INTEREST RATES, HOUSEHOLD PORTFOLIO CHOICE AND ASSET PRICE CYCLES

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Abstract

The idea that low interest rates are the primary cause of fluctuations in output and price levels through credit expansion has long been argued in the literature. However, the monetary policy framework, composed of low interest rates and quantitative easing applied by the central banks of developed countries since the 1990s, caused fluctuations in asset prices and output around a trend rather than fluctuations in the price level. The existence of such a relationship between interest rates, credit demand, and asset prices is also supported by empirical studies. In this study, we developed a stock-flow consistent system dynamics model to understand the relationship between interest rates, output, and asset price cycles arising from household behavior. Results showed that there is a unique policy interest rate that stabilizes the economy, and that a deviation of the policy rate from this rate would result in fluctuations in aggregate income and asset prices.

Key Words: Monetary policy, asset price cycles, business cycles, nonlinear methods, simulation

JEL Classification: E32, E37, E40

FAİZ ORANLARI, HANEHALKI PORTFÖY SEÇİMİ VE VARLIK FİYATI DALGALANMALARI

Öz

Düşük faiz oranlarının kredi genişlemesi üzerinden gelir ve fiyat düzeyinde dalgalanmalara neden olabileceği literatürde uzun zamandan beri ileri sürülmektedir. Ancak özellikle 2008 küresel resesyonundan bu yana gelişmiş ülkelerin merkez bankalarının uyguladıkları düşük faiz ve niceliksel genişlemeyi içeren para politikası çerçevesinin, mal fiyatlarını dalgalandırmak yerine, gelirde ve finansal varlıkların fiyatlarında genel bir yükseliş trendi ile birlikte dalgalanmalara yol açtığı gözlenmektedir. Faiz oranları, kredi talebi ve varlık fiyatları arasında bu tür bir ilişkinin mevcudiyeti ampirik çalışmalar tarafından da desteklenmektedir. Bu çalışmada, faiz oranı, toplam gelir ve varlık fiyatı döngüleri arasındaki hanehalkı davranışından kaynaklanan ilişkiyi açıklamak için stok-akım tutarlı bir sistem dinamiği modeli geliştirilmiştir. Sonuçlar, ekonomiyi istikrara kavuşturan tek bir faiz oranının bulunduğunu ve politika faiz oranının bundan farklı olması halinde toplam gelirin ve varlık fiyatlarının dalgalandığını ortaya koymuştur.

Anahtar Sözcükler: Para politikası, varlık fiyatı çevrimleri, konjonktür dalgaları, doğrusal olmayan yöntemler, simülasyon.

JEL Sınıflandırması: E32, E37, E40

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1. Introduction

In the last few decades, interest rates have become the main monetary policy instrument used by central banks to achieve price stability. While the Taylor rule is the primary analytical framework that is used to understand the interaction of interest rates with the aggregate variables of the economy, such as output, unemployment, and the price level, efforts for understanding the macroeconomic effects of interest rates goes back more than a century in economics literature. One branch in the literature emphasized their role in the amount of credit demanded as the primary mechanism through which interest rates affect the whole economy. Wicksell was probably the first economist to formulate a monetary policy approach based on the interest rate rule (Woodford, 2003). Wicksell (2007 [1898]) particularly focused on the effects of interest rates on credit demand and claimed that low interest rates cause an increase in the price level through credit expansion. Wicksell discriminated the credit interest rate from the *natural rate*, which he defined as the interest rate that keeps commodity prices stable.[3] While the natural interest rate depends on the scarcity of savings, the credit interest rate is determined by the banking sector. When the credit interest rate decreases below the natural interest rate, entrepreneurs increase their credit demand for increasing their investments. Therefore, according to Wicksell, the primary reason for price fluctuations is the difference between these two rates (Fontana, 2007). Like Wicksell, Mises (1963, 1998 [1949]) argued that credit expansion, triggered by low interest rates, is the primary cause of business cycles.[4]

On the other hand, other studies suggest that interest rates affect the economy primarily through asset prices. For instance, Arestis and Sawyer (2011) claimed Wicksell's (2007 [1898]) argument could also be interpreted as interest rates affecting asset prices. Following this line of argument, low interest rates reduce borrowing costs, stimulate investments through credit demand and cause an increase in asset prices (Ubl, 2014). Barbera and Weise (2010) argue that the Wicksellian view also provides a powerful theoretical framework for analysing the Minsky's (1992) financial fragility hypothesis, which came up once again with the last global economic downturn after the 2007 mortgage market collapse. According to Minsky, the stability of the economy causes an increase in the risk appetite of investors, which leads them to overborrow. As a result, asset prices increase to unsustainable

[3] In his words, "*There is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them.*" (Wicksell, 2007 [1898])

[4] In his words, "*trade cycle*." (Mises, 1998 [1949])

levels (Palley, 2007). Supporting Minsky's argument, Roubini (2007) suggests that in periods of increasing risk appetites, investors' overborrowing and excess demand on financial assets cause a bubble in their prices and the debt service of investors depends on the continuous increase in the price of these assets. He adds that the major part of the subprime mortgage credits enters in the Ponzi debts, as was the case in the hi-tech bubble of the late 1990's. In that period, households increased their consumption by overborrowing and negative savings, which were financed by the consumer credits. Similarly, according to Nesvetailova (2007), in a boom period of the economy, financial agents miscalculate the risks with the contribution of financial innovations and risk management techniques, and as a consequence of resulting overoptimism, they demand high levels of credits. As a result, asset prices increase, entrepreneurs overinvest in physical capital and consumer expenditures increase in general.

Empirical studies support the existence of such a relationship between interest rate, credit demand, asset prices, and output. Mendoza and Terrones (2008) argue that macroeconomic data reveal the systematic relationship between credit booms and the rise of asset prices. Similarly, Chen, Kontonikas, and Montagnoli (2012) showed that cyclical components of interest rates, asset prices, credit and output are concurrent in the US. Dees (2016) studied data from 38 countries for the period between 1987 and 2013 and showed that the amount of credit and asset prices can explain real economic fluctuations. Claessens, Kose, and Terrones (2011) showed that a period of economic growth that is supported with credit and accompanied by an increase in asset prices is usually followed by a financial crisis.

When we look at the data after the 1980s, we observe that while interest rates dropped to low levels, commodity prices remained stable due to the transformation of the capitalist economic system[5]. Indeed, the average consumer price inflation in 5-year periods decreased from 4.7% to 1.7%, and its standard deviation fell from 2.3 to 0.7 in the US between 1981 and 2020.[6] Likewise, world consumer price inflation dropped from 8.7% to 2%, and its standard deviation dropped from 2% to 0.5% over the same periods.[7] The relative stability of the price level allowed and encouraged central banks of the major developed countries to

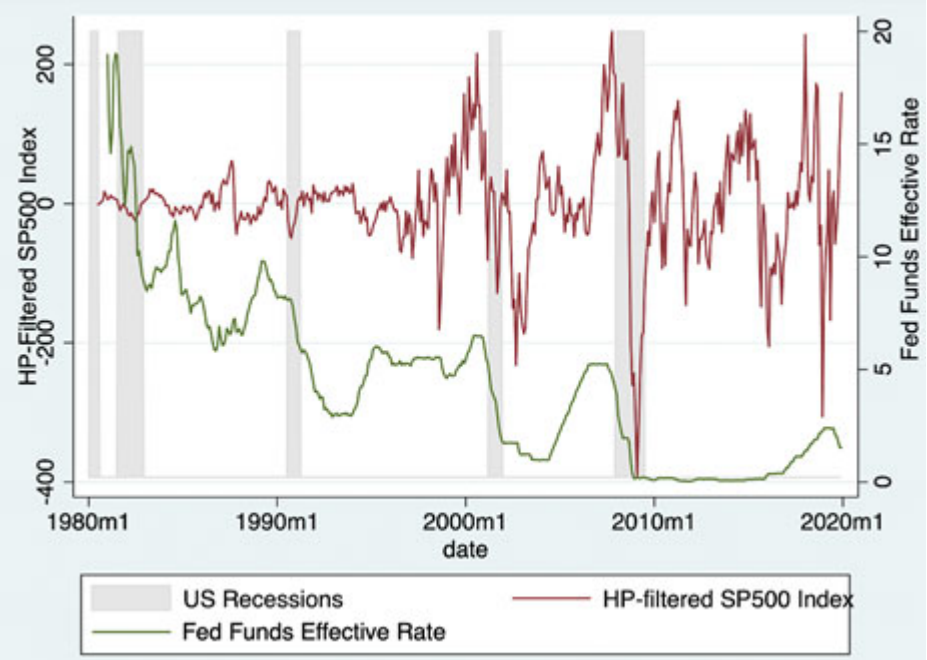
[5] Integration of China, India, and East Europe into the global market economy increased the global labor supply from 1.5 billion to 3 billion (Bean, 2006), resulting in downward pressure on wages worldwide. With the progress in communication and transportation technologies, the firms of developed countries could transfer their production facilities to low-cost countries, which enabled them to keep production costs low.

[6] The US Consumer Price Index (CPI) was retrieved from the FRED system of St. Louis Fed.

[7] The world consumer price inflation data was retrieved from the online data system of the Worldbank.

apply a loose monetary policy with low interest rates. Even though the excess liquidity that emerged due to the low interest rates has not caused price inflation, it flowed to financial assets such as equities, and the volatility of asset prices increased. The same pattern was evident in the period after the Great Recession of 2008, in which central banks of developed countries kept the interest rates low and applied further expansionary monetary policies to stimulate the economy. Figure 1 exhibits the time series for S&P 500 as being the most important equity index and the Fed funds effective rate as the policy rate of the central bank issuing the world reserve currency in the period 1980-2020.[8] Data shows that asset price volatility increases with a decrease in the policy interest rate, especially after the second half of the 1990s. Therefore, excess credit demand stimulated by low interest rates might have had destabilizing effects on asset prices.

Figure 1: The S&P500 and the Fed Funds Effective Rate Data in the US



[8] The Fed Funds Effective Rate data was retrieved from the FRED system of St. Louis Fed and S&P500 Index data was retrieved from finance.yahoo.com. Since long-term factors such as technological progress and economic growth create a trend in stock prices, we detrended the latter data using the HP filter.

In this study, we build a stock-flow-consistent system dynamics model to understand the interaction between interest rates, asset prices, and output. As data from the last 40 years suggests that household debt is more relevant than firm and government debt in explaining the movements in aggregate income (Mian and Sufi, 2018), we focus on the dynamics that emerge due to consumption, borrowing, and portfolio choice behaviors of households. Particularly, interest rates affect household behavior primarily through the portfolio choice between riskless deposits and risky equities. Asset prices are determined by households' portfolio choice, which has important repercussions on household consumption and borrowing behavior through wealth effects. The monetary authority can affect these dynamics through the determination of the policy interest rate. The solution of our model's dynamic equilibrium conditions shows that there is a unique interest rate that stabilizes the economy and the simulation results show that the deviation of the policy interest rate from its stabilizing level would cause continuous fluctuations in the economy.

This study's outline is as follows: After this brief introduction, in Section 2, we give a brief overview of the stock-flow consistent framework and system dynamics methodology we used in this paper. Then in Section 3, we exhibit our model. Section 4 presents the simulation results. Finally, Section 5 concludes the study.

2. Methodology

In this paper, we built a System Dynamics (SD) model based on the Stock-Flow Consistent (SFC) Framework. The SFC framework relies on a careful distinction between stock and flow variables. Each agent is represented with a balance sheet (stocks), and flows of goods and funds between them are recorded carefully. The SFC framework is particularly useful for elaborating on the financial relations between economic agents and their effects on the economy (Godley and Lavoie, 2006).

SD is a methodology that seeks to understand the dynamic behavior of complex adaptive systems consisting of nonlinear causal feedback relationships between their components (Forrester, 1961, 1969; Sterman, 2000). SD is based on the assumption that behaviors of complex systems emerge as a result of their structures; therefore, it focuses on the structural problems and behavioral patterns, such as growth, decline, and oscillation, that these systems are inclined to exhibit in the medium- to long-run (Barlas, 2007; Ford, 1999; Meadows, 1980, 2008).

The SFC framework and the SD methodology complement each other and can be used together to understand and simulate an economy's dynamic behavior consisting of nonlinear relationships among its sectors.

3. Model

The dynamic hypothesis is given in Figure 2. Arrows indicate causal relationships between the variables, and plus and minus signs indicate the direction of causality. Finally, double-bars on arrows indicate the existence of delays in the relationship. The important reinforcing and balancing feedback loops are labeled in red and green, respectively. We will elaborate on these feedback loops in the next section while explaining the simulation results.

There are four sectors in the model: households (*h*), firms (*f*), banks (*b*), and the central bank (*cb*). To focus on the dynamics of asset price cycles resulting from household behavior, we simplified the behavior of firms, banks, and the central bank. Additionally, the aggregate price level is normalized to 1 to focus on the asset price dynamics.

Variables in the model can be either stock or flow, denoted with a boldface font (***X***) and a regular font (*X*). Regarding stocks, we denote sectors that hold them as an asset on their balance sheet with a subscript and sectors that hold them as a liability with a superscript. As for the flows, we denote sectors for which the flow causes an increase in assets or a decrease in liabilities (use of funds) with a subscript; and sectors for which the flow causes an increase in liabilities or a decrease in assets (source of funds) with a superscript. Variables and parameters with a "tilde" ($\tilde{X}$) indicate their "desired" or "planned" levels, those with a "hat" ($\hat{X}$) indicate their target levels, and those with a "bar" ($\bar{X}$) indicate their normal or average levels. Finally, the estimated or expected value of a variable is denoted with an expectation function, *E[X]*.

The balance sheet and transaction matrices of the economy are given in Tables 1 and 2, respectively.

3.1.Households

Households hold consumer durables ($\boldsymbol{DR_h}$), bank deposits ($\boldsymbol{DP_h^b}$), and firm and bank equities ($\boldsymbol{EQ^f}$, $\boldsymbol{EQ^b}$) as assets; loans ($\boldsymbol{L_b^h}$), and net worth ($\boldsymbol{NW^h}$) as liabilities (Eq.1).

$$\boldsymbol{DR_h} + \boldsymbol{DP_h^b} + \boldsymbol{EQ^f} + \boldsymbol{EQ^b} = \boldsymbol{L_b^h} + \boldsymbol{NW^h} \quad (1)$$

Figure 2: The Dynamic Hypothesis

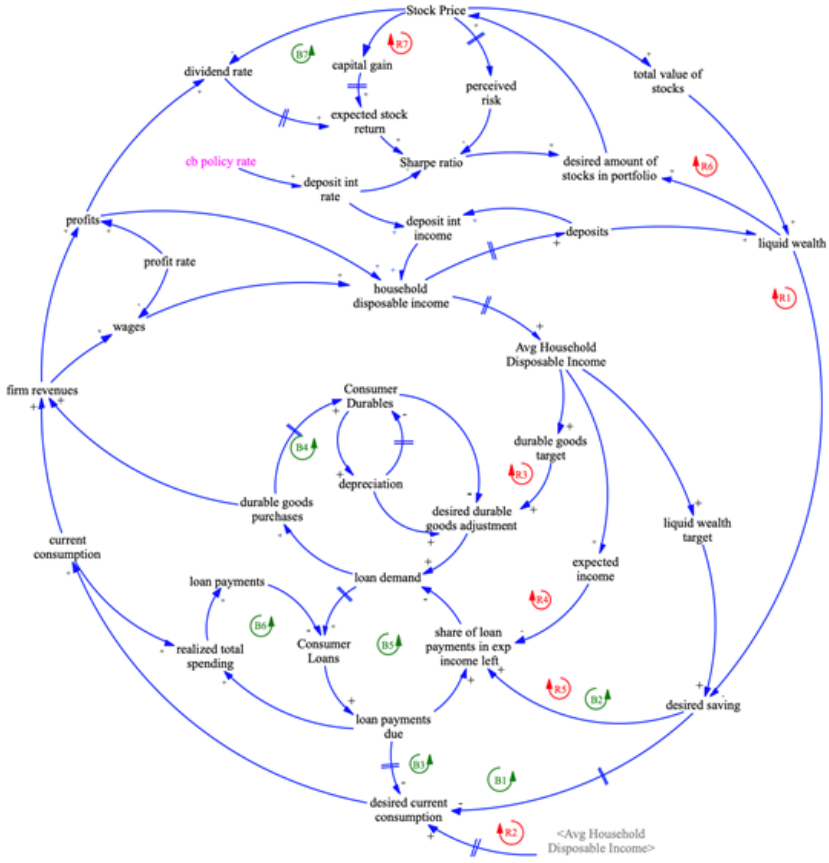


Table 1: The Balance Sheet of the Economy

	Households	Firms	Banks	Central Bank	Σ
Consumer Durables	$+DR_h$				$+DR_h$
Deposits	$+DP_h^b$	$+DP_f^b$	$-DP^b$		0
Equities	$+EQ_h$	$-EQ^f$	$-EQ^b$		0
Loans	$-L^h$		$+L_b$		0
Net Worth	$-NW^h$	$-NW^f$	$-NW^b$		$-DR_h$
Σ	0	0	0	0	0

Table 2: The Transaction Matrix of the Economy

	Households		Firms	Banks	Central Bank	Σ
	Current	Capital				
Current Consumption	$-C_o - CC^h$		$+C_o + CC_f$			0
Durable Purchases		$-CD^h$	$+CD_f$			0
Amortization	$-\delta DR_h$	$+\delta DR_h$				0
Wages	$+WB_h$		$-WB^f$			0
Profits and Dividends	$+DV_h + PR_h$		$-DV^f$	$-PR^b$		0
INTEREST ON:						
Bank Deposits	$+r^{dp}DP_h^b$		$+r^{dp}DP_f^b$	$+r^{dp}DP^b$		0
Loans	$-IP^h$			$+IP_b$		0
CHANGE IN STOCKS OF:						
Bank Deposits		$-\frac{a}{dt}DP_h^b$	$-\frac{a}{dt}DP_f^b$	$+\frac{a}{dt}DP^b$		0
Loans		$+\frac{a}{dt}L^h$		$-\frac{a}{dt}L_b^h$		0
Equities		$-\frac{a}{dt}EQ_h$	$+\frac{a}{dt}EQ^f$	$+\frac{a}{dt}EQ^b$		0
Σ	0	0	0	0	0	0

3.1.1. Household Income

Households receive wages (WB^f) from firms. Moreover, they own the equities of firms and banks; therefore, all their profits accrue to households ($q^s DV^f, PR^b$). Finally, households receive interest payments on their deposits (Eq.2).

$$Y_h = WB^f + q^s DV^f + PR^b + r^{dp}DP_h^b \quad (2)$$

Since we ruled out the government behavior from the model, household disposable income is equal to their income (Eq.3).

$$YD_h = Y_h \#(3)$$

Households rely on behavioral patterns while making decisions. The whole of these behavioral patterns is called the standard of living. We assume that the standard of living is determined by households' perceived average disposable income ($\overline{YD}_h$), which adjusts to the actual disposable income with a partial adjustment process over a period of T_1 (Eq.4).

$$\frac{d}{dt}\overline{YD}_h = \frac{1}{T_1}(YD_h - \overline{YD}_h) \#(4)$$

Households observe the growth rate of average disposable income over the period T_1 (Eq.5). The expected growth rate of perceived average disposable income is equal to the perceived average growth rate of average disposable income, which is updated with a partial adjustment process (Eqs.6 and 7).

$$g_h = \frac{YD_h}{\overline{YD}_h} - 1 \#(5)$$

$$\frac{d}{dt}\bar{g}_h = \frac{1}{T_1}(g_h - \bar{g}_h) \#(6)$$

$$E[\overline{YD}_h] = (1 + \bar{g}_h)\overline{YD}_h \#(7)$$

3.1.2. Portfolio Choice, Desired Saving, and Desired Discretionary Consumption

Households have a target wealth level, and it is a positive function of their standard of living (Katona, 1974; Pickering, 1993). Household wealth consists of three kinds of assets: consumer durables, bank deposits, and stock shares (equities). Consumer durables are illiquid assets that are held for consumer services (Mishkin, 1976). We assume that households target holding a constant multiple (ω_1) of their standard of living in the form of illiquid consumer durables ($\widehat{WI}_h, \widehat{DR}_h$) (Eqs.8 and 9).

$$\widehat{WI}_h = \widehat{DR}_h \#(8)$$

$$\widehat{WI}_h = \omega_1 \overline{YD}_h \#(9)$$

On the other hand, bank deposits and equities are liquid assets, the primary function of which is to preserve the purchasing power. The sum of these two comprises the liquid part of the wealth in the household portfolio ($\widehat{WL}_h$). We assume that households target holding a constant multiple (ω_1, ω_2) of their standard of living in the form of liquid assets (Eq.10).

$$\widehat{WL}_h = \omega_2 \overline{YD}_h \#(10)$$

Bank deposits and stock shares are heterogeneous in their risk and return profiles. Bank deposits are riskless assets as they pay interest at a constant rate (r^{dp}). In contrast, stock shares are risky assets as their return changes with time. Households determine the share of stocks to be held in the portfolio based on the Sharpe ratio (Eq.11).

$$SR = \frac{(r^s - r^{dp})}{\sigma_s} \#(11)$$

Here, r^s is the return and σ_s is the perceived risk of stock shares. The desired share of stocks in the portfolio is determined with an S-shaped logistic function (Eq.12). The rest of the portfolio is held in bank deposits (Eq. 13).

$$\widetilde{EQ}_h = \frac{1}{1 + e^{-\gamma_1 (SR - 1)}} \widetilde{WL}_h \#(12)$$

$$\widetilde{DP}_h^h = \widetilde{WL}_h - EQ_h \#(13)$$

The desired saving is determined with a stock-adjustment process (Eq.14). Households have a desire to save ($\tilde{S}_h$) out of their disposable income to close the gap between their target and actual levels of liquid assets in deposit adjustment time, T_2.

$$\tilde{S}_h = \frac{\widetilde{WL}_h - WL_h}{T_2} \#(14)$$

The remaining part of perceived average disposable income after necessities, loan payments due, and desired saving, if any, reflects the amount that households are willing to spare for discretionary consumption. However, the level of desired discretionary consumption ($\widetilde{CC}_h$) relies on habits, and, since habit formation takes time (Katona, 1974), it adjusts slowly to new levels over a period of T_3 (Eq.15).

$$\frac{d}{dt} CC_h = \frac{max\left[(\widetilde{YD}_h - C_0 - \widetilde{DP}_h - \tilde{S}_h), 0\right] - \widetilde{CC}_h}{T_3} \#(15)$$

3.1.3. Planned Consumer Durables Demand and Loan Demand

Consumer durables demand is commonly modelled with a stock-adjustment mechanism (Grieves, 1983; Hymans, 1970; Juster & Wachtel, 1972; Mishkin, 1976). In order to reach the consumer durables target in consumer durables adjustment time (T_4), households have a desire to purchase some part of the difference between the actual and target levels, in addition to the depreciated stock (Eq.16).

$$\widetilde{CD}_h = \frac{\widetilde{DR}_h - DR_h}{T_4} + \delta DR_h \#(16)$$

We assume that consumers finance all of their consumer durables purchases with loans. Therefore, the primary determinant of loan demand is the desired consumer durables purchases. Another factor affecting loan demand is the share of loan payments due (Θ) in expected income left after desired saving and necessities (Eq.17).

$$\Theta = \frac{\overline{LP}_h}{E[YD_h] - C_0 - \overline{S}_h} \#(17)$$

We assume that households want to limit their loan payments to a certain share ($\bar{\Theta}$) of their expected income left after desired savings and necessities. The actual share of loan payments relative to the desired share of loan payments affects the new loan demand via an inverse-S-shaped function (Eq.18). As the actual share of loan payments increases relative to its desired level, the loan demand decreases (Eq.19).

$$\Phi = f\left(\frac{\Theta}{\bar{\Theta}}\right) \#(18)$$

$$LD_h = \Phi \overline{CD}^h \#(19)$$

The realized consumer durables purchases are determined by the total amount of loans granted to households by banks (Eq.20).

$$CD^h = LR_h \#(20)$$

As consumer durables depreciate at a constant rate (δ), the change in consumer durables stock is equal to the difference between consumer durables purchases and depreciation (Eq.21).

$$\frac{d}{dt} DR_h = CD^h - \delta DR_h \#(21)$$

3.1.4. Realized Consumption and Realized Loan Payments

The sum of necessities (C_0), desired discretionary consumption ($\overline{CC}^h$), and loan payments due ($\overline{LP}^h$) constitute the desired total spending ($\overline{TS}^h$) of households (Eq.22).

$$\overline{TS}^h = C_0 + \overline{CC}^h + \overline{LP}^h \#(22)$$

We assume that households are willing to hold a multiple of their desired total spending as a buffer ($\bar{\Upsilon}$) in order to be able to maintain the current level of spending at least for some time in case of an income loss. The actual level of buffer-stock ratio (Υ) is found as the ratio of the current level of bank deposits to desired total spending (Eq.23).

$$\Upsilon = \frac{DP_h^h}{\overline{TS}^h} \#(23)$$

Households determine the realized total spending based on the actual level of buffer-stock ratio relative to its desired level with an S-shaped function (Eq.24). As the actual buffer-stock ratio decreases towards the desired level, households will increasingly cut their spending. However, since they have to pay for necessities in all circumstances, this spending cut does not apply to necessities (Eq.25).

$$\Lambda = f\left(\frac{\Upsilon}{\overline{\Upsilon}}\right) \#(24)$$

$$TS^h = \Lambda\left(\overline{CC}^h + \overline{LP}^h\right) + C_0 \#(25)$$

Households use the realization ratio of total desired spending after necessities (Λ) to allocate the amount to be spent between loan payments and discretionary consumption with an S-shaped function (Eqs.26 and 27). As the realization ratio decreases, the decrease in the amount spared for loan payments increases.

$$\Gamma = f(\Lambda) \#(26)$$

$$LP^h = \Gamma\Lambda\overline{LP}^h \#(27)$$

The amount of realized total spending left after realized loan payments and necessities is spent for discretionary consumption (Eq.28).

$$CC^h = TS^h - LP^h - C_0 \#(28)$$

Households' total consumption is equal to the sum of necessities, discretionary consumption, and, consumer durables purchases (Eq.29).

$$C^h = C_0 + CC^h + CD^h \#(29)$$

3.1.5.Realized Savings

Households' realized savings (S_h) is equal to the difference between cash inflows and cash outflows (Eq.30).

$$\frac{d}{dt}DP_h^h = S_h = YD_h - TS^h \#(30)$$

3.2.Firms

In order to focus on the dynamics of consumption, we simplify the behavior of firms. Firms do not have any physical capital and use labor as the only factor in production. We assume that firms always have enough capacity to meet consumer demand and do not hold inventory. The total demand for the goods that firms produce is equal to total household consumption. Since firms meet all the demand for their goods by assumption, their sales are equal to total demand. Firms also receive interest income for their deposits in the bank. Hence, their total revenue (R_f) is equal to the sum of their sales and interest income (Eq.31).

$$R_f = C^h + r^{dp} DP_f^b \#(31)$$

Firms hold bank deposits (DP_f^b) as assets for receiving and making payments. The net change in firms' bank deposits is equal to the difference between total revenues and wage and profit payments in the current period (Eq.32).

$$\frac{d}{dt} DP_f^b = R_f - WB^f - PR^f \#(32)$$

Households hold all the equities of firms in the form of stock shares. The number of outstanding shares (q^s) is constant, and they trade in the stock market. Therefore, the value of firm equities (EQ^f) changes with the stock prices (p^s) (Eq.33).

$$EQ^f = q^s p^s \#(33)$$

We assume that labor is the only input in the production process, and the profit rate (π) is constant and exogenous to the economy. Firms do not retain any part of their profits (PR_f). Therefore, all firm revenues are distributed to households in the form of either wage (WB^f) or dividends (DV^f) with a constant delay (Eqs.34-36).

$$PR^f = \pi R_{f-1} \#(34)$$

$$DV^f = \frac{PR^f}{q^s} \#(35)$$

$$WB^f = (1-\pi) R_{f-1} \#(36)$$

3.3.The Stock Market

The return of stocks (r^s) is equal to the sum of the dividend rate (d) and the rate of capital gain (g^s) (Eq.37-39).

$$r^s = d + g^s \#(37)$$

$$d = \frac{DV^f}{p^s} \#(38)$$

$$g^s = \frac{1}{p^s}\frac{d}{dt}p^s \#(39)$$

The expected stock return is updated with a partial adjustment mechanism over a period of T_s (Eq.40).

$$\frac{d}{dt}E[r^s] = \frac{r^s - E[r^s]}{T_s} \#(40)$$

Because of the fluctuations in the stock price, stock returns are volatile; hence, stocks are risky assets. The perceived risk of stocks is calculated as the square root of average squared deviance of stock price from their expected values and updated with a partial adjustment process over a period of T_σ (Eq.41). However, we assume a minimum perceived risk of stock return ($\bar{\sigma}_s$), which arises from the long-run behavior of stock returns beyond the time scope of the model and taken as exogenous (Eq.42). The empirical finding of equity premium can be interpreted as an evidence for the existence of such a floor for the perceived risk on equities.

$$\frac{d}{dt}(\sigma_s^r)^2 = \frac{1}{T_\sigma}(r^s - E[r^s])^2 \#(41)$$

$$\sigma_s = max[\sigma_s^r, \bar{\sigma}_s] \#(42)$$

Stock shares are traded in the stock market. Since the economy is a closed system, they are exchanged among households against bank deposits. People willing to sell stock shares can only trade at the prices other people are willing to buy them, which is determined by the share of stocks desired to be held in the portfolio. Since stock shares are traded quickly, the stock price adjusts to this level (Eq.43). As bank deposits are transferred between sellers and buyers of shares, the total amount of deposits in the economy does not change as a result of this trade.

$$\frac{d}{dt}p^s = \frac{\overline{EQ}^f}{q^s} - p^s \#(43)$$

3.4.Banks

As is the case for firms, we simplify bank behavior to focus on the dynamics arising due to household behavior. Specifically, we assume that banks provide all the loans demanded by households (Eq.44).

$$LR_h = LD_h \#(44)$$

Bank loans are amortized loans. Principal payments due ($\overline{FP}^h$) and interest payments due ($\overline{IP}^h$) are calculated based on the outstanding loan stock (L_b^h) as in Eqs.45 and 46, respectively. Therefore, the total loan payments due (LP^h) is equal to the sum of these two amounts (Eq.47).

$$\overline{FP}^h = \varphi L_b^h \#(45)$$

$$\overline{IP}^h = r^{ln} L_b^h \#(46)$$

$$\overline{LP}^h = \overline{FP}^h + \overline{IP}^h \#(47)$$

Here, φ is the loan principal payment rate, and r^{ln} is the loan interest rate. The loan interest rate is assumed to be determined by banks with a markup rate (μ) over the deposit interest rate (Eq.48).

$$r^{ln} = (1 + \mu) r^{dp} \#(48)$$

where $\mu > 0$. Without loss of generality, the deposit interest rate is assumed to be equal to the central bank policy interest rate (Eq.49).

$$r^{dp} = r^{cb} \#(49)$$

Banks collect loan payments (LP^h) from households; however, the realized payments might be different from the payments due. In that case, we assume that the realized payments are first counted towards the interest part, then the remaining part, if any, is counted towards principal payments.

Banks pay interest on household and firm deposits (DP_h^b, DP_f^b) and receive interest payments from households for outstanding loans (IP^h). We assume that banks do not use any inputs for the services they produce. Banks' profits are then equal to the difference between their interest income and interest payments (Eq.50). Banks are private companies entirely owned by households. Banks do not retain any part of their profits; hence, all of the bank profits accrue to households with a constant delay.

$$PR^b = IP_{-1}^h - r^{dp}(DP_{h-1}^b + DP_{f-1}^b) \#(50)$$

3.5.The Central Bank

The central bank does not have any assets or liabilities. The central bank conducts the monetary policy by changing the policy interest rate (r^{cb}) independently.

4. Simulation Results

The initial values of stock price and standard of living variables are normalized to 1. The time unit of the simulation is chosen as months. The model is then simulated for the baseline, the interest rate cut, and the interest rate hike scenarios. Since the dynamics of the model are qualitatively the same, the results are limited to 250 months to increase the readability of the graphs.

4.1.The Baseline Scenario

The model is solved for the dynamic equilibrium conditions where all the stocks are stable. Notably, equilibrium conditions exhibited a unique central bank policy interest rate that stabilizes the economy, given other exogenous parameters. The stabilizing level of the policy interest rate ($\bar{r}^{cb}$) is equal to the difference between the dividend rate and households' perceived minimum risk of equities, making households indifferent with regard to equities and deposits in their portfolio given their perceived risk and return characteristics (Eq.51). Referred to as the equity premium, the higher return of equities compared to risk-free assets is well-evidenced in the literature. The stabilizing level of the policy interest rate is similar to the natural interest rate concept of Wicksell. However, since we assume the aggregate price level to be constant, here, the interest rate is the one that stabilizes the asset prices.

$$\bar{r}^{cb} = d - \bar{\sigma}^2 \# (51)$$

In the baseline scenario, all the stocks are initiated at their equilibrium values. The simulation results showed that all the variables stay at their equilibrium values over the simulation period (Figure 3).

4.2.The Interest Rate Cut Scenario

In the interest rate cut scenario, all the stocks are initiated at their equilibrium values. Then at period 50, the central bank cuts the policy interest rate by 25%, relative to its initial level. The dynamic behavior of the key variables in the economy are presented in Figure 4. The mechanism of a cycle after the rate cut can be described as follows. The feedback loops that play a role in the mentioned process are given in parentheses, which are indicated in Figure 2.

Figure 3: Dynamics of Disposable Income and Stock Price in the Baseline Scenario

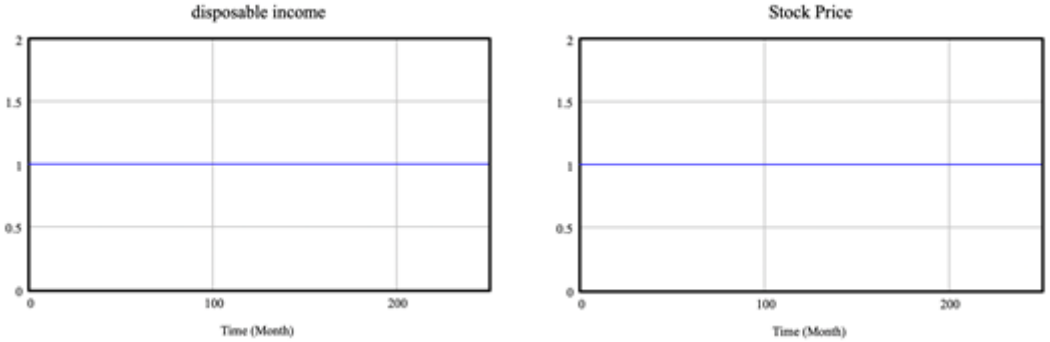
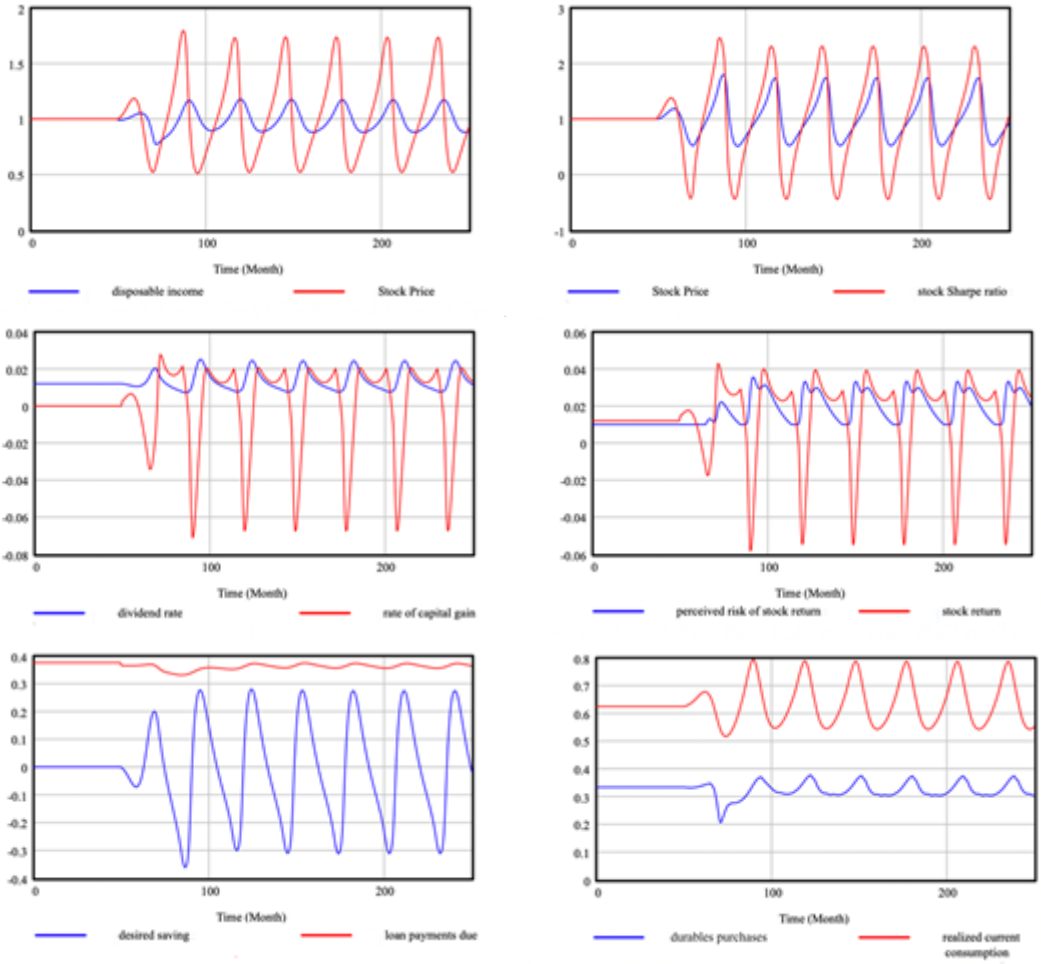


Figure 4: Dynamics of the Key Variables in the Interest Rate Cut Scenario



When the central bank cuts the policy interest rate, the relative return of equities rises, the Sharpe ratio increases, and households increase the share of equities in the portfolio. The stock price increases accordingly as a result of higher demand. The higher stock price causes an increase in households' liquid wealth, and, hence, households become less willing to save due to the wealth effect (R1). Moreover, the loan interest payments burden falls due to the fall of the loan interest rate. Both of these effects increase discretionary household consumption, which causes an increase in household income (R2). With the accompanying increase in the standard of living and consumer durables target, households' demand for consumer durables and hence, for credits, increase, reinforcing the increase in household income (R3). Even though the cut in the policy interest rate causes a decrease in the deposit interest rate and, hence, a decrease in household deposit interest income, this negative effect on household income is overwhelmed by the above-mentioned positive effects as the size of interest income is small comparing to wage and profit income.

As long as the stock price increases, households benefit from a capital gain on equities in their portfolios (R7). On the other hand, even though firm profits increase in parallel to household income, since the stock price increases faster, the dividend rate decreases (B7). With the resulting slow-down in capital gains, the stock return starts to fall after reaching a maximum point (B7>R7). As households update their expectations on stock returns, they start to decrease the weight of stocks in their portfolio. When this negative effect overcomes the positive effect of the increase in household income on liquid wealth (R6), the stock price starts to fall (B7>R6, R7).

The fall in liquid wealth resulting from falling stock prices puts upward pressure on desired savings (R1). The increase in liquid wealth target due to the increase in the standard of living reinforces this effect (B1), and desired saving starts to increase once again. Furthermore, consumer durables purchases cause an increase in the consumer loan stock and, hence, in loan payments due (B3). The discretionary household consumption starts to fall as a result of these effects. When the negative effect of discretionary consumption overcomes the positive effect of consumer durables purchases (R3), household income starts to fall (R1, B1, B3>R2, R3).

Soon after the household income starts to decrease, along with the fall of the standard of living and consumer durables target, consumer durables purchases start to decrease (R3). Moreover, as expected disposable income decreases, the share of loan payments in expected income increases (R4). The upward pressure on desired savings resulting from the negative effect of decreasing household income on liquid wealth reinforces this effect (R5),

and the credit constraint eventually steps in (B5). As a result, consumer durables purchases start to fall, which reinforces the decrease in household income.

Since stock prices fall faster than household income, the dividend rate increases once again, which slows down the decrease in stock prices (B7). With the resulting slow-down in the capital loss, stock returns start to increase after reaching a minimum point (B7>R7). As households adjust their expected returns, the Sharpe ratio starts to increase, and households have a desire to increase the share of equities in the portfolio. When the positive effect of the increase in the Sharpe ratio overcomes the negative effect of the decrease in household income on liquid wealth (R6), the stock price starts to increase once again (B7>R6, R7).

The increase in the stock price increases the liquid wealth, which puts downward pressure on desired savings (R1). The decrease in liquid wealth target because of the decrease in the standard of living (B1) reinforces this effect. Moreover, loan payments due decreases because of the decrease in consumer durables purchases resulting from both the decrease in the standard of living (B3) and the effect of the credit constraint (B5). As a result of these effects, discretionary household consumption starts to increase. When this positive effect overcomes the negative effect of the decrease in consumer durables purchases (R3), household income starts to increase once again (R1, B1, B3>R2, R3).

Soon after household income starts to increase, as consumer durables target increases (R3) and credit constraint loosens (R4, R5, B5), consumer durables purchases start to increase once again, reinforcing the increase in household income. Thus, as both household income and stock price increase, the cycle starts over.

The description above shows that it is mainly the stock price fluctuations that lead to household income fluctuations. The stock price changes because of households' portfolio selection behavior based on adaptive expectations in both relative return and risk of equities. The stock prices then affect household consumption, saving, borrowing, and debt payment decisions through household wealth. While household portfolio and stock price immediately adjust to new levels, the effects running through household income can only follow slowly with a delay. It reflects itself as firm profits, hence, the dividend rates not being able to keep up with the expected stock returns. Therefore, the difference between the adjustment speeds of the behaviors creates continuous fluctuations in the economy. Indeed, Figure 5 shows that a reduction in the adjustment speed of the household portfolio stabilizes the economy. Specifically, the amplitude of fluctuations decreases and the transition to new levels smoothens as the household expected return adjustment time (T_5) increases. In brief, the less reactive households are to changes in the stock price while adjusting their portfolio, the more stable the economy is.

We simulated the model for 10%, 50%, and 75% cuts relative to the initial policy rate to see the effect of changes in the rate of the interest rate cut on the variables' dynamics. The dynamic behaviors of the household disposable income and stock price are shown in Figure 6. Albeit mildly, the amplitude of fluctuations in the stock price increases with the rate of change in the policy rate, because the decrease in the policy interest rate erodes the power of the feedback loops involving the credit constraint (B2, B3, B5), and the consumer loan stock reaches higher levels before the balancing effects of these loops assert themselves in the dynamics. On the other hand, the average level of household disposable income increases as the rate of change in policy rate increases. This is because households can spare more of their disposable income for consumer loan principal payments due to the decrease in loan interest payments, allowing for a higher consumer durables stock that they can sustain on average. Hence, the lower the policy interest rate, the higher the consumer durables stock and household income.

4.3.The Interest Rate Hike Scenario

In the interest rate hike scenario, all the stocks are initiated at their equilibrium values. Then at period 50, the central bank raises the policy interest rate by 25% relative to its initial level. The dynamic behaviors of the key variables in the economy are presented in Figure 7.

Figure 5: Sensitivity Analysis for Household Expected Stock Return Adjustment Time in the Interest Rate Cut Scenario

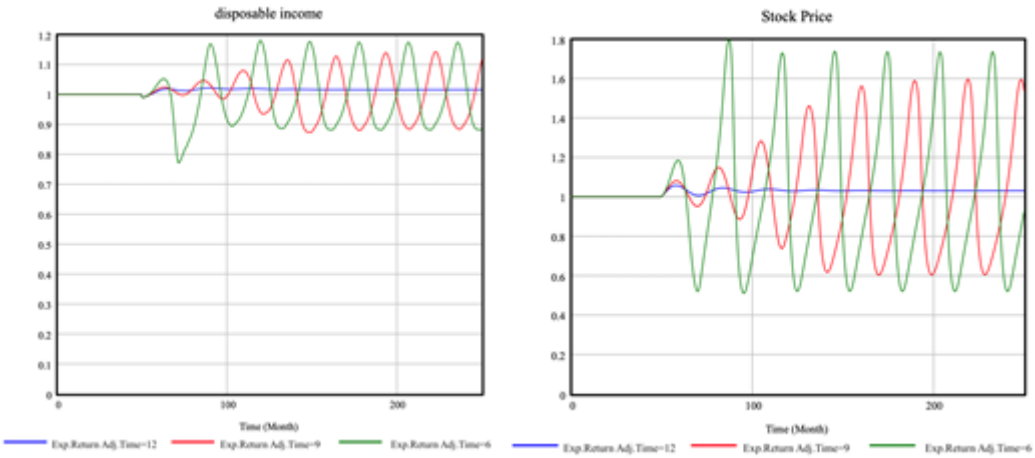
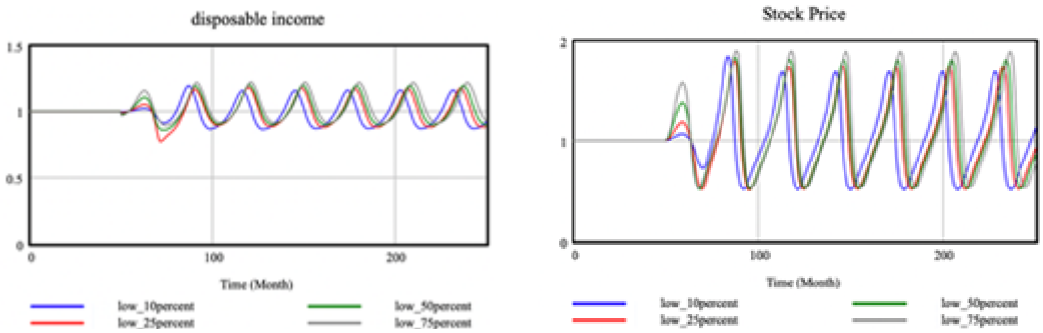


Figure 6: Dynamics of Key Variables for Different Rates of Interest Rate Cut



The dynamic behaviors of the variables in the economy are almost the mirror image of the ones in the interest rate cut scenario. However, there is one notable difference. When the economy is at the bottom of the cycle, it is the recovery of consumer durables rather than discretionary consumption which leads to the recovery of household income. The recovery of discretionary consumption occurs only after the recovery of household income. This is because the credit constraint loop (B5) gains strength with the interest rate. As loan payments due increases faster because of the increased loan interest payments due, the credit constraint becomes more binding at the cycle's downturn. However, as the consumer loan stock decreases more rapidly with low levels of loan demand, the credit constraint also loosens faster, and consumer durables purchases start to recover. In brief, the speed of change in consumer durables purchases increases with interest rates due to the nonlinear nature of the credit constraint.

As in the interest rate cut scenario, an increase in the household expected return adjustment time, namely, a slow-down in the household portfolio adjustment process, stabilizes the economy (Figure 8).

Figure 7: Dynamics of the Key Variables in the Interest Rate Hike Scenario

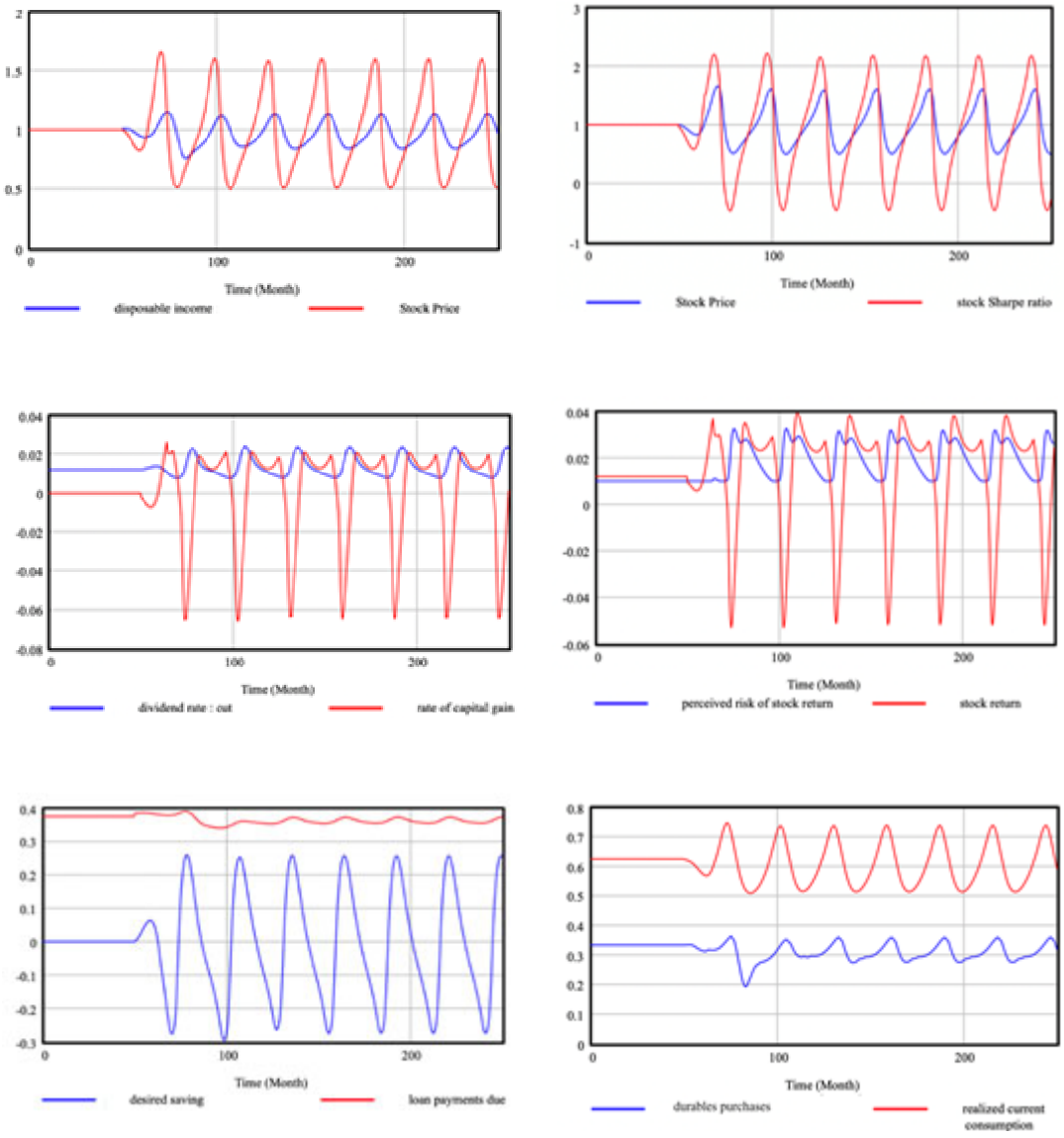


Figure 8: Sensitivity Analysis for Household Expected Stock Return Adjustment Time in the Interest Rate Hike Scenario

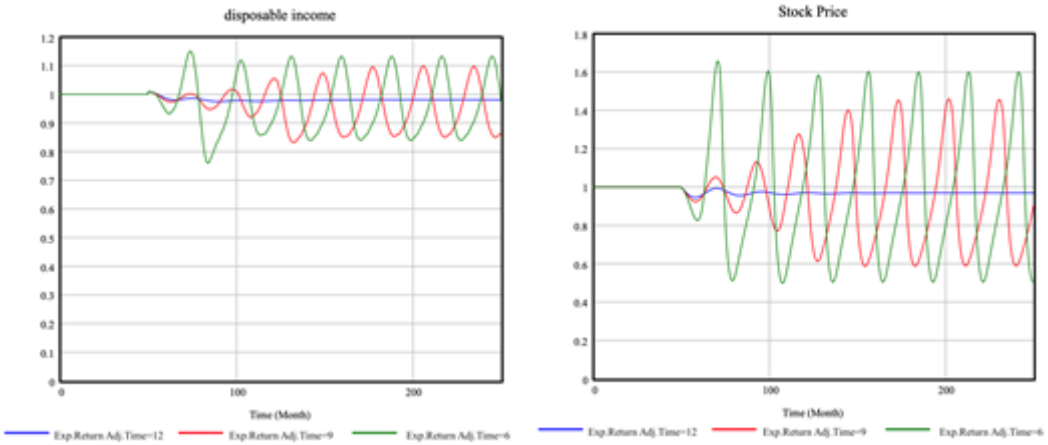
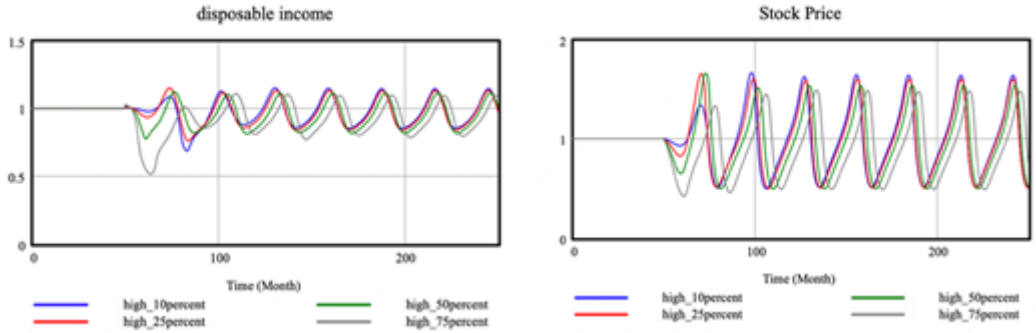


Figure 9: Dynamics of Key Variables for Different Rates of Interest Rate Hike



The model is also simulated for 10%, 50%, and 75% hikes relative to the initial policy rate to see the effect of changes in the rate of the interest rate hike on the dynamics of the variables. The dynamic behaviors of the household disposable income and stock price are shown in Figure 9. Again, the amplitude of fluctuations in the stock price decreases mildly with the rate of hike in the policy rate, because the increase in the policy interest rate empowers the feedback loops involving the credit constraint (B2, B3, B5), which prevents the consumer loan stock from reaching higher levels before the balancing effects of these loops assert themselves in the dynamics. On the other hand, the average level of household disposable income decreases with the rate of hike in the policy rate. This is because house-

holds can spare less of their disposable income for consumer loan principal payments due to the higher loan interest payments, limiting the consumer durables stock that households can sustain on average. Therefore, as in the interest rate cut scenario, the lower the interest rate, the higher the consumer durables stock and household income.

5.Conclusion

The interest rate has become the primary monetary policy instrument in the central banks of the major developed countries. After the 1990s, most of these central banks kept interest rates low and applied an expansionary monetary policy. In this period, while commodity prices remained relatively stable, the volatility of asset prices increased.

In this study, we built a stock-flow-consistent system dynamics model to understand the interaction between the interest rate and asset prices arising from household behavior. Specifically, the interest rate affected households' portfolio choice, which affects their consumption, saving, borrowing, and debt payment decisions through the wealth effect. The solution of the dynamic equilibrium conditions of the model showed a unique policy interest rate that stabilizes the economy by stabilizing the portfolio choice of households. The simulation results showed that the stock price and household income fluctuate when the policy interest rate is different from the stabilizing interest rate. The amplitude of fluctuations increases as the policy interest rate decreases because the lower interest rates erode the power of the balancing feedback loops involving the credit constraint. On the other hand, the average level of household income and the stock price increase as the policy interest rate decreases. This is because households can spare more of their disposable income for consumer loan principal payments when the interest rate is low, which allows for higher consumer durables and consumer loan stocks that they can sustain on average. The primary structural cause of the economy's continuous fluctuations is the difference between the adjustment speeds of household portfolio adjustment and other household behaviors. A slowdown in the households' portfolio adjustment process stabilizes the economy.

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