An Estimation of the Threshold Phillips Curve Model: Evidence from G7 Plus Australia

by

Chong Zhou

Submitted in partial fulfilment of the requirements
for the degree of Master of Arts

at

Dalhousie University
Halifax, Nova Scotia
December 2013

TABLE OF CONTENTS

List of Tables

List of Figures

Abstract

This paper mainly focuses on one of the new specifications of Phillips curve family, the threshold Phillips curve. By estimating the threshold model using G7 plus Australia countries quarterly data, the threshold effect is confirmed only by U.S. and Canadian Phillips curves. No strong evidence for the threshold effect was found among other countries. Moreover, the estimation results for both standard and threshold Phillips curve model indicate weak trade-off relations between inflation and unemployment. Policy makers should review Phillips curve as a forecasting tool with extra caution. Future studies can focus on specific country's threshold effect testing with detailed explanation.

Keywords: Phillips curve, Trade-off, Thresholds effect, Macroeconomic policy

List of Abbreviations Used

G7: Group of 7 wealthiest developed nations

NAIRU: Non-Accelerating Inflation Rate of Unemployment

CBO: Congressional Budget Office

OECD: Organization for Economic Co-operation and Development

HP flter: HodrickPrescott filter

Acknowledgements

I acknowledge my indebtness to Professor Lars Osberg and Professor Andrea Giusto who gave me inspiration and invaluable assistance for this study. My thanks to Professor Catherine Boulatoff, who is the second reader of this thesis, for her helpful feedbacks; Thanks are also extended to Mr. Chen Yuxin and Mr. Ma Zongming for their programming and editing assistance.

Chapter 1

Introduction

This paper starts with a core and basic question: "why Phillips curve?" Robert Solow' 37 years ago remark may fairly answer my question: "Any time seems to be the right time for reflections on the Phillips curve. So long as the actuality or threat of inflation remains a current problem, and so long as no clearly better organizing device presents itself, economists will argue about the Phillips curve" (Solow, 1976, p.3-22)[40].

Indeed, as one of the most influential findings in macroeconomics, the Phillips curve is not ready to be forgotten. As Pierre Fortin [12]once remarked, the Phillips curve "is 'enjoying' the full respect of most macroeconomic theorists and practitioners after being pronounced dead by some in the 1970s and 1980s". It is no doubt that Phillips curve was once favored by those policy makers in 1960s who believed in lowering unemployment by compromising a higher inflation; and again, no doubt, it was once questioned in 1970s by its critics who either suspected its accuracy or directly sen-

tenced its death. Even nowadays, new specifications of the inflation-unemployment trade-off relation are introduced to continue the debate. The Phillips curve is one of the headline topics in macroeconomics. It is also widely acknowledged as a macroeconomic channel in terms of monetary policy making, given the fact that most central banks nowadays are taking inflation control as a main mandate, and that no other theoretical and practical mechanism has been claimed better than the Phillips curve in terms of characterizing the relationship between inflation and unemployment. In short, we are not ready to forget and we will discuss about the Phillips curve.

Chapter two will discuss the history of the Phillips curve in a chronological order. It also serves as a literature review which may help to understand what really happened to the Phillips curve, from its birth, growing up, until the present. A full story of the Phillips curve will be told until it leads to the main focus and motivation of this paper, the threshold Phillips curve model. A brief introduction of the threshold Phillips curve model will be followed up at the end of Chapter two and it will be minutely explained in the methodology section. Chapter three will discuss the data and methodology. This paper uses G7 plus Australia countries quarterly data obtained from OECD statistics. Sample selection criteria will be explained in detail and each country's data will be sorted and presented in a descriptive statistic manner. Methodology section will be discussed after data, where the standard and threshold Phillips curve models will be discussed explicitly. This paper follows the methodology used in the U.S. papers where the threshold Phillips curve model was first introduced. Chapter four presents the empirical analysis and interpretations. Regression results will be

presented and discussed for each country respectively. Each country's result will also be compared with others for valuable explanation. The last chapter is the conclusion where the threshold effect hypothesis will be accepted or rejected accordingly. The main purpose of this paper is to summarize the Phillips curve story thoroughly and to introduce the newly born threshold Phillips curve model to a global basis. With more countries data tested and more evidence collected, we will be more confident to conclude whether the threshold Phillips curve model is applicable to other countries other than U.S., and whether the threshold model outperforms the standard model in terms of characterizing the inflation-unemployment relationship.

Chapter 2

Literature Review

2.1 Controversy: Phillips curve at the beginning

The simplest way to tell the Phillips curve story would be only one word "controversy". It was controversial even before its official birth in 1958 when A. W. Phillips [32] observed the trade-off relation between changes of unemployment and the money wage rate. There were indeed several similar works done before Mr. Phillips. One is from Irving Fisher, as mentioned by Friedman [17], Fisher published his work in 1926 [11] and had observed quite similar empirical phenomenon that Mr. Phillips did 32 year later. A main distinction between Fisher and Phillips was that Fisher took price changes while Phillips talked about wage changes as the independent variable in the trade-off equation between inflation and unemployment. Nevertheless, both of them considered price and wage move together; and they both observed negative correlation between price changes or wage changes and unemployment rate. One

thing worth mentioning is that Friedman considered Phillips' finding was based on an error that Phillips used nominal wages instead of real wages. "Every economic theorist from Adam Smith to the present would have told you that the vertical axis of labor market should refer not to the nominal wage rate but to the real wage rate" (Friedman, 1975, p.15) [17]. "How did a sophisticated mind like Phillips' come to confuse nominal wages with real wages?" (Friedman, 1975,p.16) Friedman raised and answered the question by himself: "he was led to do so by the general intellectual climate that had been engendered by the Keynesian revolution". In other words, it was natural for Phillips to consider the change in nominal wages to be equal to the change in real wages regarding that Keynesians assumed nominal and real wages move together.

Phillips was not the only person to observe the relation between unemployment and wages or prices. A.J. Brown, for example, one of the pre-Phillips curve folk, in his 1955 article (later reprinted in 1983) [8], discussed precisely the relationship between percentage change in unemployment and percentage rate of increase in wage and prices. There were more pre-Phillips curve folks (Sultan [43] in Amid et al. [2] and Tinbergen [44]) who had similar theoretical or empirical works done, but none of them became as well known and honored as Phillips curve did.

2.2 Why was it called the Phillips curve?

As the survey of old literatures continues, one question is why, among all those observations works, only Phillips curve coined its fame? Why wasn't the relation called the "Brown curve" or the "Sultan curve"? For one reason, as Lipsey said, Phillips "noticed what others had not" [23] from the data scatter map which shows little obvious relation between variables. He found that if successive points were joined according to dates or time, they formed a series of loops (Figure 2.1). setting certain time frequency, for each cycle, the loops then formed a relatively stable inverse relation between the rate of change of money wages and the unemployment. Thanks to this extraordinary noticing from some unnoticeable pattern of points, we now have the downward sloping Phillips curve.

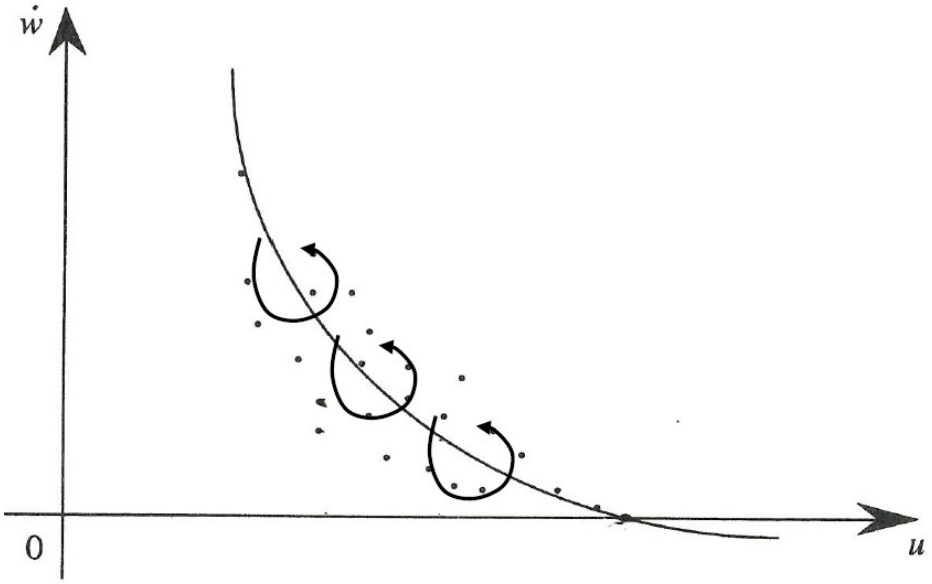

Figure 2.1: The Phillips Curve, and the Loops

As one hand alone cannot clap, the Phillips curve did not make itself well known without other's help. Samuelson and Solow , for example, were two dedicated American economists who took Phillips' work and introduced the trade-off relation to U.S. data. They demonstrated that the trade-off relation illustrated by the Phillips curve could be translated into an economic policy menu (Samuelson and Solow, 1960 [35] and Rees, 1970 [34]). Politicians could simply follow the menu and pick up a preferable inflation-unemployment combination. That was when policy makers started to regard the Phillips curve as a policy tool; and from Samuelson and Solow, the Phillips curve trade-off relation was found applicable in many other countries in terms of macroeconomic policy making. In short, it might seem a bit predestined that Phillips curve became famous. As the same question was once asked by Santomero and Seater [36] who analyzed the first twenty years of debate after Phillips' 1958 publication on the Phillips curve trade-off relation, they summarized the success of the Phillips curve in three reasons. Firstly Phillips published his observation couple of month earlier than the others; secondly his original work was critically but brilliantly extended by Lipsey [22]; and thirdly only Phillips drew the "eye-catching" curve that bears his name.

Another influential work following Phillips' 1958 publication was from Lipsey [22]. He econometrically extended Phillips' original work, with much more detailed explanation about the connection between labour market and the trade-off relation. In general, he agreed on the existence of the inverse relationship between inflation and unemployment. But in particular he criticized about the labour market assumptions under Phillips' work. Firstly Lipsey considered the relationship tested by Phillips was

biased because Phillips took only unionized labour force unemployed for the calculation of unemployment rate. Secondly Lipsey thought that Phillips had not considered the effect of changes in cost of living on the wage bargaining. Moreover, considering Phillips had given relatively more emphasizing on the supply side than demand side of labour market, Lipsey then alternatively conducted his observation and testing in a dynamic adjustment mechanism. His critical interpretation served the original Phillips work with additional theoretical complement and improvements.

2.3 The time of the Phillips curve, 1950s and 1960s

If we call the first decade of 1950s after WWII "recovery", then the priority for politicians was to improve people's living standard by creating more jobs to reduce the unemployed army. But there was a big concern for Keynesian politicians to implement government intervention, that they were hesitating between price level control and lowering unemployment. The Phillips curve happened to give them a political economic menu, that following this menu, policy makers could achieve a lower unemployment goal at the sacrifice of a higher inflation rate, an inflation they could explain according to the Phillips curve trade-off relation.

The next decade of 1960s is more of a stage for the Phillips curve to show off its contribution as a monetary policy channel, especially for the U.S. which was the largest economy since WWII. After Samuelson and Solow, more U.S. economists (Pierson,

1968 [33] and Perry, 1966 [30]) favored the Phillips curve by concluding in their researches that there exists an inverse relationship between inflation and unemployment. In other words, government intervention could help to stimulate economy and thus lower the unemployment. Following this lead, the U.S. experienced its longest uninterrupted economic expansion. Regardless of the adverse effect from Vietnam War, the economic stimulation launched by presidents Kennedy and later his tax cut did help US economy to see a robust boom with 50 percent increase in average Americans real income by the end of decade. U.S. unemployment dropped from over 6 percent to 3.3 percent (1.4 percent lowest in 1965) while inflation increased to 6.5 percent at late 1960s. [13]

2.4 Challenges for the Phillips curve, late 1960s and 1970s

As the politicians followed the trade-off relation to stimulate economies, meanwhile, the critics did not stop seeking for truth on the Phillips curve. Corry and Laidler [9], for example, noticed the uncertainty of the shape of the Phillips curve. They demonstrated that the downward sloping Phillips curve (as indicated in Figure 2.2, (c)) is not always true for any country. It could shape as Figure 2.2 (a) or (b), especially for some countries with relatively higher unemployment.

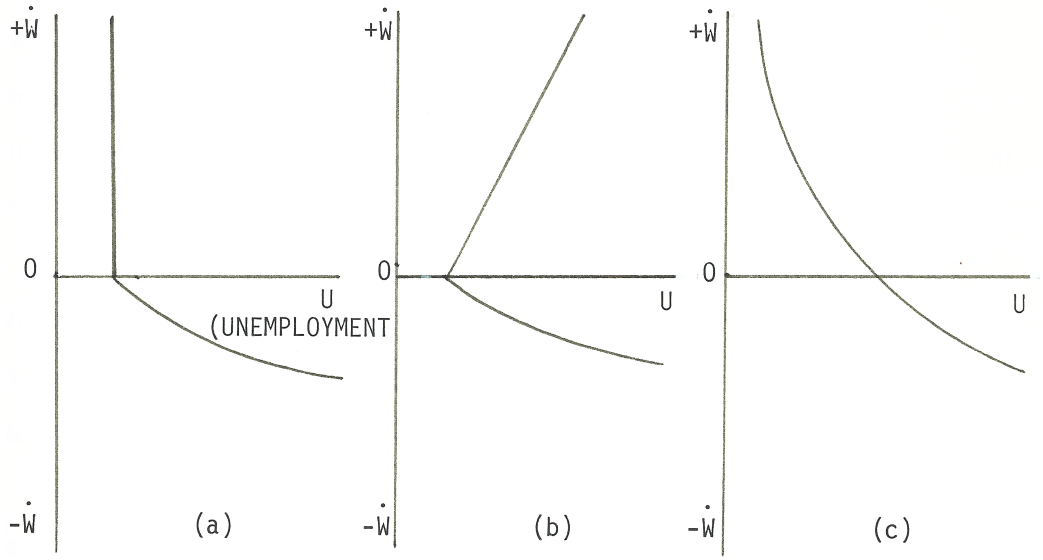

Figure 2.2: Different Shapes of The Phillips Curve

One of the most dramatic challenges for the Phillips curve trade-off relation came from a late 1960s and 1970s critique demonstrated by Friedman. In his late 1960s publications (1966 [15]and 1968 [14]), Friedman started his argument by pointing out the error of confusion between nominal and real wages in Phillips original publication. He then criticized Lipsey's analysis on the labour market for two reasons. Firstly Lipsey did not notice the error in Phillips original work thus Lipsey's analysis was fault as well. Secondly he criticized Lipsey's work by reinterpreting the wage bargaining process between employers and employees using the so called "adaptive expectations hypothesis". In that way, Friedman conducted the difference between anticipated and unanticipated inflations, which in turn contributed to demonstrating his main argument that the Keynesian favored Phillips curve trade-off relation only exists in the short run. According to Friedman's theoretical analysis, the long run Phillips curve would turn out to be vertical with a horizontal intersection called the

"natural rate of unemployment" which was determined solely by real factors such as population and technology, but not monetary factors (such as nominal money wage in Phillips' original framework).

According to Friedman's theory [16], the long run Phillips curve would be looked like the vertical line in Figure 2.3, where the parallel downward sloping curves are the short run Phillips curves.

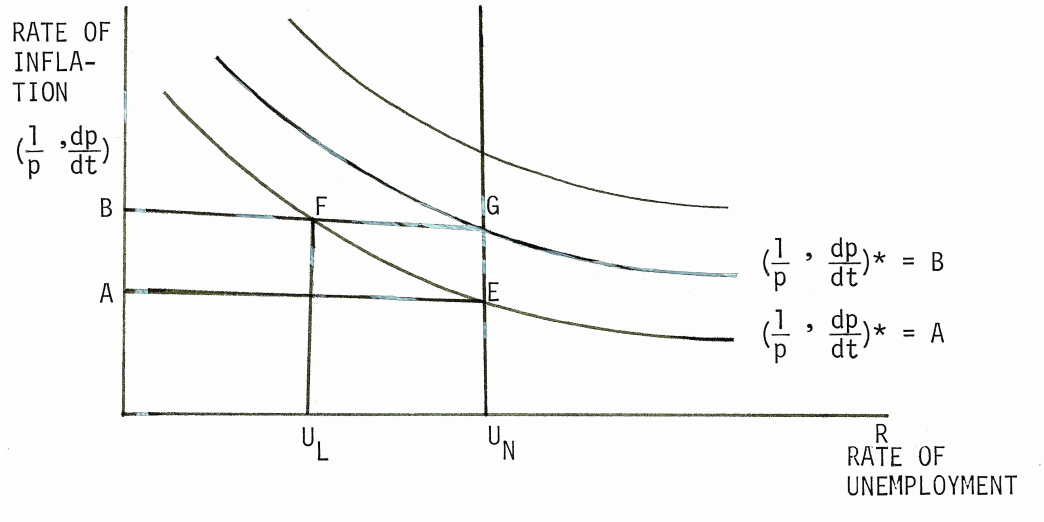

Figure 2.3: Friedman's Phillips Curves, Short Run and Long Run

As suggested by Friedman, the trade-off relation illustrated by the Phillips curve only exists in the short run, where graphically curve EF indicates the inverse relationship between rate of inflation and unemployment. If inflation increases from A to B, unemployment will decline accordingly from UN to UL in the short run. However, point F apparently is not a stable situation, as expectation adjusts gradually (according to

Friedman's adaptive expectation hypothesis), the short run Phillips curve will shift up until the unemployment rate moves back to the UN which is the natural rate of unemployment level.

After Friedman's 1968 presidential address to the American Economic Association, the traditional Phillips curve trade-off was strongly shaken. Similar arguments were also raised by Phelps who called the natural rate of unemployment the "warranted rate" [31]. As one of the monetarists, Friedman was one of the leaders in the battle against government intervention that was suggested by Keynesian economists. For monetarists, there is only one level of output and unemployment that all of the monetary policy intended to boost the economy will be eventually ineffective. That was what we now call "the neutrality of money".

However, Freidman's framework was not perfect and was questioned. For example, his explanation of the short run Phillips curve was criticized for the weak asymmetry assumption that it would be true only if employers realize price level changes quicker than employees do. According to the Livingston survey of inflationary expectations and the University of Michigan Survey Research Center date on inflationary expectations, the surveyed businessmen were not systematically outperforming the general public in terms of inflationary expectation forecasting. Therefore, this condition of asymmetry assumption does not always hold.

But one thing Friedman did notice before it actually happened was as Paul Krugman

stated in his 1995 publication, "Friedman not only showed why the apparent trade off embodied in the idea of the Phillips curve was wrong; he also predicted the emergence of combined inflation and high unemployment", a situation what we call the "stagflation". [21]

The word "stagflation" is in fact a combination of two words, namely "stagnation" and "inflation", where the former refers to economic recession with upward pressure on unemployment, and the latter refers to the threat of price level increase. In economic history, the most classical stagflation happened in U.S. during late 1970s when inflation and unemployment increased at the same time. This was absolute humiliation for the Phillips curve theory, which considers inflation and unemployment as two opposite evils that never show up together. In fact, the data during stagflation was consistent with Friedman's short run versus long run Phillips curves analysis that the short run Phillips curve was shifting upward with simultaneously increase in both inflation and unemployment.

Lucas [26], Sargent and Wallace (1973 [37] and 1975 [38]) and Barro [6] believed in and introduced to their literatures what we call "the rational expectation hypothesis". The basic idea of rational expectation is that individuals form their expectations according to the instantaneous information they have on their own market equilibrium price while the general equilibrium price level information is delayed. Therefore, there exists a deviation of expected from real price. Because each individual assumes their expectation model was correct and they adjust their expectations according to the

deviation in the last period. Thus all individuals' predictions are considered not systematically wrong in the long run. In this way, when explaining the short run Phillips curve, there is no need to assume systematic asymmetries in perceptions between workers and employers as Friedman suggested.

Different with Friedman, who accepted but set restrictions on the existence of short run Phillip curve trade-off relation, Lucas and Sargent later in 1978, according to their theory based on rational expectation, directly pronounced the short run Philips curve dead [25] . Lucas also received the Nobel Prize in 1995 for his famous theory about monetary neutrality [27]which was once informally illustrated by Friedman. According to the monetary neutrality, any government monetary policy attempting to change price without changing expected price simultaneously would fail because of the rational expectation hypothesis.

In short, the Phillips curve trade-off relation was historically questioned and criticized at the end of 1970s when it embarrassingly experienced the stagflation, and was strongly shaken and sentenced to death later by Lucas. But the application of rational expectation theory built by Lucas and other economists was also being questioned. For example, one may say that monetary authorities such as central banks usually have superior information about inflation than the public; they can simply fool the public and make the policy effective, which in turn breaks the neutrality of monetary policy claimed by Lucas.

2.5 The debate keeps on, Phillips curve after 1970s

After 1970s, the debate on the existence and the shape of the Phillips curve (if it exists) continued and last till present. New empirical researches have been done based on historical and upcoming data. Tootell [45] for example, found empirical evidence of a stable and significant trade-off between inflation and unemployment. Fuhrer [18], for another example, stated in his words, that "Phillips curve is alive and well". But as summarized by Musso [28], "the existing empirical evidence for the U.S. and other industrialised economies is mixed. Akerlof, Dickens and Perry [1] and Debelle and Laxton [10], among others, suggested a convex Philips curve is appropriate, while Gordon [19] argues in favour of a linear curve and Stiglitz [41] even of a concave one."

One thing for sure is that nevertheless Phillips curve has been successively keeping its headline topic position along with both its fans' favourable contribution and its critics' trying to nail it into grave. The decades after 1970s for Phillips curve are mingled with positive and negative turns. The positive turns came from those macroeconomists and central bankers who put their efforts trying to understand what had happened since 1970s and how exactly to explain the stagflation. The negative turns came from the monetarists and Lucas followers who were trying to collect more evidence to theoretically and empirically prove the uselessness of the Phillips curve as a policy channel in terms of inflation forecasting.

2.6 Recent works on the Phillips curve, and the threshold Phillips curve

Recent literatures are mainly trying to answer two questions: whether the Phillips curve trade-off relation between inflation and unemployment should be expected to be stable over time, and whether the Phillips curve should be used as a monetary policy tool.

Atkeson and Ohanian [4] for example, conducted a "horse race" between three NAIRU based Phillips curve models and concluded that none of these NAIRU specifications are more useful in terms of inflation forecasting than a naive model which presumes inflation at any time will be the same over next year as it has been over last year. This might be true because NAIRU, as an unobservable variable, has to be estimated. "Estimates of NAIRU is extremely sensitive to model specification, the definition of variables, and the sample period used" (Setterfield, Gordon, and Osberg, 1992, p.134 [39]). Thus performance of any NAIRU based Phillips curve forecasting model may be affected by the NAIRU itself.

Stock and Watson [42] thought Atkeson and Ohanian conclusion was taken too far. They tested the accuracy of the Phillips curve forecasts and compared the results with other different inflation forecasting models. One interesting finding was that "the performance of Philips curve forecasts is episodic", which means that there are

certain time periods when the Phillips curve forecasts are better than the others'. More importantly, the periods when Phillips curve forecasts are better than the naive model are those "in which the unemployment gap is relatively large". Similar results were found by Liu and Rudebusch [24] that the significant decline in inflation during 2008 to 2009 is largely contributed by the high level of the unemployment gap.

Following these interesting findings, two U.S. researches (Barnes and Olivei [5]; Richard, Robert and Anna [29]) introduced a new specification of Phillips curve, "the threshold Phillips curve". By saying "threshold", they set certain ranges on the unemployment gap which is defined as actual unemployment minus NAIRU, and they found a piecewise Phillips curve. Conclusion was made that the Phillips curve displays threshold effect, which means when the unemployment is deviating fiercely from the NAIRU, that is to say when unemployment gap is relatively larger or smaller than the certain thresholds, the Phillips curve is much steeper than when unemployment gap is between the two thresholds.

The new introduced threshold Phillip curve is theoretically based on Gordon's "triangle" model. By "triangle", Gordon [20] explained that the inflation has three determinants, namely the supply shock, demand pull, and built-in-inflation. This triangle model has been recognized as one of the most commonly acknowledged Phillips curve models since it takes both supply and demand as well as inflationary expectation into consideration.

Gordon's triangle model perfectly provided explanation about the stagflation. Based on the triangle linear Phillips curve model, the introduction of thresholds allows a piecewise Phillips curve to have specific explanation on episodic effect accordingly. However, this threshold Phillips curve model has only been tested using U.S. data. No evidence from other industrialized countries has been collected to prove the existence of threshold effect on Phillips curve. That is why this paper is focusing on this specific threshold Phillips curve model. Using G7 plus Australia data, and following the U.S. methodology, the test results will be presented and explained in detail in the following chapters.

Chapter 3

Statistics and Methodology

3.1 Data Sources

The main data source for this paper is the OECD statistics database which contains most developed countries economic development and financial indicators. One thing needs to be noted is that OECD has professional estimates on the time-varying NAIRU for 35 countries or areas. For this paper, a time-varying NAIRU is embedded in the threshold Phillips curve model (where unemployment gap is defined as the difference between actual unemployment and the time-varying NAIRU) while it is also the only unobservable variable. All other variables, namely inflation, unemployment and relative inflation, could be directly obtained or simply calculated using directly obtainable data. But the NAIRU unfortunately has to be estimated.

The OECD estimated time-varying NAIRU is considered satisfactory for research

purpose of this paper for two reasons. Firstly, since this paper is testing 8 countries data for a same model, each country may have different estimation on NAIRU based on different estimating method. However, it is important to keep NAIRU estimating method consistent between countries. Thus instead of using different country estimated NAIRU, this paper uses the OECD estimated time-varying NAIRU for 8 testing countries.

Secondly, there is no commonly recognized foolproof method for NAIRU estimation. As quoted above, Setterfield, Gordon, and Osberg found NAIRU estimating, which is based on the Phillips curve trade-off, is highly sensitive. The performance of NAIRU estimation was unsatisfactory that they called NAIRU to be "a will'o the wisp" [39]. Two commonly used NAIRU estimating methods are statistical filters method or simply random walk. The original U.S. papers which introduced the threshold model used CBO estimated time-varying NAIRU. The CBO estimation of NAIRU was using the HP filter method with a smoothing constant equal to 100,000 [46] and the OECD employed a similar reduced-form filtering approach that is based on the expectation-augmented Phillips curve relationship [3]. These two methods give quite similar time-varying NAIRU estimations (see Figure 3.1 in the following section). Since this paper is following the methodology used in the U.S. papers, the OECD estimated time-varying NAIRU is considered a reasonable and satisfactory estimation for this paper.

3.2 Data Description

This paper uses G7 countries plus Australia quarterly data, namely U.S., Canada, United Kingdom, Japan, France, Italy, Germany and Australia. The reason for Australia to join the testing samples is because Australia, as a member country of the British Commonwealth of Nations, shares many similarities with UK and Canada in terms of financial system structure and monetary authority mandates. Thus adding Australia into the estimation is considered necessary and meaningful. Note that U.S. has been tested by the Federal Reserves of New York and Boston and threshold effect was found on U.S. Phillips curve. This paper is following precisely the methodology used by the U.S. papers and replicating the testing of the threshold Phillips curve model using an enlarged testing sample.

As Gordon's triangle Phillips curve model indicates, inflation is driven by three determinants, demand pull, supply shock, and ineatial inflation. The threshold Phillips curve model, which is modified from the triangle model, includes the same three elements as the triangle model. In specific, this paper uses unemployment gap to represent demand pull; relative inflation of food and energy, and OECD relative inflation as supply shock variables; and lagged inflation is supposed to capture the inertia in the way inflation expectations are formed.

Demand pull variable (u, u*)

Unemployment gap (u_t-u_t*) is defined as the difference between actual unemployment, u_t and the time-varying NAIRU, u_t*. Note that the actual unemployment rate is in quarterly basis, but the time-varying NAIRU is in annual frequency. In this case, this paper converts the annual NAIRU into quarterly NAIRU using moving average approach. The quarterly unemployment gap is calculated by subtracting the converted quarterly time-varying NAIRU from quarterly unemployment rate. This moving average converted NAIRU produces very similar and satisfactory trend of unemployment gap with unemployment gap using CBO estiamted NAIRU (Figure 3.1). The CBO estimated time-varying NAIRU is in quarterly frequency and directly obtained from CBO database, thus there is no need to apply the moving average converting. By comparing the two unemployment gaps, their trends perform nearly the same. Thus base on the U.S. case, it is confident to apply the moving average converting to other countries annual NAIRU while calculating unemployment gap. In this paper, both CBO and OECD estimated time-varying NAIRU are used for U.S. unemployment gap calculation and are tested separately.

Inflation variables (π)

Inflation rate is the quarterly percentage change of Core CPI, All items non-food and non-energy, 2010=100, directly obtained from OECD statistics.

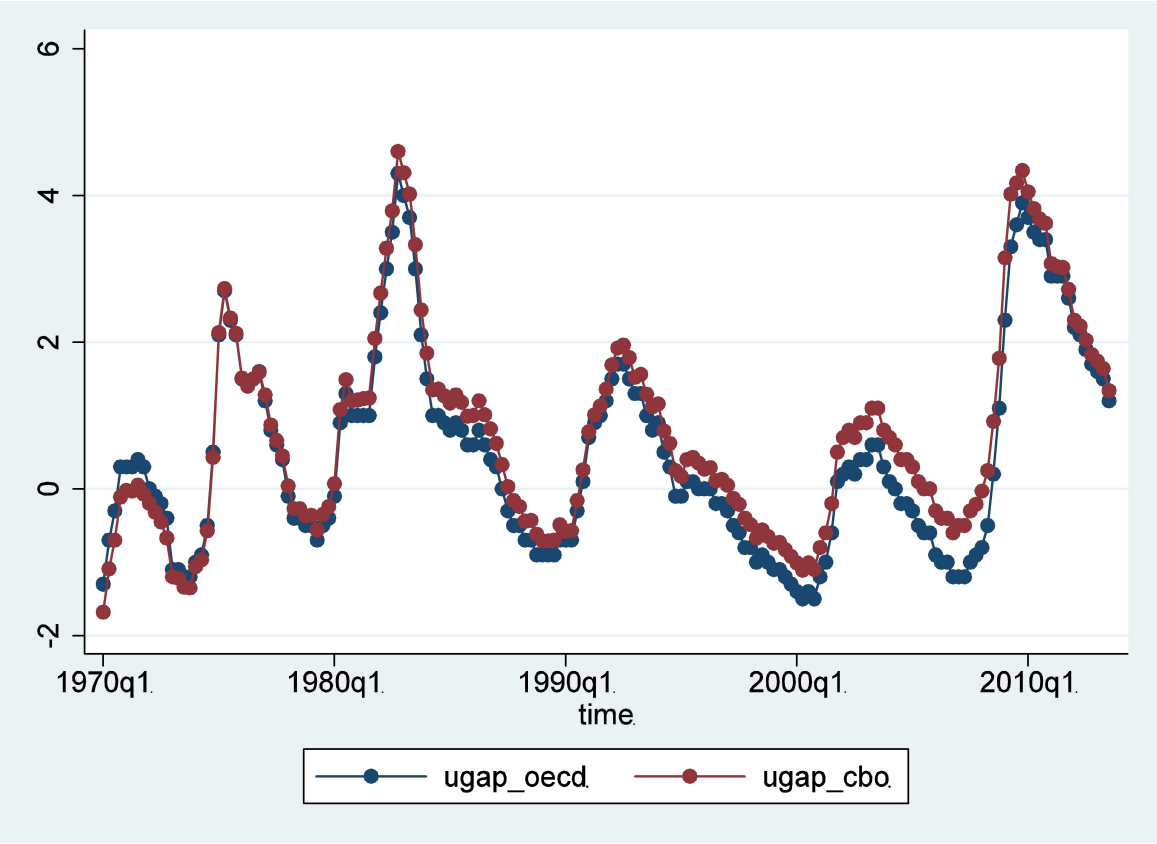

Figure 3.1: U.S. Unemployment Gap, OECD versus CBO, 1970q1 to 2013q3

Supply shock variables (Z)

Relative inflation of food and energy is percentage change of CPI/Core CPI, where CPI is the all items, 2010=100; and Core CPI as described above, both directly obtained from OECD statistics.

Another relative inflation variable is calculated using relative consumer price indices obtained from OECD. This relative price index contains information about a country's

relative competitiveness related with price changes caused by exchange rate changes.

Data statistic summary for all testing countries

Table 3.1: U.S., 1970q1 to 2013q3

Variable	Obs.	Mean	Std. Dev.	Min	Max
inflation	175	1.026	0.726	0.000	3.540
unemployment	175	6.402	1.563	3.900	10.700
ugap (OECD)	175	0.594	1.515	-1.500	5.800
ugap (CBO)	175	0.726	1.378	-1.680	4.600
relative inflation 1	175	0.029	0.537	-2.982	1.891
relative inflation 2	175	-0.162	2.389	-5.634	8.182

Table 3.2: Canada, 1976q4 to 2013q3

Variable	Obs.	Mean	Std. Dev.	Min	Max
inflation	148	1.161	1.028	-0.777	6.633
unemployment	148	6.975	1.802	4.100	11.100
ugap	148	0.429	0.955	-1.500	3.200
relative inflation 1	148	0.034	0.296	-0.644	1.023
relative inflation 2	148	0.012	4.057	-18.977	11.995

Table 3.3: UK, 1972q1 to 2013q3

Variable	Obs.	Mean	Std. Dev.	Min	Max
inflation	167	1.367	1.580	-1.190	9.938
unemployment	167	7.268	2.350	3.400	11.900
ugap	167	0.059	1.059	-2.000	2.100
relative inflation 1	167	0.042	0.508	-1.855	2.607
relative inflation 2	167	-0.048	3.305	-12.410	11.563

Table 3.4: Japan, 1970q1 to 2013q2

Variables	Obs.	Mean	Std. Dev.	Min	Max
inflation	174	0.687	1.243	-0.900	7.470
unemployment	174	3.095	1.258	1.100	5.400
ugap	174	0.271	0.471	-0.600	1.500
relative inflation 1	174	-0.011	0.383	-0.981	1.725
relative inflation 2	174	0.393	4.687	-12.539	21.631

Table 3.5: Australia, 1976q4 to 2013q3

Variables	Obs.	Mean	Std. Dev.	Min	Max
inflation	148	1.161	1.028	-0.777	6.633
unemployment	148	6.975	1.802	4.100	11.100
ugap	148	0.429	0.955	-1.500	3.200
relative inflation 1	148	0.034	0.296	-0.644	1.023
relative inflation 2	148	0.012	4.057	-18.977	11.995

Table 3.6: France, 1983q1 to 2013q2

Variables	Obs.	Mean	Std. Dev.	Min	Max
inflation	122	0.600	0.564	-0.591	3.036
unemployment	122	9.318	1.061	6.900	11.300
ugap	122	0.466	0.620	-0.900	1.600
relative inflation 1	122	0.005	0.352	-1.215	1.181
relative inflation 2	122	-0.027	1.247	-3.468	2.695

Table 3.7: Italy, 1983q1 to 2013q2

Variables	Obs.	Mean	Std. Dev.	Min	Max
inflation	122	0.993	0.728	-0.264	3.743
unemployment	122	9.070	1.483	6.000	12.100
ugap	122	0.619	0.887	-1.400	2.700
relative inflation 1	122	-0.006	0.236	-0.555	1.053
relative inflation 2	122	0.054	2.012	-10.767	5.839

Table 3.8: Germany, 1991q1 to 2013q2

Variables	Obs.	Mean	Std. Dev.	Min	Max
inflation	90	0.451	0.485	-0.231	2.906
unemployment	90	8.198	1.589	5.300	11.400
ugap	90	0.880	1.155	-1.300	3.300
relative inflation 1	90	0.036	0.289	-0.907	0.796
relative inflation 2	90	-0.079	1.451	-3.626	3.223

3.3 Models, the standard and the threshold

As suggested by Gordon "triangle model" [20], a standard time-varying NAIRU-based linear Phillips curve model can be defined as:

$$\pi_t = \sum_{i=1}^{n} \alpha_i \pi_{t-i} + \beta \mu_t + \delta \Delta u + \chi Z_t + \epsilon_t$$

where π_t is the independent variable of inflation rate. The lagged inflations, π_{t-i}, are supposed to capture the inertia in the way inflation expectations are formed. The economic intensity of demand is represented by the unemployment variables. Unemployment enters the model in two ways. First is the unemployment gap, which is defined as the difference between actual unemployment and the time-varying NAIRU, $\mu_t = u_t - u_t^*$, where u_t^* is the OECD estimated NAIRU (for U.S. both OECD and CBO estimated NAIRU are used for calculation; OECD and CBO use precisely Gondon's

"triangle model" for their NAIRU estimation); and second is the first difference of unemployment, Δu. Finally, Z_t stands for the supply shock variable which includes relative inflation of food and energy and other supply related variables.

In this model, β is the eye-catching coefficient because it indicates the general correlation between inflation and unemployment. The reason for introducing unemployment gap is because the time-varying NAIRU serves as a shifter to the short run inflation-unemployment trade-off. In this way, the standard Phillips curve model avoids the problem of inability to explain the simultaneous increase of inflation and unemployment by allowing shifts of short run Phillips curves. Then the coefficients of δ measure the effect of changes in unemployment on current inflation. And lastly, the coefficients of χ indicate the effect of any supply shock on current inflation.

Before introducing the threshold Phillip curve model explicitly, which was first introduced and tested by the U.S. researches, I would love to explain here in addition to the literature review about what they actually found by borrowing a concise figure (Figure 3.2) from the U.S. researchers.

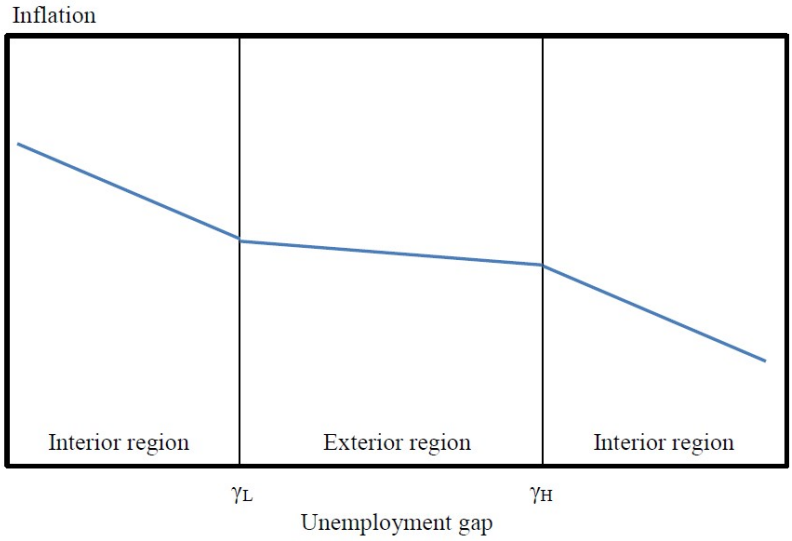

Figure 3.2: The Threshold Phillips Curve

Notes: The chart shows the response of inflation to extreme movements in the unemployment gap (the exterior regions) and to more moderate movements in the gap (the interior region). The unemployment gap is the difference between the actual unemployment rate and the NAIRU. (Source: Peach, R.; Rich, R. and Cororaton, A. "How does slack influence inflation?" Current Issues in Economics and Finance, 2011, 17, page 4) [29]

What the U.S. researchers did was setting two thresholds on the unemployment gap, so that the standard linear Phillips curve becomes piecewise as illustrated graphically in Figure 3.2. They found that the slope of the Phillips curve of the exterior region is steeper than the slope of interior region. In other words, when the unemployment gap lies outside the two thresholds, that is to say, when the unemployment is dispersing from the NAIRU at relatively larger rate, the inverse relation between inflation and unemployment is much stronger than the case where unemployment gap lies in between the two thresholds.

Intuitively, what the U.S. papers found means that when the unemployment gap is in absolute value relatively very large, that means the unemployment is fluctuating fiercely from the NAIRU, the corresponding economic situations are significant economic recession or boom; that is to say, during economic recessions and booms, the unemployment increases or decreases at relatively larger scale than when economy is during cycles between recession and boom. Unemployment fluctuates fiercely from the NAIRU during recession and boom while the economic situation changes slowly along with a relatively stable unemployment during economic cycles between recession and boom.

According to the finding of the U.S. papers, macroeconomists and practitioners believe that when during economic recessions or booms, the threshold Phillips curve model performs much better than the traditional standard Phillips curve model in terms of characterizing the inflation-unemployment relationship. The threshold model should

be used as a macroeconomic policy tool in terms of inflation forecasting.

Now we will introduce the threshold Phillips curve model in detail. The threshold Phillips curve model is defined as:

$$\pi_t = \sum_{i=1}^{n} \alpha_i \pi_{t-i} + \beta_0 \mu_t + \beta_1 D_1 \mu_t + \beta_2 D_2 \mu_t + \delta \Delta u + \chi Z_t + \epsilon_t$$

where π_t, π_{t-i}, Δu and Z_t are defined exactly the same as they are in the standard linear Phillips curve model. The main difference here is the coefficients of the unemployment gap. In particular, the threshold model allows the trade-off between inflation and unemployment to depend on the level of unemployment gap. The slope of the interior region Phillips curve is represented by β_0 when the unemployment gap lies within the interval of $[\gamma_L, \gamma_H]$. The slopes of two exterior regions Philllips curve are represented by $\beta_L = \beta_0 + \beta_1$ and $\beta_H = \beta_0 + \beta_2$ respectively where β_L is the slope of lower exterior region Phillips curve and β_H is the slope of upper exterior region Phillips curve. Dummy D_1 takes the value of 1 when unemployment gap lies in the lower bound of unemployment gap interval, or in other words, when unemployment gap is smaller than γ_L, otherwise, D_1 takes the value of 0. Dummy D_2 takes the value of 1 when unemployment gap lies in the upper bound of unemployment gap interval, or in other words, when unemployment gap is greater than γ_H, otherwise, D_2 takes the value of 0.

3.4 Estimation Method

In order to estimate the threshold Phillips curve model for 8 countries, we test the model for each country separately. The trial of testing all 8 countries together as cross-country analysis was abandoned for two reasons. Firstly, there is no possibility to put 8 countries' data together because each of them has quite different economic situation. For example, the standards for collecting consumer price index are quite different between countries. Each country's data differs in length depending on data availability. Therefore, putting 8 countries' data together is not expected to better off the analysis. Secondly, it makes no sense to test the threshold model as cross-country. Since the purpose of this paper is to find empirical evidence for the threshold Phillips curve model by introducing the threshold model to each country's data. If the threshold effect is confirmed, we can conclude that the Phillips curve does display threshold effect and the implication behind the model can be applied to other countries' macroeconomic policy making. Moreover, each country's data availability is different from others. For some periods where there is available data for country A may not have availability for country B. Therefore, there is no need to test the model under 8 countries all together.

During the estimation process, the most important issue is the determination of "optimal" values for the two thresholds γ_L and γ_H. By saying "optimal", it means the thresholds that are drawn out from the best regression, the regression gives the min-

imum root mean squared error, from all the regressions with every possible pair of thresholds. This issue is solved by the method of grid search. In detail, the estimation consists of sequential regressions on different pairs of γ_L and γ_H. In other words, we allow the thresholds to move from the lowest and highest value to the middle point of unemployment gap by 0.05 unit each regression until γ_L and γ_H reach each other. This movement are controlled by continuously changing the definition of dummy variable implemented on the unemployment gap. After γ_L and γ_H move along the whole interval of unemployment gap, the optimum result is given by the threshold model regression which gives us the minimum root mean squared error.

After we obtain the optimum values of γ_L and γ_H, we will have the estimation result under that specific pair of thresholds. This estimation is supposed to be the best fitting of the threshold model within the unemployment gap interval. If the slopes of outside thresholds regions are steeper than the slope of interior region, and if the coefficients of unemployment gap are statistically significant, then we can conclude that the threshold effect is confirmed and a piecewise threshold Phillips curve is found in this country.

Along with the estimation of the threshold Phillips curve model, the standard Phillips curve model is being tested as well. By testing the standard Phillips curve model, the trade-off, if it does exists, between inflation and unemployment could be characterized by the coefficient β. It is believed that if the negative correlation between inflation and unemployment could not be found through the standard model, then the

introduction of the threshold model is barely meaningful. Moreover, the estimation of the standard Phillips curve is used for comparison with the threshold Phillips curve model estimation. If for any country, the inverse trade-off relation between inflation and unemployment was confirmed by the standard Phillips curve model and if the threshold effect was found on this country's Phillips curve, then we could conclude that a threshold Phillips curve model outperforms the standard Phillips curve model in terms of characterizing the inflation-unemployment relationship.

Chapter 4

Empirical Analysis

4.1 Estimation Results

The estimation results for the standard and threshold Phillips curve models are presented in the following table with its optimum values of thresholds. Note that for U.S., estimations using both CBO and OECD estimated NAIRUs are tested and presented; these two results are not statistically different, with similar slopes and threshold values.

Table 4.1: Estimation results for the standard and threshold Phillips curve models

		Standard Model	Threshold Model					
Country	Obs.	β	β_0 interior	β_L lower exterior	β_H upper exterior	γ_L	γ_H	Adjusted R-square
U.S.	175	-0.07***	-0.04	-0.18**	-0.25*	0.35	2.45	0.6607
OECD		(0.03)	(0.03)	(0.08)	(0.14)	**(5.75)**	**(8.55)**	
U.S.	175	-0.07***	-0.03	-0.22**	-0.24**	0.45	2.75	0.6569
CBO		(0.03)	(0.03)	(0.10)	(0.12)	**(5.51)**	**(8.85)**	
Canada	148	-0.09***	-0.08**	-0.51*	-0.32	0.40	1.55	0.6764
		(0.04)	(0.04)	(0.29)	(0.20)	**(7.00)**	**(8.95)**	
UK	167	-0.13*	-0.16*	0.23	0.15	-0.55	0.65	0.5498
		(0.07)	(0.08)	(0.46)	(0.22)	**(7.45)**	**(7.55)**	
Japan	174	-0.20*	-0.18	-0.02	-0.08	-0.05	0.95	0.5753
		(0.11)	(0.17)	(0.34)	(0.24)	**(4.35)**	**(5.25)**	
Australia	148	-0.07	-0.10*	-0.59	-0.26	0.45	1.35	0.5254
		(0.07)	(0.06)	(0.50)	(0.88)	**(4.85)**	**(6.65)**	
France	122	-0.10**	-0.10**	1.62	0.86	0.25	0.45	0.5904
		(0.04)	(0.04)	(2.38)	(1.53)	**(8.93)**	**(9.63)**	
Italy	122	-0.01	-0.02	0.11	0.94	0.55	0.75	0.7195
		(0.03)	(0.03)	(1.23)	(0.86)	**(8.73)**	**(10.03)**	
Germany	90	-0.04	-0.03	-0.77	-0.35	0.75	1.25	0.2325
		(0.03)	(0.04)	(1.02)	(0.67)	**(5.80)**	**(7.80)**	

Note: Standard error in parenthesis, significance levels indicated by: * 0.1; ** 0.05; *** 0.01. The corresponding actual unemployment rates, $u_L = u^*_{2013q3} - \gamma_L$ or $u_H = u^*_{2013q3} + \gamma_H$, are presented in bold parenthesis.

4.2 Direct Interpretation

In the results table, the slopes of both interior and two exterior regions are reported as β_0, β_L and β_H. The optimum values of thresholds are represented as γ_L and γ_H. The slope of the standard Phillips curve is indicated by β. Firstly for the standard model all 8 countries confirmed the inverse relationship between inflation and unemployment, but with insignificant results for Australia, Italy and Germany. For those countries with significant results, namely U.S., Canada, UK, France, and Japan, downward sloping Phillips curves were found, but the slopes were quite flat. Japan gives the steepest downward sloped curve with a slope equal to -0.20. Regardless of the low significance level for some countries, the negative correlation between inflation and unemployment was found in all 8 countries. In this case, the following estimation for the threshold model can be preceded and results of the threshold model can be compared with the standard model.

For the threshold Phillips curve model, Canada and U.S. are the only two countries where statistically significant evidence for the threshold effect was found. As illustrated by Figure 4.1, Canada and U.S. threshold Phillips curves should be looked similar with the original U.S. findings. The exterior regions slopes are significantly steeper than the interior region. In particular, the replicating test on U.S. data confirmed the threshold effect found in the original U.S. papers, both under OECD and CBO estimated time-varying NAIRUs. For Canada, the result is even more notable.

The difference between slopes of interior and lower exterior region is much larger than the U.S. threshold model either in this paper or in the original papers. That means the threshold effect is, at least for some level of unemployment gap, more statistically significant on Canada Phillips curve than on the U.S. Phillips curve.

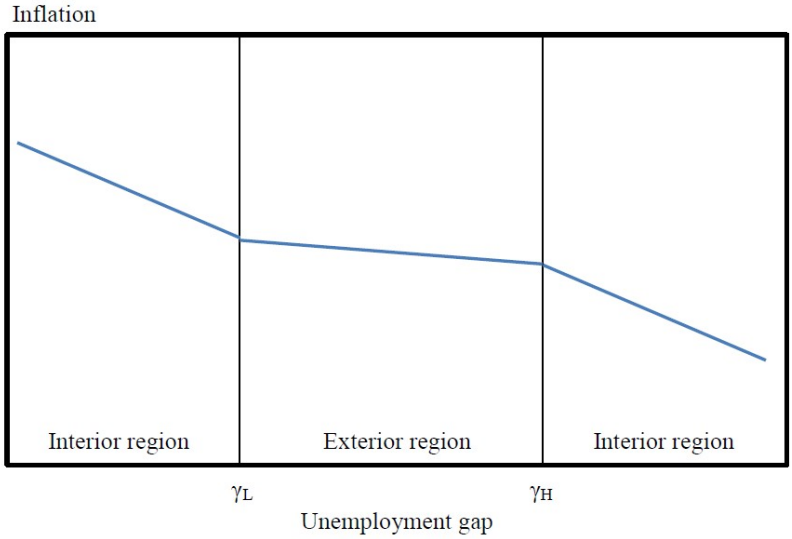

Figure 4.1: Canada and U.S. Threshold Phillips Curve

Note: The slopes of interior region for U.S. threshold Phillips curve (using OECD estimated time-varying NAIRU) in this paper is -0.04 (insignificant) and slopes of two exterior regions are -0.18 and -0.25. The slopes of interior region for U.S. threshold Phillips curve (using CBO estimated time-varying NAIRU) is -0.03 (insignificant) and slopes of two exterior regions are -0.22 and -0.24. In the original U.S. paper those slopes are -0.08 for interior region and -0.17 for two exterior regions. The slopes of interior region for Canada threshold Phillips curve is -0.08, and for exterior regions are -0.51 and -0.32 (insigficant).

For U.S. and Canada, F-test is conducted for two exterior regions slopes, with null hypothesis that two exterior regions slopes are not significantly different with each other. The results fail to reject the null thus indicate two exterior regions slopes are not significantly different with each other for both U.S. and Canada. Note for other countries, F-tests are not conducted because failed indicidual t-tests for the

coefficients indicate that each coefficient is not significantly different from 0.

For Australia and Germany, they perform quite similar in terms of slopes of the Phillips curve. They all have relatively flatter interior slopes and relatively steeper slopes for the exterior regions just like the U.S. and Canada threshold Phillips curves. However, due to low significance level, it is less confident to conclude threshold effect on Australia and Germany Phillips curves. If graphs for Australia and Germany threshold Phillips curves were drawn, they would be looked exactly the same as in U.S. and Canada cases.

Australian and German insignificant results may be explained by two reasons. Firstly, Australian central bank is well performed in terms of inflation control and unemployment balancing since 1990s. Not like U.S. and Canada, there is no extreme economic boom or recession in Australia during the last two decades. This is to some extent why Australian Phillips curve does not perform threshold effect significantly. Secondly for Germany, its central bank is also one of the strongest monetary authorities in the world, leading Germany survived the 2008 global financial crisis with minimized economic damage. The insignificant result may also be caused by the shortened testing period due to data availability issue. The OECD database collects data only for the reunified Germany since 1991, especially no estimation for the time-varying NAIRU before 1991. For research consistency consideration, this paper did not extend the limited testing period for Germany. This may partially explain the insignificant result for Germany.

For UK, France, Italy and Japan, the insignificant results indicate that the coefficients of the threshold model are not significantly different from 0. Thus for all of these countries threshold effect is rejected on their Phillips curves. Estimations for the standard model do confirm a weak trade-off relation between inflation and unemployment in these countries. Policy makers should review these countries Phillips curve trade-off with extra cautions. Otherwise, modification of the Phillips curve specification is needed with considering of each country's specific characteristics.

Based on the above analysis, 6 out of 8 countries rejected the threshold effect on their Phillips curves, either because their Philips curves simply do not display threshold effect, or because of their statistically insignificant estimation results. The replicating test for U.S. threshold Phillips curve model reconfirms the original findings using both the OECD and CBO estimated time-varying NAIRU. Canada Phillips curve is the only one who performed statistically significant result that confirms threshold effect other than U.S.. In fact, the Canada Phillips curve displays more significant threshold effect than the U.S. one.

Among U.S. and Canada whose Phillips curves confirm threshold effect, a comparison between their threshold and standard Phillips curve models may provide more valuable information. For U.S. and Canada, both of them confirm a statistically significant downward sloping standard Phillips curve. Note that the slopes for the standard Phillips curves are quite flat, which indicates that the standard Phillips

curve model has limited power in characterizing the inflation-unemployment relationship in Canada and U.S.. The interior and exterior regions slopes are significantly different after the introduction of the thresholds, which indicates that the threshold Phillips curve model can explain the inflation-unemployment trade-off relation better than the standard Phillips curve model. Therefore, we conclude that in Canada and U.S. cases, the threshold Phillips curve model outperforms the standard Phillips curve model in terms of inflation-unemployment relationship characterizing.

4.3 Indirect Interpretation

Based on the above estimation results and direct interpretation, and recalling the threshold effect finding from the original U.S. paper, one might want to ask at the first place why the U.S. Phillips curve displays threshold effect? To answer this question, the economic intuition of the threshold Phillips curve model should be reviewed with the U.S. economic development.

In my point of view, the U.S. economy has been experiencing a three-step pattern since the WWII, that is economic expansion, economic cycles in between, and economic recession. Economic expansion is mostly triggered by government interventional stimulation usually after wars or after new presidential election. Then after probably years of expansion, the economy always tends to fall into sort of tepid economic cycles where economic growth slows down and unemployment rises up. The

tepid economy continues until the economy officially turns down to recession. Then certain policy will be used to stimulate economy again, which turns the economy back into new expansion. The introduction of the thresholds on the unemployment gap divides the unemployment gap into three parts: the low interval, middle interval, and the high interval, corresponding with precisely the three steps of how U.S. economy develops. In that way, by connecting the inflation-unemployment trade-off relation with the U.S. economy developing pattern, we found U.S. Phillips curve displays threshold effect and it outperform the standard Phillips curve model.

Another question that might be asked is what is the similarity between Canada and U.S. that induces similar threshold effect on their Phillips curves? In answering this question, to begin with, Canada and U.S. are close neighbors. They share similarities in almost every aspect. U.S. has been Canadas largest economic partner so far, accounting for 74.5 percent of Canadian exports and 50.6 percent of imports as of 2012. Thus as it says, Canada and U.S. economies go through thick and thin altogether. One thing we can observe from the actual data for Canada and U.S. is that their unemployment rates all peaked at somewhat 10 percent and valleyed at 4 percent at best. As for political system, Canada and U.S. are all under political party election system. Each newly elected party always tries very hard to stimulate the economy as they promised to the people. Therefore, Canada may experience similar economic developing pattern as U.S. does; and this may also explain why Canada Philips curve displays threshold effect as U.S. Phillips curve does.

Last and less relevant but not least, I would like to express my opinion regarding macroeconomic policy making. In most cases, economic development is to some extent predictable unless when it is related to politics. Central banks are responsible for economic prediction and analysis. If it has nothing or little to do with politics, central bankers and monetary authorities should be fully able to implement the so called "preemptive" policy to prevent the economy from turning to unsatisfactory situation. However, nowadays, it always has something to do with politics. Thus when it comes to political thinking, even central bankers and monetary authorities have to do one more forecasting about the political consequences for what they were supposed to do according to their economic prediction and analysis. For example, when they predict that price tends to increase, instead of using preemptive strike to against the potential inflation, they would think of what could happen if they do nothing. Price increases, leading more upward pressure on inflation, the whole society will be looking forward to the central bankers to save the economy from inflation. They will be needed if they do nothing against the predicted inflation threat. On the other hand, if they actually prevented the inflation treat following preemptive strategy, then they will be opened to criticism. For instance, if the central bank tightens the economy earlier than the inflation ever rises, critics will "wonder out loud, no doubt why the central bank decided to tighten when the inflationary dragon was nowhere to be seen". (Blinder, 1999, p.12)[7]

In my point of view, it was the politics that make the economic forecasting complicated. Any economic forecasting based on reasonable observation of the past should be

reviewed as useful information for further prediction. That is why for this paper, the threshold Phillips curve model is tested for G7 countries and Australia. By replicating test on U.S. and by testing more countries, more empirical evidences are collected. Canada Phillips curve is confirmed to display threshold effect as U.S. Phillips curve does. The threshold Phillips curve model is considered a better macroeconomic forecasting tool than the standard Phillips curve model in U.S. and Canada. For other countries, further detailed tests are welcome. Otherwise, new specifications should be modified to explain other countries real economic data.

Chapter 5

Conclusion

As a controversial topic in macroeconomics, Phillips curve has been enjoying the popularity induced by both its favorers and critics. This paper explores the legendary history of the Phillips curve by reviewing previous literatures from the birth, growing up, till its present. At the end of literature review, this paper introduces the main motivation, a newly defined specification of the Phillips curve, the threshold Phillips curve model.

The threshold Phillips curve model was born in the U.S. and has not yet been estimated in other countries. The basic threshold hypothesis from the U.S. paper was that when setting two certain ranges or thresholds on unemployment gap, the slopes of exterior regions are expected to be steeper than the interior region. In other words, when unemployment gap lies outside the two thresholds, the slope of the Phillips curve is supposed to be steeper than when unemployment gap lies between the two thresh-

olds. If that is the case, conclusion could be made that a threshold Phillips curve model is better than the standard Phillips curve model in terms of characterizing the inflation-unemployment trade-off relationship.

Following the methodology applied in the U.S. paper, this paper estimates the threshold Phillips curve model using G7 countries plus Australia quarterly data. Testing of the U.S. Phillips curve is replicated following the same method using both OECD and CBO estimated time-varying NAIRU. The biggest challenge during estimation is to determine the optimum values for the thresholds that were set on unemployment gap. Grid search method is used for each individual country's estimation. By conducting a loop program for the grid search, the optimum value of the thresholds for each country and its corresponding estimation results are collected and discussed. Only Canada and U.S. Phillips curves were found to display threshold effect. All other countries results indicate that either no threshold effect can be found or no significant evidence to support the threshold hypothesis. Based on the results, conclusion is made that firstly the Canada and U.S. Phillips curve display threshold effect and the threshold Phillips curve model outperforms the standard Phillips curve model in terms of characterizing the trade-off relation between inflation and unemployment; secondly, the threshold Phillips curve model may not be applicable to other countries unless proper modification can be done or detailed further testing based on better data availability can be conducted.

Potential explanations for the results and interpretations are discussed in detail. 8

countries are sorted into 4 groups according to their performance in estimation results for discussion. Direct interpretation explained why only Canada and U.S. Phillips curves display threshold effect and why other countries' do not. This paper also covers the political thinking behind economic forecasting process as indirect interpretation. Suggestion for future research is to follow this paper's finding and focus on any specific country or group of countries to conduct further estimation on the threshold Phillips curve model according to each country's specific economic situation.

Bibliography

[1] George A Akerlof, William T Dickens, George L Perry, Robert J Gordon, and N Gregory Mankiw. The macroeconomics of low inflation. *Brookings papers on economic activity*, 1996(1):1–76, 1996.

[2] E Amid-Hozour, DT Dick, and Richard L Lucier. Sultan schedule and phillips curve: An historical note. *Economica*, 38(151):319–20, 1971.

[3] Robert Arnold. Reestimating the phillipscurve and the nairu. *Congressional Budget Office Working Paper Series*, 2008-06, 2008.

[4] Andrew Atkeson and Lee E Ohanian. Are phillips curves useful for forecasting inflation? *Federal Reserve Bank of Minneapolis Quarterly Review*, 25(1):2–11, 2001.

[5] Michelle L Barnes and Giovanni P Olivei. Inside and outside bounds: Threshold estimates of the phillips curve. *New England Economic Review*, pages 3–18, 2003.

[6] Robert J Barro. Rational expectations and the role of monetary policy. 1976.

[7] Alan S Blinder. *Central Banking in Theory and Practice: Alan S. Blinder*. Mit press, 1999.

[8] Arthur Joseph Brown. *The great inflation, 1939-1951.* Garland, 1983.

[9] Bernard Corry and David Laidler. The phillips relation: a theoretical explanation. *Economica*, 34(134):189–197, 1967.

[10] Guy Debelle and Douglas Laxton. Is the phillips curve really a curve? some evidence for canada, the united kingdom, and the united states. *Staff Papers-International Monetary Fund*, pages 249–282, 1997.

[11] Irving Fisher. Statistical relation between unemployment and price changes, a. *Int'l Lab. Rev.*, 13:785, 1926.

[12] Pierre Fortin. The bank of canada and the inflation-unemployment trade-off. *Macroeconomics, Monetary Policy, and Financial Stability: A Festschrift in Honour of Charles Freedman*, pages 3–24, 2004.

[13] Michael John French. *United States Economic History Since 1945.* Manchester University Press, 1997.

[14] M. Friedman. The role of monetary policy. *The American Economic Review*, 58(1), 1968.

[15] Milton Friedman. What price guideposts? *Guidelines, Informal Controls, and the Market Place*, pages 17–39, 1966.

[16] Milton Friedman. Nobel lecture: inflation and unemployment. *The Journal of Political Economy*, pages 451–472, 1977.

[17] Milton Friedman and David EW Laidler. *Unemployment versus inflation?: an evaluation of the Phillips curve*. Institute of economic affairs, 1975.

[18] Jeffrey C Fuhrer. The phillips curve is alive and well. *New England Economic Review*, (Mar):41–56, 1995.

[19] Robert J Gordon. The time-varying nairu and its implications for economic policy. Technical report, National Bureau of Economic Research, 1997.

[20] Robert J Gordon. The history of the phillips curve: consensus and bifurcation. *Economica*, 78(309):10–50, 2011.

[21] Paul R Krugman. *Peddling prosperity: economic sense and nonsense in the age of diminished expectations*. WW Norton & Company, 1995.

[22] Richard G Lipsey. The relation between unemployment and the rate of change of money wage rates in the united kingdom, 1862-1957: a further analysis. *Economica*, pages 1–31, 1960.

[23] Richard G Lipsey. The place of the phillips curve in macroeconomic models. Technical report, 1976.

[24] Zheng Liu and Glenn Rudebusch. Inflation: mind the gap. *FRBSF Economic Letter*, 2:1–4, 2010.

[25] Robert Eo Lucas and Thomas J Sargent. After keynesian macroeconomics. *PUBLIC ADMINISTRATION AND PUBLIC POLICY*, 98:981–1002, 2002.

[26] Robert E Lucas Jr. Econometric testing of the natural rate hypothesis. *The Econometrics of Price Determination*, 50:59, 1972.

[27] Robert E Lucas Jr. Expectations and the neutrality of money. *Journal of economic theory*, 4(2):103–124, 1972.

[28] Alberto Musso, A Stracca, and DJC van Dijk. Instability and nonlinearity in the euro-area philips curve. *International Journal of Central Banking*, 5(2):181–212, 2009.

[29] Richard Peach, Robert Rich, and Anna Cororaton. How does slack influence inflation? *Current Issues in Economics and Finance*, 17(3), 2011.

[30] George L Perry. *Unemployment, money wage rates, and inflation*. The MIT Press, 1966.

[31] Edmund S Phelps and Armen A Alchian. *Microeconomic foundations of employment and inflation theory*. Norton New York, 1970.

[32] Alban W Phillips. The relation between unemployment and the rate of change of money wage rates in the united kingdom, 1861–19571. *economica*, 25(100):283–299, 1958.

[33] Gail Pierson. The effect of union strength on the us" phillips curve". *The American Economic Review*, 58(3):456–467, 1968.

[34] Albert Rees. The phillips curve as a menu for policy choice. *Economica*, 37(147):227–238, 1970.

[35] Paul A Samuelson and Robert M Solow. Analytical aspects of anti-inflation policy. *The American Economic Review*, 50(2):177–194, 1960.

[36] Anthony M Santomero and John J Seater. The inflation-unemployment trade-off: A critique of the literature. *Journal of Economic Literature*, 16(2):499–544, 1978.

[37] Thomas J Sargent and Neil Wallace. The stability of models of money and growth with perfect foresight. *Econometrica: Journal of the Econometric Society*, pages 1043–1048, 1973.

[38] Thomas J Sargent and Neil Wallace. " rational" expectations, the optimal monetary instrument, and the optimal money supply rule. *The Journal of Political Economy*, pages 241–254, 1975.

[39] Mark A Setterfield, Daniel V Gordon, and Lars Osberg. Searching for a will o'the wisp: An empirical study of the nairu in canada. *European Economic Review*, 36(1):119–136, 1992.

[40] Robert Solow. Down the phillips curve with gun and camera. *Inflation, Trade and Taxes: Essays in Honor of Alice Bourneuf*, 3:22, 1976.

[41] Joseph Stiglitz. Reflections on the natural rate hypothesis. *The Journal of Economic Perspectives*, 11(1):3–10, 1997.

[42] James H Stock and Mark W Watson. Phillips curve inflation forecasts. Technical report, National Bureau of Economic Research, 2008.

[43] Paul Sultan. *Labor economics*. Holt, 1957.

[44] Jan Tinbergen. Business cycles in the united kingdom, 1870-1914. 1951.

[45] Geoffrey MB Tootell. Restructuring, the nairu, and the phillips curve. *New England Economic Review*, pages 31–31, 1994.

[46] Dave Turner, Laurence Boone, Claude Giorno, Mara Meacci, Dave Rae, and Pete Richardson. Estimating the structural rate of unemployment for the oecd countries. *OECD Economic Studies*, 33(2):171–216, 2001.