

Profits, Redistribution of Income and Dynamic Efficiency

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(Link to most current version.)

Abstract

The issue of dynamic efficiency is central to the analysis of household savings, firm investment, and government debt. However, previous tests for dynamic efficiency do not account for the increase in the profit share of output over the last thirty years. In this paper, I present a model in which an increase in markups increases capital accumulation and pushes the economy toward dynamic inefficiency. In the model, an increase in markups redistributes income from households with a low marginal propensity to save to households with a high marginal propensity to save, thus increasing the aggregate savings rate and depressing the marginal product of capital and the interest rate. Using the model, I derive a measurable test of dynamic efficiency that accounts for imperfect competition and markups. I implement the test using data for the U.S. non-financial corporate sector and I find that the economy fails to satisfy my criteria for dynamic efficiency. At the same time, the existing test of dynamic efficiency, which does not account for markups, falsely concludes that the economy satisfies the criteria for dynamic efficiency by a wide margin.

*I thank Lars Hansen, Stavros Panageas, Amit Seru, Hugo Sonnenschein, Amir Sufi, Willem van Vliet, Tony Zhang, Luigi Zingales, Eric Zwick, and seminar participants at the University of Chicago and MFM summer session for their comments and feedback. Email address: sbarkai@chicagobooth.edu.

1 Introduction

Dynamic efficiency is central to the analysis of household savings, firm investment and government debt. Past studies have concluded that all advanced economies satisfy the criteria for dynamic efficiency by a wide margin. The existing tests of dynamic efficiency that are implemented in these studies assume perfect competition and that there are no profits in the economy. However, recent work has shown that the share of profits in output has increased dramatically over the last 30 years (Barkai (2016)). Once we account for profits, the U.S. non-financial corporate sector fails to satisfy the criteria for dynamic efficiency.

In this paper, I present a model in which an increase in markups increases capital accumulation and pushes the economy toward dynamic inefficiency. Using the model, I derive a measurable test of dynamic efficiency that accounts for imperfect competition and markups. I show that in the presence of markups, existing tests of dynamic efficiency are biased toward finding that an economy is dynamically efficient. I implement the test using data for the U.S. non-financial corporate sector over the period 1984–2014, and I find that the economy fails to satisfy my criteria for dynamic efficiency. At the same time, the existing test of dynamic efficiency, which does not account for markups, falsely concludes that the economy satisfies the criteria for dynamic efficiency by a wide margin.

I present a variation on the classic overlapping-generations model of Diamond (1965), in which I allow for imperfect competition in production. The key feature of the model is that an increase in markups and profits transfers income from agents with a low marginal propensity to save to agents with a high marginal propensity to save. This transfer of income increases the aggregate savings rate and capital accumulation and decreases capital productivity. The increase in the savings rate and the decline in capital productivity can lead to an overaccumulation of capital, which is dynamically inefficient. This simple model matches some additional qualitative features of the data: an increase in markups causes a decline in the shares of labor and capital and a decline in the real interest rate.

In the model, I shut down the usual distortions associated with imperfect competition. Labor is inelastically supplied and does not respond to the decline in the wage rate and the savings rate of each particular agent is fixed and does not respond to the decline in the interest rate. The only mechanism through which markups affect quantities is through the redistribution of income – without the redistribution of income, the interest rate and wages still adjust, but labor, capital, and output remain constant.

In the model, I derive my test dynamic efficiency based on the Golden Rule of Phelps (1961). The economy is dynamically efficient if the return on capital is greater than investment. In a model without profits, the return on capital is equal to gross value added less payments to labor (gross operating surplus). However, the return on capital is strictly less than gross operating surplus in an economy with profits. Following Abel

et al. (1989), I show that my test of dynamic efficiency is robust to any assumptions of household behavior and firm ownership. Additionally, I show that the test is robust to a possibly unobserved capital stock, in which case it is a test for overaccumulation of observed capital.

I implement the test of dynamic efficiency using data for the U.S. non-financial corporate sector over the period 1984–2014. I find that the economy fails to satisfy the criteria for dynamic efficiency. Over the sample period, the investment rate increases and the marginal product of capital declines sharply. Specifically, in the mid-2000s the investment rate overtakes marginal capital productivity; however, after the recession the investment rate drops below marginal capital productivity. These results are robust to a possibly unobserved capital stock, decreasing returns to scale, the tax treatment of capital and debt, and the composition of debt and equity financing. At the same time, the existing test of dynamic efficiency, which does not account for markups, falsely concludes that the economy satisfies the criteria for dynamic efficiency by a wide margin.

The recent work of Geerolf (2013) updates the estimates of Abel et al. (1989), after further accounting for mixed income and land rents. By considering the corporate sector, I avoid all issues related to the treatment of mixed income. I further avoid all issues related to residential housing: by studying the corporate sector I focus on firm production and possible overaccumulation of firm capital, rather than the production of housing services and possible overaccumulation of residential housing.

This paper also relates to a large literature on the decline in interest rates across advanced economies (Caballero et al. (2008), Eggertsson and Mehrotra (2014), Bean et al. (2015), Caballero et al. (2015), Eggertsson et al. (2016), and Hall (2016)). In Eggertsson and Mehrotra (2014), a deleveraging shock creates an oversupply of savings, thus depressing the interest rate. In Hall (2016) a shift in the composition of investors, toward those investors with higher risk aversion and who believe in higher probabilities of bad events, reduces the risk free rate. My model presents a new mechanism: an increase in profits redistributes income from households with a low marginal propensity to save to households with a high marginal propensity to save, thus increasing the aggregate savings rate and depressing the interest rate.

2 Model

In this section I present a variation on the classic overlapping-generations model of Diamond (1965), in which I allow for imperfect competition in production. In the model, an increase in markups redistributes income from households with a low marginal propensity to save to households with a high marginal propensity to save, thus increasing the aggregate savings rate and depressing the marginal product of capital and the interest rate. Using the model, I derive a measurable test of dynamic efficiency that accounts for imperfect competition and markups.

2.1 Model Setup

2.1.1 Final Goods Producer

The corporate sector is made up of a unit measure of firms, each producing a differentiated intermediate good. The final good is produced in perfect competition as a CES aggregate of the intermediate goods

$$Y_t = \left(\int_0^1 y_{i,t}^{\frac{\varepsilon_t-1}{\varepsilon_t}} di \right)^{\frac{\varepsilon_t}{\varepsilon_t-1}} \quad (2.1)$$

where $\varepsilon_t > 1$ is the elasticity of substitution between goods. The profits of the final goods producer are $P_t^Y Y_t - \int_0^1 p_{i,t} y_{i,t} di$, where P_t^Y is the exogenous price level of output and $p_{i,t}$ is the endogenous price of intermediate good i . The solution to the cost minimization problem, together with the zero profit condition of the final goods producer, leads to the following demand function for intermediate good i :

$$D_t(p_{i,t}) = Y_t \left(\frac{p_{i,t}}{P_t^Y} \right)^{-\varepsilon_t} \quad (2.2)$$

2.1.2 Firms

Firm i produces intermediate good $y_{i,t}$ using the constant returns to scale production function

$$y_{i,t} = A k_{i,t}^\alpha l_{i,t}^{1-\alpha} \quad (2.3)$$

where $k_{i,t}$ is the amount of capital used in production and $l_{i,t}$ is the amount of labor used in production. In period $t-1$ the firm exchanges one-period nominal bonds for dollars and purchases capital $k_{i,t}$ at the nominal price P_{t-1}^K . In period t the firm hires labor in a competitive spot market at the nominal wage rate w_t and produces good $y_{i,t}$ which is sold at price $p_{i,t}$ (y). After production the firm pays the face value of its debt and sells the undepreciated capital at the the nominal price P_t^K . The firm's nominal profits are

$$\begin{aligned} \pi_{i,t} &= \max_{k_{i,t}, l_{i,t}} p_{i,t} y_{i,t} - (1+i_t) P_{t-1}^K k_{i,t} - w_t l_{i,t} + (1-\delta_t) P_t^K k_{i,t} \\ &= \max_{k_{i,t}, l_{i,t}} p_{i,t} y_{i,t} - R_t P_{t-1}^K k_{i,t} - w_t l_{i,t} \end{aligned} \quad (2.4)$$

where $R_t = i_t - (1-\delta_t) \frac{P_t^K - P_{t-1}^K}{P_{t-1}^K} + \delta_t$ is the required rate of return on capital.

The profit maximization problem of the firm determines the demand for labor and capital inputs, as well as profits, as a function of the current period nominal interest rate, the current period nominal wage

rate, and aggregate output. The first-order condition for capital is $p_{i,t} \frac{\partial f}{\partial k} = \mu_t R_t P_{t-1}^K$, where $\mu_t = \frac{\varepsilon_t}{\varepsilon_t - 1}$ is the equilibrium markup over marginal cost. Similarly, the first-order condition for labor is $p_{i,t} \frac{\partial f}{\partial l} = \mu_t w_t$. Integrating demand across firms determines the corporate sector demand for labor and capital inputs, as well as profits, as a function of the nominal interest rate, the nominal wage rate, and aggregate output.

2.1.3 Households

The cohort born in period t is of size $N_t = (1+n)^t N_0$. Each household is endowed with a single unit of labor when young. The old cohort in year 0 own the pre-existing capital stock K_0 . Households live for two periods and have preferences over consumption in the two periods given by

$$U(c_t^y, c_{t+1}^o) = \log(c_t^y) + \beta \log(c_{t+1}^o) \quad (2.5)$$

The economy has a single savings vehicle in the form of a nominal bond: investment of 1 dollar in period t pays $1 + i_{t+1}$ dollars in period $t + 1$. In addition to labor income, the young receive the profits of the corporate sector. By abuse of notation, I will denote the per-worker transfer of profits by π_t . We can write the household lifetime budget constraint as

$$P_t^Y c_t^y + \frac{1}{1 + i_{t+1}} P_{t+1}^Y c_{t+1}^o = w_t + \pi_t \quad (2.6)$$

where the left-hand side is lifetime spending and the right-hand side is lifetime income.

The utility maximization problem of the household determines household consumption and savings as a function of the nominal interest rate, the nominal wage rate, and nominal corporate profits. The young consume a fraction $\frac{1}{1+\beta}$ of their income and save a fraction $\frac{\beta}{1+\beta}$ of their income: nominal expenditures on consumption of the period t cohort when young is equal to $P_t^Y c_t^y = \frac{1}{1+\beta} (w_t + \pi_t)$, the nominal savings of the period t cohort when young is equal to $s_t = \frac{\beta}{1+\beta} (w_t + \pi_t)$, and the nominal expenditures on consumption of the period t cohort when old is $P_{t+1}^Y c_{t+1}^o = (1 + i_{t+1}) \frac{\beta}{1+\beta} (w_t + \pi_t)$.

Aggregating across households, aggregate period t nominal expenditures on consumption of the young is equal to a fraction $\frac{1}{1+\beta}$ of the labor and profit income of the young $P_t^Y C_t^y = \frac{1}{1+\beta} (w_t L_t + \Pi_t)$ where L_t is the total quantity of labor used in production and Π_t are the total profits of firms; the period t nominal expenditures on consumption of the old is equal to the gross return on their savings $P_t^Y C_t^o = (1 + i_t) \frac{\beta}{1+\beta} (w_{t-1} + \pi_{t-1})$; aggregate period t nominal savings of the young is equal to $S_t = \frac{\beta}{1+\beta} (w_t L_t + \Pi_t)$.

2.1.4 Capital Creation

I assume that all agents in the model have free access to a constant returns to scale technology that converts output into capital at a ratio of 1 : κ_t . I further assume that this technology is fully reversible.¹ Arbitrage implies that, in period t , κ_t units of capital must have the same market value as 1 unit of output. This pins down the relative price of capital

$$\frac{P_t^K}{P_t^Y} = \kappa_t^{-1} \quad (2.7)$$

Since the old consume all of their savings as well as the interest on their savings, the nominal value of the capital stock that will be available in period $t + 1$ equals the savings of the young in period t

$$P_t^K K_{t+1} = \frac{\beta}{1 + \beta} (w_t L_t + \Pi_t) \quad (2.8)$$

The evolution of the capital stock can also be written in the form of first differences as $P_t^K K_{t+1} - P_{t-1}^K K_t = S_t - P_{t-1}^K K_t$, where the left-hand side is the net change in the nominal value of the capital stock and the right-hand side is net investment, which is equal to the investment of the young less the dis-investment of the old.

2.1.5 Equilibrium

In equilibrium three markets will need to clear: the labor market, the capital market, and the market for consumption goods. The labor market clearing condition equates the household supply of labor with the corporate sector demand for labor. The capital market clearing condition equates the nominal value of household savings $S_t = \frac{\beta}{1 + \beta} (w_t L_t + \Pi_t)$ with the nominal value of the corporate sector demand for capital $P_t^K K_{t+1}$. The aggregate resource constraint of the economy, measured in nominal dollars, can be written as

$$P_t^Y Y_t = P_t^Y C_t^y + P_t^Y C_t^o + P_t^K [K_{t+1} - (1 - \delta) K_t] \quad (2.9)$$

By Walras' law the aggregate resource constraint of the economy will hold if the labor and capital markets clear and the households are on their budget constraint. An equilibrium² is a vector of prices $(i_t^*, w_t^*)_{t \in \mathbb{N}}$ that satisfy the aggregate resource constraint and clear all markets in all periods. Since all firms face the same factor costs and produce using the same technology, in equilibrium³ they use the same capital $k_{i,t} = K_t$

¹Without this assumption, the relative price of capital is pinned down as long as investment is positive. In the data, investment in each asset is positive in each period. Moreover, the data show no substantial movement in the relative price of capital over the sample period.

²Firm optimization requires that firms have beliefs over aggregate output Y_t – equilibrium further requires that firm beliefs hold true.

³With a constant returns to scale production technology and the specified market structure there is no indeterminacy in the firm's maximization problem. In more general cases, indeterminacy may arise, in which case there can exist non-symmetric

and labor $l_{i,t} = L_t$ inputs, produce the same quantity of output $y_t = Y_t$, and sell this output at the same per-unit price $p_{i,t} = P_t^Y$.

2.1.6 Income Distribution

Aggregating across firms, aggregate production takes the form $Y_t = AK_t^\alpha L_t^{1-\alpha}$. The aggregate demand for capital and labor are given by the equations $P_t^Y \alpha \frac{Y_t}{K_t} = \mu R_t P_{t-1}^K$ and $P_t^Y (1-\alpha) \frac{Y_t}{L_t} = \mu w_t$. Rearranging these equations we have the following expressions for the labor, capital, and profit shares of gross value added

$$S^K = \mu^{-1} \alpha \quad (2.10)$$

$$S^L = \mu^{-1} (1 - \alpha) \quad (2.11)$$

$$S^\Pi = 1 - \mu^{-1} \quad (2.12)$$

The young receive the combined share of labor in profit, which is equal to $S^L + S^\Pi = 1 - \mu^{-1} \alpha$, and the old receive the capital share, which is equal to $S^K = \mu^{-1} \alpha$. An increase in markups increases the share of gross value added that the young receive and decreases the share of gross value added that the old receive.

2.2 Dynamics and Steady State

For the remainder of this section, I normalize the path of the price level and the relative price of capital to 1. By abuse of notation, let $k_t = \frac{K_t}{L_t}$ and let $y_t = \frac{Y_t}{L_t}$. The market clearing conditions together with the share equations 2.10–2.12 imply the following equilibrium dynamics of the capital stock

$$k_{t+1} = (1+n)^{-1} \frac{\beta}{1+\beta} (1 - \mu^{-1} \alpha) A k_t^\alpha \quad (2.13)$$

The steady state of the economy is characterized by the equation $k^* = (1+n)^{-1} \frac{\beta}{1+\beta} (1 - \mu^{-1} \alpha) A (k^*)^\alpha$. Solving for the steady state capital-to-labor ratio we have

$$k^* = \left((1+n)^{-1} \frac{\beta}{1+\beta} (1 - \mu^{-1} \alpha) A \right)^{\frac{1}{1-\alpha}} \quad (2.14)$$

Steady state output-to-labor ratio is $y^* = A \left((1+n)^{-1} \frac{\beta}{1+\beta} (1 - \mu^{-1} \alpha) A \right)^{\frac{\alpha}{1-\alpha}}$. Substituting the steady state value of capital-to-labor ratio into the equilibrium capital dynamics we have $k_{t+1} = (k^*)^{1-\alpha} k_t^\alpha$. Capital equilibria. With appropriate regularity conditions, it is possible to select an equilibrium by assuming that for a given level of profits firms will choose to maximize their size.

dynamics can be rewritten as the log linear equation $\log \frac{k_{t+1}}{k^*} = \alpha \log \frac{k_t}{k^*}$. Since $\alpha < 1$ the system is globally stable and converges to steady state at rate α .

2.2.1 Comparative Statics

To study the effect of an increase in markups, it is useful to separately consider the effects of markups on the household supply of capital and on the corporate sector demand for capital. An increase in markups decreases the labor share $\left(\frac{\partial \log S^L}{\partial \log \mu} = -(1 - \alpha)\right)$, decreases the capital share $\left(\frac{\partial \log S^K}{\partial \log \mu} = -\alpha\right)$, and increases the profit share $\left(\frac{\partial \log S^\pi}{\partial \log \mu} = \frac{\mu}{1-\mu}\right)$. In total, an increase in markups increases the steady state share of gross value added that the young receive $\left(\frac{\partial \log(S^L + S^\pi)}{\partial \log \mu} = \frac{\mu^{-1}\alpha}{1-\mu^{-1}\alpha}\right)$. Since the young save a constant fraction of their income, an increase in markups increases the household sector savings rate $\left(\frac{\partial \log \frac{\beta}{1+\beta}(S^L + S^\pi)}{\partial \log \mu} = \frac{\mu^{-1}\alpha}{1-\mu^{-1}\alpha}\right)$. As a result, the steady state capital-to-labor ratio will increase.

The demand for capital is given by the corporate sector first order condition. The demand for capital and its dependence on the degree of monopoly power can best be understood by studying the firm's first order condition for capital $\frac{\partial y}{\partial k} = \mu R$. An increase in markups decreases the corporate sector demand for capital. Combining the effects of supply and demand of capital, we find that an increase in markups increases the steady state capital-to-labor ratio $\left(\frac{\partial \log k^*}{\partial \log \mu} = \frac{1}{1-\alpha} \frac{\mu^{-1}\alpha}{1-\mu^{-1}\alpha}\right)$ and decreases the steady state real interest rate and the required rate of return on capital $\left(\frac{\partial \log R^*}{\partial \log \mu} = -1 - \frac{\mu^{-1}\alpha}{1-\mu^{-1}\alpha}\right)$. Last, the increase in the capital-to-labor ratio decreases the steady state marginal product of capital $\left(\frac{\partial \log \frac{\partial y}{\partial k}}{\partial \log \mu} = -\frac{\mu^{-1}\alpha}{1-\mu^{-1}\alpha}\right)$.

2.3 Dynamic Efficiency

The study of dynamic efficiency is based on the Golden Rule of Phelps (1961). The steady state resource constraint can be written in per capita terms as

$$c^* = y(k^*) - (n + \delta)k^* \quad (2.15)$$

Differentiating both sides with respect to capital gives us the equation

$$\frac{\partial c^*}{\partial k^*} = \mu R^* - (n + \delta) \quad (2.16)$$

If the steady state capital stock exceeds that of the golden rule level, if $\frac{\partial c^*}{\partial k^*} < 0$, then a decrease in the capital stock will increase steady state consumption without the need for any agent to postpone or reduce her consumption. Formally, assume that entering period t we are in a steady state with a capital-labor ratio that exceeds that of the golden rule. Consider a permanent decrease in capital of $dk < 0$ in all future

periods. Consumption per capita in period t increases by $dc_t = -(1+n)dk$ and consumption in all future periods increases by $dc_{t+i} = (\mu R^* - (n+\delta))dk$. Since total per-capita consumption increases in each and every period, there is a division of consumption between the young and old in each period that increases the consumption of all agents in all periods. The converse is also true: if the steady state capital stock is less than that of the golden rule then the economy is Pareto efficient, as shown by Samuelson (1968).

Rearranging equation 2.16, this shows that the economy is dynamically efficient if and only if

$$\mu R^* > n + \delta \quad (2.17)$$

In the case of perfect competition ($\mu = 1$), subtracting δ from both sides recovers the Diamond (1965) criteria for dynamic efficiency $r^* > n$. The comparative static $\frac{\partial \log \frac{\partial y}{\partial k}}{\partial \log \mu} = -\frac{\mu^{-1}\alpha}{1-\mu^{-1}\alpha}$ shows that an increase in markups decreases the steady state value of $\frac{\partial y}{\partial k} = \mu R^*$ and therefore increases the set of parameters for which the steady state of the economy is dynamically inefficient.

Multiplying the efficiency criteria by the capital stock gives us the equivalent flow test of dynamic efficiency. The economy is dynamically efficient if and only if

$$\mu R^* K^* > I^* \quad (2.18)$$

where the left-hand side is the steady state total social benefits provided by the capital stock (paid to the owners of capital and paid to the owners of profits) and the right-hand side is steady state gross investment.

2.4 Robustness

Following Abel et al. (1989), I examine a generalization of the Diamond (1965) economy, which allows for a very general production technology. Assume an aggregate production technology

$$Y_t = F(I_{t-1}, I_{t-2}, \dots, I_{t-n}; L_t, \theta_t) \quad (2.19)$$

where I_t is the gross investment in capital in period t and θ_t is any vector of state variables, which can include the entire history of state variables. Following the original notation, I will denote by F_t^i the partial derivative $\frac{\partial F(I_{t-1}, I_{t-2}, \dots, I_{t-n}; L_t, \theta_t)}{\partial I_{t-i}}$. Let $R_{t,i}$ be the required rate of return in period t on capital of vintage $t-i$. Note that $\sum_{1 \leq i} R_{t,i} I_{t-i}$ are the total capital payments in period t . Depreciation of capital is embedded in the production function as well as in the required rate of return; for example, if capital of vintage $t-i$ has fully depreciated then $\frac{\partial F(I_{t-1}, I_{t-2}, \dots, I_{t-n}; L_t, \theta_t)}{\partial I_{t-i}} = 0$ and $R_{t,i} = 0$.

I assume that in period t firms charge a markup over cost equal to μ_t . I make no assumption on the properties of θ (which can also include an unobserved stock of capital), nor do I assume that F displays constant returns to scale in capital and labor. Furthermore, I do not make any assumptions on household behavior or on the structure of firm ownership.

Proposition 1. *If for some positive ε we have $\mu_t \sum_{1 \leq i} R_{t,i} I_{t-i} < (1 - \varepsilon) I_t$ in all periods and all states of nature then the equilibrium is dynamically inefficient.⁴*

Proof. The proof presented here is a minor variation on the proof that appears in the original paper. Consider a consumption-savings plan that increases the consumption of each period 1 old household by ϵ and leaves the consumption of all other households unchanged. To execute this plan, the young in period 1 would need to transfer ϵN_0 units of consumption to the old; in order to maintain the original level of consumption of the period 1 young households, period 1 investment would need to decline by $-dI_1 = \epsilon N_0$. The dI_1 change in investment would reduce the output in period 2 by $F_2^1 dI_1$. To maintain the original level of consumption in period 2, period 2 investment would need to fall by $dI_2 = F_2^1 dI_1$. More generally, period t investment would need to fall by

$$dI_t = \sum_{i=1}^n F_t^i dI_{t-i} \quad (2.20)$$

This consumption-savings plan is feasible as long as the needed reduction in gross investment is no larger than the original level of gross investment. Let $\Delta_t = \frac{dI_t}{I_t}$. In terms of Δ , the consumption-savings plan is feasible as long as $\Delta_t > -1$ in all periods and in all states of nature. Dividing both sides of equation 2.20 by I_t gives us the following homogeneous linear difference equation in Δ_t

$$\Delta_t = \sum_{i=1}^n \frac{F_t^i I_{t-i}}{I_t} \Delta_{t-i} \quad (2.21)$$

If the coefficients $\left(\frac{F_t^i I_{t-i}}{I_t}\right)_{i=1}^n$ are always positive and always sum to a number strictly less than 1, then (for small enough ϵ) Δ_t always remains greater than -1 , making the Pareto improving consumption-savings plan feasible. All that is left is to show that $\sum_{i=1}^n \frac{F_t^i I_{t-i}}{I_t} < 1$ when $\mu_t \sum_{1 \leq i} R_{t,i} I_{t-i} < I_t$. To see that this is the case, note that $\sum_{i=1}^n F_t^i I_{t-i}$ is the total return on capital, which in turn is equal to $\mu_t \sum_{1 \leq i} R_{t,i} I_{t-i}$. \square

2.5 Discussion

The key input into the test of dynamic efficiency is the marginal product of capital. Standard tests of dynamic efficiency measure the marginal product of capital in one of two ways. The first approach measures

⁴The partial converse of this statement is also true: if for some positive ε we have $\mu_t \sum_{1 \leq i} R_{t,i} I_{t-i} > (1 - \varepsilon) I_t$ in all periods and all states of nature, then the equilibrium is dynamically efficient.

the marginal capital as the sum of the real interest rate and the depreciation rate⁵ $R = r + \delta$. Such an approach understates the marginal product of capital in the presence of markups. Indeed it calculates the marginal product of capital as R instead of μR . This leads to a possible false rejection of efficiency, as would be the case when $\mu R > n + \delta > R$.

A more common approach measures the marginal product of capital as the ratio of gross operating surplus (value added less labor compensation) to capital.⁶ Such an approach will overestimate the marginal product of capital in the presence of markups. This approach correctly attributes to capital the profits that are generated from paying capital below its marginal cost, but it incorrectly attributes to capital those profits that are generated from paying labor below its marginal cost. Profits Π are earned by paying capital and labor below their marginal product: $\Pi = (\mu - 1)(RK + wL)$. Inferring the marginal product of capital from gross operating surplus involves calculating the marginal product as $\mu R + \frac{(\mu-1)wL}{K}$ instead of μR . This leads to a possible false acceptance of efficiency, as would be the case when $\mu R < n + \delta < \mu R + \frac{(\mu-1)wL}{K}$. The data suggest that this is a possible concern.

3 Testing Dynamic Efficiency

This section presents the empirical test of dynamic efficiency. I show that over several years in the recent past the U.S. non-financial corporate sector fails to satisfy the criteria for dynamic efficiency. By contrast, I show that the existing empirical test that indirectly measure the marginal product of capital as the ratio of gross operating surplus to capital greatly overestimates the marginal product of capital and leads one to falsely conclude that over the period 1984–2014 the U.S. non-financial corporate sector was without a doubt dynamically efficient.

3.1 Mapping to the Data

I assume that the true model of accounting for the U.S. non-financial corporate sector in current dollars is

$$P_t^Y Y_t = w_t L_t + R_t P_{t-1}^K K_t + \Pi_t \quad (3.1)$$

P_t^Y is the current dollar price of output and $P_t^Y Y_t$ is the current dollar value of gross value added. w_t is the current dollar wage rate and $w_t L_t$ is the total current dollar expenditures on labor. R_t is the required rate of return on capital, P_{t-1}^K is the price of capital purchased in period $t - 1$, K_t is the stock of capital used in production in period t and is equal to the stock of capital available at the end of period $t - 1$, and $R_t P_{t-1}^K K_t$

⁵See, for example, Feldstein (1976).

⁶See, for example, Feldstein and Summers (1977), Abel et al. (1989), and Poterba (1998).

is the total current dollar capital payments. Π_t is the current dollar profits. This can be written in shares of gross value added as

$$1 = S_t^L + S_t^K + S_t^\Pi \quad (3.2)$$

where $S_t^L = \frac{w_t L_t}{P_t^Y Y_t}$ is the labor share, $S_t^K = \frac{R_t P_{t-1}^K K_t}{P_t^Y Y_t}$ is the capital share, and $S_t^\Pi = \frac{\Pi_t}{P_t^Y Y_t}$ is the profit share.

In the data, nominal gross value added $P^Y Y$ is the sum of expenditures on labor wL , gross operating surplus, and taxes on production and imports less subsidies. By separating gross operating surplus into capital payments $RP^K K$ and profits Π , we get

$$P^Y Y = wL + RP^K K + \Pi + \text{taxes on production and imports less subsidies} \quad (3.3)$$

Unlike taxes on corporate profits, it is unclear how to allocate taxes on production across capital, labor, and profits. Consistent with the model of production in the previous section, I construct markups as

$$\mu_t = \frac{w_t L_t + R_t P_{t-1}^K K_t + \Pi_t}{w_t L_t + R_t P_{t-1}^K K_t} \quad (3.4)$$

This construction of markups has three implicit assumptions: first, it assumes that the production function displays constant returns to scale; second, it assumes that gross value added in excess of capital and labor costs are economic profits, rather than the return on unobserved factors of production; third, it allocates the taxes on production across capital, labor, and profits in proportion to their share of gross value added. I will discuss the first two assumption later in this section.

3.1.1 The Required Rate of Return on Capital

The construction of the required rate of return on capital follows Hall and Jorgenson (1967) and is equal to the rental rate of capital that occurs in equilibrium. The required rate of return on capital of type s is⁷

$$R_s = (i - \mathbb{E}[\pi_s] + \delta_s) \quad (3.5)$$

where i is the nominal cost of borrowing in financial markets, π_s is the inflation rate of capital of type s , and δ_s is the depreciation rate of capital of type s . Nominal payments to capital of type s are $E_s = R_s P_s^K K_s$, where $P_s^K K_s$ is the replacement cost of the capital stock of type s . Summing across the different types of capital, total capital payments are $E = \sum_s R_s P_s^K K_s$ and the aggregate required return on capital is

⁷The model of production presented in Section 2 has, in equilibrium, a required rate of return on capital equal to $R_s = (i - (1 - \delta_s) \mathbb{E}[\pi_s] + \delta_s)$. The formula presented in equation 3.5 is more widely used in the literature. In the data, the two versions yield similar results.

$R = \frac{E}{\sum_s P_s^K K_s}$, where $\sum_s P_s^K K_s$ is the replacement cost of the aggregate capital stock. The capital share is

$$S^K = \frac{\sum_s R_s P_s^K K_s}{P^Y Y} \quad (3.6)$$

where $\sum_s R_s P_s^K K_s$ are total capital payments and $P^Y Y$ is nominal gross value added.

3.1.2 Test of Dynamic Efficiency

The test of dynamic efficiency as it appears in equation 2.18 requires the calculation of real values of capital and investment and is therefore sensitive to the way in which we calculate the price of capital and investment. By reporting the test statistic as a share of real gross value added, rather than in levels, we avoid such issues altogether. Dividing by the real value of gross value added we can express the test statistic in nominal terms $\frac{\mu_t R_t \frac{P_{t-1}^K}{P_t^Y} K_t - \frac{P_t^I}{P_t^Y} I_t}{Y} = \frac{\mu_t R_t P_{t-1}^K K_t - P_t^I I_t}{P_t^Y Y}$ where $\mu_t \times R_t P_{t-1}^K K_t$ is the markup times the total capital payments in period t , $P_t^I I_t$ is nominal gross investment in period t , and $P_t^Y Y$ is nominal gross value added in period t . The economy is dynamically efficient if

$$\frac{\mu_t R_t P_{t-1}^K K_t - P_t^I I_t}{P_t^Y Y} > 0 \quad (3.7)$$

3.2 Data

Data on nominal gross value added are taken from the National Income and Productivity Accounts (NIPA) Table 1.14. Data on compensation of employees are taken from the NIPA Table 1.14. Compensation of employees includes all wages in salaries, whether paid in cash or in kind, and includes employer costs of health insurance and pension contributions. Compensation of employees also includes the exercising of most stock options; stock options are recorded when exercised (the time at which the employee incurs a tax liability) and are valued at their recorded tax value (the difference between the market price and the exercise price). Compensation of employees further includes compensation of corporate officers.

Capital data are taken from the Bureau of Economic Analysis (BEA) Fixed Asset Table 4. The BEA capital data provide measures of the capital stock, the depreciation rate of capital and inflation for three categories of capital (structures, equipment, and intellectual property products), as well as a capital aggregate. The 14th comprehensive revision of NIPA in 2013 expanded its recognition of intangible capital beyond software to include expenditures for R&D and for entertainment, literary, and artistic originals as fixed investments. Consistent with Abel et al. (1989), I measure gross investment as investment in capital along with increases in inventories. Data on inventories are taken from the Integrated Macroeconomic Ac-

counts for the United States Table S.5.a. The results are robust to excluding increases in inventories from the measure of gross investment.

The data cover the geographic area that consists of the fifty states and the District of Columbia. As an example, all economic activity by the foreign-owned Kia Motors automobile manufacturing plant in West Point, Georgia, is included in the data and is reflected in the measures of value added, investment, capital, and compensation of employees. By contrast, all economic activity by the U.S.-owned Ford automobile manufacturing plant in Almussafes, Spain, is not included in the data and is not reflected in the measures of value added, investment, capital, and compensation of employees.

The construction of the required rate of return on capital requires that I specify the nominal cost of borrowing in financial markets, i , and asset-specific expected inflation, $\mathbb{E}[\pi]$. In the main results, I set i equal to the yield on Moody's Aaa bond portfolio. In the robustness subsection that follows the main results, I show that using the equity cost of capital or the weighted average cost of capital across debt and equity generates similar results. Throughout the results, asset-specific expected inflation is calculated as a three-year moving average of realized inflation. Replacing expected inflation with realized inflation generates very similar results.

3.3 Results

Figure 1 plots the time series of the test of dynamic efficiency of equation 3.7 for the U.S. non-financial corporate sector. The economy is dynamically efficient if the test statistic is greater than zero. The U.S. non-financial corporate sector shows signs of inefficiency in the mid-2000s. Figure 2 breaks down the test of dynamic efficiency into its two components: investment and the return on capital – the economy is dynamically efficient if the return on capital is always greater than investment. The figure shows that over the sample period, the rate of investment slowly rises and the return on capital (as a share of gross value added) sharply declines. The decline in the return on capital is another manifestation of the large decline in the capital share of gross value added documented by Barkai (2016). In the mid-2000s investment overtakes the return on capital, violating the condition for dynamic efficiency.

Alternative methods of testing dynamic efficiency calculate the return on capital as the ratio of gross operating surplus to the capital stock. These methods are valid under the assumption of zero profits, but they overestimate the marginal product of capital in the presence of markups. Figure 3 plots the time series of the test of dynamic efficiency of equation 3.7 as well as the test of dynamic efficiency of Abel et al. (1989)⁸ for the

⁸Abel et al. (1989) measure the marginal product of capital as the ratio of gross profits (value added less labor compensation) to capital. In my calculations, I have altered this method to account for taxes on production and imports less subsidies. Figure 3 compares my test of dynamic efficiency to one that calculates the marginal product of capital as the ratio of gross operating surplus to capital. The results and the comparison are robust to the treatment of taxes on production and imports less subsidies.

U.S. non-financial corporate sector. The approach of Abel et al. (1989), which assumes zero profits, would lead one to incorrectly conclude that the U.S. non-financial corporate sector at all times appears efficient and by a large margin. At no point does the Abel test statistic drop below 5.5% of gross value added. By contrast, the approach that I have taken in this paper, which accounts for the possibility of markups and profits, shows that the U.S. non-financial corporate violates the condition for dynamic efficiency.

3.4 Robustness

In this section I show that my finding is robust to the assumptions of constant returns to scale, a possible unobserved capital stock, and alternative constructions of the required rate of return on capital that account for equity financing and taxes.

3.4.1 Measuring Markups

I construct markups as $\mu_t = \frac{w_t L_t + R_t P_{t-1}^K K_t + \Pi_t}{w_t L_t + R_t P_{t-1}^K K_t}$. This construction of markups has two important assumptions: first, it assumes that the production function displays constant returns to scale; second, it assumes that gross value added in excess of capital and labor costs are economic profits, rather than the return on unobserved factors of production.

In place of the assumption of constant returns to scale, assume that the intermediate good is produced using a production technology that is homogeneous of degree γ . In this case the true price markup is $\mu_t = \gamma \times \frac{w_t L_t + R_t P_{t-1}^K K_t + \Pi_t}{w_t L_t + R_t P_{t-1}^K K_t}$. As long as we assume that production displays constant or decreasing returns to scale⁹ ($\gamma \leq 1$), my estimate of markups is an upper bound on true markups and my estimate of the return on capital ($\mu R P^K K$) is an upper bound on the true return on capital. Since the economy is efficient when the return on capital is greater than investment, by providing an upper bound on the return on capital I am understating the possibility and magnitude of inefficiency.

Instead of assuming that gross value added in excess of capital and labor costs are economic profits, assume that part of these profits are the costs of an unobserved factor of production X . We can decompose my measure of profits into economic profits (Π_t^{Econ}) and the cost of the unobserved factor of production ($R^X P^X X$). In this case the true price markup is $\mu_t = \frac{w_t L_t + R_t P_{t-1}^K K_t}{w_t L_t + R_t P_{t-1}^K K_t + R^X P^X X} \times \frac{w_t L_t + R_t P_{t-1}^K K_t + \Pi_t}{w_t L_t + R_t P_{t-1}^K K_t}$. Since the cost of the potentially unobserved factor of production X is non-negative, the term $\frac{w_t L_t + R_t P_{t-1}^K K_t}{w_t L_t + R_t P_{t-1}^K K_t + R^X P^X X}$ is weakly smaller than 1. As a result, my estimate of markups is an upper bound on true markups and my estimate of the return on capital ($\mu R P^K K$) is an upper bound on the true return on observed capital. As I showed in section 2.4, $\frac{mpk \times K - I}{Y}$ is a valid test for the efficient accumulation of observed capital, even if there exists a stock of unobserved capital. Since the economy is efficient when

⁹This assumption is supported by Burnside et al. (1995), Burnside (1996), and Basu and Fernald (1997).

the return on capital is greater than investment, by providing an upper bound on the return on capital I am understating the possibility and magnitude of inefficiency.

In summary, the assumption that the production function displays constant returns to scale and that gross value added in excess of capital and labor costs are economic profits, rather than the return on unobserved factors of production, biases my estimation in favor of finding efficiency. This strengthens my result that in the recent past the U.S. non-financial corporate sector fails to satisfy the criteria for dynamic efficiency.

3.4.2 Debt and Equity Costs of Capital

Thus far, I have assumed that the cost of borrowing in financial markets is equal to the yield on Moody's Aaa bond portfolio. I now show that using the equity cost of capital or the weighted average cost of capital across debt and equity leads to similar estimates of the required rate of return on capital after 1997. Furthermore, I show that the yield on Moody's Aaa bond portfolio that I used in the main analysis is similar in both levels and trends to the Bank of America Merrill Lynch representative bond portfolio in the overlapping period 1997–2014. As a result, tests of dynamic efficiency that are based on equity costs of capital or on the weighted average cost of capital are very similar to those that I presented in the main results.

Unlike the debt cost of capital, which is observable in market data, the equity cost of capital is unobserved. Thus, constructing the equity cost of capital requires a model of equity prices that relates observed financial market data to the unobserved equity cost of capital. A standard model for constructing the equity cost of capital is the Dividend Discount Model (DDM). In the DDM¹⁰ the equity cost of capital is the sum of the risk-free rate and the equity risk premium, and the risk premium is equal to the dividend price ratio. Building on this model, I construct the equity cost of capital as the sum of the yield on the ten-year U.S. treasury and the dividend price ratio of the S&P 500.

Figure 4 plots the debt cost of capital and the equity cost of capital. The debt cost of capital is equal to the yield on Moody's Aaa and the equity cost of capital is equal to the sum of the yield on the ten-year U.S. treasury and the dividend price ratio of the S&P 500. Before 1997 the equity cost of capital was higher than the debt cost of capital, but after 1997 the two costs of capital were extremely similar. As a result, tests of dynamic efficiency that are based on equity costs of capital or on the weighted average cost of capital are very similar to those that I presented in the main results for the period after 1997 – this includes the period of the mid-2000s during which the U.S. non-financial corporate sector fails to satisfy the criteria for dynamic efficiency.

Figure 5 plots the yield on Moody's Aaa bond portfolio, Moody's Baa bond portfolio, and the Bank of

¹⁰This result is based on the assumption that the growth rate of dividends is constant and is equal to the risk-free rate.

America Merrill Lynch representative bond portfolio.¹¹ In the overlapping period 1997–2014, Moody’s Aaa bond portfolio and the Bank of America Merrill Lynch representative bond portfolio display similar levels and trends. With the exception of the great recession, the Bank of America Merrill Lynch representative bond portfolio has always had a yield equal to or below the yield on Moody’s Aaa bond portfolio. While Moody’s Aaa has a higher grade than the representative portfolio, it also has a longer maturity and this may explain why the two portfolios have similar yields throughout the sample. The figure also shows that Moody’s Baa bond portfolio closely tracks the time series trend of the Moody’s Aaa bond portfolio, although the two portfolios have a different price level. The U.S. non-financial corporate sector fails to satisfy the criteria for dynamic efficiency, when one calculates the required rate of return on capital using the yield on the Bank of America Merrill Lynch representative bond portfolio, or the yield on Moody’s Baa bond portfolio.

3.4.3 Taxes

I now consider specifications of the required rate of return on capital that include the tax treatment of capital and debt. The two specifications are common in the literature.¹² The first specification accounts for the tax treatment of capital. Unlike compensation of labor, investment in capital is not fully expansible and as a result the corporate tax rate increases the firm’s cost of capital inputs. In order to account for the tax treatment of capital, the required rate of return on capital of type s must be

$$R_s = (i - \mathbb{E}[\pi_s] + \delta_s) \frac{1 - z_s \tau}{1 - \tau} \quad (3.8)$$

where τ is the corporate income tax rate and z_s is the net present value of depreciation allowances of capital of type s . The second specification accounts for the tax treatment of both capital and debt. Since interest payments on debt are tax-deductible, the financing of capital with debt lowers the firms’ cost of capital inputs. In order to account for the tax treatment of both capital and debt, the required rate of return on capital of type s must be

$$R_s = (i \times (1 - \tau) - \mathbb{E}[\pi_s] + \delta_s) \frac{1 - z_s \tau}{1 - \tau} \quad (3.9)$$

I take data on the corporate tax rate from the OECD Tax Database and data on capital allowance from

¹¹The BofA Merrill Lynch US Corporate Master Effective Yield ”tracks the performance of US dollar denominated investment grade rated corporate debt publically issued in the US domestic market. To qualify for inclusion in the index, securities must have an investment grade rating (based on an average of Moody’s, S&P, and Fitch) and an investment grade rated country of risk (based on an average of Moody’s, S&P, and Fitch foreign currency long term sovereign debt ratings). Each security must have greater than 1 year of remaining maturity, a fixed coupon schedule, and a minimum amount outstanding of \$250 million.”

¹²See, for example, Hall and Jorgenson (1967), King and Fullerton (1984), and Gilchrist and Zakrajsek (2007). Past research has included an investment tax credit in the calculation of the required rate of return on capital; the investment tax credit expired in 1983, which is prior to the start of my sample.

the Tax Foundation. Figure 6 plots the time series of the test of dynamic efficiency for the U.S. non-financial corporate sector for the various specifications of the required rate of return on capital. The economy is dynamically efficient if the test statistic is greater than zero. I find that specifications of the required rate of return that include the tax treatment of capital and debt show that the U.S. non-financial corporate sector fails to satisfy the criteria for dynamic efficiency.

3.5 Discussion

Abel et al. (1989) measure the marginal product of capital as the ratio of gross operating surplus (value added less labor compensation) to capital. This approach overestimates the marginal product of capital in the presence of markups. This approach correctly attributes to capital the profits that are generated from paying capital below its marginal cost, but it incorrectly attributes to capital those profits that are generated from paying labor below its marginal cost. Recall that economic profits Π are earned by paying capital and labor below their marginal product: $\Pi = (\mu - 1)(RK + wL)$. Inferring the marginal product of capital from gross operating surplus involves calculating the marginal product as $\mu R + \frac{(\mu-1)wL}{K}$ instead of μR . Inferring the marginal product of capital from gross operating surplus leads to a false acceptance of efficiency.

The recent work of Geerolf (2013) updates the estimates of Abel et al. (1989). As in the case of Abel et al. (1989), the author measures the marginal product of capital as the ratio of gross operating surplus to capital. Geerolf finds that the results of are sensitive to the treatment of mixed income and land rents. In particular, using improved methods of allocating mixed income and improved measures of land rents the author finds some evidence of inefficiency in advanced economies. By contrast, in this paper I consider the corporate sector, and thus avoid all issues related to the treatment of mixed income. I further avoid all issues related to residential housing. By studying the corporate sector I focus on firm production and possible overaccumulation of firm capital, rather than the production of housing services and possible overaccumulation of residential housing. In the results, I show that the Abel et al. (1989) test of dynamic efficiency is satisfied by a large margin. As a fraction of gross operating surplus, land rental would need to be very large in order to overturn the results of Abel et al. (1989). The critical issue is not the treatment of land rentals or mixed income, but the attribution of profits to capital.

4 Conclusion

In this paper, I present a model in which an increase in markups increases capital accumulation and pushes the economy toward dynamic inefficiency. In the model, an increase in markups redistributes income from households with a low marginal propensity to save to households with a high marginal propensity to save, thus

increasing the aggregate savings rate and depressing the marginal product of capital and the interest rate. Using the model, I derive a measurable test of dynamic efficiency that accounts for imperfect competition and markups. I show that my test of dynamic efficiency is robust to any assumptions of household behavior, corporate ownership. I implement the test using data for the U.S. non-financial corporate sector and I find that the economy fails to satisfy my criteria for dynamic efficiency. At the same time, the existing test of dynamic efficiency, which does not account for markups, falsely concludes that the economy satisfies the criteria for dynamic efficiency by a wide margin.

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Figure 1: **Test of Dynamic Efficiency**

The figure shows the test of dynamic efficiency for the U.S. non-financial corporate sector over the period 1984–2014. The economy is dynamically efficient if $\frac{mpk \times K - I}{Y} > 0$. The marginal product of capital is calculated as $\mu R P^K K$. The required rate of return on capital is calculated as $R = (i - \mathbb{E}[\pi] + \delta)$. Capital includes both physical capital and intangible capital. The cost of borrowing is set to Moody's Aaa and expected inflation is calculated as a three-year moving average. See Section 3 for further details.

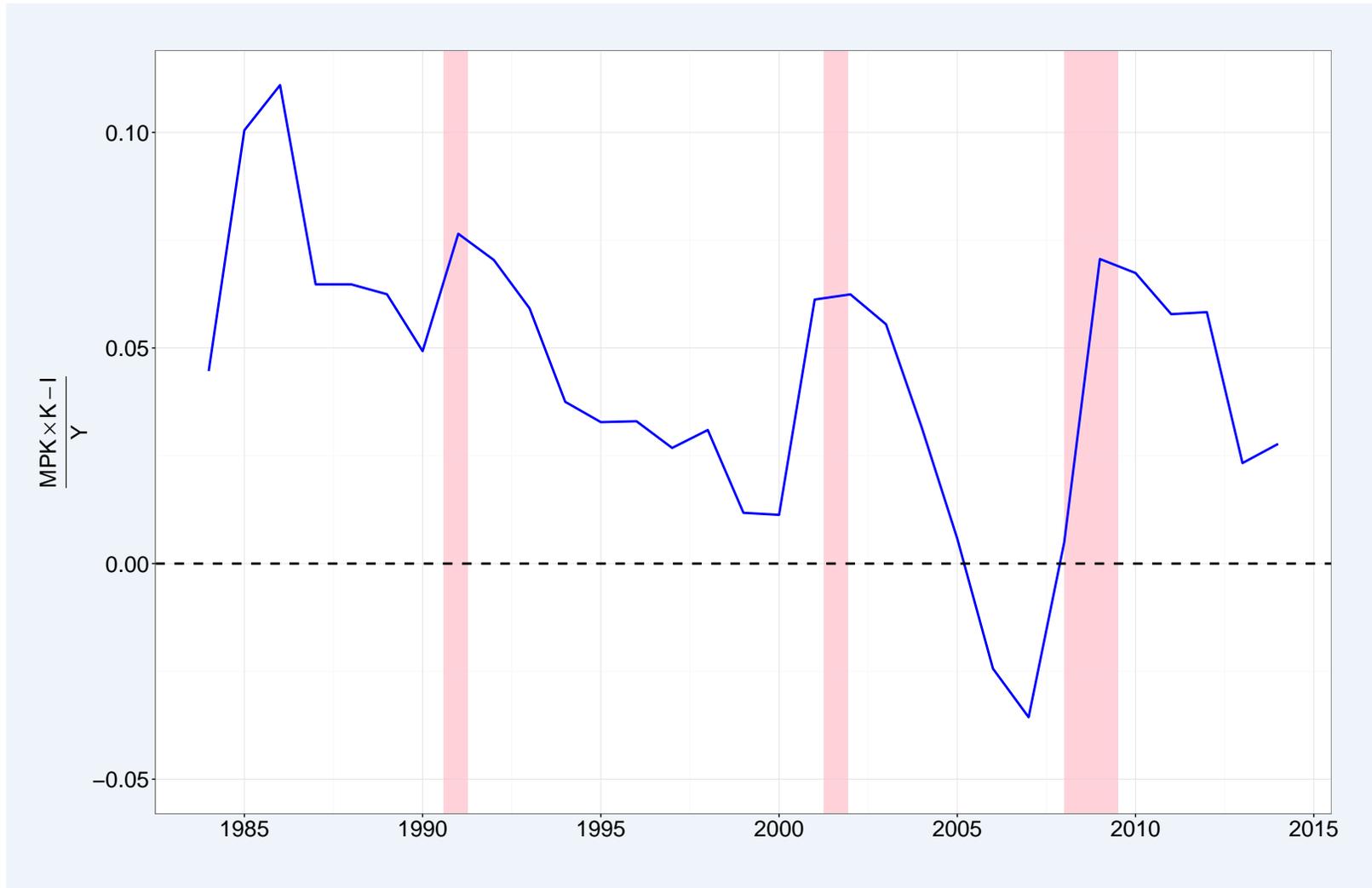


Figure 2: **Investment and the Return on Capital**

The figure shows the rate of investment and the return on capital for the U.S. non-financial corporate sector over the period 1984–2014. The economy is dynamically efficient if $\frac{mpk \times K}{Y} > \frac{I}{Y}$. The marginal product of capital is calculated as $\mu R P^K K$. The required rate of return on capital is calculated as $R = (i - \mathbb{E}[\pi] + \delta)$. Capital includes both physical capital and intangible capital. The cost of borrowing is set to Moody's Aaa and expected inflation is calculated as a three-year moving average. See Section 3 for further details.

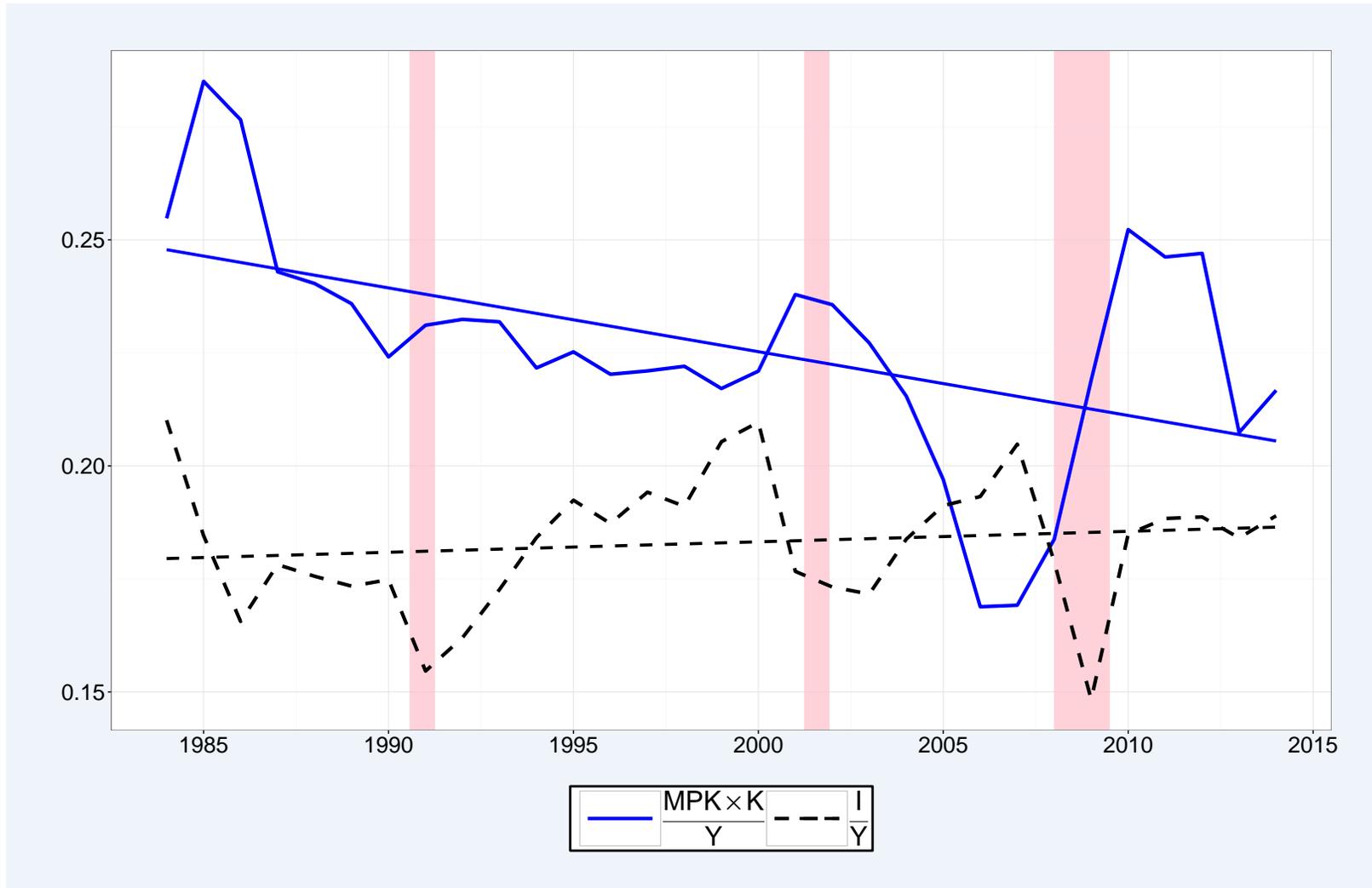


Figure 3: **Test of Dynamic Efficiency - Comparison to Abel et al. (1989)**

The figure compares the test of dynamic efficiency to the test of Abel et al. (1989) (which assumes zero profits) for the U.S. non-financial corporate sector over the period 1984–2014. The economy is dynamically efficient if $\frac{mpk \times K - I}{Y} > 0$. The marginal product of capital is calculated as $\mu R P^K K$. The required rate of return on capital is calculated as $R = (i - \mathbb{E}[\pi] + \delta)$. Capital includes both physical capital and intangible capital. The cost of borrowing is set to Moody's Aaa and expected inflation is calculated as a three-year moving average. Abel et al. (1989) test the inequality $\frac{\text{gross operating surplus} - I}{Y} > 0$. See Section 3 for further details.

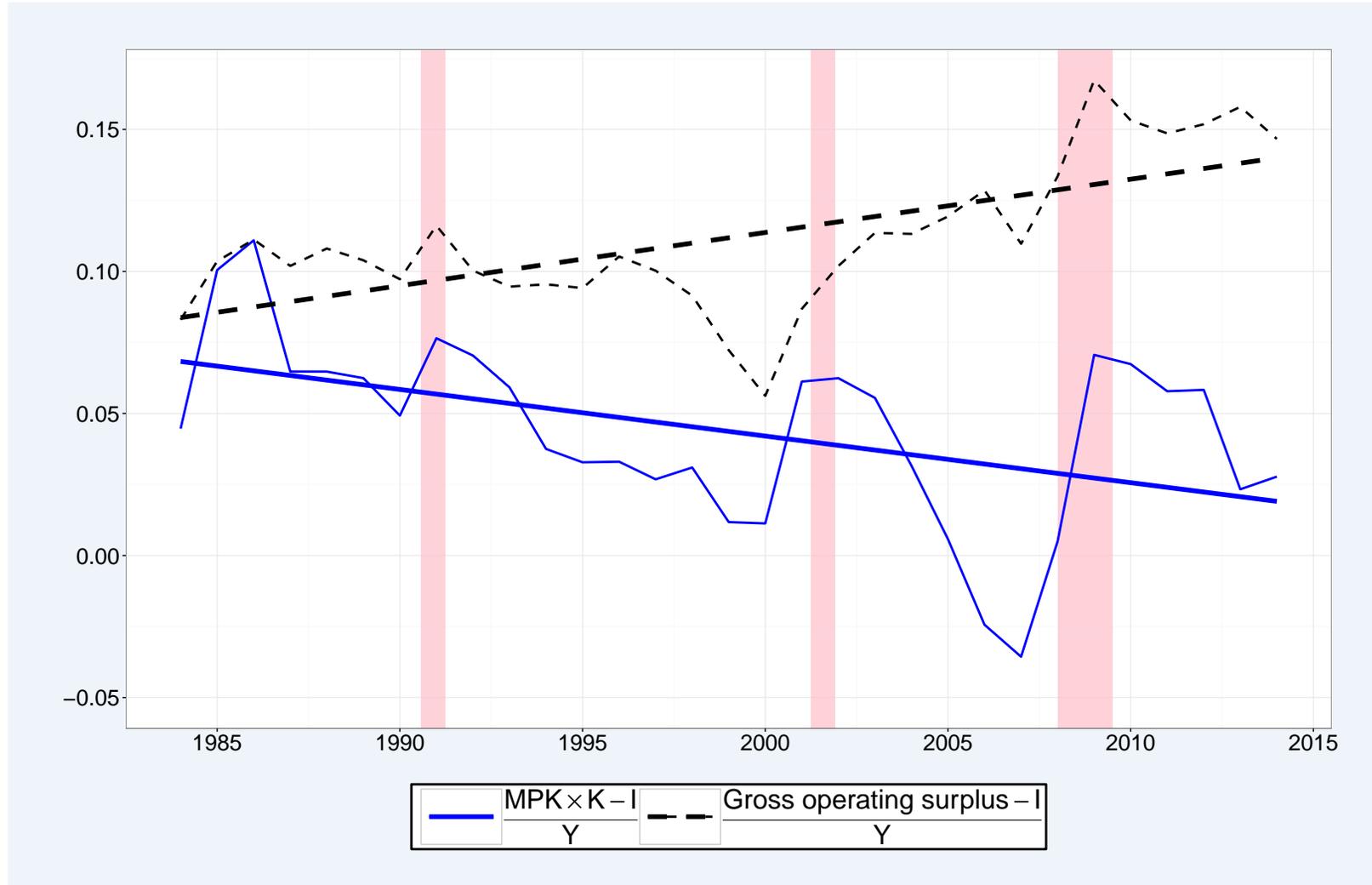


Figure 4: **Debt and Equity Costs of Capital**

This figure plots the debt cost of capital and the equity cost of capital. The debt cost of capital is set to the yield on Moody's Aaa bond portfolio and the equity cost of capital is set to the sum of the risk-free rate (yield on the ten-year treasury) and the equity risk premium (dividend price ratio of the S&P 500). See Section 3.4.2 for further details.

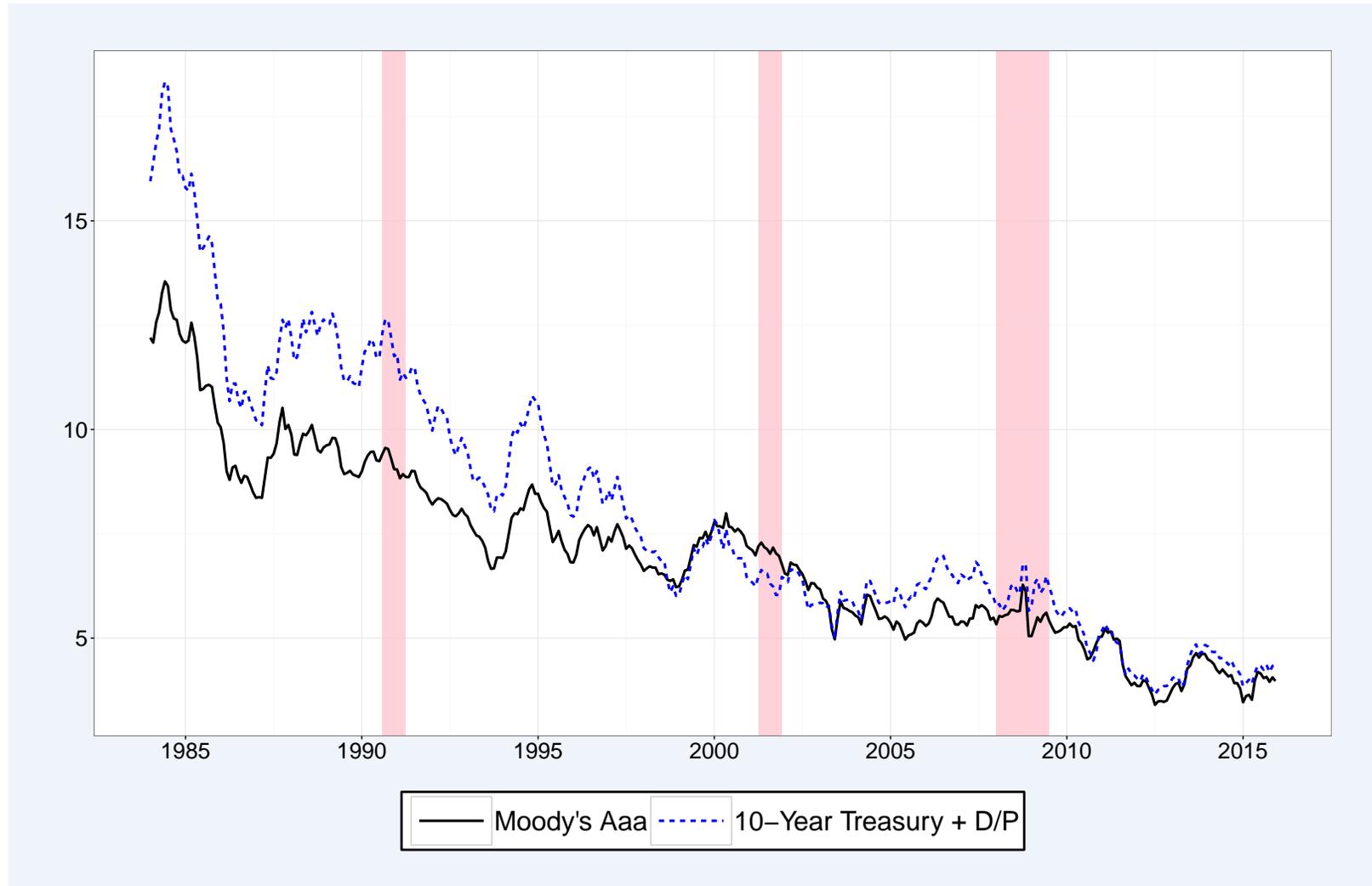


Figure 5: **Alternative Bond Portfolios**

This figure plots the yield on three bond portfolios: Moody's Aaa bond portfolio, Moody's Baa bond portfolio, and the Bank of America Merrill Lynch U.S. Corporate Master Effective bond portfolio. See Section 3.4.2 for further details.

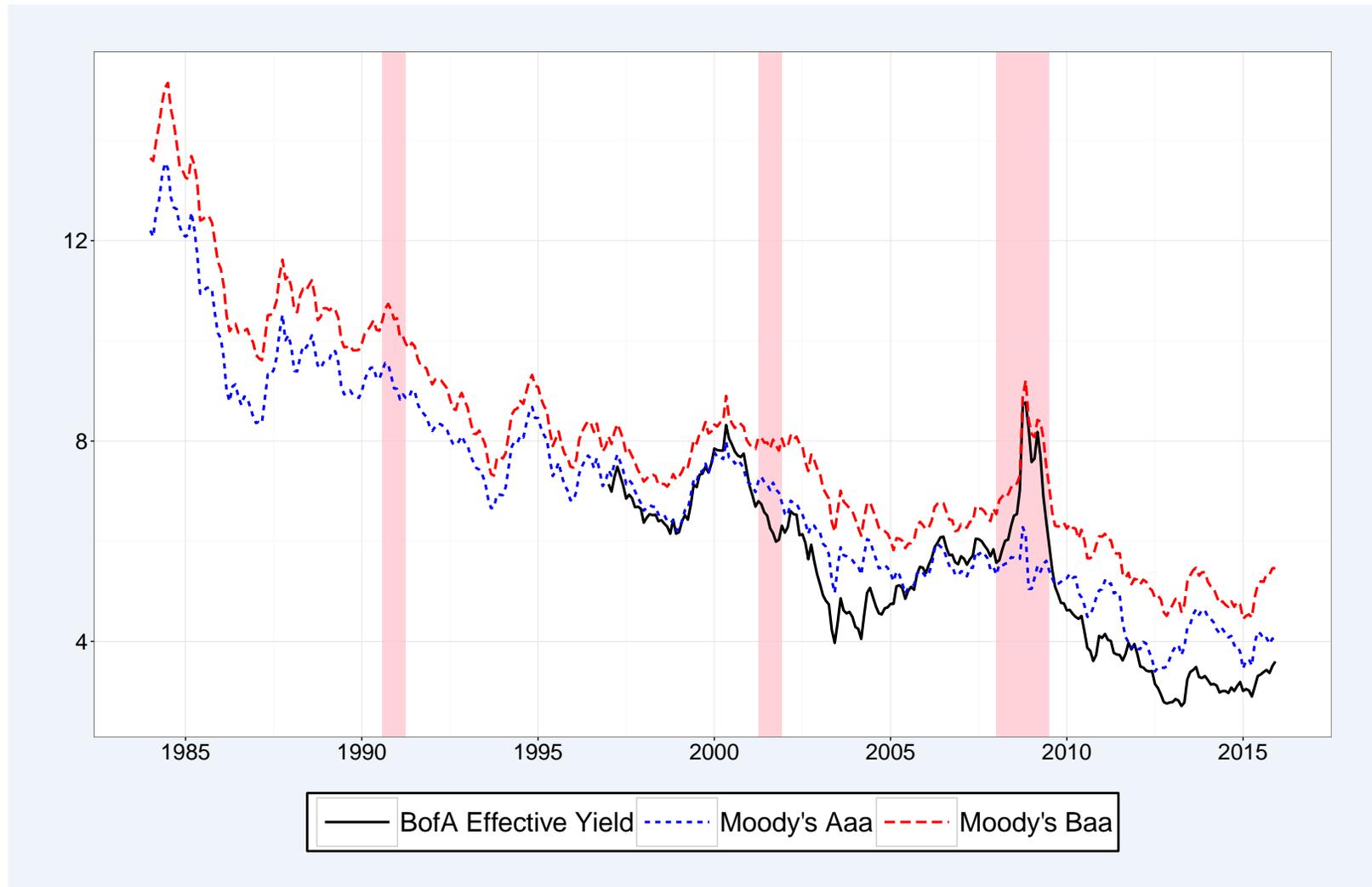


Figure 6: **Test of Dynamic Efficiency - Accounting for Taxes**

The figure shows the test of dynamic efficiency for the U.S. non-financial corporate sector over the period 1984–2014. The economy is dynamically efficient if $\frac{mpk \times K - I}{Y} > 0$. The marginal product of capital is calculated as $\mu RP^K K$. Capital includes both physical capital and intangible capital. The cost of borrowing is set to Moody's Aaa and expected inflation is calculated as a three-year moving average. See Section 3.4.3 for further details.

