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Dynamic Monetary Policy:
Preventing Bubbles and Promoting Growth

by

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Abstract

We present a new paradigm for monetary policy based on a dynamic price index (DPI). Traditionally, central banks have used a static price index such as CPI for monetary policy. However, CPI fails to capture the intertemporal cost-of-living and the dynamic aspect of inflation. This myopic failure has often led to financial bubbles and economic crises. A dramatic example is Japan's bubble burst in 1990, from which Japan could not recover for decades. Such policy mistakes can be avoided if central banks use DPI, which captures dynamic inflation and deflation adjusted for productivity changes. We propose a dynamic monetary policy with an optimal DPI target zone that can prevent bubbles and promote growth.

Keywords: monetary policy, information variable, intertemporal cost-of-living, inflation, capital price, bubble, crisis, growth, stability, FRB, BIS, target zone, Consumer Price Index (CPI), Dynamic Price Index (DPI)

Ⅰ. Introduction

In recent years, central banks around the world have experimented with a variety of "unconventional" monetary policies including inflation targeting, quantitative easing (QE), quantitative and qualitative easing (QQE), forward guidance, yield curve control, and a negative interest rate policy. Nevertheless, there is one conventional practice that central banks have never changed: the use of a static one-period price index such as CPI. In spite of experimenting with many "unconventional" policies, central banks have continued using CPI as the main information variable for monetary policy. Even "inflation targeting" remains conventional in that the target rate of inflation is set in terms of CPI. In short, all central banks around the world have consistently relied on a very conventional static one-period price index (CPI) for monetary policy.

The concept of present value is widely used in all areas of economics. For example, the present value of future returns is the key concept for financial economics and corporate finance. The reason is that firms cannot make good investment decisions without an appropriate estimate of the present value of future returns that will be generated by the planned investment. Moreover, the price of an asset is determined (defined) by the present value of its future returns.

All fields of economics today make use of the concept of present value with one big exception. That exception is monetary policy. When it comes to monetary policy, the use of present value has never been seriously considered with a few notable exceptions (see below), although it is one of the most important subjects because its impact on the real economy can be very significant in the short and intermediate run. We must correct this major shortcoming in monetary policy. Indeed, we will argue that a central bank conducting monetary policy based on a static one-period price index (CPI) is equivalent to a firm making investment decisions based on the return in one period only.

We will propose the use of a dynamic multi-period price index to improve the performance of monetary policy. We will argue that Dynamic Price Index (DPI) based on the present value of a multi-period cost-of-living is a true indicator of the dynamic trend of inflation. The idea of an "intertemporal cost-of-living" was initially proposed by Pollak (1971, 1975) and Alchian and Klein (1973). Their idea of an "intertemporal cost-of-living" was adapted in

Shibuya (1992), which developed a dynamic price index that theoretically includes capital (asset) prices. Shibuya (1992) called it Dynamic Equilibrium Price Index (DEPI), but we will refer to it as Dynamic Price Index (DPI) in this paper forward. The purpose of creating DPI was to improve the performance of monetary policy, in particular, for central banks to prevent financial bubbles and economic crises.

The use of DPI as an information variable for monetary policy resolves one of the major debates among central bankers as well as economists. That is the question of how central banks should respond to capital (asset) prices in conducting monetary policy. Should central banks take capital prices into account? Should they try to prevent capital price bubbles even if it might hinder investment and economic growth? Or should they aim at promoting growth without worrying about potential bubbles and financial crises? Should they deal with bubbles only after they actually burst so as not to kill productivity booms?

There are two opposing views about the role of capital prices in monetary policy: one is popular at the Federal Reserve Board (FRB) and another at the Bank for International Settlements (BIS). The FRB view holds that central banks should not target capital (asset) prices because tight monetary policy will constrain economic activities (in particular, investment and productivity booms) and thus economic growth.[1] In contrast, the BIS view holds that central banks should take potential capital price bubbles into account because they will cause costly financial crises when they burst. Then, the economy will fall into balance-sheet recessions and thus disrupt normal growth.[2] In short, the FRB view emphasizes *growth* while the BIS view emphasizes *stability*.

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1) See, for example, Bernanke and Gertler (2001) and Greenspan (2004)
2) See, for example, BIS (2014) and Borio (2014).

To integrate the FRB and BIS views, we will propose a dynamic monetary policy with an optimal DPI target-zone. The monetary policy that maintains the DPI inflation rate within an optimal target zone resolves the conflict between the FRB and BIS views. It achieves an optimal balance between growth and stability. In other words, DPI target zone monetary policy will prevent capital price bubbles and promote economic growth, thus resolving the apparent conflict between the two views.

We will argue that DPI target zone monetary policy should replace conventional CPI inflation targeting. The first advantage of DPI target zone monetary policy is that DPI captures the intertemporal cost-of-living and thus the dynamic aspect of inflation. The second advantage is that the DPI target zone does not need frequent policy interventions. Some degree of DPI variations and thus productivity booms would be allowed. The third advantage is that, as we have already mentioned, it can achieve an optimal balance between growth and stability.

This paper will make both theoretical and empirical improvements on the DPI that was initially developed in Shibuya (1992). First, we will make an important theoretical advancement by replacing a constant marginal product of capital in the original formulation with the equilibrium condition that the marginal product of capital is equal to the real interest rate plus the depreciation rate. This will turn out to be a very important improvement because it can now tell the difference between capital price changes due to the *fundamental* factor (the productivity of capital) and those due to the *non-fundamental* factor (the present value of future product prices).

An empirical improvement is to update the DPI data and evaluate the Japanese monetary policy from 1986 to 2017. During the period of three decades, DPI and CPI moved in opposite directions several times: for example, 1986–1988 (Japan's emerging Bubble Economy), 1990–1992 (after Japan's

Bubble Burst), 1999 (Japan's IT Bubble), 2008 (Global Financial Crisis). In all of these episodes, with hindsight, it was DPI that signaled the right direction for monetary policy. Thus, Japanese economic history shows the superiority of DPI over CPI.

The rest of the paper is organized as follows: Section II derives a new formula for DPI with an important theoretical improvement. Section III applies the new DPI to evaluate Japanese monetary policy. Section IV proposes a dynamic monetary policy with an optimal DPI target zone to prevent bubbles and promote growth. It integrates the FRB and BIS views by achieving an optimal balance between growth and stability. Section V concludes the paper with a summary and future research directions.

Ⅱ. A New Formula for Dynamic Price Index

This section first derives the original formula for DPI and discusses its shortcoming. The shortcoming comes from the assumption of a constant marginal product of capital made in the original DPI formulation. To overcome this shortcoming, we make a critical improvement by utilizing the optimality condition that the marginal product of capital is equal to the real interest rate plus the depreciation rate of capital. That turns out to have very critical implications for monetary policy.

A. Intertemporal Cost-of-Living and Expenditure Function

We formalize the intertemporal cost-of-living as the present value of a multi-period cost-of-living. We can represent it by an expenditure function that minimizes the present value of expenditures over future periods to achieve a given level of utility. Given the expenditure function, we can define an intertemporal price index at time t as a ratio of the expenditure function at time t to that of a base year.

Let $P=(p_0,p_1,\cdots,p_n)$ stand for an intertemporal price vector for periods ($t = 0, 1, \cdots, n$ where $0 \le n \le \infty$), $X=(x_0,x_1,\cdots,x_n)$ for a corresponding consumption vector, and $I=(i_0,i_1,\cdots,i_n)$ for an interest rate vector. Then, the expenditure function is given by

$$E = p_0 x_0 + \sum_{t=1}^{n} p_t x_t \prod_{s=0}^{t-1}(1+i_s)^{-1} = \sum_{t=0}^{n} \hat{p}_t x_t \tag{1}$$

where $\hat{p}_0 = p_0$ and $\hat{p}_t = p_t \prod_{s=0}^{t-1}(1+i_s)^{-1}$ for $t \ge 1$. They represent the *futures prices*, which we define as the present values of future product prices.

Consider the following expenditure minimization problem:

$$E(\hat{P}, U) \equiv \min_{\{x_t\}} \sum_{t=0}^{n} \hat{p}_t x_t \text{ subject to } U(x_0,x_1,\cdots,x_n)=U \tag{2}$$

where $U(x_0,x_1,\cdots,x_n)$ represents the intertemporal utility function and $\hat{P}=(\hat{p}_0,\hat{p}_1,\cdots,\hat{p}_n)$ the futures price vector. Expenditure function $E(\hat{P},U)$ represents the minimum intertemporal cost-of-living that is required to achieve utility level U under price vector $\hat{P}$.

The intertemporal utility function typically takes the following form:

$$U(x_0,x_1,\cdots,x_n) = \sum_{t=0}^{n}\left(\frac{1}{1+\rho}\right)^t u(x_t) \tag{3}$$

where ρ = the rate of time preference, $u(x_t)$ = one-period utility function.

Let us assume $u(x_t)=\ln(x_t)$ and exponentially transform the utility function. Then, we obtain the following Cobb Douglas intertemporal utility function (we retain the same symbol U for convenience):[3)]

$$U(x_0,x_1,\cdots,x_n) = \prod_{t=0}^{n} x_t^{\alpha_t} \tag{4}$$

3) If we assume a homothetic (such as Cobb-Douglass) intertemporal utility function, IPI becomes independent of U. See Shibuya (1992) for details.

where $\alpha_t = (1+\rho)^{-t} / \{\sum_{s=0}^{n}(1+\rho)^{-s}\}$, which are the normalized factors of time preference that add up to one.

Then, expenditure function (2) will take the following explicit form:

$$E(\hat{P}, U) = \left(\prod_{t=0}^{n} \alpha_t^{\alpha_t} \right)^{-1} \left(\prod_{t=0}^{n} \hat{p}_t^{\alpha_t} \right) \bullet U \tag{5}$$

which represents the minimum intertemporal cost-of-living that is required to achieve utility level U under price vector $\hat{P}$.

B. Intertemporal Price Index

The intertemporal price index (IPI) is obtained from the above expenditure function, and it captures a change in the intertemporal cost-of-living. Let $\hat{P}^T = (\hat{p}_0^T, \hat{p}_1^T, \cdots, \hat{p}_n^T)$ be the futures price vector seen from year T, and $\hat{P}^S = (\hat{p}_0^S, \hat{p}_1^S, \cdots, \hat{p}_n^S)$ the futures price vector seen from year S (the base year). Then, IPI is defined as the ratio of the two expenditure functions, which correspond to futures price vectors $\hat{P}^T$ and $\hat{P}^S$:

$$\text{IPI} = \frac{E(\hat{P}^T, U)}{E(\hat{P}^S, U)} \tag{6}$$

Now substituing expentiture function (5) into IPI, we obtain the following IPI formula:

$$\text{IPI} = \prod_{t=0}^{n} \left(\frac{\hat{p}_t^T}{\hat{p}_t^S} \right)^{\alpha_t} \tag{7}$$

It shows that a change in intertemporal cost-of-living under a constant utility level can be expressed as a weighted geometric mean of current and futures price changes between two regimes $(\hat{p}_t^T / \hat{p}_t^S)$.

C. The Original Formula for Dynamic Price Index

We use "capital price" instead of "asset price," although they are often exchangeable. The reason for our usage of “capital price” is the following: First, capital is used in production while many assets are not actually used in production. For example, a piece of land is an asset, but it is not capital if not used as an input in production. Second, capital includes both physical and *human capital* that enter into a production function. And capital in a modern economy is represented by *business organizations* that consist of physical and human capital. In short, what is relevant to production is capital and not asset. For these reasons, we use “capital” instead of “asset.”

1. Capital Price and Futures Prices

Capital price (q_0) is equal to the present value of capital returns over future periods. And a return on capital (R_t) is equal to product price (p_t) times the marginal product of capital (MPK_t). Thus, the return on capital in period t is given by

$$R_t = p_t \bullet MPK_t \tag{8}$$

Therefore, capital price (q_0) is determined as follows:

$$\begin{aligned} q_0 &= \sum_{t=1}^{\infty}(1-\delta)^{t-1}R_t\prod_{s=0}^{t-1}(1+i_t)^{-1} \\ &= \sum_{t=1}^{\infty}(1-\delta)^{t-1}p_t MPK_t\prod_{s=0}^{t-1}(1+i_t)^{-1} \\ &= \sum_{t=1}^{\infty}(1-\delta)^{t-1}p_t MPK\prod_{s=0}^{t-1}(1+i_t)^{-1} \end{aligned} \tag{9}$$

where δ is the depreciation rate of capital, and the last equation defines MPK as the *mean* marginal product of capital. Then, this equation can be rewritten using futures prices ($\hat{p}_t$) as follows:

$$q_0 = \sum_{t=1}^{\infty} (1-\delta)^{t-1} MPK \bullet \hat{p}_t$$

$$= \sum_{t=1}^{\infty} (1-\delta)^{t-1} MPK \bullet \hat{p} \quad (10)$$

The last equation defined $\hat{p}$ as the *mean* futures price.

Finally, we obtain the following simple relationship between capital price (q_0), the *mean* marginal product of capital (MPK), and the *mean* futures price ($\hat{p}$):

$$q_0 = MPK \bullet \hat{p} / \delta \quad (11)$$

from which we obtain the *mean* futures price of product as follows:

$$\hat{p} = \delta q_0 / MPK \quad (12)$$

This implies that the *mean* futures price, which represents the present value of future product prices, is a function of the current capital price.

We should note that the purpose of utilizing the *mean* futures price and the *mean* marginal product of capital is essentially to reduce many future periods into one future period (the future). As a result, we can simplify our analysis as if we were to live in two periods (the present and the future). It will simplify our derivation of the DPI formula without loss of generality.

2. The Original Formula for DPI and its Shortcoming

Dynamic Price Index (DPI) is obtained from combining the intertemporal price index (IPI) and the mean futures price ($\hat{p}$). Substituting $\hat{p}$ for $\hat{p}_t$ ($t \geq 1$) in IPI in equation (7), we can formulate DPI as follows:

$$\text{DPI} = \left(\frac{p_0^T}{p_0^S}\right)^{\alpha_0} \prod_{t=1}^{n} \left(\frac{\delta q_0^T / MPK^T}{\delta q_0^S / MPK^S}\right)^{\alpha_t}$$

$$= \left(\frac{p_0^T}{p_0^S}\right)^{\alpha_0} \left(\frac{q_0^T}{q_0^S}\right)^{1-\alpha_0} \tag{13}$$

where $\alpha_0 = 1/\sum_{s=0}^{n}(1+\rho)^{-s}$.

The second equation was derived on the assumption that the marginal product of capital is constant between two price regimes: $MPK^T = MPK^S$. DPI is formulated as a geometric mean of the current product price inflation and capital price inflation.4)

The main shortcoming of the original DPI formula was its inability to distinguish between the following two cases: an increase in capital price may be due to an increase in the marginal product of capital or due to an increase in the present value of future product prices. The original DPI could not theoretically differentiate between these two cases. DPI should capture only the latter case, which is the true case of dynamic inflation.

The problem arises from the assumption that the marginal product of capital remains constant between two regimes（T and S）. Because of this problem, targeting DPI becomes essentially equivalent to targeting capital prices. Then, the same criticism applies that targeting capital prices may kill productivity booms. Is there a way to resolve this potential problem?

D. A New Formula for Dynamic Price Index

We can resolve this problem of the original formulation of DPI by utilizing an equilibrium relationship or an optimality condition for investment that holds between the marginal product of capital（net of depreciation）and the real interest rate. This resolution will lead us to deepen our understanding of

4） We obtain DPI = p_0^T / p_0^S if $n = 0$ ($\alpha_0 = 1$). This shows that a conventional one-period price index（CPI）is a special case and a subset of DPI.

the mechanism of capital price inflation and its implications for monetary policy.

1. Marginal Product of Capital and the Real Interest Rate

The marginal product of capital is equal to the real interest rate plus the depreciation rate of capital: $MPK = r + \delta$. This robust relationship is obtained as a solution to an optimal investment decision: that is, the marginal return to investment net of depreciation must be equal to the real rental cost of capital, which is the real interest rate.

Substituting this relationship into DPI, we obtain the following new formulation of DPI:[5)]

$$\text{DPI} = \left(\frac{p_0^T}{p_0^S}\right)^{\alpha_0} \prod_{t=1}^{n} \left(\frac{\delta q_0^T / MPK^T}{\delta q_0^S / MPK^S}\right)^{\alpha_t}$$

$$= \left(\frac{p_0^T}{p_0^S}\right)^{\alpha_0} \left(\frac{\dfrac{q_0^T}{(r^T + \delta)}}{\dfrac{q_0^S}{(r^S + \delta)}}\right)^{1-\alpha_0} \qquad (14)$$

where $\alpha_0 = 1 / \sum_{s=0}^{n} (1+\rho)^{-s}$.

DPI is newly formulated as a geometric mean of the current product price inflation (CPI) and the capital price inflation that is adjusted for a change in the real interest rate. Capital price inflation needs to be adjusted for a change in the real interest rate so that DPI can correctly capture the futures price inflation, that is, a change in the present value of future product prices.

This new DPI formulation is very important because it will provide us

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5) Shibuya (1992) stated in footnote 12 that $MPK = r + \delta$ holds in a balanced growth path but stopped short of actually utilizing it for DPI.

with critical insights into the mechanism of capital price bubbles as well as critical implications for monetary policy. In particular, it emphasizes the special relationship between the capital price (q) and the real interest rate (r). In short, if they move in the same direction, a capital price change will reflect a productivity change. But if they move in an opposite direction, a capital price change will reflect either an increase or decrease in the present value of future product prices. The latter case will be captured by DPI.

2. The Important Implications of the New DPI Formula

The main shortcoming of the original formulation of DPI was that it assumed a constant marginal product of capital. As a result, DPI could not tell if a high capital price was due to an increase in the marginal product of capital or due to an increase in the present value of future product prices. Only the latter should be regarded as true inflation in a dynamic sense. The original formulation of DPI could not distinguish the difference between the two cases because DPI would move exactly the same way.

This problem is resolved by the new formulation of DPI because it can now distinguish between those two different cases. If a higher capital price reflects an increase in the marginal product of capital, it will be offset by a corresponding increase in the real interest rate so that DPI will not rise. In other words, DPI will rise only if a higher capital price comes from an increase in the present value of future product prices. Therefore, we can now tell from DPI if a change in capital price is due to *a change in the productivity of capital* or due to *dynamic inflation and deflation* defined as a rise and fall of the present value of future product prices.

The new formulation of DPI has a very important practical implication for monetary policy. If a higher capital price is accompanied by an increase in the real interest rate, it is not dynamic inflation (therefore it cannot be a bubble). It reflects an increase in the marginal product of capital and DPI will not rise. However, if a higher capital price is accompanied or caused by a fall in the real interest rate, then it is dynamic inflation (therefore it is a potential bubble) and DPI will rise. This dynamic inflation should be controlled by monetary policy before it develops into a full-fledged bubble.

To sum up: if capital price and the real interest rate move in the same direction, it reflects a change in the productivity of capital. However, if they move in opposite directions, then they are either dynamic inflation or deflation. The former case does not affect DPI, but the latter case is captured by DPI. Therefore, DPI is a true indicator of dynamic inflation and deflation.

3. A Numerical Representation of the New DPI

We will calculate DPI in order to evaluate the performance of monetary policy. We set the number of periods in the price regimes (T and S) to be 10 years (n=10). The depreciation rate of capital (δ) is estimated to be approximately 9.6% in Hayashi (1991). The rate of time preference (ρ) is estimated to be approximately 0.25 in Frederick, Loewenstein, and O'Donoghue (2002). Thus, we obtain the estimate of α_0 as follows:

$$\alpha_0 = 1/\sum_{s=0}^{10}(1+\rho)^{-s} = 0.219 \tag{15}$$

With those estimates of parameters, DPI is calculated as follows :

$$\text{DPI} = \left(\frac{p_0^T}{p_0^S}\right)^{0.219}\left(\frac{\dfrac{q_0^T}{r^T+0.096}}{\dfrac{q_0^S}{r^S+0.096}}\right)^{0.781} \tag{16}$$

This formula will be used in the evaluation of Japanese monetary policy in the next section. We should note that changes in parameters affect the quantitative measure (scale) of DPI, but not the qualitative characteristics of DPI movements. As a result, the evaluation of monetary policy is robust with respect to parameter changes.

Ⅲ. Evaluating Japanese Monetary Policy

In this section, we will produce the time-series of DPI inflation for Japan and evaluate the performance of the Japanese monetary policy from the DPI perspective of dynamic inflation (bubbles) and deflation (balance-sheet recessions). We will identify some of the major policy mistakes of the Bank of Japan (BOJ). That will reveal the superiority of DPI over CPI as an information variable for conducting monetary policy.

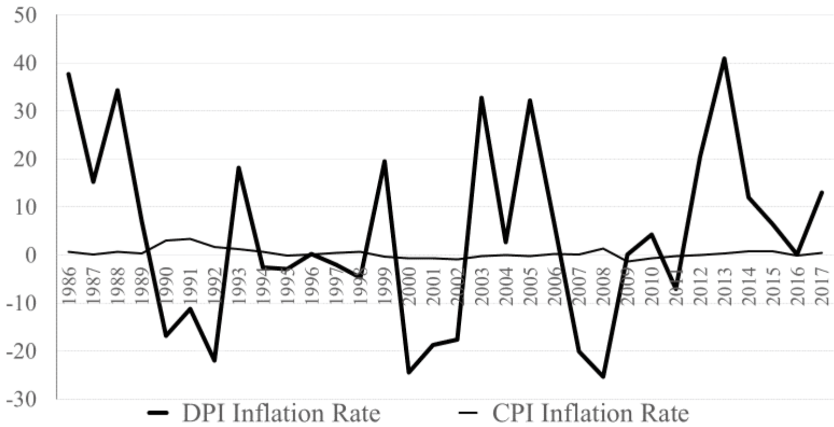
A. DPI versus CPI Inflation

Chart 1 shows annual percentage changes of DPI and CPI in 1986-2017. While CPI has been relatively stable during the period, DPI shows larger variations. In sharp contrast to CPI, DPI exhibits inflation and deflation very clearly. In other words, DPI is more sensitive to changes in the conditions of the economy, while CPI is rigid because it is a static one-period price index. It suggests that DPI contains more information about the changing condition of the economy, and therefore DPI is a more useful information variable for monetary policy.

Moreover, DPI and CPI often exhibits opposite movements (Chart 1). For example, DPI was high and CPI low in 1986-1988 (Japan's Bubble Economy), DPI was low and CPI high in 1990-1992 (after Japan's Bubble Burst), DPI was high and CPI low in 1999 (Japan's IT Bubble), DPI was low and CPI high in 2008 (Global Financial Crisis). During those periods, DPI and CPI signaled the opposite direction of inflation and thus implied the opposite direction for monetary policy. Those cases offer the best opportunities to test which price index contains more useful information for monetary policy. In retrospect, we know with hindsight that DPI indicated the right direction for monetary policy in each of those cases.

Chart 1

Annual Percentage Changes of DPI and CPI (1986-2017)



Source: Calculated by the authors. Annual DPI percentage changes using the stock price (Nikkei 225) as the capital price and annual CPI percentage changes, eliminating the impact of changes in consumption tax. See Yuan (2019) for details.

B. Monetary Policy Mistakes from the DPI Perspective

Equipped with DPI, we can now identify the monetary policy mistakes of the past (1986-2017). The first major mistake was from 1986 to 1989 before Japan's bubble economy burst in 1990. The average annual DPI inflation rate had been over 20% during that period. In other words, DPI indicated that dynamic inflation emerging long before 1990 when the bubble burst. If the Bank of Japan (BOJ) had implemented tight monetary policy, Japan's bubble economy could have been prevented. However, the BOJ's monetary policy was to reduce the discounted rate until 1989. That was a very expansionary monetary policy, which was the opposite of what DPI indicated. Although the BOJ was aware that the land and stock prices were very high, an increase in the discounted rate was not started until May 1989. The change in monetary policy was too late to prevent the emergence of Japan's bubble economy in the late 1980s and its eventual burst in 1990.

The second mistake occurred in 1990–1992 when monetary policy had been too tight after the 1990 bubble burst. In fact, DPI dropped nearly 20% a year continuously during the period (1990–1992), indicating a strong need for an aggressive monetary policy. During this period, however, looking at a rising CPI inflation, the BOJ continued its tight policy, in contradiction to what DPI indicated. This monetary policy mistake had worsened the financial crisis of commercial banks with large amounts of non-performing loans. It had eventually led to a prolonged economic stagnation called Japan's "lost decades."

The third mistake happened in 2000–2002 just after Japan's IT bubble had burst. In fact, DPI dropped again nearly 20% a year during that period, which was comparable to what had happened in 1990–1992. DPI indicated a strong need for an aggressive monetary policy. However, the BOJ did not implement a strong enough expansionary policy until December 2002 when it increased the monetary base through money market operations.

The fourth mistake was its expansionary monetary policy in 2003–2005, which was the period of the so-called "Structural Reform" under Prime Minister Koizumi. The BOJ continued to increase the monetary base through money market operations while the DPI inflation rate was high above 15% on average during the period. It produced a mini bubble in the stock market during Koizumi's "Structural Reform" in 2003–2005.

The fifth mistake happened from 2007 to 2008. In 2007–2008, the American subprime crisis emerged, and its negative impact had spread to many other countries. It led to the world financial crisis in the following years. According to DPI which dropped 20% annually in 2007-2008, there was a significant deflationary pressure in the economy. DPI indicated a strong need for an aggressive monetary policy. However, from December in 2007 to October in 2008, the BOJ implemented a tight monetary policy, raising the overnight call rate from 0.25 % to 0.5%. Then, the BOJ eased its monetary policy, but it was apparently too late and too weak. The economy did not recover to the pre-crisis level until 2013.

The sixth mistake occurred from 2013 to 2014. The BOJ started a very aggressive monetary policy under Prime Minister Abe in 2013. DPI rose 40% in 2013, which was comparable to the highest DPI inflation rate during Japan's bubble economy in the late 1980s. However, DPI indicated a rising inflation rate in 2012, which implied that the economy had already started to recover from deflation. Therefore, the BOJ needed only a mildly expansionary policy in 2013. Nevertheless, the BOJ implemented the most aggressive monetary policy in history, and the DPI inflation rate jumped above 40% in 2013. The monetary policy should have been less aggressive so that growth would become sustainable.

Ⅳ. Dynamic Monetary Policy with a DPI Target Zone

This chapter develops a new paradigm of dynamic monetary policy with an optimal DPI target zone. First, we present a basic dynamic stochastic model of growth and inflation, partly utilizing an exchange rate target zone model of Krugman (1991, 1992). Second, we explore the implication of dynamic monetary policy with a DPI target zone. Third, determining an optimal target zone for DPI, we integrate the FRB and BIS views on the role of monetary policy with respect to capital prices.

A. A Dynamic Stochastic Model of Economic Growth and Inflation

We consider a dynamic stochastic model of economic growth and inflation. The DPI inflation rate (π) and output (y) are determined by

$$\pi = m + g + \frac{\varepsilon E(d\pi)}{dt} \tag{17}$$

$$y = \exp(g - f) \tag{18}$$

where π is the DPI inflation rate, m a monetary policy variable such as a change in money supply, y output (real GDP), and g a growth variable that represents a fundamental variable of the economy incorporating shifts in production, technology, and productivity, f a financial crisis variable that takes value c (>0) if a crisis occurs and 0 if no crisis. The effect of a crisis on economic growth is permanent. The expectation term captures the effect of an expected change in the DPI inflation rate, which depends on the dynamic stance of monetary policy.

The growth variable (g) is assumed to generate a Brownian motion with drift as follows:

$$dg = \mu dt + \sigma d\omega \tag{19}$$

The general solution for the DPI inflation rate of the economy defined by equation (17) – (19) for a given monetary policy becomes as follows:

$$\pi = m + g + \varepsilon\mu + A\exp(\lambda_1 g) + B\exp(\lambda_2 g) \tag{20}$$

where λ_1 and λ_2 are parameters to be determined by applying Ito's formula. A and B are parameters to be determined by the dynamic stance of monetary policy.[6)]

The first three terms in equation (20) represent the fundamental DPI inflation rate that will prevail if no change in monetary policy is implemented,

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6) The explicit solutions for those parameters can be obtained, but they are not necessary for the present analysis. See Krugman (1991, 1992).

that is, keeping m constant. The last two exponential terms represent a deviation of the DPI inflation rate from the fundamental value due to monetary policy interventions.

B. The DPI Target Zone Model of Monetary Policy

We will consider two cases of dynamic locus of the DPI inflation rate (π) with respect to the growth variable (g): one for no monetary intervention, and another for DPI target zone monetary policy.

First, we consider a case in which the central bank maintains its monetary policy (m) at the initial level. Then, the expected DPI inflation should be determined by the fundamental variable (g) only: it is equal to the fundamental rate defined by the first three terms in equation (20). Therefore, we have $A = 0$ and $B = 0$ under no monetary intervention. In this case, the DPI inflation rate locus is given by a line FF (Chart 2).[7)]

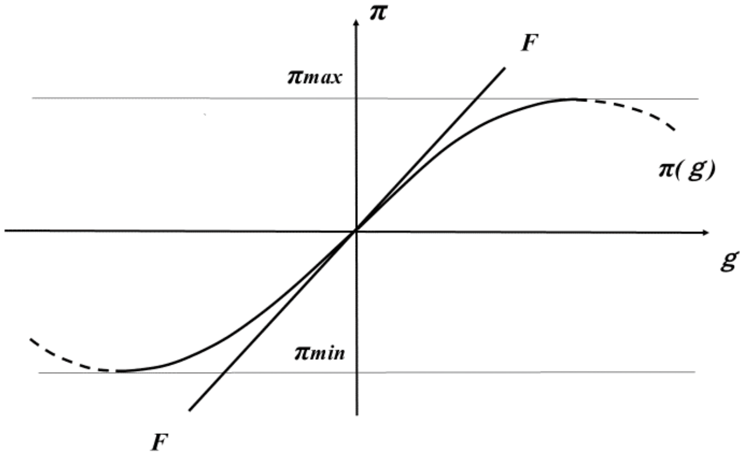
Next, we consider the case in which the central bank implements a DPI target zone monetary policy with its upper band ($\pi_{\max}$) and lower band ($\pi_{\min}$). When the DPI inflation rate reaches the upper (lower) band, the central bank will reduce (increase) m to keep π within the zone. In this case, it is well known from the "smooth pasting" condition that A and B must be chosen so that the DPI inflation rate locus is tangent to the upper and lower bands (Chart 2). With DPI target zone monetary policy in place, the DPI inflation rate locus takes a form of S-curve.

7) We can also consider a case in which DPI inflation positively feedbacks to the expectation, which generates bubbles in the absence of preventive monetary policy.

Chart 2

The DPI Inflation Rate Locus

with and without DPI Target Zone Monetary Policy



It is important to emphasize that “smooth pasting” is a *general* result of DPI target zone monetary policy. Monetary policy does not have any limitation similar to the availability of foreign reserves that constrains the capability of currency interventions. In the exchange rate models, “smooth pasting” is a *special* case in which foreign reserves are sufficiently large. In DPI target zone monetary policy, we have no such limitation. Therefore, unlike the exchange rate models, a credibility problem does not arise in the case of dynamic monetary policy with a DPI target zone.

C. Preventing Bubbles and Promoting Growth

With no credibility problem, the dynamic monetary policy with a DPI target zone should work effectively. That is, central banks could prevent bubbles and promote growth with an implementation of DPI target zone monetary policy. It has a stabilizing effect on the DPI inflation rate by means of controlling expectation (Chart 2) so that it can prevent bubbles and balance-sheet recessions. We will show that it can achieve an optimal balance between growth and stability.

We consider the effects of DPI target zone monetary policy on bubbles (financial crises) and economic growth. The growth rate of the economy defined by equation (17) – (19) can be expressed as follows:

$$\frac{dy}{y} = (\mu + \frac{1}{2}\sigma^2)dt + \sigma d\omega - df \tag{21}$$

Thus, the expected long-run growth rate is given by

$$E\left(\frac{dy}{y}\right) = (\mu + \frac{1}{2}\sigma^2)dt - E(df) \tag{22}$$

There exists a trade-off between *stability* and *growth*: the smaller is growth variance σ^2, the slower is the expected growth in the long run.[8)] In addition, the long-run growth rate will be higher if no crisis is expected because we will have $E(df) = 0$. A crisis will cause a permanent loss on the level of real GDP. Thus, preventing crises such as extreme DPI inflation (bubbles) and deflation (recessions) can promote growth. This is achieved by the dynamic monetary policy with an optimal DPI target zone.

We make an assumption that growth variance σ^2 is an increasing function of the DPI target zone width ($\pi_{max} - \pi_{min}$).[9)] That is, the narrower (wider) the target zone is, the smaller (larger) the growth variance will be. Thus, we assume the following functional relationship:

$$\sigma = \sigma(\pi_{max} - \pi_{min}) \tag{23}$$

8) This positive relationship between growth variance and growth rate is observed in Figure 10 of Bernanke (2013).

9) An indirect evidence for this assumption is found in Figure 10 and 11 of Bernanke (2013), which show a positive correlation between CPI variability and GDP variability.

where $\sigma'(\bullet) > 0$, $\sigma''(\bullet) < 0$ and $\sigma(\bullet)$ has a finite limit.. Then, it follows from equation (22) that frequent monetary interventions with a narrower DPI target zone will reduce the long-run growth rate. This proposition corroborates the FRB view that frequent monetary interventions are detrimental to economic growth.

D. Finding an Optimal DPI Target Zone

The next question is to find an optimal DPI target zone for monetary policy, which balances growth and stability. Now assume without loss of generality that there are critical upper and lower values for π beyond which crises (“outliners”) will emerge.[10] Let us name such critical values π_{hcp} and π_{lcp}, respectively. Then, it is easy to prove that the optimal DPI target zone is given by $\pi_{\max} = \pi_{hcp}$ and $\pi_{\min} = \pi_{lcp}$, assuming that the expected cost of crises $(0 \leq \mathrm{E}(df) \leq \mathrm{c})$ is sufficiently large.[11] The optimal target zone will maximize growth variance (σ^2) without generating a crisis ($f = 0$ and $df = 0$). And, therefore, it will optimize economic growth $E(dy/y)$ while preventing the economy from falling into inflationary and deflationary crisis states that are “outliners” of the target zone.

Capital prices are known to exhibit larger variations than the level implied by variations of the real economy. Shiller (1981, 2005) concluded that

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10) Alternatively, we may assume that f is a continuously increasing function of the DPI target zone width. Then we can derive the optimal target zone from the first order condition that $2\sigma'(\bullet) = f'(\bullet)$. A more sophisticated and realistic model can be constructed with an application of techniques and models in Dixit and Pindyck (1994), although the main conclusion of this paper should not be affected.

11) The cost of Japan’s financial and economic crises due to the 1990 bubble burst was sufficiently large, in fact, too large by any measure. No doubt, it should have been avoided. How about other episodes? That is a question to be answered by a cost-benefit analysis of bubbles and long-term growth. Nevertheless, a good strategy is provided by DPI target zone monetary policy because central banks can optimally select the target zone from the risk management point of view.

stock market volatility was greater than could be explained by subsequent dividends. Capital prices tend to overreact to shifts in the real economy. In fact, we know many historical episodes of bubbles and bursts. Capital markets often produce crises of bubble bursts and subsequent balance-sheet recessions as a result of volatile market sentiments.[12)] However, such potential crises are captured by DPI as they show up as dynamic inflationary and deflationary “outliners.”

Therefore, it is imperative that the central bank keep DPI inflation and deflation within a set of appropriate bands. The upper band should be set to prevent financial bubbles. The lower band should be set to prevent the economy from falling into a prolonged state of deflation and slow growth. In short, if the central bank successfully implements DPI target zone monetary policy, it will prevent bubbles and promote growth.

A remaining practical and empirical question is how to find the actual optimal upper and lower bands of the target zone for an economy. It depends on special conditions of the economy. Each economy is at a different stage of development and has a different set of economic conditions. Therefore, an optimal DPI target zone should be determined after carefully considering those differences. In the case of Japan, based on the historical data (Chart 1), it seems reasonable to set up the upper band at 15% and the lower band at −10% as the initial values. Those bands should be adjusted as the central bank learns from experiences of DPI target zone monetary policy.

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12) Such market sentiments are called “animal spirits” by Keynes (1936) and Akerlof and Shiller (2009). Those authors might consider “animal spirits” as part of the fundamentals. Shiller (2005) called them “irrational exuberance.” We should add “irrational depression” to the list. They all feedback to capital prices in the market. Thus, a vicious cycle can emerge generating bubbles and bursts (“black swans”). Such “black swans” will be prevented by the dynamic monetary policy with an optimal DPI target zone, which is designed to control expectations.

E. Integrating the FRB and BIS Views

There are two conflicting views on how central banks should respond to capital prices. The FRB view holds that central banks should not target capital prices because preemptive tight monetary policy will run the risk of curtailing productivity booms and thus economic growth. In contrast, the BIS view holds that central banks should respond to capital price inflation with preemptive tightening before it develops into full-fledged bubbles because the burst of bubbles will bring costly financial crises and severe balance-sheet recessions.

We could resolve the apparent conflict of the two views by the following monetary policy strategy: (1) allow rising capital prices so long as it reflects a higher productivity of capital, but (2) implement restrictive policy if rising capital prices come from dynamic inflation before they develop into full-fledged bubbles. Both views agree that central banks should implement aggressive monetary policy once bubbles burst. To achieve this policy goal, however, we need a reliable dynamic multi-period price index that can distinguish between capital price changes due to the productivity of capital and due to the present value of future product prices. This is where DPI comes into picture.

With the new DPI formula, this policy goal can be achieved because DPI changes only if capital price changes come from future product prices, but not if they come from the productivity of capital. At the same time, a monetary policy based on DPI gives a specific answer to the question of how central banks should respond to capital prices: changes in capital prices should affect monetary policy only to the extent that they affect DPI. In other words, central banks should target DPI but not capital prices (the stock market) directly.

V. Conclusion

We have developed a new DPI formula that can tell the difference between capital price changes due to changes in the present value of future product prices (*dynamic inflation and deflation*) and those due to changes in the productivity of capital. DPI can now correctly measure *dynamic inflation and deflation adjusted for productivity changes*. Therefore, central banks should use DPI to identify dynamic inflation and deflation before they develop into a full-fledged bubble or cause the economy to fall into a prolonged balance-sheet recession. DPI is a superior, comprehensive, and quickly available information variable for monetary policy. Thus, central banks should target DPI instead of CPI.

We have proposed *a dynamic monetary policy with an optimal DPI target zone*, which can achieve the twin goals of preventing bubbles and promoting growth. It balances growth and stability by optimally selecting the upper and lower bands of the target zone. Thus, DPI integrates the FRB and BIS views, and answers the question of how central banks should respond to capital prices. In short, central banks should not target capital prices directly but implement DPI target zone monetary policy in order to achieve an optimal combination of growth and stability.

The application of DPI for evaluating Japan's monetary policy has been very successful in identifying policy mistakes. As future research, we plan to analyze and evaluate the monetary policies of many other countries from the DPI perspective. We expect that an extended application of DPI to many other countries will reveal the superiority of DPI over CPI as the main information variable for monetary policy. The superiority of DPI comes from the fact that it captures dynamic inflation and deflation adjusted for changes in the productivity of capital.

Another direction of future research is to develop a stochastic macroeconomic model of dynamic growth and inflation that is more sophisticated and realistic than the simple model presented in this paper. It should help us understand the relationship between capital prices, investment decisions, technological innovations, animal spirits, bubbles, financial crises, balance-sheet recessions, and long-run economic growth. It should also help us understand the role of DPI target zone monetary policy from the risk management point of view.

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