MACROPRUDENTIAL REGULATION AND INVESTMENT DYNAMICS UNDER IMPERFECT BANKING COMPETITION

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Abstract

The global financial crisis has shifted attention towards macroprudential regulation to mitigate the effects of banking behavior on systemic risk. In this paper, we provide a model to investigate the effect of bank capital regulation on the investment cycle, in the context of a second-order accelerator framework. In traditional investment accelerator models, the speed at which firms adjust their investment is typically treated as a fixed, exogenous parameter. However, this assumption overlooks a crucial reality: the pace of investment heavily depends on the cost of financing provided by the banking sector. Our analysis bridges this gap by embedding an imperfectly competitive (Cournot) banking market into the macroeconomic accelerator framework. We explicitly endogenize the firm's speed of investment adjustment, modeling it as a function of the equilibrium lending rate. Numerical simulations, calibrated using key Euro Area parameters over the 2007-2025 period, validate our theoretical insights, highlighting key trade-offs for effective macroprudential policy design.

Keywords: Macroprudential regulation, bank capital, second-order accelerator, Cournot model

JEL Classification: G28, G21, E32, L13

1. Introduction

In the aftermath of the global economic crisis, macroprudential regulation has gained significant attention not only as a safeguard against potential banking failures, but also as a critical determinant of broader macroeconomic fluctuations (Vives, 2016). Consequently, the macroeconomic impact of these policies has been a subject of extensive debate, and a large literature has emerged using the bank capital channel to model them[1]. Most of them find evidence for the procyclicality of banking regulation, arguing that capital requirements often amplify business cycle fluctuations by constraining credit during downturns. However, this perspective often ignores regulatory transmission to the real investment dynamics.

From the aspect of economic dynamics[2], the second-order accelerator (SOA) mechanism provides an endogenous explanation for the origination of the investment cycle, based on the assumption of dual frictions: firms incur adjustment costs not only when modifying their target capital stock, but also when altering their flow of current investment. This structure generates investment inertia capturing the lags and frictions between the initial expenditure of funds and their final transformation into productive physical capital. Early literature developed this mechanism in continuous time (e.g., Hillinger et al., 1992), however more recent extensions are formulated in discrete time, incorporating the loan rate as well (Dalla & Varelas, 2016). Yet the limitation of these models is that they treat the speed of investment adjustment as an exogenous fixed parameter, ignoring any effects of the cost of credit.

To bridge these two strands of literature, we establish a new structural framework. We extend the traditional SOA model in discrete time by endogenizing the speed of investment adjustment, formulating it as a function of the lending rate, determined within a Cournot type oligopolistic banking sector with product differentiation. Treating capital requirements ratio as an exogenous policy parameter imposed to regulate the banking sector, we determine a novel transition path. Methodologically, we employ difference equations to capture the transition dynamics, complemented by numerical simulations. This mathematical approach isolates the exact transmission mechanism: it demonstrates how capital regulation alters the lending rate under varying degrees of loan differentiation, which dynamically shifts the endogenous speed of investment adjustment. Ultimately, our analysis explicitly quantifies how macroprudential interventions impact the amplitude and the duration of the investment cycle, highlighting the vital trade-offs between financial stability and economic adjustment speed.

The oligopolistic assumption for the banking industry complies with the European Central Bank's (ECB) structural financial indicators for the European Union's (EU) banking sector at the

[1] Drumond (2009) provides a detailed discussion of these studies, concentrating on the regulatory framework under Basel II Accord.
[2] Orlando & Sportelli (2021) provide a rationale for the application of dynamical systems and mathematical approaches to business cycles.

end of 2025[3]. These indicators show a decrease in the number of bank offices in the EU by 2.62% and an EU average degree of banking concentration of 69.33%. Our framework follows the industrial organization approach to banking (Matthews et al., 2024; VanHoose, 2022), which applies standard models of perfect and imperfect competition to the banking sector (Freixas & Rochet, 2023). The benchmark model in this field was the Monti-Klein (Klein, 1971; Monti, 1972) framework for a monopolistic bank. Then, an oligopolistic extension was provided by Freixas & Rochet (2023). Most of the models in the field employ different games of banking behavior aiming to address either the transmission of monetary policy or the stability of the financial sector (Cantu et al., 2024; Dalla, 2025; Dalla & Varelas, 2019; Schliephake, 2016; Schliephake & Kirstein, 2013; VanHoose, 2007; Vives, 2019).

Our analysis demonstrates that under realistic macroeconomic calibrations, where the investment accelerator effect is sufficiently strong to generate cycles and the firms' speed of investment adjustment is structurally bounded, the economy remains within a stable cyclical path. Consequently, macroprudential policy interventions do not alter the underlying stability itself but rather dictate the dynamic properties of the business cycle. By calibrating the model using key the Euro Area parameters (2007-2025), we explicitly quantify the impact of capital requirements on the duration of the investment cycle across varying degrees of loan differentiation.

2. Model Setup

2.1 The Banking Sector

Consider an oligopolistic banking sector with 2 identical banks. Banks are engaged in a static Cournot model with product differentiation and prudential regulation. Banks behave like traditional financial intermediaries, maintaining two types of assets, loans (L) and reserves (R), and financing them by deposits (D) and equity capital (E). Therefore, the oligopolistic banks simultaneously choose the volume of loans and deposits that maximize their profit function subject to their balance sheet constraint. This maximization problem of the individual bank is described by:

[3] European Central Bank, Press Release: EU Structural Financial Indicators: End of 2025, Published: 12 June 2026, https://www.ecb.europa.eu/press/pr/date/2026/html/ecb.pr260612~ab34769159.en.html (Accessed: 14/06/2026)

$$\max_{L_i,D_i} \Pi_i = r_L^i(L_i, L_j) \cdot L_i + r \cdot M_i - r_D^i(D_i, D_j) \cdot D_j - C_i(L_i, D_i), i = 1,2 \;\&\; i \neq j \quad \textbf{(1)}$$

where r_L^i: the interest rate on loans of bank *i*, L_i: bank's *i* individual volume of loans, r_D^i: the interest rate on deposits of bank i, D_i: the volume of deposits of the individual bank, M_i: the net position of the individual bank, and C_i: the cost function of the individual bank.

The net position of bank i (M_i) represents the difference between the bank's assets and liabilities. Its functional form is given by:

$$M_i = (1 - a) \cdot D_i - L_i + E_i, \quad i = 1,2, \; a \in (0,1) \qquad \textbf{(2)}$$

where α: the minimum reserve requirements, and E_i: bank's i equity capital. Each bank either lends its positive net position or borrows against a negative one at the exogenous interbank rate (r) setting by Central Bank.

Based on the minimum capital requirements regulation, we assume that the bank capital of the individual bank is equal to the latter, and is defined as a fraction of its loans:

$$E_i = \rho L_i, \; \rho \in (0,1) \qquad \textbf{(3)}$$

where ρ: the capital requirements ratio.

Furthermore, for analytical tractability, we assume that management costs are additive and the same for both banks, with the cost function given by:

$$C_i = C_i(L_i, D_i) = \theta_L L_i + \theta_D D_i, \; \theta_L, \theta_D > 0 \;\&i = 1,2 \qquad \textbf{(4)}$$

where θ_L & θ_D: the marginal cost of loans and deposits respectively, which are constant and equal for both banks.

Under the assumption of loan differentiation, its bank faces the following inverse demand function for loans:

$$r_L^i = r_L(L_i, L_j) = b_0 - b_1 L_i - b_2 L_j, \quad b_0, b_1, b_2 > 0, \; b_1 \neq b_2, \; i = 1,2 \;\&\; i \neq j \quad \textbf{(5)}$$

where b_0 is the intercept, b_1 is its slope, and b_2 measures the cross - interest rate effects. Assuming that loans act as imperfect substitutes (Dixit, 1979), the coefficients are strictly positive with $b_1 > b_2$. The degree of loan differentiation is determined by the spread between these parameters. In the limiting case where $b_1 = b_2$, loans are homogenous. Conversely, when $b_2 = 0$, bank *i* behaves as a monopolist in its segment of the differentiated loan market, as its loans are perfectly insulated from rival supply.

By symmetry, the individual inverse supply function of deposits is:

$$r_D^i = r_D^i(D_i, D_j) = d_0 + d_1 D_i + d_2 D_j,\ d_0, d_1, d_2 > 0,\ d_1 \neq d_2, i = 1,2\ \&\ i \neq j \quad \textbf{(6)}$$

where the parameters $d_0 > 0, d_1 > 0$ and $d_2 > 0$ correspond to the intercept, the slope, and the cross - deposit rate effects respectively. Analogous to the loan market, deposits are modelled as imperfect substitutes ($d_1 > d_2$). Thus, the degree of deposit differentiation intensifies as the wedge between $d_1 and\ d_2$ widens.

The equilibrium loan and deposit rates are:

$$r_L^* = r_L^{1*} = r_L^{2*} = \frac{b_1 b_0 + (b_1 + b_2)(\theta_L + r(1-\rho))}{2b_1 + b_2} \quad \textbf{(7)}$$

and

$$r_D^* = r_D^{1*} = r_D^{2*} = \frac{d_1 d_0 + (d_1 + d_2)(-\theta_D + r(1-a))}{2d_1 + d_2} \quad \textbf{(8)}$$

Then, given an increase in capital requirements ratio, bank capital increases, forcing banks to invest in loans to satisfy their balance sheet constraint. Therefore, the loan rate declines.[4] So,

$$\frac{\partial r_L^*}{\partial \rho} = -\frac{(b_1 + b_2)r}{2b_1 + b_2} < 0 \quad \textbf{(9)}$$

2.2 The Second Order Accelerator (SOA) Mechanism

The investment decision is described by the second-order accelerator (SOA) model in discrete time, which provides a mechanism of endogenous generation of investment cycles based on the standard flexible accelerator (Hillinger et al. 1992; Hillinger, 2005). Its main characteristic is the incorporation of adjustment costs in the capital stock and the rate of investment as well, with the latter representing the inertia of investment. The benchmark framework is a three-equation model that is structured by the partial adjustment mechanism for fixed investment towards its desired level (Eq. 10), the definition of net investment (Eq. 11), and a behavioral equation that reflects the desired level of investment (Eq. 12). Therefore:

$$I_t - I_{t-1} = c(I_t^* - I_{t-1}),\ 0 < c < 1 \quad \textbf{(10)}$$

$$I_t = K_t - K_{t-1} \quad \textbf{(11)}$$

[4] Loan and deposit markets are separated. Hence, the increase in loans does not influence the deposit market.

$$I_t^* = b(K_t^* - K_{t-1}), b > 0 \quad \textbf{(12)}$$

where c: the speed of investment adjustment, I_t^*: the desired level of fixed investment, I_t: the actual level of fixed investment, K_t: the actual capital, and K_t^*: the desired level of capital[5].

Now, we depart from the standard literature by endogenizing the speed of investment adjustment (c) and connecting it directly with the credit market. Rather than treating c as an arbitrary constant, we assume it is a decreasing function of the loan rate (r_L):

$$c = c(r_L),\ \ c'(r_L) < 0 \quad \textbf{(13)}$$

This specification reflects that higher borrowing costs increase the adjustment costs faced by firms, thereby slowing down the speed at which they adjust their current investment towards the desired investment level. In our framework, the interest rate of loans (r_L) is determined endogenously within the static Cournot banking sector. Since the credit market game is static and its structural parameters are time-invariant, the resulting equilibrium loan rate is a constant value over the investment planning horizon, denoted as r_L^*. Consequently, the speed of adjustment $c = c(r_L^*(\rho))$ enters the accelerator equation as a constant parameter. This crucial property ensures that the difference equation retains constant coefficients, maintaining its mathematical tractability while successfully embedding the regulatory transmission channel.

From Eqs. (10) – (13), we obtain the following second- order linear equation that determines the dynamic trajectory of capital:

$$K_t + [c(r_L^*(\rho)) \cdot (b+1) - 2]K_{t-1} + (1 - c(r_L^*(\rho)))K_{t-2} = c(r_L^*(\rho)) \cdot b \cdot K^* \ \ \textbf{(14)}.$$

For the remainder of our analysis, we concentrate on the parameter space that yields cyclical economic behavior, that is for $c(\cdot)(b+1)^2 < 4b$. Then, the general solution of Eq. (14) is:

$$K_t = \mu^t(A_1 cos\omega t + A_2 sin\omega t) + K^* \quad \textbf{(15)}$$

where μ: the amplitude, and $A_1 \& A_2 \in \mathcal{R}$ are arbitrary constants.

Thus, the movement of capital is a trigonometric oscillation with decreasing amplitude $\mu = \sqrt{1 - c(\cdot)} < 1$ and period equal to $T = 2\pi/\omega$, where ω is the angular frequency and is given by[6]:

[5] For the rest of our analysis, the desired level of capital is considered stable due to the finite time path and therefore is annotated by K^*.

[6] $u(\cdot)$ is introduced as an auxiliary function to simplify the subsequent comparative static derivations.

$$\omega = arccos\left(-\frac{c(\cdot)(b+1)-2}{2\sqrt{1-c(\cdot)}}\right) = arccos(u(c(\cdot))) \quad \mathbf{(16)}$$

3. Macroprudential Regulatory Effects on Investment Cycle Dynamics

This section investigates the macroeconomic implications of banking regulation. Specifically, we conduct a comparative static analysis to evaluate how variations in macroprudential policy, captured by the capital requirements ratio (ρ), transmit through the credit market to alter the structural characteristics of the real economy's cyclical fluctuations.

The transmission mechanism in our model operates sequentially: a regulatory shift modifies the equilibrium lending rate in the static Cournot banking sector, which in turn determines the speed of investment adjustment (c) of the real sector. Using the total derivatives of the investment cycle's amplitude (μ) and period (T) with respect to the capital requirements ratio (ρ), we assess whether stricter capital requirements act as a stabilizer of economic volatility, and how they influence the duration of the cycle structurally.

To begin with the total derivative of the amplitude (μ) with respect to the capital requirements ratio (ρ), we have:

$$\frac{d\mu}{d\rho} = \frac{\partial\mu}{\partial c}\cdot\frac{\partial c}{\partial r_L}\cdot\frac{\partial r_L^*}{\partial\rho} = -\left(\frac{1}{2\sqrt{1-c}}\right)\cdot\frac{\partial c}{\partial r_L}\cdot\frac{\partial r_L^*}{\partial\rho} < 0 \quad \mathbf{(17)}$$

Hence, stricter regulation performs as a macroeconomic stabilizer. By inducing a shift in the Cournot banking equilibrium that ultimately lowers the lending rate, this policy accelerates the real sector's investment adjustment process.

Turning to the regulatory effects on the investment cycle's period, it is analytically convenient to derive first the partial derivative of the angular frequency (ω) with respect to the speed of investment adjustment (c):

$$\frac{\partial\omega}{\partial c} = -\frac{u'(c)}{\sqrt{1-u(c)^2}} = -\frac{c(b+1)-2b}{4(1-c)^{\frac{3}{2}}\cdot\sqrt{1-u(c)^2}} \quad \mathbf{(18)}$$

The sign of Eq. (18) is entirely determined by the sign of the numerator, $(c(b+1)-2b)$. Specifically, $\partial\omega/\partial c$ is positive (negative) if and only if $c(b+1) < 2b$ ($c(b+1) > 2b$).

We can now evaluate the overall impact of regulation on the duration of the investment cycle (T), using the chain rule:

$$\frac{dT}{d\rho} = \frac{\partial T}{\partial \omega} \cdot \frac{\partial \omega}{\partial c} \cdot \frac{\partial c}{\partial r_L} \cdot \frac{\partial r_L^*}{\partial \rho} \Longrightarrow$$

$$\frac{dT}{d\rho} = -\left(\frac{2\pi}{\omega^2}\right) \cdot \frac{\partial \omega}{\partial c} \cdot \frac{\partial c}{\partial r_L} \cdot \frac{\partial r_L^*}{\partial \rho} \qquad \mathbf{(19)}$$

Given the established negative signs of the partial derivatives within the credit channel ($\partial r_L^*/\partial \rho < 0$) and investment adjustment one ($\partial c/\partial r_L^* < 0$), the sign of Eq. (19) is strictly opposite to that of $\partial \omega/\partial c$. This, yields that stricter capital requirements compress the investment cycle temporally ($dT/d\rho < 0$)provided that $c(b+1) < 2b$, whereas they prolong the cycle ($dT/d\rho > 0$) when $c(b+1) > 2b$. Consequently, the effect of macroprudential policy on the cycle's duration is conditional on the structural parameters of the real sector.

4. Calibration and Simulation

To assess the impact of capital requirements on the duration of the investment cycle for different degrees of loan differentiation, we calibrate and simulate the model using Euro Area data. The parameters of the banking sector are derived from the European Central Bank (ECB) Statistics (European Central Bank, 2026). The interbank rate (r) is assigned to 0.0134, reflecting the average Euribor rate over the period 2007-2025. The capital requirements ratio (ρ) is set to 0.08, corresponding to the average capital buffer in the Euro Area for the reference period. Regarding the structural parameters, the slope of the individual inverse demand function of loans (b_1) is normalized to 1. The loan substitutability parameter (b_2) is set to 0.5, indicating a moderate degree of differentiation in the credit market. Also, the parameters θ_L and b_0 are assigned to 0.01 and 0.05 respectively, without loss of generality.

Now, to capture the transmission channel between the financial sector and the real economy, we define the speed of investment adjustment (c) as an inverse fractional function of the equilibrium lending rate (r_L^*):

$$c = \frac{c_0}{1 + c_1 \cdot r_L^*} \qquad \mathbf{(20)}$$

The maximum speed of adjustment, c_0, is set to 0.95. While theoretically it holds that $0 < c < 1$, restricting c_0 strictly below unity implies non-financial frictions, such as physical capital installation costs and time-to-build lags, that prevent instantaneous capital adjustment even when borrowing is costless. The sensitivity parameter, c_1, is calibrated to 80, establishing a transmission channel where borrowing costs impose severe frictions on the investment adjustment. Finally, the macroeconomic parameters are assigned stylized values. Specifically, the behavior parameter (b) is set to 1.5. Similarly, the desired level of capital (K^*) and the initial conditions K_0 & K_1 are set to 15, 8, and 20, respectively, without loss of generality. Consequently, as the equilibrium cost of credit (r_L^*) rises, financial constraints progressively dampen the firms' ability to adjust their investment, strictly maintaining the stability of the model.

Our analysis is conducted for four different regulatory scenarios: (a) an unregulated banking sector ($\rho = 0$), (b) EU – level regulation ($\rho = 0.08$), (c) moderate regulation ($\rho = 0.30$), and (d) strict regulation ($\rho = 0.60$). **Fig. 1** illustrates the time path of the actual capital (K_t) in each case. The system exhibits oscillations with decreasing amplitude that converge towards the desired level of capital (K^*) under all regulatory regimes. However, stricter regulation tends to accelerate the investment cycle. Consequently, macroprudential policy interventions do not alter the stability of the system but rather dictate the dynamic properties of the business cycle.

Fig. 1 about here

Moreover, we examine the impact of macroprudential regulation on the amplitude (μ) and the period (T) of the investment cycle under different cases of banking conduct. More specifically, holding the parameter b_1 constant at unity, we calculate the resulting amplitude and period for various values of b_2. A null value of this parameter ($b_2 = 0$) indicates maximum loan differentiation, meaning that each bank operates as a monopolist in its respective segment of the loan market. As the value of b_2 increases towards b_1, loan substitutability increases. In the case where $b_1 = b_2 = 1$, loans become perfect substitutes. **Fig.2** shows the relationship between investment cycle amplitude and the parameter b_2 for each regulatory scenario. Each curve corresponds to a different regulatory regime: the highest curve depicts the absence of regulation, followed by the EU-level regulation, the moderate regulation, and finally, the case of strict regulation. It can be clearly seen that in all the examined cases, the curves exhibit negative slopes, implying that the investment cycle amplitude is lower for higher levels of loan substitutability.

Fig. 2 about here

Similarly, **Fig. 3** compares the relationship between investment cycle period (T) and the parameter b_2 across the examined regulatory scenarios. As in Fig. 2, the four curves correspond, from top to bottom, to the absence of regulation, EU-level regulation, moderate regulation, and strict regulation respectively. It can be observed that the duration of the investment cycle shortens as loan differentiation decreases, that is for higher values of the parameter b_2.

Fig. 3 about here

Table 1 summarizes the numerical results for the amplitude (μ) and period (T) of the investment cycle across the four regulatory regimes and varying degrees of loan substitutability (b_2). The findings suggest the existence of a dual stabilizing effect. Firstly, holding the market structure constant, a shift towards stricter macroprudential regulation systematically dampens cyclical volatility and shortens the cycle's duration. For instance, under maximum loan differentiation ($b_2 = 0$), moving from no regulation to strict regulation reduces the amplitude from 0.8710 to 0.8586, and the period from 9.81 to 9.34 periods. Secondly, increasing loan substitutability acts as an additional endogenous stabilizer. Within any given regulatory framework, transitioning from local monopolies ($b_2 = 0$) to perfect substitutes ($b_2 = b_1 = 1$) consistently yields lower values for both μ and T. Ultimately, the highest cyclical volatility is observed in unregulated, monopolistic loan markets, while the most accelerated cycles occur under strict regulation combined with perfectly substitutable loans.

TABLE 1: The investment cycle amplitude (μ) and period (T) under different regulatory scenarios.

	No Regulation ($\boldsymbol{\rho = 0}$)		**EU- Level Regulation ($\boldsymbol{\rho = 0.08}$)**		**Moderate Regulation ($\boldsymbol{\rho = 0.3}$)**		**Strict Regulation ($\boldsymbol{\rho = 0.6}$)**	
$\boldsymbol{b_2}$	**μ**	**T**	**μ**	**T**	**μ**	**T**	**μ**	**T**
0	0.8710	9.81	0.8695	9.75	0.8651	9.58	0.8586	9.34
0.1	0.8692	9.74	0.8675	9.67	0.8628	9.49	0.8557	9.24
0.2	0.8675	9.67	0.8657	9.60	0.8606	9.41	0.8530	9.15
0.3	0.8659	9.61	0.8640	9.54	0.8586	9.34	0.8505	9.06
0.4	0.8644	9.55	0.8625	9.48	0.8567	9.27	0.8481	8.99
0.5	0.8630	9.50	0.8610	9.42	0.8549	9.21	0.8458	8.91

0.6	0.8617	9.45	0.8596	9.37	0.8532	9.15	0.8436	8.85
0.7	0.8605	9.41	0.8582	9.33	0.8516	9.10	0.8415	8.78
0.8	0.8593	9.36	0.8570	9.28	0.8501	9.05	0.8395	8.72
0.9	0.8582	9.33	0.8558	9.24	0.8486	9.00	0.8377	8.67
1	0.8572	9.29	0.8547	9.20	0.8473	8.96	0.8359	8.62

Source: Own calculations using data from the ECB Statistics (European Central Bank, 2026)

5. Conclusions

This paper presents a framework to model the transmission channel of macroprudential regulation to investment cycle. To achieve this, we extend the SOA model, assuming that the speed of investment adjustment is a negative function of the lending rate. This rate is determined within the static Cournot banking sector characterized by product differentiation and regulatory capital requirements. A regulatory shift modifies the equilibrium lending rate, subsequently affecting the speed of investment adjustment. Through this mechanism, we assess whether tighter capital constraints dampen economic volatility, and how they influence the overall duration of the cycle.

These theoretical insights are strongly corroborated by numerical simulations calibrated using key Euro Area parameters over the 2007-2025 period. Our findings confirm that stricter macroprudential regulation indeed performs as a macroeconomic stabilizer. Specifically, by inducing a decrease in the lending rate, tighter regulatory policy accelerates the real sector's investment adjustment process, thereby dampening the amplitude of the investment cycle. Furthermore, our framework yields a policy trade-off: under the realistic structural characteristics necessary to generate business cycles, stricter capital requirements unambiguously compress the cycle's duration. Therefore, while macroprudential regulation shields the real economy from severe fluctuations, it leads to a higher-frequency investment cycle.

While our analysis presents this novel regulatory transmission channel, it relies on a static Cournot banking equilibrium, implying that the lending rate remains time-invariant over a given cycle. An interesting extension for future research is to introduce explicit time dynamics into the banking sector. This extension would provide a more complex framework where fluctuating credit conditions dynamically interact with investment inertia throughout the progression of the business cycle.

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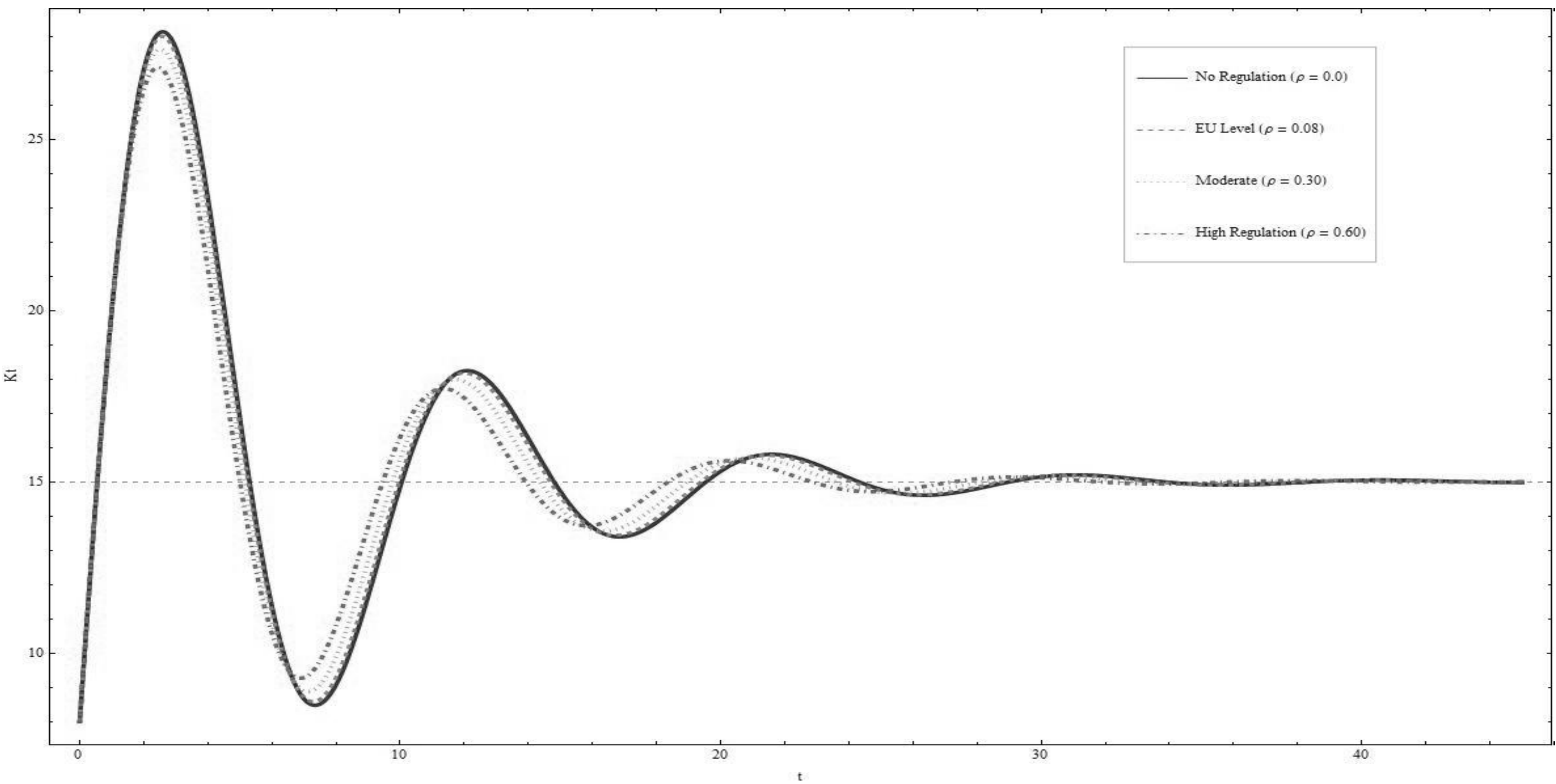

Figure 1: Time path of the actual capital (K_t) under different regulatory scenarios.

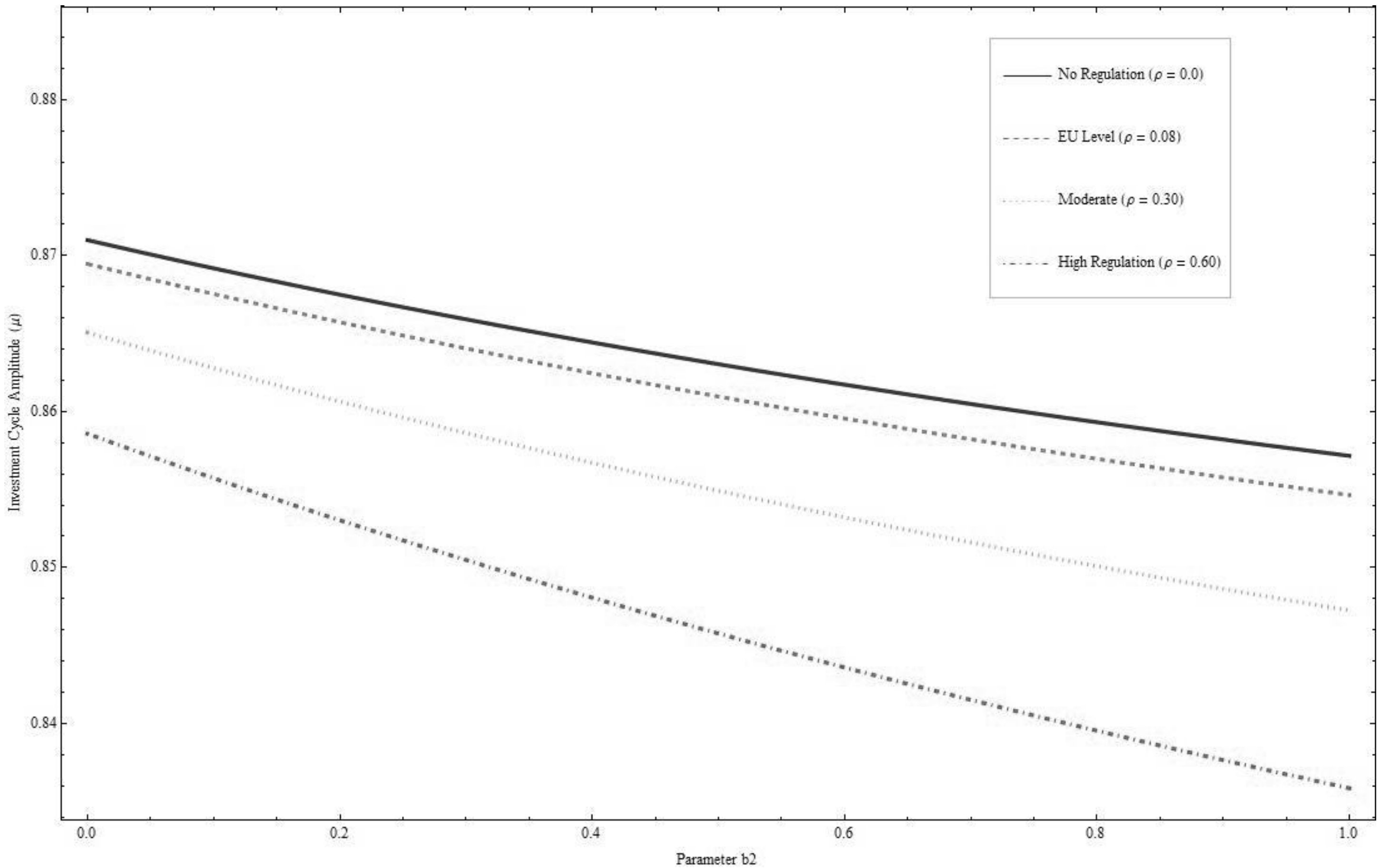

Figure 2: Investment cycle amplitude and loan substitutability under different regulatory scenarios.

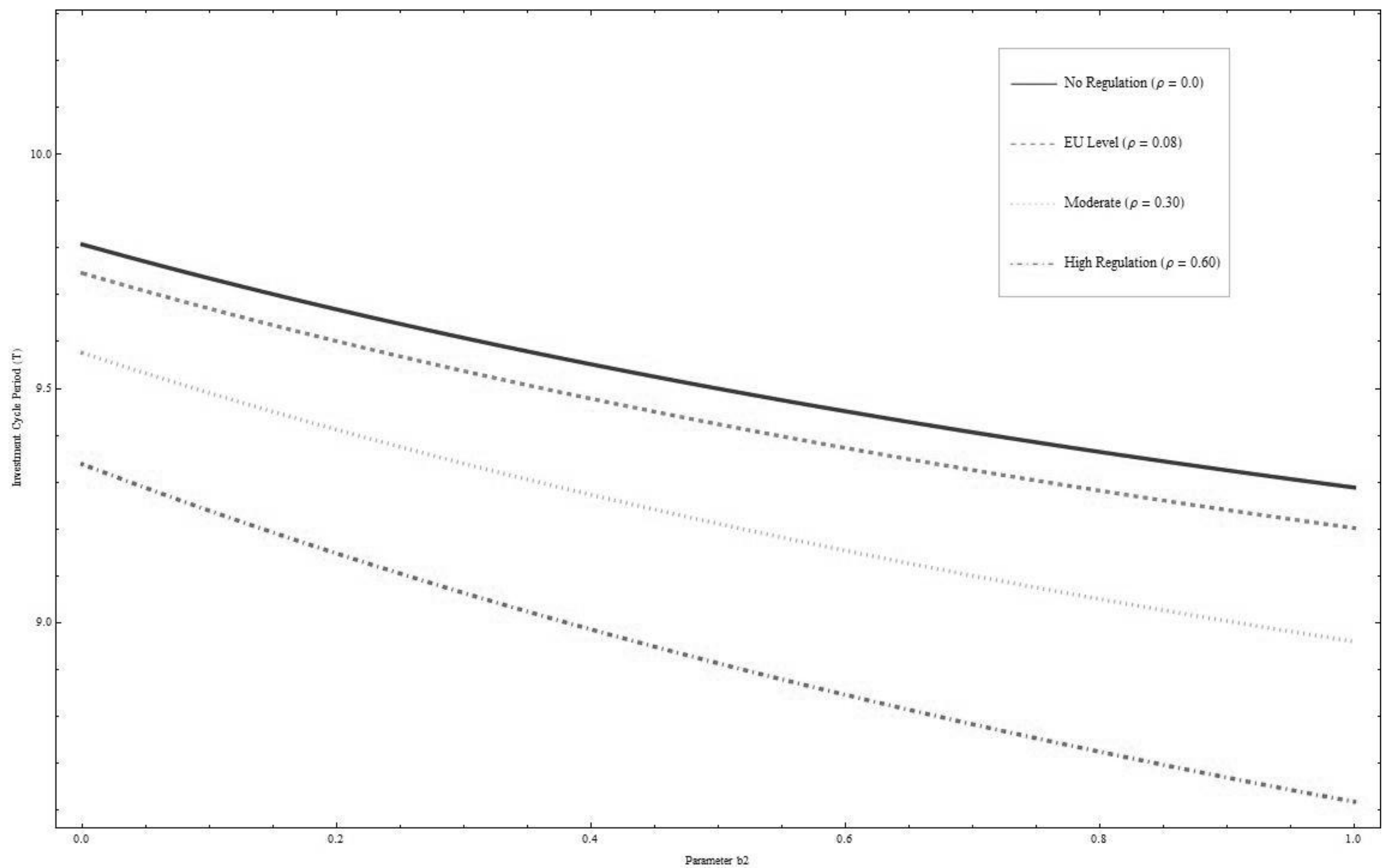

Figure 3: Investment cycle period and loan substitutability under different regulatory scenarios.