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Abstract

The paper examines the relationship between inflation and the degree of tightness in the goods market by considering the capacity utilization rate as an inflation indicator in fitting the New Keynesian Phillips curve under the IS-LM framework. The theoretical model is developed on the basis of the intertemporal optimization specification with rational forward-looking agents, and is further empirically tested with Ordinary Least Squares estimates using the 1980-2013 data for Japan and the United States. We find that capacity utilization reflects actual output under the absence of unexpected events in an economy and it acts as a reliable inflation indicator. We also confirm that capacity utilization had a positive effect on inflation for both countries except for the “Great Recession” periods in the United States when the financial crisis and government interventions signal inflationary movement. We further show that estimates mirror theoretical propositions to conclude the economic recession, rather than the depression, was apparent for both countries.

Key Words: Phillips Curve, Capacity Utilization, Inflation, Monetary Policy

JEL Classification: D24, E32, E37

1 Introduction

Understanding the dynamics of economic slumps is one of the most important issues in macroeconomics. The subprime financial crisis in 2007 in the United States quickly spread to international

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financial markets and other countries, and it eventually resulted in the Great Recession. Meanwhile, the asset bubble that burst in 1991 caused a long-run economic stagnation, known as the “Lost Two Decades.”¹ The economic downturn further led to a long-term deflation despite of the Bank of Japan’s effort to stimulate the economic activity by keeping the short-term interest rate close to zero in Japan.

Keynes was a pioneer who made every effort possible to explain the occurrence of massive and persistent unemployment. His famous 1936 book, *The General Theory*, challenged the classical economics paradigm with his principle of effective demand and liquidity preference, and led to the important conclusion that the main cause of involuntary unemployment is a shortage of aggregate demand. Hicks (1937) later presented the IS-LM model in line with Keynes’s ideas. By emphasizing the interaction between the goods and money markets, his model clearly shows that the level of output and the rate of interest can be affected by either fiscal or monetary policy, or both.² Although the IS-LM model was a useful and powerful tool at that time, it lacked microfoundations regarding the behavior of economic agents and the price equation reflecting the state of the goods market. This indicates that there is room for further development of the IS-LM model.

The purpose of the present paper is to develop an optimizing IS-LM model by using the capacity utilization version of the New Keynesian Phillips curve.³ Our theoretical model has three important features. First, we adopt the principle of effective demand, which was proposed by Keynes (1936). By adjusting the capacity utilization rate, firms seek to match the production

¹Blanchard (2011) gave a detailed account of Japan’s prolonged slump by preparing an independent section in his undergraduate-level book. On this point, see Section 22-3 of his book for detail.

²For instance, suppose that the central bank increases the nominal quantity of money through monetary policy. As a consequence, it shifts the LM curve down and to the right. This leads to a lower rate of interest and a higher level of output: the Keynesian IS-LM framework rejects the neutrality of money, which is an important classical axiom.

³Yoshida (2004) utilizes a money-in-the-utility-function model. In addition, it should be noted that Ono (1994), in his excellent book, showed that persistent recession can occur by using the money-in-the-utility-function approach. One of the key assumptions in his model is that the utility of money is insatiable. He formalized this assumption as follows: $\lim_{m \rightarrow \infty} v'(m) > 0$, where $v(m)$ represents the utility of money holdings (m) in real terms. This implies that the marginal utility of money remains positive even if the level of real money balances diverges to infinity.

level with the level of aggregate demand in the whole economy. The quantity adjustment process is sufficiently rapid so that the process always achieves short-run equilibrium in the goods market. Second, in order to incorporate money into our model, we use a transaction cost approach, which assumes that households incur transaction costs when they conduct trade and exchange activities in the goods market.⁴ It further assumes that the use of money provides a convenient way of purchasing commodities and consequently reduces transaction costs in the process of exchange. This setting reflects one of the main functions of money: a medium of exchange. Third, we consider price stickiness by introducing the New Keynesian Phillips curve, which assumes that current inflation depends on future inflationary expectations and the current output gap. In particular, we connect the output gap with capacity utilization in our model.

This paper further empirically tests the proposed theoretical propositions for Japan and the United States using 1980–2013 monthly data. Existing empirical evidence shows that output fluctuation is well explained by the level of capacity utilization (Miyazawa, 2012; Meza and Quintin, 2007); hence, capacity utilization is considered as a reliable indicator of future changes in inflation (Garner, 1994). Our empirical approach extends the literature by incorporating the following two tactics. First, we consider two measures of the normal rate of capacity output when measuring capacity utilization: the first-measure capture the *overall effect* of economic conditions that has on production capacity; and the second-measure assesses the effect of *recent changes* in economic conditions that has on production capacity. It allows us to analyze how the value of the output-capacity ratio is influenced by changes in economic conditions. Second, we evaluate the role of capacity utilization on the movement of inflation during three notable periods: the whole period of 1980m1 to 2013m6, the “Japan’s Lost Two Decades” period of 1991m02 to 2011m02, and the “Great Recession” period of 2007m12 to 2009m12. It allows us

⁴A number of studies employ the transaction cost approach. See Dornbusch and Frenkel (1973), Wang and Yip (1992), Guidotti and Végh (1993), Jha, Wang, and Yip (2002), Itaya and Mino (2003), and Chang, Tsai, and Chang (2011) for detail.

to examine the relationship between capacity utilization and inflation for Japan and the United States under economic climate where it unpredictably fluctuates over three decades.

This study first finds that capacity utilization is considered as a reliable indicator for future changes in inflation when production capacity truly reflects actual production in an economy. Estimates show that the effect of capacity utilization on inflation is nonexistent when the realized value of the output-capacity ratio is measured in the long term during the whole period in Japan and the “Lost Two Decades” period in the United States. This result is likely to be caused by the fact that production capacity did not entirely reflect actual production changes due to a series of unexpected major events. For Japan, those events include shocks from stock prices, monetary policy, demand and technology, and sudden capital loss and lifeline disruptions that struck in Japan’s economy over three decades. For the United States, those events comprise the 1990s IT revolution and the rapid increase in intangible investment, which is often referred as a “productivity paradox” (Triplett, 1999), that smacked in the U.S. economy. Yet, when the realized value of the output-capacity ratio is measured in the short term, which captures the effect of *recent* changes in economic conditions on production capacity, capacity utilization had a positive effect on inflation, suggesting that the economy experiences high unemployment and low inflation and that the recession is present during the whole period in Japan and the “Lost Two Decades” period in the United States.

This paper contributes to the existing literature on the New Keynesian Phillips curve by extending the theoretical model to examine the occurrence of persistent economic slumps within the dynamic general equilibrium framework. It sheds additional light on the literature by empirically estimating the slope of the Phillips curve and confirming that capacity utilization is indeed a reliable predictor of inflation when an economy is not experiencing unexpected major events. Our study further examines the recession path and shows the presence of economic recessions both in Japan and the United States during the period 1980–2013. The findings of

this study will help to determine appropriate monetary policies to stimulate the economy, via the New Keynesian Phillips curve, in Japan and the United States, and potentially in other developed nations, during economic downturns.

The paper proceeds as follows. Section 2 presents an optimizing IS-LM model incorporating the New Keynesian Phillips curve. Section 3 examines dynamic properties of the system and provides our theoretical results. Section 4 summarizes relevant macro indicators, such as inflation, the growth rate of nominal money supply, and capacity utilization, for Japan and the United States. Section 5 estimates the New Keynesian Phillips curve for Japan and the United States for the three periods: the whole period of 1980m1 to 2013m6, the “Lost Two Decades” period, and the “Great Recession” period. Finally, we summarize and conclude in Section 6.

2 The model

We consider an infinite-horizon economy in continuous time and suppose that there are two markets where goods and equities are traded and exchanged by means of money: the goods market and the equity market. Moreover, the economy is populated by three agents: a representative household, a representative firm, and the government. We describe the behavior of these agents in turn.

2.1 The household

The representative household’s lifetime utility is given by

$$\int_0^{\infty} \ln(c_t) \exp(-\rho t) dt, \tag{1}$$

where c denotes consumption and ρ is the subjective rate of time preference.

There are two assets in the economy: equities E and money m . The real value of the financial wealth is given by $a = qE + m$, where q denotes the relative price of equities in terms of current output.

The budget constraint of the household in real terms can be written as

$$\dot{a}_t = r_t a_t - (1 + s(m_t))c_t + \tau_t - (r_t + \pi_t)m_t, \quad (2)$$

where r is the real interest rate, τ is real lump-sum transfers from the government (lump-sum taxes, if negative), π represents the inflation rate, and m is real money balances.

We adopt the transaction cost approach to introduce money explicitly into our model. The household incurs transaction costs when it carries out trades and exchanges in the goods market. It takes $(1 + s(m))c$ units of output to increase consumption by c units. Note that the additional amount $s(m)$ per unit of consumption must be prepared by the household in the process of exchange.

The function $s(m)$ denotes real costs associated with consumption expenditure and satisfies the following properties:⁵ $s(m) > 0$, $s'(m) < 0$, $s''(m) > 0$, $\lim_{m \rightarrow 0} s(m) = \infty$, and $\lim_{m \rightarrow \infty} s(m) = 0$. To ensure positive money holdings, we add an assumption that $\lim_{m \rightarrow 0} s'(m) = -\infty$.

The decision problem of the household is to maximize (1) subject to (2). We can obtain the optimal solution by using the maximum principle. For this purpose we set up the Hamiltonian function

$$H = \ln c_t + \lambda_t [r_t a_t - (1 + s(m_t))c_t + \tau_t - (r_t + \pi_t)m_t], \quad (3)$$

where λ_t is a costate variable.

The first-order conditions can be written as

$$\frac{1}{c} = \lambda [1 + s(m)] \quad (4)$$

$$-s'(m)c = r + \pi \quad (5)$$

$$\dot{\lambda} = (\rho - r)\lambda, \quad (6)$$

⁵In order to obtain clear results, we assume such a simple formulation that depends on one variable alone, m . A similar type of function is adopted in Dornbusch and Frenkel (1973, p.151).

with the transversality condition given by

$$\lim_{t \rightarrow \infty} a_t \lambda_t e^{-\rho t} = 0. \quad (7)$$

To avoid the household from running a Ponzi game, we have to impose the following condition:

$$\lim_{s \rightarrow \infty} a_s \exp\left(-\int_0^s r_v dv\right) \geq 0. \quad (8)$$

This condition is referred to as the no-Ponzi game condition. On this point, for example, see Blanchard and Fisher (1989). Using (6) and (7), we can obtain $\lim_{s \rightarrow \infty} a_s \exp\left(-\int_0^s r_v dv\right) = 0$. This implies that the transversality condition (7) is equivalent to the no-Ponzi game condition being satisfied with strict equality. In addition, It is worthwhile to point out that (7) is a key condition to check which of the dynamic trajectories are the dynamic general equilibrium paths. We shall use it frequently in Section 3.3.

2.2 The firm

We assume the Keynesian principle of effective demand in the goods market. The firm controls the utilization rate of capital stock at a given price level to meet the quantity demanded in the whole economy. In other words, the level of output is determined by the demand side of the economy, and not by the supply side.

There is an efficient level of production, y^e . The efficient level is attained when the capital stock is fully utilized;

$$y^e = \sigma k, \quad \sigma = \text{const.} > 0, \quad (9)$$

where σ is the efficient output-capital ratio.

In our framework a flexible price mechanism does not correct the state of disequilibrium in the goods market, so that the level of aggregate demand does not always match with the efficient level of output. We suppose that a rapid quantity adjustment mechanism works in the goods

market with infinite speed: the firm instantaneously controls the utilization rate of capital stock according to the state of economy. If the level of aggregate demand is denoted by D_t , then the utilization rate u_t is determined by

$$u_t = D_t/y^e.$$

When $u_t < 1$, the existing capital stock is underutilized and the firm holds idle capacity because of the shortage of aggregate demand. In contrast, when $u_t > 1$, the capital stock is overutilized and the firm matches the production level with excessive aggregate demand relative to the efficient level. In addition, the situation of $u_t = 1$ implies that the capital stock is fully utilized and the firm attains the efficient level of output.

Let us now turn to the consideration of the financial structure of the firm. We assume that the firm issues no additional equities, so that the supply of equity is fixed:

$$E_t^s = E = \text{const.}$$

Since we assume for simplicity that there are no production costs, profits are equal to total revenues in real terms. Based on the principle of effective demand, total revenues are equivalent to aggregate demand. Furthermore, we assume that all profits are paid out as dividends to stockholders. Thus we can obtain:

$$d_t = D_t/E, \tag{10}$$

where d_t is the real value of dividend payments per equity.

We shall now move on to the discussion about the rate of return on equities. If q_t is the relative price of equities in terms of output, the total return per equity to the holders is given by $\dot{q} + d$: the sum of capital gains and dividend payments. Thus, we have the rate of return on equities:

$$r_t = \frac{\dot{q}_t}{q_t} + \frac{d_t}{q_t}. \tag{11}$$

Integrating (11) leads to

$$q_t = \int_t^\infty d_v \exp\left(-\int_t^v r_s ds\right) dv, \quad (12)$$

This equation implies that the market value of a unit of equity at time t amounts to the present discounted value of the stream of dividend payments (or profits) between times t and infinity.

2.3 The government

We assume that the consolidated government carries out both fiscal and monetary policies. The newly issued money is injected into the economy through lump-sum transfers to the household:

$$\dot{M}_t^s = p_t \tau_t, \quad (13)$$

where M^s is the nominal money supply. This equation can be interpreted as the government budget constraint, since we assume no government spending in the goods market and no government bond issue in the financial market to focus on the effect of monetary policy.

The government maintains a constant rate of nominal monetary growth,

$$\dot{M}_t^s / M_t^s = \theta, \quad (14)$$

where θ is a constant. A sustained monetary expansion occurs when $\theta > 0$ and a permanent monetary contraction emerges when $\theta < 0$. In the latter case the government levies lump-sum taxes on the household.

2.4 Price stickiness

The New Keynesian Phillips curve is an important building block in the major stream of modern macroeconomic research. Such a treatment can be found in Woodford (2003), Walsh (2010) and Galí (2015), among others. The standard formulation of the New Keynesian Phillips curve is expressed as

$$\pi_t = E_t(\pi_{t+1}) + \alpha(\text{output gap}), \quad \alpha > 0, \quad (15)$$

where $E_t(\pi_{t+1})$ is the expectation of π_{t+1} formed at time t . The New Keynesian Phillips curve is essentially the same as the traditional expectations-augmented Phillips curve in appearance. Nevertheless, there is a notable difference between the two curves: the derivation of the former curve is based on the explicit optimizing behavior of firms. For example, Calvo (1983) provided the staggered price setting approach and obtains the New Keynesian Phillips curve. In his model, at each moment in time, a fraction of firms adjust their optimal prices, while the remaining firms do not change their prices. For the individual firm, the adjustment opportunities occur according to a Poisson process. This setting entails price stickiness in the goods market. There is another approach to the New Keynesian Phillips curve: Rotemberg (1982) developed the quadratic price adjustment cost approach, which provides the microfoundations of sticky price models.

To analyze the inflation dynamics in a tractable model, we introduce a monetarist hypothesis regarding inflationary expectations:

$$E_t(\pi_{t+1}) = \theta. \tag{16}$$

This means that inflationary expectations are based on the growth rate of the nominal money supply. It is important to keep in mind that, according to this hypothesis, the government is able to manage inflationary expectations in the whole economy by means of the control of the nominal money stock. This idea is based on the quantity theory of money; changes in the nominal money supply lead to proportional changes in the price level. For example, Friedman (1968) recommended the steady growth of a specified monetary aggregate and emphasized the importance of publicly announced policy to avoid large fluctuations in economic activity.

Assuming that the output gap is measured by

$$\frac{D_t - y^e}{y^e}, \tag{17}$$

we can obtain our version of the New Keynesian Phillips curve as follows

$$\pi_t = \theta + \alpha \left(\frac{D_t}{y^e} - 1 \right), \quad \alpha > 0. \tag{18}$$

Summarizing the above discussion, we can obtain the capacity utilization version of the New Keynesian Phillips curve as follows

$$\pi_t = \theta + \alpha(u_t - 1), \quad \alpha > 0, \quad (19)$$

This equation indicates that the current rate of inflation is governed by the growth rate of the nominal money supply and the degree of excess demand in the goods market.

3 Dynamic general equilibrium

3.1 Dynamic system

In this subsection we provide the system of differential equations and analyse our monetary optimizing model from a dynamic point of view.

$$\dot{\lambda} = (\rho + \theta - \alpha)\lambda + \frac{s'(m)}{1 + s(m)} + \frac{\alpha}{y^e}, \quad (20)$$

$$\dot{m} = -\alpha \left(\frac{1}{\lambda y^e} - 1 \right) m, \quad (21)$$

and the transversality condition (7).

Let us define a function $\phi(m)$ by

$$\phi(m) = \frac{s'(m)}{1 + s(m)}.$$

Then, from the properties of $s(m)$ mentioned in Section 2.1, we can see that $\phi(m) < 0$ for all $m > 0$ and $\lim_{m \rightarrow +\infty} \phi(m) = 0$. For analytical tractability we assume that $\phi(m)$ is strictly increasing, $\phi'(m) > 0$, and $\lim_{m \rightarrow 0} \phi(m) = -\infty$. An example of the transaction cost function satisfying the above conditions is given by $s(m) = b_1 m^{-b_2}$, where $b_1 > 0$ and $b_2 > 0$. This is a typical function that has a constant elasticity with respect to money.

3.2 Phase diagram

Our main task in this section is to obtain a qualitative description of the global properties of our model with the help of phase diagram analysis. To construct the phase diagram, first consider

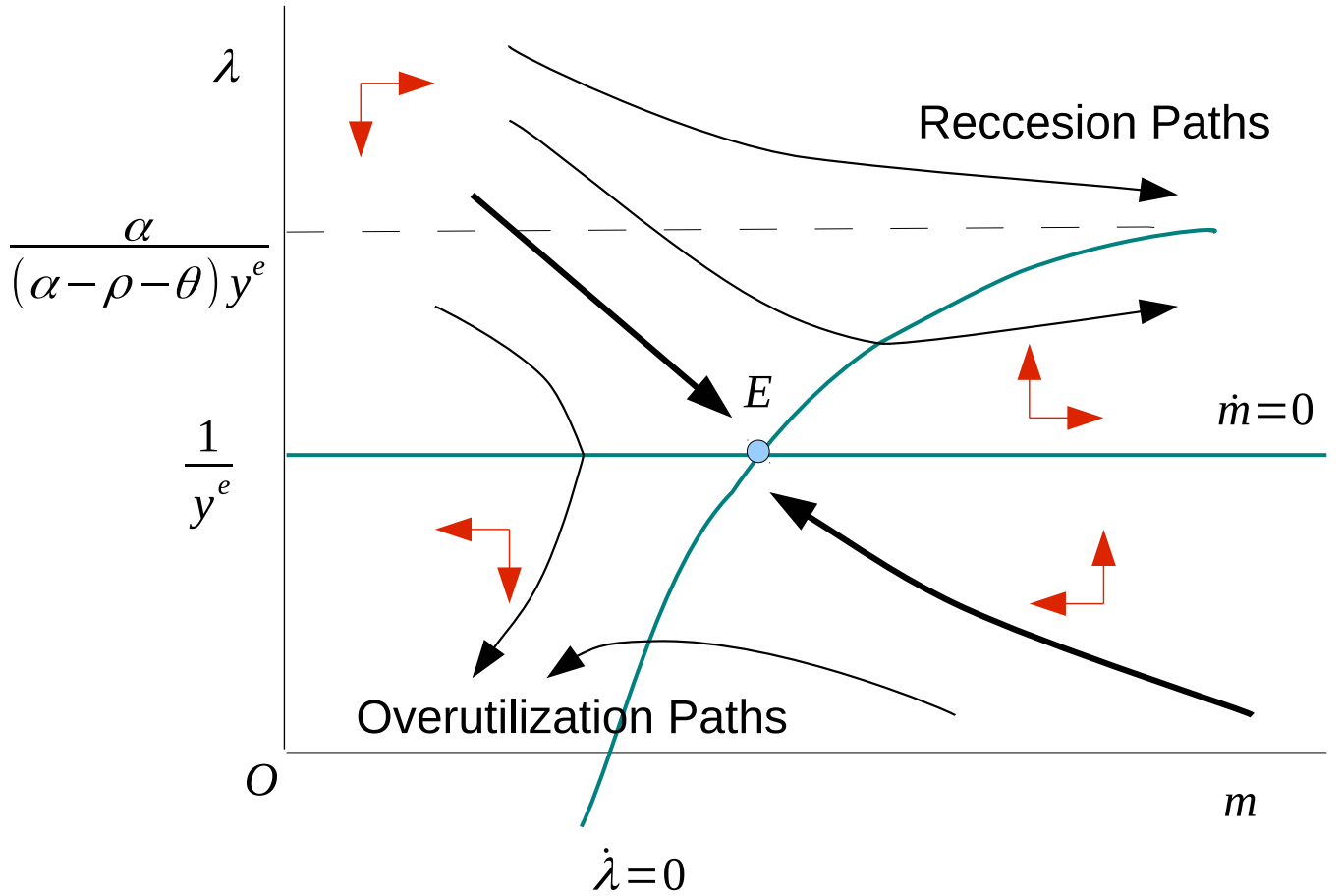


Figure 1: Recession paths: $0 < \theta + \rho < \alpha$

the $\dot{m} = 0$ locus, which is a horizontal line at $\lambda = 1/y^e$. Next we turn to the $\dot{\lambda} = 0$ locus, which is defined by

$$\lambda = \frac{1}{\alpha - \rho - \theta} \left(\frac{s'(m)}{1 + s(m)} + \frac{\alpha}{y^e} \right) \equiv F(m). \quad (22)$$

Since the shape of the $\dot{\lambda} = 0$ locus depends on the sign of $(\alpha - \rho - \theta)$, we divide the analysis into three cases according to whether α is less than, greater than, or equal to $\rho + \theta$.

Case 1: $\alpha > \rho + \theta$ (Recession paths)

The phase diagram is illustrated in Figure 1. Because $F'(m) = \phi'(m)/(\alpha - \rho - \theta) > 0$ in this case, the $\dot{\lambda} = 0$ locus is upward sloping. Furthermore, it has a unique intercept on the m axis because $\lim_{m \rightarrow 0} F(m) = -\infty$ and $\lim_{m \rightarrow +\infty} F(m) = \alpha/[(\alpha - \rho - \theta)y^e] > 0$. It is very important to notice that the $\dot{\lambda} = 0$ locus is asymptotic to the line $\lambda = \alpha/[(\alpha - \rho - \theta)y^e]$. In addition, it

is indicated that $\dot{\lambda} < 0$ for any point to the left of the $\dot{\lambda} = 0$ locus, while $\dot{\lambda} > 0$ for any point to the right of it. On the other hand, from (21), we can see that $\dot{m} < 0$ above the $\dot{m} = 0$ locus and $\dot{m} > 0$ below it.

The steady state (m^*, λ^*) is obtained by the intersection of the $\dot{m} = 0$ locus and the $\dot{\lambda} = 0$ locus. The values can easily be calculated and they fulfill

$$-\frac{s'(m^*)}{1+s(m^*)}y^e = \rho + \theta, \quad \lambda^* = 1/y^e. \quad (23)$$

The arrows of motion are plotted in the phase diagram and we can see that the steady state is globally saddle-point stable. We are now ready to investigate the dynamic properties of the economy from the point of view of global dynamics. There are three categories of dynamic trajectories: the full-utilization paths, overutilization paths, and underutilization paths.

On the overutilization paths, the costate variable λ has a decreasing tendency and the value eventually becomes negative, as shown in Figure 1. This implies that the level of consumption becomes negative since λ is the reciprocal of aggregate demand. On this point, see (4). Thus we can rule out the overutilization paths as dynamic general equilibrium paths.

The full-utilization path is represented by a saddle path. The economy moves along the stable saddle path and converges to the efficient level of output monotonically.

On the underutilization paths, the consumption level approaches $(\alpha - \rho - \theta)y^e/\alpha$, which is below the efficient level of output, y^e . Thus, it is appropriate to say that the underutilization path in this case is a ‘recession’ path. Furthermore, it should be stressed that the level of real balances diverges to infinity on the recession paths. In this circumstance, (5) implies that the nominal interest rate falls to zero and thus the household prefers to hold a great deal of money. Such a situation corresponds to the *liquidity trap*, which is pointed out by Keynes (1936).

Case 2: $\rho + \theta > \alpha$ (Depression paths)

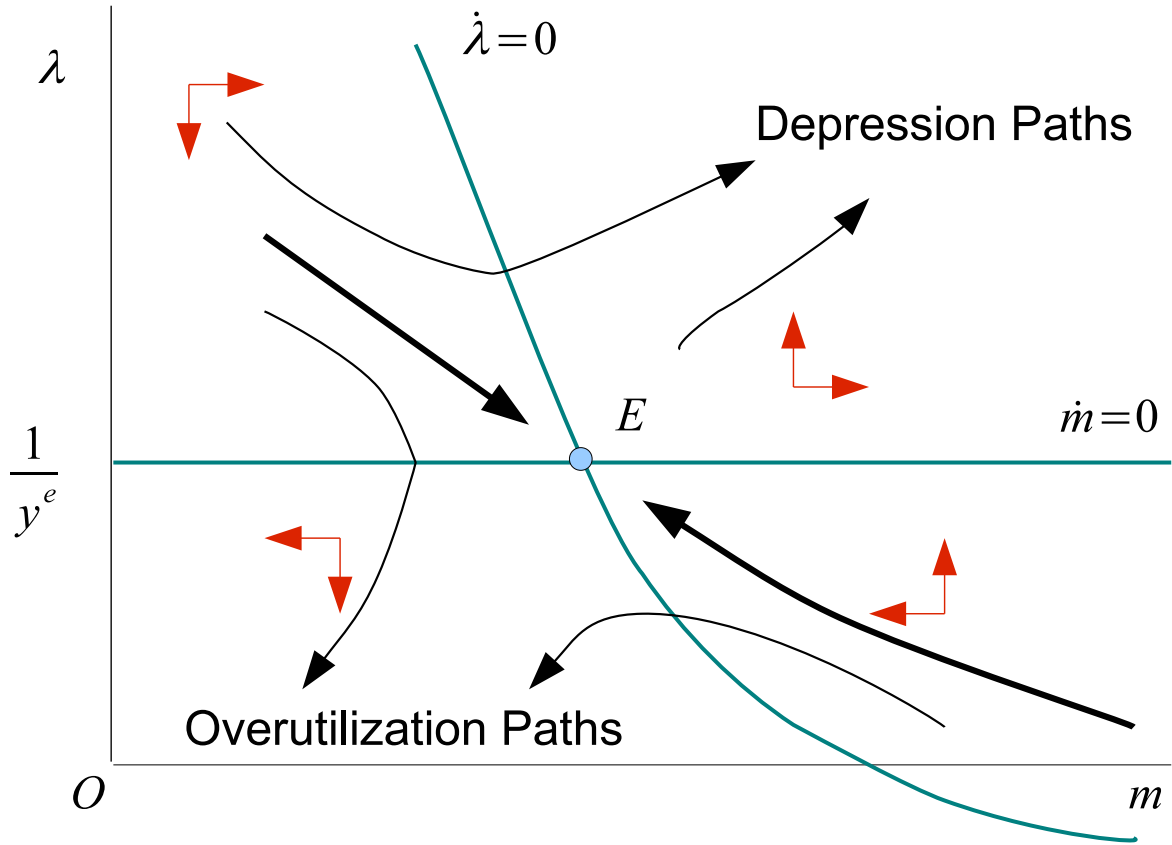


Figure 2: Depression paths: $\alpha < \theta + \rho$

The phase diagram is given in Figure 2. The analytical procedure is the same as that employed in Case 1. The downward-sloping curve is the $\dot{\lambda} = 0$ locus, which intersects the positive part of the m axis only once. This is because $F'(m) = \phi'(m)/(\alpha - \rho - \theta) < 0$, $\lim_{m \rightarrow 0} F(m) = +\infty$, and $\lim_{m \rightarrow +\infty} F(m) = \alpha/[(\alpha - \rho - \theta)y^e] < 0$. The horizontal line is the $\dot{m} = 0$ locus: $\lambda = 1/y^e$.

Due to these two loci, we can draw the direction of motion according to the differential equations. It is easy to verify that the steady state is a saddle point in the global sense.

In this case also, there are three types of dynamic trajectories: the full-utilization path, the depression paths, and the overutilization paths. There is no need to go into details about the full-utilization path and the overutilization paths since we have already considered the properties of these two paths enough in Case 1.

In particular, we shall discuss the depression paths: both λ and m diverge to infinity as $t \rightarrow \infty$. From (4) we can see that the level of consumption shrinks to zero on the depression paths. Moreover we can easily show that the nominal interest rate converges to zero as $t \rightarrow \infty$ by using (5). Thus, it is obvious that any depression path in our framework is accompanied by the liquidity trap.

Case 3: $\alpha = \rho + \theta$ (Depression paths)

This case can be classified as a special case of Case 2. If we notice that the $\dot{\lambda} = 0$ locus is vertical at $m = m^*$ such that $\phi(m) + \alpha/y^e = 0$, all the remaining factors are identical to those in Case 2. We can therefore find three types of dynamic trajectories in Case 3: the full-utilization path, the depression paths, and the overutilization paths.

3.3 Checking the transversality condition

So far we have argued the behavior of trajectories in our monetary model. Let us now consider the validity of the transversality condition. To verify the optimality of dynamic trajectories, we check the transversality condition (7). Since $a = qE + m$, it suffices to examine the following condition

$$\lim_{t \rightarrow \infty} (m_t + q_t E) \lambda_t e^{-\rho t} = 0. \quad (24)$$

By using (6) and (11), we obtain

$$\begin{aligned} \frac{\dot{q}_t}{q_t} + \frac{\dot{\lambda}_t}{\lambda_t} - \rho &= \left(r_t - \frac{d_t}{q_t} \right) + (\rho - r_t) - \rho \\ &= -\frac{d_t}{q_t} < 0, \end{aligned} \quad (25)$$

and

$$\begin{aligned} \frac{\dot{m}_t}{m_t} + \frac{\dot{\lambda}_t}{\lambda_t} - \rho &= (\theta - \pi_t) + (\rho - r_t) - \rho \\ &= \theta - (r_t + \pi_t). \end{aligned} \quad (26)$$

The question we now have to consider here is which types of dynamic trajectories should be regarded as dynamic general equilibrium paths. For our purpose we shall check the validity of the transversality condition in the following three cases, respectively: the full-utilization paths, recession paths, and depression paths. First, we examine the full-utilization path, which is represented by the stable arm converging to the steady state. Since the real financial wealth a is constant at the steady state, it is evident that the full-utilization path satisfies the transversality condition.

Then, we consider the recession paths. As mentioned above, the nominal interest rate falls to zero as $t \rightarrow \infty$. Accordingly, we can recognize that the transversality condition is satisfied when $\theta < 0$ and it is violated when $\theta > 0$ by using (25) and (26).

Finally, we deal with the depression paths. In this case also, the nominal interest rate drops to zero as $t \rightarrow \infty$. Consequently, by using (25) and (26), we obtain the same result: the transversality condition is satisfied when $\theta < 0$, while it is violated when $\theta > 0$.

The above discussion can be summarized in the following proposition:

Proposition 1. (1) *Suppose that monetary policy is expansionary: $\theta > 0$. Then the dynamic general equilibrium path is described by the saddle path.*

(2) *Suppose that monetary policy is contractionary: $\theta < 0$. Then the economy displays the indeterminacy of equilibrium:*

(2A) *If $\alpha > \rho + \theta$, every recession path, as well as the saddle path, emerges as a dynamic general equilibrium path.*

(2B) *If $\alpha \leq \rho + \theta$, every depression path, as well as the saddle path, appears as a dynamic general equilibrium path.*

Proposition 1 provides an important policy implication. The government is able to stimulate the level of consumption and avoid the liquidity trap situation by using expansive monetary

policy. Moreover, we have to emphasize that even a low growth rate of the money supply in our theoretical case has a sufficient effect to avoid the liquidity trap and establish the full-utilization path as long as it is positive: $\theta > 0$.

What is significant in our argument is that we assume a constant growth rate rule for the nominal money supply. This rule might seem to be contradictory to current monetary policy rule from the practical point of view, but it is not always the case. It is certain that the current practice of central banks in many countries is characterized by the interest rate control. As suggested by Taylor (1993), central banks should follow to adjust the nominal interest rate in response to changes in inflation and output. That is, monetary policy should be conducted by the the choice of the interest rate rather than the growth rate of nominal money supply.

The experience of the Great Recession, however, tells us that central banks should take the unconventional monetary policy actions such as quantitative easing instead of the Taylor rule. If once the economy falls in the liquidity trap with a zero nominal interest rate, the Taylor rule can no longer be operative because of the difficulty in reducing the nominal short-term interest rate below zero. In fact, the nominal short-term interest rate in the United States has declined to almost zero since the end of 2008. In such an extraordinary situation the Federal Reserve of the United States has implemented three rounds of quantitative easing since the onset of the Great Recession: a first round starting in November 2008, a second round announced in November 2010, and a third round beginning in September 2012. The aim of the Fed is to induce higher inflationary expectations through massive increases in the money supply. This episode about expansionary monetary policy shows that the control of monetary aggregate, rather than the short-run nominal interest rate, could play an important role in the conduct of monetary policy.

4 An application to the recent data for Japan and the United States

4.1 Data description

We further empirically test the theoretical predictions using monthly data from 1980m1 to 2013m6 for both Japan and the United States. The macro indicators include: (1) inflation (π), which is rated by the change in the seasonally adjusted Producer Price Index (PPI) for both countries; (2) the rate of growth of money supply (θ), which is computed by the change in the seasonally adjusted monthly average money supply: (i) M2+CDs for Japan; and (ii) M2 for the United States; and (3) the actual rate of capacity utilization (u_t), which is measured by: (i) industrial production indices for Japan,⁶ and (ii) industrial production and capacity utilization in percent of total possible output for the United States. The details of our data sources and data description are described in Appendix 1.

4.2 Descriptive statistics

This section summarizes relevant macro indicators for Japan and the United States for the following three periods: (1) the whole periods of 1980m1–2013m6; (2) the “Lost Two Decades” periods of 1991m02–2011m02; and (3) the “Great Recession” periods of 2007m12–2009m12.

Table 1, which describes basic statistics of indicators, shows that the mean of the inflation rates (π) were 0% and 0.2% for Japan and the United States, respectively, during both the whole periods and the “Lost Two Decades” periods; yet it slightly lowered to -0.1% and 0% for these countries, respectively, during the “Great Recession” periods. These results indicate that inflation rates (π) were lower during the “Great Recession” periods relative to other two periods and that they were overall lower in Japan than the United States. It confirms that Japan is under sustained low inflation or deflation and that the United States also faces persistently low

⁶Industrial production indices are calculated with 2010 as the base year (=100), and they are multiplied by 0.767 (or 76.7%), which is the actual operation rate based in the year 2010 as defined by the Ministry of Economy, Trade and Industry. See details at <http://www.meti.go.jp/statistics/tyo/iip/index.html>.

inflation, particularly during the “Great Recession” periods.

The table also shows that the mean of the rate of growth of money supply (θ) during the whole periods is 0.37% and 0.49% for Japan and the United States, respectively, while it contracts to 0.19% for Japan and downs slightly to 0.41% for the United States during the “Lost Two Decades” periods. During the “Great Recession” periods, the rate of growth of money supply (θ) in Japan slightly increases to 0.25%, and it in the United States expands to 0.65%. These results echo the widely prevalent view on differences in controlling money supply by two countries and prove a more-progressive monetary policy was implemented by the United States during times of recession.

Table 1 further provides the actual rate of capacity utilization rates (u_t) for Japan and the United States. The mean of u_t in Japan were 85% in the whole periods, 83% in the “Lost Two Decades” periods, and down to 77% in the “Great Recession” periods. In the case of the United States, it was 79% both in the whole period and the “Lost Two Decades” period, and reduced to 75% in the “Great Recession” periods. These results confirm that capital that is being used in the production of goods was reduced during the “Great Recession” periods for both Japan and the United States. Also, Japan’s rates of capital utilization during the “Lost Two Decades” periods and the whole periods were about the same (83% vs. 85%). Furthermore, capital utilization and inflation are positively related the lower the capital utilization rates, the lower the inflation rates for both Japan and the United States.

In discussing the equilibrium dynamics, we consider the relationship between the slope of the Keynesian Phillips curve (α) and the natural rate of nominal interest ($\rho + \theta$), where ρ is the subjective discount rate⁷ and θ is the rate of growth of money supply in each period. Table 2, which provides the summary of the natural rate of nominal interest ($\rho + \theta$), shows that the mean of the natural rate of nominal interest ($\rho + \theta$) is: (1) 0.007 for Japan, and 0.008 for the

⁷The subjective discount rate (ρ) is assumed to be 0.0033 (or 0.33%), which correspond the annual discount rate of 0.04 (or 4%). See Prescott (1986) for detail.

United States during the whole periods; (2) 0.005 for Japan, and 0.007 for the United States during the “Lost Two Decades” periods; and (3) 0.006 for Japan, and 0.01 for the United States during the “Great Recession” periods.

Finally, we shall pay attention to the money contraction. It is because the negative growth rate of the money supply is a key condition for the occurrence of recession and depression paths from the theoretical point of view. This matter has been mentioned in Proposition 1. We focus on the negative growth rate of the money supply that occurs consecutively for three months or more. Our data on the rate of growth of money supply (θ) reports that there were nine contraction phases in Japan, while there were only four contraction phases in the United States during whole period of 1980m1 to 2013m6.⁸ It is reasonable to suppose that monetary policy in the United States was more active than that in Japan during the period examined.

5 Estimating the slope of the Phillips curve

5.1 Empirical strategy

We consider equation (19) in fitting the New Keynesian Phillips curve (NKPC) under the IS-LM framework, which assumes a monetarist specification of inflationary expectations formation, $E_t(\pi_{t+1}) = \theta$, for Japan and the United States. Employing a most recent historical data from 1980m1 to 2013m6, the primary interest is centered on estimating the following equation, in which an inflationary movement is measured by capacity utilization, using Ordinary Least Squares (OLS) with White heteroskedasticity-consistent standard errors:

$$\pi_t - \theta = \alpha(u_t - \tilde{u}), \quad \alpha > 0 \tag{27}$$

where π_t and θ refer to inflation rate and the rate of growth of money supply, respectively.

Finally, u_t represents the actual rate of capital utilization at time t , and \tilde{u} denotes the normal

⁸For Japan, there are nine contraction phases, which include 1992m8–1992m11, 1993m8–1993m11, 1996m8–1996m10, 2001m8–2001m10, 2003m8–2003m10, 2004m8–2004m10, 2006m5–2006m8, 2008m8–2008m10, and 2009m8–2009m10. For the United States, there are four contraction phases, which include 1992m4–1992m7, 1992m12–1993m4, 1994m8–1994m10, and 2003m9–2003m11. The rate of growth of money supply (θ) is calculated by the authors using the data utilized in this study and is available upon request.

rate of capital utilization.

In the theoretical formulation of New Keynesian Phillips curve (19) we have $\tilde{u} \equiv 1$. It is, however, rather restrictive from the empirical point of view. For this reason, the empirical analyses consider two different measures of the normal rate of capital utilization, \tilde{u} . The first measure, $\tilde{u}_{\bar{t}}$, is calculated by the mean of total capital utilization observations in the period to measure the realized value of the output-capacity ratio.⁹ It intends to capture the *overall* effect of economic conditions (recessions or depressions) that has on production capacity for each period examined. On the other hand, the second measure, $\tilde{u}_{MA(24)}$, is defined as the mean of the most recent two-year (or 24 months) observations.¹⁰ It assesses the effect of *recent* changes in economic conditions that has on production capacity for each period examined. These two different measures of the normal rate of capital utilization allow us to examine how the value of the output-capacity ratio, which signals the movement of inflation, is influenced by the changes in economic conditions.

5.2 Unit root tests

Prior to the estimation of the New Keynesian Phillips curve, it is necessary to ensure that relevant macro series in the data are stationary when estimating the equation; hence, we perform the unit root tests for the following terms: (1) inflation (π); (2) the rate of growth of money supply (θ); (3) the actual rate of capital utilization (u_t); (4) the deviation of the actual rate of inflation from its expected inflation rate ($\pi_t - \theta$); and (5) the deviation of the actual rate of capacity utilization from its normal rate, ($u_t - \tilde{u}$), which is defined as capacity utilization (CU).

Based on Table 3, which shows the results of the augmented Dickey-Fuller (ADF) and the Phillips Perron (PP) tests, inflation (π), the rate of growth of money supply (θ), and the deviation of the actual rate of inflation from its expected inflation rate ($\pi_t - \theta$) are stationary

⁹Total observation is 402 for the period 1980m1–2013m6, 241 for the period 1991m2–2011m2, and 19 for the period 2007m12–2009m6.

¹⁰The normal rate of capital utilization, ($\tilde{u}_{MA(24)}$), is calculated using the following equation: $\tilde{u}_{MA(24)} = (u_{t-1} + u_{t-2} + \dots + u_{t-24})/24$.

for both Japan and the United States. The results of the PP test for the first measure of the deviation of the actual rate of capital utilization from its normal mean ($u_t - \tilde{u}_{\bar{t}}$) with the use of the mean of total 402 capital utilization observations in the 1980m1–2013m6 period ($\tilde{u}_{t=402}$) are rather inconclusive; however, the result of ADF confirm that the indicator is stationary for both Japan and the United States. Furthermore, the alternative measure of the deviation of the actual rate of capital utilization from its normal mean ($u_t - \tilde{u}_{MA(24)}$) based on the most recent two-year normal rate of capital utilization observations $\tilde{u}_{MA(24)}$ is stationary for both countries.

5.3 Empirical results

This section examines the empirical results of the Ordinary Least Squares estimates using Tables 4. Estimates are obtained for Japan and the United States by three periods, separately, using two measures of the normal rate of capital utilization (\tilde{u}), where the first, ($u_t - \tilde{u}_{\bar{t}}$), captures the *overall* effect of economic conditions that has on production capacity, and the second, ($u_t - \tilde{u}_{MA(24)}$), assesses the effect of *recent* changes in economic conditions that has on production capacity.

5.3.1 The slope of the New Keynesian Phillips curve for Japan

A. The whole period of 1980m1–2013m6

Column (1-1) in Table 4 shows that the coefficient (α) in equation (27) of the first measure, ($u_t - \tilde{u}_{\bar{t}}$), is 0.001 and is statistically insignificant at the 1% level. This result implies that capacity utilization has no effect on inflation and other factors have explained the movement of inflation during the whole period, when the realized value of the output-capacity ratio (\tilde{u}) is measured as the mean of total capital utilization observations in the period. On the other hand, Column (1-2) in the table presents that the coefficient of the second measure, ($u_t - \tilde{u}_{MA(24)}$), is 0.027 and is statistically significant at the 1% level. It indicates that capacity utilization had a positive effect on inflation in the whole period, when the realized value of the output-capacity

ratio (\tilde{u}) is calculated from the mean of the most recent two-year (or 24 months) observations.

These incoherent results indicate that the ability of capacity utilization to measure inflationary movement depends on whether production capacity truly reflects actual production under changing in economic conditions. The statistically-insignificant estimate in the first measure is likely to be caused by numerous lagged and/or the unforeseen (positive or negative) responses in production capacity, which is not accurately transmitted to actual output changes, due to a series of unexpected events over three decades. These significant events include stock price shocks during the bubble period,¹¹ multiple monetary policy shocks over the whole period,¹² workweek length reductions,¹³ demand shocks¹⁴ and technology shocks¹⁵ during the Japan's lost decades, and capital loss and lifeline disruptions due to the Great East Japan earthquake and tsunami in 2011¹⁶ that struck in Japan's economy. Yet, the statistically-significant estimate in the second measure, which captures the effect of *recent* changes in economic conditions on production capacity, confirms that the Japanese economy experiences high unemployment and low inflation and that the recession is present during the whole period.

In assessing the equilibrium dynamics during the whole period, the mean of the natural rate of nominal interest rate ($\rho + \theta$), which is 0.007 as shown in Table 2, is well *below* the slope of the New Keynesian Phillips curve (α), which is 0.027 and is statistically significant as in Column (1-2) in Table 4, when capacity utilization explains the movement of inflation. This result suggests that the economic *recession* is confirmed during the whole periods and it mirrors the reported

¹¹Stock price disturbances have led a long-lasting negative effect on output, especially during the bubble period. See Miyao (2002) for detail.

¹²Monetary shocks had a persistent effect on output, especially during the late 1980s and the early 1990s. See Sugo and Ueda (2008), Miyao (2002), Shioji (2000), and Kim (1999) for detail.

¹³The reduction in workweek length (to 40 hours (8 hours a day/5 days a week) due to the revision of the Labor Standard Law and the increase in the number of national holidays) during the 1990s reduced output growth. See Hayashi and Prescott (2002) for detail.

¹⁴Demand shocks, in particular an investment adjustment cost shock, reduced output since the beginning of the 1990s. See Sugo and Ueda (2008) for detail.

¹⁵Technology shocks have reduced output through the decline in capital utilization rates during the Japan's lost decade. See Miyazawa (2012) for detail.

¹⁶The 2011 Great East Japan earthquake and tsunami reduced production capacity in the Tohoku and Kanto regions as a result of facility damage and lifeline disruptions. See Kajitani and Tatano (2014) for detail.

economic stagnation in Japan. At the same time, the statistically-insignificant estimate Column (1-1) also indicates that the role of capacity utilization, as an inflation indicator, appears to be at minimal during the unexceptionally long economic stagnation under the sequence of unexpected events when production capacity does not truly reflect actual output.

B. The “Lost Two Decades” period of 1991m02–2011m02

Table 4 further presents that the coefficients (α) of the first measure ($u_t - \tilde{u}_{\bar{t}}$), shown in Column (2-1), and the second measure ($u_t - \tilde{u}_{MA(24)}$), shown in Column (2-2), are 0.028 and 0.031, respectively, and that both are statistically significant at the 1% level. These results report a positive relationship between capacity utilization and inflation during the “Lost Two Decades” period in Japan. Indeed, economic downturn led to an increase in unemployment and a decrease in production capacity, which caused price and wage to decrease and inflation to decline in the “Lost Decades,” which confirms the existence of an inverse relationship between unemployment and inflation.

To confirm the empirical findings, the mean of the natural rate of nominal interest rate ($\rho + \theta$) in Table 2, which is 0.005, is well below the slope of the New Keynesian Phillips curve (α) that is statistically significant and measured as 0.028 and 0.031 in Column (2) in Table 4. This result verifies that the economic *recession* is also apparent during the “Lost Two Decades” period in Japan.

C. The “Great Recession” period of 2007m12–2009m12

The similar trend persists for the “Great Recession” periods in Japan. Columns 3-1 and 3-2 in Table 4 also shows that the coefficients (α) of the first measure ($u_t - \tilde{u}_{\bar{t}}$) and the second measure ($u_t - \tilde{u}_{MA(24)}$) are 0.044 and 0.053, respectively, and both are statistically significant at the 1% level. These results confirm that the positive relationship between capacity utilization and inflation exist; hence, the “Great Recession” has led a high unemployment and a low inflation.

In consistent with the empirical results, the mean of the natural rate of nominal interest

$(\rho + \theta)$ during the “Great Recession,” which is 0.006 in Table 2, is well *below* the slope of the New Keynesian Phillips curve (α), which is 0.044 and 0.053 that are both statistically significant, as shown in Column (3) in Table 4. This result shows that the economic *recession* is also confirmed during the “Great Recession” in Japan.

5.3.2 The slope of the New Keynesian Phillips curve for the United States

A. The whole period of 1980m1–2013m6

Columns (1-1)’ and (1-2)’ in Table 4 shows that the coefficients (α) of the first measure ($u_t - \tilde{u}_{\bar{t}}$) and the second measure ($u_t - \tilde{u}_{MA(24)}$) are 0.032 and 0.041, respectively, and that both are statistically significant at the 1% level. These results indicate that capacity utilization had a positive effect on inflation during the whole periods in the United States and further confirm that the economy in this period has experienced high unemployment and low inflation.

In assessing the equilibrium dynamics during the whole period, the mean of the natural rate of nominal interest ($\rho + \theta$), which is 0.008 as shown in Table 2, is well *below* the slope of the New Keynesian Phillips curve (α) in Columns (1-1’ and 1-2’) in Table 4. Empirical results along with theoretical propositions confirm the presence of economic recession during the whole period in the United States. One could, however, argue that the U.S. economy was on the *saddle path*, instead of the recession, due to effective monetary policy implemented by the Federal Reserve Bank to promote the economic activity since reported money contraction was at minimal during the whole period in the United States.

B. The “Lost Two Decades” period of 1991m02–2011m02

A slightly different picture is drawn from estimates in the United States during the “Japan’s Lost Two Decades” period. Column (2-1)’ in Table 4 shows that the coefficient (α) of the first measure, ($u_t - \tilde{u}_{\bar{t}}$), is 0.013, and is statistically insignificant. This result indicates that other factors, rather than capacity utilization, have had an influence on inflation, when the

realized value of the output-capacity ratio (\tilde{u}) is measured as the mean of total capital utilization observations in the period. Conversely, the coefficient of the second measure, $(u_t - \tilde{u}_{MA(24)})$, shown in Column (2-2)', is 0.08 and is statistically significant at the 1% level. It indicates that capacity utilization had a positive effect on inflation, when the realized value of the output-capacity ratio (\tilde{u}) is calculated from the mean of the most recent two-year observations.

These inconsistent results are obtained from the ability of capacity utilization to measure inflationary movement, again, depends on whether production capacity truly reflects actual production under changing in economic conditions. The statistically-insignificant estimate in the first measure is likely to be explained by unanticipated multiple lagged and/or the unforeseen (positive or negative) responses in production capacity, which does not fully reflect actual production, due to significant events during the period in the United States. These events include a rapid change in technological progress¹⁷ and a sizeable increase in intangible investment,¹⁸ which was an important contributor to fluctuations in the economy during the 1990s "IT revolution" in the United States (Hansen and Prescott, 1993). But, the statistically-significant estimate in the second measure, which captures the effect of *recent* changes in economic conditions on production capacity, confirms that the U.S. economy experiences high unemployment and low inflation during the "Lost Two Decades" period.

In examining the equilibrium dynamics in the United States, the mean of the natural rate of nominal interest ($\rho + \theta$), which is 0.007 as shown in Table 2, is *below* the slope of the New Keynesian Phillips curve (α) that is 0.081 and is statistically significant as in Column (2') in Table 4, when capacity utilization explains the movement of inflation. Hence, theoretical prediction also confirms that economic recession was present during this period. This finding,

¹⁷Technological change during the 1990s reduced input usage and capital utilization, while output unchanged. Existing studies show that technological change reduces: (i) capital utilization by 0.2-2.3 % points (Bansak et al., 2007); (ii) reduce input usage and falls capacity utilization, while reporting no changes in output (Basu et al., 2006); (iii) increased labor productivity and productivity growth (Oliner et al., 2008); and (iv) underestimated aggregate productivity growth (Brynjolfsson and Hitt, 2003).

¹⁸Intangible investment raised output and labor productivity. See McGrattan and Prescott (2010) and Corrado et al. (2009) for detail.

however, contradicts the reported economic growth during the 1990s “IT revolution” era and further suggests that technology shocks hinder the ability of capacity utilization to accurately measure actual output changes, which is often referred as a “productivity paradox” (Triplett, 1999), during the “Lost Two Decades” period in the United States.

C. The “Great Recession” period of 2007m12–2009m12

A compelling story is drawn for the “Great Recession” period in the United States. Table 4 shows that the coefficients (α) of the first measure ($u_t - \tilde{u}_t$), shown in Columns (3-1)’, and the second measure ($u_t - \tilde{u}_{MA(24)}$), shown in (3-2)’, are 0.046 and 0.085, respectively, and that both are statistically insignificant.

These results confirm that capacity utilization fails to explain the movement of inflation during the “Great Recession” period in the United States. The potential reason for this contradictory, yet expected, finding is the lagged and/or the unforeseen negative responses that are not fully reflected in production capacity as a result of the financial crisis of 2007–2009. During this period, the movement of inflation was likely to have been directed by other factors, such as the volatile asset market and various government interventions that were intended to promote economic recovery after the financial crisis. Notably, policymakers and regulators offered the Troubled Asset Relief Program¹⁹ and the Exchange Stabilization Fund²⁰ to stabilize the banking sector and to deal with the failure of large financial firms (Swagel, 2015; and others).

The analysis of the natural rate of nominal interest ($\rho+\theta$) and the slope of the New Keynesian Phillips curve (α), which assess the equilibrium dynamics, are unlikely to evaluate economic conditions because capacity utilization fails to explain the movement of inflation. It is, instead, confirmed that unforeseen and unexpected events, such as the financial crisis and government

¹⁹The Troubled Asset Relief Program includes the initial response to the manifestation of the crisis in August 2007 relied on conventional tools of monetary policy and moderate regulatory discretion. See Swagel (2015) for detail.

²⁰The Exchange Stabilization Fund includes the \$50 billion to set up an insurance program to insure depositors in money market funds that is secured by the US Department of the Treasury in 2008. See Swagel (2015) for detail.

interventions, are likely to be major factors that could explain the movement of inflation and economy during the “Great Recession” periods in the United States.

6 Conclusion

The paper examines the capacity utilization rate as an inflation indicator in fitting the New Keynesian Phillips curve under the IS-LM framework. To accomplish this, a theoretical model is developed by incorporating the dynamic optimizing behavior of private agents, and is further empirically tested with Ordinary Least Squares estimates using 1980–2013 monthly data for Japan and the United States. Furthermore, we examine the equilibrium dynamics and assess the occurrence of economic slumps for both countries.

This study offers three notable findings. First, production capacity does not fully reflect actual output when a series of unexpected events strike an economy over a long period of time. Hence, the effect of capacity utilization on inflation is nonexistent when the realized value of the output capacity ratio is measured in the long term, yet it does when the realized value is measured in the short term. This phenomenon was observed in Japan during the whole period of 1980m1 to 2013m6 and in the United States during the “Lost Two Decades” period of 1991m02 to 2011m02. Second, estimates along with theoretical propositions confirm that capacity utilization had a positive effect on inflation and that economic recessions were present in Japan during both the “Lost Two Decades” and the “Great Recession” periods and in the United States during the whole period. Lastly, capacity utilization fails to explain the movement of inflation in the United States during the “Great Recession” period, which confirms that other factors, such as unstable asset markets and various government interventions, are the driving forces for changes in inflation.

This paper contributes to the existing literature on the New Keynesian Phillips curve by theoretically extending the model to examine the occurrence of persistent economic slumps

within the dynamic general equilibrium framework. It sheds further light on the literature by empirically estimating the slope of the Phillips curve for Japan and the United States using a most recent data from 1980 to 2013. Our study reveals that capacity utilization is a reliable predictor of inflation when an economy does not experience unexpected major events. It further confirms the presence of economic recessions both in Japan and the United States during the period 1980–2013. The findings of our study will help to determine appropriate monetary policies to stimulate the economy, via the New Keynesian Phillips curve, in Japan and the United States, and potentially in other developed nations, during economic slumps.

Table 1: Basic Statistics

Japan				
	π	θ	u	PPI
Mean				
1980m01-2013m06: Whole Period	-0.000046	0.00373	0.8455	104.1448
1991m02-2011m02: The Lost Two Decades	-0.000321	0.00190	0.8261	101.0278
2007m12-2009m06: Great Recession Period	-0.001249	0.00246	0.7726	103.9105
Std. Dev.				
1980m01-2013m06: Whole Period	0.004344	0.00887	0.0720	5.9495
1991m02-2011m02: The Lost Two Decades	0.003902	0.00659	0.0643	4.0392
2007m12-2009m06: Great Recession Period	0.010743	0.00437	0.1433	3.0917
Std. Error				
1980m01-2013m06: Whole Period	0.000217	0.00044	0.0036	0.2967
1991m02-2011m02: The Lost Two Decades	0.000251	0.00042	0.0041	0.2602
2007m12-2009m06: Great Recession Period	0.002465	0.00100	0.0329	0.7093
Min				
1980m01-2013m06: Whole Period	-0.019337	-0.01281	0.5315	94.1000
1991m02-2011m02: The Lost Two Decades	-0.019337	-0.01281	0.5315	94.1000
2007m12-2009m06: Great Recession Period	-0.019337	-0.00452	0.5315	99.6000
Max				
1980m01-2013m06: Whole Period	0.031022	0.04194	0.9680	115.5000
1991m02-2011m02: The Lost Two Decades	0.022472	0.02477	0.9603	109.3000
2007m12-2009m06: Great Recession Period	0.022472	0.01063	0.9158	109.3000
The United States				
	π	θ	u	PPI
Mean				
1980m01-2013m06: Whole Period	0.002192	0.00492	0.7940	134.2973
1991m02-2011m02: The Lost Two Decades	0.001785	0.00413	0.7937	144.0498
2007m12-2009m06: Great Recession Period	0.000451	0.00669	0.7478	174.9421
Std. Dev.				
1980m01-2013m06: Whole Period	0.005696	0.00390	0.0373	29.0051
1991m02-2011m02: The Lost Two Decades	0.006115	0.00364	0.0401	18.8144
2007m12-2009m06: Great Recession Period	0.013411	0.00597	0.0519	4.7294
Std. Error				
1980m01-2013m06: Whole Period	0.000284	0.00019	0.0019	1.4466
1991m02-2011m02: The Lost Two Decades	0.000394	0.00023	0.0026	1.2119
2007m12-2009m06: Great Recession Period	0.003077	0.00137	0.0119	1.0850
Min				
1980m01-2013m06: Whole Period	-0.030286	-0.00988	0.6693	83.4000
1991m02-2011m02: The Lost Two Decades	-0.030286	-0.00988	0.6693	121.1000
2007m12-2009m06: Great Recession Period	-0.030286	-0.00097	0.6693	169.2000
Max				
1980m01-2013m06: Whole Period	0.019048	0.02633	0.8522	197.4000
1991m02-2011m02: The Lost Two Decades	0.018779	0.02158	0.8501	187.6000
2007m12-2009m06: Great Recession Period	0.018779	0.02158	0.8076	183.4000

Notes: The numbers of observation are 402 for the whole period, 241 for the lost two decades, 19 for the great recession period.

Table 2: Natural Rate of Nominal Interest ($\rho + \theta$)

Japan					
Period	Obs	Mean	Std. Dev.	Min	Max
1980m01-2013m06: Whole Period	402	0.00703	0.00887	-0.00951	0.04524
1991m02-2011m02: The Lost Two Decades	241	0.00520	0.00659	-0.00951	0.02807
2007m12-2009m06: Great Recession Period	19	0.00576	0.00437	-0.00122	0.01393
The United States					
Period	Obs	Mean	Std. Dev.	Min	Max
1980m01-2013m06: Whole Period	402	0.00822	0.00390	-0.00658	0.02963
1991m02-2011m02: The Lost Two Decades	241	0.00743	0.00364	-0.00658	0.02488
2007m12-2009m06: Great Recession Period	19	0.00999	0.00597	0.00233	0.02488

Table 3: Unit Root Tests

Japan						
	π	θ	u	$\pi - \theta$	$u_t - \tilde{u}_{n=402}$	$u_t - \tilde{u}_{MA(24)}$
ADF (1)	-8.950***	-22.809***	-2.601*	-16.947***	-2.601*	-4.155***
ADF (2)	-7.249***	-11.107***	-2.842*	-8.754***	-2.842*	-4.625***
ADF (3)	-6.848***	-9.355***	-2.914**	-7.720***	-2.914**	-4.814***
PP (1)	-10.646***	-22.582***	-2.536	-19.863***	-2.536	-3.991***
PP (2)	-10.712***	-23.317***	-2.632*	-19.880***	-2.632*	-4.167***
PP (3)	-10.828***	-23.150***	-2.697*	-19.865***	-2.697*	-4.292***
The United States						
	π	θ	u	$\pi - \theta$	$u_t - \tilde{u}_{n=402}$	$u_t - \tilde{u}_{MA(24)}$
ADF (1)	-11.265***	-9.373***	-2.106	-9.914***	-2.106	-2.832*
ADF (2)	-9.564***	-7.496***	-2.614*	-8.858***	-2.614*	-3.751***
ADF (3)	-8.027***	-7.588***	-3.076**	-7.970***	-3.076**	-4.571***
PP (1)	-15.244***	-12.298***	-1.853	-13.768***	-1.853	-2.343
PP (2)	-15.301***	-12.332***	-2.010	-13.921***	-2.010	-2.615*
PP (3)	-15.342***	-12.581***	-2.152	-14.028***	-2.152	-2.853**

Notes: ADF=Augmented Dickey-Fuller Test. PP=Phillips Perron Test. The tests include a constant and the number in brackets indicates the number of first difference terms included in the regression. ***, **, * indicate stationary at the 1%, 5% and 10% level, respectively.

Table 4: Estimation results

Period	1980m1 – 2013m6 (Whole Periods)		1991m2 – 2011m2 (the Lost 2 Decades)		2007m12 – 2009m6 (Great Recession)	
Observations	n=402		n=241		n=19	
	$u_t - \tilde{u}_{n=402}$	$u_t - \tilde{u}_{MA(24)}$	$u_t - \tilde{u}_{n=241}$	$u_t - \tilde{u}_{MA(24)}$	$u_t - \tilde{u}_{n=19}$	$u_t - \tilde{u}_{MA(24)}$
JAPAN	(1-1)	(1-2)	(2-1)	(2-2)	(3-1)	(3-2)
Intercept	-0.004*** (0.000)	-0.004*** (0.000)	-0.002*** (0.000)	-0.002*** (0.000)	-0.004 (0.002)	0.002 (0.003)
$u_t - \tilde{u}$	0.001 (0.006)	0.027*** (0.009)	0.028*** (0.007)	0.031*** (0.009)	0.044*** (0.015)	0.053** (0.018)
R-Squared	0.000	0.020	0.061	0.059	0.288	0.308
The United States	(1-1)'	(1-2)'	(2-1)'	(2-2)'	(3-1)'	(3-2)'
Intercept	-0.003*** (0.000)	-0.003*** (0.000)	-0.002*** (0.000)	-0.002*** (0.000)	-0.006 (0.004)	-0.002 (0.004)
$u_t - \tilde{u}$	0.032** (0.013)	0.041** (0.017)	0.013 (0.029)	0.081*** (0.065)	0.046 (0.079)	0.085
R-Squared	0.027	0.025	0.005	0.082	0.020	0.042

Notes: Standard errors are shown in parentheses. ***, **, * indicate significant at the 1%, 5% and 10% level, respectively.

APPENDIX 1: Data Source and Definition

(Date Accessed: August, 2015)

Japan		
Producer Price Index (PPI)	Variable Name	Corporate Goods Price Index, 2010 base, Producer Price Index, All commodities
	Data Source	Bank of Japan
	URL	http://www.stat-search.boj.or.jp/
Money Supply (M2)	Variable Name	M2+CDs, Average Amounts Outstanding, (Reference) Money Stock
	Data Source	Bank of Japan
	URL	http://www.stat-search.boj.or.jp/
Capacity Utilization (CU)	Variable Name	Industrial Production Indices, base in 2010=100
	Data Source	Ministry of Economy, Trade and Industry
	URL	http://www.meti.go.jp/statistics/tyo/iip/b2010_result-2.html
The United States		
Producer Price Index (PPI)	Variable Name	PPI: overall seas adjusted, index in 1982 dollars (sa)
	Data Source	BLS and EconStats
	URL	http://www.econstats.com
Money Supply (M2)	Variable Name	M2: seasonally adjusted, in billions of dollars
	Data Source	BLS and EconStats
	URL	http://www.econstats.com
Capacity Utilization (CU)	Variable Name	US Industrial Production and Capacity Utilization, Capacity Utilization Total (sa)
	Data Source	Board of Governors of the Federal Reserve System
	URL	http://www.federalreserve.gov/releases/g17/download.htm

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