ESSAYS ON
A NEW KEYNESIAN PERSPECTIVE FOR JAPAN

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI'I IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

IN
ECONOMICS

AUGUST 2005

By
Dolores Anne Galea'i Sanchez

Dissertation Committee:
Carl S. Bonham, Chairperson
Byron S. Gangnes
Carl E. Walsh
Xiaojun Wang
William A. Lampe
Acknowledgements

A work like this, shortcomings notwithstanding, is not accomplished without the help of others. Thanks to Professor Carl Bonham for chairing my dissertation committee, ensuring financial support, his teaching, leadership and counsel. Thanks to Professor Carl Walsh for unselfishly guiding this project throughout, spurring my effort by example. Thanks to Professor Bill Lampe for teaching me linear algebra, basic notions in set theory and for many helpful, nurturing conversations along the way. Thanks to Professors Theresa Greaney, Xiaojun Wang, and Byron Gangnes for sharing insights on Japan’s economy, rational expectations, and for moral support. Thanks to Professors emeriti Marcellus Snow and Burnham Campbell for revealing my first glimpse at the promise of Euler’s equation and macroeconomic research. Thanks also to the writings of the Bible and Mary Baker Eddy and those seeking to exemplify their teachings.

I have been fortunate in friendship. Thanks to Steve. Thanks to Porntawee and Somchai, my first colleagues, for sharing my interest in DSGE models, econometric software, \LaTeX{} and the love of a good laugh. Thanks also to Yuah, Vilasinee, Nina, Tomomi, Ari, Kimberly, Comfort, Kulakarn, Archie and Jackie. I can hardly wait to see us take our places. And dearer still, thanks to childhood friends Karl and Berna and their Sophia, Matthew, and to Dr. and Dr. Espaldon for sharing the secret of thriving in both career and family and making me feel a part of theirs.

These essays are dedicated to my Dad and Mom, Pedro and Florida Sanchez, with loving gratitude. Thank you for your example and for including me in your joint utility function, a remarkably forward looking and benevolent act. It is a joy to see an end and realize it is a beginning.

In what remains, all errors and shortcomings are mine alone.
Abstract

This study looks at dynamics in Japan's aggregate demand and supply over the period, 1972-2003, using the New Keynesian/New Neoclassical Synthesis model. This model incorporates sticky prices to the optimization problems of households and firms within a context of rational expectations. Overall, the results are similar to those using U.S. and Euro area data. The aggregate supply model, also known as the new Keynesian Phillips curve predicts inflation depends on next period's inflation and a measure of real marginal cost and allows for the estimation of the degree of rigidity and subjective discount rate, both structural parameters. The results suggest the new Keynesian Phillips curve is a reasonable approximation of Japan's inflation, especially when the model is extended to allow for inflation inertia. Specifically, the results predict Japan firms are forward looking and adjust prices every 2-3 quarters. Structural stability tests indicate parameter breakpoints occur in 1990 or 1996; near the end of the asset price bubble or start of the prolonged deflationary period. Aggregate demand is determined by future real output and real interest rates with the latter permitting evaluation of the impact of monetary policy. However, dissimilar to the new Keynesian Phillips curve, the Euler equation for output does not have much explanatory power as a theory of aggregate demand for Japan. Although allowing for output inertia and an open economy influence through the exchange rate channel predicts forward looking behavior dominates, the impact of real interest rates is effectively zero. Throughout this thesis, the empirical evidence suggests the Generalized Method of Moments is sensitive to the way the orthogonality condition is written and this is consistent with evidence on the U.S. and Euro area. However, for Japan, the variation in parameter magnitudes across equivalent moment conditions is much greater.
Contents

Acknowledgements ......................................................... iii
Abstract ....................................................................... iv

1 Introduction ................................................................. 1

2 Inflation Dynamics in Japan: Evidence of Price Rigidity and Structural Breaks .............................................................. 6
  2.1 Introduction .................................................................. 6
  2.2 Inflation Adjustment and Sticky Price Models ................. 8
    2.2.1 Theoretical Framework and Baseline Model ............. 9
    2.2.2 A Hybrid Model .................................................. 14
  2.3 Econometric Specification ............................................. 15
    2.3.1 Rational Expectations .......................................... 16
    2.3.2 Empirical Strategy .............................................. 16
    2.3.3 Reduced and Structural Model Specifications .......... 17
  2.4 Results ....................................................................... 18
    2.4.1 Data .................................................................. 18
    2.4.2 Estimates of the New Keynesian Phillips Curve for Japan ................................. 23
    2.4.3 Robustness Tests ............................................... 30
  2.5 Conclusion .................................................................. 37
3 **Inflation Dynamics in Japan: The Calvo Model and Wage Rigidity**

3.1 Introduction ................................................. 39

3.2 Theory Framework and Estimation Strategy .......................... 40
   3.2.1 The New Keynesian Phillips Curve with variable marginal cost ........ 43
   3.2.2 A Hybrid New Keynesian Phillips Curve .............................. 46

3.3 Results .......................................................... 47
   3.3.1 Baseline Estimates: The Reduced Form .................. 48
   3.3.2 Structural Estimates of the New Keynesian Phillips curve . . . . . . . . . . . . 49
   3.3.3 Hybrid Estimates .............................................. 51
   3.3.4 Parameter Stability Tests .................................. 53

3.4 Dynamics and Frictions affecting Real Marginal Cost ............... 56

3.5 Conclusion ..................................................... 60

4 **Aggregate Demand: Forward Looking Agents and the Zero Lower Bound**

4.1 Introduction .................................................. 61

4.2 Framework ..................................................... 63

4.3 Results .......................................................... 65
   4.3.1 Data ......................................................... 66
   4.3.2 Empirical Results ............................................... 69

4.4 Conclusion ..................................................... 76

Bibliography .................................................................. 77
## List of Tables

2.1 Basic Statistics for Inflation and Real Marginal Cost ........................................ 22
2.2 Reduced Model Estimates with Year-on-Year Inflation for Japan, 1972-2003 ........ 27
2.3 Structural Estimates with Year-on-Year Inflation for Japan, 1972-2003 .............. 28
2.4 Structural Estimates with Year-on-Year Inflation .............................................. 29
2.5 Structural Estimates of the Hybrid Model for Japan, 1972-2003 ......................... 32
2.6 Results of Model Stability Tests ................................................................. 35

3.1 New Keynesian Phillips Curve for Japan, 1972-2003 ....................................... 50
3.2 The Hybrid New Keynesian Phillips Curve for Japan, 1972-2003 ....................... 54
3.3 Results of Parameter Stability Tests .................................................................. 57

4.1 GMM Estimates of New Keynesian Aggregate Demand for Japan ..................... 70
4.2 GMM Estimates of Closed Economy Hybrid New Keynesian Aggregate Demand for Japan ................................................................. 71
4.3 GMM Estimates of Open Economy Hybrid New Keynesian Aggregate Demand for Japan ................................................................. 73
4.4 Open Economy Hybrid New Keynesian Aggregate Demand for Japan, (Exogenous Instruments) ................................................................. 74
4.5 Open Economy Nested New Keynesian Aggregate Demand for Japan ................ 75
List of Figures

2.1 Japan and United States Inflation, 1972-2003 ...................... 19
2.2 Japan Inflation and Unit Labor Cost Measures, 1971-2003 .......... 21
2.3 Japan Inflation and Real Output Gap Measures, 1972-2003 .......... 23
2.4 Nominal Rigidity using a 9 year Rolling Regression, 1982-1995 .... 36

3.1 Actual and Predicted Inflation with CRTS production: Japan, 1972-2003 ........ 52
3.2 Actual and Predicted Inflation with DRTS production: Japan, 1972-2003 ........ 53
3.3 Actual and Predicted Hybrid Inflation with DRTS production: Japan, 1972-2003 .... 55
3.4 Actual and Predicted Hybrid Inflation with CRTS production: Japan, 1972-2003 .... 56
3.5 Wage Markup for Japan, 1972-2003 ........................................ 59

4.1 Real Output Gap Measures, Japan 1971-2003 ...................... 66
4.2 Real Effective Exchange Rate, 1974-2001 .......................... 67
4.3 Forward Looking Real Interest Rates for Japan, 1971-2003 .......... 68
The devotion of thought to an honest achievement makes the achievement possible.

—Mary Baker Eddy
Chapter 1

Introduction

As Japan's history of stellar post-war economic growth and low inflation gave way to a torpid decline and deflation at the end of the century, it raised ongoing questions on the ability of economic models to capture the dynamics of Japan's experience. This is especially relevant as indicators suggest Japan is making a slow recovery. The following chapters consist of three essays, which collectively investigate the applicability of New Keynesian models to Japan's economy for the years, 1972-2003. The New Keynesian models also known in the literature as New Neoclassical Synthesis model, incorporates sticky prices and is derived from micro principles in the context of rational expectations. This framework predicts households and firms are forward-looking in forming their expectations all within the context of rational expectations. Taken together, this work provides further evidence on the efficacy of micro based models of aggregate behavior from the perspective of a country with dynamics that form a natural experiment. While a few studies look at Japan's economy in this context, none utilize a completely New Keynesian framework.

Two questions are addressed in the following chapters. The first is whether it is reasonable to model Japan's inflation from the standpoint of households and monopolistically competitive firms, both of which are assumed to optimize intertemporally in a context where firms are unable to set prices every period. The second reaches further to consider whether it is reasonable to model Japan's economy using a small New Keynesian monetary model to assess the impact of Japan's monetary policy. In this case, reasonableness is ascertained by the empirical adequacy of the estimated parameters, e.g.,
their consistency with theory implications, fit, robustness and more importantly, their plausibility. The model’s plausibility is best gauged by comparison to New Keynesian studies on the U.S. To answer the first question, evidence presented in this paper suggests that forward looking behavior and real marginal cost provide a reasonable approximation of Japan’s inflation over the last thirty years, although work remains to verify the results in robustness studies. However, the limitations of the New Neoclassical Synthesis model for Japan’s price adjustment are consistent with those for the U.S. and ongoing work in this area will likely provide improvements to applications of this framework to Japan. With respect to the use of the New Keynesian/New Neoclassical Synthesis model in an optimal monetary policy setting for Japan, much remains to be done in to bring the aggregate demand side of the model into a more credible representation of Japan’s real output dynamics. This is because the estimates of the Euler equation of output for Japan suggest the model does not have much explanatory power. Although forward looking behavior dominates in the open economy New Neoclassical Synthesis/New Keynesian model, the implication is that real interest rates do not influence the path of real GDP. Plainly, this is unsatisfactory although the results are similar to that for the U.S.

Throughout this work and others like it, e.g., Fuhrer and Moore (1995), Galí and Gertler (1999), Galí Gertler and López Salido (2001), Sbordone (2002), Fuhrer and Rudebush (2004), and Cogley and Sbordone (2005), the subtleties between backward and forward looking models for both aggregate demand and supply are central to the research agenda. However, the attention given these frameworks or “competing models” extends beyond methodological concerns and empirical performance although these are important to the discussion. This is because the New Neoclassical Synthesis/New Keynesian framework holds within it both satisfaction of the Lucas critique and the potential for welfare analysis—two aspects not readily achieved in ad hoc behavioral models. Collectively, empirical works like those mentioned previously form a robustness study that highlights shortcomings in both theory and estimation methodology. McCallum (1999) argues that a research strategy built on robustness tests is a key component for progress in the field, although he is speaking specifically to the design of optimal monetary policy rules rather than the specification and measure comparisons closer to the heart of this study. However, my work is consistent with McCallum’s overall agenda because the framework for aggregate
demand and aggregate supply are essential to the evaluation of optimal monetary policy rules. Specifically, attention in this thesis is focused on the impact of different measures on models of aggregate supply and demand that are purely backward looking, purely forward looking or a hybrid or both in modeling Japan's macroeconomic dynamics over the last thirty years.

Chapter 2 provides evidence on the fit of a New Keynesian Phillips curve to Japan using a conventional form of price rigidity. The model predicts the appropriate measure of real economic activity is real marginal cost, which can be measured by either a real output gap or a measure of labor's income share of GDP. In this essay, results are reported for a primitive model, which assumes a very simple technology—the Cobb Douglas production function with constant returns to scale. This technology implies that marginal cost is constant in the sense that it does not vary with influences like labor's marginal productivity across firms. The results suggest theory-consistent results, reasonable fit and evidence that forward-looking behavior dominates backward looking behavior. At the same time, the impact of real marginal cost on inflation is small and suggests the sticky price model fails to generate sufficient inflation inertia. In addition, the different measures for real marginal cost imply Japanese firms go 3 to 9 quarters between price adjustments surrounding the 6-quarter wait typically found for the U.S. A common critique is the waiting period is implausibly long; some researchers suggest a 2 to 3 quarter wait is more credible.

Chapter 3 provides further evidence on the fit of the New Keynesian Phillips curve for Japan over the years 1972-2003. It is motivated by the sense that Japan’s degree of price rigidity found in the typical model shown in Chapter 2 is implausibly severe and may be unduly affected by assumption that firms face constant returns to scare in production. Chapter 3 shows that relaxing this assumption implies variations in real marginal cost explains 20 to 30 percent of the variation in Japan's inflation when a generalized production function for the firm is used. In addition, the degree of rigidity is much less under this assumption and implies Japan firms adjust prices every 2 to 3 quarters refuting claims that the New Keynesian Phillips curve necessarily overestimates price rigidity. Tests for pure parameter and thus, model stability indicate structural breaks occur in the estimated coefficients. The break point dates under different specifications coincide with either Japan's land and asset price bubble
or deflationary period. A simple decomposition of labor market rigidities implies a substantial degree of wage rigidity may influence the dynamic behavior of real marginal cost and when incorporated into the New Keynesian framework may further improve the model's empirical performance. Robustness tests that nest forward and backward looking behavior imply that forward looking behavior dominates, a key aspect of the New Keynesian framework.

Chapter 4 provides evidence on the fit of the Euler equation for output in closed and open economy setting as well as in purely forward, purely backward and hybrid contexts. As a model of Japan's economy, the importance of forward looking rather than backward looking behavior might be expected to perform well given the country's downturn over the sample. It is reasonable to expect specifications that depend on lagged measures of real output to overestimate demand in a recessionary environment. For Japan, the purely forward looking model predicts real interest rates have no effect on demand. It is likely estimates for Japan are exacerbated by the extended slowdown in the 1990s, deflation and the zero lower bound on nominal interest rates. Under the open economy specification, forward looking behavior dominates backward looking behavior. And, while the real interest rate is statistically significant with the hypothesized sign, its magnitude is, again implausibly small for a thirty year sample. For closed economy specifications, backward looking behavior tends to dominate and the influence of the real interest rate, the channel for monetary policy, is statistically insignificant.

At this point, it is difficult to precisely identify the reason why the Euler output model provides more credible estimates than the aggregate demand one under the New Keynesian/New Neoclassical Synthesis framework. It may be that the assumptions for the real interest rate are inappropriate or that additional sources of persistence such as habit formation need to be incorporated. The estimator, the Generalized Method of Moments, used in this study may also affect the parameter estimates. Another source of failure on the demand side of the model may be inherent to Japan data, e.g., the zero interest rate policy and decade long recession. However, the greater issue is the ability of the model to describe the dynamics of Japan's economy rather than the ability of Japan's experience to explain the features of any particular model. In this sense, the evidence supports the conclusion that the New Neoclassical Synthesis hybrid inflation model holds some promise while the analogous specification for real output
does not. At the same time, this is unlikely to be a permanent conclusion, research in this literature is active and informed by empirical results such as those provided herein. It is hoped that this thesis will lead to insights that are useful to discussions of Japan’s economy and monetary policy over the last 30 years and to monetary economics, generally.
Chapter 2

Inflation Dynamics in Japan: Evidence of Price Rigidity and Structural Breaks

2.1 Introduction

For over two decades, Japan's inflation rate has been falling, passing into deflation in 1996 for the second time during the 90s where it remained, more or less, through 2003. This study discusses Japan's inflation between 1972 and 2003 using estimates of the New Keynesian Phillips curve. This model of inflation adjustment is used to represent aggregate supply in small macro monetary models, which are known as New Keynesian or New Neoclassical Synthesis models in the literature. Their main features are: households and firms dynamically optimize; rigidity is the only source of economic fluctuations; and decision making takes place within the context of rational expectations. The New Keynesian Phillips curve arises from a closed economy with households and monopolistically competitive firms that optimize in a dynamic setting. It is further assumed that firms set prices based on expectations because they are unable to set prices every period despite their market power. Intuitive reasons for this peculiarity include overlapping wage contracts (Taylor, 1980) or information costs associated with optimization. The New Keynesian Phillips curve predicts that inflation is determined by real marginal cost and next period's expected inflation. The reliance on next period's inflation rather than last period's is

\footnote{Eichenbaum and Fisher (2004) distinguish optimization costs, e.g., those associated with information gathering, negotiation and communication, overlapping contracts faced by firms with market power from menu costs where the latter are costs associated with changing the price of every good.}
used to distinguish the New Keynesian Phillips curve as being forward looking from the Phillips curve which is analogously described as backwards looking. A key issue in the literature is the empirical success of an inflation model which vests all macroeconomic influences such as demand or supply shocks in a single measure—real marginal cost.

The basic inquiry of this study is whether the New Keynesian Phillips curve is a reasonable model for Japan's inflation. The model's reasonableness is determined by the adequacy of empirical results in terms of the estimated parameters—their magnitudes, hypothesized signs, statistical significance, fit and robustness tests as well as how they compare to recent studies on Japan's inflation. This study belongs to three strands in the macroeconomics/monetary economics literature. First, its theory and methodological underpinnings stem from Yun (1996), Goodfriend and King (1997), Rotemberg and Woodford (1997), Clarida, Galf and Gertler (1999), Galf and Gertler (1999), Galf, Gertler and López-Salido (2001) and Sbordone (2002). Second, it follows several suggestions found in empirical studies for forward looking models assuming rational expectations, including Hansen (1982), Hansen and Singleton (1982), Rudd and Whelan (2001), Neiss and Nelson (2002), Eichenbaum and Fisher (2003), and Nason and Smith (2003). Third, as a study on Japan's economy using models with microfoundations, it is closely related to Coenen and Wieland (2003) and Leith and Malley (2003). In an earlier working paper version of Coenen and Wieland (2003), the authors report they are unable to estimate the New Keynesian Phillips curve using Calvo's (1983) model of nominal rigidity. Leith and Malley (2002) derive and estimate a open economy New Keynesian Phillips curve that uses Calvo (1983) rigidity and allows for import substitution. Unlike these Japan studies, this thesis utilizes a more general framework, the closed economy New Keynesian Phillips curve including Calvo's (1983) sticky price model. The benefit of this approach is that it provides an immediate comparison to similar works on the U.S. and the European area, e.g., Galf and Gertler (1999), Galf et al (2001), Rudd and Whelan (2001), Eichenbaum and Fisher (2003). Finally, this work provides comparisons to recent studies of mainstream Phillips curves for Japan, e.g., Higo and Nakada (1999), Hirose and Kamada (2003), and Kamada and Muto (2000).

Overall, the results suggest the New Keynesian Phillips curve is a reasonable description of Japan's
inflation dynamics, although there is room for improvement in the methodology and estimates of rigid­
ity. Specifically, four important conclusions are drawn from the results. First, when Japan’s inflation is
estimated using a structural model, output gap and wage based measures for real marginal cost suggest
Japan’s price level is fairly rigid and imply Japan firms go 3 to 9 quarters between price adjustments.
Second, in nested models, forward looking price setting behavior dominates backwards looking behav­
suggest significant structural breaks in 1996, around the start of Japan’s deflationary period. Fourth,
detrended real output performs poorly as a measure of real marginal cost for Japan. This result is sim­
ilar to findings for the U.S. and the Euro area and explains why early estimates of the New Keynesian
Phillips curves rejected the model. For example, Coenen and Wieland (2003) reject this model when
using detrended output rather than unit labor cost to measure real marginal cost.

This Chapter is comprised of five sections. Section 2.1 is the introduction. Section 2.2 presents
the major results in the theory of the New Keynesian Phillips curve and the hybrid, or nested, model.
Having presented the implications of the model, Section 2.3 contains the econometric specification and
issues raised in the literature concerning the prevailing methodology for estimating New Keynesian
Phillips curves and nested models of inflation. Section 2.4 presents the results. Section 2.5 offers
concluding remarks.

2.2 Inflation Adjustment and Sticky Price Models

Yun (1996), Goodfriend and King (1997), and Rotemberg and Woodford (1998), Clarida, Galf and
Gertler (1999) each make significant contributions to the development of New Keynesian/New Neo­
classical Synthesis models. As stated earlier, three features of these models are their microfoundations,
assumption of nominal rigidity and rational expectations context. Explicitly accounting for nominal
rigidity enables evaluations of short run monetary policy. Walsh (2003) and Woodford (2003) provide
thorough expositions on these models and their application to monetary policy. This section briefly
discusses some of the mechanics involved in deriving the New Keynesian Phillips curve.
2.2.1 Theoretical Framework and Baseline Model

The New Keynesian Phillips curve is derived from the dynamic decisions of households and firms. The representative household maximizes the expected present discounted value of utility, $U$, in consumption, $C$, real money balances, $M/P$, and leisure, $-N$, given its budget constraint. Consumption, $C$, is an aggregate of consumption goods based on Dixit and Stiglitz (1977). It is assumed that each element, $C$, $M/P$, and $N$, in the utility function, $U_t$, has a constant intertemporal elasticity. The household’s dynamic utility function is:

$$U_t(C, \frac{M}{P}, N) = E_t \sum_{i=0}^{\infty} \beta^i \left[ \frac{C_t^{1-\sigma}}{1-\sigma} + \frac{\gamma}{1-b} \left( \frac{M_t}{P_t} \right)^{1-b} - \frac{N_t^{1+\xi}}{1+\xi} \right]$$  \hspace{1cm} (2.1)$$

$\beta$ is the subjective discount rate, $\sigma$, $b$, and $\xi$ are positive parameters on the respective rates of intertemporal substitution. The composite consumption good, $C_t$, stems from household consumption of individual goods, $c_{jt}$, produced by firms $j \in [0, 1]$:

$$\left[ \int_0^1 \frac{r^1}{c_{jt} \theta^\theta} \frac{\theta^\theta-1}{\theta^\theta-1} \right] = C_t$$ \hspace{1cm} (2.2)$$

The parameter, $\theta$, is the price elasticity of demand for individual goods, which is assumed to be constant and identical for each firm. It implies that the corresponding demand functions are linear and identical across firms. The household’s decision is modeled using the Dixit and Stiglitz (1977) approach. First, the household optimally chooses individual goods, $c_{jt}$, to minimize the cost of attaining the composite good, $C_t$. This stage yields the demand for individual goods and the aggregate price level, $P_t$. In this stage, the household minimizes its cost for consuming each good:

$$\min_{c_{jt}} \int_0^1 p_{jt} c_{jt} dj \hspace{1cm} (2.3)$$

$^2$The parameter, $N$ represents labor units.
subject to \[ \int_0^1 c_{jt}^{\theta-1} dj \geq C_t, \] the constraint on the composite good in equation (2.2). After some rearranging, the first order conditions imply the demand for good \( j \):

\[ c_{jt} = \left( \frac{P_j}{P_t} \right)^{-\theta} C_t \] (2.4)

where \( P_t \) is the price level arising from the Lagrangian multiplier in the minimization problem. Second, given the overall cost of attaining any level of the composite good \( C_t \), the household chooses consumption, leisure and money holdings optimally based on its expected utility in equation (2.1) and its real-valued budget constraint:

\[ C_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} = \left( \frac{W_t}{P_t} \right) N_t + \frac{M_{t-1}}{P_t} + \left( 1 + \frac{i_{t-1}}{P} \right) \left( \frac{B_{t-1}}{P_t} \right) \Pi_t \] (2.5)

where \( M \) and \( B \) are the households money holdings in currency and one period bonds, respectively. \( W \) is the nominal wage, \( i \) is the nominal interest rate on bonds and \( \Pi \) are real profits household receive from firms. Three first order conditions follow from this optimization problem. The first describes consumption over time (Euler’s equation), a second relates real money balances to the nominal interest rate and the third relates real wages to leisure and consumption of the composite good.

Each firm \( j \) produces a single good, \( c_{jt} \) in time \( t \) and competes monopolistically with the other firms. They each face three constraints. The firm’s production technology is assumed to have no capital and constant returns to scale in labor.\(^3\) Second, the firm’s demand function stems from the household’s decision summarized in equation (2.4) and the assumption of constant price elasticity of demand, \( \sigma \) implies the optimizing firm has a constant marginal cost. Finally, firms cannot change prices at will. The last constraint is the basis for nominal rigidity.

Sbordone (2002) explains that the unit labor cost is the appropriate measure of real marginal cost when one assumes a simple technology such as the Cobb Douglas production function. Similarly,\(^3\) McCallum and Nelson (1997) argue that the assumption of an exogenous capital stock is not a critical flaw to macroeconomic models for short run analysis even when they are applied to sample periods of many years duration. This is primarily because a typical year’s investment is a relatively small compared to the existing capital stock. They illustrate the lack of correlation between capital and real output using US quarterly data and two measures of capital: net private non-residential fixed capital and a combination of private residential, government capital and household stock of consumer durables.
this chapter reports results based on the assumption that firms produce under a Cobb Douglas with constant returns to scale, which implies that real marginal cost is constant. Although simplifying, this assumption also reflects the idea that as an industrialized economy, Japan has no gains to be made from further specialization and is the same assumption used by Galf and Gertler (1999). To see the implication that unit labor cost rather than an output gap determines inflation, consider the following.

Denote the firm’s production function: \( Y_{jt} = AN_{jt} \), with output, \( Y_{jt} \), labor, \( N_{jt} \), and \( A_t \), a productivity disturbance. The optimizing firm then chooses the level of employment that minimizes the real wage given the firm’s budget constraint, which is determined by its demand. The Lagrangian for this decision problem using real rather than nominal variables is:

\[
L = \min_{N_{jt}} \left( \frac{W_{jt}}{P_t} \right) N_{jt} + \psi_t(e_{jt} - A_t N_{jt})
\]

Since it is assumed that all firms are alike in this regard, we can drop the firm subscript, \( j \). The first order condition of this problem is:

\[
\psi_t = \frac{W_t/P_t}{A_t}
\]

where \( \psi_t \) is the firm’s real marginal cost in \( t \), \( W \) and \( P \) are nominal wage and price. \( A \) is an aggregate productivity shock where it is assumed that \( E(A_t) = 1 \). Thus, real marginal cost is equivalent to real wages adjusted for aggregate productivity and its expected value is the real wage. The Cobb-Douglas production function with constant returns to scale implies that real marginal cost is the same as the average level of real marginal cost. In turn, this implies that average real marginal cost can be approximated by average unit labor costs.\(^4\)

Nominal rigidity enters into the framework following Calvo (1983), which divides the firms in the economy in time \( t \) between those that are able to change their prices and those that are not. He assigns an exogenous probability, \( \alpha \), that firms do not optimally adjust prices in time \( t \) and further specifies that

\[^4\text{When there are decreasing returns to scale, the production function becomes } Y_{jt} = AN_{jt}^\alpha, \text{ where } \alpha \in (0, 1) \text{ determines labor's input share of output. Real marginal cost in this case is weighted by the factor governing the return to labor, } \psi_t = \frac{W_t N_{jt}^\alpha}{A_t}. \text{ Gall, et al (2001); Sbordone (2002), and Eichenbaum and Fisher (2004) argue that this assumption generates more plausible estimates of rigidity and the influence of real marginal cost on inflation. Chapter 3 presents the implications of this assumption with respect to Japan inflation.}\]
each firm’s decision to set prices in period \( t \) is independent of any other firm’s decision to do so. The independence between events means that the economy’s degree of rigidity can be computed by forming the product of the individual probabilities. Each firm produces a single good using the same production technology. In addition, they face identical demand curves due to the assumption that demand elasticity, \( \theta \), is identical across all firms and constant.

The firm’s decision problem is to choose its price, \( p_{jt} \), to maximize the present discounted value of its profits, \( T_t \), given real marginal cost, \( \psi_t \), and its opportunities to change prices determined by \( 1 - \alpha \):

\[
T_t = E_t \sum_{i=0}^{\infty} \alpha^i \beta^i \left( \frac{C_{t+i}}{C_t} \right)^{-\sigma} \left[ \left( \frac{p_{jt}}{P_{t+i}} \right)^{1-\theta} - \psi_{t+i} \left( \frac{p_{jt}}{P_{t+i}} \right)^{-\theta} \right] C_{t+i} \quad (2.8)
\]

This implies that the optimal relative price for any firm that adjusts its price in time \( t \) is:

\[
\frac{p^*_t}{P_t} = \frac{\theta}{\theta - 1} \left[ \frac{E_t \sum_{i=0}^{\infty} (\alpha \beta)^i C_{t+i}^{1-\sigma} \psi_{t+i} \left( \frac{p_{jt}}{P_{t+i}} \right)^{\theta}}{E_t \sum_{i=0}^{\infty} (\alpha \beta)^i C_{t+i}^{1-\sigma} \left( \frac{P_{t+i}}{P_t} \right)^{\theta-1}} \right] \quad (2.9)
\]

In time \( t \), \( p^*_t \) is the optimal price charged by price adjusting firms, \( P_t \) is the aggregate price level, \( C_t \) is the aggregate consumption good and \( \psi_t \) is the firm’s real marginal cost. The ratio, \( \frac{\theta}{\theta - 1} \), exceeds one and is interpreted as the constant markup charged by firms due to their monopoly power. The parameter, \( \alpha \in [0, 1] \), denotes the probability that a firm does not adjust its price in time \( t \) and it is interpreted as measuring the degree of nominal rigidity. Fewer firms adjust prices each period and the time elapsed between adjustments increases as \( \alpha \) approaches one. Thus, large values for \( \alpha \) means firms place more weight on expected future marginal cost when they are able to set their price. This model implies perfect price flexibility occurs at \( \alpha = 0 \) and complete price rigidity at \( \alpha = 1 \). In addition, it implies that the expected time between price changes is \( \frac{1}{1-\alpha} \). Equations (2.9) shows firms which set prices in time \( t \) find it optimal to hedge against future changes in real marginal costs that may occur when they are unable to adjust prices, evidenced by \( \psi_{t+i} \), in the numerator.

Since monopolistic competition implies the presence of a large number of firms, \( (1 - \alpha) \) is both

\[5\text{When } \alpha = 0, \text{ there is no nominal rigidity; each firm optimally adjusts its prices every period and charges price: } p^*_t = \frac{\theta}{1-\beta} P_t \psi_t. \text{ That is, each firm sets its price equal to a constant markup over its nominal marginal cost, } P_t \psi_t. \text{ As predicted by theory, the monopolistically competitive firm charges a price that exceeds marginal cost and output is inefficiently low.} \]
the probability and share of firms that are price adjusters in t. At the economy's level, this relationship is used to express the price level in time t, $P_t$, in terms of the two types of firms—those which adjust prices and those which do not:

$$P_t = [(1 - \alpha)(p_t^*)^{1 - \theta} + \alpha(P_{t-1}^{1-\theta})]^{\frac{1}{1-\theta}}$$ (2.10)

In time $t$, adjusting firms charge the optimal price, $p_t^*$ while those unable to do so charge last period's aggregate price, $P_{t-1}$. Log linearizing equations (2.9) and (2.10) around a zero average inflation rate yields the New Keynesian Phillips Curve:

$$\pi_t = \beta E_t(\pi_{t+1}) + \kappa \hat{\psi}_t$$ (2.11)

where $E_t(\pi_{t+1})$ is next period's inflation rate expected in time $t$ and $\hat{\psi}_t$ is average real marginal cost expressed as a percent deviation from its steady state. The slope parameter, $\kappa$ is determined by structural parameters: $\alpha$, the timing of price adjustments, and $\beta$ the subjective discount rate:

$$\kappa = \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha}$$ (2.12)

Thus, $\kappa$ is rising as the degree of nominal rigidity, $\alpha$, gets smaller. That is, increased price flexibility leads to increased influence of real marginal cost on inflation. This formulation of $\kappa$ follows directly from the optimization problems of households and firms, Calvo’s (1983) price rigidity and the assumption of constant returns to scale. The scale of production implies real marginal cost, $\psi$, is constant across firms in $t$ and thus, marginal cost equals average cost. 6 A different assumption of production technology, such as decreasing returns to scale would result in a variable marginal cost and introduce the impact of two new parameters—price elasticity and labor’s input share—to the slope parameter, $\kappa$. Equation (2.11) predicts that the only dynamics imparted to inflation come through $\hat{\psi}_t$, the gap between real marginal cost and its steady state value. Intuitively, inflation depends on the marginal cost faced by firms in the economy as shown in equation (2.11). These firms engage in contracts which require them

---

6Note that although marginal cost is the same for each firm in $t$, the value of $\psi_t$ does vary over time.
to maintain prices set previously even though they have market power and could otherwise re-optimize their prices every period. Recognizing this limitation forces them to be forward looking in their price setting by considering the marginal cost they face in the future when they are unable to re-optimize prices. This behavior across all firms causes a lumpiness in individual price setting that at the economy level is the source of price rigidity. This idea becomes clearer when equation (2.11) is iterated forward:

$$\pi_t = \kappa \sum_{i=0}^{\infty} \beta^i E_t \hat{\psi}_{t+i}$$

(2.13)

Equation (2.13) shows that past inflation has no effect on determining current inflation unless it affects real marginal cost, $\psi_t$. The real output gap, $\hat{y}_t$, can be substituted for $\hat{\psi}_t$ in equation (2.11) by reasoning found similar to that of Rotemberg and Woodford (1997) who derive a proportional relationship between the two variables: $mc_t = \vartheta \hat{y}_t$ in which $\vartheta$ is the output elasticity of marginal cost, $mc$. With this relationship, the New Keynesian Phillips curve can be rewritten in terms of on output gap rather than marginal cost:

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \vartheta \hat{y}_t$$

(2.14)

In an earlier working paper version of Coenen and Wieland (2003), the authors report they are unable to estimate an inflation model using Calvo’s price rigidity using equation (2.14). Although we use different estimation strategies, our results are similar. As shown in Tables 2.2 and 2.3, detrended real output has the poorest performance across different measures of real marginal cost.

### 2.2.2 A Hybrid Model

Galf and Gertler (1999) test the hypothesis that firms are forward looking by nesting a backward looking inflation model in the New Keynesian Phillips curve which is done in spirit of Hall’s (1978) test of the permanent income hypothesis. Simply, the hybrid New Keynesian Phillips curve adds a new regressor on the right hand side, lagged inflation, $\pi_{t-1}$. As a test of the New Keynesian Phillips curve, we hypothesize that if inflation is truly forward looking then $\eta_b$, the parameter on lagged inflation should be statistically insignificant or very small relative to that on next period’s inflation, $\eta_f$. They extend
Calvo's (1983) price timing model by dividing the set of firms that are able to adjust prices into those choosing prices optimally and those who choose a backwards looking price instead. Optimal price setters choose price $p^f$ implied by previous discussion and equations (2.9) and (2.10):

$$p^f_t = (1 - \alpha \beta) \sum_{i=0}^{\infty} (\alpha \beta)^i E_t[\hat{\psi}_{t+k} + p_{t+k}]$$  \hspace{1cm} (2.15)

The remaining share of price adjusting firms, denoted $\omega$, choose a backwards looking price that is based on information from the previous period:

$$\bar{p}^b_t = p_{t-1} + \pi_{t-1}$$  \hspace{1cm} (2.16)

Equations (2.15) and (2.16) imply a new price for all price adjusting firms under the hybrid model:

$$\bar{p}^h_t = (1 - \omega) p^f_t + \omega \bar{p}^b_t$$  \hspace{1cm} (2.17)

Combining equations (2.16)-(2.17), Gali and Gertler (1999) form a hybrid Phillips curve:

$$\pi_t = \bar{\kappa} \hat{\psi}_t + \eta_f E_t \pi_{t+1} + \eta_b \pi_{t-1}$$  \hspace{1cm} (2.18)

where $\bar{\kappa} \equiv (1 - \omega)(1 - \alpha)(1 - \alpha \beta)\phi^{-1}$, $\eta_f \equiv \alpha \beta \phi^{-1}$, $\eta_b \equiv \omega \phi^{-1}$ and $\phi = \alpha + \omega[1 - \alpha(1 - \beta)]$.

### 2.3 Econometric Specification

This section discusses the assumptions and models used to estimate Japan's New Keynesian Phillips curve. In this study, households and firms are assumed to form their expectations rationally. This assumption dictates the selection of regressors and the choice of estimator.

The New Keynesian Phillips curve partly derived in Section 2.2 implies two analytically equivalent specifications. Although theory suggests that these specifications are simply two sides of the same coin,
the results in this Chapter show them to have fairly different implications. This is because of the fluctuation in the parameter values across specifications using the same measure of real marginal cost. The first is sometimes called a reduced form or the standard model because it specifies inflation as a linear function of real marginal cost and expected future inflation in the parameters $\kappa$ and $\beta$, respectively. The second specification, which is sometimes called the structural form specifies a nonlinear relation between inflation and real marginal cost in which $\kappa$ depends on both structural parameters, $\alpha$ and $\beta$ as shown in equation (2.12). In addition, to these models, the hybrid inflation model is also estimated. Following these procedures enables comparisons across recent studies on other countries.

2.3.1 Rational Expectations

Rational expectations implies that firms and household make no systematic errors when forming their expectations of inflation. Analytically, this translates to: $\pi_{t+1} = E_t \pi_{t+1} + \nu_{t+1}$ where $\nu_{t+1}$ is an iid error term and orthogonal to $E \pi_{t+1}$. This means that the New Keynesian Phillips Curve shown in equation (2.11) can be rewritten in terms of observed inflation in period $t + 1$:

$$\pi_t = \beta E_t (\pi_{t+1}) + \kappa \psi_t + \epsilon_t$$
$$= \beta \pi_{t+1} + \kappa \psi_t + \epsilon_t$$

(2.19)

where $\epsilon_t = \epsilon_t - \nu_{t+1}$. For completeness, the assumption of rational expectations does not imply a specific choice for real marginal cost, $\psi$. However based on previous discussion, two measures for real marginal cost are used. The first is labor’s income share of GDP and the second is a real output gap. The latter implies a linear relation between real marginal cost and real output.

2.3.2 Empirical Strategy

Hansen (1982) and Hansen and Singleton (1982) prove that the generalized method of moments (GMM) is a consistent estimator for models employing rational expectations.\footnote{As discussed in Greene (2003), the GMM estimator chooses a parameter vector, $\Theta$, to minimize a weighted square of the model's moment conditions, $\tilde{m}(\Theta)$ and $W$, a positive definite matrix: $\min_q \left( \tilde{m}(\Theta)^T W \tilde{m}(\Theta) \right)$ where $^T$ is the transpose operator and $n$ is sample size.} Essentially, dynamic stochastic
general equilibrium models arise from stochastic Euler equations that must hold in equilibrium, which is the same technique leading to the New Keynesian Phillips Curve shown in equation (2.11). In turn, the equilibrium conditions provide a set of orthogonality conditions in which the GMM is a consistent estimator with a normal distribution. Although Coenen and Wieland (2003) and Sbordone (2002) use a different empirical strategy, the lion's share of recent literature feature the GMM estimator e.g., Eichenbaum and Fisher (2003), Galf and Gertler (1999), Galf, et al. (2001), and Rudd and Whelan (2001). It is well known that aggregate variables entail measurement error. The GMM estimator remedies this through the use of an instrument vector, $z_t$, which is correlated with real marginal cost and inflation but not with the error term. No specific distribution is assumed for the disturbance term but the orthogonal relationship between the instrument set and error term form the basis of consistent estimation using GMM. An additional benefit of using GMM is that the parameters are robust in the presence of serial correlation or heteroscedasticity.

2.3.3 Reduced and Structural Model Specifications

The reduced and structural models for this study are shown in equations (2.11) and (2.12). Measurement error in the aggregate variable, $\psi_t$, make it necessary to choose a set of $L$ variables or instruments, denoted $Z$, which are correlated with $\pi_{t+1}$ and $\psi_t$ but not $\varepsilon_t$. The products of the moment conditions and each row $z_t$ of the instrument set, yield a system of $L$ orthogonal equations:

$$
E_t\{\{\pi_t - \beta \pi_{t+1} - \kappa \psi_t\}z_{t,t}\} = 0
$$

(2.20)

Equation (2.20) is the reduced model estimated in this study.

When there are more instruments than parameters, the model is overidentified and these overidentifying restrictions form the basis of a Wald test of the model's specification, known as the J-statistic. The J-statistic is computed as the product of the minimized function value, $q_n$, from the optimized GMM estimator for sample size $n$. Under the (null) hypothesis that the overidentifying restrictions are satisfied, the J-statistic has a $\chi^2$ distribution asymptotically with $L - K$ degrees of freedom. A $p$-value is often reported with this statistic and it is the probability that the test statistic exceeds the sample statistic, $J$. 

17
if the (null) hypothesis is true. Thus, low p-values reject the restrictions placed on the model.

The structural specification is formed by expressing $\kappa$ in terms of $\alpha$ and $\beta$ as shown in equation (2.12):

$$E_t\{(\pi_t - \frac{(1 - \alpha)(1 - \beta\alpha)}{\alpha}\hat{\psi}_t - \beta\pi_{t+1})z_{it}\} = 0$$  \hspace{1cm} (2.21)

Gali and Gertler (1999) recommend using an analytically equivalent but alternate normalization to address the issue that GMM is sometimes sensitive to the way orthogonality conditions are normalized in small samples. This specification is:

$$E_t\{(\alpha\pi_t - (1 - \alpha)(1 - \beta\alpha)\hat{\psi}_t - \alpha\beta\pi_{t+1})z_{it}\} = 0$$  \hspace{1cm} (2.22)

2.4 Results

This section presents evidence on the fit of the New Keynesian Phillips Curve for Japan using quarterly data over the period 1972:Q3-2003:Q3. As discussed in this section, two measures for inflation are used in addition to four measures of real marginal cost, two of which are wage based while the remaining two are real output gaps.

2.4.1 Data

The data come from quarterly and monthly reports issued by the Japan Economic and Social Research Institute (ESRI), various issues of the Monthly Statistical Bulletin of Japan, and online data sources at the Bank of Japan.

In this study, inflation is computed in two ways: year-on-year and quarterly growth in the GDP deflator. In addition, four measures of real marginal cost are used. Two of these measures are based on Japan’s wage share of real GDP and the remaining two are different versions of the real output gap. Japan’s nominal wages are measured in two ways. One measure is the monthly average of total cash earnings per employee in firms of 30 or more employees. These gross cash earnings are pre-tax, pre-savings, pre-union dues and include overtime and bonus pay. The second measure computes wages per
man hour, the ratio of total cash earnings to the monthly average of hours worked per person in firms with at least 30 employees. This measure is used by Gordon (1982) and Kimura and Ueda (1997) and it captures the average firm’s decision to control costs by varying the number of labor hours. Each of these series is seasonally adjusted using the X-12 Arima procedure created by the U.S. Census Bureau. The real output gap measures are detrended and Hodrick-Prescott (HP-) filtered. Quadratically detrended output is the residual of real GDP regressed on time and time squared; this is the output gap used in all of the U.S. estimates mentioned in this study except those by Neiss and Nelson (2002). The HP-filtered output gap for Japan is chosen based on Hirose and Kamada’s (2003) work on (traditional) Phillips curves. Average real marginal cost based on labor’s income share is computed by the log deviation of real marginal cost from its steady state which is set equal to the sample mean.

Figure 2.1: Japan and United States Inflation, 1972-2003

Figure 2.1 shows quarterly inflation rates for the U.S. and Japan over the sample period, 1972-2003; it is measured by quarterly log difference in the CPI. By inspection, inflation’s downward trend for both over the last 30 years is quite clear, especially for Japan. As was the case in every industrialized nation, the first OPEC oil crisis in 1973 triggered a run up in Japan’s inflation, which peaked at 8.7% in the

---

8Neiss and Nelson (2002) generate a series for potential output as a distributed lag of demand and supply shocks implied by a calibration of preference and production parameters, using data from the U.S., the U.K. and Australia.
second quarter of 1974. The peak in US quarterly inflation, 3.9% came at the end of the second OPEC crisis in 1980:Q1. Compared to the U.S. quarterly high at 2.9%, the peak in Japan's inflation was extraordinarily high. However, by the time the second OPEC crisis occurred in the late seventies, Japan had begun to explore fuel efficient alternatives and thus, its inflation run up was dampened considerably and by 1980, Japan's inflation had fallen below that of the U.S. where it has remained since then. For much of the 1980s, Japan's economy was a model for the rest of the world. Economic growth was steady though much less pronounced than its post WWII "catch-up" years and inflation was relatively low. However, asset and land prices began to rise in the late 1980s prompting many in the popular press to wonder whether Japan's economy was overheated. The bubble economy from 1988-1991 caused by speculation in land and asset prices is also evidenced by the brief run up in inflation corresponding to that period. Japan's monetary policymakers are sometimes blamed for worsening the situation by refusing to raise the discount rate, which would have reigned in speculative behavior. However, Mishkin and Ito (2004) argue that though the Bank of Japan could have done more to slow down the economy, it is unlikely that monetary policy alone could have averted the bubble and its subsequent bursting in 1991. Japan's ill-famed deflationary period starts in 1995 briefly easing later that year before falling below zero again in late 1996, and again in 1998 where Japan remained through the end of the sample, 2003:Q3. For the New Keynesian Phillips curve then, the issue is to determine the extent to which an inflation model dependent only on future values of itself and real marginal cost can describe the turnabout in Japan's experience and capture the peak of the OPEC years and troughs during the deflationary period.

Turning to the wage based measures shown in Figure 2.2, the per man hour measure for average real marginal cost, \( \hat{\psi}_t \) starts to diverge from the other wage measure in the late 1980s, intensifying in the post bubble economy. The rise in real wages per man hour suggests Japanese firms chose to reduce the average number of working hours per month more than cash wages and employment in response to changing market conditions. This behavior is consistent with arguments put forth by Gordon (1982) and Kimura and Ueda (1997). One explanation for the divergence is that firms chose to shorten work hours rather than to lay off workers in response to the fall in demand associated with the end of the
bubble economy when asset values deteriorated and loan defaults began to rise. Movements in both measures of real marginal cost lag that in inflation while imitating its peak and valley motion prior to the asset and land price bubble. This behavior is consistent with the New Keynesian prediction that movements in inflation lead that of real marginal cost, i.e., households and firms are forward looking. The relationship is less obvious after 1988, although the lagged relationship appears to hold though the year 2000. Figure 2.3 shows inflation with the output-based measures of real marginal cost, i.e., detrended output and the HP-filtered output gap. The pattern of movement suggests that drops in detrended output preceded that of inflation in the early part of the sample as well as during the 90s, which is both consistent with the U.S. experience and at odds with the New Keynesian prediction. Higo and Nakada (1999) provide evidence that the output gap leads inflation with a correlation coefficient of 0.6 and 0.8 for the periods 1978-86 and 1987-97, respectively. The tendency for movements in the output gap to lead changes in inflation is thought to be the main reason why New Keynesian Phillips curves for the U.S. engender skepticism among researchers, e.g., Fuhrer and Moore (1995), Eller and Gordon (2003), Rudd and Whelan (2001), Eichenbaum and Fisher (2004).

Table 2.1 shows means and standard deviations for the inflation and real marginal cost variables for each decade in the sample. For comparison, U.S. inflation rates are included.
Table 2.1: Basic Statistics for Inflation and Real Marginal Cost

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. CPI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1. Annual Inflation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Inflation</td>
<td>0.09</td>
<td>0.02</td>
<td>0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Inflation</td>
<td>0.07</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>2. Quarterly Inflation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quarterly Inflation</td>
<td>0.021</td>
<td>0.006</td>
<td>0.003</td>
<td>-0.002</td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quarterly Inflation</td>
<td>0.018</td>
<td>0.013</td>
<td>0.007</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>B. Real Marginal Cost for Japan (ψ_t)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor’s Income Share Per Man Hour</td>
<td>0.125</td>
<td>0.135</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Labor’s Income Share</strong></td>
<td>0.225</td>
<td>0.225</td>
<td>0.21</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>HP Real Output Gap</strong></td>
<td>0.00</td>
<td>-0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Detrended Real Output Gap</strong></td>
<td>0.07</td>
<td>-0.07</td>
<td>0.00</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*Table Notes: Statistical mean and (standard deviation). Data Source: U.S. BEA and various editions of Japan Monthly Statistical Bulletin*
2.4.2 Estimates of the New Keynesian Phillips Curve for Japan

This section discusses estimates of the New Keynesian Phillips curve for Japan shown in Tables 2.2 through 2.5. The empirical exercise features the reduced, structural and hybrid forms with alternate estimations across two instrument sets, two measures of inflation, and four measures of real marginal cost, $\hat{\psi}_t$. Admittedly extensive, this approach integrates measures and procedures identified in the literature. Overall, real marginal cost is theory consistent and statistically significant. In addition, the $J$-test of overidentifying restrictions is not rejected in most models. However, the New Keynesian Phillips curve is sensitive across reduced and structural forms and between quarter-on-quarter and year-on-year inflation rates. It is also sensitive to the manner in which the nonlinearity is expressed in the moment condition. As is the case in U.S. studies, detrended real output gap performs poorly in most instances.

Two instrument sets, denoted $Z_1$ and $Z_2$, are used to address a concern that the number of in-
struments in $Z$ can lead to misleading inferences about the validity of the overidentifying restrictions (Eichenbaum and Fisher, 2003). Each instrument set consists of lags of inflation, real output gaps, wage growth, CPI inflation and the spread between the 10-year Japan Government bond (JGB) and a 2 or 3 month (Gensaki) Japan treasury bill. These elements correspond to the basic set of instruments used in Galí and Gertler (1999). The two sets differ only in the number of lags of each instrument, where $Z_1 = \{1, Z_{t-j}, j = 0, 1, 2, 3\}'$ and $Z_2 = \{1, Z_{t-j}, j = 0, 1\}'$.

The four measures for real marginal cost, $\hat{\psi}_t$ are: labor’s average income share, labor’s average income share per man hour, quadratically detrended real output, and HP-filtered real output gap. Labor’s income share is the closest to the theory implied measure of real marginal cost under constant returns to scale technology, $\frac{W_N}{P_r}$. Labor’s income share per man hour adjusts the real wage bill by average hours which Gordon (1982) asserts firms use to temporarily buffer changes in aggregate demand while taking a “wait and see” approach before choosing to change employment levels.

**Reduced Form Estimates for Japan**

As a whole, the reduced form New Keynesian Phillips curves for Japan using quarterly inflation are weak compared to estimates using year-on-year inflation and thus are not shown. While the J-test does not reject the overidentifying restrictions, the values for $\kappa$ under all $\hat{\psi}$ measures in the reduced model using quarterly inflation are negative. Estimates based on year-on-year inflation are shown in Table 2.2. They are similar to those found for the U.S. by Galí and Gertler (1999). Specifically when $\hat{\psi}_t$ is wage based, $\kappa^{US}$ is 0.023 compared to Japan values, of $\kappa^{JP} = 0.027$ under Z1 and $\kappa^{JP} = 0.019$ under Z2. Also, the output gap measures for Japan show $\kappa^{JP}$ is negative which is consistent with U.S. evidence where $\kappa^{US}$ is -0.016. The overidentifying restrictions are not rejected under Z2 except for detrended output. For Z1, the model restrictions are uniformly rejected except in the case where labor’s income share is used for $\hat{\psi}_t$. These are not promising results for the validity of New Keynesian Phillips curves. However, they do indicate a common result for the reduced model applied to industrialized countries and suggest sensitivity in the GMM estimator with respect to how the model is written.

---

9For early parts of the sample, Japan has no 3-month bill and in later parts of the sample, there is no 2-month bill. Thus, the string of short term interest rates is generated by splicing both sets of observations together.
Structural Estimates for Japan

For inflation models using structural parameters, the J-test of overidentifying restrictions is not rejected across the range of possible specifications, e.g., normalization, instrument sets, alternate measures of inflation and real marginal cost. Since the thrust of tests on New Keynesian inflation models center on the degree of rigidity, the remaining discussion focuses on $\alpha$. For expositional ease, the following discussion is loosely organized in three groups. The first focuses on the results in Table 2.3, which show estimates for using year-on-year inflation based on equation (2.22). These results imply the smallest number of quarters between price adjustments for all measures of real marginal cost. The second group compares values for $\alpha$ across both normalizations, equations (2.21) and (2.22). The third group compares the estimates for rigidity under year on year and quarter on quarter inflation.

First, comparing results between the instrument sets $Z_1$ and $Z_2$ in Table 2.3, nominal rigidity intensifies under the smaller set, $Z_2$. Under $Z_1$, the per man hour wage share shows $\alpha = 0.748$, implying Japan firms adjust prices about once a year and that Japan’s prices are relatively flexible. However under $Z_2$, $\alpha = 0.807$ which corresponds to optimal price adjustments every 5 quarters, i.e., less than once a year. Eichenbaum and Fisher (2003) argue a 2 to 3 quarter wait is a reasonable rate of price adjustment for the U.S. Taking this argument into consideration alongside Gordon’s (1982) assertion that U.S. wages are more rigid than Japan suggests that a 5-quarter wait for Japan is implausibly long. Under this standard, the HP-filtered output gap performs best implying a 3 or 4 quarter wait under $Z_1$ and $Z_2$, respectively. At $\kappa = 0.136$ and $\kappa = 0.075$, the magnitudes are credible and prices are their most flexible with this measure. In addition, at $\kappa = 0.136$, the impact of real marginal cost is fairly close to the influence of the HP-filtered output gap found by Hirose and Kamada’s (2003) estimates of a (traditional) Phillips curve over the period 1980:Q1-2000:Q3. When $\hat{\psi}_t$ is measured by labor’s income share and detrended output, the results deteriorate across instrument sets. For detrended output under $Z_1$, the model fails to converge while under $Z_2$, $\kappa = 0.014$. When $\hat{\psi}_t$ is labor’s income share, the magnitude of $\kappa = 0.027$ is small due mostly to relatively rigid prices, $\alpha = 0.84$.

The subjective discount rate is about 1 under both instrument sets suggesting expectations of future inflation have a nominal impact on current inflation. Under both instrument sets, $\kappa$ is at least as large
as corresponding values for the U.S.\(^\text{10}\) The values for \(\alpha\) suggest Japan prices are fairly rigid over the sample, 1972-2003 and stand in stark contrast to Gordon (1982). He provides evidence that Japan wages are fairly flexible over the period 1963-80 and argues that this is due to the Japan's semiannual bonus system.

Second, the structural estimates are sensitive to the way the nonlinearity is written. For labor’s income share per man hour and both instrument sets, Tables 2.3 and 2.4 show \(\alpha\) is either 0.748 or 0.833, implying a wait between 3 and 6 quarters for price adjustments, a substantial difference in an economic sense. In several instances, Table 2.4 shows \(\alpha\) as statistically insignificant. These kinds of differences repeat when quarterly inflation is used as well. Galí and Gertler (1999) suggest some fluctuation between specifications may be due to the sensitivity of the GMM estimator in small samples. Another possible explanation may be the procedure used to estimate the parameters. The results in this study are estimated using Cliff’s (2003) MatLab GMM toolbox, which uses an optimization approach to locate the parameters that minimize the GMM objective function. The optimization technique relies on convergence criterion which is distinct from the iterative process used to identify the weighting matrix. Throughout the specifications used in this thesis, when the moment condition is expressed as a ratio, i.e., \(E(\pi_t - \beta \pi_{t+1} - \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \hat{\psi}_t)\), the estimated parameters are inconsistent with theory. On the other hand, the estimated parameters are consistent with theory when the slope parameter in the moment conditions is expressed as a product: \(E(\alpha \pi_t - \alpha \beta \pi_{t+1} - (1 - \alpha)(1 - \alpha\beta) \hat{\psi}_t)\). Due to this observation, it is thought the convergence search for the minimum value may be affected when a slope term is expressed as a ratio.

Third, when the parameters are estimated using different inflation measures, quarter to quarter growth in the GDP deflator implies greater price rigidity of the two under either instrument set. This may result from increased fluctuations inherent in quarterly growth rates compared to year-on-year ones. For example, under quarterly inflation and Z1, \(\alpha = 0.860\) for labor’s share per man hour which exceed its value under year-on-year inflation. Similarly, for the HP-filtered real output gap, \(\alpha = 0.837\) under quarterly inflation compared to 0.69 as shown in Table 2.3.

\(^{10}\)Galí and Gertler (1999) show \(\kappa\) ranges between 0.021 and 0.047 in structural models for the U.S.
Table 2.2: Reduced Model Estimates with Year-on-Year Inflation for Japan, 1972-2003

\[ \pi_t = \beta \pi_{t+1} + \kappa \hat{\psi}_t + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Measure for ( \hat{\psi}_t )</th>
<th>( \beta )</th>
<th>( \kappa )</th>
<th>( J_T )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Instruments: ( {1, Z_t, \ldots, Z_{t-3}}' )</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share</td>
<td>1.268**</td>
<td>0.021**</td>
<td>30.01</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.009)</td>
<td>[0.149]</td>
</tr>
<tr>
<td>Labor's Income Share Per Man Hour</td>
<td>1.088**</td>
<td>0.043**</td>
<td>58.28</td>
</tr>
<tr>
<td></td>
<td>(0.206)</td>
<td>(0.015)</td>
<td>[0.0001]</td>
</tr>
<tr>
<td>HP-Filtered Real Output Gap</td>
<td>0.698**</td>
<td>-0.497*</td>
<td>92.60</td>
</tr>
<tr>
<td></td>
<td>(0.141)</td>
<td>(0.333)</td>
<td>[0.000]</td>
</tr>
<tr>
<td>Detrended Real Output Gap</td>
<td>0.492**</td>
<td>-0.028</td>
<td>69.36</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.022)</td>
<td>[0.000]</td>
</tr>
<tr>
<td><strong>B. Instruments: ( {1, Z_t, \bar{Z}_{t-1}}' )</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share</td>
<td>1.414**</td>
<td>0.027</td>
<td>22.19</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.025)</td>
<td>[0.023]</td>
</tr>
<tr>
<td>Labor's Income Share Per Man Hour</td>
<td>1.470**</td>
<td>0.019**</td>
<td>9.14</td>
</tr>
<tr>
<td></td>
<td>(0.100)</td>
<td>(0.036)</td>
<td>[0.609]</td>
</tr>
<tr>
<td>HP-Filtered Real Output Gap</td>
<td>1.381**</td>
<td>-0.089</td>
<td>20.96</td>
</tr>
<tr>
<td></td>
<td>(0.148)</td>
<td>(0.279)</td>
<td>[0.034]</td>
</tr>
<tr>
<td>Detrended Real Output Gap</td>
<td>1.353**</td>
<td>-0.052**</td>
<td>36.01</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.019)</td>
<td>[0.000]</td>
</tr>
</tbody>
</table>

Table Notes: GMM Estimates using quarterly data over the full sample period 1972-Q3-2003-Q3. Instrument sets, \( Z_1 \) and \( Z_2 \) include lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. \( \beta \) is the subjective discount rate and \( \kappa \) is the parameter on real marginal cost alternately measured as labor's income share and the real output gap. Inflation is measured as the year-on-year rate of change in the GDP deflator. Standard errors are shown in parentheses; the p-value for the J-statistic is in brackets. ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively.
Table 2.3: Structural Estimates with Year-on-Year Inflation for Japan, 1972-2003

Orthogonality Condition Eq. (2.22): \( E_t\{(\alpha_\pi - (1 - \alpha)(1 - \alpha\beta)\hat{\psi}_t - \alpha\beta_\pi_{t+1})z_{it}\} = 0 \)

<table>
<thead>
<tr>
<th>Measure for ( \hat{\psi}_t )</th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( \kappa )</th>
<th>( \frac{1}{1-\alpha} )</th>
<th>( J_T )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Instruments: ( {1, Z_t, ..., Z_{t-3}}' )</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share</td>
<td>0.841**</td>
<td>1.02**</td>
<td>0.027</td>
<td>6</td>
<td>30.45</td>
</tr>
<tr>
<td>(0.168)</td>
<td>(0.018)</td>
<td>[0.137]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share Per Man Hour</td>
<td>0.748**</td>
<td>0.981**</td>
<td>0.090</td>
<td>4</td>
<td>13.54</td>
</tr>
<tr>
<td>(0.012)</td>
<td>(0.012)</td>
<td>[0.939]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-Filtered Real Output Gap</td>
<td>0.690**</td>
<td>1.012**</td>
<td>0.136</td>
<td>3</td>
<td>11.04</td>
</tr>
<tr>
<td>(0.011)</td>
<td>(0.159)</td>
<td>[0.983]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B. Instruments: ( {1, Z_t, Z_{t-1}}' )</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share</td>
<td>0.930**</td>
<td>1.037**</td>
<td>0.003</td>
<td>14</td>
<td>7.59</td>
</tr>
<tr>
<td>(0.064)</td>
<td>(0.017)</td>
<td>[0.750]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share Per Man Hour</td>
<td>0.807**</td>
<td>1.024**</td>
<td>0.042</td>
<td>5</td>
<td>6.15</td>
</tr>
<tr>
<td>(0.0319)</td>
<td>(0.023)</td>
<td>[0.863]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-Filtered Real Output Gap</td>
<td>0.752**</td>
<td>1.026**</td>
<td>0.075</td>
<td>4</td>
<td>4.42</td>
</tr>
<tr>
<td>(0.178)</td>
<td>(0.024)</td>
<td>[0.956]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detrended Real Output Gap</td>
<td>0.873**</td>
<td>1.032**</td>
<td>0.014</td>
<td>8</td>
<td>4.91</td>
</tr>
<tr>
<td>(0.050)</td>
<td>(0.023)</td>
<td>[0.935]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table Notes:** GMM Estimates using quarterly data over the full sample period 1972:Q3-2003:Q3. \( \kappa \) is computed based on \( \alpha \) and \( \beta \). Instrument sets, Z1 and Z2 include lags of inflation, wage growth, CPI inflation, the real output gap and the spread between short and long term government bond. \( \beta \) is the subjective discount rate and \( \alpha \) is the degree of nominal rigidity. Prices are increasingly rigid as \( \alpha \) approaches 1. \( \frac{1}{1-\alpha} \) is the number of quarters between price adjustments. Inflation is measured as the year-on-year log difference in the GDP deflator. Standard errors are shown in parentheses; the p-value for the J-statistic is in brackets. ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively. See text.
Table 2.4: Structural Estimates with Year-on-Year Inflation

Orthogonality Condition Eq. (2.21): $E_t\{(1-\alpha)(1-\alpha\beta)^{1-\alpha}\hat{\psi}_t - \beta \pi_{t+1} Z_{it}\} = 0$

<table>
<thead>
<tr>
<th>Measure for $\hat{\psi}_t$</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\kappa$</th>
<th>$\frac{1}{1-\alpha}$</th>
<th>$J_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Instruments: $Z_1 = {1, Z_t, ..., Z_{t-3}}'$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share</td>
<td>0.990</td>
<td>1.02**</td>
<td>DNE</td>
<td>1</td>
<td>21.29</td>
</tr>
<tr>
<td></td>
<td>(9.167)</td>
<td>(0.015)</td>
<td></td>
<td></td>
<td>[0.564]</td>
</tr>
<tr>
<td>Labor's Income Share Per Labor Hour</td>
<td>0.833**</td>
<td>0.99**</td>
<td>0.035</td>
<td>6</td>
<td>19.52</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.014)</td>
<td></td>
<td></td>
<td>[0.670]</td>
</tr>
<tr>
<td>HP-Filtered Real Output Gap</td>
<td>1.026**</td>
<td>1.017**</td>
<td>0.001</td>
<td>$\infty$</td>
<td>10.25</td>
</tr>
<tr>
<td></td>
<td>(0.446)</td>
<td>(0.009)</td>
<td></td>
<td></td>
<td>[0.983]</td>
</tr>
</tbody>
</table>

B. Instruments: $Z_2 = \{1, Z_t, Z_{t-1}\}'$

| Labor's Income Share        | 0.988   | 1.024** | DNE     | 1               | 5.61  |
|                             | (21.061)| (0.017) |         |                 | [0.898]|
| Labor's Income Share Per Labor Hour | 0.807** | 1.024** | 0.042   | 5               | 6.15  |
|                             | (0.0319)| (0.023) |         |                 | [0.863]|
| HP-Filtered Real Output Gap | 0.985   | 1.030** | DNE     | 1               | 4.74  |
|                             | (82.00) | (0.019) |         |                 | [0.943]|
| Detrended Real Output Gap   | 1.073** | 1.032** | 0.007   | -14             | 4.66  |
|                             | (0.060) | (0.023) |         |                 | [0.946]|

Table Notes: GMM Estimates using quarterly data over the full sample period 1972:Q3-2003:Q3. $\kappa$ is computed based on $\alpha$ and $\beta$. Instrument sets, $Z_1$ and $Z_2$ include lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. $\beta$ is the subjective discount rate and $\alpha$ is the degree of nominal rigidity. Prices are increasingly rigid as $\alpha$ approaches 1. $\frac{1}{1-\alpha}$ is the number of quarters between price adjustments. Inflation is measured as the annual log difference in the GDP deflator. Standard errors are shown in parentheses; the p-value for the $J$-statistic is in brackets. ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively. See text.
Implications of the New Keynesian Phillips curve for Japan

Taken together, the estimates under both reduced and structural forms suggest a number of findings, some of which are similar to recent studies while others are unique to this thesis. First, the influences on Japan’s inflation path are similar to that of the U.S. when the reduced model is estimated using year-on-year inflation. That is, the subjective discount rate is effectively one, wage based real marginal cost measures have positive but very small parameters, and those under the real output gap measures have the wrong sign or are statistically insignificant. Second, although the structural model using year-on-year inflation is somewhat sensitive to the normalization used, the implied degrees of rigidity are close to one another across normalizations for both labor’s share per man hour and the HP filtered real output gap. In addition, the implied estimate for $\kappa$ when the HP-filtered output gap is used is comparable to that of recent estimations of Japan’s inflation adjustment using the mainstream Phillips curve. Third, estimates involving inflation rates measured as the quarterly growth of the GDP deflator perform poorly under both the reduced and structural models. Fourth, under both types of inflation measures, quadratically detrended real output as a measure of real marginal cost yields parameters that are inconsistent with theory.

2.4.3 Robustness Tests

An important aspect of empirical work involves considering how the model performs in closely drawn but alternative scenarios. One common extension nests two opposing theories such as the traditional and New Keynesian Phillips curves in a hybrid model. Another approach to robustness is to consider whether the parameters in the model are constant throughout the sample, which in this case includes historical events such as the two OPEC oil supply shocks and the Asian financial crisis.

Japan Estimates for the Hybrid Model

Table 2.5 displays the structural estimates of the hybrid model for Japan using year-on-year and quarterly inflation. Under year-on-year inflation, forward looking behavior is more important than backward looking behavior when $\psi_t$ is wage based, but the parameter values on $\eta_f$ and $\eta_b$ are fairly close. In ad-
dition, this is at odds with the estimate $\omega = 0.78$, the share of price adjusting firms that follow a backwards looking price rule. Under the HP-filtered output gap, backward looking behavior dominates, which is reinforced by $\omega = 0.699$. Under quarterly inflation, the distinction between backwards and forward looking behavior is more evident. For example, $\eta_T$ is 0.764 under labor's share per man hour and $\omega = 0.252$, which is closer to that for the U.S. $\omega^{US} = 0.265$\(^{11}\) When year-on-year inflation is used with detrended output gap, the estimator fails to converge. This also happened during the estimation using quarterly inflation and the Hodrick Prescott filtered output gap. Otherwise, none of the models reject the overidentifying restrictions as shown in the large p-values under the $J_T$ statistic, where values as low as 5% are considered sufficient to maintain the null.

When the hybrid parameters are compared to those in Table 2.3, the results indicate that including backward looking behavior does not substantially alter the parameter values for $\alpha$ and $\beta$. Prices are still quite rigid across labor's income share per man hour and the output gap in this context. The hybrid model predicts that Japan firms wait about 5 quarters between price adjustments under year-on-year inflation and wage per man hour measures or 7 quarters under quarterly inflation. The price adjustment period is much shorter when $\hat{\nu}_t$ is the HP-filtered output gap. Under year-on-year inflation, $\alpha = 0.639$ implying a 3 quarter wait which increases to 4 quarters when quarterly inflation and detrended real output are used. Real marginal cost is most influential under year-on-year inflation where $\bar{\kappa}$ is 0.011 for wages per man hour and 0.068 for the HP filtered real output gap.

Another approach to the hybrid model for Japan follows Nason and Smith's (2003) suggested pre-tests to ensure $\pi_{t-1}$ is identified in the hybrid model. The first issue is to test for Granger noncausality between $\hat{\nu}_t$ and $\pi_t$. Second, they recommend projecting $\hat{\pi}_t$ on 6 lags and testing the lag length using the AIC and BIC tests. The minimized test values correspond to the number of lags specified for $\hat{\nu}_t$ in the instrument set. Following their recommendations, the instrument set is limited to lagged inflation and the number of lags in $\hat{\nu}_t$ resulting from the AIC and BIC tests. When $\hat{\nu}_t$ is a wage based measure, the estimator failed to converge. With the output based measures, the parameter denoting the share of backwards looking firms was not statistically different from zero. This means that under Nason and

\(^{11}\)See Gali and Gertler (1999).
Table 2.5: Structural Estimates of the Hybrid Model for Japan, 1972-2003

\[ \pi_t = \eta_f \pi_{t+1} + \kappa \tilde{\psi}_t + \eta_b \pi_{t-1} \]

<table>
<thead>
<tr>
<th></th>
<th>( \alpha )</th>
<th>( \beta )</th>
<th>( \omega )</th>
<th>( \eta_f )</th>
<th>( \eta_b )</th>
<th>( \kappa )</th>
<th>( J_T )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Year-on-Year Inflation, ( Z = Z_2 )</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income Share</td>
<td>0.856**</td>
<td>1.054**</td>
<td>0.780**</td>
<td>0.540</td>
<td>0.467</td>
<td>0.002</td>
<td>6.66</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.035)</td>
<td>(0.071)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income Share Per Man Hour</td>
<td>0.789**</td>
<td>1.03**</td>
<td>0.598**</td>
<td>0.580</td>
<td>0.427</td>
<td>0.011</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td>(0.032)</td>
<td>(0.029)</td>
<td>(0.047)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-Filtered Real Output Gap</td>
<td>0.639**</td>
<td>0.998**</td>
<td>0.669**</td>
<td>0.487</td>
<td>0.512</td>
<td>0.033</td>
<td>5.85</td>
</tr>
<tr>
<td></td>
<td>(0.180)</td>
<td>(0.038)</td>
<td>(0.071)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **B. Quarterly Inflation \( Z = Z_1 \)** |             |             |             |             |             |             |             |
| Income Share   | 0.899**     | 1.067**     | 0.232**     | 0.837       | 0.202       | 0.003       | 10.635      |
|                | (0.030)     | (0.042)     | (0.071)     |             |             |             |             |
| Income Share Per Man Hour | 0.850**     | 0.989**     | 0.252**     | 0.764       | 0.229       | 0.016       | 10.129      |
|                | (0.016)     | (0.027)     | (0.067)     |             |             |             |             |
| Detrended Real Output Gap | 0.729**     | 0.567**     | 0.890**     | 0.311       | 0.661       | 0.015       | 11.203      |
|                | (0.085)     | (0.121)     | (0.035)     |             |             |             |             |

**Table Notes:** GMM Estimates using year-on-year quarterly data over the full sample period 1972-Q3-2003-Q3. Instrument sets, \( Z_1 \) and \( Z_2 \) include lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. \( \beta \) is the subjective discount rate and \( \alpha \) is the degree of nominal rigidity, \( \omega \) is the share of firms following a price rule that is backward looking. When \( \tilde{\psi} \) is measured using an Hodrick Prescott filtered output gap the model barely converged and yielded unreliable estimates due to a nearly singular matrix. Inflation is measured as the log difference in the GDP deflator. Standard errors are shown in parentheses; the p-value for the J-statistic is in brackets. ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively.
Smith’s (2003) model, the hybrid model simply becomes a forward looking one because the parameter on lagged inflation is not significantly different from zero.

Leith and Malley (2002) also estimate a hybrid model for the G-7 nations taking an open economy approach. They embed a terms of trade effect to capture changes in demand for domestic goods relative to foreign ones as well as changes in the price of foreign intermediate goods relative to other inputs. The model specifies production in terms of a fixed capital stock with decreasing returns to labor and imported intermediate goods. In addition, the real marginal cost term is adjusted to include the impact of foreign intermediate goods on labor costs, the cost of intermediate goods relative to domestic prices, and the effect that tradeoffs between foreign intermediate goods and labor have on average firm output. Since it is also assumed that each firm faces the same production function, the adjustment term is constant across all firms. With a quarterly sample 1960(1)-1999(4) and using OECD data, their GMM estimates of a hybrid model for Japan are statistically significant and have the hypothesized signs:

\[ \pi_t = (1 - \omega)\beta\pi_{t+1} + \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha} \hat{\eta}_t + \omega\pi_{t-1} + \epsilon_t \]

where \( \alpha \) is computed based on the structural components of the degree of nominal rigidity, \( \alpha = 0.63 \), and the subjective discount rate, \( \beta = 0.65 \) and the share of firms following a backwards looking rule of thumb in setting prices at time \( t \), \( \omega = 0.3^* \). The value for \( \alpha \) implies the time between optimal price adjustments is roughly 3 quarters, which is about the same length found under the hybrid model in Table 2.5 using year-on-year \( \pi \) and the HP-filtered \( \hat{\eta}_t \). Compared to the results in Table 2.5, the spread between forward and backward looking behavior is broader under Leith and Malley’s (2002) model. Moreover, \( \kappa \), the impact of real marginal cost on inflation is much stronger in their open economy hybrid model.

Coenen and Wieland (2003) estimate a small three country model with rational expectations to fit inflation and output dynamics in Japan, the U.S. and the U.K. They test three forms of nominal rigidity: Calvo (1983), Fuhrer and Moore (1995), and Taylor (1980). Coenen and Wieland (2003) use detrended output as the measure of real marginal cost. They report that they are unable to estimate the model
using Calvo (1983) rigidity without allowing for persistence in the supply shock. To do this, they model inflation as a backwards looking phenomena and specify the error term as an AR(1) process with parameter $\rho$ measuring the degree of serial correlation in the supply shock. Their results are:

\begin{align*}
\pi_t &= 0.99\pi_{t-1} + 0.0071\hat{\psi}_t + u_t \\
u_t &= 0.8863u_{t-1} + 0.007\epsilon_{it}
\end{align*}

The poor performance of detrended output as a measure of real marginal cost is consistent with the evidence in this thesis as well as evidence for the U.S. (Gali and Gertler, 1999) and the European area (Gali et al, 2001). In addition, although Coenen and Wieland (2003) find a positive slope for detrended output, the parameter has a smaller magnitude than those found in the forward looking estimates for $\kappa$ shown in Table 2.3. This suggests the New Keynesian Phillips curve is superior in capturing inflation persistence in Japan data.

**Structural Breaks within the GMM Framework**

Table 2.6 displays results from tests for parameter stability over the full sample. This involves testing whether the degree of nominal rigidity and rate of time preference are shifting over time. For example the OPEC crises-induced inflation spikes during the 1970s as well as the extended deflationary period from 1996 to 2003 suggest that these $\alpha$ and $\beta$ may not remain constant over the full sample. In addition, Walsh (2004) focuses on the impact of parameter misspecification in monetary policy rules, which includes the impact of an incorrect value for the degree of nominal price rigidity. In the optimal monetary policy setting, he identifies two costs of this sort of parameter misspecification. First, it affects the weights in the social welfare loss function which the policymaker seeks to minimize. Second, the degree of price rigidity determines some of the coefficients in the optimal monetary policy rule and an incorrect value distorts the coefficients in the rule.

Nyblom (1989) and Andrews (1993), derive statistical tests for parameter instability when the breakpoint is unknown using the GMM estimator. Essentially, they test whether the estimated coefficient is changing over time by hypothesizing that the parameter is constant over the entire sample. Tests such
Table 2.6: Results of Model Stability Tests

<table>
<thead>
<tr>
<th>Statistical Test</th>
<th>SupLR</th>
<th>SupLR*</th>
<th>Nyblom</th>
<th>Nyblom*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Quarterly Inflation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share Per Man Hour</td>
<td>1133</td>
<td>16522</td>
<td>95</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1996:Q4</td>
<td>1996:Q4</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>HP Filtered Real Output Gap</td>
<td>250</td>
<td>11941</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1996:Q4</td>
<td>1996:Q2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>B. Year-on-Year Inflation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor's Income Share Per Man Hour</td>
<td>51</td>
<td>22775</td>
<td>5.96</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1982:Q2</td>
<td>1982:Q2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>HP Filtered Real Output Gap</td>
<td>7.77</td>
<td>6831</td>
<td>0.8</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>(0.36)</td>
<td>(0.00)</td>
<td>(0.24)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1992:Q3</td>
<td>1996:Q3</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*Table Notes:* (p-value) The null hypothesis for Andrews' SupLR and Nyblom's tests are that $\alpha$ and $\beta$ are stable over the sample. SupLR* and Nyblom* test $\alpha$ and $\beta$ for statistical significance and structural breaks simultaneously as provided in Rossi (2004).
as these are nonstandard because the parameter governing the change point appears only under the alternative hypothesis and not the under the null.

![Image](image.png)

Figure 2.4: Nominal Rigidity using a 9 year Rolling Regression, 1982-1995

The Nyblom statistic tests whether the parameters are constant against the possibility that they follow a random walk process. Andrews' SupLR tests parameter constancy against the alternative that there is a breakpoint at some point in the sample determined using a likelihood ratio test over a partition of the sample. For these tests, the partition spans 1982-1996 to capture the disinflationary trend in the data. Rossi (2004) provides optimal versions for both Nyblom and Andrews which permit a test of statistical significance and structural breaks. Rossi argues that two stage tests that separate the test for significance from stability do not have the optimal weighted average power for alternatives that are equally likely. The structural models under equation (2.22) for both quarterly and year-on-year inflation are evaluated using these tests. Table 2.6 shows that the test statistics are highly significant and very large. Nonetheless, the structural break under quarterly inflation for both the HP filtered output gap and wage per man hour measures occur in the same year, 1996. Under year-on-year inflation, the structural break differs according to the measure and test. In this case, the Andrews SupLR test identifies the end of Japan's bubble economy as the break, although Rossi's optimal test, SupLR* chooses 1996:Q3, closer to the deflationary period. With year-on-year \( \pi \) and labor's share per man hour, the structural break occurs in 1982:Q2 for both SupLR and SupLR*. This date corresponds to the peak in wage based
real marginal cost shown in Figure 2.2.

Figure 2.4 shows the temporal evolution for \( \alpha \) based on a rolling regression using a 9-year window over the period 1982-95 under quarterly inflation and the HP-filtered real marginal cost. While this is not a definitive test for instability, the path of \( \alpha \) appears to trend over the period, whereas a stable parameter would be reflected in path with less variation.

### 2.5 Conclusion

In conclusion, Japan’s inflation dynamics from the New Keynesian perspective suggest several results that are consistent with both recent evidence on Japan’s inflation using mainstream models and with recent evidence on the U.S. First, similar to earlier works on the U.S., the New Keynesian inflation model for Japan is sensitive to its specification. Reduced specifications do not yield theory implied results, which is similar to evidence for the U.S. and U.K. However, structural models featuring real marginal cost measured by real wages or the output gap are statistically significant and theory consistent. In addition, these measures—real wages per man hour and HP-filtered real output gap—are also preferred measures in Phillips curve models for Japan. Year-on-Year inflation predicts firms adjust prices every 3 to 5 quarters. On the other hand, when quarter to quarter growth is used for inflation, Japan firms exhibit much more sluggish behavior, adjusting every 4 to 9 quarters. This is also consistent with evidence that American firms adjust every 6 quarters on average (Galf and Gertler [1999]). Using the detrended real output gap does not perform as well and this finding is also consistent with earlier work on traditional Phillips curves for Japan and with New Keynesian Phillips curve estimates for the U.S. Estimates for the hybrid model suggest that forward looking behavior is more important than backward looking behavior, but not by a substantial margin. Finally, parameter instability tests suggest that Japan’s deflationary period marks a structural break in the sample. This suggests that the degree of rigidity, \( \alpha \), has a dynamic aspect as well.

Ongoing work relaxes the assumption of constant returns to scale technology to consider the impact of variable marginal cost. The objective in this case is to further explore the credibility of the New Keynesian Phillips curve for Japan by considering how the degree of rigidity varies under different...
production technologies. In addition, it will decompose the output gap into a component due to price stickiness and wage stickiness. Other ongoing work evaluates Japan's economy within a small macro monetary model using the New Keynesian Phillips curve and the hybrid model to represent aggregate supply. This effort considers the impact of the zero lower bound using a common monetary policy rule such as that by Taylor (1993) in a forward looking model.
Chapter 3

Inflation Dynamics in Japan: The Calvo Model and Wage Rigidity

3.1 Introduction

This chapter provides further evidence of the fit of the New Keynesian Phillips curve for Japan over the period 1972-2003. The approach in this chapter follows Galí, Gertler and López Salido (2001) and is motivated by the sense that the degree of Japan's price rigidity found in Chapter 2 is implausibly severe. They show that a simple alteration in the firm's production function, which determines the measure of real marginal cost, yields a more credible degree of rigidity for the U.S. and the Euro area. As this Chapter shows, a similar improvement occurs for Japan. Specifically, allowing for a more general production schedule predicts that real marginal cost explains 20 to 30 percent of the variation in inflation, a substantial increase in explanatory power over the more typical specification discussed in Chapter 2. In addition, the degree of rigidity is much less under this assumption and implies Japan firms adjust prices every 2 to 3 quarters refuting claims that the New Keynesian Phillips curve overestimates price rigidity. Tests for parameter, and thus, model stability give evidence of structural breaks in the estimated coefficients. The break point dates under different specifications coincide with either Japan's land and asset price bubble or deflationary period. A simple decomposition of labor market rigidities implies a substantial degree of wage rigidity influences the dynamic behavior of real marginal cost, which when incorporated to the New Keynesian framework may further improve the model's empirical performance. Robustness tests that nest forward and backward looking behavior imply that forward
looking behavior dominates, which is a key aspect of the New Keynesian framework.

The remainder of this chapter consists of four sections. Section 3.2 briefly discusses the model's framework, Section 3.3 presents the estimation strategy and results, Section 3.4 discusses evidence on labor market rigidities in Japan and Section 3.5 offers a few concluding remarks.

3.2 Theory Framework and Estimation Strategy

This section describes aspects of the New Keynesian Phillips curve that are most relevant to the empirical task at hand. Original derivations of the new Neoclassical Synthesis/New Keynesian framework include Yun (1996), Goodfriend and King (1997), Rotemberg and Woodford (1998) and Clarida, Galf and Gertler (1999), with Walsh (2003) and Woodford (2003) each providing a comprehensive and current treatment.

The New Keynesian Phillips curve is a model of price adjustment which relates the path of inflation, \( \pi_t \), to expectations of future inflation and real marginal cost, \( \psi_t \). It stems from dynamic optimal decision making by households and firms. Following Woodford (2003), a log linear approximation around zero average inflation and steady state equilibrium yields:

\[
\pi_t = \beta E_t \pi_{t+1} + \kappa \hat{\psi}_t
\]

(3.1)

where \( \kappa \) is the persistence in inflation attributable to a real marginal cost. Recall, as shown in equation (2.12), \( \kappa = \frac{(1-\alpha)(1-\alpha^2)}{\alpha} \). The parameter, \( \alpha \), is the degree of nominal rigidity and is the probability that a firm does not optimally adjust its price in \( t \) (Calvo, 1983). The parameter \( \beta \) is the subjective discount rate and \( \hat{\psi} \) is the deviation of real marginal cost from its steady state equilibrium.

The New Keynesian Phillips curve is similar in spirit to the Phillips (1958) curve typically used to model aggregate supply in small macro monetary models:

\[
\pi_t = \sum_{k=1}^{4} \gamma_k \pi_{t-k} + \delta \hat{y}_t
\]

(3.2)

where \( \hat{y}_t \) is a real output gap. The Phillips curve in equation (3.2) is sometimes called "expectations
"augmented" and includes lags and other explanatory variables to incorporate information affecting expectations. It is assumed that $\sum_{k=1}^{4} \gamma_k = 1$ to ensure that the impact of past inflation is nominal. Rudebusch and Svensson (1999) argue that equation (3.2) fits U.S. data fairly well during the post war period, 1960-1999. They find that the real output gap has a statistically significant impact on inflation, $\delta = 0.14$ and while $\sum_{k=1}^{4} \gamma_k$ is not statistically different from one.

Using detrended real GDP for the output gap, $\hat{y}$, the corresponding Phillips curve for Japan, over the period 1971:Q3-2003:Q3 is:

$$\pi_t = 0.0010 + 0.460 \pi_{t-1} + 0.259 \pi_{t-2} + 0.368 \pi_{t-3} - 0.226 \pi_{t-4} + 0.031 \hat{y}_t$$

$$\text{(0.001)} \quad \text{(0.074)} \quad \text{(0.076)} \quad \text{(0.089)} \quad \text{(0.091)} \quad \text{(0.223)}$$ (3.3)

where the standard errors are reported in parentheses. The results for Japan are not as promising as that for the U.S. Although the parameter on real output is statistically significant, at $\delta = 0.031$ the impact is smaller. In addition for the estimated parameters, $\sum_{k=1}^{4} \gamma_k = 0.861$ and a t-statistic test rejects the hypothesis that the cumulative impact of lagged inflation sums to one. These results can be compared to Coenen and Wieland (2003) who find $\delta = 0.019$ over the years 1980-1997, using quadratically detrended output for the output gap and $\sum_{k=1}^{4} \gamma_k = 0.6698$. Higo and Nakada (1999) estimate equation (3.2) for Japan and show $\delta = 0.07$ for the years 1978-86 and $\delta = 0.24$ for the years 1987-96. They also provide evidence that the output gap leads inflation with a correlation coefficient of 0.6 and 0.8 for the periods 1978-86 and 1987-97, respectively. These results provide two useful insights. First, the strong evidence that detrended output leads inflation illustrates why output gap measures of real marginal cost are inappropriate for estimates of the New Keynesian Phillips curve, which predicts the opposite—inflation leads real marginal cost. Second, they suggest a magnitude for $\kappa$ that is consistent with the degree of inflation inertia observed in the data for the backwards looking model.

Nonetheless, deeper issues remain with the Phillips curve specification. First, there is no consensus on the interpretation of the coefficients on lagged inflation, $\gamma_{t-k}$ (Rudd and Whelan, 2001). Outside of the micro foundations context, the conventional view is that firms form their expectations of current

\footnote{The output gap measure used in Higo and Nakada (1999) is the difference between GDP and potential GDP. Potential output is based on estimated production functions following Watanabe (1997).}
inflation in a backward looking manner, which causes them to incorporate past inflation rates into current wage and price contracts. Lagged values enter the specification as a proxy for expectations of future conditions (Woodford, 2003). However, this approach fails to accommodate announced changes in future policy, i.e., the Lucas (1972, 1976) critique. That is, equation (3.2) is inherently a reduced form rather than one reflecting structural relations in parameters affecting economic decisionmaking. Another issue with adaptive expectations is that in a disinflationary and deflationary environment like Japan's, a purely backward looking model such as equation (3.2) would likely over-predict inflation.

On the other hand, the New Keynesian Phillips curve in Equation (3.1) arises from the dynamic decision making problems of households and firms, incorporates nominal rigidity and rational expectations. It satisfies the Lucas critique by linking optimal behavior by households and firms to structural parameters such as the degree of price stickiness and rate of time preference. From these conditions, optimal policy rules can be derived that would be invariant to policy changes. In addition, being tied to utility functions, New Neoclassical Synthesis/New Keynesian models also allow for welfare analysis. Galí and Gertler (1999) and Sbordone (2002) are early works that provide estimates of the New Keynesian Phillips curve for the U.S. They show that real marginal cost may be approximated by the unit labor cost. Chapter 2 provides estimates for Japan over the period 1972:Q3 to 2003:Q3 that are consistent with the U.S. but only when the inflation measure is year on year growth rather than quarterly growth, the theory implied measure. However, empirical evidence on the New Keynesian Phillips curve implies too high a degree of price rigidity and as a result, the impact of real marginal cost is quite small. This suggests purely forward looking behavior is insufficient to generate the magnitude of inflation persistence observed in the adaptive expectations framework. Empirical evidence has led to extensions of the New Keynesian theory to explicitly incorporate lagged inflation and thus, introduce inflation inertia to the model. As discussed in section 2.2.2, Galí and Gertler (1999) derive a sticky price model where some firms use their opportunity to re-optimize by choosing a backwards looking price instead. In an earlier working paper, Christiano, Eichenbaum and Evans (2005) derive a hybrid model in the New Keynesian setting with Calvo (1983) rigidity. Lagged inflation is introduced to the model by assuming that the firm which cannot reoptimize in time $t$ instead chooses to index its price to past inflation. Mankiw
and Reis (2002) incorporate past inflation by deriving an optimization model in which information, rather than a firm's price, is sticky. They divide the set of firms resetting prices between those who do so optimally and those who rely on old plans and outdated information. Eichenbaum and Fisher (2004) extend Mankiw and Reis (2002) to include Calvo's (1983) sticky price model. Based on U.S. data, Eichenbaum and Fisher (2004) conclude that this model also implies too high a degree of price rigidity. Under the Galí and Gertler (1999) hybrid model estimated in Chapter 2, empirical evidence supportive of the theory is an improvement over the more primitive model without inflation inertia. However, it still implies too high a degree of price rigidity and thus too little inflation persistence. Motivated by the pursuit of more plausible estimates of price rigidity, Galí et al (2001) change the assumption that firms produce under constant returns to scale to one that assumes they face decreasing returns to scale. Although this is discussed in the next section, briefly, they find this generates a more credible estimate of rigidity for the U.S. and Euro area. Using U.S. data, Cogley and Sbordone (2005) conclude that the New Keynesian Phillips curve is structurally invariant. Their finding contradicts results in this Chapter which show structural breaks occur in Japan data during the early 1990s.

3.2.1 The New Keynesian Phillips Curve with variable marginal cost

Galí et al (2001) generate variable marginal cost in the New Keynesian Phillips curve by assuming the average firm has diminishing returns to scale. This means doubling inputs will less than double output and is an assumption sometimes used to describe production in large scale firms where the ratio of management to workers is small or capital use is very large, e.g., manufacturing sectors. These conditions are thought to introduce inefficiencies due to coordination problems or inefficient management of labor and capital that can cause output increases to lag increases in inputs. In the New Keynesian setting, it introduces a firm-specific parameter, i.e., labor's input share of production.

Consistent with McCallum and Nelson (1997), it is assumed capital is homogenous and can be reallocated instantly after a shock. Hence, capital is excluded from the production function. Although this is a standard assumption for New Keynesian models, recent works point to that as a potential weakness in empirical estimations using this framework. Christiano, Eichenbaum and Fisher (2005)
recommend adding a variable for capital utilization which imparts sluggishness to marginal cost by dampening the rise in rental capital that would otherwise occur in a positive monetary policy shock. Eichenbaum and Fisher (2005) argue that including firm specific capital will yield a higher degree of price rigidity, particularly if empirically plausible costs of adjusting capital exist. Altig, Christiano, Eichenbaum and Linde (2004) also allow for firm specific capital that varies over time with changes in the rate of investment. Note that this thesis provides benchmark estimates for Japan of the primitive or first generation New Keyneisan inflation model for closed economy with neither capital nor government influences.

Abstracting from capital, the production function with diminishing returns is: \( Y_{jt} = A_t N_{jt}^{1-a} \), where \( a \in (0,1) \). Firm \( j \)'s output in time \( t \) is \( Y_{jt} \), \( N_{jt} \) is the firm's demand for labor and \( A_t \) is technology where it is assumed that \( E(A_t) = 1 \). The parameter \( a \in (0,1) \) affects labor's input share of output, \( (1-a) \), and the curvature of the production function. Similar to the model used in Section 2, each firm's demand curve is assumed to be isoleastic with elasticity parameter, \( \theta \), except in this Chapter, it is no longer assumed that \( \theta = 1 \). Price rigidity enters the framework using Calvo's (1983) mechanism, where for any time \( t \), \( (1-a) \) is the probability a firm will adjust its price by reoptimizing. The assumption that a firm with market power will not choose to reoptimize its price in every period reflects the notion that firms find reoptimizing costly and will choose to do so occasionally and in other periods use a backwards looking rule of thumb (Galf and Gertler, 1999) or index prices based on past inflation (Christiano et. al., 2001). One way to compensate the potential losses in this kind of price setting behavior is for firms to optimally set their prices based on expectations of future marginal cost, which explains the forward looking behavior of firms.

In real terms, a measure of real marginal cost arises from firm \( j \)'s decision to minimize the cost of its demand for labor (Sbordone, 2002, Walsh, 2003):

\[
L = \min_{N_{jt}} \left( \frac{W_t}{P_t} \right) N_{jt} + \psi_t(Y_{jt} - A_t N_{jt}^{1-a})
\]

where \( \frac{W_t}{P_t} \) is firm \( j \)'s optimal real wage in time \( t \) expressed in terms of nominal wages, \( W_t \), and the price
level, $P_t$. For each firm, $j$, the first order conditions imply real marginal cost, $\psi_{jt}$ is the unit labor cost:

$$\psi_{jt} = \frac{W_t N_{jt}}{(1-a)P_t Y_{jt}}$$

which varies with the value of each firm's input parameter $a$. So long as $a < 1$, firms face different real marginal costs for different production levels. In addition, a firm's real marginal cost falls with increases in price. Intuitively, firms with relatively higher prices sell fewer goods. Since it is assumed consumption equals production, the firm with a higher price will sell fewer goods relative to other firms and thus produce less and demand less labor. Since firm level data is not readily available aggregate data is used to form "average" real marginal cost: $\psi_t = \frac{W_t N_t}{(1-a)P_t Y_t}$, based on wages, $W$, employment $N$, and GDP, $PY$ and a calibrated value for $a$, the input share parameter.

In the dynamic setting, the assumption of firm specific real marginal cost drives a wedge between the firms that reoptimize prices and those which do not. Consider the situation facing the firm in time $t+k$ when its last opportunity to optimally set its price occurred in time $t$ and denote its real marginal cost (in deviation form), $\hat{\psi}_{t,t+k}$. Galf et al (2001), based on Sbordone (2002) and Woodford (1996) show:

$$\hat{\psi}_{t,t+k} = \hat{\psi}_{t+k} - \frac{a_\theta}{1-a} (p_t^* - p_{t+k}^*)$$

Equation (3.6) shows that when $p_t^*$, the optimal price in $t$ is high relative to $p_{t+k}^*$, the optimal price in $t+k$, the firm will have a lower marginal cost than other firms because it is selling relatively fewer goods. If instead, firms faced constant returns to scale in production then $a=0$ and all firms would have the same marginal cost in time $t+k$.

For the New Keynesian Phillips curve, allowing for firm specific marginal cost in this manner alters equation (3.1) by introducing a new term, $\zeta$:

$$\pi_t = \beta E_t(\pi_{t+1}) + \kappa \zeta \hat{\psi}_t$$

where $\kappa = \frac{(1-a)(1-a\theta)}{a}$ and $\zeta = \frac{(1-a)}{[1+a(\theta-1)]}$. In this case, the slope parameter depends on both the structural parameters, $\alpha$ and $\beta$ as well as $a$ and $\theta$. The decomposition of the slope parameters is
somewhat arbitrary and is done to show directly the impact of allowing for variable marginal cost. It also separates the estimated structural parameters, $\alpha$ and $\beta$ from the calibrated ones, $\alpha$ and $\theta$, which is part of the empirical strategy used in the estimation exercise. Regardless of the production function, equations (3.1) and (3.7) show that price rigidity does not generate any inertia or persistence in inflation dynamics. Both equations imply that inflation is forward looking and can jump immediately with changes in current real marginal cost or expected future inflation, which contradicts empirical evidence (Fuhrer and Moore, 1995, Walsh, 2003).

3.2.2 A Hybrid New Keynesian Phillips Curve

That lack of persistence in the New Keynesian Phillips curve has led researchers to extend theory to account for an influence of lagged inflation. Galí and Gertler (1999) do so by assuming that some of the firms that are able to reset prices in $t$ choose instead to set price based on a backward looking rule of thumb. As a practical matter, this entails adding lagged inflation, $\pi_{t-1}$, to the right hand side but the hybrid models maintain their microfoundations and thus permit estimates of structural parameters. As a test of the New Keynesian Phillips curve, we hypothesize that if inflation is truly forward looking then $\eta_b$, the parameter on lagged inflation, should be statistically insignificant or very small relative to that on next period's inflation, $\eta_f$. In their extension of this model, Galí et al (2001) incorporate variable marginal cost to the hybrid New Keynesian Phillips curve derived in Galí and Gertler (1999). For the hybrid model, it is assumed that some share, $\omega$, of the firms able to change prices in time $t$ choose a price based on a backwards looking rule of thumb. That is, they choose last period's price adjusted for average inflation, $\bar{\pi}$. Under these conditions, Galí et al (2001) show the hybrid New Keynesian Phillips curve with variable marginal cost:

$$\pi_t = \bar{\kappa}\pi_t + \eta_f \pi_{t+1} + \eta_b \pi_{t-1}$$

(3.8)

where $\bar{\kappa} = \frac{(1-\omega)(1-\alpha)(1-\beta)}{\phi}$, $\eta_f \equiv \alpha \beta \phi^{-1}$, $\eta_b \equiv \omega \phi^{-1}$ and $\phi = \alpha + \omega(1 - \alpha(1 - \beta))$. 

46
3.3 Results

This section presents estimates for Japan’s inflation over the period 1972:Q2-2003:Q3 using the New Keynesian Phillips curve.

The data used in this thesis are found in various issues of the Monthly Statistical Bulletin of Japan and at websites for the Bank of Japan and Economic and Social Research Institute (ESRI) of Japan. The model is evaluated using two measures of inflation, the GDP deflator and CPI, both computed as the quarterly log difference. Next period’s expected inflation, $E_t(\pi_{t+1})$, is measured, consistent with rational expectations, using the observed value.²

Average real marginal cost, $\tilde{\psi}$, is measured by the log deviation in unit labor cost from its steady state value, the sample average. The unit labor cost for Japan stems from equation (3.5) in which wages, $W$ are average monthly cash earnings, and employment, $N$, per hour, $h$, expressed as a share of Japan’s GDP $P_Y$: $ulc = \frac{W_i N_i}{(1-a)P_Y h_i}$. This is the measure used in Gordon’s (1982) influential work on wages in Japan, the U.S. and the U.K. and adjusts unit labor costs for changes in hours. This adjustment is particularly helpful for Japan, which implemented a shortened work week during the sample period.

In addition, to focus attention on the structural parameters, $\alpha$ and $\beta$, these are estimated using calibrated values for the marginal product and price elasticity parameters, $a$ and $\theta$. The use of calibrated values is the same technique followed in Gali et al (2001). Gali et al (2001) obtain average measures of the input share and demand elasticity, respectively denoted $\bar{\alpha}$ and $\bar{\theta}$ from the average mark up, $\bar{\mu}$, and average labor income share, $\bar{S} = \frac{W_i N_i}{P_Y h_i}$. It can be shown that the average mark up is the inverse of real marginal cost, $\bar{\mu} = (\bar{\psi})^{-1}$. Under these conditions then, the average input share:

$$\bar{\alpha} \equiv 1 - \frac{\bar{S}}{\bar{\mu}}$$

(3.9)

The estimates in this Chapter rely on calibrated values for $\bar{\alpha}$ and $\bar{\theta}$, which are computed based on existing literature. Using an annual frequency, Hayashi and Prescott (2003) compute Japan’s wage share over the period 1970-2000, which includes costs in excess of wages that are borne by the firm in hiring.

²See discussion in previous chapter.
Based on this, then the average wage is, $\bar{S} = 0.648$. In addition, Martins, Scarpetta, and Pilat (1996) estimate the mark up in the manufacturing sectors of OECD nations over the period, 1970-1992. This is used to compute $\bar{\mu}$, the average markup as the sample average across manufacturing sectors for the period: $\bar{\mu} = 1.2$, which implies $\alpha = 0.46$ for Japan. Similarly, $\kappa$, depends on the elasticity of demand, $\theta$, which is related to the markup: $\kappa = \frac{\theta}{\bar{\mu} - 1}$. Together these imply $\kappa = 6$ and $\zeta = 0.15$.

Hansen (1982) and Hansen and Singleton (1982) prove that the Generalized Method of Moments is a consistent estimator for dynamic macro models with rational expectations arising from Euler equations. These are the conditions underlying the structural and hybrid models shown in equations (3.7) and (3.8). The empirical strategy is to estimate the model using instruments to account for measurement error known to exist in aggregated data. The instruments also act as restrictions on the model that can then be tested using a J-statistic. The vector of instruments, $z_t$ consists of 4 lags each of inflation, real marginal cost, wage growth, the real GDP output gap, CPI inflation, and the spread between a short term and long term nominal interest rate. This is the same set used by Galí and Gertler (1999) and Galí et al (2001).

### 3.3.1 Baseline Estimates: The Reduced Form

Equation (3.1) may be estimated as a linear equation in $\kappa$. Galí and Gertler (1999) call this the reduced model to distinguish it from the specification which depends on the structural parameters, $\alpha$ and $\beta$. Theory implies that these specifications are identical and should yield equivalent estimates. Thus, comparing the results for the reduced form to the structural ones is an informal test of the GMM estimator, which is known to be sensitive in small samples to both the instrument set and the way the orthogonality condition is written (Fuhrer, Moore and Schuh, 1995). For Japan, 1972:Q3-2003:Q3, the New Keynesian Phillips curve in reduced form in quarterly growth in the GDP deflator is:

$$
\pi_t = 0.98\pi_{t+1} + 0.05\bar{\psi}_t
$$

(3.10)

$$
(0.019) \quad (0.018) \quad \frac{J}{[0.97]}
$$

---

3Galí et al (2001) use $S^{Euro} = 0.6667$ and $S^{US} = 0.75$ for the Euro region and United States and $\mu = 1.1$ for both areas.
and when inflation is quarterly growth in the CPI, it is:

\[ \pi_t = 0.98\pi_{t+1} + 0.06\tilde{\psi}_t \]

\[ J = 14.96 \]

(0.020) \hspace{1cm} (0.017) \hspace{1cm} [0.90]

The standard errors are placed in parentheses below the coefficients. For either inflation measure, the \( J \) statistic, which tests whether the overidentifying restrictions are valid, is not rejected based on the p-value shown in brackets. The subjective discount rate, \( \beta \), is effectively one and significant, and the parameter on real marginal cost, \( \tilde{\psi}_t \), is positive and significant. Under variable marginal cost, \( \kappa \) is larger than that found with constant marginal cost, where \( \kappa^{CRTS} = 0.04 \). However, under either inflation measures, \( \kappa^{JP} \), Japan’s marginal cost parameter, is substantially smaller than those for the Euro Area and U.S. estimated by Galf et al (2001), where \( \kappa^{EA} = 0.09 \) and \( \kappa^{US} = 0.25 \), respectively. Higo and Nakada (1999), who find parameter values between 0.07 and 0.24 for subsamples between 1978 and 1996 when \( \tilde{\psi}_t \) is detrended real output.

### 3.3.2 Structural Estimates of the New Keynesian Phillips curve

The structural parameters, \( \alpha \) (degree of rigidity) and \( \beta \) (subjective discount rate), are jointly estimated using two equivalent normalizations of the New Keynesian Phillips curve implied by substituting equation (2.12) into equation (3.7). The first normalization is:

\[ \mathbb{E}_t\{\alpha\pi_t - (1 - \alpha)(1 - \beta\alpha)\tilde{\psi}_t - \alpha\beta\pi_{t+1}\} = 0 \]

(3.12)

The second is:

\[ \mathbb{E}_t\{\pi_t - \frac{(1 - \alpha)(1 - \beta\alpha)}{\alpha}\tilde{\psi}_t - \beta\pi_{t+1}\} = 0 \]

(3.13)

Table 3.1, rows (1) and (2), present estimates of equations (3.12) and (3.13), respectively. It also includes estimates for constant marginal cost \( (\alpha = 0, \zeta = 1) \), for comparison. While there is some variation across the normalizations, equations (3.12) and (3.13), the results suggest the New Keynesian Phillips curve with variable marginal cost is a good approximation for Japan’s inflation. First, the J-test
Table 3.1: New Keynesian Phillips Curve for Japan, 1972-2003

<table>
<thead>
<tr>
<th></th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\kappa$</th>
<th>$\frac{1}{1-\alpha}$</th>
<th>$J_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu = 1.2, \ a = 0.46$ (Variable Marginal Cost)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GDP Deflator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.63**</td>
<td>0.98**</td>
<td>0.22</td>
<td>3</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
<td></td>
<td>[0.99]</td>
</tr>
<tr>
<td>(2)</td>
<td>0.82**</td>
<td>0.97**</td>
<td>0.05</td>
<td>6</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.02)</td>
<td></td>
<td></td>
<td>[0.89]</td>
</tr>
<tr>
<td><strong>CPI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.58**</td>
<td>0.97**</td>
<td>0.32</td>
<td>2.4</td>
<td>9.22</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.03)</td>
<td></td>
<td></td>
<td>[0.995]</td>
</tr>
<tr>
<td>(2)</td>
<td>0.80**</td>
<td>0.98**</td>
<td>0.05</td>
<td>5</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.02)</td>
<td></td>
<td></td>
<td>[0.89]</td>
</tr>
<tr>
<td>$a = 0, \ \zeta = 1$ (Constant Marginal Cost)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GDP Deflator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.86**</td>
<td>0.98**</td>
<td>0.03</td>
<td>7</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
<td></td>
<td>[0.97]</td>
</tr>
<tr>
<td>(2)</td>
<td>0.89**</td>
<td>1.03**</td>
<td>0.01</td>
<td>8</td>
<td>5.52</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.03)</td>
<td></td>
<td></td>
<td>[0.90]</td>
</tr>
<tr>
<td><strong>CPI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.85**</td>
<td>1.00**</td>
<td>0.03</td>
<td>7</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td></td>
<td></td>
<td>[0.9967]</td>
</tr>
<tr>
<td>(2)</td>
<td>0.92**</td>
<td>0.98**</td>
<td>0.008</td>
<td>13</td>
<td>12.80</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td></td>
<td></td>
<td>[0.96]</td>
</tr>
</tbody>
</table>

*Table Notes:* Parameters $a$ and $\mu$, the parameter on labor's marginal product and the firm's mark up are calibrated. Sample Period: 1972-2003 using quarterly data. Rows (1) and (2) correspond to equations (3.12) and (3.13), respectively. $\kappa$ is computed based on the degree of nominal rigidity $\alpha$, and the subjective discount rate, $\beta$. The instrument set includes four lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. The ratio, $\frac{1}{1-\alpha}$, is the number of quarters between price adjustments and $J$ corresponds to the Hansen test of overidentifying restrictions with brackets below indicating the p-value. Standard errors are shown in parentheses while "**" and "*" indicate a significant t-test at the 1% and 5% significance levels, respectively. Inflation, $\pi$, is alternately measured as the quarterly log difference in the GDP deflator and the CPI. See text.
statistics, \((J_T)\), show the overidentifying restrictions are not rejected. Under both inflation measures, the subjective discount rate, \(\beta\) is effectively one with either variable or constant marginal cost. The degree of rigidity, \(\alpha\) is of similar magnitude when either the GDP deflator or CPI is used to measure inflation. However, the magnitude for \(\alpha\) varies across the normalization of the Euler equation. In general, equation (3.13), yields a higher degree of rigidity in both inflation measures and across both types of marginal cost, variable or constant. For variable marginal cost, the specification based on equation (3.12), predicts Japan firms wait 2-3 quarters between making price adjustments, a substantial increase in price flexibility over the case with constant marginal cost, which predicts a 7 quarter wait. However, the estimates of equation (3.13), imply a greater degree of rigidity with firms waiting between 5 and 6 quarters to reset prices. Galt and Gertler (1999) and Galf et al (2001) find that rigidity increases under equation (3.13) as well, but to a much lesser extent. Typically, the increase in waiting time is about one quarter. Under this specification, the slope parameter for Japan shown in Table 3.1, \(\kappa = 0.05\) for both GDP deflator CPI inflation which exceeds \(\delta = 0.031\), the output gap parameter for the non-optimal Phillips curve shown in equation (3.3) as well as that found by Coenen and Wieland (2003) but smaller than that found by Higo and Nakada (1999). Compared to New Keynesian Phillips curve estimates for the U.S. and the Euro area, Japan’s estimate for \(\kappa\) is much smaller. For these countries, \(\kappa = 0.665\), for the U.S. and \(\kappa = 0.228\) for the European area (Galf et al, 2001).

Figure 3.1 shows predicted and actual inflation based on CPI inflation in row (1) shown in Table 3.1. Figure 3.2 shows predicted and actual inflation with diminishing returns to scale and CPI inflation in row (1) of the same Table.

### 3.3.3 Hybrid Estimates

Table 3.3.3 presents results for the hybrid model. Similar to the structural model, the hybrid model in equation (3.8) is estimated using two normalizations:

\[
E_t\{(\phi \pi_t - (1 - \omega)(1 - \alpha)(1 - \alpha \beta)\psi_t - \alpha \beta \pi_{t+1} - \omega \pi_{t-1})\sigma_t\} = 0
\]  

(3.14)
Figure 3.1: Actual and Predicted Inflation with CRTS production: Japan, 1972-2003

and

$$E_t(\pi_t - \frac{(1 - \omega)(1 - \alpha)}{\phi}\zeta \hat{\psi}_t - \frac{\alpha \beta}{\phi} \pi_{t+1} - \frac{\omega}{\phi} \pi_{t-1})z_u = 0 \quad (3.15)$$

where $\phi = \alpha + \omega[1 - \alpha(1 - \beta)]$.

Overall, the model is not rejected based on the $J$-statistic. However, the estimates bear out Gálf and Gertler's (1999) assertion that GMM is sensitive to the specification in small samples. Clearly, the normalization in equation (3.14), yields more plausible estimates. Gálf and Gertler (1999) and Gálf et al. (2001) find the same result but the disparity for Japan estimates is more pronounced. Row (1) for both GDP deflator and CPI inflation show forward looking behavior dominates backward looking behavior, i.e., $\eta_f > \eta_b$. However, for CPI inflation, $\omega$, the share of firms setting prices using a backward looking rule of thumb is negative and significant. The degree of rigidity in the moment condition $\alpha$ is multiplied across the moment condition is about 0.60 for both inflation measures which suggest firms reset prices once a year, roughly every 3 quarters. When GDP deflator inflation is used with this same moment condition, $\alpha$ increases to 0.7 percent, which if statistically significant would predict a 3-quarter wait. The estimated rigidity deteriorates the most under this specification with CPI inflation,

$^4$For example, under variable marginal cost, Gálf et al. (2001) find the waiting period between price setting varies by less than 1 quarter, and rigidity, $\alpha$, increases by 7 to 11 percent, while retaining statistical significance.

52
where $\alpha = 1.34$ and is statistically significant. Otherwise, variable marginal cost performs better as a measure than constant marginal cost which predicts a 7 quarter wait between price changes under the linear moment condition. Figure 3.3 show predicted and actual paths for GDP deflator inflation in the hybrid model with decreasing returns to scale. Figure 3.4 shows the paths of predicted and actual GDP deflator inflation in the hybrid model when production has constant returns to scale.

### 3.3.4 Parameter Stability Tests

Andrews (1993) designs tests of structural stability for parameters estimated using the GMM. These are similar in nature Chow tests for structural breaks in the OLS context. Specifically, Andrews (1983) provides the basis for the hypothesis that a parameter is constant over the sample against the alternative that it is not when the break point date is unknown and unspecified. The break point is determined by ranking the test statistics over a partition of the whole sample and selecting the statistic with the largest
Table 3.2: The Hybrid New Keynesian Phillips Curve for Japan, 1972-2003

<table>
<thead>
<tr>
<th></th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\omega$</th>
<th>$\eta_f$</th>
<th>$\eta_b$</th>
<th>$\kappa$</th>
<th>$\frac{1}{1-\mu}$</th>
<th>$J_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>$\mu = 1.2$, $\alpha = 0.46$</strong> (Variable Marginal Cost)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GDP Deflator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.61**</td>
<td>0.97**</td>
<td>0.16**</td>
<td>0.77</td>
<td>0.21</td>
<td>0.17</td>
<td>3</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.06)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.06)</td>
<td></td>
<td>(0.99)</td>
</tr>
<tr>
<td>(2)</td>
<td>0.67</td>
<td>1.48</td>
<td>0.98</td>
<td>0.5</td>
<td>0.5</td>
<td>0.00</td>
<td>3</td>
<td>7.87</td>
</tr>
<tr>
<td></td>
<td>(67.82)</td>
<td>(155.5)</td>
<td>(3.63)</td>
<td>(0.99)</td>
<td>(0.99)</td>
<td>(0.99)</td>
<td></td>
<td>(0.9957)</td>
</tr>
<tr>
<td><strong>CPI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.63**</td>
<td>0.99**</td>
<td>-0.21**</td>
<td>1.45</td>
<td>-0.49</td>
<td>0.41</td>
<td>3</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.05)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.05)</td>
<td></td>
<td>(0.99)</td>
</tr>
<tr>
<td>(2)</td>
<td>1.34**</td>
<td>1.0**</td>
<td>1.06**</td>
<td>0.56</td>
<td>0.44</td>
<td>0.00</td>
<td>-3</td>
<td>8.95</td>
</tr>
<tr>
<td></td>
<td>(0.55)</td>
<td>(0.36)</td>
<td>(0.16)</td>
<td>(0.55)</td>
<td>(0.36)</td>
<td>(0.16)</td>
<td></td>
<td>(0.99)</td>
</tr>
<tr>
<td><strong>$a = 0$, $\zeta = 1$</strong> (Constant Marginal Cost)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GDP Deflator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.85**</td>
<td>0.99**</td>
<td>0.25**</td>
<td>0.76</td>
<td>0.23</td>
<td>0.02</td>
<td>7</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.07)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.07)</td>
<td></td>
<td>(0.98)</td>
</tr>
<tr>
<td>(2)</td>
<td>0.32</td>
<td>3.15</td>
<td>0.99**</td>
<td>0.48</td>
<td>0.52</td>
<td>0.00</td>
<td>1</td>
<td>7.90</td>
</tr>
<tr>
<td></td>
<td>(18.6)</td>
<td>(181.0)</td>
<td>(0.38)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.38)</td>
<td></td>
<td>(0.9956)</td>
</tr>
<tr>
<td><strong>CPI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.86**</td>
<td>1.00**</td>
<td>-0.29**</td>
<td>1.49</td>
<td>-0.49</td>
<td>0.04</td>
<td>7</td>
<td>8.65</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.03)</td>
<td></td>
<td>(0.99)</td>
</tr>
<tr>
<td>(2)</td>
<td>1.00</td>
<td>0.99**</td>
<td>0.70</td>
<td>0.59</td>
<td>0.41</td>
<td>0.00</td>
<td>$\infty$</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td>(23.5)</td>
<td>(0.27)</td>
<td>(16.2)</td>
<td>(0.23)</td>
<td>(0.23)</td>
<td>(16.2)</td>
<td></td>
<td>(0.98)</td>
</tr>
</tbody>
</table>

*Table Notes:* Parameters $\alpha$ and $\mu$, the parameter on labor's marginal product and the firm's mark up are calibrated. Sample Period: 1972-2003 using quarterly data. Rows (1) and (2) correspond to equations (3.14) and (3.15) respectively. The instrument set includes four lags of inflation, wage growth, CPI inflation, the real output gap and the spread between a short and long term government bond. $\frac{1}{1-\mu}$ is the number of quarters between price adjustments and $J$ corresponds to the Hansen test of overidentifying restrictions with brackets below indicating the $p$-value. Standard errors are shown in parentheses while ** and * indicate a significant t-test at the 1% and 5% significance levels, respectively. Inflation, $\pi$, is alternately measured as the quarterly log difference in the GDP deflator and the CPI. See text.
Figure 3.3: Actual and Predicted Hybrid Inflation with DRTS production: Japan, 1972-2003

magnitude. For this exercise we focus on the later part of the sample, 1988-1996 which includes the asset and land price bubble, 1988-91, and deflationary episodes. This section discusses results for tests of pure, rather than partial, structural change where the former evaluates all parameters jointly and is based on a likelihood ratio-like test. Procedurally, the stability test occurs separately from the test for statistical significance. Rossi (2004) develops tests that evaluate estimated parameters for a structural break and statistical significance simultaneously, which she shows to have an optimal weighted average power against equally likely alternatives.

Table 3.3 reports results of tests for pure structural strange when inflation is quarterly growth in the GDP deflator or CPI inflation.5 “SupLR” and “SupLR*” denote Andrews (1993) supremum likelihood ratio and Rossi’s (2004) optimal version of Andrews. As a whole, the results suggest pure structural change occurs under both inflation measures and model specifications either at the bubble period or during the deflationary episode. Under Andrews (1993), the analytically equivalent model for GDP deflator inflation, based on equation (3.12) suggests structural breaks occur in 1996:Q4 when marginal cost is variable or constant. Roughly, this is the start of the deflationary episode. Rossi’s (2004) optimal tests for the same inflation and variable marginal cost suggest the structural break occurs in 1990:Q3,

5Pure structural change refers to tests involving the full set of parameters (Andrews, 1993).
during the asset and land price bubble and near a turning point in Japan’s inflation rate. For the moment condition arising most immediately from the optimization problem, the supremum likelihood ratio test (SupLR) suggests the break occurs at the start of bubble, 1988:Q2. Rossi’s (2004) optimal test for the same specification suggests the deflationary period, 1994:Q4. For CPI inflation, the tests statistics indicate similar disparities around the two events.6

3.4 Dynamics and Frictions affecting Real Marginal Cost

This section considers a model that imparts a stochastic process to the New Keynesian Phillips curve. It is well known that the New Keynesian Phillips curve imparts no dynamics to inflation except for those dynamics inherent to real marginal cost (Walsh, 2003, Woodford, 2003). Galf et al (2001) derive a simple decomposition of real marginal cost that enables a deeper analysis of the factors affecting its dynamic path and acts as a source of a stochastic shock for the New Keynesian Phillips curve.

Suppose the representative household’s preferences for consumption and leisure, $\sum_{t=0}^{\infty} \beta^t U(C_t, N_t)$ are separable within $U(C_t, N_t)$. By assuming firms and households optimize, Galf et al (2001) express

---

6A later draft will discuss similar tests for the hybrid model. It is thought that this will provide another robustness test for the nested model.
Table 3.3: Results of Parameter Stability Tests

<table>
<thead>
<tr>
<th>Statistical Test</th>
<th>SupLR</th>
<th>SupLR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP Deflator Inflation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Marginal Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equation (3.12)</td>
<td>115.96</td>
<td>1072.7</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1996:Q4</td>
<td>1990:Q3</td>
</tr>
<tr>
<td>Equation (3.13)</td>
<td>105.7</td>
<td>1224.9</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1988:Q2</td>
<td>1996:Q4</td>
</tr>
<tr>
<td>Constant Marginal Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a = 0)</td>
<td>1133</td>
<td>16522</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1996:Q4</td>
<td>1996:Q4</td>
</tr>
<tr>
<td>CPI Inflation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Marginal Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equation (3.12)</td>
<td>382.7</td>
<td>1123.1</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1990:Q1</td>
<td>1995:Q2</td>
</tr>
<tr>
<td>Equation (3.13)</td>
<td>383.4</td>
<td>2442.6</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Date of Structural Break</td>
<td>1988:Q2</td>
<td>1996:Q4</td>
</tr>
</tbody>
</table>

the relationship between real wages and household preferences as:

\[
\frac{W_t}{P_t} = -\frac{U_{N,t}}{U_{C,t}} \mu^w_t
\]  

(3.16)

where \(-\frac{U_{N,t}}{U_{C,t}}\) is the marginal rate of substitution between consumption and labor. Equation (3.16) relates the real wage to the household's marginal rate of substitution between leisure and consumption. The random disturbance term, \(\mu^w_t\), represents the marginal cost the household faces for supplying additional labor (measured in consumption units) that typically would arise in an imperfect labor market.\(^7\) The disturbance term \(\mu^w_t\) is interpreted as the gross wage mark up demanded by households when they have "market power," analogous to the gross price markup over marginal cost held by firms with monopoly power. It is assumed the household cannot be forced to supply labor to the point where the marginal rate of substitution exceeds marginal cost which constrains \(\mu^w_t \geq 1\). When \(\mu^w_t = 1\), the real wage equals the household's marginal cost of supplying labor, i.e., a perfectly competitive labor market. When \(\mu^w_t > 1\), labor market frictions exist, which could be caused by households having some form of monopoly power in the labor market, nominal wage rigidities, or distortionary taxes, for example.

Using the result that the real wage equals the marginal product of labor in equilibrium, real marginal cost can be expressed in terms of equation (3.16):

\[
\psi_t = \frac{(W_t/P_t)}{(1 - \alpha)(Y_t/N_t)} = -\frac{U_{N,t}/C_{N,t}}{(1 - \alpha)Y_t/N_t} \mu^w_t
\]  

(3.17)

Equation (3.17) relates real marginal cost, \(\psi_t\), to the household's real marginal cost of supplying labor. The right side of equation (3.17) can be interpreted as equating the unit labor cost for the firm to the household's wage markup, \(\mu^w_t\), and the ratio of the household's marginal cost to the marginal product of labor. Galf et al (2001) describe the ratio as an "inefficiency wedge." When \(\frac{U_{N,t}/C_{N,t}}{(1 - \alpha)Y_t/N_t} = 1\), output is at its potential and the household's marginal cost is identical to the firm's marginal product of labor.

When it is less than 1, i.e., \((1 - \alpha)Y_t/N_t > -U_{N,t}/U_{C,t}\), output is below potential. Intuitively, this means the gains to the firm from one extra unit of labor for the firm exceeds the household's benefit.

\(^7\)Another source for \(\mu^w\) is a shift that might occur in the marginal utility of leisure (Walsh, 2003).
from exchanging one more unit of consumption for one more unit of labor.

Separability in the preferences implies, \( U(C_t, N_t) = \ln C_t - \frac{1}{1+\phi} N_t^{1+\phi} \). This implies \( U_{C,t} = \frac{1}{C_t} \) and \( U_{N,t} = -N_t^\phi \), where \( \phi \) is the inverse of the elasticity of labor supply, which is set at unity, for analytical ease. Log linearizing equation (3.17) yields the following expression for real marginal cost:

\[
\psi_t = \ln \mu^w_t + [(c_t + \phi n_t) - (y_t - n_t)]
\]

(3.18)

where the log of the wage markup is given by, \( \ln \mu^w_t = (w_t - p_t) - (c_t + \phi n_t) \). Lower case variables denote natural logarithms. The other expression in brackets on the right hand side of equation (3.18) is the inefficiency wedge. The remainder of this section discusses the application of this model to Japan.

Consumption is measured as the log of seasonally adjusted private consumption (rather than household consumption, which is limited to observations from 1994). This series is collected by the Japan’s Economic and Social Research Institute (ESRI). The employment variable is employment per household which is measured as the log difference between employment and the labor force per hour, which are published in the Japan Monthly Statistical Bulletin. The parameters are log linearized around the steady state, which is defined to be the sample mean. Figure 3.5 shows Japan’s wage markup, \( \mu^w \), compared to real marginal cost, \( \psi_t \). It is clear that the wage markup fell steeply over the first half of
the sample, perhaps due to weakening in labor union power and the popularity of the Japan's Liberal Democratic Party (LDP). This result starkly contrasts the Euro area experience documented by Gali et al (2001), which shows $\mu_t^w$ (for the Euro area) rising over the same period but falling though the late 80s, rising in the early 90s and tapering off in the second half of that decade.

3.5 Conclusion

The discussion in this chapter indicates that the hybrid New Keynesian Phillips curve under decreasing returns to scale holds some promise for describing Japan's inflation, though room for improvement remains. These improvements are ongoing in the literature and encompass both theory and methodological perspectives. In terms of theory consistency, estimates reported in this Chapter predict firms go 3 quarters between reoptimizing prices although the result is not robust across specifications. This study shows evidence that forward looking behavior dominates in nested model tests and that structural breaks occur around the land and asset price bubble and deflationary episodes. There is further documentation that GMM is sensitive to equivalent specifications of the Euler equation when the sample is small. This study finds greater disparity in estimates across equivalent specifications than those found by Gali and Gertler (1999) and Gali et al (2001). Another factor affecting the New Keynesian Phillips curve estimates may be the choice of instruments. Finally, decomposition of real marginal cost expressed in terms of the household's labor supply decision suggests that explicitly modeling wage rigidity may play a role in finding improved estimates of Japan's inflation inertia in the hybrid New Keynesian/New Neoclassical Synthesis framework. Specifically, market power on the labor supply side of the economy was substantial in the first half of the sample and diminished toward the end of the period.
Chapter 4

Aggregate Demand: Forward Looking Agents and the Zero Lower Bound

4.1 Introduction

This chapter provides evidence on the fit of the New Keynesian/Neoclassical Synthesis model for Japan's aggregate demand over the period 1972-2003. Numerous recent works discuss Japan's monetary policy, e.g., Orphanides and Wieland (1999), Svensson (1999), McCallum (2001), Coenen and Wieland (2002), Hori, Tanabe, Yamane and Aoki (2002), Mishkin and Ito (2004), and Iwamura, Kudo and Watanabe (2005). Collectively, they document, evaluate or suggest remedy for Japan's ongoing economic woes. In these studies, the aggregate demand and aggregate supply models employed are usually subsidiary to the simulations and policy recommendations.

However, the subtleties between backward and forward looking models for both aggregate demand and supply are central issues in this thesis. The attention given these frameworks or "competing models" extend beyond methodological concerns and empirical performance although these are important to the discussion. This is because the New Neoclassical Synthesis/New Keynesian framework holds within it both satisfaction of the Lucas critique and the potential for welfare analysis—two aspects not readily achieved in ad hoc behavioral models (Woodford, 2004). Taken together, empirical works form a robustness study that highlights shortcomings in both theory and estimation methodology. In the New Keynesian context, Fuhrer and Rudebusch (2004) and Cogley and Nason (1995) are recent studies on
the Euler output equation. McCallum (1999) argues that a research strategy built on robustness tests is a key component for progress in the field. Although he is speaking specifically to the design of optimal monetary policy rules rather than the methodological and measure comparisons closer to the heart of this study, this thesis is consistent with McCallum's overall agenda because it compares performance across distinct but closely related models. Specifically, this chapter evaluates the impact of different measures on different specifications of the New Keynesian model for Japan's aggregate demand over the last thirty years. In this sense, it extends Fuhrer and Rudebusch (2004) to Japan and includes an exchange rate channel to represent open economy influences. By doing so, these results can be compared to studies on other industrialized nations as well as to that of Coenen and Wieland (2004) who estimate Japan's aggregate demand curve using a backwards looking, open economy model.

Similar to that for aggregate supply, the New Neoclassical Synthesis or New Keynesian aggregate demand model is derived from the dynamic optimization problems of household and firms. The resulting first order conditions for the closed economy yield an Euler equation for the path of output, which is forward looking in both output and inflation, and depends negatively on the real interest rate. It can be compared to behavioral models of aggregate demand that predict output is determined autoregressively, in an adaptive expectations framework. As a model of Japan's economy, a forward looking model might be expected to perform better than a backward looking one given the country's slowdown over the last decade. This is because specifications relying on lagged measures of real output would likely overestimate demand in a recessionary environment such as Japan's.

Briefly, this study finds forward looking models of aggregate demand for Japan have the same problems as similar estimates for the United States. That is, real interest rates and thus, monetary policy, have very little impact on real output. For Japan, the purely forward looking model implies real interest rates have no effect on demand. It is likely these estimates for Japan are exacerbated by the extended slowdown in the 1990s, deflation and the zero lower bound on nominal interest rates. Under the open economy specification which incorporates lagged output, forward looking behavior dominates backward looking behavior. And, while the the parameter on real interest rate is statistically significant with the hypothesized sign, it is effectively zero. For closed economy hybrid specifications,
backward looking behavior dominates and the influence of the real interest rate, i.e., monetary policy is statistically insignificant.

This chapter consists of five sections. Section 4.1 is the introduction. Section 4.2 sets out the theory and research strategy. Section 4.3 presents results and Section 4.4 is the conclusion.

4.2 Framework


The New Neoclassical Synthesis/New Keynesian model predicts output is determined by the Euler equation of a dynamic stochastic general equilibrium model with nominal rigidities. It can be expressed as a linear approximation around a zero-inflation steady state:

\[ y_t = \delta E_t y_{t+1} - \sigma (i_t - E_t \pi_{t+1}) \]  (4.1)

where \( y \) is a real output gap, \( i \) is the nominal interest rate and \( \pi \) is the inflation rate. \( E \) is the expectations operator. The parameter \( \delta > 0 \) determines the impact of today's expectation of output next period. The parameter, \( \sigma \), captures the influence of the real interest rate, \( (i_t - E_t \pi_{t+1}) \), on demand, reflecting the idea that a falling real interest rate stimulates borrowing which increases investment and thus, the quantity of aggregate demand. In addition with a CIES utility function \( \sigma \) is the intertemporal elasticity of substitution. The parsimonious, possibly herculean, aspect of this model assumes consumption is equal to output and in doing so abstracts from capital, government, international trade. A common
alternative to the simple or primitive output model in equation (4.1) is to allow lagged output to play a role in determining aggregate demand. Works on the nested or hybrid versions of the supply side of the model are commonplace, e.g., Galf and Gertler (1999), Galf et al (2001), Nason and Smith (2001), and Eichenbaum and Fisher (2003, 2004) and Sanchez (2004, 2005). The supply side hybrid version follows from the assumption that some firms do not select the optimal price when the opportunity to set prices arrives (Galf and Gertler 1999).

With respect to aggregate demand, the microeconomic underpinnings for the hybrid model are less established in the literature. Dennis (2003) hypothesizes lagged output on the right hand side to capture the influence of habit formation. The hybrid output equation is:

\[
y_t = (1 - \delta_h)E_t y_{t+1} + \delta_h y_{t-1} - \sigma(i_t - E_t \pi_{t+1})
\]  

(4.2)

Clarida, Galjf and Gertler (2002) derive the open economy New Keynesian demand curve from first principles:

\[
y_t = (1 - \delta_h)E_t y_{t+1} + \delta_h y_{t-1} + \gamma e_t - \sigma(i_t - E_t \pi_{t+1})
\]  

(4.3)

where \( e \) is the real exchange rate. As a nested model test of the forward looking New Neoclassical Synthesis, it is hypothesized that \( \delta_h \in (0, 0.5) \) in equations (4.2) and (4.3).

Two variants of the real interest rate are evaluated in the specifications as a robustness test. The first stems from Fuhrer and Rudebusch (2004), which is shown in the nested form for the open economy as:

\[
y_t = \delta_0 y_{t-1} + \delta_1 y_{t-2} + \delta_2 E_{t-\tau} + \gamma e_t \sigma^{-1} \left[ \sum_{j=0}^{k-1} (t+j+m-\pi_{t+j+m+1}) \right]
\]  

(4.4)

where \( \tau \) allows for flexibility in the timing of when expectations are formed, \( k \) controls the duration of the ex ante interest rate and when \( m = -1 \) the lagged real interest rate plays a role. Note that when \( k = 1 \) and \( m = \tau = \delta_0 = 0 \) equation (4.4) is identical to equation (4.3).

Coenen and Wieland (2002) estimate a backwards looking model for Japan, which Walsh (2002) shows can be re-written as a forward looking hybrid model for the open economy. The difference
between this model and Rudebusch and Fuhrer (2004) lies in the specification of the real interest rate:

\[ \hat{y}_t = \delta(L)\hat{y}_{t-1} + \delta_f E_t(y_{t+1}) + \gamma e^w_t - \sigma (r_{t-1} - r^*) \]  

(4.5)

where \( \delta(L) = \sum_{j=1}^{\eta(l)} \delta_j L^{j-1} \) allows for multiple lags of the output gap. As a test of the open economy hybrid model it is hypothesized that \( \sum_{j=1}^{\eta(l)} \delta_j \leq 0.5 \). The exchange rate, \( e^w_t \) is a trade weighted real exchange rate and \( (r_{t-1} - r^*) \) is the deviation of the real interest rate from its steady state equilibrium.

Coenen and Wieland (2002) define the term structure of the real interest rate as:

\[ l_t = E_t \left[ \frac{1}{\eta(l)} \sum_{j=1}^{\eta(l)} i_{t+j-1} \right] \]  

(4.6)

which relies on the accumulated expectations of the short term instrument rate, \( i \) over \( \eta(l) \) quarters and the term premium is assumed to be constant and equal to zero. For the estimations in this chapter, the observed value of \( i \) is substituted for its forecast. The long term ex ante real interest rate is found by subtracting inflation expectations over the following \( \eta(l) \) quarters:

\[ r_t = l_t - 4E_t \left[ \frac{1}{\eta(l)} (p_{t+\eta(l)} - p_t) \right] \]  

(4.7)

where \( p \) is the log of the price level. Section 4.3 describes the estimation strategy and presents the results.

### 4.3 Results

The models shown in Section 4.2 are estimated using the Generalized Method of Moments (GMM). Hansen (1982) and Hansen and Singleton (1982) prove that GMM is a consistent estimator for macroeconomic models with rational expectations. However, Fuhrer, Moore and Schuh (1995) show that GMM estimates are sensitive in small samples to normalization and selection of instruments. Despite the potential for biased estimates, however, authors continue to use GMM estimates as a first approximation for New Neoclassical Synthesis/New Keynesian models, e.g., Galf and Getler (1999), Galf et al
4.3.1 Data

The series for this study are found in various issues of the Monthly Statistical Bulletin of Japan as well as from online sources at the Economic Social Research Institute of Japan and the Bank of Japan websites as well as those for the U.S. Bureau of Economic Adminsitration and the U.S. Bureau of Labor Statistics.

![Graph](image)

**Figure 4.1: Real Output Gap Measures, Japan 1971-2003**

Two measures of the output gap, $y$, are used: quadratically detrended real GDP and Hodrick-Prescott (HP) filtered real GDP. Inflation, $\pi$, is measured as the quarterly growth rate of the CPI, computed as a log difference. Figure 4.1 shows the output gap measures. By inspection, the measures fluctuate similarly throughout the period, 1971-2003, although the HP filtered output gap exhibits
greater dispersion. Together the series illustrate the country’s economic difficulties, recessions for much of the 1990s and negative growth beginning in 1998 through the end of the sample. The nominal interest rate, $i$, is the quarterly average of the Call Rate. Two measures of the real exchange rate are used: a Hodrick-Prescott filtered real effective exchange rate and a trade weighted real exchange rate. The real effective exchange rate for the yen is posted online at the Bank of Japan website. Define the trade weighted real exchange rate, $e^w$: $e^w \equiv e \cdot w$ where the real exchange rate is the product of the nominal exchange rate in log form, $s_t$, and the ratio of Japan’s CPI to that of the U.S. The trade weight, $w$, is computed as the sum of Japan’s share of imports from and exports to the U.S.¹:

$$e^w = s \cdot \left[ \frac{CPI^{JP}}{CPI^{US}} \right] \cdot \left[ \frac{M^{US} + X^{US}}{M^{World} + X^{World}} \right]$$ (4.8)

where $M$ and $X$ denote Japan’s imports and exports respectively and the superscript denotes the corresponding import source or export destination.² Figure 4.2 shows the HP filter of the real effective

---

¹This is similar to Klitgaard and Orr (1998) but they include another summand equal to the product of the Japan’s exports as a share of the world’s exports and Japan’s export share and to the formula above would assign a weight of 0.5 to this and the export share in equation (4.8). For simplicity and to focus on the US Japan trade relation I set this term equal to zero.

²It is assumed that Japan’s imports from the U.S. are identical to U.S. exports to Japan, reported by the US BEA. Japan’s exports to the U.S. are likewise defined. This was necessary due to data availability.
exchange rate. The real effective rate, reported by the Bank of Japan is weighted against 15 major currencies. The appreciation observed through the 1980s reflects the growth in Japan’s competitiveness rising with demand for Japanese imports as well as the period of low and stable inflation which fueled productivity. Similarly, the depreciation towards the end of the sample echoes the turn in Japan’s fortunes as its decade long recession took hold, along with the deflationary period.

Figure 4.3: Forward Looking Real Interest Rates for Japan, 1971-2003

Figure 4.3 shows the movement of a simple real interest rates for Japan, \( r_t = i_t - \pi_{t+1} \), and \( i \) is the quarterly average Call Rate for Japan. For comparison, the real interest rate is shown when inflation is measured as quarter-on-quarter growth, \( r^Q \), and with year-on-year, \( r^A \). Inflation is measured as the respective log difference in Japan’s CPI. Japan’s real interest rate fluctuates much more broadly during the seventies when inflation is year on year growth. However, as Japan entered its period of steady and low inflation in the 1980s, the differences between \( r^Q \) and \( r^A \) become less pronounced. By the mid 1990s, during the deflationary period, the two measures essentially converge and remain quite close through the end of the sample. The impact of Japan’s zero interest rate policy (ZIRP) in response to the deflationary period shows its effect beginning 1999:Q3 when Japan’s real interest rate is closest to the lower zero bound. The ZIRP was maintained through the end of the period except for a slight deviation from 2000:Q3-2001:Q1 under the Hayami regime, during which the call rate was raised to
roughly 22 basis points, away from the unitary basis point standard typical of the ZIRP. In keeping with the New Keynesian framework, which defines inflation as the period to period change in the price level, the results in this section utilize quarter-on-quarter CPI inflation.

4.3.2 Empirical Results

The models shown in Section 4.2 are estimated using the Generalized Method of Moment as recommended by Hansen (1982) and Hansen and Singleton (1982). In all, the estimations entail both closed and open economy specifications, two types of output gaps, two exchange rate measures, different durations, \( k \), and timing, \( m \), of the ex ante real interest rate as well as two instrument sets. Fuhrer and Moore's (2004) practice of distinguishing endogenous from exogenous instruments is followed. The set of exogenous instruments consists of a relative oil price, national defense expenditures, the U.S. federal funds rate and U.S. quarterly CPI inflation. The relative oil price for Japan is approximated using the crude oil first purchase price per barrel for the U.S. expressed in yen as a share of Japan's CPI. This proxy was necessary due to a lack of consistent data over the sample period. Each instrument set consists of 1-4 lags. The results are shown in Tables 4.1-4.5.

Table 4.1 presents estimates of equation (4.1), the closed economy Euler equation derived from first principles. The Hansen J-test of overidentifying restrictions does not reject the model and this result holds across all estimates discussed in this section. The lack of a statistically significant relationship between output and real interest rates is enough to reject the primitive New Keynesian model for aggregate demand on economic grounds. Although forward looking behavior is significant, these estimates imply that real interest rates and thus, monetary policy, as approximated by the Call Rate, has no explanatory power for aggregate demand.

Estimates of the Fuhrer-Rudebusch model for the closed economy, equation (4.4), are shown in Table 4.2. This specification allows for greater variability in the composition of the ex ante real interest rate. Discussion is limited to estimates with output lagged one period for the hybrid closed economy model allowing for differing maturity length and timing in the real interest rate, \( r \). Also, with \( \tau = 0 \), Table 4.2 show estimates for just contemporaneous expectations, \( E_t \). For the closed economy model,
Table 4.1: GMM Estimates of New Keynesian Aggregate Demand for Japan

\[ y_t = \delta_f E_t y_{t+1} - \sigma E_t [(i_t - \pi_{t+1})] + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Model</th>
<th>Coefficient estimates and standard errors</th>
<th>J-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trend Instruments</td>
<td>( \delta_f )</td>
</tr>
<tr>
<td>HP, ( \pi )</td>
<td>( y, i, \pi, (1 - 4) )</td>
<td>1.069**</td>
</tr>
<tr>
<td>HP, ( \pi )</td>
<td>exog(1 - 4)</td>
<td>0.898**</td>
</tr>
<tr>
<td>QD, ( \pi )</td>
<td>( y, i, \pi, (1 - 4) )</td>
<td>1.008**</td>
</tr>
<tr>
<td>QD, ( \pi )</td>
<td>exog(1 - 4)</td>
<td>0.950**</td>
</tr>
</tbody>
</table>

Table Notes: Quarterly data; 1971:Q3-2003:Q3 for instrument set, \{y, i, \( \pi \), (1-4)\}, comprised of lags 1-4 of each regressor and 1974:Q1-2003:Q3 for exogenous (exog) instrument set. HP denotes Hodrick-Prescott filtered real output gap and QD is quadratically detrended real output. Inflation is measured as the quarterly log difference of the CPI. The exogenous instrument set consists of a relative oil price and national defense expenditures (following Fuhrer and Rudebusch, 2004). ** and * indicate a significant t-test at the 1 and 5 percent significance levels, respectively.
Table 4.2: GMM Estimates of Closed Economy Hybrid New Keynesian Aggregate Demand for Japan

\[
y_t = \delta_0 y_{t-1} + \delta_j E_t y_{t+1} - \sigma E_t \left[ \frac{1}{k} \sum_{j=0}^{k-1} (it+j+m - \pi_{t+j+m+1}) \right] + \epsilon_t
\]

<table>
<thead>
<tr>
<th>Trend</th>
<th>Instruments</th>
<th>(k)</th>
<th>(m)</th>
<th>(\delta_0)</th>
<th>(\delta_j)</th>
<th>(SE(\delta_j))</th>
<th>(\sigma)</th>
<th>(SE(\sigma))</th>
<th>(p)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>(y, i, \pi, (1-4))</td>
<td>4</td>
<td>0</td>
<td>0.517**</td>
<td>0.476**</td>
<td>(0.040)</td>
<td>-0.0002</td>
<td>(0.001)</td>
<td>0.730</td>
</tr>
<tr>
<td>HP</td>
<td>(y, i, \pi, (1-4))</td>
<td>40</td>
<td>0</td>
<td>0.517**</td>
<td>0.476**</td>
<td>(0.040)</td>
<td>-0.000002</td>
<td>(0.000)</td>
<td>0.728</td>
</tr>
<tr>
<td>HP</td>
<td>(y, i, \pi, (1-4))</td>
<td>4</td>
<td>-1</td>
<td>0.517**</td>
<td>0.476**</td>
<td>(0.040)</td>
<td>-0.000003</td>
<td>(0.00)</td>
<td>0.731</td>
</tr>
<tr>
<td>HP</td>
<td>(exog(1-4))</td>
<td>4</td>
<td>0</td>
<td>0.616**</td>
<td>0.450**</td>
<td>(0.109)</td>
<td>0.001</td>
<td>(0.002)</td>
<td>0.866</td>
</tr>
<tr>
<td>HP</td>
<td>(exog(1-4))</td>
<td>4</td>
<td>-1</td>
<td>0.615**</td>
<td>0.450**</td>
<td>(0.109)</td>
<td>0.00001</td>
<td>(0.000)</td>
<td>0.867</td>
</tr>
<tr>
<td>HP</td>
<td>(exog(1-4))</td>
<td>4</td>
<td>0</td>
<td>0.618**</td>
<td>0.450**</td>
<td>(0.110)</td>
<td>0.001</td>
<td>(0.002)</td>
<td>0.867</td>
</tr>
<tr>
<td>QD</td>
<td>(y, i, \pi, (1-4))</td>
<td>4</td>
<td>0</td>
<td>0.526**</td>
<td>0.476**</td>
<td>(0.048)</td>
<td>-0.0009</td>
<td>(0.000)</td>
<td>0.745</td>
</tr>
<tr>
<td>QD</td>
<td>(y, i, \pi, (1-4))</td>
<td>40</td>
<td>0</td>
<td>0.526**</td>
<td>0.475**</td>
<td>(0.035)</td>
<td>-0.000007</td>
<td>(0.000)</td>
<td>0.746</td>
</tr>
<tr>
<td>QD</td>
<td>(y, i, \pi, (1-4))</td>
<td>4</td>
<td>-1</td>
<td>0.526*</td>
<td>0.476**</td>
<td>(0.035)</td>
<td>-0.0007</td>
<td>(0.002)</td>
<td>0.746</td>
</tr>
<tr>
<td>QD</td>
<td>(exog(1-4))</td>
<td>4</td>
<td>0</td>
<td>0.552**</td>
<td>0.449**</td>
<td>(0.127)</td>
<td>-0.0052</td>
<td>(0.009)</td>
<td>0.821</td>
</tr>
<tr>
<td>QD</td>
<td>(exog(1-4))</td>
<td>40</td>
<td>0</td>
<td>0.554**</td>
<td>0.447**</td>
<td>(0.126)</td>
<td>-0.000004</td>
<td>(0.000)</td>
<td>0.826</td>
</tr>
<tr>
<td>QD</td>
<td>(exog(1-4))</td>
<td>4</td>
<td>-1</td>
<td>0.551**</td>
<td>0.450**</td>
<td>(0.126)</td>
<td>0.004</td>
<td>(0.007)</td>
<td>0.823</td>
</tr>
<tr>
<td>QD</td>
<td>(exog(1-4))</td>
<td>40</td>
<td>-1</td>
<td>0.543**</td>
<td>0.459**</td>
<td>(0.125)</td>
<td>-0.000003</td>
<td>(0.000)</td>
<td>0.935</td>
</tr>
</tbody>
</table>

Table Notes: Quarterly data; 1971:Q3-2003:Q3 for instrument set, \(\{y, i, \pi(1-4)\}\) and 1974:Q1-2003:Q3 for exogenous (exog) instrument set. Each instrument set consists of 4 lags of each instrument. HP denotes Hodrick-Prescott filtered real output gap and QD is quadratically detrended real output. Inflation is measured as the quarterly log difference of the CPI. \(k\) is the number quarters duration for the ex ante interest rate and \(m\) determines the timing for the interest rate, e.g., \(m = 0\) starts with the current ex ante rate while \(m = -1\) allows for lagged rates to play a role. The exogenous instrument set consists of a relative oil price and national defense expenditures (following Fuhrer and Rudebush). ** and * indicate a significant t-test at the 1 and 5 percent significance levels, respectively.
backward looking behavior tends to dominate and monetary policy through the real interest rate has no impact, as \( \sigma \) is effectively zero and not statistically significant. The parameter magnitudes are fairly uniform across specifications.

In terms of New Neoclassical Synthesis/New Keynesian models, the open economy versions, which allow for international influences through the exchange rate channel, perform somewhat better. Following Fuhrer and Rudebusch (2004), two instrument sets are used. The first entails lagged variables of the regressors, as shown in Table 4.3. The second, uses instruments that are exogenous to model—Japan’s national defense expenditures and a relative oil price. For the open economy model, additional instruments include the Federal Funds Rate and CPI inflation in the U.S. as shown in Table 4.4. For the open economy, forward looking behavior tends to dominate across the different types of exchange rates and real interest rate measures. However, neither the parameter on the real exchange rate, \( \gamma \), or real interest rate, \( \sigma \) is statistically significant, although \( \sigma \) has the hypothesized sign. When the exogenous instrument set is used, forward looking behavior continues to dominate with magnitudes that are close in value across the various specifications. The parameter on the real exchange rate, \( \sigma \), is negative and statistically significant for most specifications; however, its magnitude is small.

The open economy hybrid model based on Coenen and Wieland (2004) is shown in Table 4.5. Similar to the previous open economy models, forward looking behavior dominates but \( \sigma \), while negative, is close to zero and not statistically significant.

In backwards looking models, the influence of real interest rates is not particularly strong. The backwards looking model used by Coenen and Wieland (2002) show \( \sigma = -0.0781 \) and \( \gamma = 0.0122 \) for Japan over the period 1980-1997, a period during which zero interest rates and deflation were not prolonged.

The results reported in Tables 4.1 through 4.5 provide very weak evidence supporting the relevance of the New Neoclassical Synthesis/New Keynesian framework to explaining the dynamics of Japan’s economy. This result is similar to that found by Fuhrer and Rudebusch (2004) for the U.S. A possible explanation for this may be the tendency of the GMM estimator to produce biased estimates in small samples, which they assert may have two sources. First, the instruments may be “weak”; that is, they
Table 4.3: GMM Estimates of Open Economy Hybrid New Keynesian Aggregate Demand for Japan

\[ y_t = \delta_b y_{t-1} + \delta_f E_t y_{t+1} + \gamma e_t - \sigma E_t \left[ \frac{1}{k} \sum_{j=0}^{k-1} (i_{t+j+m} - \pi_{t+j+m+1}) \right] + d_s t \]

<table>
<thead>
<tr>
<th>Trend</th>
<th>Instruments</th>
<th>Coefficient estimates and standard errors</th>
<th>J-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k</td>
<td>m</td>
<td>(\delta_b)</td>
</tr>
<tr>
<td>HP(a)</td>
<td>4</td>
<td>0</td>
<td>0.361**</td>
</tr>
<tr>
<td>HP(b)</td>
<td>4</td>
<td>0</td>
<td>0.362**</td>
</tr>
<tr>
<td>HP(a)</td>
<td>40</td>
<td>0</td>
<td>0.362**</td>
</tr>
<tr>
<td>HP(b)</td>
<td>40</td>
<td>0</td>
<td>0.362**</td>
</tr>
<tr>
<td>HP(a)</td>
<td>4</td>
<td>-1</td>
<td>0.361**</td>
</tr>
<tr>
<td>HP(b)</td>
<td>4</td>
<td>-1</td>
<td>0.362**</td>
</tr>
<tr>
<td>HP(a)</td>
<td>40</td>
<td>-1</td>
<td>0.364**</td>
</tr>
<tr>
<td>HP(b)</td>
<td>40</td>
<td>-1</td>
<td>0.368**</td>
</tr>
<tr>
<td>QD(a)</td>
<td>4</td>
<td>0</td>
<td>0.375**</td>
</tr>
<tr>
<td>QD(b)</td>
<td>4</td>
<td>0</td>
<td>0.403**</td>
</tr>
<tr>
<td>QD(a)</td>
<td>40</td>
<td>0</td>
<td>0.443**</td>
</tr>
<tr>
<td>QD(b)</td>
<td>40</td>
<td>0</td>
<td>0.418**</td>
</tr>
<tr>
<td>QD(a)</td>
<td>4</td>
<td>-1</td>
<td>0.440*</td>
</tr>
<tr>
<td>QD(b)</td>
<td>4</td>
<td>-1</td>
<td>0.416**</td>
</tr>
<tr>
<td>QD(a)</td>
<td>40</td>
<td>-1</td>
<td>0.460*</td>
</tr>
<tr>
<td>QD(b)</td>
<td>40</td>
<td>-1</td>
<td>0.474**</td>
</tr>
</tbody>
</table>

Table Notes: \(a\) Trade weighted exchange rate by author's computation. \(b\) Hodrick Prescott filter of real effective exchange rate published by the Bank of Japan. Sample: 1971:Q3-2003:Q3 for the instrument set comprised of four lags of each of the regressors, \(\{y, i, \pi, (1-4)\}\) which consists of four lags of each endogenous variable. HP denotes Hodrick-Prescott filtered real output gap and QD is quadratically detrended real output. Inflation is measured as the quarterly log difference of the CPI. \(k\) is the number quarters duration for the ex ante interest rate and \(m\) determines the timing for the interest rate, e.g., \(m = 0\) starts with the current ex ante rate while \(m = -1\) allows for lagged rates to play a role. The exogenous instrument set consists of lags 1-4 of a relative oil price, national defense expenditures, U.S. CPI inflation and the federal funds rate. ** and * indicate a significant t-test at the 1 and 5 percent significance levels, respectively.
Table 4.4: Open Economy Hybrid New Keynesian Aggregate Demand for Japan, (Exogenous Instruments)

\[ y_t = \delta_Y y_{t-1} + \delta_f E_t y_{t+1} + \gamma e_t - \sigma E_t \left[ \sum_{j=0}^{k-1} (\pi_{t+j+m} - \pi_{t+j+m+1}) \right] + d_{st} \]

<table>
<thead>
<tr>
<th>Trend Instruments</th>
<th>Coefficient estimates and standard errors</th>
<th>J-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k</td>
<td>m</td>
</tr>
<tr>
<td>HP^a exog(1 - 4)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>HP^b exog(1 - 4)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>HP^a exog(1 - 4)</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>HP^b exog(1 - 4)</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>HP^a exog(1 - 4)</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>HP^b exog(1 - 4)</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>HP^a exog(1 - 4)</td>
<td>40</td>
<td>-1</td>
</tr>
<tr>
<td>HP^b exog(1 - 4)</td>
<td>40</td>
<td>-1</td>
</tr>
<tr>
<td>QD^a exog(1 - 4)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>QD^b exog(1 - 4)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>QD^a exog(1 - 4)</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>QD^b exog(1 - 4)</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>QD^a exog(1 - 4)</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>QD^b exog(1 - 4)</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>QD^a exog(1 - 4)</td>
<td>40</td>
<td>-1</td>
</tr>
<tr>
<td>QD^b exog(1 - 4)</td>
<td>40</td>
<td>-1</td>
</tr>
</tbody>
</table>

Table Notes: *Trade weighted exchange rate by author's computation. **Real effective exchange rate from Bank of Japan. Sample: 1974-Q1-2003-Q3 for exogenous (exog) instrument set, comprised of 4 lags of each instrument. The instruments are Japan’s national defense budget, relative oil price, the U.S. quarterly average Federal Funds Rate, and U.S. CPI inflation. “HP” denotes Hodrick-Prescott filtered real output gap and “QD” is quadratically detrended real output. Inflation is measured as the quarterly log difference of the CPI. k is the number quarters duration for the ex ante interest rate and m determines the timing for the interest rate, e.g., m = 0 starts with the current ex ante rate while m = -1 allows for lagged rates to play a role. The exogenous instrument set consists of lags 1-4 of a relative oil price, national defense expenditures, U.S. CPI inflation and the federal funds rate. ** and * indicate a significant t-test at the 1 and 5 percent significance levels, respectively.
Table 4.5: Open Economy Nested New Keynesian Aggregate Demand for Japan

\[ y_t = \delta_1 y_{t-1} + \delta_2 E_t y_{t+1} - \sigma (r_{t-1} - r^*) + \gamma e_t + ds_t \]

<table>
<thead>
<tr>
<th>Model</th>
<th>Coefficient estimates and standard errors</th>
<th>J-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( y ) Instruments ( e ) ( \delta_1 ) ( \delta_2 ) ( \sigma ) ( SE(\delta) ) ( \gamma ) ( SE(\gamma) ) ( p)-value</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>( y, r, e, (1-4) ) tw ( ^a )</td>
<td>0.382** 0.614** -0.00001 (0.000) -0.00001 (0.000) 0.627</td>
</tr>
<tr>
<td>HP</td>
<td>( y, r, e, (1-4) ) rer ( ^b )</td>
<td>0.426** 0.562** -0.00001 (0.000) -0.000005 (0.000) 0.844</td>
</tr>
<tr>
<td>HP</td>
<td>exog(1-4) tw</td>
<td>0.404** 0.612** -0.00002 (0.000) -0.00001 (0.000) 0.976</td>
</tr>
<tr>
<td>HP</td>
<td>exog(1-4) rer</td>
<td>0.404** 0.612** -0.00002 (0.000) -0.000009 (0.000) 0.976</td>
</tr>
<tr>
<td>QD</td>
<td>( y, r, e, (1-4) ) tw</td>
<td>0.437** 0.566** -0.00002 (0.000) -0.00002 (0.000) 0.707</td>
</tr>
<tr>
<td>QD</td>
<td>( y, r, e, (1-4) ) rer</td>
<td>0.419** 0.583** -0.00003 (0.000) -0.00001 (0.000) 0.955</td>
</tr>
<tr>
<td>QD</td>
<td>exog(1-4) tw</td>
<td>0.449** 0.551** -0.00004 (0.000) -0.00003 (0.000) 0.977</td>
</tr>
<tr>
<td>QD</td>
<td>exog(1-4) rer</td>
<td>0.450** 0.550** -0.00004 (0.000) -0.00002 (0.000) 0.978</td>
</tr>
</tbody>
</table>

Table Notes: FIX Quarterly data; 1971-Q3-2003:Q3 for instrument set, \( \{ y, r, e, (1-4) \} \) and 1974:Q1-2003:Q3 for exogenous (exog) instrument set. Each instrument set consists of 4 lags of each instrument. HP denotes Hodrick-Prescott filtered real output gap and QD is quadratically detrended real output. Inflation is measured as the quarterly log difference of the GDP Deflator. \( k \) is the number quarters duration for the ex ante interest rate and \( m \) determines the timing for the interest rate, e.g., \( m = 0 \) starts with the current ex ante rate while \( m = -1 \) allows for lagged rates to play a role. The exogenous instrument set consists of a relative oil price and national defense expenditures (following Fuhrer and Rudebush). ** and * indicate a significant t-test at the 1 and 5 percent significance levels, respectively.
insufficiently explain variation in the instrumented variables. Second, there are possible problems in
dynamic rational expectations models when the rational expectations restrictions implied by them are
not used to construct instruments.

4.4 Conclusion

Taken together the estimates of the Euler equation of output for Japan suggest the model does not have
much explanatory power. Although forward looking behavior dominates in the open economy New
Neoclassical Synthesis/New Keynesian model, the implication that real interest rates do not influence
real GDP over a thirty year period is a distinctly different result from similar models for the U.S. and the
Euro area. It is also different from backwards looking studies on Japan that show real interest rates to
have a statistically significant impact, although it is small as well. However, the results in this thesis are
preliminary in nature for the following reasons. First, the GMM estimator is known to produce biased
estimates of the New Keynesian model in small samples. Second, the model of the ex ante real interest
rate in this chapter is a fairly simple one. Third, the dynamics of Japan's economy from one of growth
to recession, which occurs across the sample may obscure the model's performance. This is because the
New Neoclassical Synthesis/New Keynesian model is inherently a short run model, which assumes the
long run natural rate of output does not change substantially. This may be a strong assumption given
Japan's economic performance over the past 15 years. On the other hand, it may be that the lack of
a robust statistically significant impact of real interest rates may be inherent to Japan's data. This is
because Japan's monetary policy tool, the Call Rate, takes on low values and eventually falls to zero
late in the sample. However, the greater issue is the ability of the model to describe the dynamics of
Japan's economy rather than the other way around. In this respect, the New Keynesian model for output
provides a weak characterization of Japan's aggregate demand.
Bibliography


