depends on the time preference \( (\beta) \) of the firm’s manager. However, it is not impacted by the risk aversion of the firm’s manager. Next, I explain why not all firms choose \( \bar{\psi} \) to be equal to one.

3.2 Why is the constant dividend weight not equal to one for all firms?

If \( \bar{\psi} \) is equal to one then the equity value of a firm is maximized while keeping the same historical average dividend yield. If a firm chooses such payout, a firm commits to pay a constant stream of dividends in both good times and bad times. It is natural that the shares of such firm are more valuable than shares of a firm

\(^{10}\)The expected value of \( \exp(\psi_t) \) is one as the expected value of \( \psi_t \) is zero.
with variable dividends. Especially, when in bad times dividends as well as any other financial resources are more valuable than the ones in good times. Is there any risk and return trade-off? Yes, there is. If a firm commits to pay out future cash flows to the owners of a firm, disregarding the economic and business environments, there could be a hypothetical long period of time with adverse environment and continuous losses. And if a firm continues to pay dividends, it increases its default likelihood. Thus, it is more likely that a firm will cease paying dividends or will at least cut them. According to Equations (26) and (27), the outcome of dividend cuts is a lower share price. Thus, such firms are riskier, as I will show numerically.

Perturbation techniques based on a generalized Schur decomposition are used to solve the first order approximated solution of the model. It is a unique stable rational expectations equilibrium. The dynamic of endogenous variables is explained by the exogenous processes and past values of endogenous state variables that are those endogenous variables which appear at the previous period. The first order approximation of any variable $x_t$ has the following form:

$$x_t = \bar{x} + A(y_{t-1} - \bar{y}) + Bu_t, \text{ where}$$

(34)

$y_{t-1}$ is the vector of endogenous state variables, $u_t$ is a vector of shocks, $A$ and $B$ are matrices.

I assume that the AR(1) coefficients for all shocks are equal to 0.5 (see Panel B in Table 1). It implies that the magnitude of shocks diminishes over time and two years (eight quarters) later it is less than 1% of its initial magnitude. Thus, the shock has almost no impact after two years. This assumption reflects the competitive and dynamic environment in which a firm operates. Further, the standard deviations

11See Appendix C for more details about the solution of the model.
of the shocks on variables with small steady-state values such as interest rate, \( r^* \), are set to 0.3 (see Panel C in Table 1). For other shocks, the standard deviation is 0.02. In the untabulated results, I find that the endogenous variables, especially share price, are not very sensitive to the shock to market-to-book value, \( \exp(\psi_q) \). Thus, the standard deviation of the shock is set to 0.05.\(^{12}\)

To generate an artificial dataset with heterogeneous firms, I use the following procedure. I simulate 1,000 firms for 2,100 time periods and then drop the first 100 time periods. In each simulation, shocks are random. Thus, these 1,000 time series should be unique. Then I compute in how many cases firms go bankrupt.\(^{13}\) There are at least two methods to compare the results with hypothetical cases when \( \bar{\psi} \) is not equal to 0.75. Firstly, one can run another 1,000 simulations using the same shock patterns for different values of \( \bar{\psi} \); however, if \( \bar{\psi} \) changes, then a firm’s characteristics also change. For example, if \( \bar{\psi} \) increases, a firm’s debt is unaffected but its equity value increases; thus, the firm has lower leverage. Therefore, in this case not identical firms are compared for different values of \( \bar{\psi} \). More importantly, it implies that firms with greater \( \bar{\psi} \) have lower leveraged; thus, they are less risky and it is more difficult to prove that greater \( \bar{\psi} \) increase the likelihood of default. I run 1,000 simulations another four times using the same shock patterns when \( \bar{\psi} \) is either 0.05 or 0.25, or 0.5, or 1.\(^{14}\)

Secondly, I use the previously simulated dataset (when \( \bar{\psi} = 0.75 \)) and compute hypothetical share prices under altered payout schemes. This method also has some flaws. Hypothetical share price is not used in the model. The firm’s manager still uses a simulated share price rather than a hypothetical one to make decisions,

\(^{12}\)The calibration of exogenous variables imply quite reasonable dynamic characteristics of the model (see Table 6 and Table 7 in Appendix A for correlation matrix and variance decomposition, respectively).

\(^{13}\)A firm defaults if its share price or the number of shares outstanding become non-positive.

\(^{14}\)In this case, I cannot assume that \( \bar{\psi} = 0 \) as then share price is zero.
Table 2: Firm defaults

This table presents the number of firm defaults for alternate values of $\bar{\psi}$. The sample includes 1,000 simulated firms for 2,000 time periods. In Panel A, I run another 1,000 simulations using the same shock patterns for different values of $\bar{\psi}$. In Panel B, I use the previously simulated dataset (when $\bar{\psi} = 0.75$) to compute hypothetical share prices and the number of firm defaults under altered payout schemes.

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Panel B

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also interest rate depends on a simulated share price but not on a hypothetical one. Nevertheless, together both methods should provide us convincing results. I compute hypothetical share prices and the number of firm defaults when $\bar{\psi}$ is 0, 0.25, 0.5, and 1.

Table 2 presents the results. As expected, in both cases, the number of default increases with $\bar{\psi}$. Panel A shows the number of defaults for different values of $\bar{\psi}$. Panel B shows the number of defaults for different values of $\bar{\psi}$. 
If $\bar{\psi} = 0.05$ then market (book) leverage is 0.88 (0.93). And if $\bar{\psi} = 1$ then market (book) leverage is 0.06 (0.03). In period 2,000, there are 68 defaults when $\bar{\psi} = 0.05$ and 950 defaults when $\bar{\psi} = 1$. Thus, the default risk due to high leverage is offset by the smaller value of $\bar{\psi}$. In the number of untabulated simulations, I find that the number of default depends on the covariance matrix of shocks. If the standard deviations of shocks increase, the number of defaults rises, and vice versa. However, in all cases the number of defaults increases with $\bar{\psi}$. The results imply that firms might decide to choose $\bar{\psi} < 1$ in order to reduce the default probability while keeping the same historical average payout-to-price ratio. This explain why firms use share repurchase and special dividends rather than only rigid cash dividends to disgorge excess cash to shareholders.

The exogenous variable $\psi_t$ impacts the weights of constant and variable parts of dividends while keeping the magnitude of the steady-state dividend unchanged. If the shock is positive then the weight of a constant part of dividend increases, and vice versa. Figure 1 presents the effects of the shock of one standard deviation on a firm’s share price, $P^\psi_t$. The responses are expressed as the deviations in levels from the steady state. I compute the reaction of share price for different values of shock’s AR(1) coefficient, $\rho_{\psi}$. I find that in general, share price increases with the constant part of dividends. However, we observe the temporal (for approx. 20 periods) negative impact. The impact is long lasting. For example, in case $\rho_{\psi} = 0.0001$, a manager and investors know that the constant part of dividends will effectively be higher only for one period. The impact on share price is long-term but relatively small (see Figure 1a).

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\(^{15}\)I do not show impulse responses when $\rho_{\psi}$ is zero as then the impact on share price is less than $10^{-10}$. Further, the model does not converge if $\rho_{\psi}$ is set to one. However, I compute impulse responses when $\rho_{\psi}$ is equal to the values close to zero and one, 0.0001 and 0.9999, respectively.

\(^{16}\)If $\rho_{\psi} = 0.9999$, the impact on share price becomes positive in 45\(^{th}\) period.

\(^{17}\)For example, the positive impact is observed until 265\(^{th}\) period (see Figure 4 in Appendix A).
Figure 1: The impact of the increase in the constant part of dividends (continued on the next page). This figure plots the effects of the shock of one standard deviation on a firm’s share price, $P_b$. The responses are expressed as the deviations in levels from the steady state.
To provide more detail, I analyze the benchmark case (when $\rho_{\psi} = 0.5$). When a firm’s manager realizes that there is a shock, she needs to make certain decisions that will maximize shareholder value in the long run. This could mean increasing a share price if the shock is favorable or mitigating the impact on the share price of the unfavorable shock. In this case the constant part of dividends temporally increases by one standard deviation (from 0.75 to $0.75 \times \exp(0.3) \approx 1.01$) due to, for example, the decision of the board of directors (see Figure 2a).\(^{18}\) This implies that

---

\(^{18}\)In this case, the weight of constant part of dividends, $\bar{\psi} \exp(\psi_t)$, exceeds one; thus, the weight of variable part of dividends is negative. This does not mean that the impact on the endogenous variables is unusual. Since the first order Taylor approximation is used to linearize the model, the magnitude of impulse responses is proportional to the shock. For example, if the weight increased
Figure 2: The impact of the increase in the constant part of dividends. This figure plots the impact of the shock of one standard deviation. The responses are expressed as the deviations in levels from the steady state.

the manager needs to take into account that the constant amount of cash that will be distributed to the shareholders, disregarding firm performance, increases. Since from 0.75 to 0.8, the impact on the endogenous variables would have the same dynamic but its size would be proportionally smaller.
the shock is temporal (it vanishes in approximately two years), the manager reduces investment (see Figure 2b). This leads to the lower capital stock. As a firm uses Cobb-Douglas technology, it is optimal to reduce the amount of production input, $C_t$ (see Figure 2c). Since both production factors decrease, the production volume also decreases which leads to greater price per output unit. However, the impact of lower production volume offsets higher price and the sales revenues slightly decrease.

Smaller sales revenues negatively impact net income, $\pi_t$ (see Figure 2f) and consequently share price. The manager expects that share price will be increase in the future as Equation (26) implies; thus, a firm repurchases some of its shares (see Figure 2e). This further reduces share price, $P_t^b$. Since both, share price, $P_t^b$, and the number of shares outstanding, $N_t$, decrease and a firm invests a constant part of its financial resources in the productive capital, a firm needs to borrow more funds in the external credit market (see Figure 2d). Due to the greater leverage, the effective interest rate, $r_t$, increases. The firm’s profit is negatively affected by lower sales revenue and higher interest expenses but positively affected by lower production costs and depreciation. The negative impact of lower sales revenues dominate; thus, the firm’s profit slightly decreases (see Figure 2f). The impact of the shock on dividends is positive as the decrease in net income is offset by the decrease in the number of shares outstanding and the greater weight of constant part of dividends. After the 4th quarter, a firm starts issuing new shares. The impact on share price becomes positive in the 21st period due to the proceeds from issuance of common stock and recovered earnings. Further, I analyze dividend information content.

19 The firm’s profit becomes positive in the 24th quarter.
3.3 Dividend information content

Dividend signaling theory argues that managers have better information about the firm’s expected future cash flows. Thus, managers may use dividends as a costly signal to alter market perceptions concerning future earnings prospects. The best known signaling models are the ones developed in Bhattacharya (1979), Miller and Rock (1985), and John and Williams (1985). The general implication of signaling models is that we should observe the positive relation between dividends and future firm performance. The empirical studies provide mixed evidence about whether dividends predict future earnings (see Allen and Michaely (2003) and Kalay and Lemmon (2008) for a detailed literature review).

To analyze the model’s consistency with signaling theory, I compute asymptotic autocorrelation coefficients between firm performance and dividends. Firm performance is proxied by net income, $\pi_t$, or the book value of equity per share, $P_b^t$. Empirical studies using stock returns as firm performance measures generally support dividend signaling theory (Grullon, Michaely, and Swaminathan, 2002; Michaely, Thaler, and Womack, 1995). However, if firm performance is proxied by earnings then no support is found (see, for example, Benartzi, Michaely, and Thaler, 1997; Grullon et al., 2005). For robustness, the analysis is repeated in several environments, that is for different values of AR(1) coefficients of all shocks: 0.0001, 0.25, 0.5, 0.75, and 0.9999. I compute autocorrelation coefficients up to $12^{th}$ lead.

I find that the autocorrelation coefficients between dividends, $d_t$, and share prices, $P_b^t$, are generally negative and are greater than −0.21 (see Table 3). The autocorrelation coefficients between dividends and share price in $11^{th}$ and $12^{th}$ periods are positive, except $\rho = 0.9999$. The results suggest that in general the negative relationship becomes stronger when shocks are more correlated; however, it weakens
Table 3: Autocorrelation table between dividends and lead share prices
This table presents the autocorrelation coefficients between dividends, $d_t$, and share prices, $P^b_t$, for different values of AR(1) coefficients of all shocks. The lead value is given in the parentheses.

<table>
<thead>
<tr>
<th>$P^b$</th>
<th>$d(0)$</th>
<th>$\rho = 0.0001$</th>
<th>$\rho = 0.25$</th>
<th>$\rho = 0.5$</th>
<th>$\rho = 0.75$</th>
<th>$\rho = 0.9999$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P^b(0)$</td>
<td>-0.067</td>
<td>-0.086</td>
<td>-0.109</td>
<td>-0.138</td>
<td>-0.208</td>
<td></td>
</tr>
<tr>
<td>$P^b(1)$</td>
<td>-0.060</td>
<td>-0.076</td>
<td>-0.096</td>
<td>-0.122</td>
<td>-0.200</td>
<td></td>
</tr>
<tr>
<td>$P^b(2)$</td>
<td>-0.053</td>
<td>-0.066</td>
<td>-0.084</td>
<td>-0.107</td>
<td>-0.193</td>
<td></td>
</tr>
<tr>
<td>$P^b(3)$</td>
<td>-0.046</td>
<td>-0.058</td>
<td>-0.073</td>
<td>-0.092</td>
<td>-0.185</td>
<td></td>
</tr>
<tr>
<td>$P^b(4)$</td>
<td>-0.040</td>
<td>-0.049</td>
<td>-0.062</td>
<td>-0.078</td>
<td>-0.178</td>
<td></td>
</tr>
<tr>
<td>$P^b(5)$</td>
<td>-0.033</td>
<td>-0.041</td>
<td>-0.051</td>
<td>-0.064</td>
<td>-0.172</td>
<td></td>
</tr>
<tr>
<td>$P^b(6)$</td>
<td>-0.027</td>
<td>-0.034</td>
<td>-0.041</td>
<td>-0.050</td>
<td>-0.165</td>
<td></td>
</tr>
<tr>
<td>$P^b(7)$</td>
<td>-0.021</td>
<td>-0.026</td>
<td>-0.032</td>
<td>-0.037</td>
<td>-0.158</td>
<td></td>
</tr>
<tr>
<td>$P^b(8)$</td>
<td>-0.015</td>
<td>-0.019</td>
<td>-0.022</td>
<td>-0.024</td>
<td>-0.152</td>
<td></td>
</tr>
<tr>
<td>$P^b(9)$</td>
<td>-0.010</td>
<td>-0.011</td>
<td>-0.013</td>
<td>-0.012</td>
<td>-0.145</td>
<td></td>
</tr>
<tr>
<td>$P^b(10)$</td>
<td>-0.004</td>
<td>-0.005</td>
<td>-0.004</td>
<td>0.000</td>
<td>-0.139</td>
<td></td>
</tr>
<tr>
<td>$P^b(11)$</td>
<td>0.001</td>
<td>0.002</td>
<td>0.004</td>
<td>0.012</td>
<td>-0.133</td>
<td></td>
</tr>
<tr>
<td>$P^b(12)$</td>
<td>0.006</td>
<td>0.009</td>
<td>0.013</td>
<td>0.023</td>
<td>-0.127</td>
<td></td>
</tr>
</tbody>
</table>

as the number of lead increases. Since the model is quarterly; thus, the autocorrelation coefficient for 12th lead shows the strength of relationship between today’s dividends and share price three years later. The results presented in Table 3 are inconsistent with dividend signaling theory.

Next, I compute the autocorrelation coefficients between dividends, $d_t$, and net income, $\pi_t$, for different values of AR(1) coefficients of all shocks. Table 4 reports the results. I find that autocorrelation coefficients are positive for dividends and net income if the lead value is zero and if AR(1) coefficients of shocks are equal to 0.0001 or 0.25, or 0.5, or 0.75. Otherwise, the relationship between dividends and future share price is negative. The magnitude of the autocorrelation coefficients is relatively small. Their absolute values are less than 0.21. The results presented in Table 4 generally suggest that there is a negative relationship between dividends...
Table 4: Autocorrelation table between dividends and lead net income
This table presents the autocorrelation coefficients between dividends, $d_t$, and net income, $\pi_t$, for different values of AR(1) coefficients of all shocks. The lead value is given in the parentheses.

<table>
<thead>
<tr>
<th></th>
<th>$d(0)$</th>
<th>$\rho = 0.0001$</th>
<th>$\rho = 0.25$</th>
<th>$\rho = 0.5$</th>
<th>$\rho = 0.75$</th>
<th>$\rho = 0.9999$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi(0)$</td>
<td>0.209</td>
<td>0.126</td>
<td>0.042</td>
<td>-0.049</td>
<td>-0.214</td>
<td></td>
</tr>
<tr>
<td>$\pi(1)$</td>
<td>-0.075</td>
<td>-0.038</td>
<td>-0.034</td>
<td>-0.064</td>
<td>-0.207</td>
<td></td>
</tr>
<tr>
<td>$\pi(2)$</td>
<td>-0.068</td>
<td>-0.072</td>
<td>-0.066</td>
<td>-0.072</td>
<td>-0.201</td>
<td></td>
</tr>
<tr>
<td>$\pi(3)$</td>
<td>-0.061</td>
<td>-0.074</td>
<td>-0.077</td>
<td>-0.075</td>
<td>-0.194</td>
<td></td>
</tr>
<tr>
<td>$\pi(4)$</td>
<td>-0.054</td>
<td>-0.068</td>
<td>-0.076</td>
<td>-0.073</td>
<td>-0.188</td>
<td></td>
</tr>
<tr>
<td>$\pi(5)$</td>
<td>-0.048</td>
<td>-0.060</td>
<td>-0.071</td>
<td>-0.068</td>
<td>-0.182</td>
<td></td>
</tr>
<tr>
<td>$\pi(6)$</td>
<td>-0.041</td>
<td>-0.052</td>
<td>-0.063</td>
<td>-0.061</td>
<td>-0.176</td>
<td></td>
</tr>
<tr>
<td>$\pi(7)$</td>
<td>-0.035</td>
<td>-0.044</td>
<td>-0.054</td>
<td>-0.053</td>
<td>-0.170</td>
<td></td>
</tr>
<tr>
<td>$\pi(8)$</td>
<td>-0.029</td>
<td>-0.036</td>
<td>-0.045</td>
<td>-0.044</td>
<td>-0.164</td>
<td></td>
</tr>
<tr>
<td>$\pi(9)$</td>
<td>-0.023</td>
<td>-0.029</td>
<td>-0.036</td>
<td>-0.034</td>
<td>-0.158</td>
<td></td>
</tr>
<tr>
<td>$\pi(10)$</td>
<td>-0.017</td>
<td>-0.022</td>
<td>-0.026</td>
<td>-0.023</td>
<td>-0.153</td>
<td></td>
</tr>
<tr>
<td>$\pi(11)$</td>
<td>-0.012</td>
<td>-0.015</td>
<td>-0.017</td>
<td>-0.013</td>
<td>-0.147</td>
<td></td>
</tr>
<tr>
<td>$\pi(12)$</td>
<td>-0.007</td>
<td>-0.008</td>
<td>-0.009</td>
<td>-0.002</td>
<td>-0.142</td>
<td></td>
</tr>
</tbody>
</table>

and future earnings and do not support dividend signaling theory.

Overall, the results reported in Tables 3 and 4 do not support dividend signaling theory. The results depend on a firm’s performance measure (share price vs. net income) and the environment in which a firm operates (how autocorrelated shocks are). This suggests that the empirical evidence of dividend information content is mixed due to different performance measures used in the analysis and different sample periods during which the AR(1) coefficients and standard deviations of shocks could change implying different environments. For example, it is possible that shocks have AR(1) coefficients with values close to one during 1980-1990 period and that shocks are not autocorrelated during 1990-2000 period. If it is a case, then one would find conflicting empirical evidences during different sample time periods: the

\[20\] The variances of shocks might also change over time.
relationship between dividends and future firm performance would be positive sup-
porting dividend signaling theory during one sample period and the relationship
would be negative during the other sample period implying that dividends cannot
be used to predict firm’s future performance.

The intuition of the obtained results is quite simple. Larger dividends suppress
future growth opportunities and so negatively impact future share price and profit.
However, the correlation between contemporary net income and dividends is positive
(if $\rho \leq 0.5$) because the part of net income is distributed as dividends (see Equation
(20)). If $\rho \geq 0.75$ then dividend stream depends less on the current earnings; thus,
we do not observe the positive relationship between net income and dividends.

One possible explanation for why no support for dividend signaling theory is
found is the model. It is assumed that dividends depend on the current but not
expected future net income. In the model, the manager does not purposely do any
signaling to investors and does not derive any utility from using dividends as a
signaling device. Thus, this could be a reason why we do not observe a positive
correlation between net income and dividends. The results above means that if we
do not assume that managers signal the market using dividends, the relationship
between dividends and future firm performance is unlikely to be positive as greater
dividends today lead to lower future growth and lower profits.

To show the impact of exogenous increase in dividends without the increase in
productivity, I modify the definition of dividends, $d_t$:

$$d_t = \bar{\psi} \exp(\psi_t)d \times \exp(\omega_t) + \left[1 - \bar{\psi} \exp(\psi_t)\right] \frac{\pi_t}{N_{t-1}},$$

\hspace{1cm} (35)
where \( \exp(\omega_t) \) is the shock to \( \bar{d} \):

\[
\omega_t = \rho_\omega \omega_{t-1} + \eta^{\omega}_t, \quad \text{where } \eta^{\omega}_t \sim \mathcal{N}(0, \sigma^2_\omega).
\] (36)

\( \sigma_\omega \) is set to 0.1. Figure 3 presents the impact of the dividend shock of one standard deviation on a firm’s share price, \( P^b_t \). The responses are expressed as the deviations in levels from the steady state. For robustness, I consider five different values of shock’s AR(1) coefficient, \( \rho_\omega \) and find that in all cases the impact on share price, \( P^b_t \), is negative. When \( \rho_\omega = 0.9999 \), the shock is almost permanent and the impact on share price, \( P^b_t \), is –12.36 in the 24\(^{\text{th}}\) quarter (see Figure 3e). The steady-state value of book value of share price, \( \bar{P}^b \), is 12.13 (see Table 5 in Appendix A). This implies that if the board of directors increases dividends without increasing productivity (or without respective shock to the total factor of productivity, \( \bar{A} \), a firm will default in six years.

From the perspective of the model of this paper combined with the dividend signaling hypothesis and “the dividend puzzle,”\(^{21}\) one could interpret the change in dividends as the respective change in productivity or other factors that directly affect firm’s profitability. In other words, the model, that is based on shareholder wealth maximization, is consistent with the dividend signaling hypothesis. However, Tables 3 and 4 shows that one can find conflicting empirical results depending on firm performance measure and the environment that is proxied by the different the AR(1) coefficients of shocks.

\(^{21}\)“The dividend puzzle” is the empirical evidence that market reacts positively (negatively) to the announcements of dividend increase (cut) (Black, 1976).
Figure 3: The impact of dividend increase (*continued on the next page*). This figure plots the effects of the shock of one standard deviation on a firm’s share price, $P^t$. The responses are expressed as the deviations in levels from the steady state.
Figure 3: The impact of dividend increase (continued from the previous page). This figure plots the effects of the shock of one standard deviation on a firm’s share price, $P^b_t$. The responses are expressed as the deviations in levels from the steady state.

4 Conclusion

This study reports that dividend policy is not irrelevant as argued in Miller and Modigliani (1961). I show that in the shareholder wealth maximization framework, share price depends on the smoothness of dividends. I assume that dividends per share are the weighted sum of constant amount of cash and net income per share. This paper shows that only the constant part of dividends matters as variable part does not affect share price. Firms tend to keep their dividends constant in order to maximize share price. This helps explain the dividend smoothing behavior of firms. Further, I show that firms might choose to pay not only constant cash regular
dividends in order to reduce the likelihood of dividend omission or cuts that arise from a firm’s commitment to disgorge constant amounts of cash each period. This justifies why firms use special dividends and share repurchases besides cash dividends that are relatively constant. At last, I investigate dividend information content and find conflicting results. Simulations imply that there is, in general, a negative relationship between dividends and firm performance. The results depends on firm performance measure and how autocorrelated shocks are. Thus, the results are inconclusive.

This paper contributes to the existing literature at least in two areas. First of all, this paper provides an alternative explanation for why dividends are rigid over time. I show that firm value is maximized, keeping the same dividend yield, if dividends are constant or at least rigid. The result is consistent with the opinion of managers that “the market puts a premium on stability or gradual growth in rate” (Lintner, 1956).

Further, this paper makes a methodological contribution. The study introduces a new type of model that is extensively used in macroeconomics to the literature of corporate finance. The model tries to replicate the behavior of a real firm. The model is developed using several natural assumptions. It assumes that a firm’s manager maximizes shareholder value and in each period she needs to make several decisions such as how much to produce or how much to borrow in the credit market. A manager makes decisions in order to respond to the shocks that affect a firm’s profitability and performance. In this paper, the dynamic stochastic general equilibrium model explains the puzzle of rigid dividends. I believe that this class of models can be further used in the field of corporate finance to explain a firm’s behavior.
A Additional tables and figure

Table 5: Steady-state values
This table presents the values of the variables in the steady state. The model is calibrated as in Table I.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{C}$</td>
<td>2.41</td>
</tr>
<tr>
<td>$\bar{D}$</td>
<td>2.96</td>
</tr>
<tr>
<td>$\bar{I}$</td>
<td>0.08</td>
</tr>
<tr>
<td>$\bar{K}$</td>
<td>3.02</td>
</tr>
<tr>
<td>$\bar{P}^b$</td>
<td>12.13</td>
</tr>
<tr>
<td>$\bar{P}^m$</td>
<td>24.25</td>
</tr>
<tr>
<td>$\bar{S}$</td>
<td>4.02</td>
</tr>
<tr>
<td>$\bar{Y}$</td>
<td>2.55</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td>1.58</td>
</tr>
<tr>
<td>$\bar{r}$</td>
<td>0.04</td>
</tr>
<tr>
<td>$\bar{\lambda}$</td>
<td>0.15</td>
</tr>
<tr>
<td>$\bar{\pi}$</td>
<td>1.00</td>
</tr>
</tbody>
</table>
This table presents the correlation matrix (theoretical moments).

<table>
<thead>
<tr>
<th>Variable</th>
<th>$P_t^b$</th>
<th>$N_t$</th>
<th>$P_t^m$</th>
<th>$d_t$</th>
<th>$\pi_t$</th>
<th>$D_t$</th>
<th>$K_t$</th>
<th>$I_t$</th>
<th>$S_t$</th>
<th>$C_t$</th>
<th>$r_t$</th>
<th>$Y_t$</th>
<th>$p_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_t^b$</td>
<td>1</td>
<td>0.998</td>
<td>0.996</td>
<td>-0.109</td>
<td>0.985</td>
<td>-0.838</td>
<td>0.999</td>
<td>0.675</td>
<td>0.986</td>
<td>0.982</td>
<td>-0.801</td>
<td>0.990</td>
<td>-0.984</td>
</tr>
<tr>
<td>$N_t$</td>
<td>0.998</td>
<td>1</td>
<td>0.994</td>
<td>-0.140</td>
<td>0.983</td>
<td>-0.820</td>
<td>0.999</td>
<td>0.642</td>
<td>0.985</td>
<td>0.980</td>
<td>-0.798</td>
<td>0.989</td>
<td>-0.985</td>
</tr>
<tr>
<td>$P_t^m$</td>
<td>0.996</td>
<td>0.994</td>
<td>1</td>
<td>-0.109</td>
<td>0.981</td>
<td>-0.838</td>
<td>0.995</td>
<td>0.689</td>
<td>0.982</td>
<td>0.978</td>
<td>-0.798</td>
<td>0.986</td>
<td>-0.980</td>
</tr>
<tr>
<td>$d_t$</td>
<td>-0.109</td>
<td>-0.140</td>
<td>-0.109</td>
<td>1</td>
<td>0.042</td>
<td>0.059</td>
<td>-0.123</td>
<td>0.164</td>
<td>0.025</td>
<td>0.043</td>
<td>0.018</td>
<td>-0.006</td>
<td>0.130</td>
</tr>
<tr>
<td>$\pi_t$</td>
<td>0.985</td>
<td>0.983</td>
<td>0.981</td>
<td>0.042</td>
<td>1</td>
<td>-0.808</td>
<td>0.985</td>
<td>0.660</td>
<td>0.999</td>
<td>0.998</td>
<td>-0.801</td>
<td>0.998</td>
<td>-0.970</td>
</tr>
<tr>
<td>$D_t$</td>
<td>-0.838</td>
<td>-0.820</td>
<td>-0.838</td>
<td>0.059</td>
<td>-0.808</td>
<td>1</td>
<td>-0.825</td>
<td>-0.735</td>
<td>-0.807</td>
<td>-0.804</td>
<td>0.644</td>
<td>0.613</td>
<td>0.805</td>
</tr>
<tr>
<td>$K_t$</td>
<td>0.999</td>
<td>0.999</td>
<td>0.995</td>
<td>-0.123</td>
<td>0.985</td>
<td>-0.825</td>
<td>1</td>
<td>0.660</td>
<td>0.986</td>
<td>0.982</td>
<td>-0.800</td>
<td>0.991</td>
<td>-0.985</td>
</tr>
<tr>
<td>$I_t$</td>
<td>0.675</td>
<td>0.642</td>
<td>0.689</td>
<td>0.164</td>
<td>0.660</td>
<td>-0.735</td>
<td>0.660</td>
<td>1</td>
<td>0.656</td>
<td>0.656</td>
<td>-0.557</td>
<td>0.653</td>
<td>-0.628</td>
</tr>
<tr>
<td>$S_t$</td>
<td>0.986</td>
<td>0.985</td>
<td>0.982</td>
<td>0.025</td>
<td>0.999</td>
<td>-0.807</td>
<td>0.986</td>
<td>0.656</td>
<td>1</td>
<td>0.999</td>
<td>-0.788</td>
<td>0.999</td>
<td>-0.972</td>
</tr>
<tr>
<td>$C_t$</td>
<td>0.982</td>
<td>0.980</td>
<td>0.978</td>
<td>0.043</td>
<td>0.998</td>
<td>-0.804</td>
<td>0.982</td>
<td>0.656</td>
<td>0.999</td>
<td>1</td>
<td>-0.785</td>
<td>0.998</td>
<td>-0.971</td>
</tr>
<tr>
<td>$r_t$</td>
<td>-0.801</td>
<td>-0.798</td>
<td>-0.798</td>
<td>0.018</td>
<td>-0.801</td>
<td>0.644</td>
<td>-0.800</td>
<td>-0.557</td>
<td>-0.788</td>
<td>-0.785</td>
<td>1</td>
<td>-0.792</td>
<td>0.787</td>
</tr>
<tr>
<td>$Y_t$</td>
<td>0.990</td>
<td>0.989</td>
<td>0.986</td>
<td>-0.006</td>
<td>0.998</td>
<td>-0.810</td>
<td>0.991</td>
<td>0.653</td>
<td>0.999</td>
<td>0.998</td>
<td>-0.792</td>
<td>1</td>
<td>-0.982</td>
</tr>
<tr>
<td>$p_t$</td>
<td>-0.984</td>
<td>-0.985</td>
<td>-0.980</td>
<td>0.130</td>
<td>-0.970</td>
<td>0.805</td>
<td>-0.985</td>
<td>-0.628</td>
<td>-0.972</td>
<td>-0.971</td>
<td>0.787</td>
<td>-0.982</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 7: Variance decomposition
This table shows the variance decomposition (in %), that is the independent contribution of each shock to the variance of each endogenous variable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\eta^c_t$</th>
<th>$\eta^q_t$</th>
<th>$\eta^\tau_t$</th>
<th>$\eta^\zeta_t$</th>
<th>$\eta^\kappa_t$</th>
<th>$\eta^\gamma_t$</th>
<th>$\eta^A_t$</th>
<th>$\eta^\psi_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P^b_t$</td>
<td>0.01</td>
<td>5.93</td>
<td>1.60</td>
<td>0.98</td>
<td>15.21</td>
<td>6.96</td>
<td>42.26</td>
<td>27.05</td>
</tr>
<tr>
<td>$N_t$</td>
<td>0.01</td>
<td>6.29</td>
<td>1.60</td>
<td>0.97</td>
<td>15.15</td>
<td>6.94</td>
<td>42.09</td>
<td>26.94</td>
</tr>
<tr>
<td>$P^m_t$</td>
<td>0.01</td>
<td>6.86</td>
<td>1.58</td>
<td>0.97</td>
<td>15.06</td>
<td>6.89</td>
<td>41.84</td>
<td>26.78</td>
</tr>
<tr>
<td>$d_t$</td>
<td>0.00</td>
<td>1.00</td>
<td>1.73</td>
<td>1.03</td>
<td>16.06</td>
<td>7.03</td>
<td>44.61</td>
<td>28.55</td>
</tr>
<tr>
<td>$\pi_t$</td>
<td>0.01</td>
<td>5.87</td>
<td>1.54</td>
<td>0.98</td>
<td>15.24</td>
<td>6.95</td>
<td>42.32</td>
<td>27.09</td>
</tr>
<tr>
<td>$D_t$</td>
<td>0.03</td>
<td>11.67</td>
<td>1.57</td>
<td>0.97</td>
<td>14.61</td>
<td>4.61</td>
<td>40.57</td>
<td>25.97</td>
</tr>
<tr>
<td>$K_t$</td>
<td>0.01</td>
<td>6.01</td>
<td>1.60</td>
<td>0.97</td>
<td>15.18</td>
<td>7.04</td>
<td>42.18</td>
<td>26.99</td>
</tr>
<tr>
<td>$I_t$</td>
<td>0.06</td>
<td>30.58</td>
<td>6.53</td>
<td>0.66</td>
<td>10.33</td>
<td>4.74</td>
<td>28.70</td>
<td>18.37</td>
</tr>
<tr>
<td>$S_t$</td>
<td>0.01</td>
<td>5.83</td>
<td>1.55</td>
<td>0.94</td>
<td>15.27</td>
<td>6.83</td>
<td>42.42</td>
<td>27.15</td>
</tr>
<tr>
<td>$C_t$</td>
<td>0.01</td>
<td>5.77</td>
<td>1.53</td>
<td>0.93</td>
<td>16.05</td>
<td>6.77</td>
<td>42.03</td>
<td>26.90</td>
</tr>
<tr>
<td>$r_t$</td>
<td>0.01</td>
<td>4.07</td>
<td>1.02</td>
<td>0.63</td>
<td>9.74</td>
<td>40.16</td>
<td>27.06</td>
<td>17.32</td>
</tr>
<tr>
<td>$Y_t$</td>
<td>0.01</td>
<td>5.88</td>
<td>1.56</td>
<td>0.95</td>
<td>15.42</td>
<td>6.90</td>
<td>41.87</td>
<td>27.41</td>
</tr>
<tr>
<td>$p_t$</td>
<td>0.01</td>
<td>5.84</td>
<td>1.55</td>
<td>0.95</td>
<td>15.30</td>
<td>6.84</td>
<td>42.30</td>
<td>27.20</td>
</tr>
</tbody>
</table>
Figure 4: The impact of the increase in the constant part of dividends when $\rho_\psi = 0.5$. This figure plots the effects of the shock of one standard deviation on a firm’s share price, $P_t^b$. The responses are expressed as the deviations in levels from the steady state.
B Solving for \( \bar{P}^b \) and \( \bar{P}^m \)

Equation (6) is

\[
P^m_t = P^b_t \bar{q} \exp(q_t),
\]

In the steady state, it can be written as follows:

\[
\bar{P}^m = \bar{P}^b \bar{q}.
\]  

Equation (5) is:

\[
K_t = \bar{\kappa} \exp(\kappa_t)(D_t + P^b_t N_t).
\]

It is expressed in the steady state as follows:

\[
\bar{K} = \bar{\kappa}(\bar{D} + \bar{P}^b \bar{N}).
\]  

Equation (38) implies that the steady-state value of equity, \( \bar{P}^b \bar{N} \), has the following form:

\[
\bar{P}^b \bar{N} = \frac{\bar{K}}{\bar{\kappa}} - \bar{D}.
\]  

Equation (24) is:

\[
\lambda_t \left[ \frac{\bar{q} \exp(q_{t-1})}{N_{t-1}} \left( \frac{K_{t-1}}{\bar{\kappa} \exp(\kappa_{t-1})} - D_{t-1} \right) - 2\Phi_N \left( \frac{N_t}{N_{t-1}} - 1 \right) \right]
\]

\[
= \beta \mathbb{E}_t \left\{ \lambda_{t+1} \left[ \frac{\bar{q} \exp(q_t) N_{t+1}}{(N_t)^2} \left( \frac{K_t}{\bar{\kappa} \exp(\kappa_t)} - D_t \right) - \Phi_N \left( \frac{N_{t+1}}{N_t} \right)^2 + \Phi_N + \bar{\psi} \exp(\psi_{t+1}) d \right] \right\}.
\]
Its steady-state expression is as follows:

\[
\frac{\bar{q}}{N} \left( \frac{\bar{K}}{\bar{\kappa}} - \bar{D} \right) = \beta \left[ \frac{\bar{q}}{N_t} \left( \frac{\bar{K}}{\bar{\kappa}} - \bar{D} \right) + \bar{\psi} \bar{d} \right].
\]  

(40)

Equations (37), (38), and (40) imply the following relation:

\[
\bar{P}_m = \beta \left( \bar{P}_m + \bar{\psi} \bar{d} \right).
\]  

(41)

Now we can solve for \( \bar{P}_m \) and then for \( \bar{P}_b \):

\[
\bar{P}_m = \frac{\beta \bar{\psi} \bar{d}}{1 - \beta},
\]

\[
\bar{P}_b = \frac{\beta \bar{\psi} \bar{d}}{\bar{q}(1 - \beta)}.
\]
C Solution of the model

The equilibrium of the model is defined by the evolution of shareholder value, asset composition, first-order conditions, several variable definitions (in total 14 equations) and nine shocks. The model can be written in the following form:

\[ \mathbb{E}_t[f(x_{t+1}, x_t, x_{t-1}, u_t)] = 0, \text{ where} \]

\[ x_t \text{ is a vector of endogenous variables: } [P^b_t, N_t, P^m_t, d_t, \pi_t, D_t, K_t, I_t, S_t, C_t, r_t, Y_t, p_t, \lambda_t]' . \]

\[ u_t \text{ is a vector of exogenous variables: } [q_t, \kappa_t, e_t, \tau_t, r^*_t, A_t, \zeta_t, \gamma_t, \psi_t]' . \]

\[ u_t \text{ depends on its past values and independent and identically distributed innovations, } \epsilon_t, \text{ with zero mean and variance-covariance matrix } \Sigma_\epsilon : \]

\[ u_t = F(u_{t-1}, \epsilon_t), \]

\[ \mathbb{E}_t(\epsilon_t) = 0, \]

\[ \mathbb{E}_t(\epsilon_t \epsilon'_t) = \Sigma_\epsilon. \]

The solution of the model can be expressed by certain functions called policy functions. They relate the endogenous variables with the contemporary values of exogenous variables and the lagged values of endogenous state variables:

\[ x_t = g(y_{t-1}, u_t), \text{ where} \]

\[ \text{The description of the solution of the model is mainly based on Griffoli (2011).} \]
$y_{t-1}$ is the vector of endogenous state variables.$^{23}$ In the steady state, $\bar{x} = g(\bar{y}, 0)$.

The values of endogenous variables in period $(t + 1)$ can be written as:

$$x_{t+1} = g(y_t, u_{t+1}),$$

$$= g(g(y_{t-1}, u_t), u_{t+1}).$$ (45)

Thus, $x_{t+1}$ is the following function:

$$x_{t+1} = F(y_t, u_t, u_{t+1}), \text{ where}$$ (46)

$$F(y_t, u_t, u_{t+1}) = f(g(g(y_{t-1}, u_t), u_{t+1}), g(y_{t-1}, u_t), y_{t-1}, u_t),$$ (47)

$$\mathbb{E}_t[F(y_{t-1}, u_t, u_{t+1})] = 0.$$ (48)

In the steady state, the model is expressed as follows:

$$f(\bar{y}, \bar{y}, \bar{y}, 0) = 0.$$ (49)

The first order Taylor approximation of the model results in:

$$\mathbb{E}_t[F^{(1)}(y_{t-1}, u_t, u_{t+1})] = \mathbb{E}_t \left\{ f(\bar{y}, \bar{y}, \bar{y}, 0) + f_{y_{t-1}}[g_y(g_y \hat{y} + g_u u) + g_u u'] + f_{y_t} (g_y \hat{y} + g_u u) + f_{y_{t-1}} \hat{y} + f_u u \right\}, \text{ where}$$ (50)

$$\hat{y} = y_{t-1} - \bar{y}, \ u = u_t, \ u' = u_{t+1}, \ f_{y_{t-1}} = \frac{\partial f}{\partial y_{t-1}}, \ f_{y_t} = \frac{\partial f}{\partial y_t}, \ f_{y_{t-1}} = \frac{\partial f}{\partial y_{t-1}}, \ g_y = \frac{\partial g}{\partial y_{t-1}}, \ g_u = \frac{\partial g}{\partial u_t}. $$

The expected value of future shocks is zero. Thus, Equation (50) can be rewritten

$^{23}$A vector of endogenous variables, $x_t$, also includes all endogenous state variables, $y_t$. 
as:

\[
E_t[F^{(1)}(y_{t-1}, u_t, u_{t+1})] = f(\tilde{y}, \tilde{y}, \tilde{y}, 0) + f_{y_{t+1}}[g_y(g_y \dot{y} + g_u u)] + \\
\quad + f_y(g_y \dot{y} + g_u u) + f_{y_{t-1}} \dot{y} + f_u u = \\
= (f_{y_{t+1}} g_y g_y + f_y g_y + f_{y_{t-1}}) \dot{y} + (f_{y_{t+1}} g_y g_u + f_y g_u + f_u) u = 0. \quad (51)
\]

Equation (51) has two unknowns: \(g_y\) and \(g_u\). They can be solved assuming that the contents of each parentheses must be equal to zero and using generalized Schur decomposition. To ensure that the solution is unique and stable, the Blanchard and Kahn condition and the rank condition must be satisfied. The first order approximated solution of the model is:

\[
x_t = \bar{x} + g_y \dot{y} + g_u u. \quad (52)
\]

This is a unique stable rational expectations equilibrium.
References


