PRODUCTIVITY AND INFLATION

Yong Zhang

This Thesis is submitted in partial fulfilment of the requirements of the MRes Degree at Macquarie University.

ACKNOWLEDGEMENT

Firstly, I would like to express my sincere gratitude to Prof. Tony Bryant for the continuous support of my study, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. Without his constant encouragement and insightful guidance, I could not have finished this thesis. I feel deeply grateful and fortunate to be his student.

Furthermore, I would like to thank Dr. Daehoon Nahm for his insightful comments and encouragement, but also for the hard questions which incented me to widen my research from various perspectives.

Finally, I must express my very profound gratitude to my family for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Chapter 1: Introduction

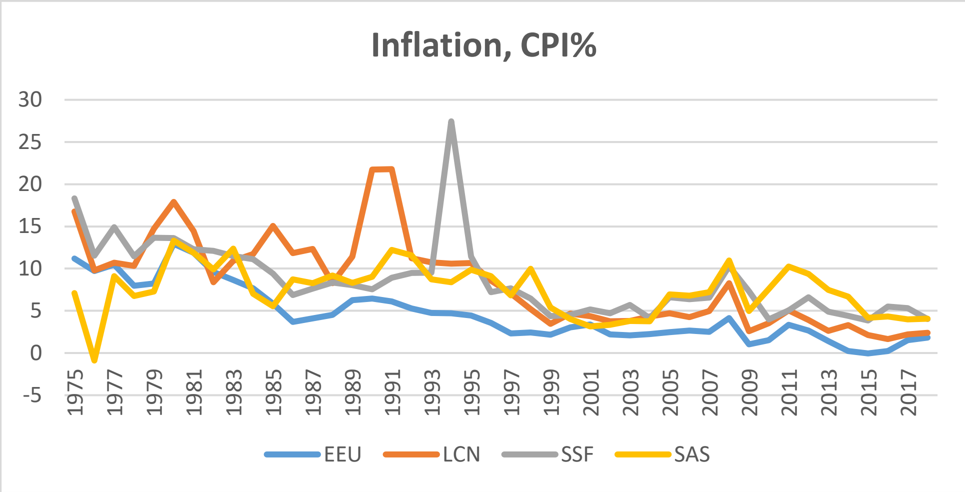
1.0 Introduction

The relationship between productivity and inflation is important in understanding the workings of modern economies, for reasons that we now briefly discuss.

1.1 An overview of inflation and productivity

Over the past few decades, much of the developed world and developing world alike have experienced the twin phenomena of declining inflation and rising productivity. There is a substantial body of research suggesting that inflation lowers the rate of productivity growth, and in turn, economic growth. Much of this research uses time series data to determine the veracity of the hypothesis that rising general price levels lead to proportional or more than proportional changes in overall productivity growth, though some recent research has raised some interesting questions about conclusions that were hitherto considered unimpeachable. However, while much of the earlier research into the relationship between productivity and inflation finds negative relationship between the two variables flowing from inflation to productivity, more recent decades have found periods of improving productivity growth juxtaposed with relatively stable inflation， Economists have more recently been interested in exploring the ways in which higher productivity driven by the explosion of information and communication technology and the internet have driven the disinflation observed in more recent decades.

Figure 1.1: Inflationary data of four regions

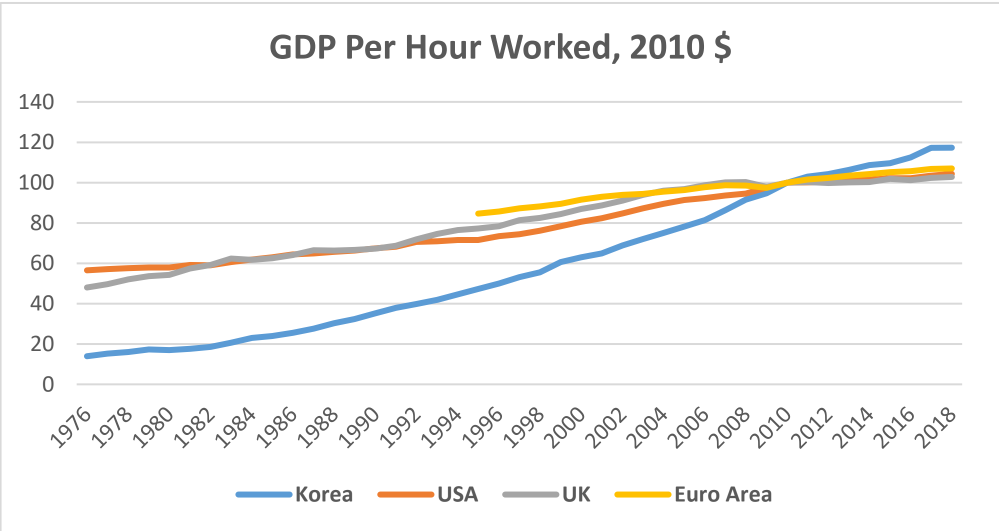


Data source: World bank, world development indicators (WDI)

The graph above depicts the annual growth rate of inflation (as measured by Consumer price Index) from 1975 to 2018 across Korea, United State of America, United Kingdom and the Europe Area consisting of 19 countries. Figure 1.1 shows that Korea started at the inflationary rate of 25.2% in the year 1975 and drops so low as 0.8% in the year 1999. The inflationary rate at year 2018 in Korea stood at 1.47%. The US economy in 1975 experience inflationary rate of 9.14% and had the highest inflationary rate in 1980 which is 13.54%. It continued to drop and it was negative which denotes deflation in the year 2009. In year 2018, the US economy closed with the inflation rate of 2.44%. The United Kingdom in 1975 has an inflation rate of 24.2% which reduced to 0.4% in 2015. By the end of 2018, the inflation rate of UK is 2.3%. Lastly in the graph, the euro area that has its inflation rate data starting from the year 1997 when the rate has dropped has a consistent rate of inflation from that time till now. In 1997 the inflation rate was 1.7% and by 2018 it was 1.8%. This has not by any means been a smooth decline. In fact, several spikes which bucked the trend were observed in different regions in the early 1990s and again in 2009, which correspond to periods of great economic upheaval. Nevertheless, the overall trend of inflation has been downward sloping as plotted above. The data also shows that much of the countries considered in the graph experienced significantly higher rates of inflation in the 1970s and 1980s, but that across the board, inflation rates generally began to fall in the 1990s.

Over the same period, productivity growth has improved, largely due to developments in science, technology. Labor productivity growth (as measured by GDP per hour worked, in 2010 constant dollars) in some regions is depicted in the graph below:

Figure 1.2: GDP per hour worked in 2010 constant dollar



Data source: OECD Data

The graph above, productivity growth has improved over the past few decades across the different economic regions of the world including the Euro Area, with the United Kingdom and the United States of America included as representative countries to capture the trend observed in more developed nations. In the largely high income countries that make up the Euro Area, GDP per hour has risen from about $80 in the mid-1990s to over $107 in in 2018. GDP per hour in the United States and in the United Kingdom have risen from relative lows of less than $60 per hour worked in the late 1970s to over a $102 per hour worked in 2018. The implication of this data is clear, over the years, workers have contributed more and more to national output in the same time period, which is a clear indication of improving labor productivity. Many economists have been interested in the causal linkage between these two events – rising productivity and declining inflation as observed in the broad historical data.

Inflation is a phenomenon that imposes serious costs/pressures on any economy. Unanticipated inflation leads to a transfer of resources from one group to another – those who lend in fixed rates or who earn incomes in nominal terms are left worse off, while those who borrow at fixed rates or make fixed nominal payments are much better off. The risks of unanticipated inflation do much damage to consumer expectations. Inflation also distorts the signaling power of the price mechanism. Ordinarily, a change in the price of one good relative to another would indicate higher demand for that good and signal to consumers the need to switch their consumption away from that good to some other good. However, in the event of inflation, economic decision makers could confuse changes in the general price level driven by inflationary pressures with changed in prices caused by shifts in demand & supply (i.e. market forces). Other costs of inflation include negative effects on government finance, wastage of resources and disruption of production. In summary, inflation reduces the value of the invisible hand- I.e. the price mechanism when it comes to signaling and providing information, leads to inefficient utilization of resources as they are diverted from more productive uses to the management of inflation alone, causes havoc to consumer expectations, instability that chokes investment and so much more. Historical data indicates a correlation between productivity and inflation, as depicted in the graphs above. Most countries as depicted above experienced low growth of productivity and high inflationary tendencies in the 1970s, though this relationship seemed to reduce in potency in the 1980s. By the same token, productivity growth increased on a general basis in the 1990s. This increase was observed to be across board, in developing and developed nations alike. Concurrently, inflation generally reduced during the 1990s. For example, the United States famously reduced inflation from double digit levels in 1979 to about 4%, in the early 1980s.

There are good *a priori* reasons to expect the existence of a negative relationship between productivity and inflation on a theoretical basis. A slower rate of productivity growth would raise business costs, which has inflationary effects. How so? Well, slower rates of productivity growth means that the same unit of input is producing fewer units of output than was previously the case; i.e. that workers are producing less output in the same number of hours, for instance. As workers produce fewer units of output, the per unit cost of labor rises. Rising labor costs would increase business costs for business owners and shrink profit margins. In a bid to pass on some of these increased costs to the final consumers, business owners would likely charge higher prices for products, which, over time, would translate to a sustained increase in the general price level.

Clearly, then, the linkage between productivity growth and inflation is of great importance to economic theory and policy. However, the exact nature of the relationship between productivity and inflation in the case of South Korea is unclear because much of the discussion is based on poor, if not altogether non-existent empirical evidence. Despite the importance of the linkage between productivity and inflation to economic growth in Korea, the nexus between productivity and inflation in Korea has not attracted much empirical attention. There is thus a clear gap in the research that needs to be filled.

1.1.1 Statement of the Problem

On a theoretical level, there is reason to believe in the existence of a negative relationship between productivity and inflation through the channels of rising labor costs and shrinking profit margins which perpetuate cost push inflation. Sure enough, statistics show that as GDP per hour worked (in 2010 US dollars) rose from $11.7 in 1971 to $117.3 in 2017 annual rate of inflation in Korea fell from 13.5% in 1971 to about 1.9% in 2017, hence the significant decline in inflation as recorded is associated with a simultaneous increase in GDP per hour worked, which is an indication of improvements in labor productivity. It would appear, then, that there is some correlation between the growth rate of productivity and the general price level in Korea. However, there is a paucity of empirical research into this issue, as much of the thrust of research has been into the inflation-productivity nexus and not the other way around. This study will thus contribute empirical evidence on the productivity-inflation nexus with specific reference to the case of South Korea.

The issue of the linkage between productivity and inflation is of great importance to economists and policy makers alike. Economic policymakers have long have promoted various policies aimed at achieving monetary stability with a view to sustained economic growth and overall development. If it is the case that productivity growth impacts inflation in a way and manner that is statistically significant, then the need to implement strategies and policies aimed at improving labor and multi factor productivity cannot be over-emphasized. However, if, on the other hand, productivity growth does not impact on inflation in a statistically significant manner, then policymakers would be better served focusing their attention elsewhere on other viable strategies such as those aimed at reducing the growth rate of money supply or otherwise curbing monetary expansion with the aim of promoting economic growth and development.

1.1.2 Objectives of the Study and Research Questions

The major objectives of this study are

i. To investigate the existence of causal relationships between productivity and inflation in South Korea and the directionality of such a relationship ~~s~~, if it exists

ii. To investigate the effect of inflation on productivity

iii. To establish the statistical significance or otherwise of the relationships

Given these objectives, the major research questions addressed here are the following:

i. Is there a causal relationship between inflation and productivity growth in South Korea?

ii. If causal relationship exists, is it uni-directional or does causality flow both ways?

iii. Is the relationship between productivity growth and inflation positive, negative, or dependent on the particular measure of productivity examined?

iv. Is the relationship between productivity and inflation in South Korea statistically significant?

1.1.3 Significance of the Study

In response to the high inflation prevalent in the 1970s and 1980s, economists have been interested in the factors that determine the general price level that subsists in a country. This interest is not merely academic; high inflation tends to retard economic growth in the short and long run, hence accurate knowledge of the determinants of inflation and the extent to which it slows down productivity that is currently being observed all over the world will affect inflation and will reveal the path for long-run, sustainable growth for developed and developing countries alike. Contrary to what was witnessed previously, the inflation rate has reduced drastically and the question arise if the reduction remains the answer to the increase in productivity experience today. This research work attempts to empirically estimate the exact nature of causal relationships between the growth rate of productivity and inflation, when considering two different measures of productivity – labor productivity and multi factor productivity. The aim of this study is to provide clear delineation of the productivity and inflation nexus thus revealing viable strategies for South Korea’s sustained growth and development.

1.1.4 Structure of this thesis

In Chapter 2, the theoretical and empirical literature will be reviewed, with the relevant literature being categorized into three broad strands; studies which find evidence of unidirectional causality from productivity to inflation, studies which find evidence of unidirectional causality but this time from inflation to productivity and studies which find no significant relationship between the two variables. This section will also present a critique of the studies on various criteria such as the productivity measure selected, the degree to which the influence of cyclical factors was incorporated into the research and the appropriateness of the econometric technique used. Chapter 3 will describe the data and methodology used. An in-depth description of selected variables, ranges and data sources as well as specified econometric model will be presented in this section. Chapter 4 will describe the tests performed to establish the empirical nature of the relationship between productivity and inflation, the interpretation of results and comments on the directionality of causality between the relevant variables. Finally, Chapter 5 will present the summary, conclusions and policy recommendations engendered by the empirical research that has been carried out.

1.2 Conclusion

Inflation is not without a cost and in evaluating various channels through which these costs are generate, it is observed that resources diverted to curb or manage inflation is at the expense of what could have been combined with labor to boost productivity. Based on this background, inflation and productivity in the macroeconomics have been under the lens of researchers in Korea in which many of the authors have examined the possible relationship between the two variables to establish its conformation with the theoretical assertions. Some empirical and theoretical fact have confirmed the existence of inverse relationship between the two. Noting that as inflation takes a downward move, so does productivity take upward trends as observed in the Korean economy in the between the period of 1971 and 2017. The improvement in labor productivity result into a decline of inflation in the economy. However, based on the studies reviewed, the possible reverse relationship has not been paid much attention to and this study seek to fill the gap by investigating the relationship between productivity and inflation with the former as the explanatory variable. So this part of this research work has given a brief introduction to the subject matter and further highlight the issues that this study want to address in the problem of statement. The objectivities and the significance of the study to policy makers and the academic world was also discussed in this section. The next chapter will address the review of previous literature.

Chapter 2: Literature Review

2.0 Introduction

Economists have long been interested in the relationship between inflation and productivity. In line with their interest, there has been a lot of empirical research on this issue.

2.1 The empirical literature

The empirical literature can be classified into four broad strands; the possibility of a unidirectional causal relationship flowing from productivity to inflation, the possibility of a unidirectional relationship flowing from inflation to productivity, the possibility that productivity has no significant effects on inflation and the possibility of an unclear or inconclusive relationship between productivity and inflation. These different strands of research have used different methodologies and produced interesting results. However, the matter of the relationship between inflation and productivity far from settled empirically, as the following review of the existing literature will show. As is common in many empirical works of literature in economics, there are conflicting findings about the relationship(s) between productivity growth and inflation – covering essentially the logical possibilities. The following is a survey of the literature, organized under the relevant headings.

2.1.1 Unidirectional from productivity to inflation

Kim et al (2013) examined the relationship between productivity growth and general price levels in Korea. They used a dataset populated with quarterly observations ranging from 1958-2002, and they analyzed the nature of the inflation-productivity relationship using Granger causality tests. After taking natural logarithms of each of the variables, they tested for stationarity and cointegration. Since the variables were found to be cointegrated, they estimated a Vector Error Correction model and then ran a Granger causality test using the estimates of the coefficients generated from the Vector error correction model. After testing for Granger causality, they found that total factor productivity caused changes in the inflation measure, Consumer Price Index and that this relationship was statistically significant. Specifically, they found that whenever total factor productivity increased by 1%, inflation would decline between 0.37 to 0.44%. In summary, Kim and Park (2013) found evidence of uni-directional causality flowing from productivity growth to inflation.

Degrauwe and Skuldeny (2000) analyzed the effects of movements in productivity growth on long-run inflation rates in the European Monetary Union. They used a panel dataset populated with observations ranging from 1971-1995 in five-year averages, with cross-section data from all European Union countries with the exception of Greece and Ireland. The average price level (i.e. price levels in the tradable and non-tradable sectors averaged out) was used as a measure of inflation while productivity was proxied by productivity differentials. Two different indices were used to proxy inflation, namely; the Consumer Price Index and the Gross Domestic Product deflator. Next, the variables were tested for stationarity using the Im- Pesaran-Shim unit root test for panel data, and the variables were found to be non-stationary at levels but became stationary after they have been differenced once. They found that productivity growth was inversely related to inflation, and this relationship was highly statistically significant. The researchers found that a 1% decline in productivity growth would on the average, lead to a 0.67% increase in inflation.

2.1.2 Unidirectional from inflation to productivity

Bitros and Panas (2005) investigated the trade-off between inflation and productivity in Greece, with specific emphasis on the nature and pattern of the relationship between inflation and total factor productivity growth in the Greek case. They looked at manufacturing industries in Greece, generating a dataset that was populated with observations ranging from 1964 -1980. Using a generalized Box-Cox cost function to get estimates for total factor productivity, they examined the effects of inflation over the time period observed. The test period conveniently included a period of lower inflation (1964-1972) and another period of higher inflation (1973-1980), and so it was very suitable for their study. They found that all the industries under examination experienced significant decreases in Total Factor Productivity following an increase in inflation. In the overall manufacturing sector; it was observed that a 10% rise in inflation would lead to a more than proportionate decrease in total factor productivity growth in the manufacturing sector; specifically, a decline of 10.2%. This negative relationship between inflation and total factor productivity was found to be highly statistically significant. Thus, Bitros and Panas (2005) found evidence of a negative relationship between inflation and total factor productivity; specifically, a uni-directional causal flow running in one direction from inflation to total factor productivity.

Ram (1984) investigated the causal relationship between inflation and the rate of growth of labor productivity in the United States of America using the Granger causality test method. He used a dataset populated with quarterly observations ranging from 1953 to 1982. He chose to use not one but two variables as proxies for inflation; namely the Gross National Product (GNP) deflator and the Consumer price index (CPI), while indices of total hourly output and total factor productivity were used to proxy productivity. His analysis showed evidence for the acceptance of the hypothesis that productivity change does not Granger-cause inflation. The F-statistics of the hypothesis testing unidirectional causality flowing from productivity to inflation were very low, and thus the researcher could not reject the null hypothesis of no causal flow from productivity to inflation.

On the other hand, he could reject the hypothesis that inflation does not Granger cause changes in productivity based on the F-statistics associated with this hypothesis test. This negative relationship was found to be highly statistically significant at the 5% level of significance. In summary; Ram found that there is a relationship between inflation and productivity in the United States; inflation was found to Granger cause changes in productivity in a manner that is statistically significant. This causality was uni-directional; flowing from inflation to productivity with no significant feedback effect.

Buck and Fitzroy (1988) examined the inflation-productivity growth nexus in Germany. They carried out their empirical research with the aim of answering one basic question: Do rising prices cause productivity to grow at a slower pace, or is it the case that a slowdown in productivity causes a rise in the general price level? The authors attempted to answer this question using German data. The dataset was populated with annual observations from 40 indices ranging from 1950 to 1977.

They found that steadily rising prices would lead to a decline in productivity – i.e. that there is an inverse relationship between inflation and productivity in West Germany. In most of the equations estimated, the coefficient of the inflation variable was found to be negative and highly statistically significant. To ensure the robustness of their work, the authors tested for the possibility of feedback effects and reverse causality flowing from productivity to inflation. On the basis of their tests, they were able to reject the hypothesis that causality flows from productivity to inflation. Thus, the authors concluded that there was evidence for the existence of a negative and highly statistical relationship between inflation and productivity; and that this causal relationship was unidirectional from inflation to productivity.

Smyth (1988) investigated the nature and pattern of the relationship between total factor productivity and inflation in Germany using a dataset populated with annual observations ranging from 1951 to 1999. The Total factor productivity measure he used was the one estimated by previous research from Siebel (1992), while inflation was proxied by the West German consumer price index (CPI). The author used standard OLS regression analysis to estimate the relationship between total factor productivity and the rate of inflation. He found that a 1% increase in the inflation lead would cause the total factor productivity growth rate to drop by 0.253%. The adjusted R squared for this regression was 0.525, meaning 52.5% of the variations in the dependent variable; total factor productivity could be explained by the independent variable; inflation, while the other 47.5% of the variations in the dependent variable could be explained by the error term.

Consequently, the author found evidence that inflation is inversely related to total factor productivity and the rate at which total factor productivity grows, and that this relationship is highly statistically significant.

Bulman and Simon (2003) examined the productivity effects of rising inflation in Australia. They used a dataset populated with annual observations ranging from 1966 to 2002.The price variables chosen were industry specific price deflators, and productivity was measured with multifactor and labor productivity proxies. Seemingly unrelated regression (SUR) methodology was used to generate estimates of the relationship that exists at the industry level and an aggregate relationship over the industries surveyed was also estimated. They found evidence of a negative relationship between inflation and productivity growth, although this causal flow varied from industry to industry. This negative relationship between inflation and productivity growth was found to be highly statistically significant. The researcher concluded that the rise in general price levels that occurred in the 1970s contributed in no small measure to the decline in productivity growth observed during that period and that this inverse relationship between inflation and productivity growth persists to this day.

Christopoulos and Tsionas (2005) investigated the relationship between the growth of productivity and the rate of inflation in European countries, using a panel dataset populated with observations ranging from 1961 to 1999. The variable chosen to proxy productivity was the annual percentage change in the real Gross Domestic Product to total employment ratio. They started their analysis by testing the panel data set for stationarity and cointegration using Im-Pesharan-Shin panel data unit root tests and a panel cointegration test statistic suggested by Pedroni (1999,2004). The stationarity test revealed that all variables are integrated of order 1; they are non-stationary in levels but become stationary after first differencing. The series were also found to be cointegrated after the cointegration test was carried out. Since the data was cointegrated, researchers used the error correction modeling technique to detect the presence or absence of short-run causality. They found evidence of unidirectional causality flowing from inflation to productivity for half of the countries examined. This relationship is negative and highly statistically significant.

Dritsakis (2004) analyzed the relationship between inflation and productivity in Romania as a case study, using a dataset populated with quarterly observations ranging from 1990 to 2003, and analyzing the short-run causality between the variables using error correction methodology. First, the researcher tested for stationarity as standard causality tests can only be applied to variables that are integrated of the same order. Next, he tested for the presence or absence of cointegrating relationships between the variables of productivity and inflation using the Johanssen-Juselius method and then obtains estimates of the coefficients using error correction modeling. Finally, the estimated vector error correction model was used to establish causality or non-causality between the variables.

All the data were non-stationary in levels but became stationary after first differencing, and the null hypothesis of no cointegrating relationships between the variables was rejected after cointegration tests were carried out. Granger causality tests on the estimates of the coefficients of the Vector error correction model showed the presence of unidirectional causality flowing from inflation to productivity. Inflation was found to Granger cause productivity.

Jarret and Selody (1982) in a landmark study on the inflation-productivity relationship in Canada, examined the nature and pattern of the relationship between productivity and inflation in Canada, using a dataset populated with quarterly observations ranging from 1963 to 1979. They examined the productivity effects of increasing inflation using bivariate, trivariate and extended reduced form models to examine the time series data they had gathered. Productivity was measured using the percentage change in the real gross domestic product to man-hours worked ratio, and used the percentage change in the gross domestic product to real domestic product ratio as a measure of inflation.

On estimating the model, they found that a 1% shock in inflation would lead to a 6.05% rise in the inflation rate in the following year and consequently, a 1.3% drop in the growth rate of productivity of labor. They found that at the initial point of impact, inflation affects productivity through man-hours, and not the growth of output, i.e., inflation led to an increase in man-hours which in turn slowed down productivity. After four years, however, the reverse becomes the case and inflation affects productivity through the growth of output and not man hours; i.e. inflation slows down the pace of productivity growth by reducing the growth rate of output. The authors found that a 1% increase in general price levels would directly lead to a 0.31% drop in labor productivity and an extra 0.38% further down the line. Thus, they found evidence of a negative relationship between inflation and productivity; a rise in the general price levels was found to slow down the rate of productivity growth.

Mahadevan and Asafu-Adjaye (2005) investigated the relationship between inflation and productivity in Australia, but this time, with regard to a specific sector of the economy – the mining sector. Thus, they were interested, not just in general productivity growth in the economy but on productivity growth in the mining sector. First, the authors used a translog cost function to get estimates of total factor productivity and then used those total factor productivity estimates as a proxy for productivity. Inflation was measured by domestic price levels and the price levels in the mining sector. The researchers used a dataset populated with time series data spanning over two decades, ranging from 1968 to 1998. The causal relationship between inflation and productivity growth in the mining sector was established using standard Granger causality tests.

The hypothesis that inflation does not Granger causes productivity was rejected at the 5% level of significance while alternative hypotheses – that mining productivity causes inflation rejected at the 5% level of significance. Thus, it is the case that there is causality flowing from domestic inflation to productivity in the mining sector in Australia and that this causal relationship is uni-directional. Mineral price levels were also found to Granger cause a negative change in mining productivity, and this causal relationship was unidirectional. Of the two price level series investigated, mineral prices had a stronger effect on mining productivity than domestic price levels did. A 1% increase in mineral prices was found to reduce mining productivity by 0.01%, which is much higher than the 0.004% decrease in the growth of productivity brought about by a 1% increase in domestic price levels. The multivariate model used by the researchers show evidence of a unidirectional relationship flowing from price levels to the growth of productivity in the mining sector in Australia.

2.1.3 No significant effect of productivity on inflation

Ojede (2015) investigated whether inflation in developing countries was caused by growth in the money supply or by slower productivity growth. He analyzed the inflation effects of decreases in productivity and increases in the money supply in developing countries. He used total factor productivity indices for 54 developing countries with datasets populated with observations ranging from 1980-2000 and proxied inflation with Consumer Price Index and Gross Domestic Product indices. He analyzed this dataset and estimated a relationship between the variables using a non-parametric, generalized method of moments and growth accounting methods. His analysis showed that a 1% increase in the growth rate of total factor of productivity would lead to a 0.14% decline in inflation. However, this negative relationship was not statistically significant.

2.1.4 Not much or unclear relationship between productivity and inflation

Tsionas (2003) examined the relationship between productivity and inflation in Europe. He obtained estimates for his total factor productivity measure by using a translog production function. In addition, the author tested the underlying data for stationarity (which was a flaw of previous studies which simply tested for Granger-causality without first establishing the stationarity or non-stationarity of underlying data series). Finally, rather than using the standard Granger causality method which is inappropriate for nonstationary data, he used a new method for testing causality; the Dolado and Lukepohl method, which is appropriate when dealing with non-stationary variables.

He found evidence of non-stationary data at levels using dickey-fuller and Philip-Perron tests, and the Johanssen maximum likelihood test showed evidence of a long-run relationship between inflation and productivity in some countries. Thus, after finding evidence of non-stationary variables which are likely cointegrated, the use of a standard Granger causality test would be inappropriate. After testing for causality with an alternative method, he found evidence of one-way causality flowing from inflation to productivity in Ireland and Finland, while there was evidence of bi-directional causality between inflation and productivity for five countries (France, the UK, Germany, Greece, and Belgium). As for the other European Union member countries, no evidence on causal flows was found. Thus, the researcher found evidence of an unclear relationship between inflation and productivity growth; there was evidence of causal relationships in some countries under observation, and no evidence of causal relationships in other countries under observation, such that the true nature of the relationship between inflation and productivity is unclear.

Narayan and Smyth (2009) investigated the productivity effects of inflation and changes in real wages in the G7 countries using a dataset populated with observations ranging from 1960 to 2004 and using panel data stationarity tests and a panel data cointegration framework. The measure of productivity used was output per hour in the manufacturing sector (which only measures productivity of labor – one factor of production), and the consumer price index was used to measure inflation. The Im-Pesharan-Shim panel unit root tests were used, as this methodology modifies the standard unit root tests for panel data.

The variables were found to be non-stationary at log-levels but became stationary after first differencing. The fact that the variables have the same order of integration (in this case, order 1) qualified the data for panel cointegration tests using the Pedroni technique, and the results of the application of that technique showed that the variables are cointegrated. The long-run estimators were then estimated using the panel FMOLS method. The researchers found that inflation did not affect productivity in a manner that is statistically significant in six out of the seven G7 countries. It was only in the UK that evidence for a statistically significant relationship between inflation and productivity was observed. Specifically, a 1% increase in inflation was found to lead to a 0.4% decrease in productivity, and this relationship was highly statistically significant. In the other six G7 countries, no evidence for a relationship between inflation and productivity was found.

Freeman and Yerger (2000) examined the effects of rising inflation on labor productivity in the manufacturing sector in 12 Organization for Economic Co-operation and Development (OECD) countries, using cross-section time series data ranging from 1955 to 1994 for 12 countries. Productivity growth rates were chosen as proxies for productivity, while the Consumer price index (CPI) was used as a proxy for inflation. A natural logarithm form of real Gross Domestic Product was also included in the model to capture the productivity effects of fluctuations in the business cycle. They tested the data for stationarity and then ran Hsiao causality tests and the standard Granger causality test to examine the flows of causality and the direction of causal flows. After controlling for cyclical effect; they found no evidence of a consistent or significant relationship between inflation and productivity. The inflation-productivity relationship was found to vary so greatly over the sample period that it was impossible to make any definitive statements about the relationship between inflation and productivity.

Papapetrou (2003) investigated the existence or otherwise of a relationship between productivity and inflation in Poland. She used a dataset populated with quarterly observations ranging from 1991 to 1998, and the econometric method used to analyze this relationship was the vector error correction methodology and Granger causality.

Her focus was on establishing the causality issue in a transition economy such as Poland. The productivity variable used by the researcher was output per person employed in the manufacturing sector; that is, labor productivity in the manufacturing sector. Inflation was measured using the consumer price index. Following the convention of empirical analysis of time series data, the data was first tested for stationarity, then tested for cointegration and lastly a vector error correction model was specified, from which Granger causality tests were run.

After the unit root tests were performed, all variables were found to be nonstationary at levels but became stationary after first differencing, and the Philip Perron stationarity test confirmed this result. The Johanssen maximum likelihood test for cointegration gave evidence for the rejection of the null hypothesis of no cointegrating relationships between the variables, and the researcher concluded that productivity and inflation in Poland were cointegrated. Next, the specified Vector Error Correction model was estimated and causality tests were performed on the estimates of the coefficients of the Vector error correction model. The Granger causality results show the possibility of a weak but nevertheless existent bi-directional causality flowing from productivity growth to inflation. This bi-directional relationship is negative, and so in the long-run, it can be argued that both inflation and productivity harm each other. However, when monetary policy is controlled for through the inclusion of interest rates, it appears that there is no significant relationship between inflation and productivity. Statistically, this evidence suggests that the relationship between productivity growth and inflation is spurious and could, in fact, be affected by another factor.

Sbordone and Kuttner (1994) looked at postwar time series data in the United States of America to examine the relationship between productivity and inflation in the American case. They sought to determine whether the negative relationship between inflation and productivity that has been documented in the empirical literature represents a long-run relationship between inflation and productivity or simply represents co-movements in the two variables driven by cyclical fluctuations in the economy.

The variable used as a proxy for productivity was the output to labor ratio in the non-farm sector, which is a measure of labor productivity, while the gross domestic product deflator was used as a measure of inflation. Simple correlation tests showed that productivity and inflation are highly and negatively correlated, with a correlation coefficient estimated as ranging between -0.36 to -0.47. Since correlation does not equal causation, the authors then carried out the standard Granger causality tests and found that when a simple bivariate model was estimated, inflation Granger caused changes in productivity in a manner that is highly statistically significant. They also found that the causal flows between inflation and productivity are unidirectional, with causality flowing from inflation to productivity and the absence of a feedback effect. The F-statistics of the Granger causality tests also give evidence that the results from the Granger causality tests are highly statistically significant.

In order to investigate whether these causality test results depicted a true structural relationship or whether they were merely the results of external factors such as fluctuations in the business cycle; the researchers introduced control variables into the equation. They added these control variables to the underlying regression equation that formed the basis for the Granger causality test in the first place. After including the gross domestic product growth rate and the federal funds rate as control variables (that is, after controlling for fluctuations through the inclusion of a gross domestic product variable and controlling for monetary policy through the inclusion of the federal funds rate) the relationship between inflation and productivity breaks down. When control variables are included, it appears that the relationship between productivity and inflation is more indicative of external factors such as the relationship between monetary policy and business cycle fluctuations than it is of a true structural relationship between inflation and productivity.

A vector autoregression model was specified to estimate the long-run relationship between the variables and after working through some identification issues and imposing identifying assumptions and restrictions, increases in price levels were associated with drops in productivity in the long run. However, when the identification assumptions and restrictions were altered, the results changed significantly. The researchers found that the relationship between inflation and productivity is not as clear-cut as conventional wisdom would have us believe, but is, in fact, quite tenuous. Test results suggest that the observed negative correlation between inflation and productivity is largely cyclical in nature and any conclusions about the long run productivity effects of rising inflation depend largely on the identification procedure and the identifying assumptions or restrictions chosen. The researchers thus concluded that it is impossible to tell whether the negative correlation between productivity growth and inflation that is observed in the data is depictive of a true structural relationship or is merely a happy by-product of other external factors.

Table 2.1: Summary of the Reviewed Studies

Author and year of study	**Study**	**Country cover**	**Year cover**	**Estimation method(s)**	**Summary of findings**
Kim and Park (2013)	Productivity growth and general price level	Korea	1958 – 2002	VECM & Granger Causality	Factor productivity granger caused inflation significantly
Degrauwe and Skuldeny (2000)	Effects of movements in productivity growth on long-run inflation rates	European Union	1971 – 1995	Pooled OLS	Inverse relationship between productivity growth and inflation. One percent decline in productivity growth lead to 0.67 percent increase in inflation

Bitros and Panas (2005)	The trade-off between inflation and productivity	Greece	1964 - 1980	Box-cox cost function	Inflation leads to significant decrease in total factor productivity of the industries under the period of consideration. Unidirectional causal relationship running from inflation to productivity
Ram 1984	Inflation and the rate of growth of labour productivity	USA	1953 – 1982	Granger Causality	No causal relationship between inflation and productivity. However, a significant inverse relationship was found between inflation and productivity
Buck and Fitzroy (1988)	Inflation and Productivity growth nexus	Germany	1950 to 1977	Causality	Negative relationship between inflation and productivity. Unidirectional causal relationship
Smyth(1988)	Nature and pattern of the relationship between total factor productivity and inflation	Germany	1951 – 1999	OLS	Increase in inflation significantly drops the productivity

Bulman and Simon (2003)	The productivity effects of rising inflation	Australia	1966 – 2002	SUR	Inverse relationship between inflation and productivity growth. Inflation n rise in the 1970s hampered productivity
Christopoulos and Tsiona (2005)	Growth of productivity and rate of inflation	Europe	1961 – 1999	ECM	A significant number of countries shows unidirectional causality running from inflation to productivity.
Dritsakis (2004)	Inflation and Productivity	Romania	1990 – 2003	ECM & Causality	Significant unidirectional causal relationship between inflation and productivity
Jarret and Selody (1982)	Inflation – Productivity relationship	Canada	1962 – 1979	Bi & Tri-variate model	A significant inverse relationship between inflation and productivity
Mahadevan and Asafu-Adjaye (2005)	Inflation and Productivity	Australia	1968 - 1998	Translog cost function and granger causality	Causal unidirectional relationship between inflation and productivity in the mining sector

Ojede (2015)	Inflation and growth in money supply	Developing Countries	1980 – 2000	GMM	Total factor productivity leads to decrease in inflation significantly.
Tsionas (2003)	Productivity and inflation	Europe		Granger Causality	Inconsistent result among the countries under study as they show bi-causal and unidirectional causal relationship between inflation and productivity
Narayan and Smyth (2009)	Productivity effects on inflation and changes in real wages	G7 Countries	1960 – 2004	Panel FMOLS	Six of the seven countries do not have productivity problem based on inflation by the last one country shows inverse relationship between inflation and productivity
Freeman and Yerger (2000)	Effect of rising inflation on labour productivity	12 OECD Countries	1995 – 1994	Hsiao & Granger Causality	Inflation and productivity do not have a significant relationship when cyclical effect was accounted for in the analysis
Papapetrou (2003)	Productivity and Inflation	Poland	1991 – 1998	VECM & Granger Causality	Existence of long-run and bi-causal relationship between productivity and inflation. The result was insignificant when interest rate was controlled for

Sbordone and Kuttner (1994)	Relation between inflation and productivity	USA		Granger Causality	Evidence of significant unidirectional relationship running from inflation to productivity

2.2 Critique of studies

The empirical literature covering the relationship between inflation and productivity is broad and often contradictory. Of the different possibilities covered, the discovery of a negative and highly statistically significant causal relationship flowing from inflation to productivity is the most common in the empirical literature. Researchers have also found evidence of clear ambiguity in the inflation-productivity relationship, while some have found evidence of causal relationships flowing in the opposite direction; this time from productivity to inflation. These studies into the nature and pattern of the relationship between inflation and productivity were very powerful and have shaped the conventional wisdom on the inflation-productivity nexus. However, they are also flawed in some ways. Some of the areas of criticism that will be considered shortly are; the productivity measure used, the inflation measure used, the inclusion (or exclusion) of cyclical factors and the appropriateness of the causality test procedure used.

2.2.1 Productivity Measure

Most of the studies reviewed used some variation of labor productivity as a measure of productivity. Ram (1984) used an index of total output per hour as a measure of productivity in his study. Freeman and Yerger (2000) used the growth rate of labor productivity as a proxy for productivity in their research work, Kim and Park (2013) used labor productivity as one of the variables which proxied productivity, De Grauwe and Skuldeny (2000) used labor productivity differentials to measure productivity, Narayan and Smyth (2009) measured productivity with hourly output in the manufacturing sector, Papapetrou (2003) used labor productivity in the manufacturing sector as a proxy for labor productivity, Jarret and Selody (1982) used the percentage change in output per man hour worked ratio as a proxy for labor productivity, Sbordone and Kuttner (1994) used the ratio of output to labor in the non-farm sector to represent productivity and so forth.

Each of these studies chose some measure of labor productivity as a proxy for total productivity. These measures of productivity, however, only measure the productivity of labor, and labor is just one factor of production. Thus, labor productivity alone is a partial measure of productivity. Measuring productivity by output per worker measures is dated. More than that, any study that used labor productivity as a measure of productivity is likely to be understating the true effects of inflation on productivity (or vice versa). Thus, a major flaw of these studies is that they used a single labor productivity variable as a measure of productivity, and are thus likely to have understated or misrepresented the true effects of inflation on productivity (or vice versa).

Some studies, such as Bitros and Panas (2005), Tsionas (2003), Smyth (1995) and so forth avoid this trap by estimating production functions in order to get direct estimates for total factor productivity, not just labor productivity.

However, as Bitros and Panas (2005) pointed out, some of the studies that did use total factor productivity measures did not differentiate/distinguish the effect inflation has on total factor of productivity from the impact technical change or other factors have on total factor productivity. It is possible, they reasoned, for researchers to obtain results that attribute to inflation changes in total factor productivity that could have been caused by other factors, thus overstating the effects of inflation on productivity.

2.2.2 Inflation Measure

Another point of criticism lies in the inflation measure used. Some studies used Gross national product (GNP) or Gross Domestic Product (GDP) deflators as their own measures of inflation. One criticism of this practice is the fact that the GDP or GNP deflator is also derived from computing output, and so using a measure that is partially dependent on real output might make the estimation biased. Thus, consumer price index, which is derived in a manner that is independent of how real output is calculated is a superior measure, and so should be used when choosing a variable to proxy inflation.

Yet another criticism of earlier studies lies in the inclusion or exclusion of cyclical variables to control for cyclical fluctuations. Simply testing for causality in a simple two-variable model without controlling for cyclical fluctuations could produce results that are spurious. Adding cyclical variables to control for fluctuations in the business cycle could throw more light on the relationship between inflation and productivity growth. Interestingly, some of the few studies that included cyclical variables in their models found that without the inclusion of cyclical variables, clear and unambiguous relationships between inflation and productivity were observed, but when external factors such as cyclical fluctuations and monetary policy were introduced into the model and controlled for, the seemingly unambiguous relationship between inflation and productivity growth changed.

2.2.3 Empirical Methods

Perhaps the greatest criticism of earlier research lies in the inappropriateness of econometric technique used. Much of the earlier studies simply ran standard Granger causality tests on the variables and proceeded to make inferences about the directionality of causal relationships without first establishing the stationarity or non-stationarity of underlying variables. Most studies did not test for stationarity between the variables. If the data used was non-stationary, the results obtained from such analyses would be spurious. Using standard Granger Causality F-tests with non-stationary variables produces spurious results because Granger causality cannot be used with non-stationary variables. This poor choice of econometric technique has surely produced results that are not representative of the true relationship between inflation and productivity. In a nutshell, the major criticisms of existing literature can be broadly depicted by the questions and answers below:

i. What measure of productivity was used in the study? Studied which only used labor productivity understated the true productivity effects of rising inflation.

ii. What measure of inflation was used in the study? CPI is superior to GDP deflator.

iii. Did the researchers check the underlying data for stationarity? If they just ran Granger causality tests without first establishing the stationarity of the underlying data series, their results could be spurious because standard Granger causality tests are inappropriate for nonstationary data.

iv. Did they make allowances for cyclical fluctuations by introducing cyclical factors? If cyclical factors are not controlled for, co-movements between inflation and productivity cannot be determined.

2.3 The theoretical literature

The prediction of the relationship between productivity and inflation by theoretical literature is an inversely relation. The negative relationship is been blamed on the effect that inflation has on firms plan as regarding investment in which it curtails their expansion and how it erodes workers purchasing power which subsequently affects their motivation and effort put into work. All the aforementioned reasons no doubt trigger the negative a priori expectation between productivity and inflation. Due to the fact that real wages and productivity are positively related since higher real wages would serve as a motivation for the workers and also increase the opportunity cost of job loss which will stimulate greater work effort to avoid it. Furthermore, higher wages increase the marginal productivity of labor through the idea of capital for labor substitution. According to the monetarist, inflation is always and everywhere a monetary phenomenon that arises from a more rapid expansion in the quantity of money than in total output which is a function of productivity. One of the theories of inflation that closely addresses productivity is the cost push theory (Tontonchi, 2011; Ladu and Meleddu, 2016).

Cost Push Theory is based on the fact that inflation is caused by wage increases enforced by unions and profit increases by employers. The transmission of their activities tends to affect productivity level. Cost push theory also came to be known as New Inflation. Cost-Push inflation is argued to be the base of the rise in money wages more rapidly than the productivity of labor in the economy. The labor unions press employers to grant wage increases considerably in other to meet up with their needs, thereby raising the cost of production of commodities putting employers at worse in the area of their returns. In response to this, the employer raise prices of their products putting the workers at worse. Higher wages enable workers to buy as much as before, in spite of higher prices but the increase in prices of the commodity induces unions to request more higher wages. In this way, the wage-cost spiral countries, thereby, leading to cost-push or wage-push inflation. Also, there is profit push inflation and all these tends to reduce productivity. Cost-push inflation may be further aggravated by upward adjustment of wages to compensate for rise in cost of living. A few sectors of the economy may be affected by increase in money wages and prices of their products may be rising. In many cases, their products are used as inputs for the production of commodities in other sectors. As a result, cost of production of other sectors will rise and thereby push up the prices of their products. Thus wage-push inflation in a few sectors of the economy may soon lead to inflationary rise in prices in the entire economy. Further, an increase in the price of imported raw materials may turn out to be cost-push inflation (Bulman and Simon, 2003).

Another cause of Cost-Push inflation is profit-push inflation. Oligopolist and monopolist firms raise the price of their products to offset the rise in labor and cost of production to earn higher profits. There being imperfect competition in the case of such firms, they are able to administered price of their products. Profit-push inflation is therefore called administered-price inflation or price-push inflation. The effect all this inflationary move has on the economy is connected from the channel of productivity (Dritsakis, 2004; Ladu and Meleddu, 2016).

2.4 Conclusion

Various questions have been asked in shedding more light into the macroeconomics of inflation and productivity. The possible causal link and directions of causality can be running from inflation to productivity or from productivity to inflation. This section of this paper has attempted to explain some of the relevant concepts that will ease the understanding of the two main variables of interest. More so, theoretically and empirical review of the studies related to this research work have been examined in which various views and conclusion of different scholars have been employed as a guideline in one area or the other. The next section of the work will address the methodology that will be used in getting the empirical evidence.

Chapter 3: Data, Model and Empirical Methodology

3.0 Introduction

This Chapter provides a description of the variables used, the model specification, method of analysis and the source of data.

3.1 Data

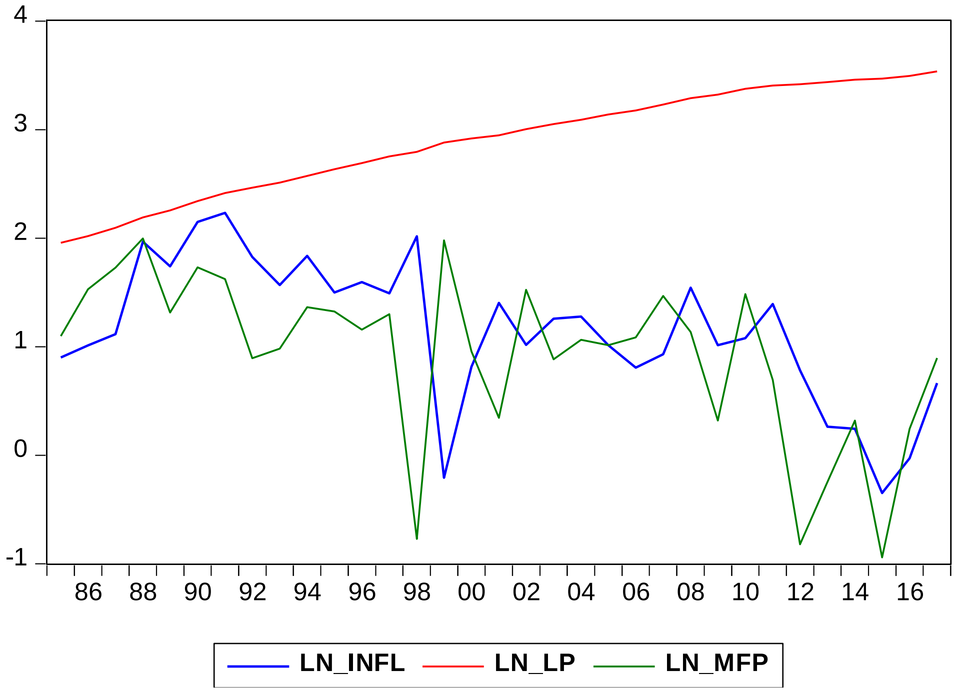
This study examines the relationship between productivity and inflation by looking at two different measures of productivity; labor productivity and total factor productivity. The review of literature earlier performed revealed that many studies into the inflation-productivity nexus have used labor productivity as the only measure of productivity. However, labor is not the only factor of production; and using such a partial measure of productivity as labor productivity produces results that understate the true effect of productivity on inflation. Consequently, the effect of factor substitution between labor and capital are taken into account by using a more robust measure of productivity – multi-factor productivity (MFP).

Labor productivity data from OECD database was used to obtain estimates for the GDP per hour worked for Korea. GDP per hour worked is a measure of the efficiency with which labor is used in the process of production. Labor input is proxied by the total hours worked by all people participating in the production process, while the measure of output chosen is GDP (USD constant prices 2010). Gross Domestic Product per hours worked serves as a measure of labor productivity, though partial as the effect of factor substitution between labor and capital is not taken into account when viewing labor productivity data alone. Annual time series data ranging from 1985 to 2017 was obtained from the OECD database. The annual time series data was picked due to the unavailability of all the variables in quarterly measure.

Multifactor productivity (MFP) data was obtained by estimating Solow residuals from time series Data ranging from 1985 – 2016. Multifactor productivity (MFP) captures the total efficiency with which labour and capital inputs are combinedly used in the production process. The changes in the value of the MFP covers other factors that affect productivity. These factors include but are not limited to effects of changes in adjustment costs, economies of scale, management practices, brand names, organizational change, general knowledge, network effects, spillovers from production factors, the effects of imperfect competition and measurement errors. Growth in MFP is measured as a residual basically as part of GDP growth that cannot be explained by changes whatsoever in labour and capital inputs. If labor and capital remained constant between two periods, any changes in GDP over the same periods would be attributable to changes in MFP. It is measured in annual growth rates.

A visual plot of the data to examine the trend is essential in this time series analysis. Consequently, the data of the time series used is plotted below:

Figure 3.1: Trend of inflation, labour productivity and multifactor productivity



Where:

LN_INFL = Natural Logarithm of Inflation

LN_LP = Natural Logarithm of Labor Productivity

LN_MFP = Natural Logarithm of Multifactor productivity

The first impression from observing this visual plot of the relationship between inflation, labor productivity and multifactor productivity is that there is a relationship between these three variables.

GDP per hour of work has been trending upwards over time, while inflation appears to have been trending downwards over time (albeit with many fluctuations). This suggests a negative relationship between these variables; as labor productivity rises over time, inflation has been falling over time (although the decline has not been smooth). However, the causal directionality of this relationship is unclear based on this plot alone.

More interestingly, the relationship between multi factor productivity (MFP) and inflation is depicted in the graph above.

The relationship between inflation and multi factor productivity (MFP) seemed largely steady from the mid-1980s to 1997; both series seemed to be trending in the same direction; dips in the MFP trend line were associated with dips in the inflation trend line and vice versa. In 1997/1998, however, there was a sharp change. The trendline shows a sharp change in the relationship between multifactor productivity (MFP) and inflation; namely, a strongly negative relationship between the two series; dips in MFP are associated with corresponding increases in inflation, and declining inflation is associated with corresponding increases in multifactor productivity (MFP). Thus, the initial observation is that multifactor productivity is significantly and negatively correlated with inflation, and that this relationship became much stronger post 1997, likely due to the technological progress that followed the Asian financial crisis of 1997. This conclusion is validated by earlier research which concluded that the stronger productivity-inflation relationship post 1997 Asian financial crisis was due to structural reform and technological advancement (Kim et al, 2013).

3.2 Model Specification

The model to investigate the relationship between inflation and productivity is based on the following functional relationship which is specified as:

INFL = F (LP) (3.1)

INFL = F (MFP) (3.2)

Where:

INFL = inflation which is captured by the CPI

MFP = Multifactor productivity

LP = Labour productivity

3.3 Econometric Method

Following the standard procedure of time series analysis, this model will be estimated by testing for stationarity, testing for cointegration and then carrying out the error correction estimation. Empirical analysis based on time series data assumes that the underlying time series data are stationary. Using non-stationary estimation would likely lead researchers to find statistically significant relationships between variables when there are no apriori theoretical reasons to expect such relationships. This, in a nutshell, is the phenomenon of spurious regression, first discovered by Yule (1897). However, if the evidence shows the existence of cointegration between non-stationary variables, then the regression would not be spurious but would represent the existence of long-run equilibrium relationship between the variables.

Bearing in mind the serious consequences of using non-stationary data for my empirical analysis and ultimately the result cannot be used for prediction, forecasting or hypothesis testing, the first step is to test for stationarity of the data. One way to do this is to use the unit root test. Several procedures have been developed for testing for the presence of unit roots, but this study uses the Augmented Dickey-Fuller (ADF) test. The null hypothesis of the test is that there is the presence of unit root and the failure to reject the null hypothesis leads to conducting the test on further differences of the series. Further differencing is conducted until stationarity is reached and the null hypothesis is rejected. The further differencing reveals the order of integration of the variables used in the study.

The next step is testing for cointegration. Reason for this lies in the fact that a linear combination of two or more non-stationary series may be stationary. If such stationarity exists then, time series are said to be co-integrated. A traditional cointegration test involves testing for the presence or absence of cointegration between series of the same order of integration through forming a cointegration equation. Economically speaking, if two variables are cointegrated, there exists a long-run equilibrium relationship between them. A lack of cointegration suggests that the variables have no long-run relationships; in principle, they can arbitrarily wander far from each other. This study uses the traditional Johansen cointegration test to test for cointegration between the variables.

If the variables are cointegrated, the third step is error correction modelling (ECM). If cointegration is proven to exist, then there is a long-term or equilibrium relationship between the variables. In the short-run, however, there may be disequilibrium. The ECM corrects for this disequilibrium and indicates the speed of adjustment from short-run disequilibrium to a state of long-run equilibrium. The ECM coefficient is expected to lie between zero and -1.

Finally, since the objective of this research paper is to establish the directionality of any causal relationships between inflation and productivity, the last step is to carry out Granger causality test based on Toda-Yamamoto (1995) method for Granger causality estimates to ascertain the direction in which the causal relationship runs.

3.4 Conclusion

This section presents the methodology of this research work. Two measures of productivity which are labour productivity and multifactor productivity were employed in examining the relationship with inflation. Annual time series data collected from OECD database ranging from 1985 – 2017 was used. Augmented-Dickey Fuller was used to testing for the unit root and the cointegration test was conducted using the Johansen and Bounds Cointegration Test. Based on the existence of a long-run relationship, the error correction model and vector error correction model were employed to examine the relationship and Toda-Yamamoto was used to examine the causal relationship between the variables.

Chapter 4: Results and Analysis

4.0 Introduction

In this chapter, the results obtained from implementing the methodology described in the previous chapter on the data also described there, are presented.

4.1 Descriptive Statistics

This section starts with the descriptive statistics of the variables used for this study. The descriptive statistics of the variables will give us insight into the statistical properties of the variables. The table below shows the data of the descriptive variables to explain productivity and inflation of Korea from the period (1985-2017).

Table 4.1: Descriptive Statistics of the Variables

Variables	**INFL**	**LP**	**MFP**
Mean	3.786909	19.94555	3.148256
Median	3.049660	19.03559	2.957373
Maximum	9.333361	34.30000	7.359275
Minimum	0.706208	7.082466	0.389630
Std. Dev.	2.215499	8.635260	1.798186
Skewness	0.799397	0.125535	0.503694
Kurtosis	2.983256	1.676062	2.891342
Jarque-Bera	3.515077	2.496792	1.411623
P-value of JB statistic	0.172469	0.286965	0.493708

The descriptive statistics as presented in table 4.1 starts with the measure of center of tendency and it begins with the mean which captures the average value of the variables. The median is the middle value when we sorted the observation. Next is the measure of dispersion starting with the minimum and maximum value of the variable shows the range of the variable and the standard deviation shows the deviation around the mean value of the variables. Next is the measure of Normality. The skewness measures the degree of asymmetric around the mean value of the series. The normal skewness has a zero value of skewness which means that the distribution is not symmetric as noted in the variables of INFL, LP and MFP. The positive skewness denotes that the curve has a long right tail and a higher value while the negative skewness shows that the distribution is having a long-left tail and a lower value as evident in the LP series.

The Kurtosis measures the peakness or the flatness of the distribution of the series. A series is said to be mesokurtic if it has the kurtosis of 3 and this means the distribution is normally distributed. However, the series in these variables are platykurtic (negative peaked) as the kurtosis variables are lower than 3. The Jarque-Bera test statistics measure the difference of the skewness and kurtosis of the series with those of the normal distribution. The probability underneath shows the probability value of the Jarque-Bera statistics. It has the null hypothesis that the variables are normally distributed. Since the p-value of all the variables are higher than the 5% level of significance, we do not reject the null hypothesis of normal distribution.

4.2 Unit Root Test

Specifically, the order of integration of the variables is essential to be considered since studies have shown that in most time-series studies, the consistency doctrine of the OLS is violated. As a result, the classical t-Statistic, F-Statistic and Durbin Watson statistic values are based on such estimate that may yield biased and inconsistent result, leading to the so-called spurious regression problem (Granger & Newbold, 1974). Stationarity of the series implies that the mean, variance and covariance are constant over time. The order of integration is found using the Augmented Dickey-Fuller (ADF) set of unit root test. The result is presented in Table 4.2 below:

Table 4.2: Unit Root Test (ADF)

Variables	**At Level**			**At First Difference**			**Comments**
	t-Stat	t-Critical Value	Prob.	t-Stat	t-Critical Value	Prob.	
INFL	-1.3095	-2.9639	0.6119	-5.5452	-2.963	0.0001	I(1)
MFP	-4.2266	-2.9571	0.0023				I(0)
LP	1.2839	-2.9571	0.9980	-4.2023	-2.960	0.0026	I(1)

The INFL variable have an ADF tau-c statistic absolute value of 1.3095 which is lower than the ADF test critical absolute value at the 5% level of significance, which is 2.96. The p-value of the test statistic is 0.6119 and it is not statistically significant at the 5% level of significance. Thus, the we fail to reject the null hypothesis that the series is not stationary. We will therefore apply first difference to the series. After the first differencing, the absolute value of the Augmented Dickey-Fuller test for the INFL series has a tau statistic of 5.5452 and this is higher than the ADF test critical values at the 5% level of significance, which is 2.9639. Also, the probability value of the test is 0.0001 and this is lesser than the 5% level of significance. Thus, the null hypothesis that the first difference of INFL has a unit root is rejected, and I conclude that the variable INFL becomes stationary after first differencing. Hence, these variables are integrated of order 1, or I(1).

The value of the MFP tau-c statistic for the ADF is 4.2266 and it is very much higher than the absolute tau statistic at the 5% level of significance, which is 2.9571. The p-value of the ADF is statistically significant at the 5% level of significance. We, therefore, conclude that the multifactor productivity series is stationary at the level and integrated of order zero. The value of the ADF test statistic for the variable LP is 1.2839. This is less than the absolute value of the critical value at the 5% level of significance, which is 2.957. Also, the probability value of the ADF test statistic is 0.9980, which is greater than 0.05. Thus, the null hypothesis that LP has a unit root cannot be rejected, and we conclude that the variable LP is non-stationary at level. After first differencing, the absolute value of the test statistic is 4.2023. This is greater than the test critical value at the 5% level of significance, 2.960. Also, the p-value of the test statistic is 0.0026, which is less than 0.05 significance level. Thus, the null hypothesis that LP has a unit root is rejected, and we conclude that the variable LP becomes stationary after first differencing. This variable is also integrated of order one or I(1).

Given that the series of the variables of the equation (3.1) are integrated of the same order, we will apply the Johansen cointegration which is fully discussed in section 4.4. The variables of the second equation are integrated of different order, that is, combination of I(0) and I(1). Based on this, the Johansen cointegration test is no longer valid but we still need to however, test for the cointegration in order to ascertain if there is long run relationship. To achieve this, we will use the bounds test that is proposed by Pesaran, Shin and Smith (2001).

4.3 Lag Selection

Equation one start with the optimal lag selection. One of the guideline is to choose the model with the lowest Akaike Information Criterion value because the lower the value of the AIC the better the model. To get the optimal lag, we run the model in unrestricted VAR model with the assumption that the variables are not cointegrated and made use of the lag length criteria. There are different criteria to base the decision on and these include sequential modified LR test statistic; Final Prediction Error (FPE); Akaike Information Criterion (AIC); Schwarz Information Criterion (SIC) and Hannan-Quinn Information Criterion (HQ). Based on table 4.3 below, all the criteria picks lag 0 as the optimal lag form the model. However, based on the assumption of having the order of VAR to be at least one, we therefore run the analysis with lag two as suggested by the LR criteria.

Table 4.3: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-51.84468	NA*	2.400720*	3.713426*	3.807723*	3.742959*
1	-51.60311	0.433171	2.530956	3.765731	3.907176	3.810030
2	-51.60302	0.000151	2.714434	3.834691	4.023283	3.893756
3	-51.55917	0.072584	2.904421	3.900632	4.136373	3.974463
4	-50.65410	1.435614	2.931058	3.907180	4.190068	3.995777

4.4 INFL and LP

Table 4.4 and 4.5 presents the Johansen cointegration test result which consist of the Trace test and the Maximum Eigenvalue test. The test shows the number of cointegrated equations and based on the null hypothesis, one will decide to go with the null or alternate hypothesis that conforms to the 5 percent specified level of significance. Trace test and Maximum Eigenvalue test shows that one cointegrating equation exist. This means there is long-run relationship among the variables and the estimation will be involve the long-run and the error correction model.

Table 4.4: Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.395497	17.53250	15.49471	0.0243
At most 1	0.043565	1.425349	3.841466	0.2325

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.5: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.395497	16.10715	14.26460	0.0253
At most 1	0.043565	1.425349	3.841466	0.2325

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

4.5 The Model for INFL and LP

VECM Estimate

Table 4.6 below presents the vector error correction model estimate showing the dynamic short-run in which the relationship between inflation and labour productivity turns out positive as denoted by the coefficient C(3) and that is contrary to what we have in the long-run where a negative relationship exist between the two variables. The value of inflation in the first period as noted by C(2) exhibited a negative relationship. The error correction term C(1) came out statistically significant and negative. Examining the coefficient of C(1) indicates that the long-run equilibrium relationship between INFL and LP is given by $INFL_t = 8.1472 - 0.214LP$, which means that there exist a negative long-run relationship between INFL and LP. The speed of adjustment of the relationship is 0.78. This shows that if there be any shock 78 per cent of it will be corrected in the following period, there will be convergence among the variables.

D(INFL) = C(1)*(INFL(-1) + 0.213999565485*LP(-1) - 8.14721885498) + C(2)*D(INFL(-1)) + C(3)*D(LP(-1)) + C(4)

Table 4.6: VECM estimates with Inflation as the dependent variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.786028	0.196938	-3.991247	0.0005
C(2)	-0.028439	0.166640	-0.170663	0.8658
C(3)	1.011656	0.930342	1.087402	0.2865
C(4)	-0.869796	0.822922	-1.056961	0.2999
R-squared	0.462209	F-statistic		7.7351
		Prob(F-statistic)		0.0006
Adjusted R-squared	0.402454	Durbin-Watson stat		2.0752

4.6 Bounds Cointegration Test for INFL and MFP

The bounds cointegration test is used when the order of integration is not the same as we have with the variable of inflation and multifactor productivity. It has the null hypothesis that there is no cointegration. The decision criteria is that if the calculated F-statistic is greater than the critical value of the upper bound I(1), then we can conclude that there is cointegration. This means there is long run relationship and we will reject the null hypothesis. We will then run the long run model and error correction model (ECM). However, if the calculated F-statistic comes out lower than the critical value of the lower bound I(0), then we can conclude that there is no cointegration. This means there is no existence of long run relationship and we will accept the null hypothesis. We will then run the short run model alone but if the F-statistic value falls between the value of lower bound I(0) and the upper bound I(1), the test will be considered inconclusive. The cointegration test is performed on the level form of the variable with restricted intercept and the result is presented in Table 4.7 below. The F test which is used in evaluating this result is conducted on the co-efficient based on the level term.

The long-run relationship test and based on the 1% level of significance, the calculated F-statistic (8.36) is higher than the upper bound (5.58) we reject the null hypothesis and then conclude that there is long run relationship between the variables of the study. This shows that if there are shocks in the individual series in the short run which affect their movement, inflation responds to the disequilibrium error. We will therefore run the long run model and the error correction model (ECM) with ARDL (1,4).

Table 4.7 Bound Test with restricted intercept for Long-run relationship

Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
Asymptotic: n=1000				
F-statistic	8.361255	10%	3.02	3.51
k	1	5%	3.62	4.16
		2.5%	4.18	4.79
		1%	4.94	5.58

4.7 Short-run Dynamic Relationship between INFL and MFP

The result presented in table 4.8 presents the error correction model. It shows that the multifactor productivity variable in the current period maintains a positive relationship as in the long run with inflation but its impact is not statistically significant. The R-squared of 0.627 showed that the independent variables capture about 67 percent of the variability in the explained variables while the others of the fluctuations in the dependent variable can be attributed to the error term. When the unexplained and total variations are adjusted based on the corresponding degrees of freedom, the model still explains about 50 per cent of the variation in inflation as shown by the value of the adjusted R-squared. The speed of adjustment of the relationship is 0.98. This shows that if there be any shock 98 per cent of it will be corrected in the following period, there will be convergence among the variables

The F-test tests that the model is a good fit and it has the null hypothesis that all the independent variables taken together have no effect on the dependent variable. For interpreting the F-statistic, its p-value is employed. If the p-value is less than 0.05, the null hypothesis is rejected. Following this rule, it is observed that the p-value of the f-statistic is 0.037, which is less than 0.05. Thus, the null hypothesis that all the independent variables taken together have no effect on the independent variable is rejected, and we conclude that the overall model is statistically significant.

Table 4.8: ECM estimate with inflation as the dependent variable based on the ARDL lag selection – ARDL (1,4)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(INFL(-1))	0.125646	0.204825	0.613430	0.5465
D(MFP)	-0.166348	0.189489	-0.877875	0.3904
D(MFP(-1))	0.476839	0.274604	1.736460	0.0979
D(MFP(-2))	0.589037	0.301059	1.956549	0.0645
D(MFP(-3))	0.675044	0.249634	2.704137	0.0137
D(MFP(-4))	0.409672	0.166282	2.463724	0.0229
ECM(-1)	-0.986751	0.307569	-3.208221	0.0044
C	0.145380	0.302004	0.481384	0.6355
R-squared	0.627302	F-statistic		4.808963
		Prob(F-statistic)		0.002618
Adjusted R-squared	0.496858	Durbin-Watson stat		1.606924

4.8 Toda-Yamamoto for Causality

In checking the causal relationship among the variables given that the variables are integrated of different order, this study employ the Toda-Yamamoto (1995) model to ascertain the direction of casual relationship among the variables while adding one more lags to the identified lags by the lag selection criteria. Table 4.9 presents the Granger Causality test from the Toda-Yamamoto model. The result when labour productivity was the dependent variable the shows that the value of All is statistically significant meaning there is a joint causality running from inflation and multifactor productivity combined. The result further shows that there exist a causal relationship running from multifactor productivity to inflation but no causal relationship running from inflation to multifactor productivity which means there exist a unidirectional causal relationship among the two variables.

Table 4.9: Granger Casuality/Block Exogeneity Wald Test

Dependent variable: INFL			
Excluded	Chi-sq	df	Prob.
LP	3.213875	2	0.2005
MFP	8.224784	2	0.0164
All	8.948868	4	0.0624
Dependent variable: LP			
Excluded	Chi-sq	df	Prob.
INFL	1.561966	2	0.4580
MFP	8.588891	2	0.0136
All	9.670092	4	0.0464
Dependent variable: MFP			
Excluded	Chi-sq	df	Prob.
INFL	1.675423	2	0.4327
LP	0.921369	2	0.6309

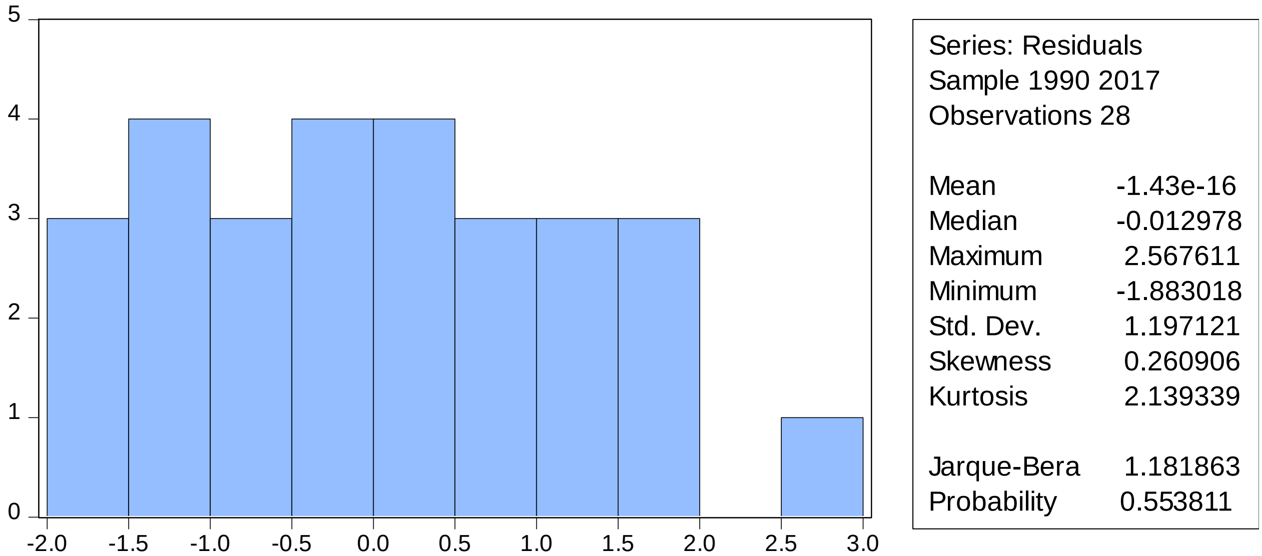
4.9 Diagnostic Check

4.9.1 Normality Test

In accessing the residual of the model and to determine the data set is well modeled by a normal distribution, we conducted the histogram normality test which help us determine the goodness of fit. It enables us to know if the sample data have the skewness and kurtosis that matches a normal distribution. The distribution of the data on the histogram is expected to be bell shaped. The main test here is the Jarque Bera test and it has the null hypothesis that is of joint form. With the p-value of the Jarque Bera test (0.5538) for the ARDL (1,4) model for INFL and MFP and (0.48047) and (0.8639) for VECM and long-run estimates for INFL and LP which is higher than the 5 per cent level of significance. We, therefore, cannot reject the null hypothesis and we conclude that the variables used in this study are normally distributed.

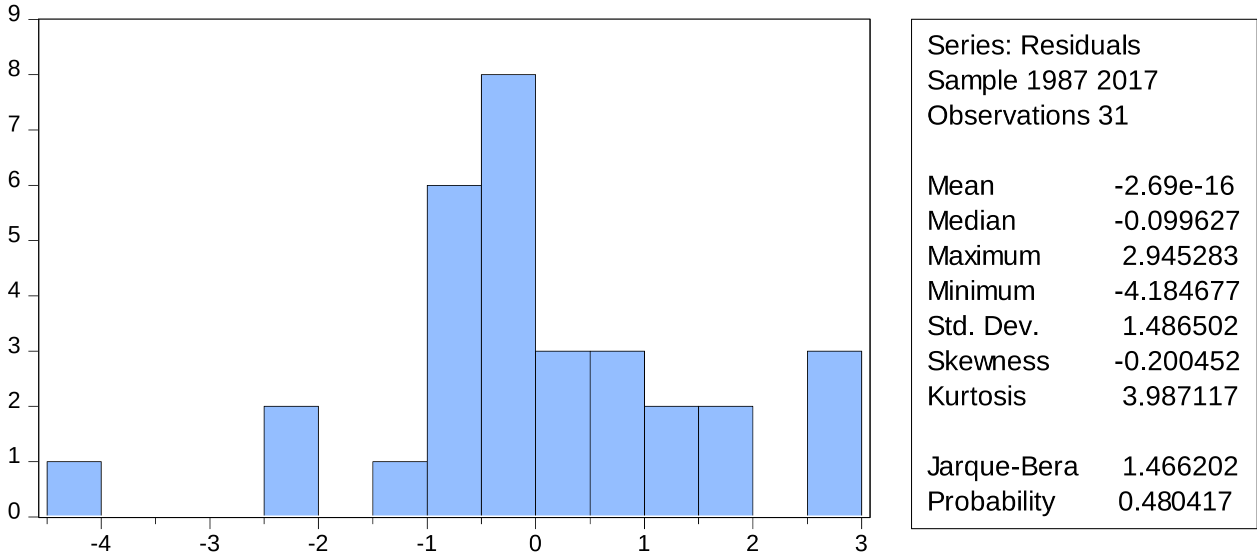
Figure 4.1: Normality Test

For ARDL

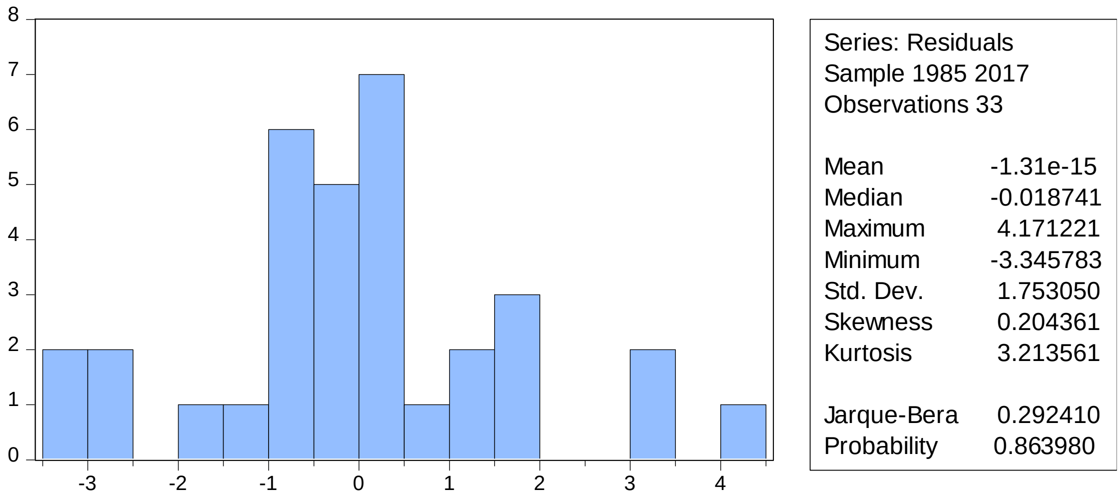


For VECM and Long-run Estimate for INFL and LP

VECM



Long-run Estimate



4.9.2 Lagrange Multiplier (LM) Test for autocorrelation

In checking for the presence of serial correlation, the Breusch Godfrey serial correlation LM test was carried out. The test of LM is applied to check for autocorrelation in the errors of the regression. The test statistics used in the test is derived from the residual of the model being considered in the regression analysis to check that it does not predict itself. It has the null hypothesis of no serial correlation of any order up to p as against the alternative hypothesis of the presence of serial correlation. With the p-value of the LM test (0.2629) and (0.2035) of order two for ARDL and ECM estimates respectively that is greater than the specified 5 per cent level, we fail to reject the null hypothesis and assumed that the model used for this study does not suffer from the problem of serial correlation.

Table 4.10 Breusch-Godfrey Serial Correlation LM Test

For ARDL

F-statistic	1.404181	Prob. F(2,25)	0.2629
Obs*R-squared	3.014844	Prob. Chi-Square(2)	0.2215

For VECM

F-statistic	0.766812	Prob. F(2,25)	0.4751
Obs*R-squared	1.791777	Prob. Chi-Square(2)	0.4082

4.9.3 Heteroskedasticity Test

Also taking it further by confirming the result obtained earlier, we test for heteroskedasticity. In other to be sure that the variance of the errors from the regression is not dependent on the values of the independent variables and we employed the Breusch- Pagen-Koenker test to clarify this. This test also examined if the errors in regression are differently scattered and it has the null hypothesis of presence of homoscedasticity against the alternative hypothesis of the presence of heteroscedasticity. The p-value for the LM test for ARDL and ECM estimates also is higher than the 5 per cent level of significance and we can therefore accept the null hypothesis and the assumption of homoscedasticity is not violated.

Table 4.11: Heteroskedasticity Test: Breusch-Pagan-Godfrey

For ARDL

F-statistic	0.912463	Prob. F(4,27)	0.5170
Obs*R-squared	6.777621	Prob. Chi-Square(4)	0.4524
Scaled explained SS	1.969900	Prob. Chi-Square(4)	0.9615

For VECM

F-statistic	1.331501	Prob. F(1,31)	0.2847
Obs*R-squared	5.270579	Prob. Chi-Square(1)	0.2606
Scaled explained SS	5.971517	Prob. Chi-Square(1)	0.2013

4.9.4 Test for Stability

The stability of the time path of the process in the model is examined with the CUSUM test to check whether their norms is greater than unity. The existence of parameter instability is established if the cumulative sum of the residuals goes outside the area between the two critical line in the graph. From the figure in 4.2, the CUSUM line remains within the 5 per cent significance boundary and we will reject the null hypothesis of instability. Based on this, we can conclude that our model is stable.

Figure 4.2: CUSUM Test

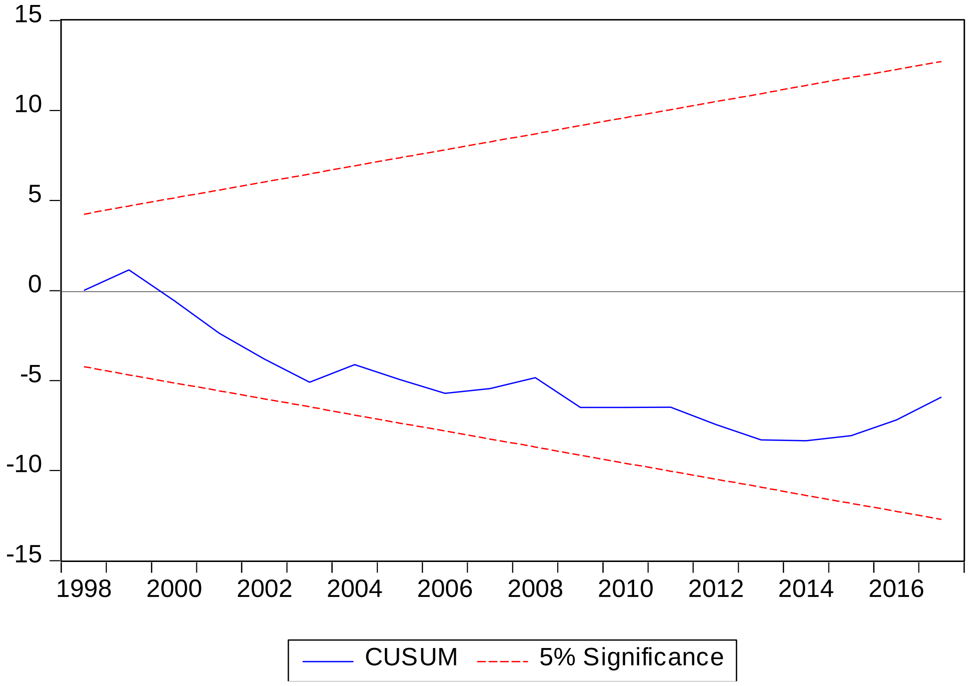
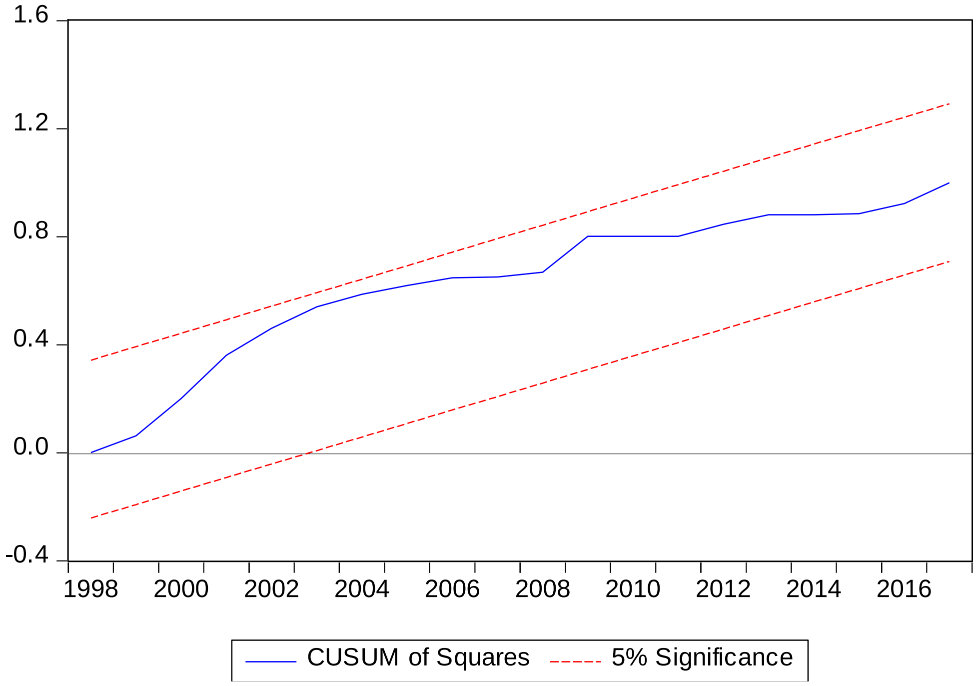


Figure 4.3: CUSUM Square Test



4.10 Conclusion

In examining the relationship between inflation and productivity, in this section, we have been able to provide empirical evidence for this study. Starting with the descriptive statistics and the trend analysis of the variables. We run the unit root test in which the variables are stationary of different order between level and first difference. We, therefore, conduct the Johansen Cointegration test for variables integrated of the same order while we used Bounds test for variables with different integration order in which we have a long run relationship between the dependent variable and the independent variables. After running the error correction model, we discover a positive relationship between inflation and labour productivity while inflation and multifactor productivity exhibit inverse relationship in the current period however positive relationship in other periods. Also, there is causality unidirectional causal relationship running from this result further confirms the view of A. W. Phillips in which he identified tradeoff between inflation and unemployment (productivity). As soon as an economy pursue inflation targeting, there is a level of productivity that it will gives off and vice versa. This result has shown that the economy of Korea is not an exemption of the fundamental assumption of macroeconomic theory. So, if productivity in the Korean economy increases, the inflation level will be reduced. The result further shows that if there be a shock, it will come back to equilibrium from the side of multifactor variable.

Chapter 5: Conclusion and Recommendation

5.0 Introduction

This chapter presents the conclusion of the study and recommendation based on the results obtained from the previous chapter.

5.1 Conclusion

This study contributes to the empirical literature on the reverse relationship between inflation and productivity. The sole purpose of the study is to examine the effects of productivity on inflation. This is a sharp deviation from previous studies that focus on the effects of inflation on productivity growth. The productivity variable is further disaggregated into labour and multifactor productivity. The study covers the period of 1985 to 2017 with inflation, labour productivity and multifactor productivity variables. Due to the stationarity of the inflation and multifactor productivity variables that is not uniform which have a level and first-order integration, the auto-regressive distributed lag (ARDL) model was employed in the empirical section using the Bounds test while the second model which involves inflation and labour productivity that is stationary at the same level have the Johansen Cointegration test to examine the existence of a long-run relationship. There is an existence of a long-run relationship between the productivity and inflation in the two models and this result in employing the ECM for further analysis. The result shows that an inverse relationship exists between productivity and inflation, however, the impact is not significant.

To examine the causal relationship between productivity and inflation, the Toda-Yamamoto causality test was employed. It was found out concerning the Korean economic that there exists no form of a causal relationship between labour productivity and inflation. Inflation and multifactor productivity show that there exists a unidirectional causal relationship running from multifactor productivity to inflation. Similarly, with the view of Kim, Lim and Park (2012), a negative impact of productivity on inflation as well as a unidirectional causal relationship was established showing consistency in the economy of Korea right from their time of study to this present study which has exhibited low inflation and high output growth in the economy. This makes it possible to draw an inference that the favourable macroeconomic conditions obtainable in the Korean economy may be the end effect of the productivity growth witnessed. According to them, the negative effect of productivity growth on inflation to the fore scene of the Korean economy after the Asian crisis of 1997. This crisis led to the drop witnessed in the labour force as it became imminent to restructure the labour market and the corporate sector of the economy giving a flexible labour market. Inflationary pressure is been steady as the flexible labour market brings about high productivity growth while keeping the wage rate consistent. More so, the slow wage growth is also linked with the inflation targeting by the Bank of Korea.

5.2 Policy Implications

Based on the result obtained in this study of productivity and inflation, the following policies are recommended in the study:

i. Policymakers should plan to put in more attention on anti-inflationary monetary policies in other to safeguard the negative relationship between productivity and inflation.
ii. Furthermore, policy to enhance productivity should be embarked on as increase in output result in lower inflation.
iii. Policymakers need to consider the long-run implication of their decisions on productivity and inflation as there exist a cointegration or long-run between the two macroeconomic variables.

5.3 Importance of findings to research discipline

This research work has contributed to literature by advancing the discourse on productivity and inflation in the Korean economy. disaggregating productivity into labour and multifactor, we are able to find out the existence of long-run relationship between the two. More so, causal relationship has shown that it is only a unidirectional causal relationship that exist between the two. Students and academician taking up a research on related study can build on this.

5.4 Limitations and future research

This study provides more details to productivity and inflation however the research encounters some limitations. One of such is the availability of data for the variables used in proxying the case study. Some of the variables recent data has not been published yet leading to the scope covered.

Future research can advance the research work relating to productivity and inflation by employing other sources of measuring inflation to examine the consistency of the result. In similar manner, more control variables can be introduced into the model in order to examine possible changes that will occur in productivity and inflation in the Korean economy.

References

Bitros, G. and Panas, E. (2005). The Inflation-Productivity Trade-Off Revisited. *SSRN Electronic Journal*.

Buck, A. and Fitzroy, F. (1988). Inflation and Productivity Growth in the Federal Republic of Germany. *Journal of Post Keynesian Economics*, 10(3), pp.428-444.

Bulman, T. and Simon, J. (2003). Productivity and Inflation. *Reserve Bank of Australia Research Discussion Paper.*

Christopoulos, D. and Tsionas, E. (2005). Productivity growth and inflation in Europe: Evidence from panel cointegration tests. *Empirical Economics*, 30(1), pp.137-150.

De Grauwe, P. and Skuldeny, F. (2000). Inflation and Productivity Differentials in EMU.*Hairault JO., Kempf H. (eds) Market Imperfections and Macroeconomic Dynamics.* Springer, Boston, MA

Dritsakis, N. (2004). A Causal Relationship between Inflation and Productivity: An Empirical Approach for Romania. *American Journal of Applied Sciences*, 1(2), pp.121-128.

Freeman, D. and Yerger, D. (2000). Does inflation lower productivity? Time series evidence on the impact of inflation on labor productivity in 12 OECD nations. *Atlantic Economic Journal*, 28(3), pp.315-332.

Hondroyiannis, G. and Papapetrou, E. (1998). Temporal causality and the inflation-productivity relationship: Evidence from eight low inflation OECD countries. *International Review of Economics & Finance*, 7(1), pp.117-135.

Jarrett, J. and Selody, J. (1982). The Productivity-Inflation Nexus in Canada, 1963-1979. *The Review of Economics and Statistics*, 64(3), p.361.

Kim, S., Lim, H. and Park, D. (2013). Does productivity growth lower inflation in Korea?. *Applied Economics*, 45(16), pp.2183-2190.

Mahadevan, R. and Asafu-Adjaye, J. (2005). The productivity–inflation nexus: the case of the Australian mining sector. *Energy Economics*, 27(1), pp.209-224.

Narayan, P. and Smyth, R. (2009). The effect of inflation and real wages on productivity: new evidence from a panel of G7 countries. *Applied Economics*, 41(10), pp.1285-1291.

Ojede, A. (2015). Is inflation in developing countries driven by low productivity or monetary growth?. *Economics Letters*, 133, pp.96-99.

Papapetrou, E. (2003). The Inflation and Productivity Relationship in Poland. *Journal of Economics and Business*, 6(2), pp.11-33.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.

Ram, R. (1984). Causal Ordering Across Inflation and Productivity Growth in The Post-War United States. *The Review of Economics and Statistics*, 66(3), p.472.

Sbordone, A. and Kuttner, K. (1994). Does Inflation reduce Productivity? Economic Perspectives, 18(6), pp.2-14

Smyth, D. (1995). Inflation and total factor productivity in Germany. *Weltwirtschaftliches Archiv*, 131(2), pp.403-405.

Tsionas, E. (2003). Inflation and Productivity: Empirical Evidence from Europe. *Review of International Economics*, 11(1), pp.114-129.

Yule, G. U. (1897). On the significance of Bravais' formulae for regression, &c., in the case of skew correlation. *Proceedings of the Royal Society of London*, *60*(359-367), 477-489.