THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ECONOMICS

Dissecting the Phillips Curve

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SPRING 2022

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Economics
with honors in Economics

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ABSTRACT

In this paper, the core objective was to analyze and break down the components of the Phillips Curve. By doing so, two questions could be answered: has the Phillips Curve gone dormant and if so, is a potential cause a breakdown of assumed causal links between wage inflation, unemployment, and price inflation. Imploring a variety of methodologies including vector error correction models, vector autoregressive models, and granger causality, this paper was able to examine each relation of the Phillips Curve and provide insight into the strength of its components. Specifically, the Wage Phillips Curve still shows a significant relationship between unemployment and wages, and there is also a significant, positive relationship between the inflations of prices and wages. However, there is little evidence that a relationship exists between price inflation and unemployment, demonstrating the weakness of the conceptual Phillips Curve.

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ACKNOWLEDGEMENTS

First and foremost, thank you to Professor Russell Chuderwicz for your constant support and guidance throughout my years at Penn State. These past few years, it has been a great privelage to be able to attend the *Chuderwicz School of Economics* as I consider your economic teachings most influential for the lens in which I view the world of macroeconomics today. I also would like to thank my older brother Nate for not only serving as a constant role model in academia and life, but for being the quality of friend that words do not suffice.

Chapter 1 – Introduction

For years, an important tool to macroeconomic policy had been the Phillips Curve; the idea that there was an inverse relationship between unemployment and inflation has influenced target unemployment goals. However, through the decades, the importance of the Phillips Curve has steadily declined as the slope of the curve has slowly approached zero. Essentially, this paper has set out to dissect the Phillips Curve, both in its literature and in its components to discover where exactly the flaw in the curve has developed and to empirically show why the curve is no longer reliable in the world of macroeconomics.

As this paper shows, there has been an evolution of the Phillips Curve throughout the years. Given that, it is of importance to study both its origins, its theoretical implications, and how it has changed over time periods. Utilizing a variety of different methodologies on time-series data, as well as standard OLS regression, this paper is able to both prove and grant insight into the deterioration of the Phillips Curve. Specifically, this paper utilized vector autoregressions and granger causality to examine the variables of wage inflation, price inflation, and the unemployment gap. In doing so, this paper is able to answer whether or not the flaws in the Phillip Curve lie in the breakdown of foundational relationships or if the answer is more theoretical in nature. Additionally, by using OLS regressions, the decline of the Phillips Curve slope was demonstrated to verify recent changes in Federal Reserve policy.

Chapter 2 - Literature Review

When analyzing the current literature on the Phillips Curve, it is first important to establish when the relationship was first formulated. Though a formal model and relationship was credited to William Phillips, the idea of a relationship between unemployment and inflation can date back to the 18th Century. Though not mathematically supported or empirically validated, banker John Law proposed through his logic that printed money should stimulate the economy and therefore create more jobs and ultimately lower unemployment (Humphrey, 1985).

Effectively, the first purported relationship was the same inverse relationship between unemployment and inflation that is claimed today. Many other early economists and philosophers such as David Hume or Jan Tinbergen also theorized and attempted to support this relationship before William Phillips first published a paper on the matter in 1958 (Humphrey, 1985). The relevance here is that before there was statistical data and actual econometric backing for the Phillips Curve, proposals for theoretical relationships between unemployment and inflation were being formulated and defended. This potentially makes it difficult to discern which papers are objectively analyzing the Phillips Curve versus fitting the data into their model.

Original Phillips Curve

The original Phillips Curve studied the relationship between wage growth and unemployment, using data from the United Kingdom from 1861 to 1957 to support his findings. While the most significant contribution was the empirical support, another key note was that the

theoretical work in the original paper further suggested the relationship was non-linear (Fuhrer, 1995). Thus, moving forward in the literature review, analyzing the effects wages have on inflation and unemployment in addition to the exact relationship they take become increasingly important to understanding why the relationship has since gone dormant.

Unemployment and Wages

When looking at the theoretical underlining of the Phillips Curve, at its core it represents a relationship between the labor market and monetary policy, suggesting the two are connected, affecting each other (Cooley, 1999). The thinking behind wage setting is that as people search for jobs, they must consider both the wages they lose by not accepting any job at the time and the wages they miss out on once they accept a job. Therefore, the point where an unemployed worker accepts the job will be when the expected earnings forgone by continuing to search exceeds the future earnings by the next job (Mortensen, 1970).

On the demand side of the labor, the wage offer only comes after the skill level of the potential employee is known. Ultimately, the wage that workers consider to be fair and accept will affect the actual wage and be rooted in past wage increases (Ball, 2001). In one study looking at the "duration of unemployment and the Phillips curve," it is proposed that the difference between the proportional rate of change in wages and the rate expected by employers is inversely related to the unemployment ratio. Therefore, in the modern Phillips Curve, adjustments to wage changes should shift the curve (Mortensen, 1970).

When further looking at how the labor market relates to wage changes and inflation, one must consider how wage changes relate to labor supply. Specifically, another study by Robert

Lucas (1969) shows that wage changes are negatively related to the excess supply of the labor market, the unemployment rate. With this established, the Wage Phillips Curve can then be looked at and how this can affect the New Keynesian Phillips Curve as well as the Phillips Curve.

Wage Phillips Curve

Considering the relation of unemployment and inflation, the first link connecting the two is that of unemployment and wage inflation, followed by the relation of wage and price inflation. Since the former is represented by the original or Wage Phillips Curve, evaluating it becomes extremely important when considering why the modern Phillips Curve has become defunct. In one study of the Wage Phillips Curve by Jordi Galli (2011), a newer model of the Wage Phillips Curve differed from the original Phillips Curve in two ways: the coefficients are independent of policy regime and wage inflation is a forward looking variable.

To break these down, beginning with the former, unlike the original Phillips Curve, the relation between unemployment and wage inflation is assumed to be unaffected by whether or not a given regime is restrictive or open in fiscal policy, thus more broadly applying the curve. As for the latter, the original Phillips Curve is viewed as more stagnant, not accounting for time or the effect future expectations may play on the relationship. Here, the model developed in this particular paper allows for the possibility of wage expectations to influence current wage growth. In doing so, a model was developed with slightly more explanatory power than the original, however still not one that satisfies statistical requirements for widespread use. Given that, this

model holds interesting insight into potential relations, but does not have enough support for replication in this paper.

Another study by Leduc looked at strictly the relationship between wage growth and unemployment, trying to replicate the spirit of Phillips' original paper (2017). Using city-level data over the last 25 years, the paper studied two different time periods in the United States of 1991 to 2008 and 2009 to 2015. It is important to note that this paper used state and city level data to avoid large, macroeconomic shocks that could skew results. The findings again were two-fold: there was a relationship depicted for the first period but not for the second. For the time period of 1991 to 2008, there was a significant, negative relationship between wage changes and the level of unemployment, whereas the relationship had effectively flattened in the second period and the explanatory nature of the curve had decreased as well (2017).

In the study, what was discovered was that a better measurement for unemployment is the slack; the difference between the natural rate of unemployment and actual rate of unemployment. The ten-year trailing average for each city was calculated to formulate the natural rate of unemployment and the model chose to account for labor productivity growth as well (Leduc, 2017). When considering the current literature, this paper will attempt to study the model of wage growth and unemployment when evaluating why the Phillips Curve has flattened.

The paper did not seem to provide any true explanation or reasoning for the time split of 2008 in the data, causing the results to be, while intriguing, weighted less. Macroeconomic shocks that affect results can still be avoided through control variables, again bringing questions to this particular paper's methodology. Overall, this relation of wage inflation and unemployment can still be tested, but with differing methodology and sources of data.

Wage Inflation and Price Inflation

With the first link between unemployment and wage inflation considered, it is also crucial to observe the current writing on wage inflation and price inflation as that is the second link to unemployment and inflation. One study found that overall there is little evidence to suggest that increases in wages actually leads to an increase in prices (Hess, 2000).

Additionally, the paper proposes that the opposite might in fact be true, that price increases may lead to wage increases. When attempting to understand this relationship, one key note is that there are effectively two different reasons why wages would inflate: forceful reasons and willing reasons. While seemingly rudimentary, the purpose of such an acknowledgement is to state that when wages increase, it is not a given that prices should increase as well. If wages increase due to productivity changes of the employees and employers are willingly matching the new value of the worker with a new wage, then it is unlikely to see inflation to result from this. However, if wages are forcefully increased, whether through supply shortages or fiscal interventions like a minimum wage, then price inflation is more likely to result from such a change. The aforementioned study also found that when researching and developing models with inflation, unit labor costs can track inflation closely (Hess, 2000).

As was the case with unemployment and wage inflation, it will be important for this paper to again study this relationship when analyzing why the Phillips Curve has proven less significant over time. The differences here will be that while this paper had a number of different focuses when concerned to price inflation, this paper is strictly concerned with the relation of price and wages. Granger causality will again be used in this paper, but tests for the stationarity of the variables will be conducted and reported in the paper to determine the correct methodology, a notable absence in this particular study.

Moving forward with the literature review, it will be of importance to examine the New Keynesian Phillips Curve, particular studies that support the claim that the Phillips Curve has flattened, studies that exist that attempt to support the existence of the Phillips Curve, and reasons why the Phillips Curve might be less significant today than in previous decades in the United States.

New Keynesian Phillips Curve

At its core, the New Keynesian Phillips Curve demonstrates the relationship between inflation and marginal cost. As expected, when marginal costs increase, so too will the inflation (Dennis, 2007). Additionally, another important contribution made by the New Keynesian version of the Phillips Curve is accounting for expectations. Specifically, the model incorporates the ability for future expectations of inflation to affect current prices. This is a strong, logical addition to the Phillips Curve since in practice, if a firm expects prices to increase in the future, they would counteract the experienced inflation by raising their prices in the present.

Critics of the New Keynesian Phillips Curve cite the implied assumption that if inflation increases with higher marginal costs, then the presence of disinflation should create an economic boom with lower marginal costs. However, this is far from reality as disinflation actually causes higher unemployment, slowed growth, and recessions over a period of time (Dennis, 2007).

When adjustments have been made to the New Keynesian Phillips Curve, the problem then lies in the lack of the explanatory value within the models. Though it lies in conflict with the scientific method, some papers attempt to have the data fit their model rather than blindly test a hypothesis with theoretical backing.

A study using European data also rejected the New Keynesian Phillips Curve (Bardsen, 2004). Some models of the New Keynesian Phillips Curve have produced significant results, however as mentioned prior the weight to these results should be lessened due to the explanatory nature of the models.

In Jeremy Rudd's evaluation of the new Keynesian Phillips Curve, he claims that the model does a poor job explaining lagged inflation (2005). Finally, another study found little evidence that there is a general relationship between marginal cost and inflation (Nason, 2008).

John M. Roberts ran New Keynesian Phillips Curve models incorporating sticky prices into two categories: state-dependent and time-dependent. With time-dependent models, the firms set prices whereas state-dependent models only have price changes when underlying determinants such as demand or costs reach certain bounds (Roberts, 1995). The results from time-dependent models found that a one percent increase in the demand for a particular good should result in, on average, an increase by 50 basis points in the firm's price (Roberts, 1995).

Sticky Prices & Sticky Information

An interesting caveat to the conventional thinking of the Phillips Curve can be found in a study conducted by Gregory Mankiw (2002). In this paper, the assumption of sticky prices is challenged and replaced with sticky information, the idea that information disseminates slowly through firms as opposed to prices. The study finds that monetary policy shocks have the largest effect on inflation with a significant delay.

In this proposed model, prices change constantly however managers are slow to adapt pricing strategies. With such thinking, announced and expected disinflation could have the ability to lead to economic booms rather than recessions. The idea that sticky information should

be the centerfold as opposed to sticky prices is not extremely prominent in the economic literature, only being supported in a few studies when considering inflation effects (19).

Strength of Phillips Curve Relationship

When considering if there is a strong relationship that exists between unemployment and inflation, there are a plethora of studies to turn to for answers. By analyzing a long-term relationship, Robert Lucas discovered using data from the United States periods 1904 to 1929 and 1946 to 1965 there is no long-run Phillips Curve that is observable (1969). This study should be weighted less than others by the sheer fact it was published in 1969, hindering the paper's ability to consider more recent data of the last 60 years.

Another study analyzed Western European data, which while is outside of the scope for this paper only concerning itself with US data, is still useful seeing as the similarities exist between the US and developed, Western European nations. In this study, it was again found that long-term unemployment does not have a statistically noticeable effect on inflation (Llaudes, 2005). Though it should be noted, however, that this paper also makes the contention that aggregate unemployment numbers can present a distorted image of true unemployment as the relation to inflation is only truly affected by those who are recently employed or unemployed compared to those who have been searching for a job for a while (Llaudes, 2005). While an interesting assertion, other literature could not be found to add support to this claim.

Using state-level data Anil Kumar received similar results, finding long-run unemployment holds little weight over the change in average price growth (2016). There was however some evidence to support a short-run relationship between the two when considering

average and median price growth (Kumar, 2016). Jonathan Hazell found that the slope of the Phillips Curve is not only small, but has been steadily decreasing since the 1980s (2020).

Strong evidence for the presence of the Phillips Curve was in Malaysia, a country with very different institutions and policies than the United States (Furuoka, 2007). With a more stable regime such as the United States, expectations are more rooted for inflation and can therefore affect the amount inflation can actually influence unemployment (Gordon, 2011). This study was solely included to present a more well-rounded picture of the Phillips Curve internationally, though adds little weight to the studies of this paper.

When trying to understand the shape of a potential Phillips Curve, again it is important to note that this is relative to the evidence available supporting the existence of a Phillips Curve, which is more minimal as established. One study claims that the Federal Reserve should presume a convex shape, as it suggests more of an ability to stabilize inflation (Laxton, 1999). Another study supports this as failure to stabilize the business cycle will result in higher rates of unemployment (Debelle, 1997). However, the Federal Reserve has acknowledged the failures of the Phillips Curve in assisting monetary policy as they have recently denounced the non-accelerating inflation rate of unemployment, otherwise known as NAIRU (Timiraos, 2021). Instead, the Federal Reserve shall wait to see if both actual and expected inflation are set to run above the target rate before intervening, suggesting a dormant state of the Phillips Curve as unemployment can fall as fast as it may wish as long as it does not aggravate inflation (Timiraos, 2021).

Why the Phillips Curve is Changing

The final question to examine is what has happened to the Phillips Curve? In a paper by John Roberts, the 1970s and 1980s provided solid research ground for inflation due to the drastic changes that could be observed (1999). Once past the episode of stagflation, unemployment fell below 6% and even below 5% but inflation also began to decrease. Overall, Roberts discovered that baseline Phillips Curve models tend to overpredict inflation indicating that NAIRU is either much lower than expected or is non-existent. It was also observed that models with longer inflation lags may prove to be more unstable when actually attempting to predict future outcomes (Roberts, 1999).

The idea of there being no long-run trade-off has been supported by Friedman and Phelps, as the appearance of which was simply considered to be an identification problem (King, 1994). Overall evidence again suggests there to be no Long Run Phillips Curve past the 1970s. Inflation tends to be more dependent on expected inflation than it is on past inflation (Blanchard, 2016), and thus as expected inflation becomes more anchored changes in unemployment occur without many observable changes to the rate of inflation. In a country like the US, there tends to be relatively stable macroeconomic policy, thus causing inflationary expectations to be relatively stable compared to other countries (Gordon, 2011). Shocks in the aggregate demand create a temporarily negative correlation between unemployment and inflation, however aggregate supply shocks will create a positive correlation such as in the 1970s that responds well to policy changes (Gordon, 2011). The general findings are what this paper expects to see, as the Phillips Curve has not shown much life in recent decades.

A study by Ken Kuttner attempted to develop a new model for the Phillips Curve with no satisfactory conclusions, however a few reasons as to why the Phillips Curve is dormant were

tested: data problems, globalization, marginal cost definitional problems. While labor share of nominal output was found to not be the most ideal metric, none of the listed reasons above proved to explain the extent of the problem with new or existing models for the Phillips Curve (Kuttner, 2010).

One paper theorizes that the effect inflation holds on unemployment is dependent on how open the particular economy is, contending that more open economies have steeper curves. However, there was little direct evidence to support this claim and appears to be in exact conflict with the relation observed in the United States (Temple, 2002).

For studying inflation expectations of firms, Olivier Coibion found that households have similar expectations towards inflation as do firms (2015). Increases in the price of goods such as oil can increase household expectations for inflation, also indicating firms expect higher inflation.

Overall, the literature appears to support the idea that the Phillips Curve has flattened, if not has become non-existent in the past few decades. The reasons why stem from the Wage Phillips Curve to inflationary expectations, all of which are relevant to the research of this paper when considering the links of wage to unemployment and wage to inflation.

Chapter 3 - Data

To research and test the true relationship of the components of the Phillips Curve and Wage Phillips Curve, I utilized historical time series data. By doing so, this creates the most comprehensive and inclusive approach in both verifying previously researched relationships and breaking down the failures of the Phillips Curve.

For data, this specific study relied on the Federal Reserve Economic Data (FRED), which is free to access on fred.stlouisfed.org. The data utilized is quarterly ranging from 1949 to 2021, with modifications being utilized depending on the availability of data. For example, information on wage inflation was not collected until 1964, thus any regression using nominal wage data is restricted to 1964 and forward. Inflationary data was calculated using FRED's *Consumer Price Index for All Urban Consumers* and taking the percentage change from one time period to the next. For ease of access, the table below lists out the data sourced from FRED.

Table 1 - Data Set

Variable Name	Sample Range	Source from FRED
CPI_Inflation	1947Q1 – 2021Q4	*Consumer Price Index for All Urban Consumers*
Wage_Inflation	1964Q1 – 2021Q4	*Average Hourly Earnings of Production, Total Private*
Unem_gap	1949Q1 – 2021Q4	*Unemployment Rate - Natural Rate of Unemployment*

Chapter 4 - Methodologies

Unit-Root Testing

With the nature of the economic variables in use, it is paramount to use unit-root testing to determine the stationarity of such variables. For this paper, the Augmented Dickey-Fuller (ADF) test was used to carry out this task, as it is an extremely common test in econometrics for unit-roots. Since non-stationary variables may be rooted in confounding variables, issues of spuriousness may arise hindering the desired conclusions. Effectively, biased standard errors render any conclusion valueless when analyzing hypothesis tests. Non-stationary variables do this with biased standard errors, creating a simple illusion of a correlation rather than a true relationship. Thus, the biggest problem that presents itself is the usage of a standard OLS regression, as the presence of non-stationary variables would skew the results.

For example, a standard OLS regression may in fact show a positive relationship between the popular example of ice cream sales and murders. Intrinsic to that relationship is the temperature of the weather, as warm weather holds a positive correlation with both ice cream sales and murder rates. Obviously, there is no actual relationship between ice cream and homicide, however the confounding variable of weather masks it as such. In the listed example, it is quite obvious to see the lack of a true correlation, however it becomes much more difficult when using economic variables with the potential of actually being related.

Since it is necessary to discover whether or not the variables are themselves stationary or non-stationary, the ADF unit-root test was needed to move forward in this paper. The following is an example of how the ADF test is standardly conducted on a sample variable, X:

1. $X_t = \text{Constant} + \boldsymbol{\beta} X_{t-1} + \varepsilon_t$

Subtract X_{t-1} on both sides to create the change in X on the left-hand side

2. $\Delta X_t = \text{Constant} + (\boldsymbol{\beta}-1)X_{t-1} + \varepsilon_t$

The ADF terms are lags of the dependent variable, ΔX_t

3. $\Delta X_t = \text{Constant} + \delta X_{t-1} + \psi_J \Delta X_{t-J} + \varepsilon_t$

Where (δ) represents ($\boldsymbol{\beta}$-1)

If there is a unit-root present, that would mean that $\boldsymbol{\beta} = 1$ and subsequently $\delta = 0$. In the provided example, if $\delta = 0$, then X would be considered to be non-stationary. The test is conducted with the null hypothesis being there is a unit-root, and thus depending on the α-level the p-value produced will either cause the null hypothesis to be rejected or failed to be rejected. If the null can be rejected, then the variable X is considered not to have a unit-root and to be stationary, meaning OLS regressions can be run. On the right-hand side of the equation above, the lagged dependent variable is present to counteract any serial correlation issues of the residual.

The results for the ADF test on CPI Inflation, Wage Inflation, and the Unemployment Gap throughout the entirety of their sample produced the following, along with a brief analysis:

Table 2 - Unit Root Tests on Entire Sample

Variable Name	Sample Range (Quarterly)	T-Statistic	One Sided P-Value
CPI Inflation	1947-2021	-2.2537	.1880
Wage Inflation	1964-2021	-1.8890	.3371

Unemployment Gap	1949-2021	-3.9743	.0018

CPI Inflation

Again, this data collected on CPI Inflation is from FRED. Similar to wages, as expected, an extremely high p-value can be observed with CPI. At any critical value, the null hypothesis that CPI contains a unit root cannot be rejected and standard OLS involving CPI would present potential biases.

Wage Inflation

From FRED, nominal wages are represented by the "average hourly earnings of Production, Total Private." The results indicate that for any critical value, the null hypothesis that wages contain a unit-root cannot be rejected. Given the significant probability, it is highly likely a unit root is present, and thus standard OLS equations involving wages may not be appropriate.

Unemployment Gap

For the unemployment gap, it was measured using FRED data: Unemployment Rate - Natural Rate of Unemployment. Unlike CPI and Wage Inflation, the probability is significantly lower than any α-level, allowing the null hypothesis to be rejected at the 10%, the 5%, and the 1% level. Thus, there is no unit-root present, suggesting the unemployment gap is stationary and standard OLS regressions are not affected by this variable's presence throughout the entirety of its sample.

Time-Split

Moving forward, the relations inherent to the Phillips Curve will be split into two respective times, before 1982 then 1982 to present. The reason for this split will be two-fold, as post 1982 data will be free of the episode of stagflation where inflation and unemployment uncharacteristically rose together, as well as being past the Bretton Woods Agreement which dissolved in 1972 when the US Dollar was de-pegged from the gold standard. This split will allow the analysis of post-1982 data to be more representative of the current economy, as well as allow it to shed more insight into how the Phillips Curve more accurately works. With this split, it will be important to consider how the variables of Price Inflation and Wage Inflation differ in regards to unit roots for the two time periods. The results for the ADF Test are as followed:

Table 3 - Unit Root Test (Time Split)

Variable Name	Sample Range (Quarterly)	T-Statistic	One Sided P-Value
CPI Inflation	1947-1981	-2.1784	.2156
Wage Inflation	1964-1981	-2.1479	.2271
CPI Inflation	1982-2021	-4.7691	.0001
Wage Inflation	1982-2021	-4.4516	.0004

CPI Inflation

For CPI Inflation, the time split proved to be important as the stationarity of the variable changes in the two different periods. Before 1982, the null hypothesis that a unit root is present cannot be rejected, however the null can be rejected at the 1% level from 1982 till 2021.

Wage Inflation

Similarly, the time split caused a juxtaposition in the stationarity of Wage Inflation. While the null hypothesis for a unit root cannot be rejected pre-1982, it can be rejected again at the 1% level for the time period 1982-2021. This will cause a shift in methodologies for the time periods of 1947-1981 and 1982-2021, respectfully.

Methodology: 1964-1981

Cointegration Test

Since both wages and prices are non-stationary, standard OLS regressions are not useful for discerning a true relationship betwixt the two. Per Kilian, variables are effectively cointegrated if "they share a common stochastic trend such that a linear combination of these variables is stationary" (2017). Thus, while both variables on their own are themselves non-stationary, it is possible that a combination of the two is, infact, stationary. This information will be helpful in order to observe the relationship of the two variables in differing methodologies outside of OLS regressions.

To test cointegration a Johansen Cointegration test was conducted, producing the following results:

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.182529	16.03553	15.49471	0.0414
At most 1	0.051613	3.338504	3.841465	0.0677

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

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.182529	12.69703	14.26460	0.0871
At most 1	0.051613	3.338504	3.841465	0.0677

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 1 - Cointegration Test

The listed results are as expected given the relationship established in the Hess (2000) paper of wages and prices. The cointegration test suggests that both wage and prices move in the same direction, an important foundation for the research concerning the true relationship of the Phillips Curve.

VEC Model

Understanding that the two variables are I(1) and cointegrated allows further testing to be conducted, specifically a Vector Error Correction Model (VECM). As long as two variables are cointegrated and stationary at their first differences, a VECM can be utilized (Kilian, 2017). The cointegration equation is below:

Price_Inflation = 3.0294 + (1.4695)Wage_Inflation

The following test results demonstrates from where the coefficients were derived:

Sample (adjusted): 1965Q4 1981Q4
Included observations: 65 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
CPI_INFLATION(-1)	1.000000
WAGE_INFLATION(-1)	-1.469541 (0.30335) [-4.84431]
C	3.029469

Error Correction:	D(CPI_INFL...	D(WAGE_INFLATION)

Figure 2 - VEC Test

Methodology: 1982-2021

Since both variables are I(0) for this time period, there will be no spurious problems employing a standard OLS equation involving price inflation, wage inflation, and the

unemployment gap given it was stationary for the entire time period. A vector autoregression (VAR) on price and wage inflation as well as the unemployment gap can be conducted. The reasoning for using a VAR is due to its usefulness in "forecasting economic time series" (Papana, 2014). Control variables for the VAR will be both growth in oil prices and growth in labor productivity, as the growth functions have also been tested for unit roots. Furthermore, this paper will use Granger Causality to study the relation of inflation between prices and wages with the unemployment gap. Granger Causality is helpful for determining the order in which time series data may occur. That is to say, Granger Causality is not sufficient to say that X causes Y, however it can show that X precedes Y, demonstrating a strong correlation.

Chapter 5 - Results

Time Period: 1965Q1-1981Q4

When interpreting the VEC results, one of the most useful tools for observing one variable's effect on the other is an Impulse Response Function (IRF). Essentially, IRFs demonstrate graphically the effect of shocking one variable has on the other over a lagged period of time (Lütkepohl, 2010). In this paper, the main concern has been dissecting the components of the Phillips Curve, including price inflation, wage inflation, and the unemployment gap. For the time period of 1965 to 1981, the methodology was focused more so on the relationship of the two inflationary variables, price and wages. On the horizontal axis of the IRF is the time measured in quarters, as the number 3 for example would represent 3 quarters or. 9 months after the shock occurred. Any positive number above on the Y-Axis would represent a positive relationship as the variable increases in response to the shock.

Below is the IRF from the VEC on the variables CPI_Inflation and Wage_Inflation using oil growth and productivity growth as controls. The main concern and focus is on the top right graph, as the logic should be upward pressure on wages creates an upward pressure on prices. Here, the IRF demonstrates that for this specific time period, the theorized relationship for price inflation and wage inflation holds. When wage inflation increases, the effect on price inflation is to increase over the next 10 quarters, suggesting this relationship is strong during the time period. The main focus, however, should be on the results from the next time period as these results also consider the unemployment gap and can offer more explanatory power as to the relations of the Phillips Curve variables. The value of these results will be to compare the

relation of price and wage inflation to the next period to discover if a relation is just as strong in the next period or if the relationship falls apart, creating a kink in the Phillips Curve.

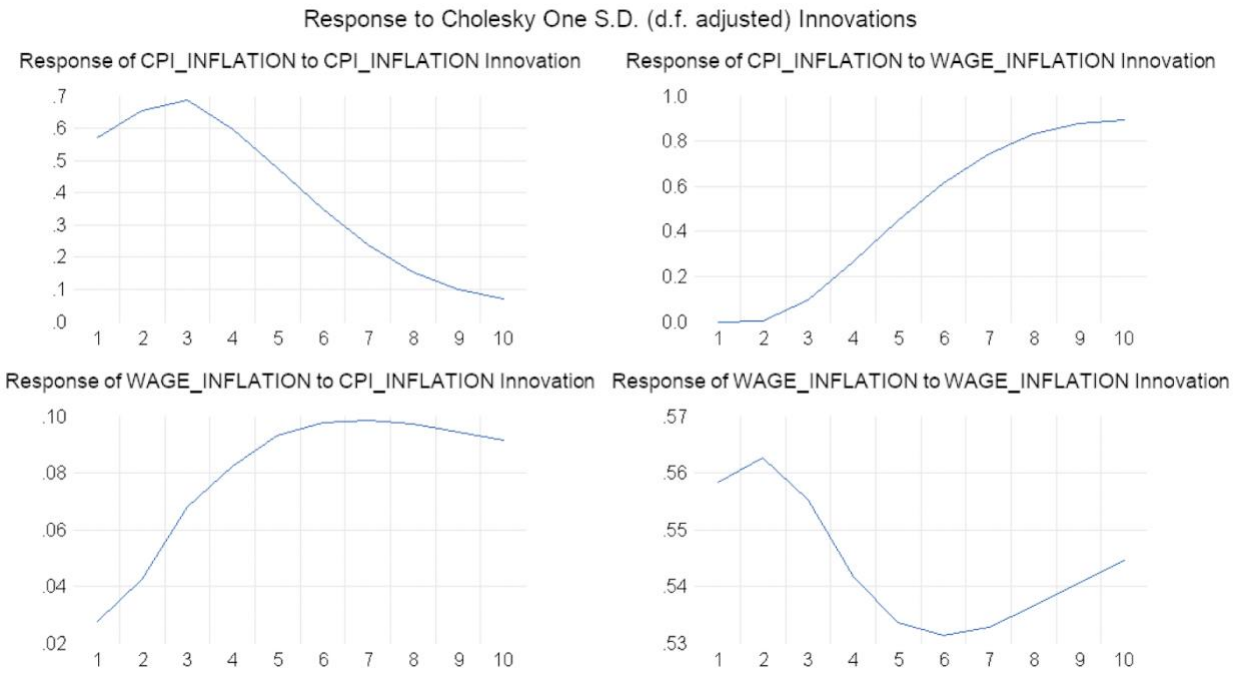

Figure 3 - VEC IRF

Time Period: 1982Q1-2021Q4

Again, for the three-variable VAR involving price inflation, wage inflation, and the unemployment gap, an IRF was generated to best interpret the relationship of these macroeconomic variables. Unlike the first time period, the unemployment gap was included in this test as all three variables were stationary for the given time period. With the IRF for this time period, not only can the effect wage inflation has on price inflation be observed, but so too can the original Wage Phillips Curve and the Phillips Curve relation. The Akaike Information Criterion was used to find the optimal lag length, which was determined to be ten.

With the results posted below, there are a few graphs of particular importance to note. The first IRF to be examined is the response of CPI_Inflation to Wage_Inflation. As with the previous period, a significant relationship can be observed, meaning that wage inflation does affect price inflation. As wage inflation is shocked, one can expect price inflation to respond in the same direction for roughly one year.

The next graph to take note of is the response of wage inflation to the unemployment gap, represented by the variable, Unem_Gap. For roughly the first three periods, again the relationship suggests that a shock to wage inflation shall cause the unemployment gap to decrease, the negative relationship supported in the Leduc study, however with different methodology this time supporting the findings.

The final graph of importance is the response of CPI_Inflation to the Unem_Gap. With this IRF, what can be observed is that there is no significant relationship between unemployment and price inflation. That is, an increase to the unemployment gap does not produce a decrease to price inflation. While the debunked nature of the Phillips Curve is not surprising, what is surprising is that both of the links to the modern Phillips Curve, wage inflation and the unemployment gap, along with wage and price inflation have significant relationships.

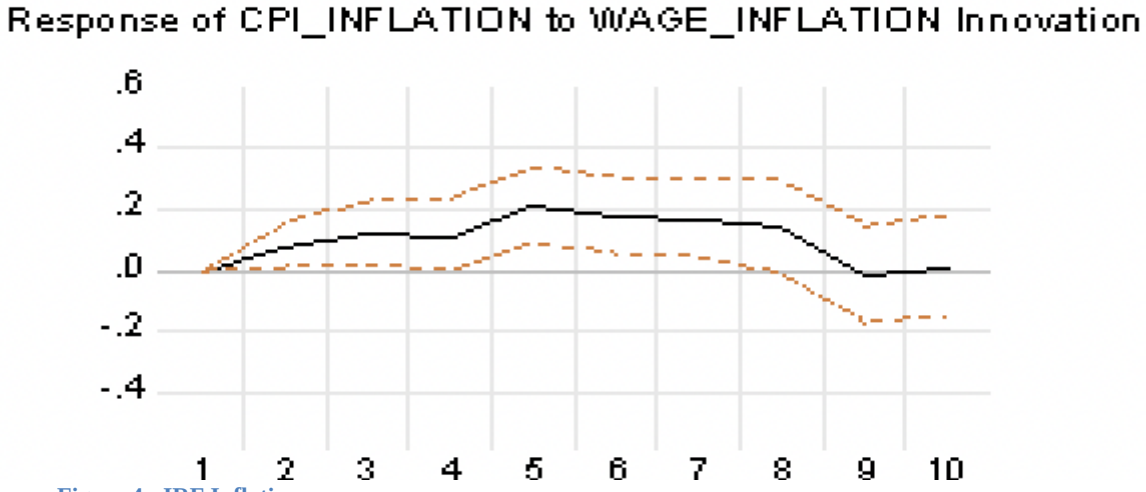

Figure 4 - IRF Inflation

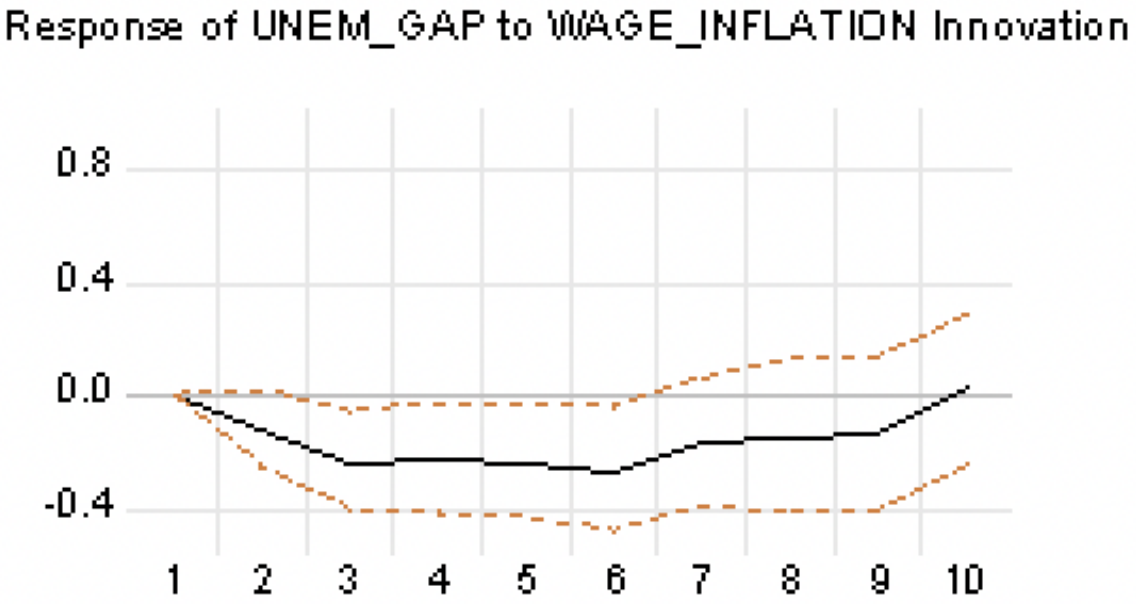

Figure 5 - IRF WPC

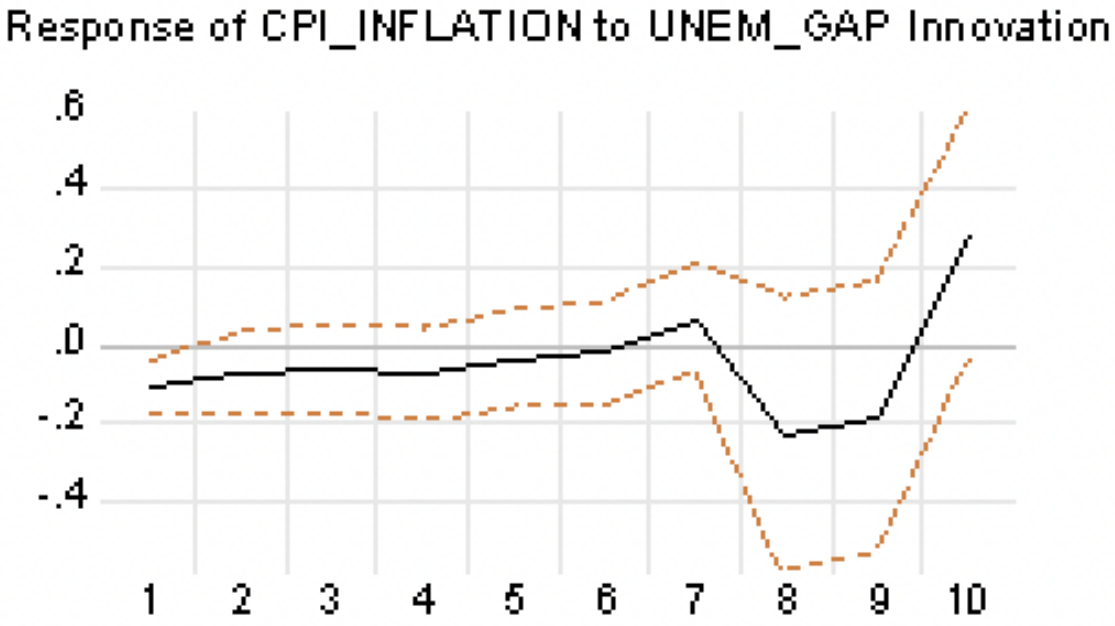

Figure 6 - IRF PC

Exploring the Granger Causality between the three macroeconomic variables is another useful tool to shed light on the extent of the Phillips Curve relations. For the test, four lags were used as the data is quarterly, producing the following results:

Null Hypothesis:	Obs	F-Statistic	Prob.
WAGE_INFLATION does not Granger Cause CPI_INFLATION	160	3.97502	0.0043
CPI_INFLATION does not Granger Cause WAGE_INFLATION		4.09690	0.0035
UNEM_GAP does not Granger Cause CPI_INFLATION	160	1.49339	0.2070
CPI_INFLATION does not Granger Cause UNEM_GAP		1.63935	0.1672
UNEM_GAP does not Granger Cause WAGE_INFLATION	160	4.71142	0.0013
WAGE_INFLATION does not Granger Cause UNEM_GAP		3.91296	0.0047

Figure 7 - GC

From the Granger Causality Test, similar results can be reached as with the IRF from the VAR. At the 1% level, the null hypothesis that wage inflation does not granger cause price inflation can be rejected. For the top row, however, the results from the Hess (2000) paper are similar in that the null hypothesis that price inflation does not granger cause wage inflation also can be rejected. Therefore, while the two are related, these results suggest problems of endogeneity and prove it is difficult to conclude which truly causes or precedes the other.

This result is expected as it relates to the wage inflation spiral. As higher prices are announced, eventually laborers demand higher wages, creating the first wave of wage inflation. In response, prices may increase even further to offset the increased input costs, starting the cycle over again to be repeated.

The third row shows the Wage Phillips Curve relationship, showing at the 1% level wage inflation and the unemployment gap are related. However, an issue of endogeneity still exists as neither of the null hypotheses can be rejected.

The second row produces similar results to the IRF of the VAR, showing that one cannot conclude a relationship between price inflation and the unemployment gap exists. This is true at the 1%, the 5%, and the 10% level.

Since all three variables are stationary for this time period, an OLS regression can be conducted in an attempt to see the Phillips Curve relationship. For this regression, Mishkin's modern Phillips Curve was used (2011). In the equation, inflation = expected inflation + (Beta) unemployment gap + cost-push shocks. As established, the cost-push shocks for this paper have been oil prices and productivity, thus that was kept constant for this regressions as well. Assuming adaptive expectations, the expected inflation is simply one lagged inflation. Expected inflation is subtracted on both sides of the equation creating Mishkin's equation: Change in inflation = (Beta) unemployment gap + cost-push shocks.

For time periods, an analysis by the *Wall Street Journal* was replicated, analyzing the Phillips Curve in three separate time periods to observe the evolution of its slope: (1) 1978-1993,

(2) 1978-2003, (3) 1978-2017 (Ip, 2018). The results from the regressions on the quarterly data are as follows:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.011523	0.173037	0.066591	0.9471
UNEM_GAP(-1)	-0.291667	0.077854	-3.746340	0.0004
OILGROW(-1)	0.001738	0.003263	0.532500	0.5965
PRODGROW(-1)	0.130911	0.073012	1.793022	0.0784

R-squared	0.228284	Mean dependent var	-0.057868
Adjusted R-squared	0.186942	S.D. dependent var	0.824858
S.E. of regression	0.743772	Akaike info criterion	2.310175
Sum squared resid	30.97899	Schwarz criterion	2.449798
Log likelihood	-65.30525	Hannan-Quinn criter.	2.364789
F-statistic	5.521864	Durbin-Watson stat	1.533584
Prob(F-statistic)	0.002154		

Figure 8 - OLS PC 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.073142	0.114175	-0.640614	0.5232
UNEM_GAP(-1)	-0.171082	0.052905	-3.233762	0.0017
OILGROW(-1)	0.001116	0.001978	0.564161	0.5739
PRODGROW(-1)	0.061777	0.041757	1.479457	0.1422

R-squared	0.135252	Mean dependent var	-0.044156
Adjusted R-squared	0.109309	S.D. dependent var	0.669753
S.E. of regression	0.632089	Akaike info criterion	1.958129
Sum squared resid	39.95362	Schwarz criterion	2.059836
Log likelihood	-97.82268	Hannan-Quinn criter.	1.999333
F-statistic	5.213531	Durbin-Watson stat	1.370307
Prob(F-statistic)	0.002189		

Figure 9 - OLS PC 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.115773	0.101083	-1.145328	0.2538
UNEM_GAP(-1)	-0.083247	0.044139	-1.886019	0.0612
OILGROW(-1)	0.000328	0.001785	0.183594	0.8546
PRODGROW(-1)	0.085208	0.038817	2.195119	0.0296

R-squared	0.051287	Mean dependent var	-0.028039
Adjusted R-squared	0.033043	S.D. dependent var	0.761894
S.E. of regression	0.749201	Akaike info criterion	2.285064
Sum squared resid	87.56317	Schwarz criterion	2.361943
Log likelihood	-178.8051	Hannan-Quinn criter.	2.316282
F-statistic	2.811113	Durbin-Watson stat	1.498115
Prob(F-statistic)	0.041314		

Figure 10 - OLS PC 3

These results demonstrate the declining nature of the importance of the Phillips Curve. In the first time period from 1978-1993, the slope is -.29 and significant. For the second time period, the slope decreases by 12 basis points to -.17 as the r-squared value of the model declines. For the time period of 1978-2017, the slope again declines to -.08, however is only significant at the 10% level and has an extremely low r-squared value. These tests demonstrate the failing nature of the Phillips Curve, as suggested by previous tests and adds insight into why the Fed announced they had moved away from NAIRU and now focus on maximizing unemployment.

Lastly, it is of interest in this paper to observe the current relationship of the unemployment gap and price inflation. To narrow the focus on the broad nature of "current,"

focus will be placed on data after the beginning of the global pandemic, deemed to be March of 2020. Unfortunately, due to the limited nature of the data available for this time period, specific tests or regressions would not be appropriate as the sample is not large enough for any strong conclusions. Simply, a graph is provided showing how the two variables have moved over time

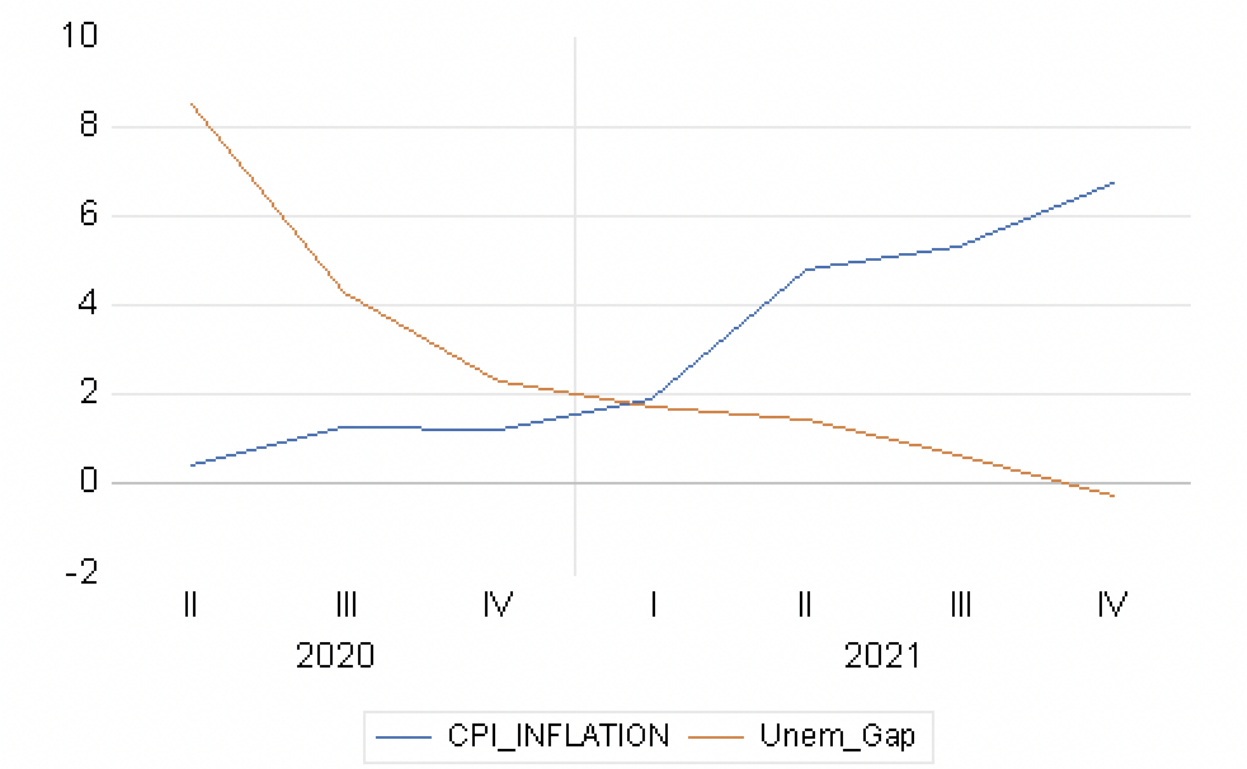

Figure 11 - PC Trend

With this graph, what can be observed is a simple, negative correlation between the two variables, with the unemployment gap declining rapidly then at a steadier pace and inflation rising gradually then at a greater rate. This paper would view it as premature to render any opinions on what truly has caused this graph, however with the large societal changes that have taken place since the start of the pandemic (increased online work access, larger government assistance, increased shutdowns), this should be a relation that is studied in closer detail in the

future. This simplified graph shows the potential for an awakening of a proven dormant Phillips Curve from the last 40 years.

Chapter 6 - Concluding Remarks

The goal of this paper was to observe and analyze the different components of the Phillips Curve, with respect to the variables of wage inflation, price inflation, and unemployment. Though the Phillips Curve has been dormant over the last few decades, understanding why that was and if there is hope for a return of the Phillips Curve was of particular importance to this paper.

By dissecting the Phillips Curve into three parts, the Wage Phillips Curve, the inflation relation of wage and price, and the modern Phillips Curve, a greater understanding was able to be obtained. Through a different methodology than the cited literature of Leduc, the Wage Phillips Curve was proven to be alive and of significant importance. By repeating Hess's Granger Causality tests, the inflation relation was also determined to be alive and of significant importance. However, the relationship of price inflation and the unemployment gap could not be established, suggesting the common teaching of an inverse relationship between unemployment and inflation to be untrue in reality.

The shocking result is that the Phillips Curve is not transitive; that is to say while wage inflation may reduce unemployment and wage inflation leads to price inflation, price inflation does not per se lead to a decrease in unemployment. If the Phillips Curve had been defunct and one of the previous two relationships had also not been significant, one could have concluded there was a kink in the Phillips Curve causing it to have little weight in modern macroeconomics. However, due to these results, further studies should take place investigating possible reasons for the insignificant relationship of unemployment and inflation. One possible suggestion might be due to the interconnections of the world economy, inflation on a national level is much more

influenced by the effects of globalization and international markets than the national unemployment rate and labor market.

The final graphic depicting the most recent movements of the unemployment gap and price inflation also create an interest for future research. The changing dynamics of the economy in a post-pandemic world may prove to create a shift in the nature of the relationship betwixt unemployment and inflation. Due to the data availability and the brevity this paper was written after the pandemic, no well-grounded conclusions can be formed currently. However, through further research into what has hindered the Phillips Curve relationships and how those dynamics might have changed during the pandemic, this paper holds optimism that future research may shed light on a return of the Phillips Curve, though that is not currently the case. This paper also recommends that future research consider not only the implications fiscal policy changes may have on the Phillips Curve, but too the effect globalization has had on inflation expectations and its direct relation to unemployment.

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