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MASTER'S THESIS

**AN EMPIRICAL ANALYSIS OF THE NEW
KEYNESIAN PHILLIPS CURVE FOR LARGE
AND OPEN ECONOMIES: THE CASE OF G7
COUNTRIES**

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ABSTRACT

AN EMPIRICAL ANALYSIS OF NEW KEYNESIAN PHILLIPS CURVE FOR LARGE AND OPEN ECONOMIES: THE CASE OF G7 COUNTRIES

The main aim of this study is to investigate inflation dynamics in large and open countries by using the closed and open economy New Keynesian Phillips Curve (NKPC) models considering the openness degree and economic size of countries. Even though the open economy NKPC models include foreign trade factors as openness parameters, these models do not take into account the economic size of countries. However, the foreign trade elasticity of the domestic marginal cost in open and large countries is usually higher than in open and small countries due to scale economies. High foreign trade elasticity of domestic marginal cost might lead to insignificant openness parameters in estimations of open economy models without considering the economic size for open and large countries. In addition, in the empirical literature, whereas the closed economy NKPC models appear to better explain the dynamics of inflation in some open and large countries, the open economy NKPC models appear to better explain inflation dynamics in open and small countries.

Therefore, the impact of foreign trade factors as openness parameters on domestic inflation might depend on not only openness degree but also the economic size of countries. Since the number of studies focused on inflation dynamics of only large and open countries is limited, a consensus regarding the impact of economic size on the role of foreign trade factors on domestic inflation has not been achieved for large and open economies. In this sense, an orderly analysis is needed to determine which model better explains the inflation dynamics in open and large countries considering both openness degree and economic size of countries.

In this study, two closed economy and three open economy versions of NKPC models are estimated by the Generalized Method of Moments (GMM) to investigate inflation dynamics for open and large countries considering the economic size as well as openness degree. The sample of large and open economies subject to empirical analysis in this study involves G7 countries. The so-called NKPC models are estimated for G7 countries both individually and as a group over the two different sample periods. The first sample period covers all available data and the second starts with the introduction of inflation targeting regime for each G7 country.

The estimation results show that openness parameters in estimations of open economy models are either statistically insignificant or incorrectly signed for large and open countries. Considering estimated explanatory variables in the models, the closed economy models better explain inflation dynamics in open and large countries. The structural parameters regarding domestic factors such as expected inflation and real economic activities are more significant and correctly signed in closed economy models. Among open economy models, the open economy model, which uses the real effective exchange rate as an openness parameter instead of the relative price of imports, is more successful in explaining the inflation dynamics in open and large countries. The inflation process in large and open countries is based on both forward-looking and backward-looking expectations. In addition, the price rigidity and duration of price adjustment of domestic firms significantly increased in G7 countries during the inflation targeting regime.

Keywords: New Keynesian Phillips Curve, G7 Countries, Inflation Dynamics, Openness Degree, Economic Size, Price Rigidities

ÖZ

BÜYÜK VE AÇIK EKONOMİLER İÇİN YENİ KEYNESYEN PHILLIPS EĞRİSİ'NİN AMPİRİK BİR ANALİZİ: G7 ÜLKELERİ ÖRNEĞİ

Bu çalışmanın temel amacı, kapalı ve açık ekonomi Yeni Keynesyen Phillips Eğrisi (YKPE) modellerini kullanarak büyük ve açık ülkelerde enflasyonun dinamiklerini açıklık derecesi ve ekonomik büyüklüğü göz önünde bulundurarak araştırmaktır. Açık ekonomi YKPE modelleri, açıklık parametresi olarak dış ticaret faktörleri barındırsalar da bu modeller ülkelerin ekonomik büyüklüklerini göz önünde bulundurmazlar. Ancak, açık ve büyük ülkelerdeki marjinal maliyetlerin dış ticaret esnekliği, açık ve küçük ülkelerdekinden ölçek ekonomilerinden dolayı genelde daha yüksektir. Yüksek marjinal maliyetlerin dış ticaret esnekliği, ekonomik büyüklük göz önünde bulundurulmadan açık ekonomi modellerinin tahmininde, anlamsız açıklık parametrelerine yol açabilmektedir. Ayrıca, ampirik literatürde, kapalı ekonomi YKPE modellerinin bazı açık ve büyük ülkelerdeki enflasyon dinamiklerini daha iyi açıkladığı görünürken, açık ekonomi YKPE modellerinin bazı açık ve küçük ülkelerdeki enflasyon dinamiklerini daha iyi açıkladığı görünmektedir.

Böylece, açıklık parametresi olarak dış ticaret faktörlerinin iç enflasyon üzerindeki etkisi sadece açıklığa bağlı değil aynı zamanda ülkelerin ekonomik büyüklüğüne de bağlı olabilir. Sadece açık ve büyük ülkelerin enflasyon dinamiklerine odaklanan çalışmaların sayısı sınırlı olduğundan dolayı; büyük ve açık ekonomiler için, ekonomik büyüklüğün dış ticaret faktörlerinin iç enflasyondaki rolü üzerine etkisine ilişkin bir mutabakat sağlanamamıştır. Bu bağlamda, büyük ve açık ülkelerde, açıklık derecesi ve ekonomik büyüklük göz önünde bulundurularak, büyük ve açık ülkelerde, hangi modelin enflasyonun dinamiklerini daha iyi açıkladığını tespit edecek düzenli bir çalışmaya ihtiyaç bulunmaktadır.

Bu çalışmada, açık ve büyük ülkelerdeki enflasyonun dinamiklerini açıklamak için, iki kapalı ekonomi ve üç açık ekonomi YKPE modeli Genelleştirilmiş Momentler Yöntemi (GMY) ile tahmin edilmiştir. Bu çalışmada araştırmaya tabii tutulan büyük ve açık ülkeler G7 ülkeleridir. YKPE modelleri G7 ülkeleri için hem bireysel hem de grup olarak iki ayrı örneklem dönemi boyunca tahmin edilmiştir. İlk örneklem periyodu ulaşılabilen tüm bölünmemiş verileri kapsar, ikinci örneklem periyodu ise her bir G7 ülkesi için enflasyon hedefleme rejiminin kabulünden başlar.

Tahmin sonuçları göstermiştir ki; büyük ve açık ülkelerde, açık ekonomi modellerinin tahminindeki açıklık parametreleri ya istatikselsel olarak anlamsızdır ya da teorik olarak yanlış işaretlenmiştir. Modellerdeki tahmin edilen açıklayıcı değişkenler göz önüne alındığında; kapalı ekonomi modeller, büyük ve açık ülkelerdeki enflasyonun dinamiklerini daha iyi açıklamaktadır. Reel ekonomik aktivite ve beklenen enflasyon gibi içsel faktörlere ilişkin yapısal parametreler, tahmin edilen kapalı ekonomi modellerde daha anlamlı ve teorik olarak doğru işaretlenmiştir. Açık ekonomi modeller arasında, ithalatın göreceli fiyatı yerine reel efektif döviz kurunu açıklık parametresi olarak kullanan açık ekonomi YKPE modeli, büyük ve açık ülkelerde enflasyonun dinamiklerini açıklamada daha başarılıdır. Büyük ve açık ülkelerde enflasyon süreci hem ileriye dönük hem de geriye dönük beklentilere dayalıdır. Ayrıca, G7 ülkelerinde, fiyat katılıkları ve fiyat ayarlama süreleri enflasyon hedefleme rejimi boyunca önemli ölçüde artmıştır.

Anahtar Kelimeler: Yeni Keynesyen Phillips Eğrisi, G7 Ülkeleri, Enflasyonun Dinamikleri, Açıklık Dercesi, Ekonomik Büyüklük, Fiyat Katılıkları

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LIST OF ABBREVIATIONS

ADF:	Augmented Dickey-Fuller
CAN:	Canada
CEHNKPC:	Closed Economy Hybrid New Keynesian Phillips Curve
CENKPC:	Closed Economy New Keynesian Phillips Curve
DEU:	Germany
ECB:	European Central Bank
FRA:	France
GDP:	Gross Domestic Product
GLS:	Generalized Least Squares
GMM:	Generalized Method of Moment
GM-NKPC:	Gali and Monacelli New Keynesian Phillips Curve
HP-Filter:	Hodrick-Prescott Filter
ILO:	International Labour Organization
JPN:	Japan
ML:	Maximum Likelihood
MM:	Method of Moments
NKPC:	New Keynesian Phillips Curve
OECD:	Organization for Economic Cooperation and Development
OEHNKPC:	Open Economy Hybrid New Keynesian Phillips Curve
OENKPC:	Open Economy New Keynesian Phillips Curve
OLS:	Ordinary Least Squares
OMC:	Open Economy Marginal Cost Index
PP:	Phillips-Perron
UK:	United Kingdom
US:	United States

INTRODUCTION

This study aims to comprehensively investigate inflation dynamics and it attempts to find out the best NKPC model that explains inflation dynamics in open and large countries better. In the NKPC literature, the driving forces behind inflation have been widely discussed with the closed economy and open economy NKPC models over and over again. Discussions about model selection have not provided a general answer to which model NKPC is more proper to capture inflation dynamics. Even though open economy NKPC models include foreign trade factors regarding the international trade such as real effective exchange rate or relative price of import as well as closed economy variables, consensus about open economy models has not been achieved regarding open and large countries. Since open and large economies have distinctive dynamics and NKPC models do not theoretically take into account the size of countries, a specific and extensive investigation should be conducted for them.

The NKPC models aim to explain inflation dynamics based on Dynamic Stochastic General Equilibrium focusing on microeconomic foundations. Compared to the Phillips Curve, the NKPC models contain real marginal cost and real economic activities as well as lagged inflation and expected future inflation as significant variables for the inflation process. In addition to that, open economy versions of the NKPC models suggest that inflation is a function of foreign trade factors such as real effective exchange rate or relative price of imports along with domestic factors. These foreign trade factors regarding international trade affect domestic inflation depending on the openness degree of countries. In addition to its strong theoretical underpinnings, the NKPC models provide extensive information about structural parameters such as price rigidity and time discount factor. Nonetheless, in the empirical literature, the empirical validity of the NKPC models has been discussed for a long time.

The empirical literature provides a lot of evidence related validity of both closed and open economy models for several countries. Although estimations of open economy models have gained an acceleration due to an increase in globalization, every open economy model does not explain inflation dynamics in every open economy country. The empirical studies do not take into account the size of countries as well as their openness degree. Even though the existing empirical literature provides empirical evidence for small and open economies, limited studies focusing on only open and large countries provide conflicting evidence.

In the light of these discussions, two closed economy models and three open economy models are estimated by using the GMM method to provide an extensive review of inflation dynamics and which NKPC model better explains the inflation process in open and large economies. Since inflation targeting regimes are breakpoints that can affect expectations of economic agents about future inflation, two different sample periods are used in this study. Whereas the first sample period covers all available data, the second sample period starts with the introduction of inflation targeting regime. As open and large economies, G7 countries are handled individually and as a group.

To this end, the rest of this study is organized as follows. In the first chapter, inflation dynamics are theoretically examined. The definition and evolution of the Phillips Curve are located in the same chapter. The second chapter contains the empirical results of NKPC in the literature. In this chapter, we discuss empirical findings of both baseline and open economy NKPC. Additionally, we discuss empirical evidence of studies, which investigate the relationship between inflation and globalization in the same chapter. The macroeconomic outlook for each of the G7 countries, including their openness and size, is given in the third chapter of the thesis. In the final chapter, we estimate five versions of the NKPC with two different sample periods for G7 countries: closed economy, closed economy hybrid, open

economy, open economy hybrid NKPC, and a special version of the open economy NKPC that include real effective exchange rate instead of relative import price.



CHAPTER ONE

A THEORETICAL REVIEW OF INFLATION DYNAMICS

In macroeconomics, one of the important issues is inflation and its dynamics. Inflation is a signal that provides to take right decisions for economic agents. A steady increase in price level may falsify the price mechanism in the market. That is why, unless inflation is stable, economic agents try to predict future inflation to avoid wrong decisions. On the other hand, monetary authorities take into account inflation when they regulate the market. Moreover, price stability is one of the duties of central banks regulated by laws. Therefore, economic agents and monetary authorities want to know the dynamics of inflation.

The discussions about inflation dynamics that have not been completed yet were initiated by Phillips in 1958. Phillips (1958) found empirical evidence regarding the relationship between unemployment and the rate of money wage. The relationship between unemployment and the rate of money wage transformed into the relationship between unemployment and inflation thanks to contributions of Lipsey (1960) and Hansen (1970). According to the Phillips Curve, there is a negative relationship between unemployment and inflation. During the 1960s, the data support this trade-off between inflation and unemployment for the UK and the US.

However, the stagflation in the 1970s led to criticism about the Phillips Curve at both theoretical and empirical levels. The Phillips Curve was criticized for not allowing unemployment and inflation variables to move in the same direction. The model's explanatory power about inflation dynamics gradually diminished in the 1970s due to the increase in both unemployment and inflation, simultaneously. The criticism regarding the Phillips Curve contributed to its evaluation. Hence the Phillips Curve was developed and augmented with expectation models such as adaptive expectations and rational expectations.

The Expectations-Augmented Phillips Curve is based on criticisms of Friedman (1968) and Phelps (1967, 1968) about the relationship supported by the Phillips Curve. According to Friedman (1968), the supply of labour depends on real wages rather than nominal wages. In the labour market, workers make mistakes due to money illusions in the short run. However, they learn from their previous mistake and they make fewer mistakes in the next period. Thus, the relationship between inflation and unemployment is valid only in the short run. Since the expectation of economic agents is a significant variable for the inflation process, expected inflation added to the Phillips Curve thanks to these contributions.

According to another approach, the dynamics of inflation can be explained by the NKPC models based on microeconomic foundations and preferences of economic agents. The NKPC models are built on the Dynamic Stochastic General Equilibrium (DSGE) models and Calvo's Price Model. In the NKPC models, inflation is a function of real economic activities and marginal cost. Since real economic activities and marginal cost are domestic variables, the NKPC is named as closed economy NKPC model.

The fact that the increase in globalization coincided with the decrease in inflation after the 1980s brought up researches on the relationship between them into agenda. The research on the relationship between globalization and inflation led to derivations of new versions of the NKPC models known as open economy NKPC models that include not only domestic factors but also foreign trade factors. The open economy models nest the closed economy models since it also includes explanatory variables of closed economy models.

Therefore, the NKPC models can be classified as the closed economy and open economy NKPC. If these models include past inflation, they are called as hybrid models such as closed economy hybrid NKPC or open economy hybrid NKPC. Additionally, Gali and Monacelli (1999) derived a special version of open

economy models (GM-NKPC) that uses real effective exchange rate as a foreign trade factor instead of the relative price of import.

Consequently, there are several versions of the NKPC models in the literature. They provide a comprehensive review and perspective regarding inflation dynamics. In this chapter, first of all, the Phillips Curve and its evolutions are presented and theoretically discussed. Before the presentation of the NKPC models, Calvo's sticky price model, which is the foundation of NKPC models, is presented as well as optimal reset price regarding the preferences of firms in the market. Finally, this chapter concludes presentations of five different NKPC models: closed economy, closed economy hybrid, open economy, open economy hybrid NKPC and GM-NKPC.

1.1. The Origin of Phillips Curve

The origin of the Phillips Curve dates back to the empirical study of Phillips (1958) regarding the relationship between unemployment and the rate of change of money wage for the United Kingdom from 1861 to 1957. The purpose of Phillips' study is to investigate whether the data supports the hypothesis that the rate of change of money wage can be explained by the level of unemployment and the rate of change of unemployment for the UK (Phillips, 1958). Phillips found that the data support this hypothesis for the UK over the three different sample periods: 1861-1913, 1913-1948 and 1948-1957. As a result of the study, there is a negative relationship between these two macroeconomic indicators for the UK.

However, the results of Phillips' empirical study (1958) show that this relationship between the money wage and unemployment is not linear. When unemployment is low and demand for labour is high, the employer's wage offer increases rapidly. On the other hand, when unemployment is high and demand for labour is low, workers do not agree extremely low wage and wage rates decrease

slowly. It means that wage rates are not downward flexible as can be seen from Figure 1.1.

Figure 1.1: The Phillips Curve



Source: A. W. Phillips, The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, *Economica*, 1958, pp.285

As seen from Figure 1.1, the Phillips Curve has a negative slope and represents the relationship between the money wage and unemployment. When unemployment increases, the rate of change of money wage rates decreases. The reason for this non-linear relationship is that when unemployment is extraordinarily high workers are reluctant to work at an extraordinarily low wage and they prefer more leisure time. In other words, the rate of change of money wage rates is downward rigid.

The equation form of the Phillips Curve is as follows:

$$y + a = bx^c \quad (1.1)$$

$$\log(y + a) = \log(b) + c \log(x) \quad (1.2)$$

Equation 1.2 specifies a logarithmic form of the Phillips Curve. In Equation 1.2, y is the rate of change of wage rate and x is the unemployment rate. The terms of b and c are constant term and a is chosen by trail and error (Phillips, 1958).

1.2. Interpretation of the Phillips Curve

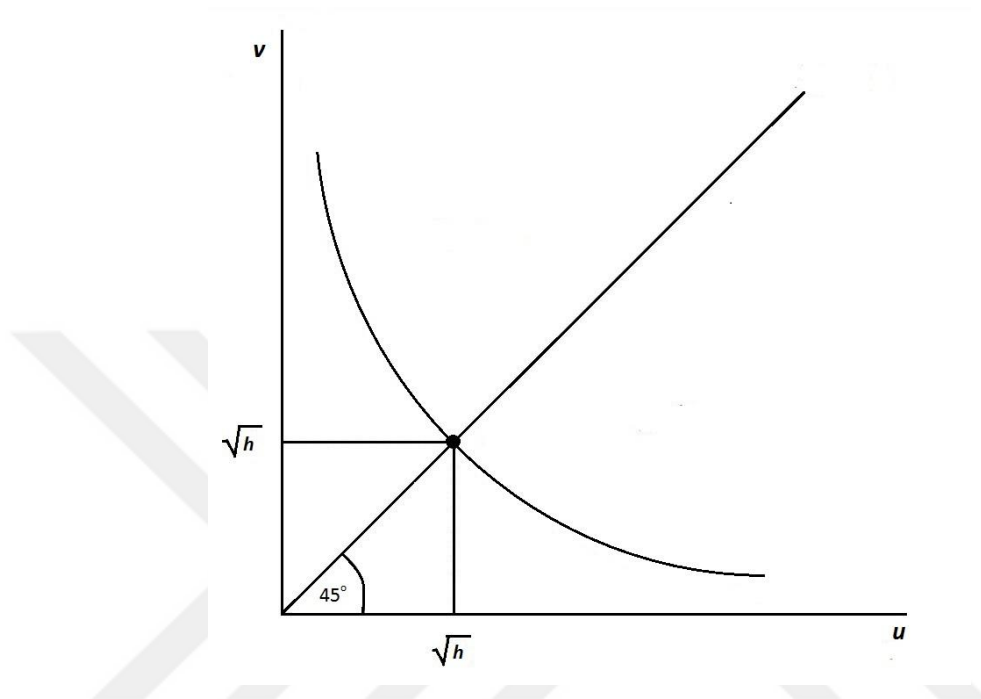
Even though Phillips (1958) provides empirical evidence of the relationship between money wage and unemployment, Phillips' study does not indicate the presence of a causal relationship between unemployment and the money wage. Later, this empirical relationship was transformed into a theoretical relationship between inflation and unemployment by the studies of Lipsey (1960) and Hansen (1970). They provide a theoretical foundation for the empirical relationship observed by Phillips (1958).

Lipsey (1960) theoretically explains the observed relationship, which supported by data for the UK, based on the supply and demand mechanism in the labour market. According to the demand and supply mechanism in the labour market, wage level is a function of demand for labour like goods and services market. The higher demand for labour leads to a higher wage level. Similarly, the higher supply of labour leads to a lower wage level. Since higher unemployment leads to an increase in supply of labour, it is theoretically expected that higher unemployment

leads to lower wage level. Lipsey's theoretical contribution to this relationship involves the combination of two postulated relationships: (i) "a positive linear relationship between the rate of increase in money wages and the excess demand for labour" and (ii) "a negative non-linear relationship between excess demand and unemployment.

Lipsey's model (1960) was then refined and extended by Hansen (1970). Hansen (1970) described friction coefficient in the labour market by using the relationship between the excess demand for labour, unemployment and the vacancy in the labour market. Hansen (1970) analyzes Phillips Curve adding friction coefficient to model. The friction coefficient is affected by rigidities in the labor market. The position of the Phillips Curve depends on the friction coefficient. An increase in friction in the labour market brings about the Phillips Curve to shift to the right. Furthermore, the hyperbolic relationship between vacancy in the labour market and unemployment was statistically analyzed by Hansen with data over the sample period from 1953 to 1964 (Hansen, 1970).

Figure 1.2: The Relationship Between Unemployment, Excess Demand and Vacancy in Labour Market



Source: Bent Hansen, Excess Demand, Unemployment, Vacancies, and Wages, Quarterly Journal of Economics, 1970, p. 9

Figure 1.2 summarizes that Hansen's contribution to the Phillips Curve. In Figure 1.2, v is a vacancy and u is unemployment. Thus, the UV curve represents vacancy and unemployment in the absence of excess demand for labour situation.

Samuelson and Solow (1960) used inflation rate instead of the percentage change in wages in the Phillips relationship. They linked wages to prices assuming that firms employ a mark-up pricing method. Since an increase in labour cost reflects to production cost and then to inflation, the relationship between unemployment and percentage change in wages is transformed into the relationship between unemployment and inflation.

Additionally, Samuelson and Solow (1960) examined unemployment rate corresponding to each inflation rate for the US. They show the inflation rate required for desired unemployment level. According to their study, 4-5% unemployment rate brings about 2.5% inflation rate. The inflation rate should be 4-5% to keep unemployment rate at 3% in the US.

Figure 1.3: The Relationship Between Unemployment and Average Price Rise



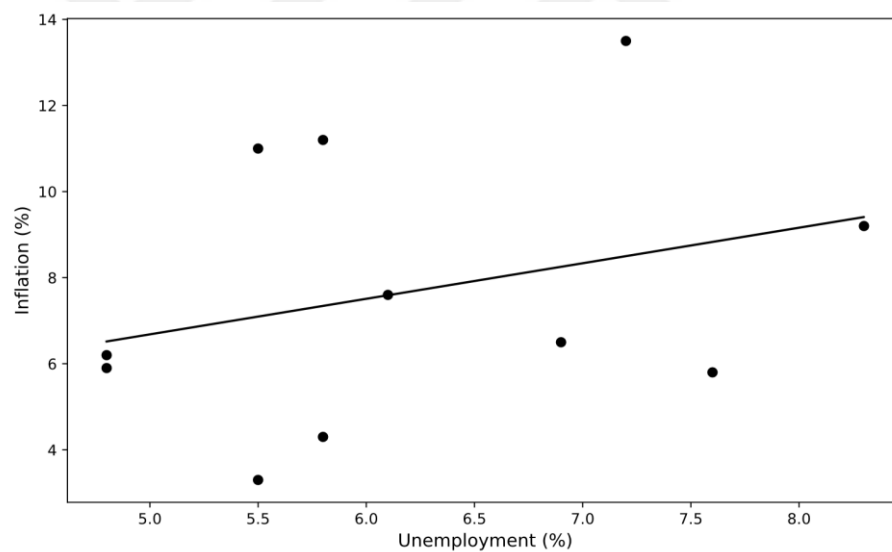
Source: Paul A. Samuelson, Robert M. Solow, *Analytic Aspects of Anti-Inflation Policy*, American Economic Association, 1960, p. 192

As seen in Figure 1.3, wage inflation is turned into price inflation by Samuelson and Solow (1960). Therefore, the Phillips Curve has become a representation of the relationship between inflation and unemployment thanks to the contributions of Samuelson and Solow (1960). However, Samuelson and Solow (1960) argued that this negative relationship predicted by the Phillips Curve is acceptable in only the short-run. According to them, if policy indicators of the

Phillips Curve are continuously used in the short run, the basis of this relationship will be destroyed in the long run.

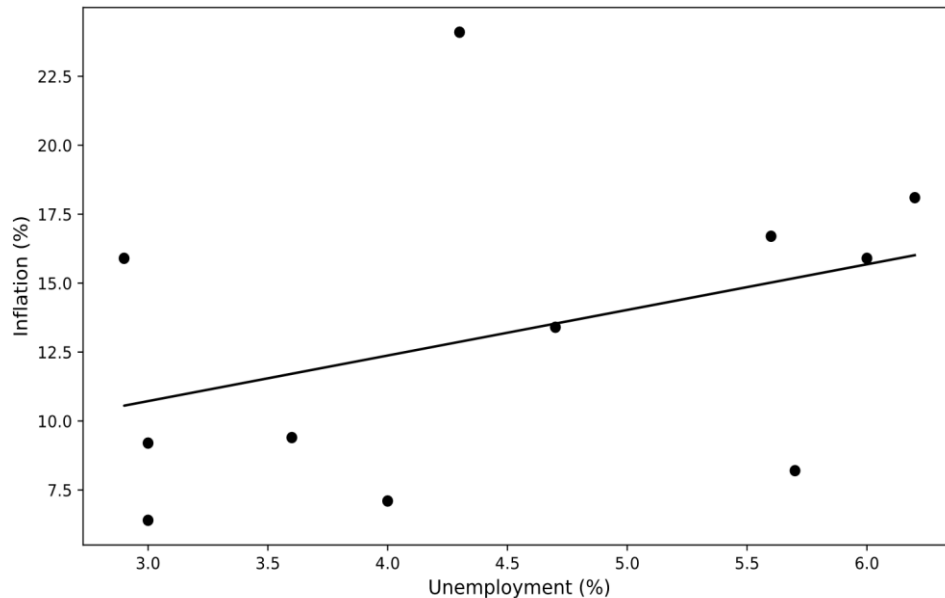
Even though Phillips' study (1958) was an attempt to determine an unemployment rate consistent with price stability, economists and policy makers built consensus on a trade-off between inflation and unemployment until the late 1960s (Leeson, 1997). The overwhelming majority of them used this relationship between inflation and employment in order to estimate inflation in this period.

Figure 1.4: The Relationship Between Unemployment and Inflation in the US over 1970-1980



Source: OECD, Labour Force Statistics and General Statistics, <https://stats.oecd.org/>

Figure 1.5: The Relationship Between Unemployment and Inflation in the US over 1970-1980



Source: OECD, Labour Force Statistics and General Statistics, <https://stats.oecd.org/>

Figure 1.4 and Figure 1.5 shows that positive correlation between inflation and unemployment in the US and the UK in the 1970s. The stagflation raised doubt on the validity of the Phillips Curve. Therefore, different variables such as expectations were added to the Phillips Curve to explain inflation dynamics. The Phillips Curve augmented with expectations about the future is reviewed in the next section.

1.3. Expectations-Augmented Phillips Curve

The stable relationship between inflation and unemployment is rejected by Friedman (1968) and Phelps (1967, 1968). They criticized the Phillips Curve on mainly two points. The first point is about the assumption that there is a stable and

long-run trade-off between inflation and unemployment. The second point is related to the fact that the wage variable added to the Phillips Curve model is nominal. According to Friedman (1968), demand for labour and supply of labour depends on real wage rather than nominal wage. Firms and workers interest in real wages instead of the nominal wage. However, there is an asymmetric knowledge among economic agents. While firms tend to react to a new situation rapidly due to perfect knowledge, workers tend to react to new real wage slowly due to imperfect knowledge. Therefore, low real wage leads to a decrease in unemployment in the short run owing to the difference between the velocity of reaction of firms and workers.

Friedman (1968) argued that the inflation-unemployment trade-off is only valid in the short run. In the long run, workers start to take into account the increase in the price of goods and services and they realize a decrease in their real wages. Therefore, workers demand higher nominal wage to compensate for their decreasing real wages. The expectations about the future are important for workers and firms when they negotiate wage bargains. Since they do not know inflation in the next period, they generate an expectation about future inflation. Therefore, they negotiate wage bargains for the next period depending on their expectations.

Since expectation affects production cost through wage bargains, Friedman (1968) added expectations about the future value of inflation to the Phillips Curve model as an additional explanatory variable. This is called the expectations-augmented Phillips Curve and can be shown as follows:

$$\dot{P} = f(u) + \beta \dot{P}^e \quad (1.3)$$

Equation 1.3 represents the expectations-augmented Phillips Curve. The change in price level is modeled as a function of unemployment and expected change

in the price level. The coefficient β is between 0 and 1 and it determines the effect of expected inflation on the current inflation rate.

In sum, expected inflation plays a crucial role in the inflation process. Therefore, the question of “How are expectations formed by economic agents?” should be answered. There are two main expectation models in this regard. They are Irving Fisher’s Adaptive Expectation Model (1930) and John Muth’s Rational Expectation model (1961).

According to Friedman (1968), inflation expectations are formed adaptively. It means that economic agents set their inflation expectations in terms of the past inflation rate. As a result of this approach, Friedman (1968) augmented the Phillips Curve with adaptive expectations. On the other hand, Lucas (1973), Sargent(1973) and Wallace (1975) augmented the Phillips Curve with rational expectations, using Muth’s Rational Expectations Model that does not include systematic error. These two expectations models are reviewed in the next sub-section in detail.

1.3.1. Adaptive Expectations

Since it is difficult to measure inflation expectations directly, a proxy variable is used to measure inflation expectations. Fisher (1911) used a distributed lag model in order to measure expected inflation. The adaptive expectation is a way of predicting a current expectation of economic agents about the future based on their experiences. According to the adaptive expectation hypothesis, economic agents form their expectations about the future depending on the past period. In other words, expectations of economic agents about what will happen in the future are based on what has happened in the past period. In this context, expected inflation is determined by actual inflation in the past.

The adaptive expectation model is usually used in terms of the price level as follows;

$$P_t^e = P_{t-1}^e + (1 - \lambda)(P_{t-1} - P_{t-1}^e) \quad (1.4)$$

where current expected level of price at time t , P_t^e , is based on the past expected price level P_{t-1}^e and past actual price level P_{t-1} . As can be seen from the adaptive expectation model, the part of $(P_{t-1} - P_{t-1}^e)$ indicates the difference between actual and expected level of prices at time $t-1$. The Equation 1.4 implies that economic agents make a mistake when they form expectations. However, expectations are revised by economic agents in proportion to $(1 - \lambda)$. Thus, economic agents gradually adapt and they improve expectations about what will happen in the future.

The Equation 1.4 can be arranged by substituting past expected price level as follows:

$$P_t^e = (1 - \lambda) \sum_{n=1}^n \lambda^{n-1} P_{t-n} \quad (1.5)$$

In this backward model, current expected inflation is expressed in terms of past actual inflation rates only. As seen in the Equation 1.5, there is a gap in time between the actual inflation rate and expected inflation leaving a space for monetary policy effectiveness. Money authorities can reduce unemployment below the natural unemployment by expanding aggregate demand through monetary expansion in the short run. The reason for which monetary authorities can use monetary policy is

asymmetric knowledge between money authorities and economic agents in the short run. However, this knowledge difference between monetary authorities and economic agents disappears in the long run. In this case, the long-run Phillips curve is vertical due to the fact that economic agents update their expectations in terms of new conditions. Consequently, adaptive expectation-augmented Phillips Curve has different dynamics in the short and long run.

Friedman (1968) and Phelps (1968) distinguished the expectation augmented Phillips Curve as long-run and short-run. According to them, even though there is always a trade-off between inflation and unemployment in the short run, it is temporary in the long run. Friedman emphasizes the notion of the natural unemployment rate in the long run. The natural unemployment rate is a notion that refers to the existing unemployment rate even in a balanced labour market. Since inflation does not affect unemployment in the long run, the long-run Phillips Curve is vertical at the natural unemployment rate. The natural unemployment rate is not stable but it is determined by real variables in the long run. (Friedman, 1968; Phelps, 1968)

1.3.2. Rational Expectations

The basic idea behind the rational expectations hypothesis is that consistent bias in expected inflation is inconsistent with the rationality of economic agents (Santomero & Seater, 1978). According to the rational expectation hypothesis that associated with the study of Muth (1961), economic agents use not only previous knowledge about inflation but also all available information when they form their expectation about the future. Contrary to the adaptive expectations model, in the rational expectation model, forecasting errors cannot have any systematic component, they are entirely random and hence expectations are correct on average. The result is that economic agents cannot be surprised systematically (Muth, 1961). Thus, economic agents are rational.

In the 1970s, new models based on Muth's (1961) rational expectation hypothesis were developed by Lucas (1973), Sargent (1973) and Wallace (1975). According to Sargent and Wallace (1975), all of the economic agents are rational and they do not make systematic error forever. Thus, economic agents use all available information when they form an expectation about the future. This available information set also involves previous period errors. It means that economic agents learn from their previous mistakes. Economic agents can make a mistake but they correct their mistake in the next period. (Sargent, 1973; Sargent & Wallace, 1975)

The rational expectation hypothesis indicates that there is a bilateral relationship between macroeconomic variables and expectations about them. The economic agent's mistakes must be random with mean zero. It does not mean that economic agents always make a true prediction about the future. It just means that economic agents are rational when they form their expectations.

In the economic literature, there are two main versions of the rational expectation hypothesis: weak and strong version. The weak version of the hypothesis indicates that in forming expectation about variables rational economic agents efficiently use information which they believe determine these variables. In the strong version, the economic agent's expectations about macroeconomic variables are based on mathematical foundations about the conditional expected value of these variables.

Thus, weak and strong versions of the rational expectation hypothesis are expressed mathematically as follows;

Weak Version:
$$\dot{p}_t^e = E\{\dot{p}_t | \Omega_{t-1}\} \quad (1.6)$$

Strong Version:

$$\dot{P}_t^e = \dot{P}_t + \varepsilon_t \quad (1.7)$$

In the weak version of the rational expectation hypothesis, $\dot{P}_t^e$ is expected inflation and $E\{\dot{P}_t|\Omega_{t-1}\}$ is the rational expectation of inflation on condition that all available information set until the previous period (Ω_{t-1}). In the strong version of the hypothesis, it is assumed that the current inflation rate involves the whole information set and economic agents cannot completely use all information about inflation. Therefore, expected inflation depends on current inflation with a random error term. By definition of the rational expectation hypothesis, error term (ε_t) is random and it has zero mean. The reason for that economic agents does not make mistake forever.

Comparing to the adaptive expectation hypothesis, the rational expectation hypothesis is based on not only backward-looking but also forward-looking approach. Additionally, economic agents form expectations without systematic error over time. They learn from their previous error. Shortly, in the rational expectation hypothesis, expectations are unbiased and consistent, statistically. Since economic agents have a rational expectation, there is a trade-off between inflation and unemployment as long as inflation is a surprise. Contrary to the adaptive expectation hypothesis, rational expectation suggests surprise policy rather than rule-based policy.

One of the important criticisms in the literature is related to the weak version of the rational expectation hypothesis. Economic agents cannot use all available information when they form their expectation about any variable because of the cost of obtaining information about the factor which they believe determine that variable. The fact that economic agents obtain information is not always rational. If the cost of

obtaining information is higher than the marginal utility of true prediction about the future, economic agents would not obtain information.

Lucas (1973) provided empirical evidence to the rational expectation model. According to Lucas, validity of the Phillips Curve depends on aggregate demand policies. Lucas argued that even if economic agents are rational, they can form incorrect expectations about the future due to an increase in volatility of aggregate demand shocks. The trade-off between inflation and unemployment is structural. The Phillips Curve should be defined again in terms of all of the economic variables and their relationship with each other. If the Phillips Curve is based on microeconomics basis, it can be possible to understand inflation dynamics in detail. (Lucas, 1972, 1973, 1976)

The major reason for these criticisms is to ignore the relationship between firms and consumers by expectation augmented Phillips Curve (Lucas, 1973). In the 1980s, dynamic stochastic general equilibrium models based on the microeconomic basis was developed. Furthermore, inflation dynamics were examined based on microeconomic foundations as well as other developments. Therefore, the New Keynesian Phillips Curve is based on the optimization behaviors of economic agents that were developed as a result of these criticisms as presented in the next section.

1.4. New Keynesian Approach to Phillips Curve

Until this section, the origin of the Phillips Curve and its evolution are discussed. Firstly, the importance of expectations has been discovered for Phillips Curve, and then different expectation models were integrated into the Phillips Curve model. Despite these improvements, the expectations-augmented Phillips Curve may not be enough to explain inflation dynamics according to recent developments in economies. Until that time, the Phillips Curve used only aggregate variables such as

unemployment and it did not adequately take into account behaviors of economic agents to explain inflation dynamics (Fuhrer, 1995).

According to Lucas (1976), however, even if economic agents react to changes in economic policy due to rational expectations, we can not know whether historical changes in economic policy are large enough to affect expectations in Phillips Curve. The results of new economic policies are not exactly known considering historical results of economic policies. Because a new economy policy can change the existing structure. Thus, it is proposed that aggregate variables such as inflation should be explained based on microeconomic foundations so that structural changes in aggregate variables can be clearly monitored.

Developed in the early 1980s, Dynamic Stochastic General Equilibrium (DSGE) models are based on microeconomic foundations and they focus on preferences of economic agents such as firms and households. DSGE models meet the needs that arise as a result of “Lucas Critique”. Therefore, inflation function as an aggregate variable has been built on DSGE models considering optimization problems of economic agents. These models, which explain the inflation process based on DSGE models, are called the New Keynesian Phillips Curve (NKPC) models.

In the literature, there are several NKPC models. They can be separated into two main groups as closed economy models and open economy models. Whereas closed economy models do not directly take into account foreign trade variables, open economy models include foreign trade variables as explanatory variables for the inflation process. In this section, two closed economy and three open economy versions of NKPC models and their derivation are theoretically investigated. Before the derivation of NKPC models, in this section, we discuss the Calvo Pricing model and optimization problems of economic agents as microeconomic foundations.

1.4.1. Calvo Pricing Model

The NKPC models are based on Calvo's Pricing model (Calvo, 1983). Even though the model of Taylor (1980) and Fischer (1977) about wage rigidity is a more realistic specification, Calvo's Pricing model is more useful in order to analyze inflation and price rigidity. Thus, Gali et al. (1999) derived the NKPC by using Calvo sticky pricing model (Calvo, 1983).

According to the Calvo sticky pricing model, all firms operate in a monopolistic market and their price adjusting decisions are based on a monopolistic profit maximization problem. Each of these monopolistic firms faces a constant price elasticity of the demand curve for their own goods. Therefore, these firms adjust their prices periodically and their prices remain stable for a certain period of time.

Equation 1.8 specifies the average time during which the prices of monopolistic firms remain unchanged.

$$(1 - \theta) \sum_{k=0}^{\infty} k \theta^{k-1} = \frac{1}{(1 - \theta)} \quad (1.8)$$

where θ represents price rigidity and it is between zero and one. If $\theta=1$, it means that the price is rigid. The term $(1-\theta)$ indicates a fraction of firms that will adjust their prices in any given period. The period number is represented by parameter k . As a result, the aggregate price level is the result of each monopolistic firm's price adjustment as follows;

$$P_t = \left(\int_0^1 P_{i,t}^{1-\eta} di \right)^{\frac{1}{1-\eta}} \quad (1.9)$$

The left side of Equation 1.9 P_t is equal to the total of the price level of each firm. The aggregate price level can be rewritten, considering optimal reset price Z_t^* defined by the $(1-\theta)$ fraction of firms as follows;

$$P_t = \left((1-\theta)(Z_t^*)^{1-\eta} + \theta P_{t-1}^{1-\eta} \right)^{\frac{1}{1-\eta}} \quad (1.10)$$

where Z_t^* represents the optimal price reset of monopolistic firms in the period t . A log-linearization of the aggregate price level in the Equation 1.10 around a zero-inflation steady state yields Equation 1.11 as follows;

$$p_t = (1-\theta)z_t^* + \theta p_{t-1} \quad (1.11)$$

As can be seen from Equation 1.11, the aggregate price level on the monopolistic market is a combination of the optimal reset price of firms z_t^* and the past price level p_{t-1} regarding θ . The derivation of log-linearization is presented in Appendix A (Fall 2000). The derivation of the optimal reset price is presented in the next section (Whelan, 2005).

1.4.2. Optimal Reset Price

In this section, the derivation of the optimal reset price is presented. In the monopolistic market, firms optimize their price in order to minimize their future losses (Whelan, 2005). Firms' future losses are expressed by as follows;

$$L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t(z_t^* - p_{t+k}^*)^2 \quad (1.12)$$

The first-order condition for the optimal reset price z_t^* is obtained by the derivation of monopolistic firms' loss function results as follows;

$$2 \sum_{k=0}^{\infty} (\theta\beta)^k E_t(z_t^* - p_{t+k}^*) = 0 \quad (1.13)$$

$$2 \sum_{k=0}^{\infty} (\theta\beta)^k E_t(z_t^* - p_{t+k}^*) = 0 \quad (1.14)$$

The above equation can be rewritten;

$$z_t^* \sum_{k=0}^{\infty} (\theta\beta)^k = \sum_{k=0}^{\infty} (\theta\beta)^k E_t p_{t+k}^* \quad (1.15)$$

where

$$\sum_{k=0}^{\infty} (\theta\beta)^k = 1/(1 - \theta\beta) \quad (1.16)$$

Therefore, monopolistic firms' optimal reset price is obtained as follows;

$$z_t^* = (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t \{p_{t+k}^*\} \quad (1.17)$$

The optimal price p_t^* is can be specified as follows;

$$p_t^* = \mu + mc_t \quad (1.18)$$

Thus, optimal reset price, which includes optimal price p_t^* , can be rewritten as follows;

$$z_t^* = (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t(\mu + mc_{t+k}) \quad (1.19)$$

So far, Calvo's sticky-pricing model and the optimal reset price, which located in his pricing model, are investigated. The New Keynesian Phillips Curve is derived by Gali et al. (1999) by using Calvo sticky-pricing model in Equation 1.10. The NKPC models are presented in the next section.

1.4.3. The Closed Economy NKPC

The closed economy version of NKPC is a price model that is derived by Dynamic Stochastic General Equilibrium models. These models have two important assumptions. The first assumption is that firms adjust their prices by stages at different times. Secondly, these firms operate in a monopolistic competition market. Therefore, these firms, which operate in a monopolistic competition market, have the power to determine prices (Calvo, 1983). In the closed economy version of NKPC known as pure forward-looking NKPC, the domestic inflation process is explained by expected inflation and real economic activities.

In Calvo's pricing model, firms do not change prices unless they receive a signal. As a result, prices remain stable in a particular period. The closed economy NKPC that based on Calvo's pricing model can be defined as follows;

$$\pi_t = \lambda mc_t + \beta E_t \pi_{t+1} \quad (1.20)$$

$$\lambda = (1 - \theta)(1 - \theta\beta)\theta^{-1} \quad (1.21)$$

where each firm adjusts its prices with a fixed probability $(1-\theta)$ and its prices are stable or proportional to trend inflation with probability θ . β is a discount factor and mc_t is the real marginal cost as a proxy for real economic activities. Inflation and expected inflation are represented by π and $E_t\pi_{t+1}$, respectively. In the model, structural parameters of the equation are represented by λ . This structural parameter λ indicates the sensitivity of inflation to real marginal costs and it represents the slope of closed economy NKPC.

As seen in Equation 1.20, inflation (π) is a function of real marginal cost and expected inflation. Compared to the Phillips Curve models such as the expectation-augmented Phillips curve, the closed economy NKPC model includes important differences. Firstly, the closed economy NKPC based on preferences of economic agents such as firms. Additionally, real marginal cost is included in the model due to Calvo's (1983) staggered price adjustment model.

However, since the measure of real marginal costs is very difficult, the output gap can be used as a proxy variable for real marginal cost. On the other hand, the output gap is a function of real marginal cost. Therefore, the closed economy NKPC can be derived with the output gap variable as follows;

$$mc_t = \tau x_t \quad (1.22)$$

$$\hat{x}_t = x_t - \bar{x}_t \quad (1.23)$$

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} \quad (1.24)$$

$$\lambda = (1 - \theta)(1 - \theta\beta)\theta^{-1} \quad (1.25)$$

The relationship between marginal cost and the output gap is specified by Equation 1.22. The output gap is a difference between potential output and actual output as can be seen in Equation 1.23. Therefore, the output gap can be used as a proxy for the real marginal cost. Although the measure of potential output is controversial, it is able to be measured by using statistical methods such as HP Filter.

In the NKPC models, used another proxy for the marginal cost is labour share of GDP. Since capital in the production function is constant in the short run, labour compensations of firms regard as marginal cost. Thus labour share of GDP is computed by using labour compensations of firms and it can be used as a proxy for real marginal cost instead of the output gap.

1.4.4. The Closed Economy Hybrid NKPC

In the closed economy version of the NKPC models, domestic current inflation is a function of expected inflation and output gap that is used as a proxy for real marginal cost. In addition to these explanatory variables, the closed economy hybrid NKPC includes past inflation as an explanatory variable. Therefore, current inflation is a function of expected inflation, marginal cost and past inflation in the closed economy hybrid NKPC. Similarly, the output gap can be used as a proxy for marginal cost by the closed economy hybrid NKPC.

Gali and Gertler derive the closed economy hybrid NKPC on their study by using Calvo's (1983) pricing model (Gali & Gertler, 1999). It can be specified adding past inflation to the closed economy model as follows:

$$\pi = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda \hat{x}_t \quad (1.26)$$

$$\lambda = (1 - \omega)(1 - \theta)(1 - \beta\theta)\phi^{-1} \quad (1.27)$$

$$\alpha_f = \beta\theta\phi^{-1} \quad (1.28)$$

$$\alpha_b = \omega\phi^{-1} \quad (1.29)$$

$$\phi = \theta + \omega(1 - \theta(1 - \beta)) \quad (1.30)$$

Equation 1.26 specifies the closed economy hybrid NKPC. In this model, whereas α_f represents the effect of expected inflation, α_b represents the effect of past inflation on inflation. The slope parameter is represented by λ and the discount factor parameter is represented by β . The parameter θ indicates the price rigidity factor. While the parameter ω represents firms that adjust their price based on past inflation, the term $(1-\omega)$ indicates firms that adjust their price based on expected inflation.

In the closed economy hybrid NKPC, if all firms in the market are forward-looking the structural parameters ω is equal to zero. In this case, all firms adjust their price considering expected inflation. As can be seen from the specification of the

closed economy hybrid NKPC, if the structural parameter ω is equal to zero, the closed economy hybrid NKPC converges to the closed economy NKPC known as pure forward-looking NKPC.

1.4.5. The Open Economy NKPC

Many developing countries' economic activities depend on foreign trade factors such as exchange rate or oil prices. In these countries, a significant majority of goods in the market is either imported product or manufactured by using imported products. Since import is a function of some foreign trade factors such as the exchange rate, these foreign trade factors have a crucial role in domestic inflation. However, closed economy models as mentioned previously section do not take into account the effect of foreign trade factors on domestic inflation, directly. The closed economy versions of the NKPC consider that these foreign trade factors affect domestic inflation through domestic marginal cost.

The open economy NKPC, which is developed by Balakrishnan and Lopez-Salido, takes into account foreign trade factors such as import prices which can affect domestic inflation (Balakrishnan & Lopez-Salido, 2002). In this model, import prices play a crucial role in the marginal cost of domestic firms. These domestic firms adjust their prices considering the weights of domestic and import inputs. Therefore, inflation is a function of real import prices, expected inflation and marginal cost. The open economy NKPC is specified as follows;

$$\pi = \beta E_t \pi_{t+1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)] \quad (1.31)$$

$$\lambda = (1 - \theta)(1 - \theta\beta)\theta^{-1} \quad (1.32)$$

In Equation 1.31, π is inflation, β is a discount factor parameter and mc is marginal cost. In the open economy NKPC, inflation is determined by import price p_t^m relative to domestic price p_t addition to other explanatory variables. The slope parameter λ indicates the jointly effect of marginal cost and relative import price on inflation. Similar to closed economy models, the output gap can be used as a proxy for marginal cost. The price rigidity is represented by parameter θ .

The openness degree of countries is represented by parameter α . The openness degree parameter α reflects the effect of the relative import price on domestic inflation. Theoretically, it must be between zero and one. The effect of relative price on inflation increases as the openness degree of countries in the open economy model. As can be seen from the specification of open economy NKPC given in Equation 1.31, if the openness degree parameter α is equal to zero, the open economy model converges to the closed economy model.

As can be seen in Equation 1.31, the open economy NKPC take into account import price and domestic price. Additionally, these parameters have an important role in inflation depend on the openness degree of countries. However, the open economy NKPC does not include past inflation as an explanatory variable. When past inflation is added to open economy NKPC as an explanatory variable, it converges to open economy hybrid NKPC. In this case, domestic inflation is directly affected by domestic factors instead of foreign trade factors.

1.4.6. The Open Economy Hybrid NKPC

The hybrid version of open economy NKPC includes past inflation addition to other independent variables of the open economy model. Thus, inflation is a function of past inflation, marginal cost, relative import price along with expected inflation. The specification of open economy hybrid NKPC can be derived as follows;

$$\pi = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)] \quad (1.33)$$

$$\alpha_f = \beta \theta \phi^{-1} \quad (1.34)$$

$$\alpha_b = \omega \phi^{-1} \quad (1.35)$$

$$\phi = \theta + \omega(1 - \theta(1 - \beta)) \quad (1.36)$$

In Equation 1.33, α_f and α_b are weights of expected inflation and past inflation, respectively. The slope of open economy hybrid NKPC is represented by parameter λ . The openness degree parameter α determines the effect of the relative import price on inflation. Similar to open economy NKPC, $\lambda(1-\alpha)$ represents the elasticity of domestic inflation to the marginal cost. The import price and domestic price are represented by p_t^m and p_t , respectively. The term $(p_t^m - p_t)$ indicates relative import price to domestic goods.

As can be seen from the specification of open economy hybrid NKPC given in Equation 1.33, the open economy hybrid NKPC nests three different NKPC models. First, if openness degree parameter α is equal to zero, the open economy hybrid model converges to the closed economy hybrid model. Secondly, if the parameter ω is equal to zero, the open economy hybrid model converges to the open economy model. Thirdly, if the parameter α_f and α_b are equal to zero and β , respectively, it converges to the open economy model.

1.4.7. The Open Economy GM-NKPC

One of the assumptions of the open economy NKPC is import variable consists of all final and intermediate goods. The open economy model has been extended by Gali and Monacelli to a new open economy model. Their new open economy known as Gali-Monacelli NKPC (henceforth GM-NKPC) model has several advantages. Firstly, it nets open economy NKPC. Additionally, the open economy GM-NKPC provides controls with the interaction of open economies to the rest of the world and explains nominal price rigidity of open economies. Their model directly includes the exchange rate as an explanatory variable instead of as a proxy for relative import price, considering the relationship between foreign trade and exchange rate. (Gali & Monacelli, 2005) (Abbas, Bhattacharya, & Sgro, 2016)

The GM-NKPC (2005) can be specified as follows;

$$\pi = \beta E_t \pi_{t+1} + \lambda mc_t + \alpha [\Delta s_t - \beta E_t \Delta s_{t+1}] \quad (1.37)$$

Compared to the previously mentioned open economy models, GM-NKPC includes the terms of foreign trade s_t and expected foreign trade instead of relative import price. According to the open economy GM-NKPC, all import goods are final consumption goods. Thus, domestic inflation is affected by the price of final consumption goods depend on the openness degree of country α .

Gali and Monacelli (2005) improve the open economy model in Equation 1.37 by using the following relationship between foreign trade s_t and the exchange rate q_t . As can be seen from Equation 1.38, there is a relation between exchange rate q_t , foreign trade s_t and openness degree of country α .

$$s_t = \frac{q_t}{(1 - \alpha)} \quad (1.38)$$

Therefore, the open economy NKPC of Gali and Monacelli (2005) can be derived as follows;

$$\pi = \beta E_t \pi_{t+1} + \lambda mc_t + \frac{\alpha}{1 - \alpha} [\Delta q_t - \beta E_t \Delta q_{t+1}] \quad (1.39)$$

According to GM-NKPC, domestic inflation is also a function of the exchange rate and expected change in the exchange rate as well as expected inflation and marginal cost. This model includes neither past inflation and relative import price. The exchange rate variable is used as an independent variable instead of a proxy for the relative price of import. The coefficient of the terms of exchange rate converges to non-linear form as $\alpha(1 - \alpha)^{-1}$.

Therefore, in this section, we examine five different NKPC models: close economy, closed economy hybrid, open economy, open economy hybrid NKPC models and GM-NKPC model. The open economy models take into account foreign trade factors compared to closed economy models. In the hybrid models, past inflation is a significant explanatory variable compared to baseline open and closed economy models. In the next chapter, we examine the empirical results of these NKPC models.

CHAPTER TWO

AN EMPIRICAL REVIEW OF NEW KEYNESIAN PHILLIPS CURVE

In the sixty years since the Phillips Curve was developed by Phillips (1958), the dynamics of inflation have been estimated by different specifications of the Phillips Curve for different countries over different periods. In particular, following Gali and Gertler (1999) who empirically estimate the New Keynesian Phillips Curve by using a proxy variable for economic activities, the number of the empirical literature on the subject has increased tremendously. Moreover, the Phillips Curve itself has been evolved theoretically during this time as well. Thus, the literature of the New Keynesian Phillips Curve has been extended with these theoretical and empirical studies which include various methods, specifications, analysis periods or countries.

This chapter reviews the empirical literature on the determinants of inflation giving particular attention to the dynamic nature of inflation. The existing literature can be classified into a number of groups considering the methods employed and the models estimated. In the overwhelming majority of the existing studies, inflation dynamics are examined with several different models. Each empirical study includes estimations of more than one model. We classified these studies in terms of previously their model specification and characteristic rather than the chronological order.

The baseline NKPC models and their hybrid versions have been empirically and theoretically tested for many countries and country groups in the existing literature. In particular, increase in trade integration between countries as a result of the increase in globalization has brought about estimation of open economy models, which include foreign trade variables, as well as closed economy models for developed countries. In addition to closed and open economy models, a special

version of NKPC models such as small open economy NKPC has been estimated and debated for emerging countries in the literature.

Considering the existing empirical literature, either aggregated data or sectoral data is used to estimate NKPC models. On the other hand, whereas some empirical studies use marginal cost, others use the output gap variable as a proxy for real economic activities. In addition to studies used rational expectation models, several empirical studies use expectations survey to measure expected future inflation in the existing literature.

In the light of the diversity of these empirical studies, the rest of this chapter proceeds as follows. First of all, the empirical results of closed economy models and their hybrid versions are investigated in this chapter. Secondly, open economy NKPC models are investigated as well as their hybrid versions. Since there is a lot of measure method of expectations such as survey method or rational expectations, the importance of expectations in the empirical literature of NKPC is mentioned. Finally, the relationship between NKPC and globalization, which related to the subject of this study, is discussed.

2.1. Empirical Findings of The Closed Economy Models

The closed economy New Keynesian Phillips Curve models consist of baseline NKPC and hybrid NKPC models. The difference between these forms of NKPC models is related to whether specifications of them include lagged inflation or not. Whereas inflation is a function of real economic activities and expected inflation in the specification of closed economy NKPC, closed economy hybrid NKPC specification includes past inflation in addition to other explanatory variables. In these specifications, past inflation represents backwards-looking and expected inflation represents forward-looking expectation formation. Therefore, the closed economy NKPC is also known as pure forward-looking NKPC due to the fact that it

does not include past inflation terms. The hybrid version of closed economy NCPC consists of backward-looking along with forward-looking terms.

In this section, the empirical results of these two main close economy NKPC model are examined. The pure forward-looking NKPC known also as the closed economy or baseline NKPC is specified in Equation 2.1. The second model is the closed economy hybrid NKPC model nested also pure forward-looking NKPC. The closed economy hybrid NKPC model is specified in Equation 2.2.

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \tilde{x}_t \quad (2.1)$$

where,

$$\tilde{x}_t = x_t - \bar{x}_t$$

$$\lambda = (1 - \theta)(1 - \beta\theta)\theta^{-1}$$

$$\pi_t = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda \tilde{x}_t \quad (2.2)$$

where,

$$\tilde{x}_t = x_t - \bar{x}_t$$

$$\lambda = (1 - \omega)(1 - \theta)(1 - \beta\theta)\phi^{-1}$$

$$\alpha_f = \beta\theta\phi^{-1}$$

$$\alpha_f = \omega\phi^{-1}$$

$$\phi = \theta + \omega[1 - \theta(1 - \beta)]$$

2.1.1. Inflation Dynamics: The role of Backward and Forward Looking Expectation Formation

In this sub-section, we examine the empirical results of the baseline and hybrid version of closed economy NKPC models in the empirical literature. The difference between baseline and hybrid models is related to whether model specification includes past inflation as well as expected inflation and real economic activities or not. If the past inflation variable is correctly signed and statistically significant in the estimation of closed economy hybrid NKPC, this means that firms adjust their price considering backward-looking expectation formation. Similarly, if the expected inflation variable is correctly signed and statistically significant in the estimation of closed economy NKPC, this means that firms adjust their price considering forward-looking expectation formation. Therefore, the empirical studies

tested closed economy models have discussed whether firms adjust their prices based on the past (backward-looking) or the future (forward-looking).

Another discussion in the empirical literature is related to the measurement of real economic activities. Measurement of real economic activities plays a crucial role in the empirical studies of NKPC so as to correctly capture inflation dynamics. In early empirical studies, it was thought that the output gap is an appropriate proxy variable for real economic activities and it is anticipated to have a positive sign. Since the potential output is not exactly known, the output gap is not exactly known. The biased output gap may bring about incorrectly signed variables.

In order to avoid this problem, Gali and Gertler (1999), Sbordone (2002) and Woodford (2001) propose to use marginal cost as a proxy for the output gap due to bias on potential output. Gali and Gertler (1999) derived a theoretical framework of the use of marginal cost as a proxy for output gap based theoretical relationship between marginal cost and the output gap. Therefore, real economic activities are represented by the output gap, and marginal cost can be used as a proxy for output gap.

Gali and Gertler (1999) compute marginal cost by using labour share of GDP. The constant cost of capital in the short run underlies this methodology regarding the measurement of marginal cost, theoretically. After all this line of thought, Gali and Gertler (1999) estimated both closed economy NKPC and closed economy hybrid NKPC by using GMM estimation for the US over the sample period from 1960 to 1997.

As a result of their study (1999), both forward and backward looking are statistically significant and correctly signed. However, forward looking is more dominant than backward looking on determination of the current domestic inflation rate in the US economy. While forward-looking coefficient ranges from 0,59 to 0,87

backward-looking coefficient range from 0,08 to 0,38. Moreover, Gali and Gertler (1999) compared the use of marginal cost to output gap for both models. In both models, the use of the output gap, which is computed by using GDP trend, bring about statistically insignificant explanatory variables.

Similarly, Gali et al. (2001) investigated inflation dynamics for the Euro Area. Similar to Gali and Gertler's (1999) method, they also test NKPC with marginal cost as a proxy for real economic activities instead of the output gap. They provide evidence on the fit of the closed economy NKPC and its hybrid version for the Euro Area over the sample period 1970-1998. Their paper demonstrate that the NKPC, which includes labour share as a proxy for real economic activities, is meaningful for inflation dynamics of the Euro Area. In both models, labour share is not only statistically significant but also correctly signed (between 0 and 1). The main finding of their study is that forward-looking parameter is quantitatively greater than past inflation although both of them are statistically significant in the Euro Area over the sample period 1970-1998. This finding shows that forward looking is a dominant forcing variable rather than previously inflation.

The estimation results obtained by Gali et al. (2001) are objected by Rudd and Whelan (2005). The reason for this objection is that they use both lagged inflation and expected inflation along with GMM estimation. According to Rudd and Whelan (2005), the estimated forward inflation coefficient is biased upwards due to the fact that expected inflation is already affected by lagged inflation. That is why, similarly, the estimated lagged inflation coefficient is biased downwards.

Therefore, Rudd and Whelan (2005) focused on closed economy NKPC instead of its hybrid version in order to capture inflation dynamics for the US economy. They estimated the closed economy NKPC using the same data period in Gali and Gertler (1999). They found that forward looking expectation is not an important variable against lagged inflation variable for inflation dynamics for the US

economy. According to their study (2005), marginal cost is not a proper proxy for real economic activities.

Rudd and Whelan (2007), in their another study, investigate labour share and output gap movements over the period from 1960 to 2000. In this time period, 7 economic recession is observed for the US economy. During all these 7 recession periods, while the labour share increased output gap decreased. As a proxy for real economic activities, the labour share (non-farm sector) displayed counter-cyclical movements instead of pro-cyclically movements. As a result, they suggested that output gap, which is computed by GDP trend, is a better proxy for real economic activities than marginal cost contrary to studies of Gali and Gertler (1999), Sbordone (2002) and Gali, et al. (2001).

Another economist who questioned and criticized the estimation result and methodology of Gali and Gertler (1999) is Linde (2005). Similarly, Linde (2005) criticizes the use of GMM estimation in the NKPC models. The paper of Linde (2005) estimates a simple NKPC stick price model by means of Monte Carlo simulation and find that the use of GMM estimation to estimate NKPC bring about biased estimator coefficients. As a result of the paper, which includes reduced-form parameters, it is proposed that full information maximum likelihood should be used in order to obtain a better and unbiased estimation coefficient in the NKPC model. In that case, the data rejected the validity of NKPC for the US economy.

However, Gali et al. (2005) refused procedure adopted by Linde (2005) and Rudd and Whelan (2005). According to Gali et al. (2005), deep parameter coefficients, which is obtained by reduced-form, do not provide a structural interpretation of NKPC. Moreover, the reason for a biased coefficient of estimators is not related to the GMM estimation. On the other hand, Gali et al. (2005) estimate closed economy NKPC again and emphasize that the use of the output gap as a proxy for real economic activities leads to a biased coefficient of estimation. That's why

the reason for the biased problem is not a structural procedure of NKPC with GMM estimation method. (Gali & Monacelli, 2005)

Recently, Lagoa (2019) tested NKPC for Euro Area over the sample period 1998-2008. Moreover, Lagoa (2019) investigated the reason for differentials in Euro Area after the creation of a single currency. Results of estimation in NKPC suggest that both forward-looking and backward-looking capture inflation dynamics for 20 Euro countries. However, the former is more dominant than the latter. Additionally, the exchange rate and its lagged play an important role for inflation process and are statistically significant. Finally, the results of the study demonstrate that the reason of differences in inflation across 20 European countries is expected inflation as well as exchange rate movements.

2.1.2. Empirical Results of Closed Economy NKPC under Atypical Specifications and Methods

In the previous sub-section, we examined typical empirical specifications of baseline and hybrid NKPC. Considering these empirical studies, whereas baseline NKPC consists of real economic activities and inflation expectation, hybrid NKPC additionally consists of lagged inflation as independent variables. In mentioned these studies, although forward-looking expectation formation is statistically significant compared to backward-looking expectation formation, methodological objections and discussions have arisen in the empirical literature. These methodological objections and discussion bring along differentiation about the empirical specifications.

In this sub-section, the empirical results of studies with extraordinary specifications are evaluated in the empirical literature. The empirical findings under typical empirical specifications mentioned in the previous section are re-evaluated under atypical empirical specifications of the NKPC models in this section. These

unusual empirical specifications provide comprehensive insight into expectations formations and the use of proxies for real economic activities.

Additionally, in this sub-section, empirical studies used different methods such as Maximum Likelihood as a result of discussion regarding the methodology mentioned in the previous sections are evaluated. This sub-section also covers empirical studies that take into account breakpoints over the sample periods. We also examine the empirical results of studies that adding other variables such as supply shocks to closed economy models in this sub-section.

Jondeau and Le Bihan (2005) tested the hybrid NKPC for the US, Euro Area and four major countries¹ in Europe. They contributed to the closed economy hybrid NKPC specification by allowing more lagged inflation in their study, contrary to typical hybrid NKPC, which includes only one past inflation. The other main purpose of their study is to explain the sensitivity of the estimates to the choice of labour cost and output gap as explanatory variables. In other words, it is to clear up whether the choice of these two proxies for real economic activities is important or not to explain the inflation process. For these main purposes, several specifications are generated by combining different lags and forcing factors. GMM and Maximum Likelihood (ML) are used as estimation methods. In their paper, the sample period runs from 1970 to 1994 as a quarterly frequency. (Jondeau & Le Bihan, 2005)

One of the important findings of Jondeau and Le Bihan (2005) is that choice of the previously mentioned two variables is not important to explain inflation dynamics for these five countries in terms of forward-looking parameters. In other words, the forward-looking expectation formation is insignificant for sample countries as independent of the choice of proxies for real economic activities. Moreover, findings indicate that regardless of the chosen specification, the

¹ Germany, France, Italy and United Kingdom

backward-looking is more dominant than forward looking for European Countries and US contrast to the results of the study of Gali and Gertler (1999), which highlights that expected inflation is more important than past inflation for U.S. inflation.

The reason for this difference between Gali and Gertler (1999) and Jondeau and Le Bihan (2005) regarding forward and backward expectation formations can be computing methodology of the degree of forward-lookingness. Whereas the former uses optimal West (1997) procedure, the latter prefer Newey-West (1993) procedure so as to more correctly compute the degree of forward lookingness. Therefore, whereas Gali and Gertler (1999) find that forward-looking component lies in the range 0.5-0.6 for inflation, according to the computing of Jondeau and Le Bihan (2005) it lies in the range 0.2-0.5.

According to another important result of Jondau and Le Bihan (2005), adding more lags and leads of inflation to model leads to an increase in statistical significance of labour share and output gap which represents real economic activities. Thus, the model with three lags and leads is more significant and meaningful in order to explain the inflation process for European countries and the US. In addition to these findings, whereas choosing the output gap with three lags and leads as a forcing factor is more appropriate for continental European countries, choosing the real unit labour cost with just one lag and lead as forcing factor is more appropriate for the UK and US. (Jondeau & Le Bihan, 2005)

Another study, which adds more lags of the output gap and past inflation variables to the model, is Bardsen et al. (2004). In addition to more lags of output gap and inflation variables, the model of Bardsen et al. (2004) includes an error correction term. They estimate NKPC with more lags of inflation and output gap for the Euro Area and the US. As a result of the estimation of their hybrid NKPC, the dominance of forward-looking against backward-looking expectation formation is

not statistically robust. Another important finding is that the use of labour share as a proxy variable for real economic activities has a fragile statistical significance. Finally, they have proposed that NKPC should not be accepted too readily under their atypical specification.

Mehra (2004) investigates the NKPC in terms of another significant variable: supply shocks. In the model specification of Mehra (2004), the relative price of import is used as a proxy for supply shocks. This hybrid specification is tested for the United States over the sample period from 1961 to 2003. In contrast to the results of most studies which suggests that expected inflation is a major determinant of current inflation, Mehra (2004) suggests that expected inflation is not a major determinant when the importance of supply shocks is not omitted. On the contrary, it suggests that backward-looking expectation formation is a more significant determinant of current domestic inflation than forward-looking expectation formation for the US economy.

Zhang et al. (2008) examined inflation dynamics in terms of change in monetary policy and periodic breakpoints. Their main motivation is that inflation inertia has an empirically significant role on the inflation process, although forward-looking expectation is theoretically important variable. They also examined a structural change in NKPC based on this inconsistency for the US from 1968 to 2005.

For this purpose, firstly structural breakpoints are determined by using the Andrews-Ploberger test in the study of Zhang et al. (2008). Thus, the years 1975, 1981 and 2001 were determined as breakpoints. Zhang et al. (2008) indicated that the reason for these structural breakpoints is change on monetary policy. Finally, NKPC is estimated by using the GMM estimation for each of these regimes.

The paper of Zhang et al. (2008) emphasizes statistical proof of these structural breakpoints. As a result of the paper, forward-looking expectation formation is relatively less important than backward-looking expectation formation to explain current inflation during the high and volatile inflation period such 1968-1981 period for the US. The forward-looking expectations formation play a more important role during low and still inflation period such post-1981 period for the US. It is revealed that the role of forward-looking expectation formation was not significant in the 1970s while it became a significant variable to explain domestic inflation in the 1980s for the US. Additionally, another structural breakpoint corresponds to around 2001 for the inflation trend of the US. The reason for the structural breakpoint in 2001 is a change in the monetary policy rule. (Zhang, Osborn, & Kim, 2008)

Castle et al. (2010) investigated the effects of structural breaks on inflation dynamics for the US and the Euro Area. In their study, 9 different dummy variables that represent structural breakpoints between 1960 and 1994 were determined by Autometrics developed by Doornik. Unlike other studies that take into account breakpoints over the sample periods, they use the new technique of impulse-indicator saturation to determine the significance of breakpoints for the inflation process. It is found that these nine dummy variables are statistically significant. Adding dummy variables to models reduces the coefficient value of forward-looking expectation formation from 0,62 to 0,25. In contrast to the results of the study of Gali and Gertler (1999), the labour share as a proxy for real economic activities was not statistically robust despite statistically significant. (Castle, Doornik, Hendry, & Nymoen, 2010)

These structural breaks, globalization, change in the monetary policies and alternative measurement of marginal cost have shifted the focus of economists to the slope of the New Keynesian Phillips Curve. The marginal cost coefficient is an important determinative of the slope of NKPC. However, many studies in the empirical literature suggest that inflation has not responded to the marginal cost for

most countries, particularly large countries such as the US even though alternative definitions of marginal cost. This indicates more flatter NKPC.

As previously mentioned, Kuttner and Robinson (2010) focused on the slope of the NKPC, and they similarly find that flatter NKPC for the US as a large and open country and Australia as a small and open country. As a result of their study (2010), NKPC has become flatter for both countries over time. Moreover, for these two countries, which represents large and small open economy respectively, sensitive of inflation to real marginal cost, which measured by using labour share, turn out to be very small and statistically insignificant. In their study (2010), four possible explanations which may be the cause of this observation were examined.

According to Kuttner and Robinson (2010), the reason for flatter NKPC may be a data problem. This problem is closely related to the difficulty of correct measurement of the output gap in real life. In a lot of studies, the output gap is tried to be measured by marginal cost. Marginal cost is represented by labour's share of nominal income. However, Kuttner and Robinson (2010) argue that the measurement of nominal income, which is commonly calculated as non-farm income in studies, may include problems. Because there is not a consensus about whether non-farm income includes a stock option or fringe benefits or not. Therefore, these data problems may cause flatter NKPC.

Another plausible explanation of flatter NKPC is that labour share is not an appropriate proxy for marginal cost for all countries. According to the result of study of Kuttner and Robinson (2010), the reason why labour's share incorrectly represents marginal cost is to ignore the conditions of an open economy. They suggest that even labour's share of GDP is an unperfect proxy for real economic activities in NKPC models used CPI rather than GDP deflator. Additionally, estimation of the weight of imported goods in consumption has difficulty for each country with an open economy.

The third explanation regarding flatter NKPC, which is investigated by Kuttner and Robinson (2010), is a change in price-setting behavior. Rogoff (2003, 2006) argues that the increase in globalization and competition leads to a change in price-setting behavior. However, Kuttner and Robinson (2010) object to Rogoff's hypothesis since it is misinterpreted as well as opposite results obtained in practice. According to them (2010), in practice, the slope of NKPC, which should be steeper according to Rogoff's (2006) hypothesis, is flatter. Moreover, they suggest that while the increase in globalization and openness would tend to weaken the relationship between the output gap and marginal cost, none of them affect the link from expected future cost to inflation.

The final possible reason for apparent flattening in NKPC is that even though price-setting behavior has not changed, structural models can be too simple to capture the dynamics of the inflation process (Kuttner & Robinson, 2010). The results of Kuttner and Robinson (2010) suggest that the frequency of price-setting may change depending on periods, and it may depend on the average inflation rate. Additionally, Kuttner and Robinson (2010) argued that central banks created an environment in which firms set their prices with less frequency by conducting disinflationary policy over the last two decades. Consequently, a new structural model is needed in order to fully understand inflation dynamics.

Abbas and Sgro (2011) used a different method to measure marginal cost and output gap considering the discussion about marginal cost and the output gap. They tested hybrid and baseline NKPC by adding a different set of instruments and estimation methods such as 2SLS and GMM for Australia. Their quarterly dataset ranges from 1959 to 2009. The major focus of their study (2011) is whether forward-looking baseline NKPC or hybrid NKPC is better to capture inflation dynamics for Australia.

Abbas and Sgro (2011) found that forward-looking expectation formation is statistically significant for Australia. They found that the expected inflation is larger than past inflation across all different sets of instruments. The major structural breakpoint occurred in early 1983 related to the introduction of the flexible exchange rate regime in Australia. Whereas the backward-looking expectation formation is statistically insignificant over the sample period 1959-1982, both backward-looking and forward-looking expectation formations are statistically significant over the sample period 1983-2009.

Another extraordinary specification of the NKPC models is tested by Valadkhani (2014). The study of Valadkhani (2014) focused on the importance of the output gap in the NKPC for three countries: the US, UK and Canada by using a Markov regime-switching model. Another contribution of Valadkhani (2014) is to control the effects of the output gap arising from changes in exchange rate, wages and oil prices. It means that the pure effect of the output gap on current inflation is tried to examine as independent of regimes.

The estimation results of Valadkhani (2014) indicate two important relationships. On the one hand, there is a negative relationship between inflation and changes in the nominal effective exchange rate. On the other hand, wages and oil prices positively related to inflation. In the estimation model of Valadkhani (2014), which is augmented by the Markov regime-switching model, the output gap has a positive impact on inflation for the US, UK and Canada. This finding regarding the growth rate of wages exhibits like the original Phillips Curve (1958).

The most important finding of Valadkhani (2014) is related to how inflation behaves during different conjuncture that is represented by regimes. Valadkhani (2014) determined two regimes for all sample countries. Regime 1 represents a relatively low impact of the output gap and Regime 2 represents a relatively high impact of the output gap. Results indicate that whereas Regime 1 is valid in stagnant

periods of inflation, Regime 2 is valid in fluctuation periods. In other words, whenever the inflation rate is relatively stable, the effect of the output gap on current inflation is high. When the inflation rate is relatively stable, the effect of the output gap is low, similarly.

Another important study that used the Markov switching model is Chowdhury and Sarkar (2017). They tested whether hybrid NKPC is stable or not over the sample period from 1994 to 2011 for four developing countries: Brazil, Russia, India and South Africa. They computed the output gap by using Hamilton Markov switching model modified by Kim. Their finding suggests that hybrid NKPC is not stable for these four developing countries.

Therefore, considering the empirical studies focused on the closed economy and closed economy hybrid NKPC, there are two main discussions in the estimation of the closed economy models. The first discussion is related to the measurement of real economic activities. In the studies mentioned in this section, labour share or output gap is usually used proxy for real economic activities as well as other extraordinary technical methods to measure real economic activities. The second discussion in the studies that estimated closed economy models is related to whether forward-looking or backward-looking expectation formation has a significant impact on the inflation process. Another important issue is related to the importance of breakpoints for the inflation process. Table 2.1 summarize the empirical result of all studies reviewed in this section.

Table 2.1: Empirical Findings of The Closed Economy NKPC Models

Studies	Countries	Sample Period	Estimation Method	Main Results
Gali and Gertler (1999)	US	1960-1997	GMM	Both forward and backward-looking expectations are statistically significant and correctly signed for the US.
Gali et al. (2001)	Euro Area	1970-1998	GMM	The inflation process can be explained by forward-looking expectations.
Lagoa (2019)	Euro Area and 20 Euro Countries	1998-2008	GMM	Both forward-looking and backward-looking expectations explain the inflation process for sample countries over the sample period from 1998 to 2008.

Jondeau and Le Bihan (2005)	US, Four Major European Economies and Euro Area	1970-1999	Maximum-Likelihood and GMM	When adding three lags of inflation to model, labour share is a proper proxy for real economic activities.
Mehra (2004)	US	1961-2003		The forward-looking expectation is not a major determinant unless importance of supply shocks is not omitted. The output gap variable is statistically significant but it is not correctly signed.
Zhang et al. (2008)	US	1968-2005	GMM	Forward-looking expectations are relatively less important than backward-looking expectations.
Castle et al (2010)	US and Euro Area	1960-1994	GMM	The labour share variable is not statistically robust despite statistically significant.

Abbas et al. (2011)	Australia	1959-2009	2SLS and GMM	Whereas backward-looking expectations are statistically insignificant over the period 1959-1982, both backward and forward looking expectations are statistically significant over the sample period from 1983 to 2009.
Valadkhani (2014)	US, UK and Canada	1970-2013	Markov Regime-Switching	There are two important relationships. The first: the negative relationship between change on exchange rate and inflation. The second: positive relationship between inflation and oil prices.
Chowdhury et al. (2017)	Brazil, Russia, India and South Africa	1994-2001	Hamilton Markov Switching	Hybrid NKPC is not stable for these four developing countries: Brazil, Russia, India and South Africa.

2.2. Empirical Findings of The Open Economy Models

According to the closed economy New Keynesian Phillips Curve model, the domestic inflation process is explained by expected inflation and real economic activities. The real marginal cost or output gap is used as a proxy for real economic activities. The real marginal cost is measured by using labour share of GDP. However, it is assumed that in the closed economy NKPC model, this real marginal cost is not directly affected by foreign trade factors such as relative price of import or exchange rate.

The open economy versions of the NKPC models take into account the direct role of these foreign trade factors on the domestic inflation process, in contrast to closed economy models. As mentioned in Section 1.4.4, these factors, which are thought to affect the real marginal cost of firms, have contributed to the open economy specification in different forms. In the NKPC literature, there are three main empirical open economy specifications. Two of them are baseline open economy models that do not include past inflation. The third model is a hybrid open economy model that includes past inflation as well as other explanatory parameters of the open economy model.

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_a \tilde{x}_t + \alpha [\Delta s_t - \beta E_t \Delta s_{t+1}] \quad (2.3)$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_a \tilde{x}_t + \frac{\alpha}{1 - \alpha} [\Delta q_t - \beta E_t \Delta q_{t+1}] \quad (2.4)$$

where

$$\kappa_a = \lambda(\sigma_\alpha + \varphi)$$

$$\lambda = -(1 - \theta)(1 - \beta\theta)\theta^{-1}$$

$$\sigma_\alpha = \frac{\sigma}{(1 - \alpha) + \alpha\omega}$$

$$\omega = \sigma Y + (1 - \alpha)(\alpha\eta - 1)$$

Equation 2.3 specifies GM-NKPC, which includes foreign trade factor term, derived by Gali and Monacelli. Another form of GM-NKPC, which includes exchange rate instead of the foreign trade term, is derived considering the relationship between foreign trade and real exchange rate in Equation 2.4. Both open economy models assume that all imported goods are used as consumer goods. These two models ignore the use of imported goods as intermediate goods. (Gali & Monacelli, 2005)

$$\pi_t = \beta E_t \pi_{t+1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)] \quad (2.5)$$

$$\pi_t = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)] \quad (2.6)$$

where

$$\kappa_a = \lambda(\sigma_\alpha + \varphi)$$

$$\lambda = -(1 - \theta)(1 - \beta\theta)\theta^{-1}$$

$$\sigma_\alpha = \frac{\sigma}{(1 - \alpha) + \alpha\omega}$$

$$\omega = \sigma Y + (1 - \alpha)(\alpha\eta - 1)$$

$$\alpha_f = \beta\theta\phi^{-1}$$

$$\alpha_b = \omega\phi^{-1}$$

$$\phi = \theta + \omega[1 - \theta(1 - \beta)]$$

Equation 2.5 specifies another baseline open economy NKPC. Unlike Equation 2.3 and 2.4, the relative import price is used in Equation 2.5. The open economy NKPC specification given in Equation 2.5 allows the use of import goods as intermediate goods. The hybrid open economy NKPC, which includes past inflation, is specified in Equation 2.6.

This section consists of the empirical results of these two baseline open economy models and the hybrid version of the open economy model given in Equation 2.4 – 2.6. Majority of the studies examined in this section estimate several different models such as open economy, open economy hybrid NKPC as well as

closed economy models. In order to provide integrity of the issue, firstly, empirical studies, which contribute to open economy and open economy hybrid NKPC, are examined in this section. In the rest of this section, so as to avoid confusion, the open economy and open economy hybrid NKPC refer to Equation 2.5 and 2.6, respectively. Additionally, Equation 2.3 or Equation 2.4. refers to GM-NKPC depending on their foreign trade terms.

Gali and Gertler's (1999) hybrid model started to be named as a closed model since domestic inflation was not directly affected by any foreign trade factor in their model specification. Even though the real marginal cost is indirectly affected by foreign trade factors, there is no parameter regarding these foreign trade factors in the model. In other words, foreign trade factors can affect domestic inflation only through marginal cost in the closed economy models. The foreign trade factors have no direct impact on domestic inflation process in the closed economy models. The increase in globalization after the 1980s brought the effect of foreign trade factors on the domestic inflation process.

Smets and Wouters (2002) argued that foreign trade factors play a crucial role in the domestic inflation process. According to Smets and Wouters (2002), in addition to domestic factors, foreign trade factors such as imported price inflation, the elasticity of substitution, the share of intermediate imports in production and the share of imports in final consumption have a significant impact on domestic inflation process. The effect of these foreign trade factors on domestic inflation depends on the openness degree of countries.

Smets and Wouters (2002) examined the relationship between globalization and inflation for the Euro Area. In contrast to their expectations, the results of their empirical study for the Euro Area are consistent with the findings of the closed economy model of Gali and Gertler's (1999). They found that the degree of rigidity in import prices is very close to the degree of rigidity in domestic prices.

Even though Smets and Wouters's (2002) study has not directly relevant to NKPC, it has been contributed to the development of open economy versions of NKPC models. In addition to domestic price rigidity parameters in the closed economy model, rigidity parameters of imported intermediate and final goods started to be added in open economy NKPC thanks to their contributions.

Batini et al. (2005) extended the closed economy specification of NKPC and introduced an open economy model for UK. In order to test this model, they emphasized three factors as a function of real marginal cost: employment adjustment cost, the relative price of imported production inputs and foreign competition term. According to them, employment adjustment cost plays a significant role in current inflation, but labour share variable as a proxy for the real economic activities ignores it in the closed economy models.

They estimated this open economy NKPC model developed by themselves for the UK over the sample period from 1972 to 1999. As a result of their estimation, labour share, which is adjusted by employment adjustment cost term, is correctly signed and statistically significant. Another variable real imported production input prices, which is thought to affect the inflation process as a foreign trade factor, is found statistically significant. On the other hand, the coefficients on proxy variable for foreign competition and the output gap are statistically insignificant over the sample period from 1972 to 1999.

In another study, Leith and Malley (2007) develop an open economy hybrid model. In their model, it assumes that firms set their prices under imperfect competition conditions and these firms in the market affected by foreign trade factors while setting their prices. Additionally, they construct an open economy hybrid model which nests both closed and open economy specification. This hybrid open economy model based on their new price-setting model that allows export and substitution of imported intermediate goods for the domestic labour force. Hence,

prices in the global market may affect the price-setting behavior of domestic firms through their marginal costs.

Leith and Malley (2007) estimated their open economy hybrid NKPC for G7 countries over the sample period from 1960 to 1999. Before estimating their open economy hybrid model, they derivate four different models by using different deep parameters in the main model. They estimated these four different models for G7 countries over the period 1960 to 1999. Model 1 and Model 2 represents the closed economy and open economy model, respectively. The other two models differ from each other in terms of Cobb-Douglas production function parameters.

One of the estimation results of these four models is that there is no significant difference in terms of deep parameters between models. All of these deep parameters, that firms' steady-state discount factor, frequency of price setting, the proportion of firms which adopt the rule of thumb pricing behaviour and elasticity of substitution between the labour force and imported intermediate goods, are found very close values for each country and they are statistically significant. As a result of these estimation, in the G7 countries, backward-looking pricing behaviours dominate than forward looking pricing behaviours. Estimations of the degree of nominal rigidities and backward looking rules of thumb are all highly significant for all G7 countries. (Leith & Malley, 2007)

Consequently, the estimation results of these four different models suggests that there are no significant differences between the hybrid open economy and closed economy versions of NKPC for G7 countries. Besides, the closed economy NKPC better explains inflation dynamics for G7 countries than the open economy model. The reason for this, price-setting behaviour is not affected by open economy conditions in G7 countries. Finally, Leith and Malley (2007) argued that their studies would be to incorporate the open economy NKPC into a general equilibrium framework so that the quantitative importance of an endogenous labour share on

price setting and in turn the effectiveness of monetary and fiscal policy could be established.

Rumler (2007) estimated the open economy hybrid model for the Euro Area and 9 Euro countries² over the sample period from 1980 to 2003. Additionally, Rumler extended existing NKPC literature by incorporating three domestic and imported production functions. In the study of Rumler (2007), inflation is a function of imported intermediate goods as well as domestic intermediate goods and labour share as a proxy for real economic activities. On the other hand, Rumler (2007) compared the estimation results of two open economy models with a closed economy model for the Euro Area and 9 European countries.

Whereas one of these two open economy models include only imported intermediate goods, the other open economy model includes both imported and domestic intermediate goods in the production process as well as other explanatory variables. The estimation results show that the second open economy model, which includes both imported and domestic intermediate goods variables, better explains the inflation dynamics for 9 Euro countries. When comparing closed and two open economy models, the open economy models better explain inflation process for 9 Euro countries than the closed economy model. (Rumler, 2007)

Rumler (2007) found two important relationship regarding openness degree economic size and price rigidity. When considering these 9 Euro countries in terms of the openness degree and economic size; price rigidity of large and relatively close countries is higher than price rigidity of small and relatively open countries. In the study, whereas the rank correlation between the estimated price rigidity and economic size of each 9 Euro countries is equal to 0.73, the rank correlation between

² Germany, France, Italy, Belgium, Spain, Greece, Netherlands, Austria, Finland

the estimated price rigidity and openness degree of 9 Euro countries is equal to 0.5. It means that the first relation is more pronounced than the second relation.

In the study of Rumler (2007), when considering price rigidity parameters in closed and open economy models, coefficient on price rigidity parameters in the open economy hybrid model are higher than in the closed economy model. Whereas Leith and Malley (2007) did not find a significant difference in price rigidity across closed and open economy models for G7 countries, Rumler found a significant difference across these models for these 9 European countries.

Considering two open economy models of Rumler (2007), coefficient on price rigidity in the open economy hybrid model, which includes only imported intermediate input, is higher than in the open economy model that includes both imported and domestic intermediate input. It is thought that the main reason for these differences is that the open economy hybrid model, which includes both domestic and imported intermediate inputs, has higher substitutability than the open economy model that does not allow substitution between domestic and imported intermediate goods.

In empirical study of Rumler (2007), the effects of foreign trade factors on inflation through domestic marginal cost is statistically insignificant. Rumler (2007) emphasized country size and openness degree for the effects of foreign factors on inflation. When these two opposite factors are in balance, price rigidity has not been affected by foreign trade factors. In other words, in a country that has enough size and openness degree, prices of imported intermediate and final good in the global market have not significant impact on domestic inflation process.

In another important study, Kara and Nelson (2003) focused on inflation dynamics and the relationship between inflation and exchange rate in the UK for the sample period from 1964 to 2001. Instead of considering all imported goods as final

consumer goods, in their alternative model, imported goods consist of final consumer goods and intermediate goods.

As mentioned previously, the coefficient on openness degree parameter theoretically must be positive and statistically significant in the open economy NKPC due to the fact that an increase in the openness degree causes less elasticity of inflation to the output gap. Kara and Nelson (2003) estimated the open economy NKPC by using both the labour share and output gap as a proxy for real economic activities. However, an important finding of Kara and Nelson (2003) is that openness degree parameter is signed negative contrary to theoretical expectation.

Allsopp et al. (2006) estimated open economy NKPC for the UK and Australia over the sample period from 1964 to 2002 and sub-sample period from 1980 to 2002. In their empirical study, labour income share is used as a proxy for real economic activities and is found statistically insignificant. Additionally, openness degree parameter is positive as expected but it is not statistically significant similar to Kara and Nelson (2003). The openness degree parameter is not correctly signed for Australia. On the other hand, in the sub-sample period, the openness degree parameter is not correctly signed (less than zero) despite statistically significant.

Mihailov et al. (2011) tested GM-NKPC for small and open 10 OECD countries³ by using the GMM estimation method over the sample period from 1963 to 2002. As a result, openness degree parameters are signed negative (incorrectly as theoretical) for Australia, France and Spain. On the other hand, openness degree parameters are statistically significant and signed positive (correctly as theoretical) for the other seven countries: Germany, Italy, Netherlands, United Kingdom,

³ Austria, Canada, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom.

Canada, Sweden and Switzerland. Results indicate that GM-NKPC weakly explains inflation dynamics for small open economy OECD countries. There is not strong support to the GM-NKPC in explain inflation dynamics for these 10 OECD countries.

Similarly, Abbas et al. (2015) estimated GM-NKPC, which is derived by Gali and Monacelli (2005), for Australia over the sample period from 1959 to 2010. They contributed to the existing empirical literature by deriving new specifications in terms of foreign trade and the real exchange rate. In the result of their study, however, there is no evidence about the validity of GM-NKPC similar to the studies previously mentioned. Like other structural parameters such as elasticity of substitution imported final and intermediate goods, the openness degree parameters are not statistically significant in most cases the terms of foreign trade and real exchange rate.

Finally, Abbas et al. (2016) explain inflation dynamics for four developed countries⁴ by using four different models: closed economy, open economy and open economy hybrid NKPC and GM-NKPC. They used the sample period from 1974 to 2010 for open economy models and from 1959 to 2011 for the closed economy model. The results of their paper indicate that open economy NKPC has better explanatory variables compared to GM-NKPC. Furthermore, estimation of closed economy NKPC by using disaggregated microeconomic and sectoral level data outperforms estimation by using aggregate data.

Considering empirical studies focused on open economy models in this section, although open economy models have a strong theoretical foundation regarding foreign trade factors, explanatory variables in the open economy models are not statistically significant for each open economies. The openness parameters in

⁴ Australia, Canada, New Zealand and United Kingdom

empirical studies examined in this section are either statistically insignificant or incorrectly signed in most cases for several open countries. The closed economy models better explain the inflation process for several open economies in some studies as mentioned. These results indicate the relationships observed by Rumler (2007).

Rumler (2007) found that two significant relationships. The first one is a positive relationship between size and price rigidity of countries. The second one is the negative relationship between openness degree and price rigidity of countries. The impact of foreign trade factors on the domestic inflation process depends on these two opposite relationships. If a country is enough large and open, foreign factors may not affect enough to change domestic marginal costs. Therefore, in the open economy NKPC, structural parameters about foreign trade factors may be either statistically insignificant or incorrectly signed.

The studies focused on open and large economies show that foreign trade factors may have an insignificant impact on the domestic inflation process. However, the open economy model of Mihailov et al. (2011) successfully captures inflation dynamics in small and open economies. Consequently, in addition to the openness degree of countries, the size of countries may have a significant impact on the validity of the NKPC models to explain the inflation process.

Considering the empirical literature reviewed in this section, there are two main discussions regarding open economy models. The first discussion is related to imported goods in the models. According to open economy models of some studies, important goods consist of both imported intermediate goods and imported final goods whereas some studies assume that imported goods consist of only final imported goods. The other discussion is related to determinants of the effects of foreign trade factors on domestic inflation as previously discussed. Table 2.2

summarizes the main findings and discussions of empirical studies examined open economy models.

Table 2.2: Empirical Findings of The Open Economy NKPC Models

Studies	Countries	Sample Period	Estimation Method	Main Results
Batini et al. (2005)	UK	1972-1999	GMM	The open economy NKPC explains inflation dynamics for UK. Import prices is statistically significant.
Leith and Malley (2007)	US	1959-1996	GMM	Results of estimation open economy NKPC with sectoral data indicate that two-thirds of firms are based on forward looking in price adjustments.
Bardsen et al. (2004)	UK and Euro Area	1972-1999 for UK 1971-1998 for Euro Area	GMM and 2SLS	Open economy NKPC does not capture inflation dynamics. The coefficients of open economy NKPC are not robust.

Rumler (2007)	9 Euro countries	1980-2003	GMM	Hybrid open economy NKPC capture inflation dynamics for these 9 Euro countries.
Leith and Malley (2007)	G7 Countries	1960-1999	GMM	Backward-looking pricing behaviours dominate than forward-looking pricing behaviours for G7 countries.
Kara and Nelson (2003)	UK	1964-2001	GMM	The estimated openness degree parameter is incorrectly signed.
Allsopp et al. (2006)	UK and Australia	1964-2002	GMM	The estimated openness degree parameter and labour income share are not statistically significant. The openness degree parameter is not correctly signed.

Guay et al. (2003)	Canada	1970-2000	GMM	Both openness degree parameter and labour income share are not statistically significant.
Mihailov et al (2011)	10 OECD Countries	1970-2007	GMM	The estimated openness degree parameter is not correctly signed for Australia, Spain and France and it is not statistically significant for other seven OECD countries in spite of correctly signed.
Abbas et al. (2015)	Australia	1959-2009	GMM	The openness degree parameter is not correctly signed. The price rigidity parameter is not statistically significant. The openness degree parameter with terms of foreign trade and the exchange rate does not drive the inflation process.

Abbas et al. (2016)	Australia, Canada, New Zealand and the UK	1959-2011	GMM	Open economy NKPC, which consists of intermediate goods prices, has better explanatory variables compared to open economy NKPC incorporating real exchange rate.
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2.3. The Relationship Between Globalization and Inflation Process Under Philips Curve Models

Globalization means to increase in trades of goods, services and production factors such as intermediate goods or labour between countries in the world. In other words, globalization refers to the increase in the integration of national markets with each other. Globalization makes national markets more sensitive to the dynamics of the global market. The increase in globalization provides access to cheaper sources. Domestic firms can decrease their marginal costs or increase sales as a result of increases in globalization. A decrease in marginal cost through increase in globalization would lead to a decrease in domestic inflation.

The tendency to increase in globalization in the early 1990s coincided with a decrease in the inflation rate in the world. This period has played a crucial role in the inflation process. Depending on the openness degree and size of countries, the elasticity of inflation to marginal cost might have been affected through globalization. Additionally, domestic inflation might have become more sensitive to foreign economic activities than domestic economic activities due to globalization. Because production conditions of many countries such as resource capacity, potential

production level and production techniques have changed during this globalization period.

In this section, firstly, empirical results of studies that investigate the relationship between globalization and inflation dynamics by using the Phillips Curve and its augmented versions with new variables regarding globalization are examined. Whereas some of these studies support the effect of globalization on domestic inflation, others do not support the effect of globalization on the inflation process for some countries. Secondly, how globalization and its result such as foreign competition reflect structural parameters of the Phillips Curve models is discussed. Moreover, this section also covers evidence regarding the importance of country size and openness degree in the effects of globalization on inflation.

In the early 1990s, Romer (1993) empirically investigated the relationship between inflation and globalization. In his study, 143 countries are investigated by using linear regression with data after the collapse of the Bretton Wood system in 1973. As a result of the study of Romer (1993), there is a significant and negative relationship between globalization and inflation. Romer explains this relationship by using perspectives of political stability, independence of central banks and monetary expansion.

According to Romer (1993), unanticipated monetary expansion has more negative effects in open economies compared to closed economies. Thus, in open economy countries, monetary authorities would not prefer an expansionary monetary policy that causes exchange rate depreciation. Thus, contractionary monetary policy would lead to a low inflation rate in open economies. Additionally, Romer (1993) argues that the negative relationship between openness and inflation could arise through endogenous openness or government preferences about budget policy. Moreover, Romer (1993) demonstrates that openness leads to lower average inflation

in small size countries. These findings are consistent with the results of Romer's about open economy NKPC in 2007 as previously discussed.

Gamber and Hung (2001) investigated the role of globalization in inflation dynamics for the US in the 1990s. They proposed and tested two hypotheses so as to explain how globalization affected inflation in the US. The first one is the competing-goods effect hypothesis suggests that foreign competition limits the ability of domestic firms to increase the price. The second hypothesis is that foreign resource capacity meets domestic excess demand that causes inflation.

In order to test the first hypotheses, Gamber and Hung (2001) estimate regression with panel data. For testing the second hypothesis, they estimate the Phillips Curve. Their findings suggest that both of the two hypotheses are significant for the US inflation in the 1990s. According to them, foreign resource capacity provides the ability of domestic firms to buy cheaper production inputs from foreign markets. Additionally, foreign competition, as a result of globalization, may limit the increase in domestic price. Therefore, there is a strong relationship between globalization and inflation through these two channels for the US inflation in the 1990s.

In the study of Gamber and Hung (2011), foreign resource capacity regards as the global or foreign output gap. Similar to the study of Gamber and Hung (2001), Bario and Filardo (2007) focused on the effect of foreign resource capacity in domestic inflation by expanding sample countries that contain 16 advanced countries as well as Euro Area. Their strategy is to test the traditional Phillips Curve by expanding its specification with foreign factors such as import prices and oil prices. They suggest three important findings.

One of their findings is low sensitivity of inflation to the domestic output gap due to globalization. The reason for this finding is that greater credibility of

monetary brings about stable and lower inflation. Another finding of Bario and Filardo (2007) indicates that global measures of economic slack are important and statistically significant for inflation dynamics. The third finding shows that adding domestic and foreign factors to the traditional Phillips Curve might help to capture inflation dynamics after oil shocks in the 1970s. Therefore, Bario and Filardo (2007) showed that inflation dynamics can be explained by the foreign output gap over the sample period from 1985 to 2005.

Pain et al. (2006) focused on an error correction model to observe the effect of globalization in consumer price inflation for 20 OECD countries over the sample period from 1980 to 2005. They found that globalization has reduced the sensitivity of inflation to real economic activities. Additionally, the globalization increased sensitivity of consumer price inflation to import price. This sensitivity has gradually increased during the globalization period from 1980 to 2005. However, the output gap has not played an important role in consumer price inflation for 20 OECD countries during the sample years.

According to Helbing et al. (2006), globalization does not affect inflation, directly. Instead, globalization has a meaningful role in foreign competition. An increase in foreign competition has reduced relative prices and inflation. Helbing et al. (2006) compared four country groups to observe the intensity of the effect of globalization in inflation and prices over the sample period from 1970 to 2004. As a result of their study, the effect of globalization is greater in Industrial Countries⁵ and

⁵ Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK and US

Asian Emerging Markets⁶. Another finding of them is that globalization has reduced the sensitivity of inflation to the output gap in these industrial countries, similarly.

Pehnelt (2007) investigated the relationship between globalization and inflation rate in 22 OECD countries over the sample period from 1980 to 2005. The results provided evidence of the negative relationship between globalization and inflation in 22 OECD countries. As a result of the empirical study of Pehnelt (2007), globalization contributed to the disinflation process in 22 OECD countries since the 1980s. On the other hand, the use of unemployment as a proxy for the domestic output gap is more useful to explain inflation dynamics for these OECD countries. Besides that, economic freedom, central bank independence, and flexible exchange rate policy have contributed to the disinflation process for 22 OECD countries.

However, Ihrig et al (2010) criticized findings reported by Borio and Filardo (2007). According to the results of Ihrig et al. (2010), these findings in favor of a negative relationship between globalization and inflation are not statistically robust. Thus, Ihrig et al (2010) developed an alternative model and tested it. As a result of this investigation, any evidence in favor of the effect of globalization in the inflation process is not found in 11 OECD countries. Moreover, Ihrig et al. (2010) argue that the foreign output gap parameter, which represents foreign resource capacity, is not correctly signed and this parameter is not statistically significant for most advanced countries contrary to results reported by Helbing et al. (2006).

Another study focused on the relationship between globalization and inflation is Calza (2009). Unlike others, Calza (2009) tested the specification of the Phillips Curve augmented by global output gaps. Limited evidence in favor of the impact of foreign resource capacity, which represents global output gaps, is found for Euro Area and many industrial countries over the sample period from 1979 to 2003. Thus,

⁶ China, India, Indonesia, Korea, Malaysia, the Philippines, and Thailand

global resource capacity is not a significant explanatory variable for the inflation process for many developed countries as well as developing countries.

The above studies investigate the relationship between globalization and inflation by using the Phillips Curve. These studies augmented the Phillips Curve models adding new variables regarding globalization and foreign trade factors. In order to observe the impact of globalization in the domestic inflation process, these studies focused on the global output gap known also as the foreign output gap variables. In this section, whereas some of the studies found a significant impact of globalization on the domestic inflation process for some countries, others did not. However, these Phillips Curve augmented by new variables regarding globalization have not microeconomic foundations. The empirical studies that investigate the relationship between globalization and inflation process based on microeconomic foundations and preferences of economic agents are reviewed in the next section.

2.4. The Relationship Between Globalization and Inflation Process Under NKPC Models

In this section, we examine the empirical studies that investigate the relationship between globalization and the inflation process based on the NKPC models. These models include some specific variables regarding globalization such as foreign liberalization compared to open economy models. Sbordone (2010) and Woodford (2007) extend the New Keynesian framework so as to discuss the impact of globalization and global competition on the inflation process.

Sbordone (2010) investigates the effects of globalization on the inflation process based on microeconomic foundations. In her study (2010), the effects of competition, which is brought about by the increase in international trade, in inflation dynamics are examined for the US. Another main topic in the study of Sbordone (2010) is the sensitivity of inflation to the real marginal cost of production. In order

to explain these main topics, the New Keynesian framework is used by Sbordone (2010). Additionally, Sbordone (2010) investigated the question that how is price rigidity affected by the openness of the economy, through the increase in competitiveness generated by some globalization factors such as foreign trade liberalization.

Sbordone (2010) claims that competitiveness has a two-way effect on inflation as directly and indirectly. On the one hand, competitiveness provides domestic firms cheaper production source and causes low production costs as directly. On the other hand, competitiveness creates more creative and innovative firms. Creative and innovative domestic firms produce output with lower cost by increasing productivity, as indirectly. Therefore, thanks to these mechanisms, an increase in competitiveness generated by increase globalization leads to lower inflation.

Sbordone (2010) analyzed the quantitative effect of competitiveness brought about by international trade on marginal costs as well as the effect of marginal cost that is affected by the increase in foreign trade on the slope of the Phillips Curve. She assumes that firms operate in a competitive market. The demand elasticity that depends on the relative market share of the differentiated goods is used by that study, instead of constant demand elasticity. According to the results of the study of Sbordone (2010), globalization or openness degree of countries raises price flexibility through global competitiveness. The empirical results demonstrate the negative relationship between competitiveness and rigidities. However, globalization effects on not only price rigidities but price adjustment behavior also.

According to these empirical results, there is a positive relationship between globalization and price flexibility. The main reason for this relationship is that the demand elasticities of firms increase due to the increase in imported goods. Therefore, countries with low openness degree have high price rigidities than

countries with a high degree of openness because of low demand elasticity. (Sbordone, 2010)

However, this globalization has a significant impact on not only price rigidities but also the frequency of price adjustment that is a key role in the New Keynesian Phillips Curve. Another important result of the study of Sbordone (2010) is that if the inflation rate in a country is relatively low in general, there is a very low incentive of firms to adjust their price. The reason for the low incentive to change price is that the cost of incorrectly price adjusting is very low.

The increase in globalization leads to an increase in both price flexibility and the elasticity of markup declines. These two factors determine the slope of the New Keynesian Phillips Curve. The dominant one of these two factors would either increase or decrease the price rigidities. If there is a balance between these two factors, there is an insignificant effect of openness degree of the country on price rigidities. Therefore, it is unclear whether globalization has an impact on inflation. (Sbordone, 2010)

As previously mentioned, Rumler (2007) claimed that two important relationships; between the size of countries and price rigidity and between the openness of countries and price rigidity. Similar to the findings of Rumler (2007), Sbordone (2010) found the relationship between globalization and price rigidities. However, compared to Rumler (2007), Sbordone (2010) claims that there are two opposite dimensions of this relationship. According to the findings of Sbordone (2010), globalization leads to higher price flexibility and if inflation decreases sufficiently, the propensity of firms for price adjustment frequency decreases as a result. Therefore, whereas a relatively stable and low inflation rate puts downward pressure on price flexibility due to the low cost of misalignment, a high and fluctuating inflation rate puts upward pressure on price flexibility in countries with high openness degree.

Rogoff (2003) is another economist who examines the impacts of globalization, international competition and deregulation in the inflation process as both historical and theoretical. In contrast to the quantitative analysis of Sbordone (2010), Rogoff (2003) discuss the impact of globalization on domestic inflation as qualitative analysis such as policy preferences. According to Rogoff (2003) globalization and deregulation increase competitiveness.

The results of the qualitative analysis of Rogoff (2003) demonstrate the historical period of globalization. Globalization period that started in the 1970s led to the mobilization of capital and labour in many European countries. In particular, the production of goods has started to shift countries that have low production costs during this period. Historically, during the 1980s, governments have removed restrictions in order to receive foreign investment. This mobilization of the production process decreased monopoly pricing power through the increase in global competitiveness.

According to Rogoff (2003), in addition to these indirect effects of globalization and deregulation, there are direct effects of them on inflation. One of them is to decrease on the real cost of production. All of these developments in the 1980s around the world brought about a decrease in global inflation over the next decade. However, Rogoff claimed that indirect and direct effects of globalization and deregulation in the inflation process work as simultaneous.

Another indirect effect of globalization is explained by Rogoff (2003) based on policy preferences perspective. The globalization that started in 1970 has led to less incentive to allow expansionist monetary policy. In a global environment, monetary authorities have not motivation to maintain inflationist policies.

Thus, Rogoff (2003) has reported that two causal mechanisms as a result of his study. According to these findings, on the one hand, competitiveness brought

about by globalization or deregulation leads to a relatively low real price of goods. On the other hand, competitiveness leads to an increase in price flexibility. These findings are consistent with the findings of Sbordone (2010) about the effects of openness on price flexibility. However, Rogoff (2003) does not demonstrate how a sufficiently low inflation rate has an impact on price flexibility. Thus, globalization causes high price flexibility and low inflation but it does not clear the effects of sufficiently and continuously low inflation through higher price flexibility in the next step.

The idea that the inflation process has been changed by globalization is also investigated by Ball (2006). However, Ball (2006) objected interpretation of Rogoff (2003) regarding the relationship between globalization and the inflation process. According to the results of his study, the negative correlation between globalization and the inflation process has been misinterpreted. Actually, inflation and foreign trading data indicate that there is an effect of globalization on inflation. However, the reason for the decreasing trend in inflation is related to other explanatory factors.

The first one of these two factors is the low frequency of nominal price adjustment. According to the study of Ball (2006), low inflation has caused a low frequency of nominal price adjustment. The second one of them is related to the monetary policy applied by the central banks in the process of increasing foreign trading. In the 1990s, monetary policy that applied by central banks decreased inflation. Globalization has not directly impact on inflation. In parallel with Ball (2006), Sbordone (2010) argued that countries applied deregulation policy so as to receive foreign investment.

Consequently, each study of Ball (2006) and Sbordone (2010) coincide about the effect of globalization on inflation. According to them, globalization has a limited effect on inflation. Essentially, only globalization is not enough to change inflation dynamics. If globalization causes low-frequency nominal price adjustment

and deregulation policy via central banks, it can change inflation dynamics. Ball (2006) highlights the effects of globalization on the inflation process in the UK and the US. Although foreign trade volume is higher in the UK than in the US, globalization has more affected inflation dynamics of the UK.

Guerrieri et al (2010) examine the relationship between global competition and domestic inflation in terms of the New Keynesian approach. The study of Guerrieri's et al. (2010) differs from other studies in terms of the use of foreign trade data. In contrary to other open economy models in the empirical literature, they use prices of the domestic tradable goods rather than the prices of all goods and services in the US. There are two reasons for this choice. First, the price of tradable goods reflects the effects of globalization on domestic inflation more directly than the price of all goods and services. Second, owing to the interactions between foreign and domestic producers, they argued that their open economy model is appropriate to observe the effects of globalization.

As a result of their open economy estimation that uses tradable price data, Guerrieri et al. (2010) found that foreign competition has an important role in domestic inflation for the US. Foreign competition decreased domestic good inflation by 2 percentage points in the 1990s in the US. In addition to domestic inflation, these foreign factors such as foreign competition and interaction between domestic and foreign producers affect the production process of goods according to the results of their study.

2.5. The Inflation Expectations in Estimations of NKPC

Since the development of expectations augmented Phillips Curve, the role of expectation on the inflation process has been widely discussed. As a result of these discussions, adaptive expectations or rational expectations formations have been used in empirical studies. In particular, during relatively low and stable inflation

periods, expected inflation is a significant variable to explain the current inflation rate considering empirical studies that use adaptive and rational expectation formations.

In addition to adaptive and rational expectations formation, alternative measurement techniques of expected inflation have come into existence, recently. After monetary authorities adopted explicit inflation targeting regime, in some empirical studies, inflation target of monetary authorities has been started to use as a proxy for expected inflation of economic agents. In addition to the use of inflation target of central banks as expected inflation, international institutions such as OECD forecast inflation for many countries in the world. In this section, we examine the empirical results of studies that use these alternative measurement methods of expected inflation to examine inflation dynamics instead of adaptive and rational expectations formation.

Paloviita (2006) tested baseline and closed economy hybrid NKPC for European Monetary Union Countries by using inflation forecast of OECD as a proxy for inflation expectation of economic agents. Moreover, in the study of Paloviita (2006), NKPC explained inflation dynamics in European Monetary Union Countries by using the inflation forecast of OECD as expected inflation. As a result of study of Paloviita (2006), explanatory variables are correctly signed contrary to many estimations of closed economy NKPC using rational expectation. The hybrid NKPC model, which includes both past inflation and OECD inflation forecast, outperforms closed economy NCPK clearly.

Another measurement method of inflation expectation is to use expectation surveys. These surveys reflect real expectations of economic agents about the future. Zhang et al. (2009) tested NKPC with Survey of Consumers of University of Michigan. Roberts (1995) estimated NKPC by using the expectation survey as well as Livingston Survey published by the Federal Reserve Bank of Philadelphia. There

are significant differences between estimations using survey expectation and estimations using actual past inflation as a proxy for expectation in terms of explanatory variables in the empirical literature.

Dufour et al. (2006) estimated the hybrid NKPC is estimated by using both actual inflation and expectation survey for the US and Canada. In their study, Survey of Professional Forecaster (1970-1997, quarterly) and Board of Canada Survey (1970-2000, quarterly) are used as expectation formation for the US and Canada, respectively. The results of the study of Dufour et al. (2006) point out that the model explains inflation dynamics for the US. However, the model using expectation surveys as expected inflation does not capture inflation dynamics for Canada.

Nunes (2010) integrated two rational expectation models and expectation surveys in the estimation of NKPC models. According to Nunes (2010), different economic agents may form their expectations in different ways. Nunes (2010) objected to use of surveys without considering rational expectations in the estimation of NKPC. He used expectation surveys along with rational expectation formation to estimate the NKPC models. The results of the study of Nunes (2010), which uses both survey and actual inflation expectation, indicate that the expected inflation measured by using expectation survey is a significant determinant of the inflation process. Therefore, in the estimation of NKPC models, the use of only expectation surveys without considering rational expectation formation might bring about misleading results.

In another study, Adam and Padula (2010) tested the closed economy and closed economy hybrid NKPC by using survey expectations for the US over the sample period from 1968 – 2003. They found that the results of estimated NKPC models with inflation expectation survey are consistent with theoretical expectations. The coefficients of structural parameters are correctly signed and statistically significant.

Lopez-Perez (2017) investigated whether expected inflation submitted by European Central Bank's Survey of Professional Forecasters consistent with theoretical implication derived by NKPC for the Euro Area or not. Additionally, Lopez-Perez (2017) analyzed whether expectations submitted by Survey, which is conducted by 120 professionals, are consistent with change explanatory variables of the NKPC after the financial crisis 2007. According to Lopez-Perez (2017), the reason for the chosen financial crisis in 2007 as a breakpoint is that explanatory variables of the NKPC have changed during this financial crisis.

The main finding of Lopez-Perez (2017) is that expected oil prices and unemployment submitted by European Central Bank's Survey are significant variables for inflation dynamics before the financial crisis 2007. However, the effect of unemployment in expected inflation has dramatically diminished during the financial crisis 2007. Additionally, results are consistent with flatter NKPC inflation declared by the International Monetary Fund (IMF) due to structural unemployment and better-anchored expected.

As discussed above, the estimation of NKPC with survey inflation expectation better explain inflation dynamics in some empirical studies. In these studies, in general, it is claimed that the use of actual inflation to measure inflation expectation does not reflect the real expectations of economic agents. Therefore, to better capture real expectations of economic agents, survey inflation expectation should be used rather than actual inflation.

Nevertheless, the use of survey inflation expectation is criticized in terms of the validity and reliability of surveys as well as measurement problems. These surveys may consist of misleading responses. Additionally, they are not able to reflect the correct behaviors of economic agents. Thus, the results of these NKPC studies using survey inflation expectation may be unreliable. (Abbas, Bhattacharya, & Sgro, 2016)

Marfatia (2018) estimated NKPC for the UK by using an extraordinary expectation formation over the sample period from 1991 to 2014. In the study, neither survey nor actual past inflation is used to measure expected inflation data. The expected inflation is formed by using financial market instruments: inflation-indexed bonds in the empirical study of Marfatia (2018). In order to estimate expected inflation, the difference between inflation-indexed bonds and nominal bonds, which is known as the break-even inflation rate, is used by Marfatia (2018). As a result, although the break-even inflation rate does not exactly reflect expectations about the future inflation due to market risk factors, expected inflation estimated from this approach plays a significant role in the inflation process in the UK. Additionally, Marfatia (2018) suggests that expected inflation measured by the difference between the inflation-indexed bond and nominal bond can reflect inflation expectations of economic agents unless the unobserved component approach is ignored.

Rondina (2018) objected to use of expectation surveys and proposed econometric models and Bayesian estimation so as to measure expected inflation. The reason for this proposal is that commonly used surveys roughly captured inflation expectations. Additionally, Rondina (2018) estimate inflation expectation for each agent in the US economy by using these two approaches. As a result, the household's expectations are compatible with the unobservable expectation of firms.

2.6. Weak Identification Problem of NKPC

The specification of NKPC includes expected inflation as an endogenous regressor that is changed or determined by other variables in the model. The existence of this endogenous variable (expected inflation), in the model, requires particular conditions. If other instrument variables are weakly correlated with this endogenous variable, a weak identification problem occurs. This estimation problem is able to affect the estimation results of NKPC.

Ma (2002) is the first study that tested the weak identification problem for NKPC models estimated by Gali and Gertler (2001) for the US. Ma (2002) argued that Gali and Gertler (2001) neglected two critical points for both the closed economy and closed economy hybrid models: observational equivalence and weak identification. As a result, Ma (2002) found that explanatory variables in the hybrid model are weakly identified. Additionally, backward-looking price-setting behavior of economic agents is not quantitatively important.

In comparison to an insufficient explanation of Ma (2002), Mavroeidis (2004, 2005) provides a more satisfying and analytical explanation regarding why weak identification is a crucial estimation problem for NKPC models. Mavroeidis (2005) demonstrates the drawback of the baseline GMM estimation. Mavroeidis (2014) proposes the use of robust inference procedures in order to overcome the drawback of GMM estimation.

The weak identification problem is examined by Nason and Smith (2008) for the estimation of NKPC under the GMM estimation method by using two different robust tests. Firstly, they tested NKPC for Canada, the UK and the US by using weakly identification robust tests based on Anderson and Rubin (1949). As a result, they emphasize that adding more lagged inflation and labour share to the NKPC models is able to overcome the weak identification problem. Even if NKPC consist of all New Keynesian system such as investment saving equation and monetary policy rules, the NKPC cannot be identified under the GMM estimation. (Abbas, Bhattacharya, & Sgro, 2016)

Secondly, Nason and Smith (2008) also used a weak identification robust test based on Guggenberger and Smith (2008) GEL test as well as a robust test developed by Anderson and Rubin (1949) in order to estimate the NKPC models. As a result of this process, they rejected the validity of hybrid NKPC for Canada over the sample

period. However, they found little evidence of forward-looking expectations in the estimation of NKPC models for the US and the UK.

Kleibergen and Mavroeidis (2009) examined the weak identification problem for NKPC models under the GMM estimation. They provided a satisfactory explanation about the occurrence of the weak identification problem. Thus, according to their study, limited dynamics of labour share in the model leads to weak identification problem with GMM estimation. The coefficient on labour share as a proxy real marginal cost is nearly zero. Therefore, the labour share variable is not a proper proxy for real marginal cost to explain inflation dynamics.

Additionally, Kleibergen and Mavroeidis (2009) provided the extension of conditional likelihood ratio statistics. Even if there is a weak identification problem in the NKPC models, the estimation of NKPC models provide reliable results thanks to this extension. According to these reliable results, the slope of NKPC, which is represented by structural parameters, is smaller after 1984 for the US. This situation indicates more flatter NKPC rather than steeper for the US.

Considering all studies examined in this chapter, there are three empirical discussions in the empirical literature. The first discussion is related to the specifications of the NKPC models. The second discussion consists of the effects of globalization on the inflation process. The third discussion is related to the expectation formations used in estimation NKPC models. An empirical study should take into account several points as related to these crucial discussions in the empirical literature to estimate the NKPC models. The first point is the openness degree and size of countries as related to the model specification discussion. Another important point is the foreign trade conditions of countries as related to globalization discussions. Before the estimation of the NKPC models, we examine these crucial points for our sample countries in the next chapter.

CHAPTER THREE

MACROECONOMIC OUTLOOK OF G7 COUNTRIES

This chapter aims to examine macroeconomic outlook of G7 countries chosen as large and open countries in this study. Since openness degree and size of countries are significant variables for the NKPC models, macroeconomic outlook provides a comprehensive review about openness degree and size of countries. The examination of macroeconomic conditions in G7 countries provides a comprehensive insight into the estimation results of the NKPC models.

The Group of Seven (G7) is an international economic organization that consists of seven largest economies: Canada, France, Germany, Italy, Japan, the US and the UK. As of 2019, the G7 countries have approximately 54% of global net wealth (Global Wealth Report, 2019). The G7 countries represent more than 44% of global gross domestic product. These economic magnitudes, which represented by the largest seven countries, are significant both for their own economic dynamics and for rest of the world.

The G7 countries have approximately 47.8 % of all exports worldwide in 2018. Considering the high globalization degree in the world, an economic fluctuating in the G7 countries has a significant impact on the rest of the world due to economic magnitudes of G7 countries. However, small and open countries may not have enough impact to affect the domestic variables of the G7 countries. Therefore, an examination of macroeconomic conditions in the G7 countries provides an extensive review in terms of estimation of NKPC models for G7 countries.

To this end, macroeconomic indicators, which are significant for the estimation of NKPC models, are examined over the sample period from 1980 to 2019 in this chapter. First, inflation as a dependent variable is examined for all G7

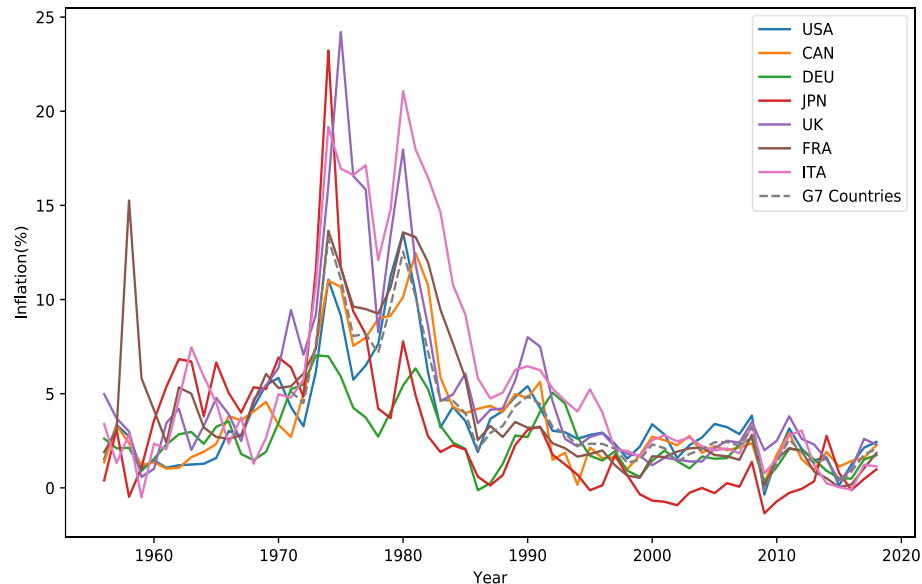
countries. Second, labour market conditions in the G7 countries are investigated. The final section contains examinations of openness and size in G7 countries.

3.1. Inflation in G7 Countries

The global economy entered the twentieth century with a greater flow of capital in human history than ever before. In this period, the production of goods and services increased and expansion of production triggered global output and trade. The domestic firms were able to buy production factors at a lower price decreased domestic inflation gradually. On the other hand, the mobility of goods and services enabled domestic households to buy cheaper final goods and services. The expansion, which continued for more than a decade, was interrupted during the First World War. The interruption was followed by the Great Depression and the Second World War.

However, the second half of the twentieth century has witnessed significant changes in the inflation rate worldwide. Economic revival and intensification of globalization supported by some policy change toward a restoration of the post-war. In addition to the domestic policies change, technical progress and international economic policies, which supported by multilateral cooperation contributed to economic revival. This restoration after post-war led to rapid economic growth in a relatively low inflation environment. The inflation rate in most industrialized countries was a single digit from the middle of the 1950s to the middle of the 1970s.

Figure 3.1: Inflation rate in G7 countries



Source: OECD, General Statistics, <https://stats.oecd.org/>

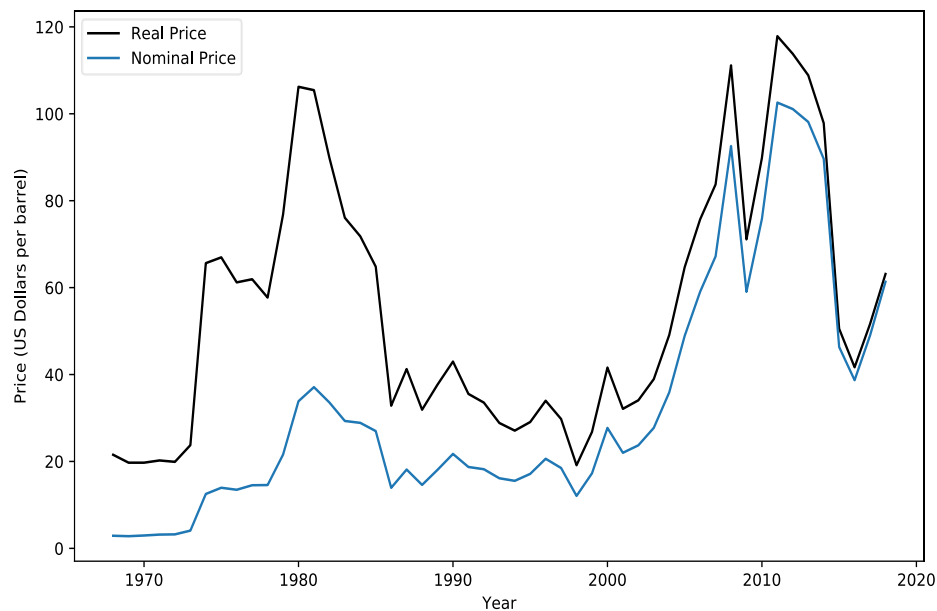
The trend of inflation in G7 countries over time is illustrated in Figure 3.1. Average inflation in G7 countries increases from around 2.31% in 1956 to above 5.12% in the early 1970s. The average inflation in G7 countries is approximately 3.82% in the period 1956-1973.

However, the 1970s marked a watershed in G7 countries. The United States, which had been incurring the current account deficit for about ten years due to Vietnam War expenditure, announced that the gold convertibility of the US dollar was suspended in 1971. Bretton Woods system in force since 1944 was abandoned by the US, Japan and major European countries in 1973. Thus, the overwhelming majority of countries have adopted a flexible exchange rate system. On the other hand, the 1973 oil crises appeared in the same period. In a very short period of time,

oil exporter countries increased nominal oil prices nearly quadrupled. As a result of oil price shock, many oil importer countries found their oil cost and some of them went into recession.

As can be seen from Figure 3.1, as of 1973, an increase in the inflation rate of G7 countries is observed. While the average inflation rate of G7 countries is a single digit in the period 1956-1973, it increases to 14.44% at the end of 1974. The rise in the inflation rate of G7 countries resulting from oil price shock continued until the middle of the 1980s. As can be seen from Figure 3.2, the real oil price had peaked in 1980 and decreased sharply in the middle of the 1980s.

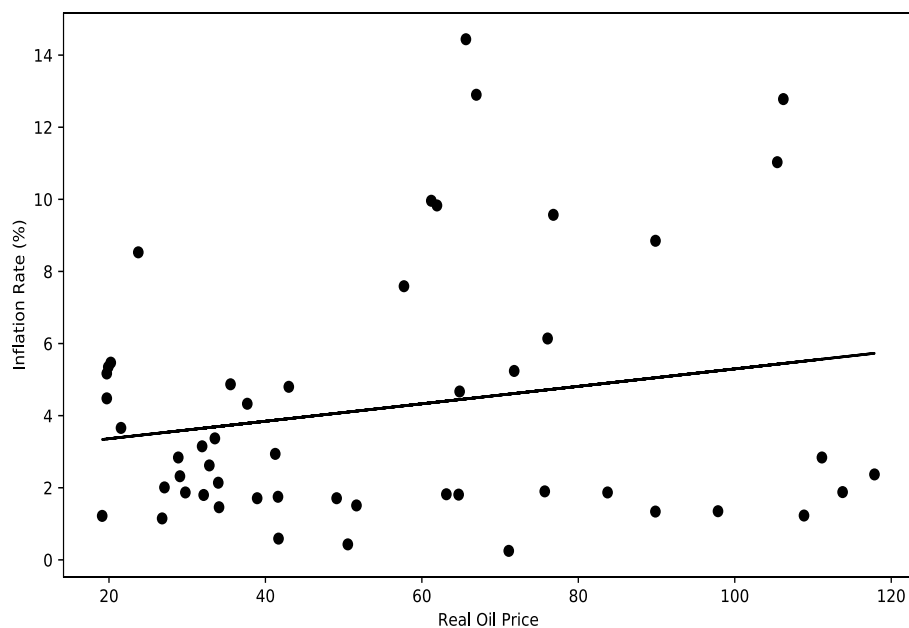
Figure 3.2: Global Oil Price



Source: U.S Energy Information Administration, Petroleum & Other Liquids,
<https://www.eia.gov/petroleum/>

During the oil crisis, inflation and oil prices moved in parallel since oil price was a significant determinant of inflation through marginal cost. As can be seen from Figure 3.3, the relationship between the inflation rate and oil price was positive and strong during this period. However, the sensitivity of inflation to oil prices has gradually decreased in G7 countries. Although there has been an increase in oil prices in the 2000s, the inflation rate of G7 countries has been continued to decline. After the middle of the 1980s, there has been a downward trend in the average inflation rate of G7 countries.

Figure 3.3: The Relationship Between Real Oil Price And Inflation Rate In G7 Countries



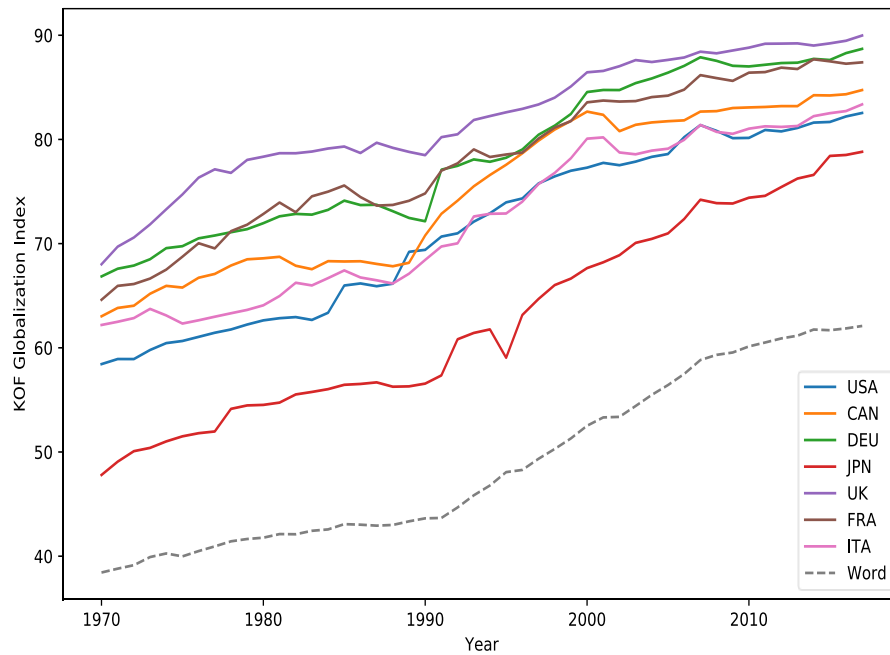
Source: OECD, General Statistics, <https://stats.oecd.org/> ; U.S Energy Information Administration, Petroleum & Other Liquids, <https://www.eia.gov/petroleum/>

As can be seen from Figure 3.1, over the past 40 years inflation has moderate considerably in G7 countries. In G7 countries, average inflation has declined from above 14% in the early 1980s to less than 5% in 2019. Japan and Italy, two of the G7 countries, witnessed negative inflation in this period. The average inflation rate of G7 countries was approximately -0.13% in 2009.

Prior to the middle of 1980, the reason for the rise in inflation regarded as an increase in oil prices. However, as can be seen from Figure 3.2 and Figure 3.1, although oil price has increased as of 2000, the inflation rate of G7 countries continued to decline in this period. In other words, the sensitivity of inflation to oil price has decreased. The reason for the fall in inflation is thought that increase in globalization according to another approach.

Even though globalization is usually measured by foreign trade between countries, its dimension includes social, financial and political fields as well as economic. Any change in one of these fields reflects others and may transform it. Recently, globalization has been addressed in more detail and it has been measured considering its components. Therefore, particular globalization indices have been created by attributing different weights to their components.

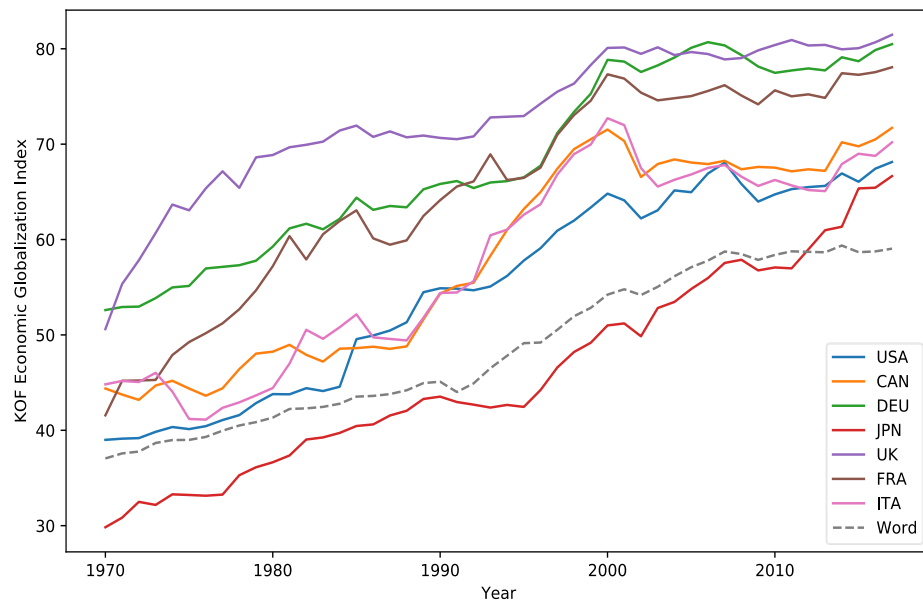
Figure 3.4: KOF Globalization Index



Source: KOF Swiss Economic Institute, <https://kof.ethz.ch/en/data/kof-time-series-database.html>

KOF Globalization Index was introduced by Dreher (2006) to examine the effect of globalization on economic growth and updated in Dreher et al. (2008). Their Globalization Index consists of 23 variables and three main dimensions: economic, political and social integrations. Gygli et al. (2019) revised KOF Globalization index by using 43 variables instead of 23 in the original version. Additionally, they measured globalization as both “de facto” and “de jure”. Figure 3.4 shows KOF Globalization Index, including economic, social and political globalization, for G7 countries and the world from 1970 to 2017.

Figure 3.5: KOF Economic Globalization Index

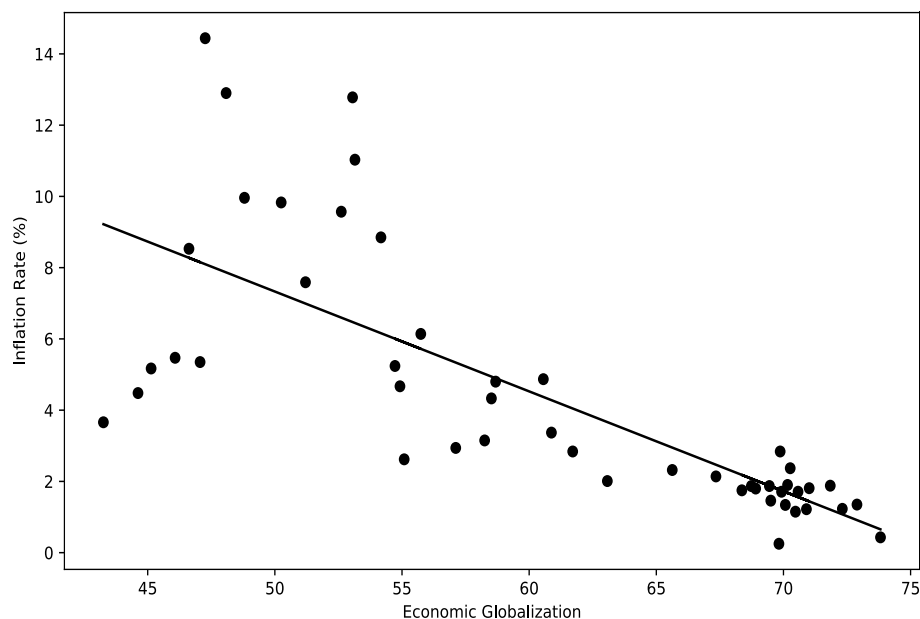


Source: KOF Swiss Economic Institute, <https://kof.ethz.ch/en/data/kof-time-series-database.html>

As can be seen from Figure 3.4, globalization has been on the rise since the early 1970s not only in G7 countries but also around the world. Considering the KOF Globalization Index, there has been an increase in social and political fields as well as economic fields. Figure 3.5 shows that economic globalization in G7 countries is greater than average of the world. Although economic globalization in Japan was less than average until the 2010s, it caught up with average in 2012. The end of the Cold War between the East and West Blocks in 1991 accelerated the globalization process. However, Figure 3.5 indicates a relatively stable trend in economic globalization in G7 countries except for Japan since 2000.

Figure 3.6 shows the basic relationship between the economic globalization index and inflation. After 1980 in G7 countries, the decreasing trend in inflation has coincided with the increasing trend in economic globalization including foreign trade. The increase in foreign trade between countries has led to a fall in sensitivity of inflation to domestic conditions.

Figure 3.6: Relationship Between Economic Globalization and Inflation Rate in G7 Countries

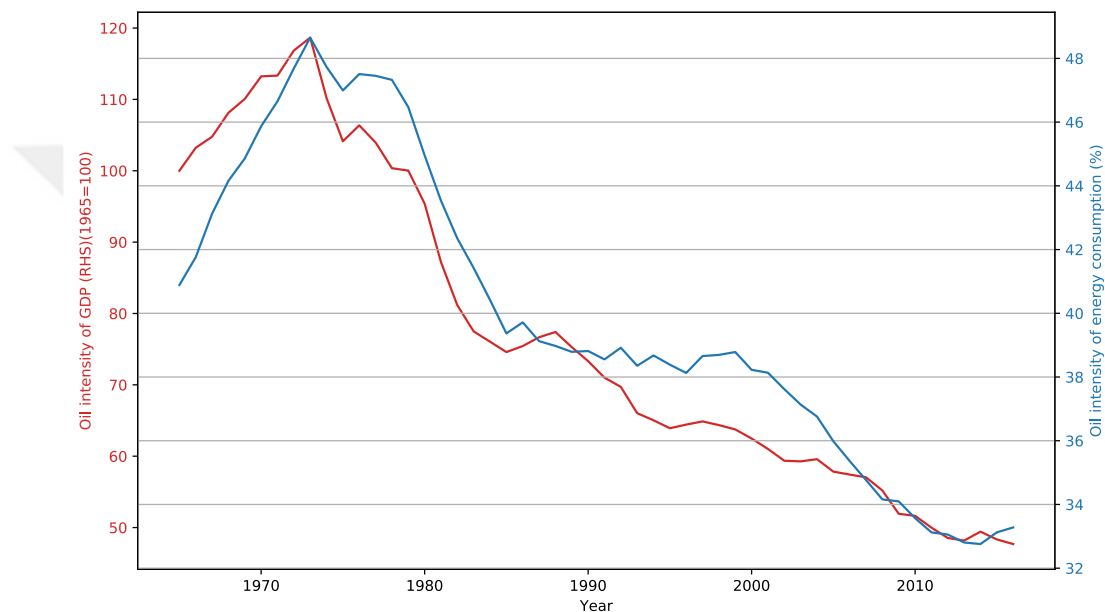


Source: OECD, General Statistics, <https://stats.oecd.org/> ; KOF Swiss Economic Institute, <https://kof.ethz.ch/en/data/kof-time-series-database.html>

Instead of domestic economic conditions, access to cheaper production factors such as raw materials in the global market following an increase in globalization has brought about a low marginal cost of production. This process has

ended up with relatively lower inflation. On the other hand, import prices have become a significant determinant of domestic inflation.

Figure 3.7: Oil Intensity of GDP and Oil Intensity of Energy Consumption in the World

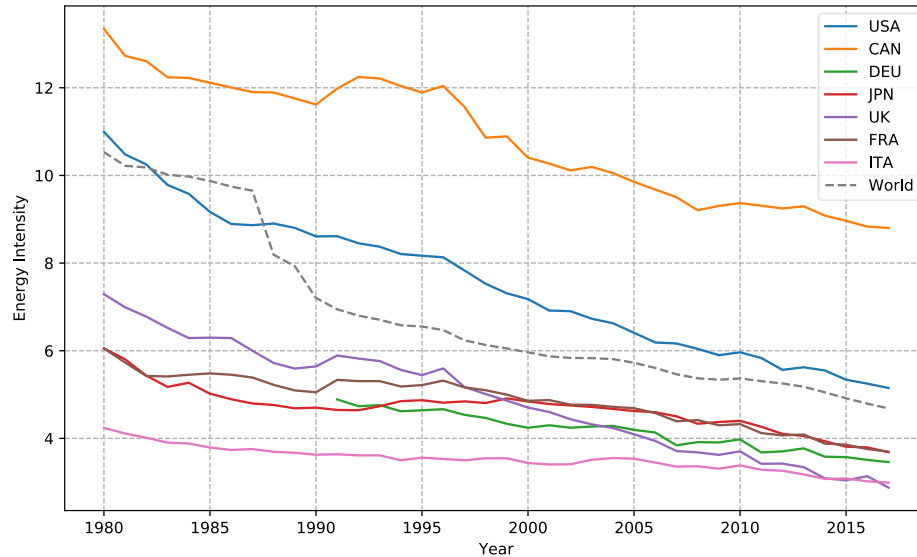


Source: World Bank, World Development Indicators,

<https://databank.worldbank.org/>

Shortly, in the G7 countries, the downward trend in the inflation rate since 1970 can be accounted for by a rise in globalization and by a fall in oil prices. Additionally, as can be seen from Figure 3.7, in this period, the oil intensity of energy consumption has reduced gradually. Besides, the energy intensity of GDP, which is calculated as units of energy per unit of GDP, has decreased since 1980, gradually as can be seen from Figure 3.8. Thus, recently, these factors have decreased the effect of energy prices (especially oil) on inflation compared to previous periods in G7 countries.

Figure 3.8: Energy Intensity of GDP in the World



Source: U.S Energy Information Administration, <https://www.eia.gov/petroleum/>

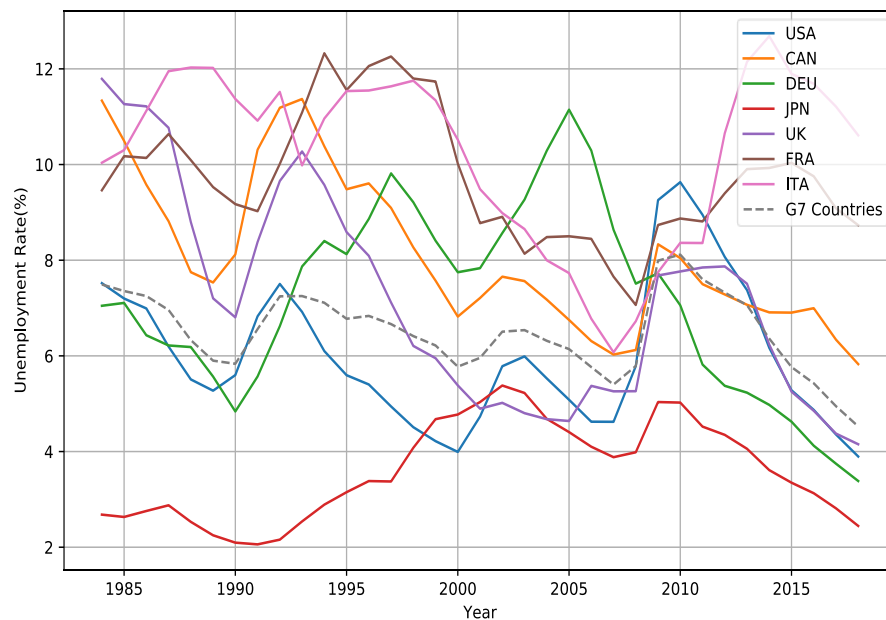
3.2. Labour Market Conditions in G7 Countries

Wage is a significant determinative of unemployment. In the short run, the wage is assumed as marginal cost due to constant capital assumption. Since marginal cost reflects prices, economists have built a relationship between inflation and unemployment since the original Phillips Curve. In this relationship network, labour market occupies an important place to understand inflation dynamics. Therefore, this section consists of labour market conditions in G7 countries.

3.2.1. Unemployment

In G7 countries, unemployment rates have fluctuated dramatically since the middle of the 1980s. As can be seen from Figure 3.9, whereas the country with the lowest unemployment rate is Japan, the country with the highest unemployment rate is Italy in 2019 among G7 countries. The unemployment rate of other G7 countries has fluctuated between 12% and 4%. On the other hand, the average unemployment rate of G7 countries equals to approximately 5% in this period. Apart from Italy and France, there has been a downward trend in the unemployment rate in G7 countries as of 2010.

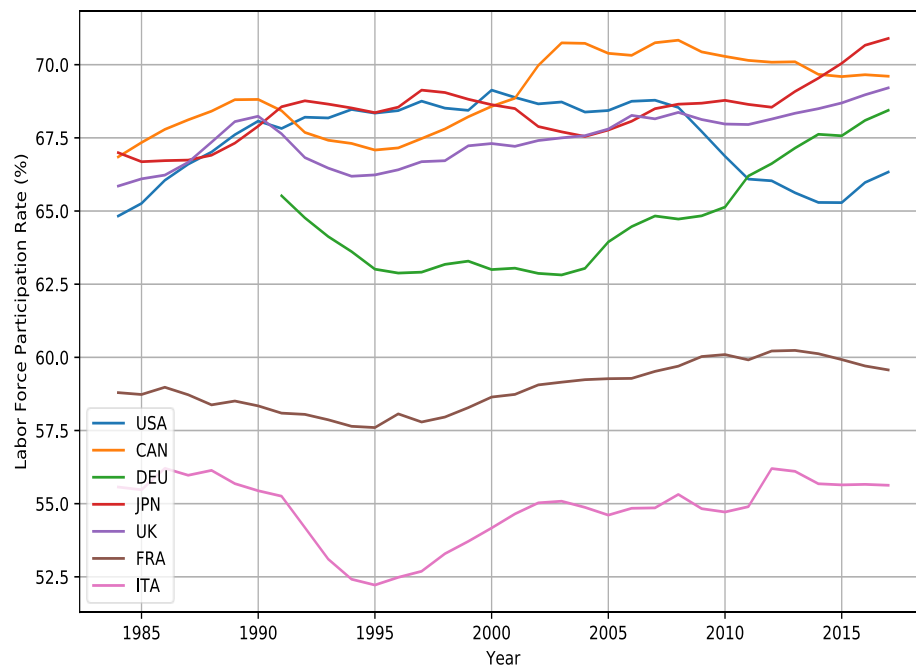
Figure 3.9: Unemployment Rate in G7 Countries



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

Even though unemployment rates of G7 countries have fluctuated dramatically, the labour force participation rate has been relatively stable. Italy has both the lowest labour force participation rate and the highest unemployment rate. As seen from Figure 3.10, labour force participation rates of Canada, the United Kingdom and Japan are very close to each other. Germany has caught up with the top three countries in the labour force participation rate. Additionally, the unemployment rate in Germany has definitively decreased in spite of an increase in the labour force participation rate.

Figure 3.10: Labour Force Participation Rate in G7 Countries



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

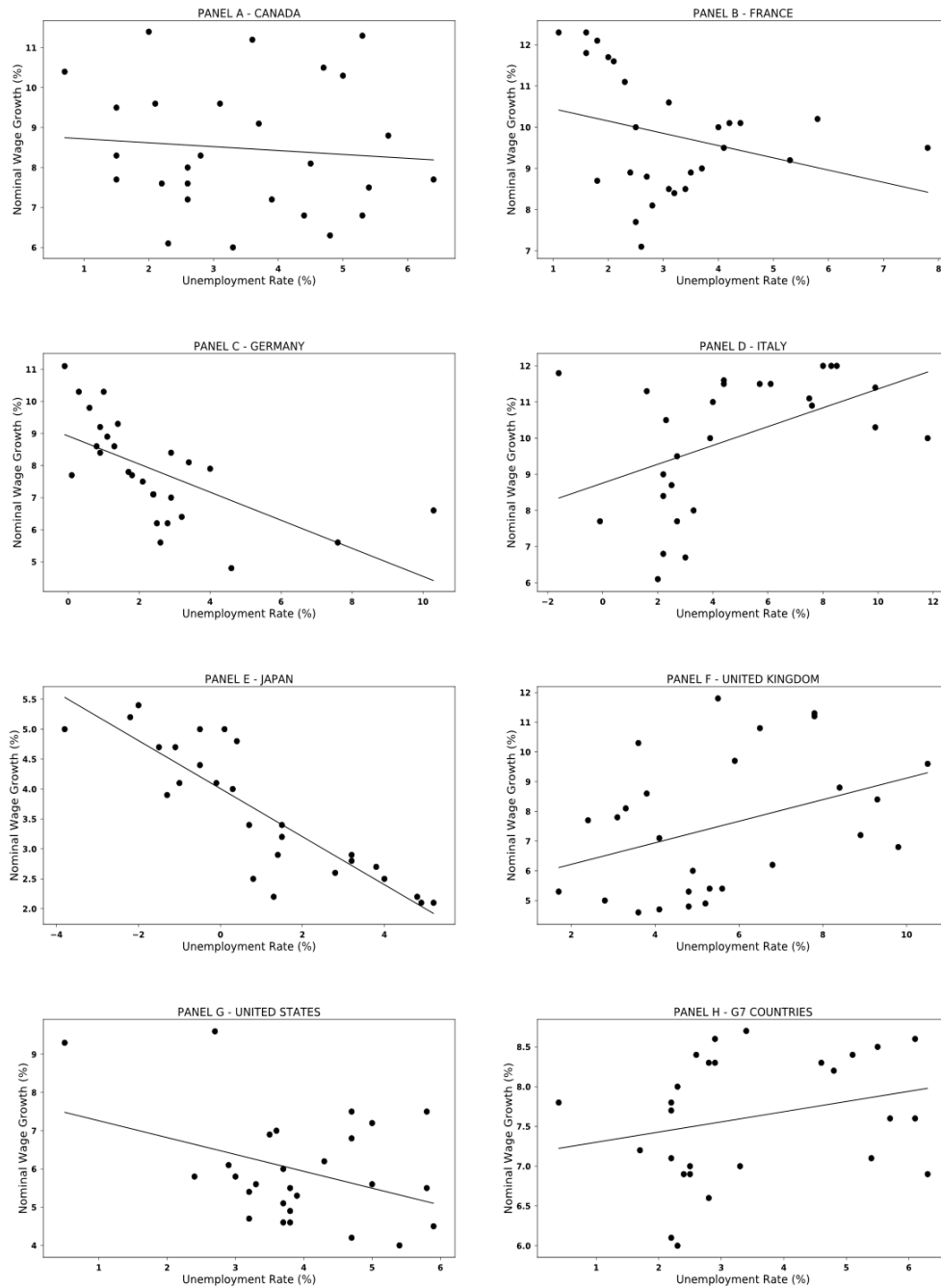
3.2.2. Real and Nominal Wage

Nominal wages are measured as compensation per employee in many economic assessment reports. Real wages are calculated using consumer expenditure deflator. The relationship between growth rates of both and unemployment is a significant indicator of the labour market. Theoretically, labour demand is a function of wage and there is a positive relationship between unemployment and wage. However, there is sometimes a negative relationship between nominal wage and unemployment due to time inconsistency.

As seen from Figure 3.11, whereas there is a negative correlation between nominal wage growth and unemployment in some G7 countries such as Germany, Japan, France, Canada and United State, in others there is a positive correlation. Besides, there is an apparent positive correlation between them in Italy and the United Kingdom. In G7 countries, a clear positive relationship between nominal wage growth and unemployment has been observed, averagely.

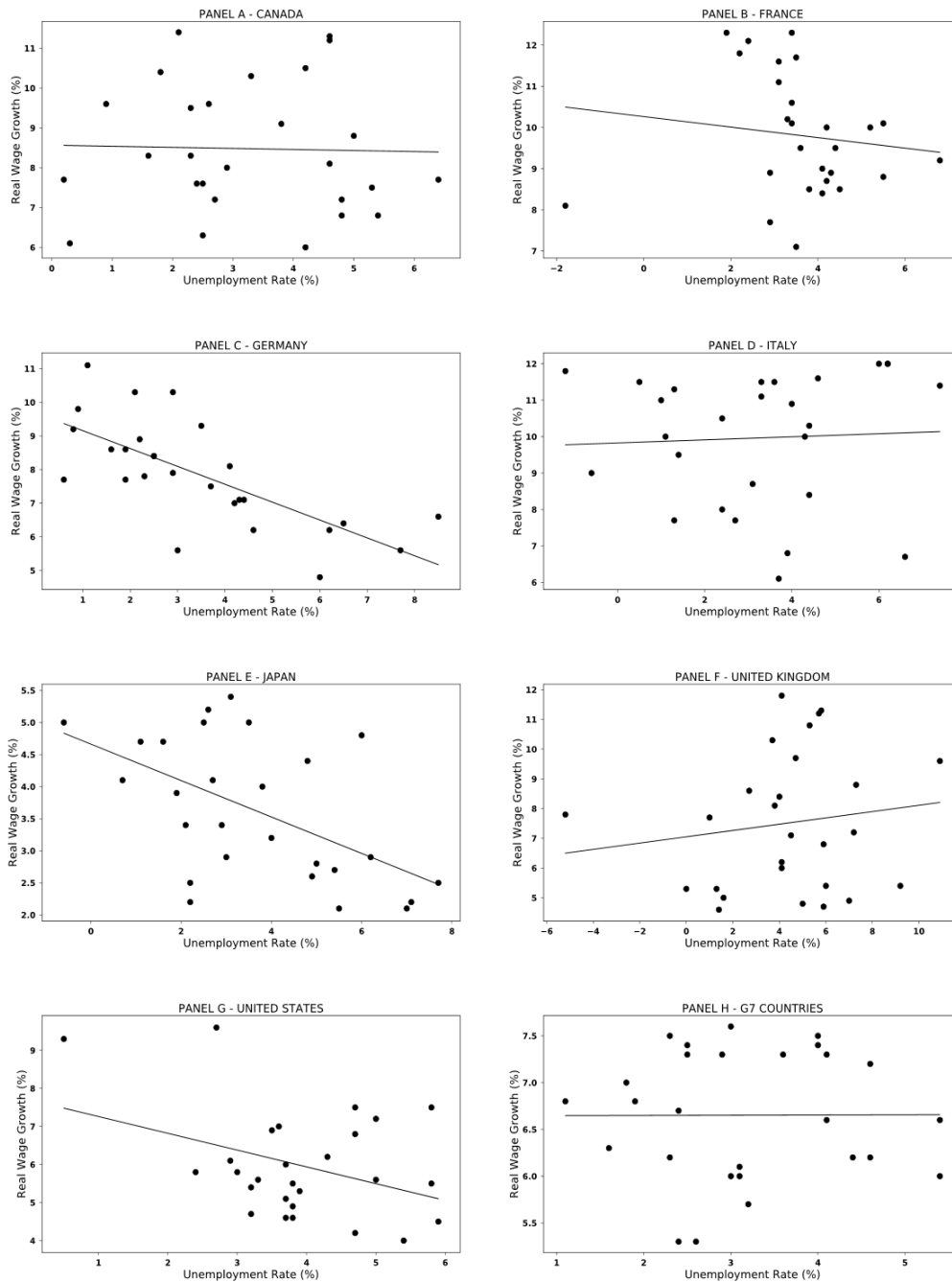
Figure 3.12 shows the relationship between the unemployment rate and real wage growth, which is nominal wage deflated using consumer expenditure deflator (2016). In Canada, France, Germany Japan, United States negative relationship between real wage growth and unemployment has been observed similar to the relationship between nominal wage growth and unemployment. On the other hand, in Italy and the United Kingdom, there has been a positive relationship contrary to others. Even though the relationship between reel wage growth and unemployment is similar to the relationship between nominal wage growth and unemployment, unemployment elasticities of real and nominal wages are different from each other. When G7 countries are considered as general, there is a relatively high correlation between nominal wage growth and unemployment but scatter graph of real wage growth and unemployment has horizontally trend line.

Figure 3.11: Relationship Between Nominal Wage and Unemployment



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

Figure 3.12: Relationship Between Real Wage and Unemployment



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

3.2.3. Unit Labour Cost and Labour Productivity

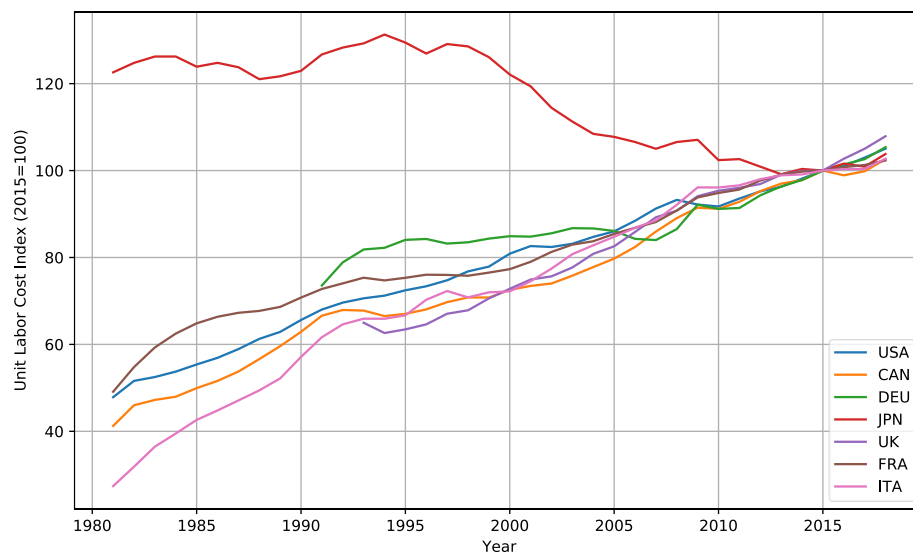
Unit labour cost is usually regarded as a proxy for international price competitiveness since it is a significant production factor. In other words, unit labour cost refers to how much workers earn to produce one unit of output. It is measured as an average labour cost per output unit. Compensation is a proper proxy for average labour cost. Thus, unit labour cost is calculated as the ratio of labour compensation to output in many studies.

$$\text{Unit Labour Cost} = \frac{\text{Compensation}}{\text{Output}} = \frac{\frac{\text{Compensation}}{\text{Hour Worked}}}{\frac{\text{Output}}{\text{Hour Worked}}} \quad (3.1)$$

$$\frac{\text{Output}}{\text{Hour Worked}} = \text{Labour Productivity} \quad (3.2)$$

In another way to express unit labour cost, it is equal to the ratio of compensation per hour over output per hour. As can be seen from Equation 3.1 and Equation 3.2, actually unit labour cost related to labour productivity, negatively. An increase in hourly output tends to decrease unit labour cost. Therefore, low unit labour cost indicates a more competitive country in the global market. However, whether the reason for low unit cost is high labour productivity or low hourly compensation should be considered. Unit labour cost is often evaluated along with labour productivity.

Figure 3.13: Unit Labour Cost Index in G7 Countries (Base Year 2015=100)

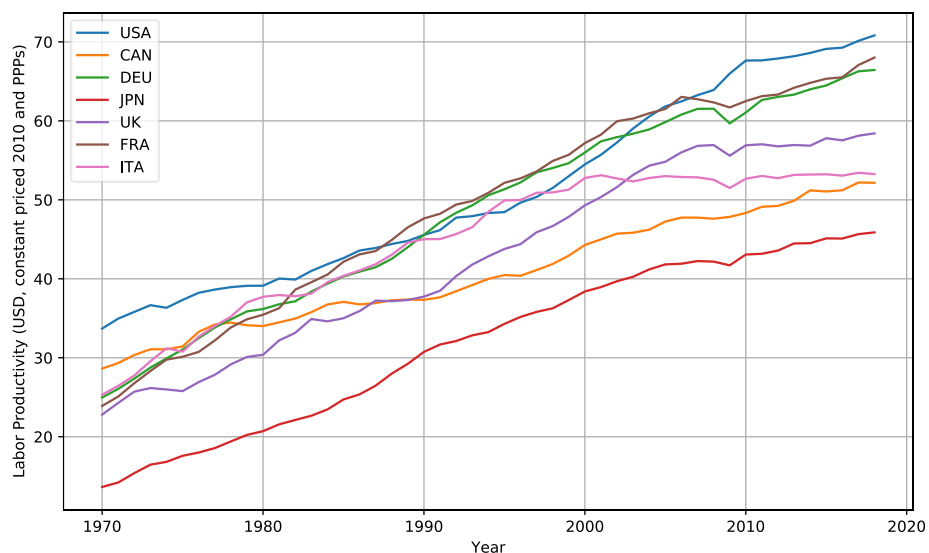


Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

Figure 3.13. shows unit labour costs, which represent price competitiveness in G7 countries. Apart from Japan, unit labour costs of other G7 countries have been similar to each other in the sample period from 1981 to 2019. Considering unit labour cost means competitiveness, Japan has less competitiveness power than other G7 countries in the global market. Nevertheless, Japan has caught up with others in terms of competitiveness since 2015. Additionally, Japan has surpassed some G7 countries such as United States, United Kingdom and Germany as of 2015. However, their labour productivity should be taken into account in order to determine the competitiveness power of countries, correctly.

Labour productivity is measured by GDP per hour worked. It represents how efficiently labour input is combined with other production factors such as capital. Labour input is also measured by total hours worked of all workers engaged in production processes and it is measured in the US dollar (constant priced 2010 and PPPs).

Figure 3.14: Labour Productivity (USD, constant priced 2010 and PPPs)



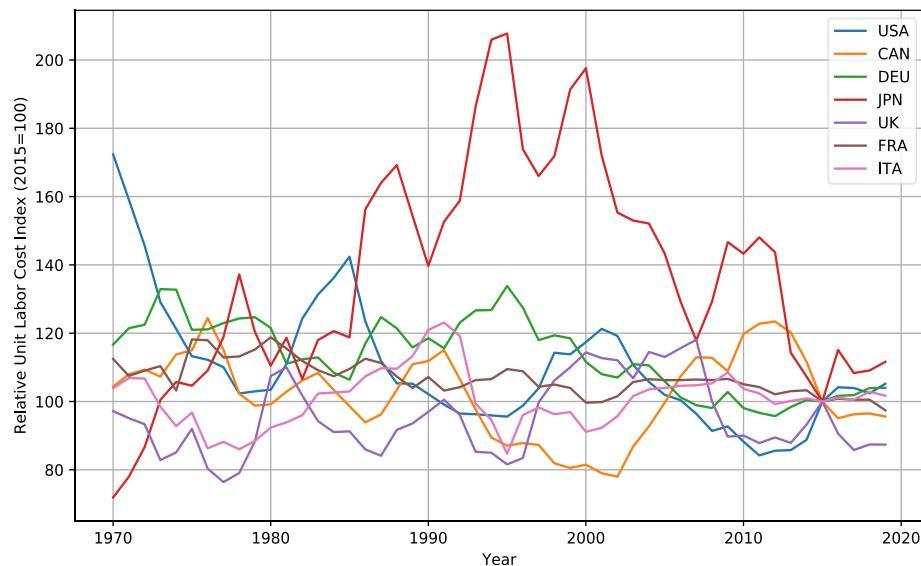
Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

Figure 3.14 shows labour productivity in G7 countries. Labour productivity has increased for all G7 countries since 1970. All of them have a relatively stable upward trend. The country with the lowest labour productivity among G7 countries is Japan over time. Considering both Figure 3.13 and Figure 3.14 together, the reason why Japan has high labour cost is its low labour productivity. Therefore, except for Japan, an increase in both labour productivity and labour cost indicates more increase in compensation per hour worked in G7 countries.

In contrary to unit labour cost, relative unit labour cost takes into account countries' trade partners. The relative unit labour cost represents a competition situation of an individual country relative to its trade partner. Similarly, a decrease in the relative unit labour cost of country regarded as high competition power and an increase in it regarded as low competition power relative to country's trade partner.

As shown in Figure 3.15, relative unit labour costs of all G7 countries have fluctuated over the sample period from 1970 to 2018. Japan has the lowest competition power compared to other G7 countries, prominently. Nonetheless, Japan has caught up with other countries in terms of competition. On the other hand, relative unit labour costs of other G7 countries exhibit much greater stability than Japan.

Figure 3.15: Relative Unit Labour Cost Index in G7 Countries



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/>

3.2.4. Labour Share and Wage Gap

The labour share is the percentage of GDP that accrues to labour and it is calculated by dividing by total compensation by GDP. Labour share is of interest to both workers and policymakers. This indicator provides a means to compare output produced by workers with the compensation they earned. In terms of the New Keynesian Phillips Curve, labour share is a proper proxy for real economic activities and also marginal cost.

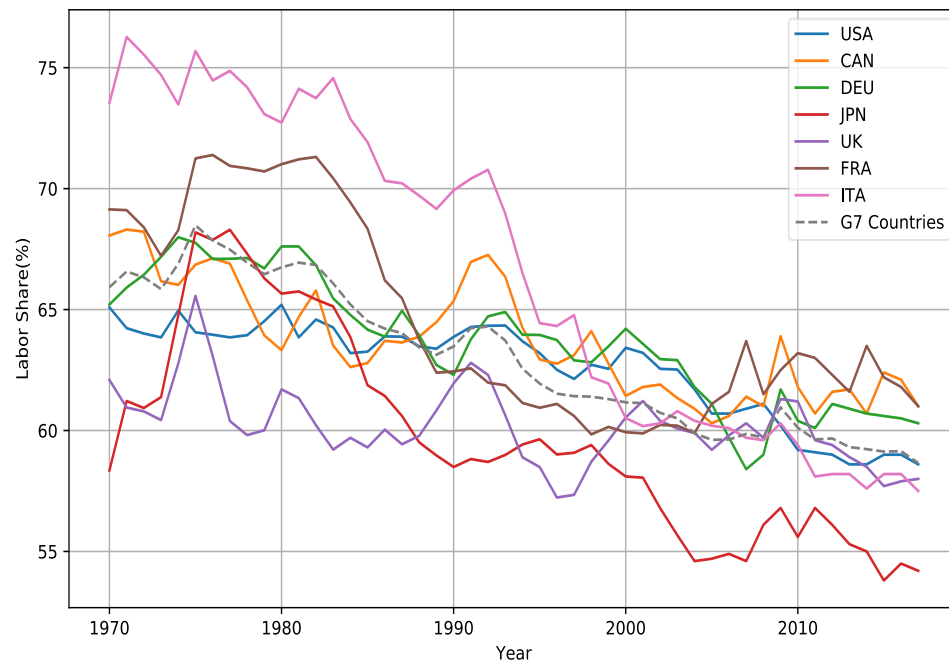
The wage gap represents the gap between labour productivity growth and real compensation growth. In macroeconomic reports, labour share is evaluated along with wage gap and the relationship between them is investigated. It is expected as theoretical and intuitional that an increase in labour share narrow the wage gap while a decrease widens the gap.

Labour share and wage gap are calculated as follows:

$$\text{Labour Share} = \frac{\text{Employee compensation}}{\text{GDP}} \quad (3.3)$$

$$\begin{aligned} \text{Wage Gap} = & \text{Growth in Labour Productivity} \\ & - \text{Growth in Compensation} \end{aligned} \quad (3.4)$$

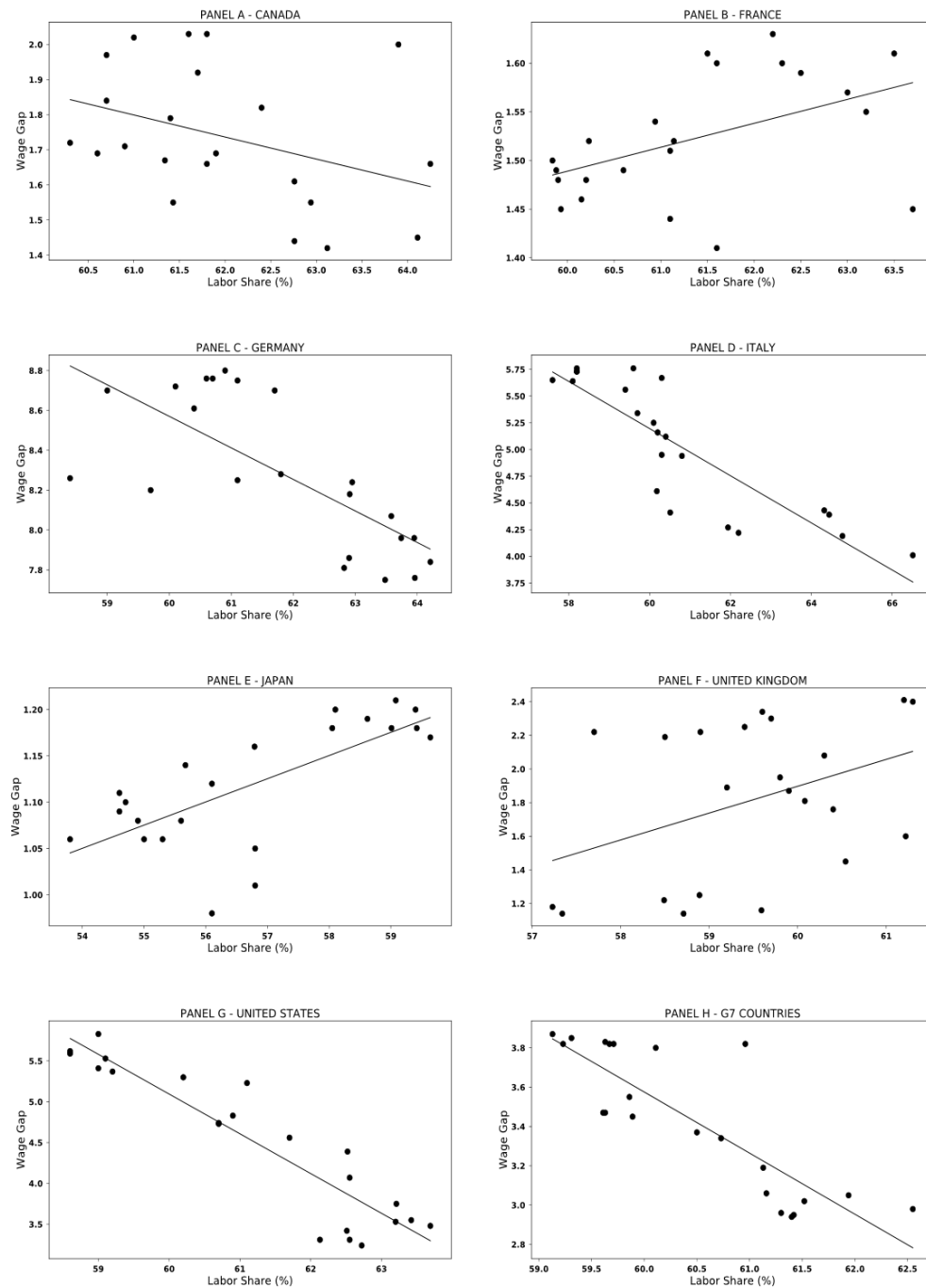
Figure 3.16: Labour Share in G7 Countries



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/> ; ILO, <https://ilostat ilo.org/>

Figure 3.16 shows the evolution of labour share in G7 countries between 1970 and 2017. First of all, labour shares of all G7 countries have declined since 1970. Although labour share fluctuated in this period, it has a downward trend for all G7 countries. The average labour share in G7 countries has declined from 66% to 59% over the sample period.

Figure 3.17: Labour Share and Wage Gap G7 Countries



Source: OEDC, Labour Force Statistics, <https://stats.oecd.org/> ; ILO, <https://ilostat ilo.org/>

Considering the increase in unit labour cost, the percentage growth of GDP is greater than employee compensation located denominator of labour share equation. Additionally, even though there is an upward trend of labour productivity, labour share has a downward trend. Particularly, since the 1990s, the labour shares of all G7 countries have declined more rapidly. In this regard, it indicates that firms have preferred capital-intensive production process instead of labour-intensive due to a decrease in the relative price of investment goods since then. The increase in elasticity of substitution between capital and labour has led to employing relatively more capital and less labour in the production process.

Figure 3.17 shows the labour share of GDP in total economy and the wage gap. In France, Japan and the United Kingdom, there is a positive relationship between labour share and wage gap, whereas there is a positive relationship between these indicators in other G7 countries. As can be seen from Figure 3.17 Panel H, in G7 countries, growth in real hourly compensation has caught up with growth in labour productivity while labour share increase. In other words, an increase in labour share has a narrowed gap between growth in labour productivity and growth in real hourly compensation.

Considering labour market conditions in G7 countries, almost any indicators have recovered recently. Whereas the unemployment rate has fluctuated since the 1980s, it definitively decreased more and more. The productivity of workers and their wages have increased in this period. Furthermore, the labour share of GDP has risen along with other related indicators such as competition. Although labour share is calculated by using GDP, in this section GDP data has not investigated, directly. As GDP is a significant indicator to correctly evaluate both labour market and other economic indicators, it is located in the next section.

3.3. Economic Size of G7 Countries

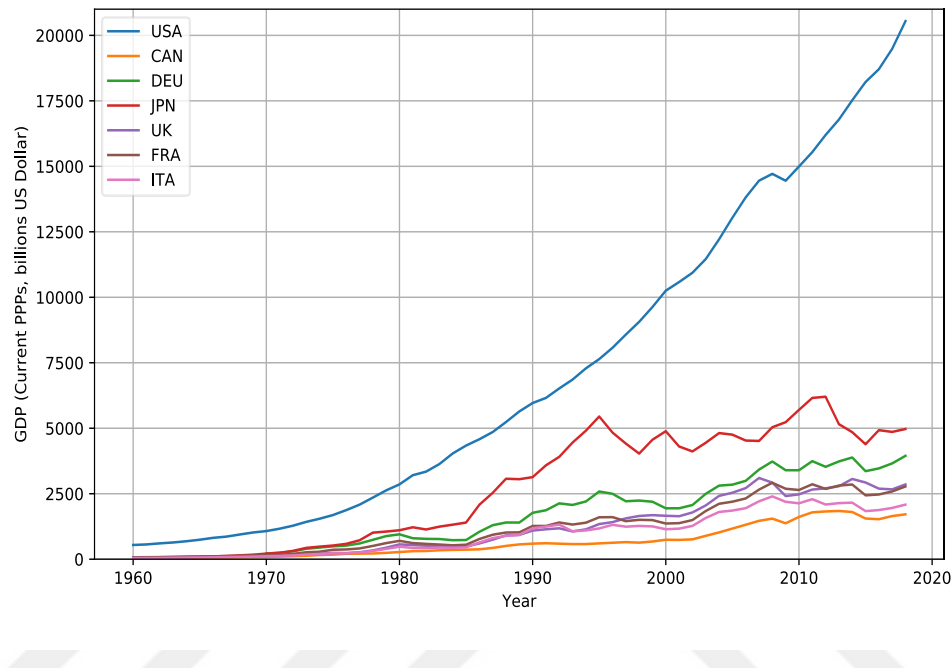
Gross Domestic Production (GDP) represents both economic size and output. It is a monetary measure of all final goods and services in a specific time period and a country. Besides being a crucial macroeconomic indicator, economic size, which is represented by GDP, occupies a significant role in the NKPC literature. In this section, GDP and its evolution are examined in G7 countries.

3.3.1. Gross Domestic Product

During the second half of the twentieth century, as a result of technical progress, GDP rapidly increased in G7 countries. The end of the Second World War accelerated such growth. By the 2000s, the total GDP of G7 countries accounted for approximately 45% of the world's GDP.

Figure 3.18 shows GDP in G7 countries over the sample period from 1960 to 2019. All of the G7 countries have exhibited important performance since 1960. Particularly the GDP gap between countries has been widened after the middle of the 1980s. The US has the greatest GDP compare to other G7 countries. The GDP ranking of almost all G7 countries has hardly changed in this period.

Figure 3.18: Gross Domestic Product in G7 Countries

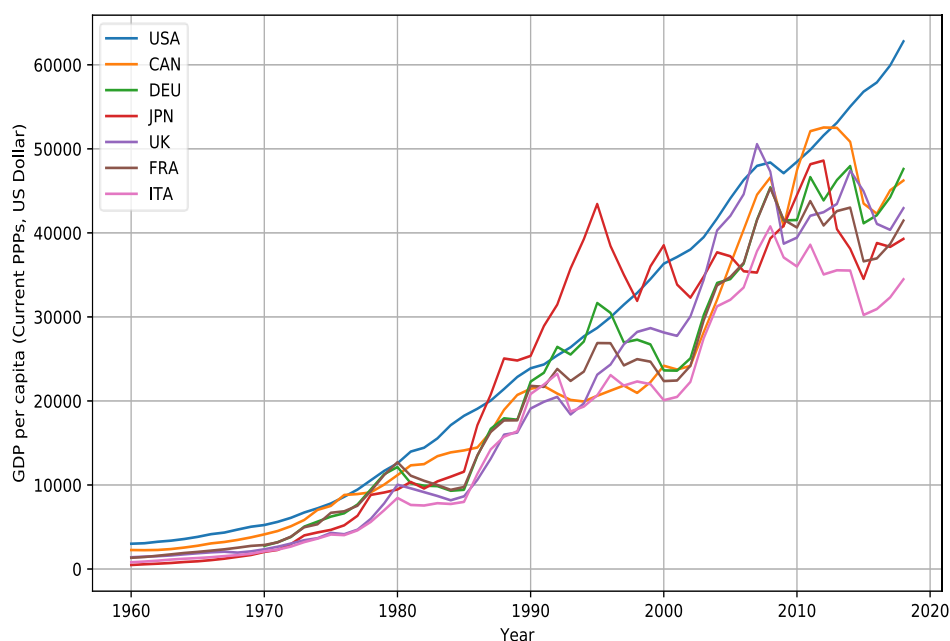


Source: World Bank, World Development Indicators,

<https://databank.worldbank.org/>

Because of the population differences of G7 countries, GDP per capita should be examined along with GDP. Figure 3.19 shows GDP per capita in G7 countries. The rapid increase in GDP and slow increase in population has accelerated GDP per capita in G7 countries. The country with the greatest GDP per capita is the US, similarly. Although Japan surpassed the US in the last decade of the 20th century, it is in the 6th place among G7 countries in recent years. In general, whereas the US has remained its leadership, the country with the lowest GDP per capita is Italy despite its negative growth in population. Nevertheless, GDP per capita in Italy is more than three times the world average.

Figure 3.19: Gross Domestic Product per Capita in G7 Countries



Source: World Bank, World Development Indicators,

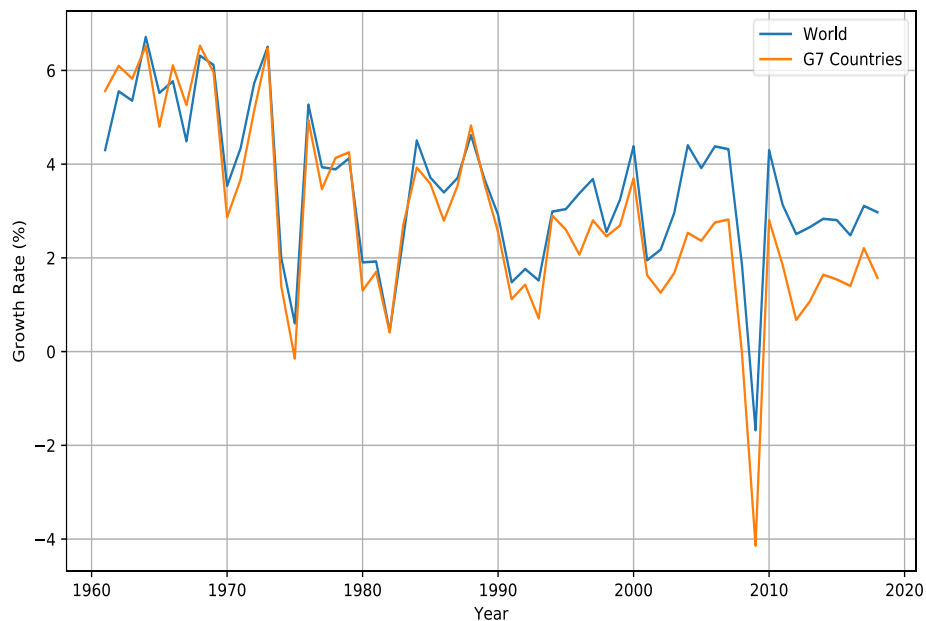
<https://databank.worldbank.org/>

Production has been steadily increasing since the industrial revolution in the 1750s thanks to technological progress. However, during the twentieth century, research and development activities have accelerated technological progress. Particularly, the inclusion of software and computer technology in the production process has provided high value-added during this period. This technological process resulted in an unprecedented increase in GDP and GDP per capita, which have peaked in the last half of the twentieth century.

3.3.2. Growth Rate

Even if G7 countries have the top 7 GDP worldwide, they usually do not exhibit the same performance in terms of growth due to the law of diminishing marginal returns. Whereas countries with low GDP have a high growth rate, countries with high GDP have a low growth rate. As seen from Figure 3.20, the GDP growth rate in G7 countries has been lower than the world average owing to lowly marginal productivity of capital.

Figure 3.20: Average Annual Growth Rates of World and G7 Countries



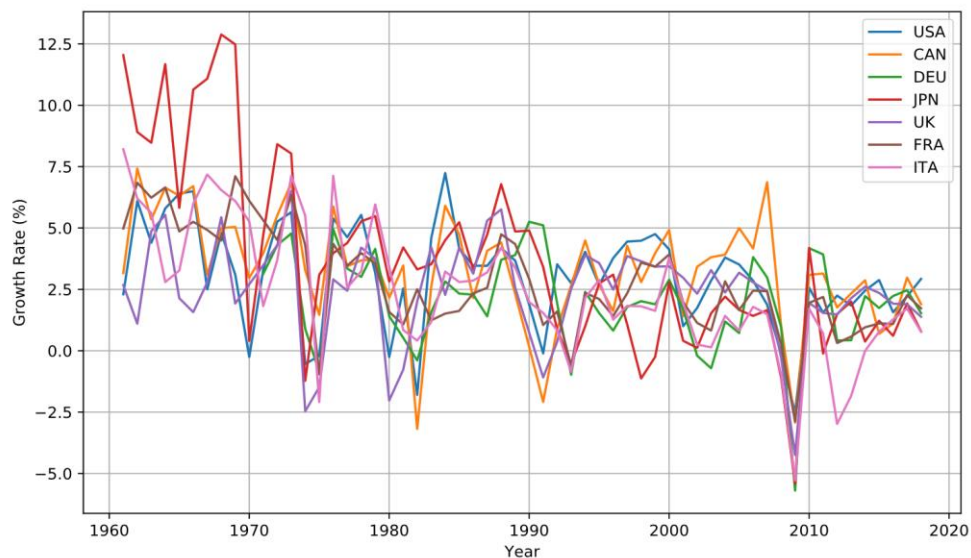
Source: World Bank, World Development Indicators,

<https://databank.worldbank.org/>

The gap between the largest economy and others has been widened steadily, especially after the 1990s. Nonetheless, fluctuations, trends and breaking points of G7 countries and the world average are similar to each other, in particular crisis period. One of the reasons for this similarity is that the GDP of G7 countries accounts for approximately 45% of the whole GDP worldwide.

Figure 3.21 shows the annual GDP growth rate of G7 countries over the sample period from 1960 to 2019. In G7 countries, growth rates have generally fluctuated between 7.5% and -2.5%. Even though the growth rate in Japan outperformed the rest of the group in the 1960s, it converged others after the 1970s. During the 1960s after the Second World War, the enormous economic growth in Japan regarded as the achievement of the recovery stage known as the Japanese Economic Miracle.

Figure 3.21: Annual Growth Rates of G7 Countries



Source: World Bank, World Development Indicators,

<https://databank.worldbank.org/>

Figure 3.21 indicates the business cycle, including expansion, peak, and contraction, in G7 countries. During the OPEC Oil Price Shock of 1973, economies of G7 countries exhibited contractions. During the Asian Crisis of 1997, which is brought about by capital flows from developed countries to East Asian countries, a recession occurred in Japan. Finally, the Financial Crisis of 2008 led to an unprevented contraction in G7 countries. Additionally, according to report by European Commission (Macroeconomic imbalances - Italy, 2012), the effects of the financial crisis of 2008 lasted longer in Italy – the third-largest economy of Euro Area – owing to mainly high government debt. Recently, the growth rates of G7 countries is equal to approximately 2.5%.

3.4. International Trade and Balance of Payments

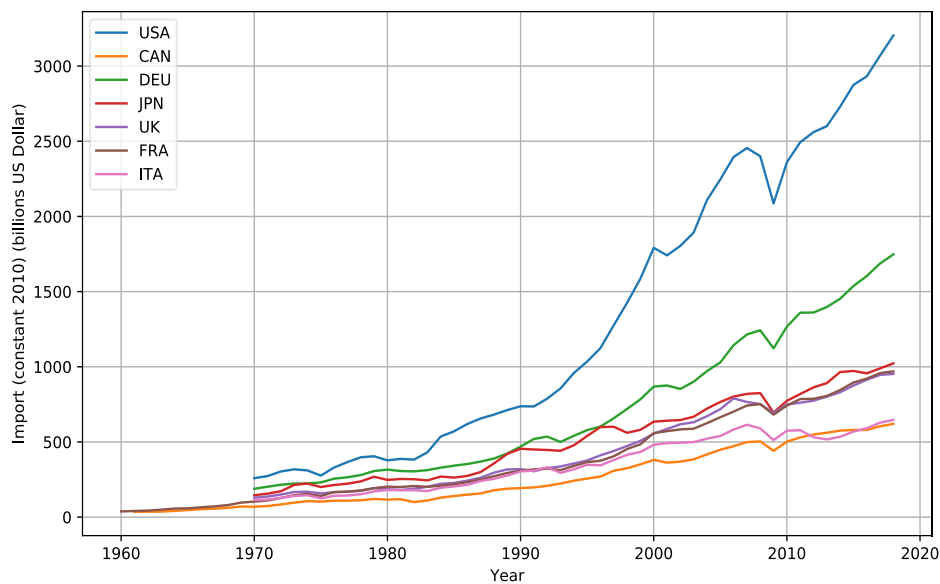
Even though macroeconomic theories assume a closed economy to analyze some phenomena regarding the economy initially, analysis is expanded by taking into account openness located in the real world. Foreign trade of final and intermediate goods may affect the domestic marginal cost, which is a significant factor for New Keynesian Phillips Curve as a proxy for real economic activities, depending on countries' size. Additionally, international trade accelerates competition among firms. Therefore, domestic prices affected by both marginal costs and increased efficiency caused by the increase in competition.

How much domestic factors related to production are affected by foreign factors depends on the size and openness degree of countries. Relatively small countries are more affected by foreign factors than relatively large countries. Similarly, relatively countries with open economies are more affected by foreign factors than countries with closed economies. As investigated in the previous section, G7 countries are the countries with the seven greatest GDP in the world, which refers to size. In this section, foreign trade and balance payments statements of G7 countries are examined in terms of openness.

3.4.1. Imports

Figure 3.22 shows imports of goods and services in G7 countries. The country with the greatest import by far is the US among G7 countries. The only drastic decline in imports occurred during the Financial Crisis of 2008. Except for this decline in 2008, there has been an upward trend in imports since 1960.

Figure 3.22: Imports of Goods and Services in G7 Countries (base year:2010, billions of US dollar)



Source: World Bank, World Development Indicators,
<https://databank.worldbank.org/>

Even though import amounts of G7 countries have a relatively consistent trend, these amounts should be evaluated along with the GDP of these countries. The

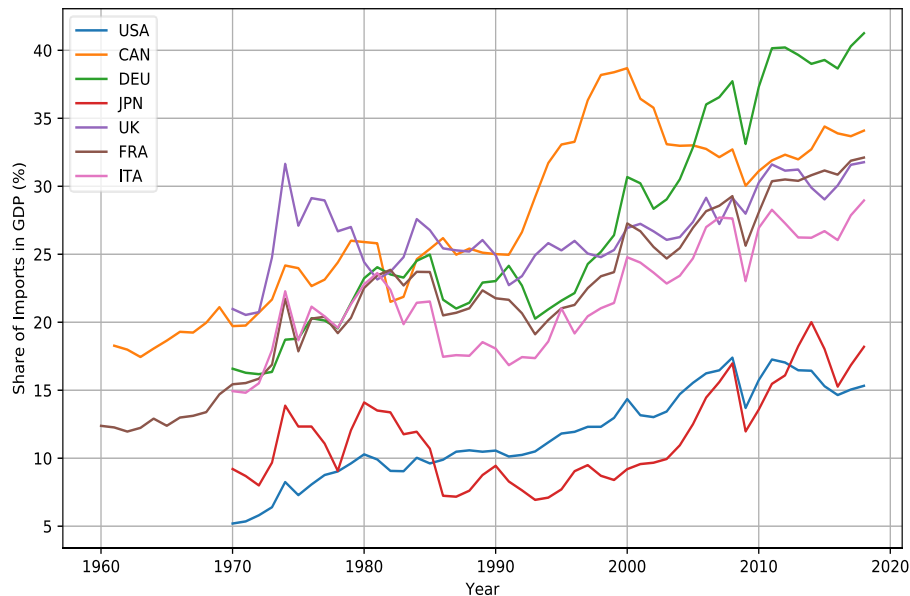
share of import in GDP ratio is computed as the sum of imports divided by GDP. It is almost used to basically measure a country's openness degree in terms of imports.

Figure 3.23 shows the share of imports in GDP for G7 countries over the sample from 1960 to 2018. First of all, although it seems that the US is the country with the greatest import, it has had the lowest import-to-GDP ratio since 2012. In the US, total imports of goods and services had accounted for about 15 percent of the US's gross domestic product in 2018. Nevertheless, there has been an upward trend with a lowly slope for the US.

On the other hand, although the country with the lowest import amount is Canada, it is one of the countries with the highest import-to-GDP ratio. Import has accounted for greater than 35 percent of its GDP since 2000. In this context, Canada has the highest openness degree, recently.

Considering both the import amount and share of imports in GDP, it is observed that both of them increased in the sample period. As seen from Figure 3.22 and Figure 3.23, an increase in both import amount and share of imports in GDP indicates that the increase in import amount has not been as much as the increase in GDP. Therefore, the openness degree in Germany has increased more than its size. Nonetheless, Germany is the country with the third-largest economy among the G7 countries despite a modest increase in size.

Figure 3.23: Share of Imports in GDP for G7 Countries (base year:2010, billions of US dollar)



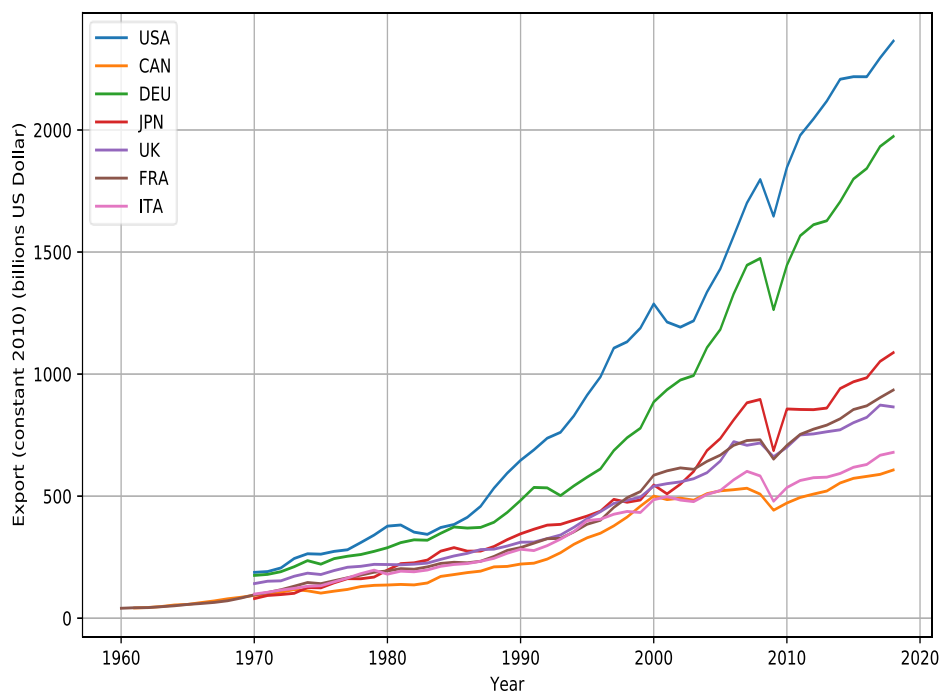
Source: World Bank, World Development Indicators,
<https://databank.worldbank.org/>

3.4.2. Exports

Export, which is an important item in the balance payments, is frequently associated with the position of countries in global markets. Figure 3.24 shows the total exports of goods and services in G7 countries. Similar to import, export has rapidly increased since the 1990s, particularly in the US and Germany. Canada has fallen behind in export amounts among other G7 countries.

As seen in Figure 3.24, there has been an upward trend in export amounts since the 1960s in spite of interruption in the financial crisis of 2008. Additionally, the economic recession, which declined real economic activities particularly in developed countries in the early 2000s, led to a decline in export amounts as profoundly as in the financial crisis of 2008 in the US. It is seen that the economic recession in 2001 did not affect the export amount of other G7 countries as much as in the financial crisis of 2008.

Figure 3.24: Exports of Goods and Services in G7 Countries (base year:2010, billions of US dollar)

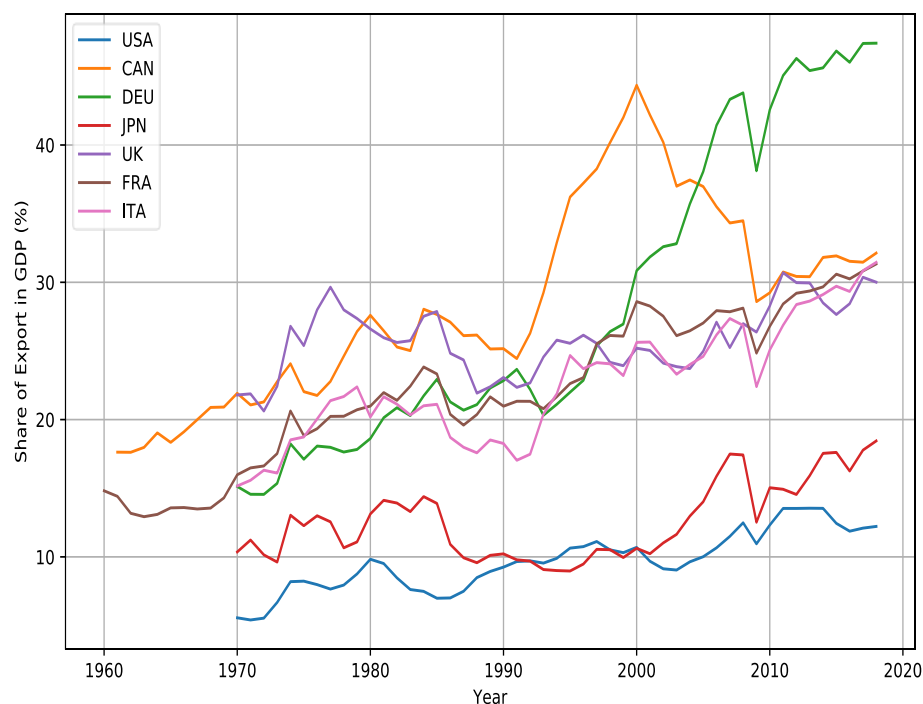


Source: World Bank, World Development Indicators,

<https://databank.worldbank.org/>

Figure 3.25 shows the share of exports in GDP for G7 countries. Comparing these two export indicators, G7 countries have more fluctuating data on the share of export in GDP. Considering export share in GDP and export amounts together, although Canada has the lowest export amounts, its share of export in GDP has one of the highest rates among G7 countries. Another highlight in Figure 3.25 is that the export amount in the US has accounted for less than 15% of GDP despite highly export amounts.

Figure 3.25: Share of Exports in GDP for G7 Countries (base year:2010, billions of US dollar)



Source: World Bank, World Development Indicators,
<https://databank.worldbank.org/>

The country with the highest share of export in GDP is Germany. Additionally, Germany become the world's second-biggest GDP by demonstrating developmental achievement following the second half of the twentieth century. In other words, it has exhibited a significant increase in both GDP and export. In 2004, Germany caught up with Canada that has the highest share of export in GDP in time. In recent years, export has accounted for approximately 48 percent of GDP in Germany.

3.4.3. Openness Degree

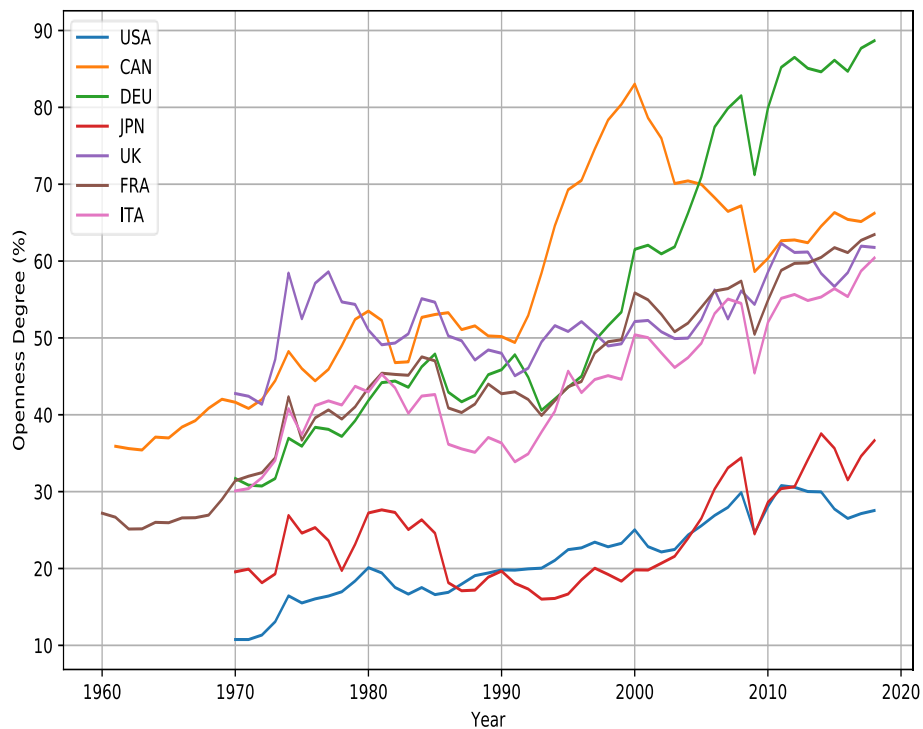
Economic openness is often related to the trade of countries with other countries. The origin of economic openness dates back to the 18th century. While it has been used to discuss absolute and comparative advantages in international economics, it appeared as a measure of foreign transactions in the political economy. Openness in economies has steadily increased since the brightest periods of the industrial revolution, and the tendency of globalization in fields of industrial and finance has accelerated it.

As openness degree increases, both domestic producers and consumers become more sensitive to the foreign factor depending on the position of their countries in the global market. In this context, foreign factors may affect domestic prices through production costs. In the New Keynesian Phillips Curve literature, as open economy models develop and parameters related to openness are included in these models, attentions have been directed to openness degree. The openness degree of a country is calculated as the percentage that its total foreign trade represents over GDP.

$$Openness\ Degree = \frac{Import + Export}{GDP} * 100 \quad (3.5)$$

As can be seen from Figure 3.26, the country with the highest openness degree is Germany. The total of imports and exports, in Germany, has accounted for approximately 90% of GDP, recently. Canada, which is the leader in openness degree from the 1990s to the mid-2000s, is now in second place. The country with the lowest openness degree is the US in spite of the high sum of import and export amounts due to high GDP.

Figure 3.26: Openness Degree of G7 Countries (%)



Source: World Bank, World Development Indicators,

<https://databank.worldbank.org/>

According to the openness degree approach, Germany is by far the most vulnerable country to foreign factors. The US is the most resistant country to foreign factors among G7 countries. However, considering the size and openness of countries together, the US is both the largest country in terms of GDP and resistant to foreign factors in terms of openness. Germany is relatively vulnerable to foreign factors in terms of openness in addition to the second-biggest economy in terms of GDP. On the other hand, even if Canada has the smallest economy among G7 countries, it is relatively highly sensitive to foreign factors. Finally, Japan has the second-largest economy among G7 countries, and it is relatively resistant to foreign factors.

CHAPTER FOUR

ESTIMATION OF NEW KEYNESIAN PHILLIPS CURVE

As mentioned in the first chapter, the NKPC models provide a comprehensive review regarding inflation dynamics based on microeconomic foundations and optimization behaviours of economic agents. Since the NKPC models include not only variables of the Phillips Curve but also new variables based on microeconomic foundations, they have significance to explain inflation process in academic arenas. In addition to the strong theoretical foundation of the NKPC models, empirical developments such as the use of marginal cost or output gap as a proxy for economic activities enable to empirically estimate the NKPC models as well as theoretical estimation. The structural parameters in the NKPC models enable to customize models in terms of features of sample countries or countries group such as closed or open economy models.

Considering macroeconomic outlook in the G7 countries as examined in Chapter Three, the G7 countries have a high openness degree along with the largest economies worldwide. Given the high globalization degree worldwide, G7 countries have a highly significant impact on other countries. Despite this significant impact of G7 countries, they may not be significantly affected by economic fluctuations in other countries due to economic size of G7 countries. However, the open economy NKPC models take into account openness degree of countries rather than their economic size and these models suggest that openness degree is a significant variable to explain inflation process for open countries.

As seen from empirical literature in Chapter Two, empirical studies focused on some of the G7 countries found that the open economy NKPC models do not explain inflation process for these countries. Openness parameters are either statistically insignificant or incorrectly signed. Additionally, there are limited empirical studies focused on G7 countries and size of countries in the empirical

studies. The existing empirical studies such as Leith and Malley (2003) did not use aggregated data and they did not estimate closed economy models for G7 countries. In the literature, there is no study focusing on all G7 countries and examining both the closed and open NKPC models with the same methodology.

In order to clarify conflicting results on the validity of the NKPC models for large and open countries in the existing literature, closed economy and open economy baseline models are estimated for G7 countries focusing on both their openness degree and economic size. In addition to these baseline models, their hybrid versions and a special version of open economy models (GM-NKPC) are estimated over the two different sample periods. Whereas the first sample period covers available all data, the second sample starts from the adoption year of inflation targeting policy.

In the estimation process of these five NKPC models, in order to avoid weak identification problems, four lags of inflation and one lag each for interest rate and the output gap are used as instrument variables based on the study of Abbas et al. (2016). Instead of marginal cost, the output gap computed by HP Filter is used as a proxy for real economic activity based on the study of Rudd and Whelan (2005). The marginal cost variable computed by using labour compensation is used as an instrument variable.

To this end, the rest of this chapter is organized as follows. Firstly, the empirical specifications and parameters of the NKPC models are presented. The second section contains estimation methodology and GMM estimation. Thirdly, we presented our data set and summary statistics. Since the GMM estimation assumes that all variables are stationary, we examine whether variables have a unit root before estimation. Finally, we estimate five different NKPC models by using GMM estimation for G7 countries over the two sample periods. The final section also covers the comparison of estimation results and findings.

4.1. Empirical NKPC Models

As mentioned in first chapter, several NKPC models have been developed in the theoretical literature and used in the empirical literature. The theoretical models include the following five main NKPC models: closed economy, closed economy hybrid, open economy, open economy hybrid NKPC and open economy GM-NKPC. The hybrid models contain past inflation as well as other main explanatory variables. The closed economy NKPC model is also known as pure forward-looking or baseline NKPC. It does not consist of foreign factors, directly. Both open economy models contain foreign factors as well as domestic factors. In this study, these five models are estimated for G7 countries.

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \tilde{x}_t \quad (4.1)$$

where

$$\tilde{x}_t = x_t - \bar{x}_t, \lambda = \frac{(1 - \theta)(1 - \beta\theta)}{\theta}$$

Equation 4.1 indicates the empirical specification of the closed economy NKPC model. According to Equation 4.1, domestic inflation is explained by expected inflation and real economic activities. Where $\tilde{x}_t$ represents real economic activities and $E_t \pi_{t+1}$ is the expected inflation. The slope parameter λ is a function of the frequency of price adjustment θ and discount factor β .

$$\pi_t = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda \tilde{x}_t \quad (4.2)$$

where

$$\tilde{x}_t = x_t - \bar{x}_t, \lambda = (1 - \omega)(1 - \theta)(1 - \beta\theta)\phi^{-1}$$

$$\alpha_f = \beta\theta\phi^{-1}$$

$$\alpha_b = \omega\phi^{-1}$$

$$\phi = \theta + \omega[1 - \theta(1 - \beta)]$$

Equation 4.2 specifies the closed economy hybrid NKPC that contains past inflation as well as other variables of the closed economy model. Where α_f and α_b indicates weights of expected future inflation and past inflation, respectively. If all firms set their price in terms of future, the term α_b is equal to nearly zero that means pure forward-looking NKPC. Similarly, frequency of price adjustment and discount factor are represented by θ and β , respectively.

$$\pi_t = \beta E_t \pi_{t+1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)] \quad (4.3)$$

$$\pi_t = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)] \quad (4.4)$$

The open economy NKPC is specified by Equation 4.3. Unlike the closed economy model, the open economy model contains the relative import price parameter $p_t^m - p_t$ as a foreign factor. The openness degree α is a measure of the effect of this foreign factor on domestic inflation. Similarly, slope parameter λ is specified discount factor and frequency of price adjustment as mentioned before in Equation 4.1.

The open economy hybrid model is located in Equation 4.4. As can be seen from Equation 4.4, domestic inflation is related to expected inflation $E_t\pi_{t+1}$, lagged inflation π_{t-1} , marginal cost and relative import price as a foreign factor. Similarly, the openness degree of the country is represented by α that reflects the effect of this foreign factor on domestic inflation. Compared to the open economy model in Equation 4.3, the open economy hybrid model contains past inflation in Equation 4.4. Weights of lagged inflation and expected inflation are represented by α_b and α_f , respectively.

The open economy model, which derived by Gali and Monacelli (2005) is a special form of open economy models. In the open economy GM-NKPC, the real effective exchange rate is used instead of the relative import price as a foreign factor based on the relationship between import price and exchange rate.

$$\pi = \beta E_t\pi_{t+1} + \lambda mc_t + \frac{\alpha}{1 - \alpha} [\Delta q_t - \beta E_t\Delta q_{t+1}] \quad (4.5)$$

The open economy GM-NKPC is specified by Equation 4.5. In the model, the terms of q_t represent the real effective exchange rate as mentioned in the first chapter.

Consequently, in this study, these five models that are located in Equation 4.1 – 4.5 are estimated for G7 countries. Two of these five models are closed economy versions and the others are open economy versions of NKPC. Chapter One consists of the derivations of all models.

4.2. Estimation Methodology: GMM Estimation

This study employed the GMM estimation method in the estimation of all closed and open economy models given in Equation 4.1 – 4.5 to control potential endogeneity problems. Another reason for the use of GMM estimation in this study is that the GMM estimation has less strict assumptions compared to OLS or GLS methods. As mentioned in Chapter Two, the GMM is widely used as an estimation method in the empirical literature to estimate NKPC models. In this section, the GMM estimation method and its assumptions are presented. This section also contains the reasons why the GMM estimation method is preferred in the estimation of the NKPC models.

The GMM estimation method was developed by Hansen (1982) and it has become one of the main estimation tools so as to estimate financial and economic data. Even though estimators of Ordinary Least Squares (OLS) or Generalized Least Squares (GLS) are consistent and unbiased under certain conditions and assumptions, these assumptions and conditions cannot be satisfied in some cases. Whereas OLS and GLS estimation methods have strict assumptions, the GMM estimation method has more flexible assumptions for consistent and unbiased estimation results.

The foundation of the GMM estimation method is the method of moments, which was introduced by Hansen (1982). The method of moments is based on the principle of equalization of sample and population. In means that as soon as the number of observations in sample increase, the value of sample converges population. However, the method of moments assumes that the number of sample

moment is equal to the number of parameters so as to estimate coefficients of parameters. The main target of the method of moments (MM) is to estimate Equation 4.6.

$$\mu = E[y] \quad (4.6)$$

$$(1/N) \sum_{i=1}^N y_i - \mu = 0 \quad (4.7)$$

Equation 4.6 and Equation 4.7 refer to population moment and sample moment conditions, respectively. The MM estimator is obtained by solving Equation 4.6 that sample moment condition. The GMM estimation is a special form of the MM estimation and it tries to minimize a quadratic form of moment conditions.

Therefore, GMM estimation method aims to determine estimator so that the theoretical relationship between explanatory variables and dependent variables is satisfied as closely as possible. The GMM estimation tries to minimize the weighted distance between the actual value and theoretical value in the model. GMM estimation, unlike maximum likelihood, OLS and GLS, does not require strong assumptions and information about the distribution of sample data.

As seen from Table 1 and Table 2, almost all empirical studies in the NKPC literature use the GMM method due to its advantage. This estimation method is appropriate for the nature of explanatory and dependent variables. Additionally, the GMM estimation is commonly used to estimate not only open economy NKPC but closed economy NKPC also with both panel and time-series data.

In this study, the GMM estimation is used to estimate five different NKPC located in section 4.1 for each G7 country. Additionally, for each G7 country, two closed economy models and three open economy models are estimated by using GMM estimation over two sample periods. Whereas the first sample covers all data available, the data in the sub-sample starts from the adoption of the inflation targeting regime for each G7 country. All data used in the estimation are chosen as annual data so that the frequencies of all data match. In the estimation models, the sub-sample period is chosen to control the structural break represented by the inception of the inflation targeting regime for each G7 country.

4.3. Data Analysis

This section contains descriptive statistics of our data set and the results of the unit root test required by the GMM estimation. Firstly, dependent, independent and instruments variables in the estimation models are introduced, and then sources of data and summary statistics of variables are presented in this section. Secondly, since GMM estimation assumes all variables are stationary as mentioned in the previous section, we test whether variables have a unit root by using ADF and PP test. The results of unit root tests are reported for each G7 country and variable.

4.3.1. Descriptive Statistic of Data

In all NKPC models given in Equation 4.1 – 4.5, inflation is the dependent variable. Whereas the closed economy baseline model involves real economic activities and expected inflation, the open economy baseline model involves relative import price as foreign trade variable along with variables of the closed economy model. Hybrid models also involve past inflation as well as variables of baseline models.

Table 4.1: Definitions and Source of Variables

Dependent Variable	Definition	Source
Inflation (π)	Inflation is measured using Consumer Price Index (All items, Growth previous period, Annual)	OECD Database, General Statistics
Independent and Instrument Variables	Definition	Source
Output Gap ($\hat{x}$)	Output Gap is proxy for real economic activity and it is computed by using GDP and HP-Filter	OECD Database, National Accounts
Expected Inflation ($E\pi$)	Expected Inflation is measured using the Rational Expectation Hypothesis.	OECD Database, General Statistics
Lagged Inflation (π_{t-1})	Inflation is in the previous period.	OECD Database, General Statistics
Labour Share (ls)	Labour's share of income is measured as $\frac{Employee\ Compensations}{GDP}$. Proxy for marginal cost.	ILO, Labour Force Statistics
Real Effective Exchange Rate ($REER$)	Proxy for the relative price of import in OE-NKPC. Independent variable in GM-NKPC	IMF, International Financial Statistics
Interest Rate (r)	Long-term government bonds interest rate. Instrument variable.	OECD Database, Finance Statistics

Table 4.1 shows the definitions and source of all variables in the estimation of NKPC models. The output gap variable computed by HP Filter is a proxy for real economic activities. While the real effective exchange rate is a proxy for relative import price in the open economy baseline and open economy hybrid models, it is an independent variable in the open economy GM-NKPC model. Although no model given in Equation 4.1-4.5 contains interest rate as an explanatory variable, the interest rate is used as an instrument variable to estimate the NKPC models with GMM estimation in this study.

The data of the inflation rate, real effective exchange rate and interest rate are obtained directly from OECD and IMF databases. The labour share data is computed by using employee compensation and GDP data as mentioned in Section 3.2.4. The output gap – the difference between potential and actual GDP – as a proxy for real economic activities is computed by using the Hodrick-Prescott Filter (HP filter) due to the fact that potential GDP is not directly obtained (Hodrick & Prescott, 1997).

Since the time series set for expected inflation is not available, expected inflation is computed by using the rational expectation model introduced by Muth (1961). The value of actual inflation in the next period is used to measure expected inflation for the current period. The real effective exchange rate is a proxy for the relative price of imports in the open economy and open economy NKPC models owing to the fact that the relative price of imports is not obtained directly. Additionally, the real effective exchange rate variable is directly used by the open economy GM-NKPC as a function of import variable. Finally, long term government bonds are used as the interest rate for estimation.

Two different data sets are used in this study: time series and panel data sets. The time-series data set is used to estimate five NKPC models for each G7 country individually. The panel data set is used to estimate five NKPC models for G7 countries as a group. Additionally, these two different data set are separated into two

sample periods. Whereas the first sample period involves all available data, the sub-sample period starts from the adoption of the inflation targeting regime for each G7 country. While some data such as inflation dates back the 1950s, availability of some data such as real effective exchange rate or labour share is restricted. Due to that, the full sample period is annually organized for the 1950-2018 period.

Even though the European Central Bank (ECB) does not formally adopt an inflation targeting regime, it has been maintaining price stability policy after the inception of the Euro currency in 1999 for Euro Union (EU) members country. Thus, 1999 is accepted as adoption year of the inflation targeting regime for three G7 countries which is member of Euro Union: France, Germany and Italy. On the other hand, the United Kingdom and Canada adopted an inflation targeting regime in 1992 and 1991, respectively. The Federal Reserve (FED) announced introduction of an inflation targeting regime in 2012 for the United States. Finally, Japan Central Bank introduced an inflation targeting regime in 2013. Consequently, the data of the sub-sample range from the introduction of inflation targeting regime to 2018.

Table 4.2 shows the summary statistics of the full sample used in this study for each G7 country. All data is collected from the International Monetary Fund (IMF) International Financial Statistics, Organization for Economic Cooperation and Development (OECD) and International Labour Organization (ILO). Even though the observation number of inflation data is greater than 60 for each G7 country, lowly the number of some independent variables such as real effective exchange rate or labour share brings about missing observation.

Table 4.2: Summary Statistics

	Obs.	Mean	Std. Dev.	Min.	Max.
Canada					
Inflation	69	3.575714	3.05941	-1.000589	12.47161
Output Gap	59	.2617698	7.989729	-16.47534	27.66962
Expected Inflation	69	3.564471	3.064197	-1.000589	12.47161
Labour Share	48	63.70521	2.316536	60.3	68.31
REER	40	91.24763	10.24297	72.76316	107.9805
Interest Rate	64	6.524031	3.192137	1.251758	14.98917
France					
Inflation	63	4.336479	3.873923	.0375144	15.26053
Output Gap	59	.3819693	11.55821	-27.84676	30.26703
Expected Inflation	63	4.347917	3.867664	.0375144	15.26053
Labour Share	48	64.55417	4.123183	59.84	71.39
REER	39	103.7925	6.066605	92.02876	118.9369
Interest Rate	59	6.970544	3.762752	.4678807	16.29167
Germany					
Inflation	63	2.584121	1.69362	-.1294139	7.032024
Output Gap	49	-.2510481	11.50826	-31.00831	28.01785
Expected Inflation	63	2.59626	1.696604	-.1294139	7.032024
Labour Share	48	63.68604	2.6088	58.4	67.99
REER	40	105.3707	7.041089	92.51543	121.2117
Interest Rate	62	5.836452	2.509003	.09	10.44167
Italy					
Inflation	63	5.627352	5.446344	-.5073529	21.06417
Output Gap	49	.4656073	10.77312	-28.95277	25.46438
Expected Inflation	63	5.579937	5.479105	-.5073529	21.06417
Labour Share	48	66.60354	6.603512	57.5	76.27
REER	39	101.2208	6.949709	89.28719	118.3757
Interest Rate	27	5.502431	3.124197	1.486433	13.26575

Japan					
Inflation	63	2.950377	4.051797	-1.352837	23.22225
Output Gap	56	3.995596	21.7685	-28.00502	120.2818
Expected Inflation	63	3.023153	4.046341	-1.352837	23.22225
Labour Share	48	59.67896	4.222911	53.8	68.3
REER	39	98.07904	18.06123	69.40429	135.3251
Interest Rate	30	2.124161	1.888661	-.06625	6.959917
United Kingdom					
Inflation	63	5.080302	4.776248	.4016064	24.20729
Output Gap	59	.2274967	10.32471	-22.71906	34.91106
Expected Inflation	63	5.025454	4.797207	.4016064	24.20729
Labour Share	48	60.18771	1.603264	57.23	65.57
REER	40	117.7239	12.2427	97.07142	143.8268
Interest Rate	59	7.458462	3.684811	1.235808	14.88333
United States					
Inflation	63	3.651506	2.73788	-.3555463	13.5492
Output Gap	59	.2299235	2.470652	-4.239482	10.46386
Expected Inflation	63	3.627299	2.763606	-.3555463	13.5492
Labour Share	48	62.56625	2.023219	58.6	65.2
REER	39	112.3401	12.62774	95.01123	150.0143
Interest Rate	63	5.956878	2.815796	1.8025	13.91083

The panel data of G7 countries as a group is annually organized by using full sample time series data in this study. The sub-sample period which is based on the inflation targeting regime is generated by the full sample data set. However, due to the fact that Japan and the United States adopted an inflation targeting regime in 2013 and 2012, respectively, the number of observations on the sub-sample data set is very lowly for them. Therefore, their low observation number on the sub-sample

period leads to statistical problems in terms of the GMM estimation, especially Japan.

4.3.2. Unit Root Test

The GMM estimation assumes all variables in the model are stationary so as to avoid spurious regression. In other words, independent and dependent variables must not have a unit root in order to obtain reliable estimation results. In this section, Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) unit root tests are employed for each G7 country's variables. To this end, we investigate whether all variables in five estimation models have a unit root or not. The null hypothesis is that variable has a unit root. In other word, variable is not stationary.

4.3.2.1. Inflation

As seen from Table 4.2, test statistics calculated by ADF and PP are less than the critical value for each G7 country. Thus, the null hypothesis that the variable has a unit root is rejected for all G7 countries. It means that inflation variables of all G7 countries have no unit root and hence they are stationary.

Table 4.3: The Results of Unit Root Test for Inflation Variable

	ADF	PP	Results
Canada	-2.837**	-2.958*	I (0)
France	-4.061*	-4.518*	I (0)
Germany	-2.748**	-2.775**	I (0)
Italy	-5.229*	-5.664*	I (0)
Japan	-4.941*	-4.999*	I (0)
UK	-6.671*	-6.088*	I (0)
US	-5.876*	-6.445*	I (0)
Critical Value (5%)	-2.964	* $p < 0.05$	
Critical Value (10%)	-2.614	** $p < 0.10$	

4.3.2.2. Output Gap

As can be seen from Table 4.3, test statistics are less than the critical value. As result of ADF and PP unit root tests for output gap variable, the null hypothesis is rejected for all G7 countries. Thus, the output gap variables are stationary for each G7 country and they have no unit root.

Table 4.4: The Results of Unit Root Test for Output Gap Variable

	ADF	PP	Results
Canada	-2.570**	-2.751**	I (0)
France	-3.667*	-3.849*	I (0)
Germany	-3.583*	-3.785*	I (0)
Italy	-3.356*	-3.578*	I (0)
Japan	-2.590**	-2.795**	I (0)
UK	-3.926*	-3.996*	I (0)
US	-3.135*	-3.147*	I (0)
Critical Value (5%)	-2.964	* $p < 0.05$	
Critical Value (10%)	-2.614	** $p < 0.10$	

4.3.2.3. Expected Inflation

Table 4.4 shows that results of ADF and PP unit root test and the test statistics are less than the critical value at a significance level of 0.05 and 0.10. As result of the unit root test, expected inflation variables have no unit root. The expected inflation variables are stationary for all G7 countries. It can be used in level value to estimate NKPC by using the GMM estimation.

Table 4.5: The Results of Unit Root Test for Expected Inflation Variable

	ADF	PP	Results
Canada	-4.955*	-5.614*	I (0)
France	-5.163*	-6.048*	I (0)
Germany	-3.533*	-3.572*	I (0)
Italy	-4.428*	-4.799*	I (0)
Japan	-3.040*	-3.059*	I (0)
UK	-4.248*	-4.146*	I (0)
US	-5.708*	-5.654*	I (0)
Critical Value (5%)	-2.964	* $p < 0.05$	
Critical Value (10%)	-2.614	** $p < 0.10$	

4.3.2.4. Labour Share

Table 4.5 shows the result of the ADF and PP unit root test for labour share variables of G7 countries. The labour share variables have a unit root in level. However, the first differences of labour share variables have no unit root. Thus, the first differences of labour share variables can be used to estimate NKPC using GMM estimation.

Table 4.6: The Results of Unit Root Test for Labour Share Variable

	ADF		PP		Results ($\alpha=0.05$)
	In Level	In First Difference	In Level	In First Difference	
Canada	-1.808	-5.809*	-1.772	-5.862*	I (1)
France	-2.432	-5.898*	-2.457	-5.958*	I (1)
Germany	-1.954	-5.085*	-1.936	-5.012*	I (1)
Italy	-0.783	-5.399*	-0.792	-5.395*	I (1)
Japan	-1.913	-5.153*	-1.846	-5.251*	I (1)
UK	-2.059	-4.197*	-2.563	-4.210*	I (1)
US	-0.568	-5.930*	-0.521	-5.972*	I (1)
Critical Value (5%)		-2.964		* $p < 0.05$	
Critical Value (10%)		-2.614		** $p < 0.10$	

4.3.2.5. Interest Rate

As can be seen from Table 4.7, the null hypothesis is not rejected at the significance level of 0.05 and 0.10. It indicates that interest rate variables have a unit root in level. However, the first differences of interest rate variables have not a unit root for all G7 countries. It must be used to estimate NKPC by GMM estimation.

Table 4.7: The Results of Unit Root Test for Interest Rate Variable

	ADF		PP		Results ($\alpha=0.05$)
	In Level	In First Difference	In Level	In First Difference	
Canada	-1.132	-7.537*	-1.053	-8.074*	I (1)
France	-1.133	-6.567*	-1.126	-6.531*	I (1)
Germany	-0.352	-6.567*	-0.267	-6.459*	I (1)
Italy	-2.723	-3.899*	-2.672	-3.903*	I (1)
Japan	-1.232	-7.134*	-1.211	-6.457*	I (1)
UK	-1.359	-5.955*	-1.430	-5.994*	I (1)
US	-1.386	-7.595*	-1.337	-8.078*	I (1)
Critical Value (5%)		-2.964		* $p < 0.05$	
Critical Value (10%)		-2.614		** $p < 0.10$	

4.3.2.6. Real Effective Exchange Rate

Table 4.7 shows the results of ADF and PP unit root tests. As a result of these unit root tests, the real effective exchange rate variables have a unit root in level. However, the first difference variables of the real effective exchange rate have no unit root for all G7 countries. They must be used to estimate NKPC for reliable estimation results.

Table 4.8: The Results of Unit Root Test for REER Variable

	ADF		PP		Results ($\alpha=0.05$)
	In Level	In First Difference	In Level	In First Difference	
Canada	-1.300	-3.763*	-1.761	-3.688*	I (1)
France	-2.374	-5.018*	-2.478	-4.958*	I (1)
Germany	-1.919	-6.103*	-2.084	-6.135*	I (1)
Italy	-2.056	-5.399*	-2.270	-5.385*	I (1)
Japan	-1.658	-4.667*	-1.795	-4.564*	I (1)
UK	-1.764	-4.894*	-1.909	-4.875*	I (1)
US	-1.742	-4.006*	-2.235	-3.879*	I (1)
Critical Value (5%)		-2.964		* $p < 0.05$	
Critical Value (10%)		-2.614		** $p < 0.10$	

As a result, except for REER, Labour Share and Interest Rate, other variables are stationary. The first difference of REER, Labour Share and Interest Rate variables have no unit root. Although REER, Labour Share and Interest Rate variables have unit root in level, they can be used in first difference to estimate the NKPC models using GMM. Since inflation, expected inflation and output gap variables have no unit root, they can be used in level to estimate the NKPC models using GMM estimation.

4.4. Estimation Results and Findings

This section provides empirical results obtained from estimating Equations 4.1 – 4.5 using GMM methodology to explain inflation dynamics for G7 countries.

To this end, for each G7 country, all structural parameters in the NKPC models are estimated over two different sample period. The estimation results of five NKPC – closed economy NKPC, closed economy Hybrid NKPC, open economy NKPC, open economy hybrid NKPC and open economy GM-NKPC– are reported in Tables 4.10 – 4.16.

Table 4.9: Structural Parameters

Structural Parameters	Description	Theoretical Expectation
β	Discount Factor Parameter	$0 \leq \beta \leq 1$
θ	Price Rigidity	$0 \leq \theta \leq 1$
α	Openness Degree	$0 \leq \alpha \leq 1$
ω	Price Indexation Degree to Past Inflation	$0 \leq \omega \leq 1$
λ	Slope for closed economy models and GM-NKPC	$0 \leq \lambda \leq 1$
$\lambda(1 - \alpha)$	Slope for open economy models	$0 \leq \lambda(1 - \alpha) \leq 1$
$\frac{1}{1 - \theta}$	Duration of Price Adjustment	

As can be seen in Table 4.9, there are five structural parameters in the result tables: discount factor parameter (β), price rigidity (θ), openness degree (α), price indexation degree to past inflation (ω) and duration of price adjustment ($1/(1-\theta)$). Additionally, the slope parameter is represented by λ . All parameters in the models must be positive and less than one, theoretically. The robust standard errors of

estimation are parentheses below the coefficients. Column 1 and column 2 represent the estimation over the first sample period and sub-sample period, respectively.

Table 4.10: Estimation Results of Closed Economy NKPC

$$\pi = \beta E_t \pi_{t+1} + \lambda \hat{x}_t$$

$$\lambda = (1 - \theta)(1 - \beta\theta)\theta^{-1}$$

Countries	β		θ		λ		N	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Canada	.967*	1.09*	.785*	.771*	.009	-.018	57	24
	(.034)	(.072)	(.056)	(.056)	(.010)	(.015)		
France	1.03*	.910*	.857*	.775*	-.004	.033	57	16
	(.036)	(.080)	(.067)	(.055)	(.005)	(.032)		
Germany	1.06*	.834*	.967	.823*	.002	.062*	47	16
	(.060)	(.044)	(28383)	(.041)	(2083)	(.025)		
Italy	1.12*	.952*	.768*	.796*	-.021	.014	26	16
	(.073)	(.123)	(.076)	(.078)	(.019)	(.041)		
Japan	1.19*	-	.913	-	.0207	-	26	4
	(.442)		(6750)		(1614)			
UK	1.01*	1.05*	1.16*	.799*	.002	-.010	57	25
	(.049)	(.075)	(.128)	(.077)	(.008)	(.015)		
US	.983*	.831*	.589*	.386*	.011	.294	57	7
	(.052)	(.031)	(.076)	(.003)	(.037)	(.057)		
G7	1.01*	1.01*	.678*	.865*	-.001	-.007	325	99
	(.023)	(.064)	(.115)	(.048)	(.003)	(.031)		

* $p < 0.05$

** $p < 0.10$

Column (1) reports estimation results estimation result over the full sample period from 1950 to 2018
Column (2) reports estimation results over the sub-sample period based on introduction of inflation targeting regime. (For France, Germany and Italy:1999 – For the UK:1992 – For Canada:1991 – For US:2012 – For Japan:2013)

Table 4.810 shows the estimation results of the closed economy NKPC over the two sample periods. Whereas column 1 reports the full sample estimation result, column 2 reports estimation results with the sub-sample period that starts from the adoption year of inflation targeting regime for each G7 country. The coefficient on the discount factor parameter β is statistically significant and correctly signed

(positive) for all G7 countries over the first sample period. However, except for Canada and the US, discount factor parameter is greater than 1 for G7 countries contrary to theoretical expectations.

Similarly, the coefficient on the discount factor parameter β is statistically significant and between 0 and 1 over the inflation targeting regime. Except for UK and Canada, it is less than 1 as theoretically expected. The price rigidity parameter θ is between 0 and 1 except for Germany and statistically significant except for Japan over the full sample period given in column 1. In the inflation targeting regime period, price rigidity and duration of price adjustment increase in G7 countries except for Italy. After the adoption of the inflation targeting regime in Italy, the duration of price adjustment of firms increased from about 17 quarters to 19.4.

In the closed economy NKPC, the slope parameter λ is computed by estimated θ and β . The slope parameter must be between 0 and 1, theoretically. Although the coefficient λ is correctly signed and statistically significant for Germany, it is either less than zero or statistically insignificant for other G7 countries over the inflation targeting regime. Similarly, the slope parameter λ is either statistically insignificant or incorrectly signed for all G7 countries over the first sample period.

The closed economy hybrid NKPC includes past inflation as an explanatory variable as well as other closed economy explanatory variables. Table 4.9 reports the estimation results of closed economy hybrid NKPC over the full sample period. Similarly, all structural parameters in the model must be positive and less than 1, theoretically. As a result of estimation, even though the coefficient on the discount factor parameter β is less than 1 and positive for Italy, UK and US, it is statistically significant for only UK and US over the full sample period at significance level of 0.05.

The rice rigidity parameter θ is statistically significant for all G7 countries individually. However, it is not statistically significant for G7 countries as a group over the first sample period. Additionally, the price rigidity parameter θ is greater than 1 for Italy and Japan despite statistical significance. The degree of price indexation to past inflation that is represented by ω is statistically significant and less than 1 as theoretically expected for G7 countries except for UK, Japan and Canada. The slope parameter λ is statistically insignificant for all G7 countries both individually and as a group.

Table 4.11: Estimation Results of Closed Economy Hybrid NKPC (over the full sample period)

$$\pi = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda \hat{x}_t$$

$$\lambda = (1 - \theta)(1 - \beta\theta)(1 - \beta\theta)\phi^{-1}, \alpha_f = \beta\theta\phi^{-1}, \alpha_b = \omega\phi^{-1}, \phi = \theta + \omega[1 - \theta(1 - \beta)]$$

Countries	β	θ	ω	λ	ϕ
	(1)	(1)	(1)	(1)	(1)
Canada	1.026*	.645*	.431	.062	1.084*
	(.097)	(.081)	(.340)	(.073)	(.377)
France	6.016	.126	.996*	.001	1.752*
	(166.9)	(3.428)	(.087)	(.011)	(.349)
Germany	1.057*	.704*	.693*	.016	1.425*
	(.238)	(.116)	(.196)	(.014)	(.196)
Italy	.273	1.081*	.842*	-.007	1.26*
	(.343)	(.086)	(.088)	(.010)	(.322)
Japan	1.874*	1.097*	.589	.018	2.25*
	(.00)	(.044)	(.428)	(.024)	(.869)
UK	.967*	.832**	.678	.007	1.492
	(.189)	(.503)	(.565)	(.052)	(.985)
US	.992*	.451*	.427*	.197	.877*
	(.114)	(.086)	(.176)	(.135)	(.206)
G7	8.784	.085	.995*	.001	1.747*
	(344.3)	(3.32)	(.067)	(.007)	(.466)

* p < 0.05

** p < 0.10

Column (1) reports estimation results estimation result over the full sample period from 1950 to 2018

Table 4.10 reports the estimation results of closed economy hybrid NKPC over the sub-sample that starts from the adoption year of inflation targeting regime for each G7 country. Since the number of observations for Japan is not sufficient structural parameters cannot be statistically computed. The coefficient on the discount factor β is either statistically insignificant or greater than 1 for each G7 country. In the closed economy hybrid NKPC model, price rigidity parameter θ is statistically significant and between 0 and 1 for only Canada.

Table 4.12: Estimation Results of Closed Economy Hybrid NKPC (over the sub-sample period)

$$\pi = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda \hat{x}_t$$

$$\lambda = (1 - \theta)(1 - \beta\theta)(1 - \beta\theta)\phi^{-1}, \alpha_f = \beta\theta\phi^{-1}, \alpha_b = \omega\phi^{-1}, \phi = \theta + \omega[1 - \theta(1 - \beta)]$$

Countries	β	θ	ω	λ	ϕ
	(2)	(2)	(2)	(2)	(2)
Canada	1.13* (.137)	.579* (.076)	.131 (.166)	.172* (.068)	.721* (.147)
France	.771 (.735)	1.06 (1.00)	.829* (.421)	-.001 (.014)	1.69* (.547)
Germany	2.99 (2.87)	1.01* (.025)	1.22* (.201)	-.0011 (.002)	4.72 (3.65)
Italy	.168 (.382)	1.06* (.097)	.797* (.116)	-.009 (.013)	1.15 (.347)
Japan	-	-	-	-	-
UK	9.14 (1004)	.093 (10.2)	.996* (.149)	.001 (.010)	1.84* (.758)
US	15.1 (1501)	.024 (2.40)	.680 (1.54)	.208 (1.02)	.940 (1.65)
G7	1.08* (.156)	.442* (.079)	.386 (.117)	.210* (.097)	.843* (.143)

* p < 0.05

** p < 0.10

Column (2) reports estimation results over the sub-sample period based on introduction of inflation targeting regime. (For France, Germany and Italy:1999 – For the UK:1992 – For Canada:1991 – For US:2012 – For Japan:2013)

Considering the first sample estimation results and the sub-sample estimation results together, inflation dynamics are exactly explained by the closed economy hybrid NKPC for each G7 country over the sub-sample. However, according to the estimation result for G7 countries as a group, the closed economy hybrid NKPC outperforms the closed economy NKPC over the sub-sample. It is clear that in both models with both sample periods, the slope parameter λ is usually statistically insignificant although it is usually correctly signed and between 0 and 1 as unexpected theoretically.

Table 4.13: Estimation Results of Open Economy NKPC

$$\pi = \beta E_t \pi_{t+1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)]$$

$$\lambda = (1 - \theta)(1 - \beta\theta)\theta^{-1}$$

Countries	β		θ		α		$\lambda(1-\alpha)$	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Canada	.783*	.314	.999*	.977*	182.8	.780	.046	.484
	(.217)	(.282)	(.049)	(.008)	(46709)	(1.21)	(.101)	(.397)
France	1.19*	.237	1.09*	.999*	-1.69*	32.73	.053*	.582
	(.059)	(.382)	(.047)	(.035)	(.242)	(1459)	(.022)	(.566)
Germany	1.05*	.616**	.865*	.999*	-1.73*	59.1	-.005	.147
	(.149)	(.344)	(.081)	(.069)	(.618)	(11123)	(.012)	(.244)
Italy	.669*	1.01*	.926*	.987	-.872*	744.3	.135	.001
	(.151)	(.267)	(.035)	(8.99)	(.396)	(3e+7)	(.114)	(.110)
Japan	1.21*	-	.803*	-	-.796	-	-.006	-
	(.249)		(.152)		(.703)		(.014)	
UK	1.01*	.874*	1.00	1.14	73.4	-19.3	.001	.001
	(.213)	(.445)	(1.72)	(.851)	(103)	(5637)	(.022)	(.027)
US	1.54*	.901	.678*	1.10	.026	117.3	.040	.001
	(.210)	(.777)	(.083)	(1.08)	(.917)	(6153)	(.047)	(.021)
G7	1.27*	.432*	.839*	.999*	-.530*	71.1	.024**	.322*
	(.065)	(.090)	(.066)	(.010)	(.286)	(1413)	(.013)	(.103)

* $p < 0.05$

** $p < 0.10$

*Column (1) reports estimation results estimation result over the full sample period from 1950 to 2018
Column (2) reports estimation results over the sub-sample period based on introduction of inflation targeting regime. (For France, Germany and Italy:1999 – For the UK:1992 – For Canada:1991 – For US:2012 – For Japan:2013)*

Table 4.11 reports the estimation results of the open economy NKPC for each G7 country over the first sample period (column 1) and the sub-sample period (column 2). The open economy NKPC includes relative import price as an explanatory variable, unlike closed economy NKPC. Additionally, estimation results have an openness degree parameter α . Thus, the openness degree is crucial for the effect of relative import price on inflation as can be seen from the estimation equation of open economy NKPC.

As can be obviously seen from estimation results in Table 4.11, the discount factor β is statistically significant and between 0 and 1 for only Italy and Canada. For other G7 countries, this coefficient is greater than 1 despite statistical significance. On the other hand, price rigidity of G7 countries is high as estimation results of open economy NKPC. The duration of price adjustment in the G7 countries is equal to approximately 6.2 years over the full sample period. The price adjustment duration increases over the sub-sample period. In both the open economy and closed economy NKPC, price adjustment duration is very close with each other over the full sample period.

As can be seen from Table 4.11, the openness degree parameters α is either statistically insignificant or different value from theoretical expectations over the first sample period. Similarly, it is imprecisely estimated over the sub-sample period. The slope parameter $\lambda(1-\alpha)$ is not statistically significant for each G7 country except for France over the full sample. However, considering the estimation results of G7 countries as a group instead of individual countries, open economy NKPC captures inflation dynamics over the full sample period.

In addition to explanatory variables of the open economy model, the open economy hybrid NKPC contains past inflation. Table 4.12 reports estimation results of open economy hybrid NKPC that includes foreign trade factors such as relative import price. The effect of the relative import price is represented by openness degree parameter α . The weight of relative import price α is positive only for Germany but statistically insignificant.

Table 4.14: Estimation Results of Open Economy Hybrid NKPC (over the full sample period)

$$\pi = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda[(1 - \alpha)mc_t + \alpha(p_t^m - p_t)]$$

$$\lambda = \frac{(1 - \omega)(1 - \theta)(1 - \beta\theta)}{\theta + \omega[1 - \theta(1 - \beta)]}, \alpha_f = \frac{\beta\theta}{\theta + \omega[1 - \theta(1 - \beta)]}, \alpha_b = \frac{\omega}{\theta + \omega[1 - \theta(1 - \beta)]}$$

Countries	β	θ	ω	α	$\lambda(1-\alpha)$
	(1)	(1)	(1)	(1)	(1)
Canada	5.919 (411.0)	.160 (11.0)	.948 (.632)	-.742 (9.35)	.002 (.019)
France	1.64* (.00)	1.07* (.067)	.602* (.077)	-2.03* (.553)	.034 (.027)
Germany	1.27 (.963)	.787 (.574)	.753 (.351)	133.2 (425557)	.0004 (.027)
Italy	1.02* (.324)	.807* (.107)	.253 (.220)	-1.65* (.493)	.061 (.060)
Japan	2.34* (1.20)	.418* (.211)	.036 (.257)	-1.48* (.663)	.052 (.049)
UK	1.56** (.806)	1.18* (.582)	1.13* (.244)	-1.13** (.686)	-.014 (.028)
US	1.59* (.374)	.627* (.157)	.075 (.378)	-51.6 (9868.3)	.006 (.041)
G7	1.84* (.00)	.961* (.023)	.540* (.099)	-.106 (.705)	-.007 (.010)

* $p < 0.05$

** $p < 0.10$

Column (1) reports estimation results estimation result over the full sample period from 1950 to 2018

As estimation results of open economy hybrid NKPC can be seen from Table 4.12, even though the discount parameter β is statistically significant, it is

imprecisely estimated over the first sample period. The price rigidity parameter θ is both statistically significant and less than 1 for the US, Japan and Italy. The parameter ω is related to the degree of firms' backward-looking price adjustment. The parameter ω is significant and less than 1 for France and G7 countries as a group. The slope parameter of open economy NKPC $\lambda(1-\alpha)$ is not statistically significant for none of the G7 countries for G7 countries both individually and as a group.

Table 4.15: Estimation Results of Open Economy Hybrid NKPC (over the sub-sample period)

$$\pi = \alpha_f E_t \pi_{t+1} + \alpha_b \pi_{t-1} + \lambda[(1-\alpha)mc_t + \alpha(p_t^m - p_t)]$$

$$\lambda = \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\theta + \omega[1-\theta(1-\beta)]}, \alpha_f = \frac{\beta\theta}{\theta + \omega[1-\theta(1-\beta)]}, \alpha_b = \frac{\omega}{\theta + \omega[1-\theta(1-\beta)]}$$

Countries	β (2)	θ (2)	ω (2)	α (2)	$\lambda(1-\alpha)$ (2)
Canada	.383 (.374)	.988* (.018)	.246 (.194)	3.59 (9.62)	-.013 (.019)
France	.290** (.168)	1.07* (.017)	-.154 (.236)	-2.11* (.094)	-.181* (.057)
Germany	30.1 (8834)	.030 (8.78)	.359 (2.07)	-.010 (5.72)	.081 (.611)
Italy	1.62 (1.88)	.470 (.545)	.450** (.245)	-1.59* (.134)	.167 (.214)
Japan	-	-	-	-	-
UK	2.39 (2.58)	.437 (.468)	.308 (.191)	-.140 (.724)	-.021 (.045)
US	3.32* (.001)	.263* (.001)	-.036* (.001)	-1.37* (.001)	1.100* (.001)
G7	.936 (194)	1.03 (4258)	.453 (1774)	-3.56 (38.4)	-.001 (.008)

* p < 0.05

** p < 0.10

Column (2) reports estimation results over the sub-sample period based on introduction of inflation targeting regime. (For France, Germany and Italy:1999 – For the UK:1992 – For Canada:1991 – For US:2012 – For Japan:2013)

Table 4.13 reports the estimation results of open economy hybrid NKPC over the sub-sample period that starts from the adoption year of inflation targeting regime for each G7 country except for Japan. Since Japan adopted the inflation targeting regime in 2014, the number of observations after 2014 is not enough for estimation. According to estimation results the effect of relative import price parameter α is also known as openness degree parameter, is not statistically significant or between 0 and 1 for G7 countries over the sub-sample period.

As can be seen from Table 4.13, the structural parameter ω is statistically significant only for Italy over the sub-sample period. According to the estimation result of the open economy hybrid NKPC, after the adoption of inflation targeting regime by European Central Bank in 1998, the effect of past inflation on price adjustment is equal to approximately 0.45 in Italy. However, there is no evidence for other G7 countries over the sub-sample period according to open economy hybrid NKPC estimation.

Although the slope parameter of open economy NKPC $\lambda(1-\alpha)$ is statistically significant for some G7 countries such as France and the US, it is imprecisely estimated for all G7 countries. Similar to full sample estimation results, the slope parameter $\lambda(1-\alpha)$ is not between 0 and 1 or statistically significant over the sub-sample period. Therefore, there is no tangible evidence about the change in the slope of NKPC after the adoption of the inflation targeting regime.

Comparing estimation results of open economy NKPC with estimation results closed economy NKPC both with the full sample and the sub-sample period, closed economy models outperform open economy models. The openness degree parameter α , which is distinctive terms of open economy NKPC that includes foreign trade factors, is not either statistically significant or between 0 and 1 for a lot of G7 countries. There is no tangible evidence about the foreign trade factors in the open economy NKPC both over the first sample and the sub-sample.

Comparing open economy NKPC with open economy GM-NKPC, developed by Gali and Monacelli (2005), GM-NKPC consists of the exchange rate as a function of inflation instead of as a proxy for a real import price. Gali and Monacelli (2005) construct their open economy model (GM-NKPC) by using an equation based on the relationship between foreign trade and exchange rate. Additionally, GM-NKPC assumes that all import goods of a country are consumed by households as final consumption goods.

Table 4.16: Estimation Results of Open Economy GM-NKPC

$$\pi = \beta E_t \pi_{t+1} + \lambda mc_t + \frac{\alpha}{(1-\alpha)} [\Delta q_t - \beta E_t \Delta q_{t+1}]$$

$$\lambda = (1-\theta)(1-\beta\theta)\theta^{-1}$$

Countries	β		θ		α		λ	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Canada	1.32*	-.627	.794*	.970*	.196*	.093*	.020	2.69**
	(.195)	(.498)	(.120)	(.001)	(.063)	(.017)	(.015)	(1.63)
France	.893*	.801*	.958*	.979*	-.144*	.006	.015	.043
	(.172)	(.234)	(.043)	(.012)	(.001)	(.028)	(.044)	(.100)
Germany	1.16*	.598	.879*	.978*	.122	.080	.005	.170
	(.220)	(.559)	(.168)	(.005)	(.078)	(.096)	(.009)	(.461)
Italy	.794*	.792*	.962*	.964*	-.005	.054	.050	.050
	(.115)	(.231)	(.006)	(.007)	(.046)	(.096)	(.051)	(.105)
Japan	1.25*	-	.782*	-	-.019	-	-.004	-
	(.257)		(.150)		(.012)		(.003)	
UK	1.46*	5.41	.722*	.189	.072**	-.011	.035*	.567
	(.104)	(5.84)	(.052)	(.201)	(.039)	(.050)	(.012)	(1.713)
US	1.21*	.963**	.871*	1.01	.010	-.19*	.013	.001
	(.277)	(.500)	(.223)	(7364)	(.033)	(.008)	(.016)	(256)
G7	1.34*	.401*	.772*	.972*	.031	.133	.016*	.374*
	(.070)	(.120)	(.041)	(.003)	(.023)	(.094)	(.004)	(.148)
* p < 0.05				** p < 0.10				

*Column (1) reports estimation results estimation result over the full sample period from 1950 to 2018
Column (2) reports estimation results over the sub-sample period based on introduction of inflation targeting regime. (For France, Germany and Italy:1999 – For the UK:1992 – For Canada:1991 – For US:2012 – For Japan:2013)*

Table 4.16 reports the estimation results of open economy GM-NKPC for G7 countries over the full sample period and the sub-sample period. The results show that the discount factor parameter β is statistically significant and correctly signed for Italy and France over the full sample period. The estimation results over the sub-sample period show that it is statistically significant and correctly signed for the US, Italy, France and G7 countries as a group.

The estimation results of open economy GM-NKPC show that the price rigidity parameter θ is correctly signed and statistically significant at significance level of 0.05 for all G7 countries over the full sample period. The estimation of the price rigidity parameter indicates that the duration of the price adjustment of firms in G7 countries is quite long. In the United Kingdom that has the shortest price adjustment duration among G7 countries, firms' price adjustment duration is equal to approximately 14 quarter years ($4 / (1-0.722) = 14.38$).

The effect of the exchange rate on the inflation parameter is known as openness degree parameter is neither statistically significant nor between 0 and 1 for G7 countries except for Canada and the UK over the full sample period. Additionally, the openness degree parameter is not only statistically significant but also between 0 and 1 only for Canada over the sub-sample period. The estimation results show that the slope parameter λ is statistically significant and correctly signed (positive) only for the UK over the full sample data.

Even though the open economy GM-NKPC explains the domestic dynamics of inflation, there is no evidence about foreign trade factors of inflation dynamics in all G7 countries. According to estimation results, the open economy GM-NKPC

outperforms both the open economy model and its hybrid version to explain inflation dynamics for G7 countries. The open economy GM-NKPC, which includes the exchange rate as an explanatory variable instead of proxy for real import prices, captures inflation dynamics of G7 countries as a group compared to other open economy NKPC models.

Table 4.17: Estimated Backward-Looking and Forward-Looking Expectations

$$\alpha_{f,c} = \beta\theta\phi^{-1}, \alpha_{b,c} = \omega\phi^{-1}, \alpha_{f,o} = \frac{\beta\theta}{\theta + \omega[1 - \theta(1 - \beta)]}, \alpha_{b,o} = \frac{\omega}{\theta + \omega[1 - \theta(1 - \beta)]}$$

Countries	$\alpha_{f,c}$		$\alpha_{b,c}$		$\alpha_{f,o}$		$\alpha_{b,o}$	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Canada	.6111*	.9137*	.3978*	.1818	.5106*	.3497	.5112*	.2269
	(.1767)	(.1906)	(.1783)	(.1961)	(.1898)	(.3064)	(.1764)	(.1572)
France	.4331*	.4860*	.5682*	.4895*	.8454*	.301**	.2868*	-.148
	(.1785)	(.1844)	(.1455)	(.1671)	(.0510)	(.1761)	(.0197)	(.2351)
Germany	.5224*	.6413*	.4862*	.2603	.5878*	1.288	.4429*	.5095
	(.1042)	(.1454)	(.0843)	(.1948)	(.1178)	(5.878)	(.0717)	(3.977)
Italy	.2344	.1557	.6675*	.6888*	.7772*	.7264*	.2380	.4273*
	(.2396)	(.3178)	(.1834)	(.2586)	(.1893)	(.1717)	(.1642)	(.2067)
Japan	.9130*	-	.2617*	-	2.064*	-	.0773	-
	(.3366)		(.0898)		(1.020)		(.5068)	
UK	.5395*	.4621*	.4545*	.5393*	.6015*	1.120*	.3689*	.3302**
	(.1106)	(.2016)	(.1149)	(.1874)	(.1057)	(.3586)	(.0607)	(.1867)
US	.5107*	.3931*	.4868*	.724**	1.366**	4.278*	.1034	-.177*
	(.1030)	(.1884)	(.1034)	(.3762)	(.7866)	(0.001)	(.4619)	(0.001)
G7	.5851*	.5710*	.4545*	.4576*	.8368*	.6640*	.3354*	.3112*
	(.0797)	(.0822)	(.0604)	(.0749)	(.0813)	(.2028)	(.0585)	(.0864)
* p < 0.05					** p < 0.10			
Column (1) reports estimation results estimation result over the full sample period from 1950 to 2018 Column (2) reports estimation results over the sub-sample period based on the introduction of inflation targeting regime. (For France, Germany and Italy:1999 – For the UK:1992 – For Canada:1991 – For US:2012 – For Japan:2013)								

Table 4.17 shows the weights of backward-looking and forward-looking expectations on domestic inflation. The estimated results are obtained from both the closed economy hybrid model and the open economy hybrid model since hybrid models contain both backward-looking and forward-looking expectations. According to estimation results in Table 4.17, both backward-looking and forward-looking expectations have a significant impact on domestic inflation. After the introduction of the inflation targeting regime, the weight of forward-looking expectation has increased in G7 countries except for the US and the UK according to estimation results obtained from the closed economy hybrid model.

Even though the estimation results in Table 4.17 do not achieve a consensus regarding change on price-setting behaviors of firms after inflation targeting regime, the estimation results emphasize that both backward-looking and forward-looking expectations are significant determinants for the inflation process. Although the introduction of inflation targeting regime affected price-setting behaviors of firms, firms adjust their prices based on not only forward-looking but also backward-looking expectations.

CONCLUSION

The consensus about the empirical and theoretical models to explain inflation dynamics has not been achieved since the development of the Phillips Curve. Although the Phillips Curve explained the inflation process before stagflation in the 1970s, the relationship between inflation and unemployment has changed and disappeared over time. The attempts to understand the dynamics of inflation have continued up to now since inflation is one of the most important phenomena. The empirical and theoretical discussion and reviews about inflation dynamics lead to the development of new models based on the microeconomic foundations and optimization behaviors of economic agents. Even though one of these models is the baseline NKPC model, its different versions such as open economy models have also been developed thanks to these discussions in the economic literature.

The open economy versions of NKPC models are built on the idea that domestic inflation is directly affected by foreign trade factors such as exchange rate and foreign trade in the open economies. In the empirical literature, the open economy models take into account the openness degree of countries, but not the economic sizes of countries. However, as mentioned in Chapter Two, the effects of foreign trade factors on the price rigidity of domestic firms depend not only on the openness degree but also on the size of the home country. The results of empirical studies in the literature indicate that the price rigidities are positively related to the size and negatively related to the openness of countries.

Additionally, in the empirical literature, the estimated openness parameters of open economy NKPC models are either incorrectly signed or statistically insignificant for many countries with a very high degree of openness. Moreover, baseline NKPC models, also known as closed economy models better explain inflation dynamics for these large countries. The estimations of the NKPC models

without considering the size of countries provide conflicting results regarding inflation dynamics in open and large countries.

The inflation dynamics are handled for the open countries, but the number of studies that investigate inflation dynamics for only open and large countries considering both economic size and openness is limited in the empirical literature. The existing empirical literature does not provide a comprehensive review of inflation dynamics in open and large countries. To sum up, there is a need for a study focusing on inflation dynamics in only large and open countries.

In this study, we investigate inflation dynamics in large and open countries using the NKPC models and considering the size and openness degree of countries. In this context, G7 countries are chosen as sample countries due to their size and openness degree. In order to discuss inflation dynamics for G7 countries with different approaches, five different NKPC models are determined, and they are estimated by using the GMM estimation method with the two different sample periods each G7 country. The annual and aggregated data are used in this study instead of sectoral data. The sample period separated into the full sample period that consists of all available data and a sub-sample period that starts from the adoption year of inflation targeting regime for each country.

Based on the estimation results of five NKPC models, we have obtained several significant findings. These estimation results provide an extensive review of inflation dynamics for G7 countries as large and open countries. The main finding of this study is that the openness parameters in the open economy and open economy hybrid models are either statistically insignificant or incorrectly signed. Since openness parameters represent the effect of foreign trade factors, this finding demonstrates that foreign trade factors have no significant impact on the domestic inflation process in G7 countries as large and open countries. In addition to open economy and open economy hybrid versions of NKPC, the estimation results of the

open economy GM-NKPC indicate that foreign trade factors are not an important determinant of the inflation process in G7 countries except for Canada.

The second important finding connects to the differences in price rigidity parameters between sample periods. The estimation results of baseline NKPC models suggest that price rigidity dramatically decreased in the domestic market after the adoption of the inflation targeting regime. It also indicates that the price adjustment frequency of domestic firms decreased after the inception of the inflation targeting regime and these firms adjust their prices considering expected future inflation rather than past inflation. However, in contrast to the estimation of baseline models, an overwhelming majority of price rigidity parameters in the estimation of hybrid models are either incorrectly signed (negative or greater than 1) or statistically insignificant for G7 countries.

Even though the inflation targeting regime has a significant impact on price rigidity and price adjustment frequency, estimation results indicate that domestic firms in G7 countries adjust their price based on not only forward-looking expectations. The domestic firms adjust their price considering backward-looking expectations along with forward-looking expectations. The inflation targeting regime affected only the weights of the forward and backward-looking expectations in the inflation process. The effect of backward-looking expectations in the inflation process decreased after the introduction of the inflation targeting regime according to estimation results. Nevertheless, backward-looking expectations are still a significant determinant of domestic inflation in G7 countries.

The individual estimation results of the models do not provide a review of the slope of the NKPC models. The slope parameters in individual estimation results are hardly ever statistically significant and incorrectly signed, especially in the closed economy models. However, the group estimation results with panel data for G7

countries support that the slope of NKPC models has increased over the sub-sample period which starts from the adoption of the inflation targeting regime.

When comparing estimated NKPC models in this study, the baseline closed economy models rather than open economy models better explain inflation dynamics for G7 countries as large and open countries. The openness parameters in open economy models are usually either statistically insignificant or incorrectly signed in G7 countries despite their high openness degree. As a result of closed economy models, the overwhelming majority of structural parameters are correctly signed and statistically significant over the full sample period. Among closed economy NKPC models, the baseline closed economy model better explains the domestic inflation in G7 countries than the closed economy hybrid models, which includes past inflation as an explanatory variable.

The estimation result of open economy GM-NKPC, which includes real effective exchange rate as an explanatory variable instead of a proxy variable, provides weak support for the role of the exchange rate in domestic inflation in G7 countries compared to the open economy and open economy hybrid models. The reason for statistically insignificant explanatory variables over the sub-sample period based on the introduction of inflation targeting regime may be a limited number of observations.

Considering the estimation results of NKPC models in the existing empirical literature, open economy models usually explain the inflation process in small and open countries. Additionally, closed economy models might explain the inflation process in open and large countries. This study shows that the model which is appropriate for a country depends on the countries' economic sizes. Whereas closed economy models might be appropriate for open economies despite the model's closeness, open economy models might not be appropriate for open economies despite the model's openness.

The above findings can be interpreted in the following way. Although the open economy models have strong theoretical foundations, these models do not address large and open countries. In open economy models, theoretical developments are needed to take into account the size of the countries along with their openness degree. Even though the NKPC models explain inflation dynamics considering the optimization behavior of economic agents and microeconomic foundations, these models do not take into account sectoral conditions and differences. Since the quality and rate of imported inputs differ by sector in the economy, the use of disaggregated data may be useful to determine the dynamics of inflation.



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APPENDIX A

The Standard Log-Linearization Method

As mentioned in the Section 1.4.1, aggregate price level is results total of price level of firms in the monopolistic market. A log-linearization of aggregate price level in the Equation 1.9 around a zero-inflation steady state is obtained by using the standard log-linearization method (Fall 2000).

$$f(X_t, Y_t) = g(W_t)$$

where X_t, Y_t and W_t are variables greater than 0. The above equation can be rewritten taking logs on both sides of equation;

$$\log(f(e^{\log(X_t)}, e^{\log(Y_t)})) = \log(g(e^{\log(W_t)}))$$

For a first order the Taylor approximation of left side of the above equation around steady state as follows;

$$\log(f(X, Y)) + \frac{1}{f(X, Y)} (f_1(X, Y)X(\log(X_t) - \log(X)) + f_2(X, Y)Y(\log(Y_t) - \log(Y)))$$

Similarly, for a first order the Taylor approximation of right side of the above equation around steady state as follows;

$$\log(g(W)) + \frac{1}{g(W)} (g'(W)W(\log(W_t) - \log(W)))$$

The log-linearization equation is rewritten by using previous equation as follows;

$$\begin{aligned} & (f_1(X, Y)X(\log(X_t) - \log(X)) + f_2(X, Y)Y(\log(Y_t) - \log(Y))) \\ & \simeq (g'(W)W(\log(W_t) - \log(W))) \end{aligned}$$

The above equation is applied on the Equation 1.9 in the Section 1.4.1

$$P_t P_{t-1}^{1-\eta} = ((1 - \theta)(Z_t^*)^{1-\eta} + \theta)^{\frac{1}{1-\eta}}$$

where Z_t^* , P_{t-1} and P_t refers X_t , Y_t and W_t , respectively.

$$f(Z_t^*, P_{t-1}) = \left[(1 - \theta)(Z_t^*)^{1-\eta} + \theta P_{t-1}^{(1-\eta)} \right]^{\frac{1}{1-\eta}}$$

and

$$g(P_t) = P_t$$

Similarly,

$$\begin{aligned} Pp_t = \frac{1}{1-\eta} & \left[(1 - \theta)(Z^*)^{(1-\eta)} + \theta P^{(1-\eta)} \right]^{\frac{\eta}{1-\eta}} \left[(1 - \theta)(1 - \eta)(Z^*)^{(-\eta)}(Z^*)_{Z_t^*} \right. \\ & \left. + \theta(1 - \eta)P^{(-\eta)}Pp_{t-1} \right] \end{aligned}$$

$$\begin{aligned} Pp_t = \frac{1}{1-\eta} & \left[(1 - \theta)(Z^*)^{(1-\eta)} + \theta P^{(1-\eta)} \right]^{\frac{\eta}{1-\eta}} [1 - \eta] \left[(1 - \theta)(Z^*)^{(1-\eta)}_{Z_t^*} \right. \\ & \left. + \theta(P^{(1-\eta)}p_{t-1}) \right] \end{aligned}$$

$$Pp_t = P^\eta [(1 - \theta)(Z^*)^{(1-\eta)} z_t^* + \theta P^{(1-\eta)} p_{t-1}]$$

The Equation 1.9 is obtained by using the assumption of $Z^* = P$ in steady state as follows;

$$Pp_t = P^\eta [(1 - \theta)P^{(1-\eta)} z_t^* + \theta P^{(1-\eta)} p_{t-1}]$$

$$Pp_t = P^\eta P^{(1-\eta)} [(1 - \theta)z_t^* + \theta p_{t-1}]$$

$$p_t = (1 - \theta)z_t^* + \theta p_{t-1}$$

Therefore, the aggregate price level in the Equation 1.20 is obtained by using standard log-linearization method.

APPENDIX B

The Derivation of the New Keynesian Phillips Curve

Here the derivation of the New Keynesian Phillips Curve is introduced by using aggregate price level and optimal reset price in the Calvo economy (Whelan, 2005). As mentioned in the Section 1.4.1, the aggregate price level is a weighted monopolistic firms' reset price and average of past inflation regarding price rigidity parameter θ as follows;

$$p_t = (1 - \theta)z_t^* + \theta p_{t-1}$$

The optimal reset price z_t^* can be written as follows;

$$z_t^* = (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t(\mu + mc_{t+k})$$

The optimal reset price equation can be arranged as follows;

$$z_t = \frac{1}{1 - \theta} [p_t - \theta p_{t-1}]$$

The first order stochastic difference equation is expressed as follows;

$$y_t = \alpha x_t + b E_t y_{t+1}$$

The above equation can be solved to give

$$y_t = \alpha \sum_{k=0}^{\infty} b^k E_t x_{t+k}$$

where

$$\alpha = 1 - \beta\theta$$

$$x_t = \mu + mc_t$$

$$b = \theta\beta$$

$$y_t = z_t$$

In this context, the reset price equation is can be rewritten as

$$z_t = \theta\beta E_t z_{t+1} + (1 - \theta\beta)(\mu + mc_t)$$

By substituting in the expression for reset price equation

$$\left[\frac{1}{1-\theta} \right] (p_t - \theta p_{t-1}) = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - \theta p_t) + (1 - \theta\beta)(\mu + mc_t)$$

The above equation is re-arranged to derivate the NKPC as follows;

$$\begin{aligned} \left[\frac{1}{1-\theta} \right] (p_t - \theta p_{t-1} - p_{t-1} + p_{t+1}) \\ = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - \theta p_t - p_t + p_t) + (1 - \theta\beta)(\mu + mc_t) \end{aligned}$$

$$\left[\frac{1}{1-\theta} \right] (p_t - p_{t-1}) + p_{t-1} = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - p_t) + \theta\beta p_t + (1 - \theta\beta)(\mu + mc_t)$$

$$\begin{aligned} \left[\frac{1}{1-\theta} \right] (p_t - p_{t-1}) + p_{t-1} - p_t \\ = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - p_t) + \theta\beta p_t - p_t + (1-\theta\beta)(\mu + mc_t) \end{aligned}$$

$$\begin{aligned} \left[\frac{1}{1-\theta} \right] [p_t - p_{t-1}] - [p_{t-1} - p_t] \\ = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - p_t) - p_t[1-\theta\beta] + [1-\theta\beta](\mu + mc_t) \end{aligned}$$

$$\left[\frac{1}{1-\theta} - 1 \right] (p_t - p_{t-1}) = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - p_t) + [1-\theta\beta](\mu + mc_t - p_t)$$

$$\left[\frac{\theta}{1-\theta} \right] (p_t - p_{t-1}) = \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - p_t) + [1-\theta\beta](\mu + mc_t - p_t)$$

Multiplying both sides of the above equation by $\left[\frac{1-\theta}{\theta} \right]$

$$\begin{aligned} \left[\frac{1-\theta}{\theta} \right] \left[\frac{\theta}{1-\theta} \right] (p_t - p_{t-1}) \\ = \left[\frac{1-\theta}{\theta} \right] \left[\frac{\theta\beta}{1-\theta} \right] (E_t p_{t+1} - p_t) + [1-\theta\beta](\mu + mc_t - p_t) \end{aligned}$$

$$\underbrace{(p_t - p_{t-1})}_{\text{inflation } (\pi_t)} = \beta \underbrace{[E_t p_{t+1} - p_t]}_{\text{expected inflation } (E_t \pi_{t+1})} + \underbrace{\frac{(1-\theta)(1-\theta\beta)}{\theta}}_{\text{slope parameter } (\lambda)} \underbrace{(\mu + mc_t - p_t)}_{\text{real marginal cost } mc^r}$$

Thus, the New Keynesian Phillips Curve:

$$\pi_t = \beta E_t \pi_{t+1} + \lambda mc_t^r$$

APPENDIX C

The Real Marginal Cost and Output Gap

In Appendix B, in the New Keynesian Phillips Curve model, the inflation is a function of expected inflation and real marginal cost. Here the relationship between real marginal cost and output is presented to use output gap as a proxy for marginal cost, empirically (Whelan, 2005). As mentioned in the previous appendix, the NKPC and the real marginal cost are written as:

$$mc_t^r = \mu + mc_t - p_t$$

$$\pi_t = \beta E_t \pi_{t+1} + \lambda mc_t^r$$

where

$$\lambda = \frac{(1 - \theta)(1 - \beta\theta)}{\theta}$$

The NKPC can be rewritten as

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1 - \theta)(1 - \beta\theta)}{\theta} mc_t^r$$

The relationship between output gap and marginal cost is described as

$$\widehat{mc}_t^r = \lambda \hat{x}_t$$

where $\hat{x}_t$ represents the output gap. Thus, the New Keynesian Phillips Curve can be rewritten by using the relationship between the real marginal cost and output gap as follows;

$$\pi_t = \beta E_t \pi_{t+1} + \gamma \hat{x}_t$$

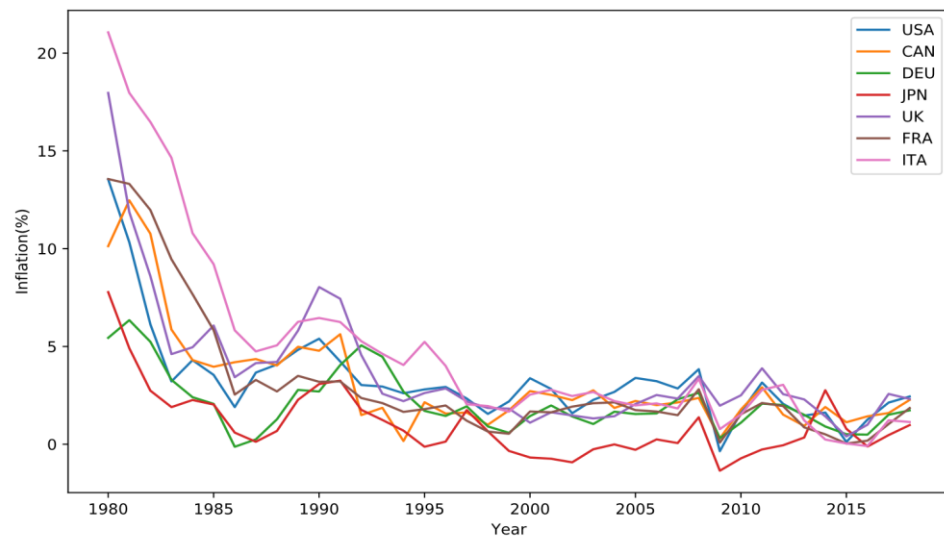
where the slope parameter is

$$\gamma = \frac{\lambda(1-\theta)(1-\theta\beta)}{\theta}$$

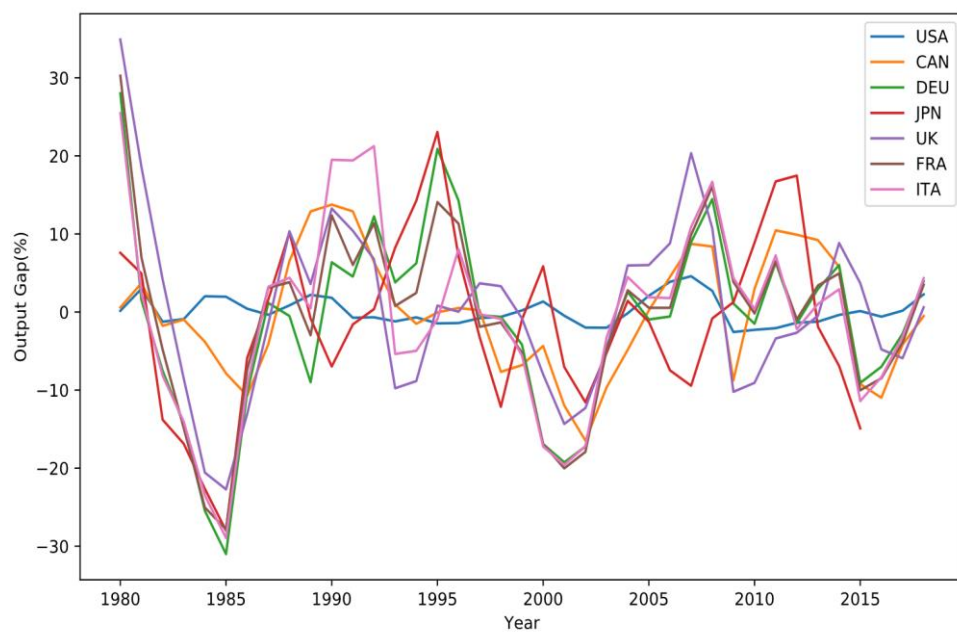
APPENDIX D

Graphic Presentation of Data

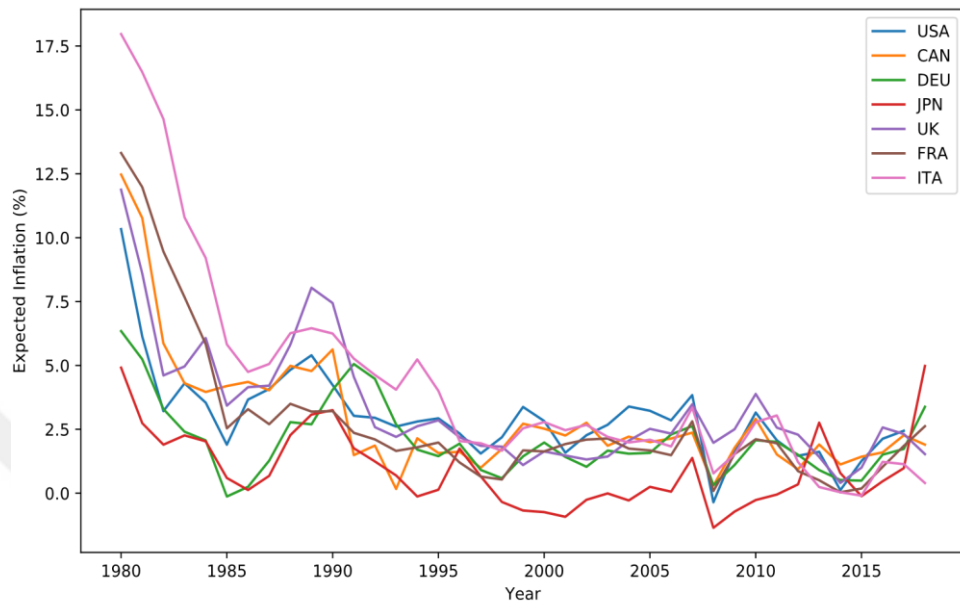
Inflation Variables for G7 Countries, 1980-2018



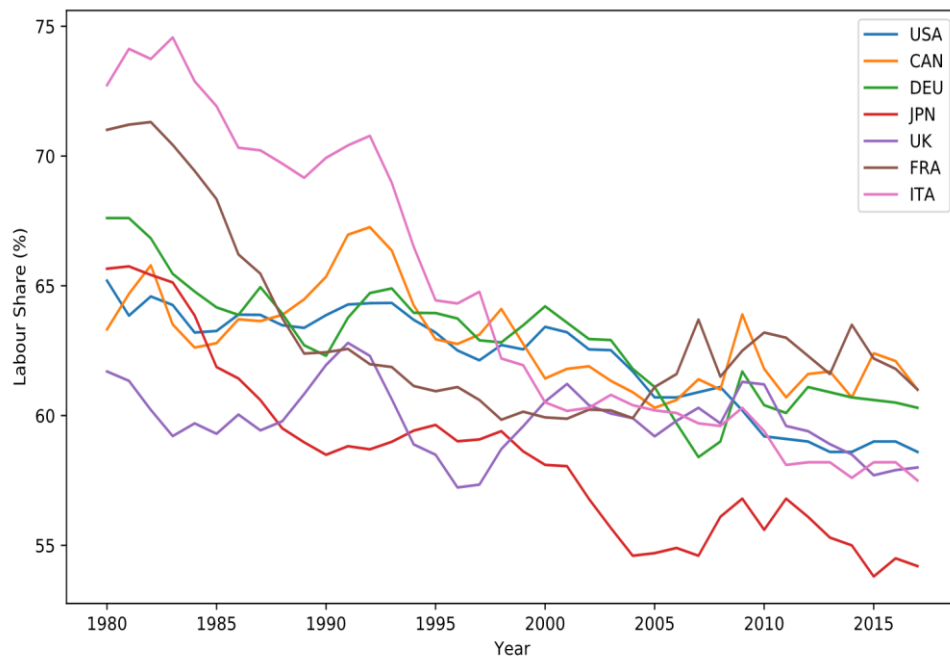
Output Gap Variables for G7 Countries, 1980-2018



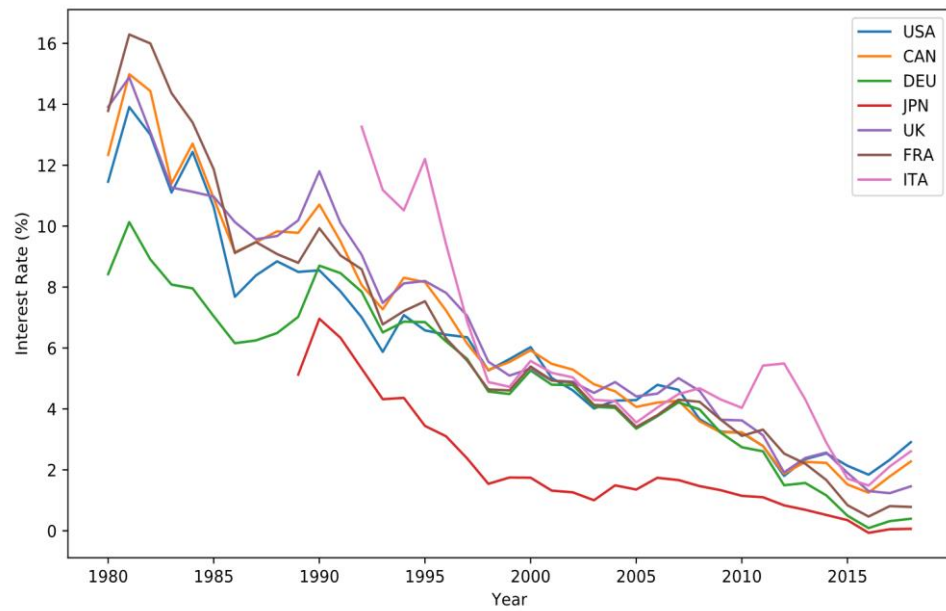
Expected Inflation Variables for G7 Countries, 1980-2018



Labour Share Variables for G7 Countries, 1980-2018



Interest Rate Variables for G7 Countries, 1980-2018



Real Effective Exchange Rate Variables for G7 Countries, 1980-2018

