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Has Automation Changed the Response of Unemployment Rate to GDP Growth?

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Abstract

Debate over the effect of technology and automation on job creation or job destruction has been an ongoing debate in economics for some time. The recent developments in automation and the speed with which machine is replacing labor in some industries has worried many economists (Krugman, 2013, Graetz, G & G Michaels, 2015). While a number of recent studies present evidence on the negative effect of automation on employment by occupations (Oschinski M & R Wyonchi, 2017), none presents empirical evidence on the effect of automation on jobs at the macroeconomics level. This study utilizes the traditional model of the relationship between the real GDP growth and unemployment rate, estimated for US economy in 1962 and publicized as Okun's Law. The relationship implies that a one percent increase in GDP growth above the normal growth of GDP results in .4 percent decrease in unemployment rate. Although the relationship between GDP growth and unemployment rate may be affected by other economic variables in the short-run, a variable that may result in structural change in this relationship in the long-run is technology and its effect on unemployment. Technological advancement may lead to substitution of capital for labor, resulting in less response of GDP growth to unemployment rate than what Okun's law proposed. The main objective of this paper is to test whether such a structural change in the relationship has occurred or not. Using data for the last sixty years for eight industrialized countries, this paper compares the average response of unemployment rate to real GDP growth in three decades of 1955-1985, with the recent three decades of 1986-2015.

1. Introduction

Robotics innovations of the 1970's and the resulting substitution of machine for labor started an extensive debate over the effect of technological advancement on employment during the 1970's and 1980's. However, concerns over technological unemployment and displacement of labor subsided in the 1990's and 2000's, as growth in information technology, artificial intelligence and other related industries created jobs that balanced the job destruction due to automation. The recent headlines in the media and research by academicians point to expectations of major displacement of low and intermediate skilled labor in the next two decades. The estimates of labor being replaced by robots during the next two decades range from 25% to about 50% of total US employment (Frey, et. al. 2013, Sachs and Kotlikoff, 2012, Ford, 2015, Freeman, 2015).

Economic theory of the relationship between technology and unemployment is inconclusive with respect to the effect of technology on employment. Theoretically, assuming a simple production function with labor-augmenting technology, the short-run effect of technology (productivity) on unemployment depends on whether the rate of growth of productivity is higher or lower than the rate of increase in real GDP. In the short run, if real GDP grows at a rate higher than the productivity growth, unemployment rate will decrease. However, if productivity grows at a rate faster than real GDP growth, then unemployment will increase.

Obviously, any technological advancement would result in increase in aggregate supply resulting in GDP growth but the effect of technology on aggregate demand would depend on whether the technological change results in production of new products or whether the technological change is a labor saving technology that would reduce demand for labor and would result in more unemployment. In the first case, innovation of new products will result in increase in aggregate demand, raising GDP and lowering the unemployment rate. In the latter case, labor-saving technological change will result in decrease in aggregate demand and the effect on GDP growth and unemployment rate will be ambiguous.

The historical data on the effect of technological advancement on unemployment has not supported the idea that technological advancement has resulted in more unemployment. However, the recent evidence cast doubt on the idea that technological changes have created more jobs than they have destroyed.

The working hypothesis of this paper is whether the technological advancements of the past three decades have changed the response of unemployment rate to GDP growth or not. We are assuming that if the current advancements in robotic industry is displacing labor and replacing it with robots, then a larger growth rate of real GDP is required to keep unemployment from rising.

Using historical data for eight industrialized countries, this paper estimates two versions of the Okun's equation for two time periods of 1955-1985 and 1986-2015. Using the estimated response of unemployment rate to GDP growth, the study tests whether there has been any structural change in response of unemployment rate to GDP growth during the selected time periods.

2. Methodology and Empirical Results

Assuming an aggregate production function Y= f (NA, K) with labor-augmenting (NA) technology, the short- run production function assumes K as constant and Y a function of only effective labor, Y= f (NA, $\bar{k}$). A simple version of this function assumes Y as a fixed proportion (λ) of effective labor in the short run, Y= λ NA. The time differentiation of this function results in $\dot{Y} = \dot{N} + \dot{A}$ or $\dot{N} = \dot{Y} - \dot{A}$, where $\dot{Y}$ is real GDP growth, $\dot{N}$ employment growth, and $\dot{A}$ is growth in productivity. Based on this equation, if Y grows faster than A, ($\dot{Y} > \dot{A}$), increase in the rate of productivity will increase employment rate and will reduce unemployment rate. If A grows faster than Y, ($\dot{Y} < \dot{A}$), the net effect on labor will be negative, resulting in more unemployment in the economy.

For a technology that results in innovation and supply of new products in markets, both aggregate demand and aggregate supply will increase. The outcome of this type of technology is an increase in real GDP, decrease in unemployment and increase in real wage. For a type of technology that results in re-organization of the manufacturing process and the use of labor-saving methods, technological advancement results in ambiguous effect on real GDP and Unemployment rate.

In the Okun's model, the effect of technology on GDP growth and unemployment rate is implicit in the expression of the relationship which is:

$$\dot{Y}_t = \beta_o + \beta_1 DU_t + \varepsilon_t \qquad (1)$$

Where $\dot{Y}_t$ is the real GDP growth, DU is the change in unemployment rate, and ε_t is the stochastic error term. Writing the equation in terms of the GDP gap,

$$DUt = \lambda\,(\dot{Y} - \dot{Y}_n) \qquad (2)$$

Where $\dot{Y}$ is the actual GDP growth and $\dot{Y}_n$ is the normal growth of GDP.

In this paper we hypothesize that, if technological advancement results in unemployment, then for the same rate of increase in real GDP around the normal growth of GDP, the change in unemployment rate should be less in recent three decades than the past three decades. That is, the response coefficient λ should be smaller in the recent decades than the past. To test this hypothesis, we have estimated equations (1) and (2) for two different time periods of 1955 to 1985 and 1986 to 2015 for eight industrialized countries.

3. Review of Literature

The literature on the relationship between real GDP growth and changes in unemployment rate for the US economy and for most of the industrialized countries presents statistically strong relationship between the two variables. The magnitude of the response, however, has changed from the initial studies to the most recent ones.

The original Okun's law model in the first difference form expresses the real GDP growth as a function of changes in unemployment rate, equation (1). The Gap Model expresses changes in unemployment rate as a function of the difference between the real GDP growth and the potential GDP growth, equation (2).

The test of the Okun's Law encounters two empirical problems. The Law refers to the relationship between the departures of the real GDP growth from the potential GDP growth. The Law also refers to the relationship between the unemployment rate and its long-term trend, i.e. the natural rate of unemployment (Naimy, 2005). Time-series econometrics suggests several methods to deal with estimating the potential GDP growth and the natural rate of unemployment. The first difference model does not require special estimation of these two trend variables. The Gap Model, however, requires that the trend cycle decomposition methods to be employed to measure these variables.

There are several ways to estimate the output gap for a country. The International Monterey Fund (IMF) utilizes different methods for different countries (De Massi, 1997). The most commonly used methods are the structural approach which is based on estimating a Cobb-Douglas production function of the form $Y_t = A_t N_t^{\alpha} K_t^{1-\alpha}$.

Other techniques involve statistical and smoothing methods of decomposing real GDP growth into its components of trend, cyclical, autocorrelation, and random. Among statistical techniques Beveridge-Nelson (1981) decomposition is widely used in many studies. Among different smoothing techniques, Hodrick-Prescott filter (1997), Baxter and King filter (1977), and Kalman filter (1960) are often used in several studies.

The Hodrick-Prescott filter can be applied and interpreted easily and is widely used for de-trending macroeconomic time series, such as GDP. As Paul Krugman (2009) puts it "Hodrick-Prescott filter is a trend estimate designed to smooth out short-term wiggles." In this study we have used Hodrick-Prescott filter to obtain an estimate of normal growth of GDP.

Okun's original study for US economy (1962) revealed that for every one percent increase in unemployment rate, the real GDP growth will decrease by 3%. This 3 to 1 trade-off between real GDP growth and unemployment rate has been tested many times. The estimated coefficients have varied statistically over time in a very small range, with the more recent estimates being closer to 2 (Freeman, 2000, Attfield and Silverstone, 1998, Moosa, 1997, Weber, 1995, Gordon, 1984).

Several economists have raised the questions of stability of Okun's Law after having observed more recent data of the economy. Prachowny (1993) criticized that many macroeconomic textbooks naively point to the stability of the Okun's Law and that each business cycles do not have exactly the same features in every expansion or contraction which affects the stability of Okun's Law. Adams and Coe (1989) pointed out that there is no necessary reason to believe that the Okun's Law should be stable overtime. They found that the average value of the Okun's coefficient for the United States is between 2.75 and 3 and the variations in the coefficient might "reflect a number of factors". Knotek (2007) found that, from 2003 to 2007, the correlation between changes in unemployment rate and real GDP growth rate was virtually zero because the real GDP growth rate averaged just 3 percent but the unemployment rate did not change over this period.

Knotek (2007) used rolling regression to estimate the Okun's coefficient over shorter time horizons and found that the relationship varied considerably. He provided a possible explanation that demographic change might have an impact on the Okun's coefficient as baby boomers entered the labor market in the 1970's.

A modified version of the Okun's Law is called the dynamic version. Assuming that both past and current output might influence the current unemployment level, it places the current and past real output growth and past changes in the unemployment rate as explanatory variables. Knotek (2007) notes that this version is not as restrictive when it comes to the timing of the relation between economic growth and changes in unemployment rate. He, however, criticized that this version does not provide simple interpretation as the original first difference version does.

4. Analysis and Interpretations

In his 1962 paper, Okun wrote that "[t]he 3 percent result [from a decrease of unemployment rate by 1 percent] implies that considerable output gains in a period of rising utilization rates stem from some or all of the following: induced increases in the size of the labor force; longer average weekly hours; and greater productivity". Okun (1970) stated that other factors and inputs such as capital inputs, labor hours, and participation rate would be changing with employment pari passu, meaning moving together.

To test whether advancements automations have changed the response of unemployment rate to GDP growth, we have estimated the two versions of the Okum's equations for eight industrialized countries for two time periods 1956-1985 and 1986-2015. The coefficients of interest are β_1 and λ of equations (1) and (2) and the change in the coefficients from one period to other.

Tab1e 1 represents the estimated coefficients and statistics of the first difference model (1). For all the regressions, the estimated coefficients were statistically significant at 99% level except for Japan and Switzerland (first period), which the coefficients were significant at 95% level. All the regressions were tested for the Classical Linear Regression Model (CLRM) assumptions and proper adjustments were applied wherever required.

Graphs 1 to 8 show the simulations of the response of unemployment rate to real GDP growth for eight countries during two different periods. We assumed real GDP growth rates of zero to six percent at an increment of .5% and graphed the simulated response during two different time periods. For all the countries the simulated response of unemployment rate change to GDP growth for the recent three decades lie below the response of unemployment rate to GDP growth in the past three decades. The simulated results confirm that, compared to the past three decades, for the same rate of change in unemployment rate, a higher rate of GDP growth is required during the recent three decades than the past three decades. This result is consistent with other conclusions of the statistical tests and provides support to the hypothesis that the technological advancements of the past three decades has replaced machine for labor and created a need for higher rate of real GDP growth to keep unemployment rate from rising.

Graph 9 shows the β_o coefficients of the response of the GDP growth to changes in unemployment rate for the first difference model (1). These coefficients can be interpreted as the normal growth of the real GDPs for the time periods of 1956-1985 and 1986-2015 for each country. For the two time periods, the normal growth of GDPs for all countries are higher during the 1956-1985 than those during the 1986-2015. These results are consistent with the economic literature that the average growth rates of industrialized nations have declined during the recent three decades, especially since the oil price increases of mid 1970's and early 1980's.

Graph 10 presents the graph of β_1, the coefficient of the response of the change in unemployment rate to the gap in GDP growth rate for eight countries during the two different time periods. For all countries the β_1 coefficients of response of unemployment to GDP growth are higher during 1956-1985 period than during the 1986-2015, except for Germany and Canada. This implies that during the recent three decades unemployment rate is less responsive to GDP growth. In other words, a higher rate of GDP growth over the normal growth of GDP is required to lower the unemployment rate. This result is consistent with the main hypothesis of this paper that technological advancements of the recent three decades have changed the response of unemployment to GDP growth. For every 1% deviation of GDP growth from its normal growth of GDP, response of unemployment to GDP growth is lower during the recent decades than the earlier decades. This leads us to believe that as capital (technology) replaces labor, a higher rate of GDP growth is required to lower unemployment rate than what was needed in 1950's, 1960's, and 1970's.

Of all the eight industrialized countries included in this paper, the β_1 coefficients of Germany and Canada for the recent decades were higher than the last three decades. However, when tested for the equality of the coefficients for the two periods, the null hypothesis of equal βs could not be rejected at 95% level of significance for Germany and Canada. That is, the response coefficients of labor to GDP growth for these two countries were not statistically different for the two different time periods.

For Germany and Canada, other than statistical reasoning, one explanation for relative differences in response of unemployment rate to GDP growth could be the immigration policies of the two countries. Germany and Canada, among other industrialized countries, have more liberal immigration policies that may make substitution of capital for labor less attractive in these countries than other industrialized countries.

Table 2 provides the estimated equations of the Gap model (2) for eight countries and two time periods. All the estimated λ coefficients of the Gap model are statistically different from zero at 99% level of significance, except for Japan during the 1956-1985 time periods.

Graph 11 shows the λ response of unemployment rate to the real GDP growth for the Gap model. The results of the Gap model are consistent with the results of the first-difference model. For all the countries the λ coefficients are relatively higher for the 1956-1985 time periods except for Germany and Canada which the response of unemployment rate to GDP growth during the two time periods are not statistically different from each other.

Table 3 represents the estimated equations for total period and its two sub-periods using the panel data. The two estimation methods of the fixed-effect (FE) and the random effect (RE) were used to estimate the equations. All the estimated β_o and β_1 coefficients of the FE and RE methods are statistically different from zero at 99% level of significance. The two methods resulted in estimated β coefficients that statistically were not different from each other. Based on the panel data regression results for the total period for eight industrialized countries, the real GDP growth of 3 % would result in no change in unemployment rate. When the regressions were run for the two sub-periods, a real GDP growth of 4.26% was needed to keep unemployment rate the same for the 1956-1985 period. For the time period (1986-2015), a real GDP growth of 2.13% was required to keep unemployment the same. During the first period a 1% decrease in unemployment rate, increased the real GDP growth by 1.91%. For the second period a 1% decrease in unemployment rate increased the real GDP growth by 1.66%.

The estimated coefficients of the panel data show that during the decades (1956-1985) the normal growth of GDP for industrialized countries on average was 4.26% compared to a decline in normal GDP growth rate of 2.13% in the recent three decades. A large part of the difference in normal growth of GDP during the two time periods was due to oil price increase of 1970's and 1980's.

The Hausman (1978) tests of consistency and efficiency of the estimated βo and β_1 coefficients of fixed effect and random effect were conducted. The Hausman test showed that the null hypothesis of the random effect estimator being consistent and efficient could not be rejected at the 99% level of confidence for all three tests of the total period and its two sub-periods (Table 3).

The results of the panel regression for eight countries were consistent with the results of the single models for each country. For the period 1956-1985, the β_o coefficient of the panel model was 4.29 which was more than twice as large as the β_o for the period 1986-2015. The β_1 coefficient of the panel model for the period 1956-1985 was -1.91 and for the period 1986-2015 was -1.66. These numbers imply that in recent years to decrease unemployment rate by 1% a higher rate of real GDP growth is required than what was needed in the decades of 1956-1985.

5. Conclusion

Using data for eight industrialized countries for two different time periods, this study estimated and compared the response of unemployment rate to the real GDP growth. The models used were traditional single equation Okun's type models estimated for each country, as well as panel data estimates for eight countries. The results of the study showed that there is a significant structural change in response of unemployment rate to real GDP growth. Compared to the traditional Okun's equation, in recent years, a much higher rate of real GDP growth is needed to reduce unemployment rate by 1%. In other words, even if the real GDP grows at a rate higher than normal growth of GDP, the growth will not reduce unemployment rate as much as it did in earlier three decades of 1956-1985. The change in response of unemployment rate to GDP growth may be the result of a structural change in these economies due to substitution of capital for labor. The advancement of artificial intelligence and automation in recent decades has made it possible for industries to replace the routine tasks of labor with machines. The value of the works completed by machines adds to real GDP, without any significant decrease in unemployment rate.

One implication of this conclusion is the expectations of rising unemployment rate, especially among less-skilled and medium-skilled labor in the future along the overall growth path of the economy. This may lead to even higher income gap between skilled and less-skilled labor in the near future. As Berg (Berg, et al., 2016) predicts, the usage of robots will create income inequality as robotic application raises the capital share and results in an uneven distribution of income between labor and capital. Paul Krugman (Krugman, 2013) predict that some of the victims of automation may even be highly-skilled labor.

The employment effect of automation suggests that the traditional policies dealing with business cycles and unemployment may be less effective in job creation and in reducing unemployment rate in the future. To deal with displacement effect of automation on labor, there maybe need for more active role by government in reallocation of income generated by machine for retraining labor in professions that are less susceptible to automation.

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Table 1: Estimated Coefficients of Model (1)

	β_o Coef	β_1 Coef	R^2	DW
USA				
1956-1985	3.67(16.73)**	-1.98(-10.1)**	.78	2.00
1986-2015	2.48(7.11)**	-1.32(-5.51)**	.55	2.25
Japan				
1956-1985	7.83(11.77)**	-6.06(-2.0)*	.12	1.36
1986-2015	1.48(2.33)**	-3.87(-3.59)**	.40	2.17
France				
1956-1985	5.37(15.22)**	-4.17(-5.92)**	.60	2.13
1986-2015	1.86(8.16)**	-1.74 (-5.76)**	.63	1.91
UK				
1956-1985	3.15(5.10)**	-1.9(-3.12)**	.45	1.98
1986-2015	1.94 (3.96)**	-1.83(-5.87)**	.69	1.62

Values in parentheses are t-values.
* 95% level of significance. ** 99% level of significance.

Table 1: (Continued). Estimated Coefficients of Model (1)

	β_o Coef	β_1 Coef	R^2	DW
Germany				
1956-1985	3.91(11.59)**	-1.87(-5.48)**	.52	1.67
1986-2015	1.46 (2.47)**	-2.26(-4.17)**	.44	1.92
Canada				
1956-1985	4.51(9.84)**	-1.37(-6.32)**	.60	2.06
1985-2015	2.26(10.25)**	-1.92(-7.42)**	.67	1.53
Switzerland				

1956-1985	2.44(1.92)	-4.51(-2.78)**	.60	1.87
1986-2015	1.90(4.10)**	-1.71(-5.24)**	.62	1.80
Australia				
1856-1985	4.32(-12.22)**	-1.32(-3.96)**	.39	1.61
1986-2015	3.13(22.10)**	-1.25(-7.73)**	.60	2.57

Values in parentheses are t-values.
* 95% level of significance. ** 99% level of significance

Table 2: Response of Unemployment Rate to GDP growth the GAP Model (2)

	λ Coef	R^2	DW
USA			
1956-1985	-.41(-10.66)**	.80	2.51
1986-2015	-.49(-6.23)**	.68	1.93
Japan			
1956-1985	-.02 (-1.5)	.07	2.53
1986-2015	-.11(-3.87)**	.47	1.83
France			
1956-1985	-.17((-3.55)**	.35	1.90
1986-2015	-.36(-4.92)**	.59	1.88
UK			
1956-1985	-.16(-2.81)**	.42	1.80
1986-2015	-.37(-5.21)**	.65	1.67

	λ Coef	R^2	DW
Germany			
1956-1985	-.23(-3.36)**	.58	1.64
1986-2015	-,19(-4.65)**	.60	1.57
Canada			
1956-1985	-.44(-6.59)	.60	1.71
1986-2015	-.39(-7.75)**	.69	1.77
Switzerland			
1956-1985	-0.48(-3.04)**	.29	2.15
1986-2015	-.33(-5.57)**	.61	1.74
Australia			
1956-1985	-.37(-4.11)**	.43	2.38
1986-2015	-.57(- 6.82)**	.63	2.13

Values in parentheses are t-values.

* 95% level of significance. ** 99% level of significance.

Table 3 A: Panel data Regressions Total period 1961-2015

	β_o Coef	β_1 Coef	R^2
Fixed Effect	3.05(28.29)**	-1.6(-12.00)**	.25
Random Effect	3.04(13.15)**	-1.6(-12.04)**	.25

Table 3 B. Panel data Regressions period 1961-1985

	β_o Coef	β_1 Coef	R^2
Fixed Effect	4.26(25.54)**	-1.91(-9.46)**	.30
Random Effect	4.26(8.91)**	-1.92(-9.53)**	.30

Table 3 C: Panel data Regressions period 1986-2015

	β_o Coef	β_1 Coef	R^2
Fixed Effect	2.13(22.36)**	-1.66(-13.62)**	.43
Random Effect	2.13(11.06)**	-1.66 (-13.60)**	.43

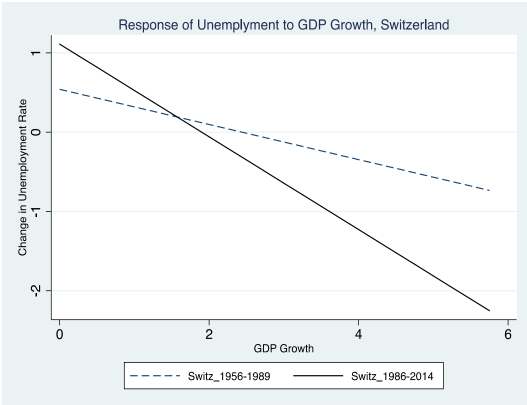
Values in parentheses are t-values.
* 95% level of significance. ** 99% level of significance

Table 4: Hausman Tests

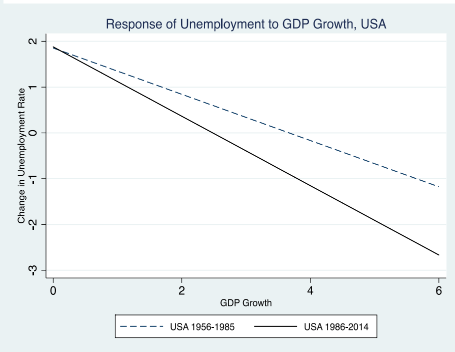
Period	Change in Unemp	(b)	(B)	(b - B)	S. E.
1961-2014	DU χ^2=.51	-1.5954 Prob>Chi2=.476	-1.5985	.0030	.00425
1961-1985	DU χ^2=.46	-1.91 Prob>Chi2=.496	-1.92	.00837	.0123
1986-2015	DU χ^2=.04	-1.6580 Prob>Chi2=.847	-1.66	.00158	.00822

Graphs of Response of Unemployment Rate to Changes in GDP Growth (Graphs 1-8)

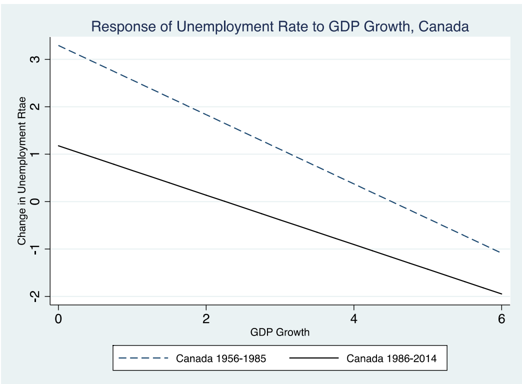
Graph 1



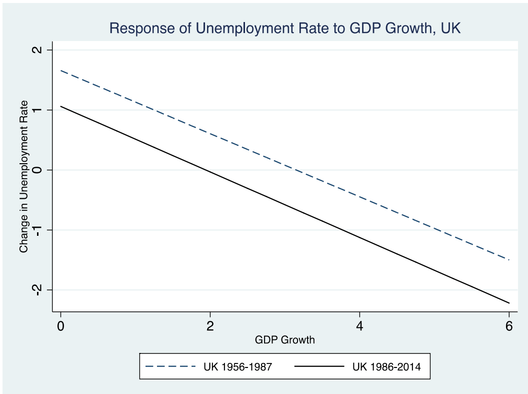
Graph 2



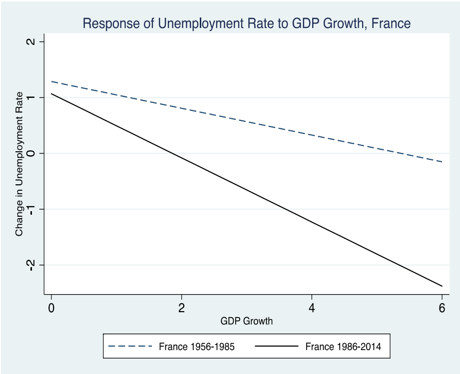
Graph 3



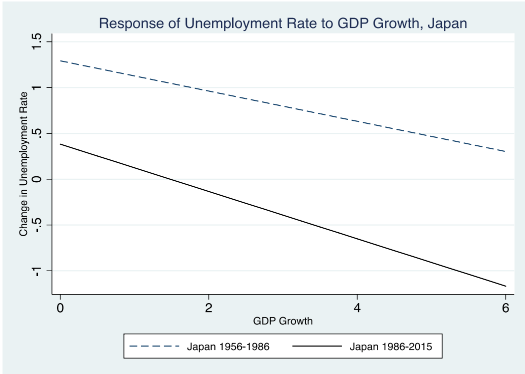
Graph 4



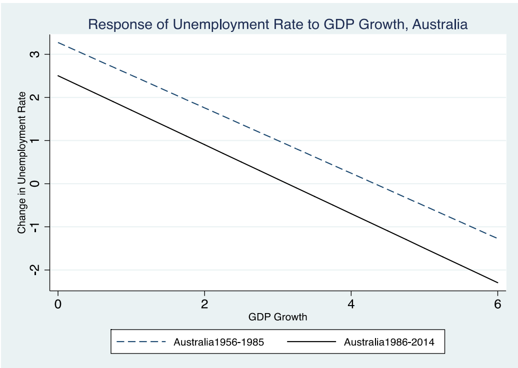
Graph 5



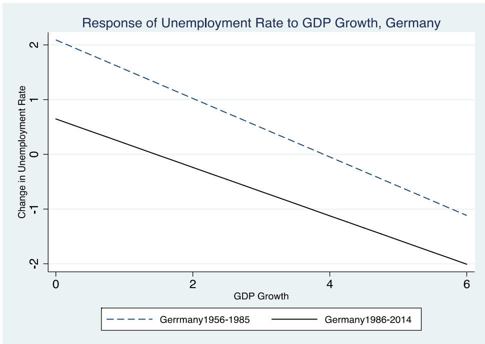
Graph 6



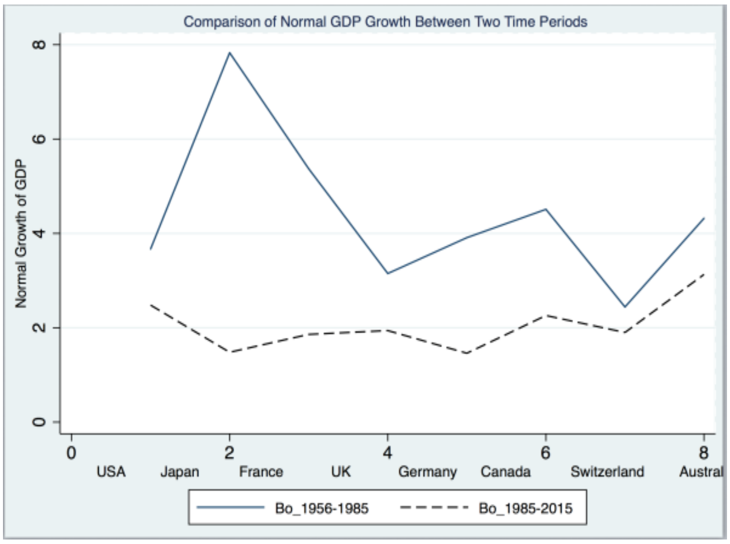
Graph 7



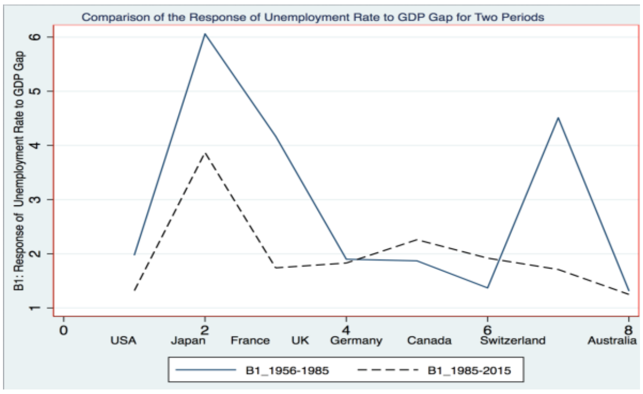
Graph 8



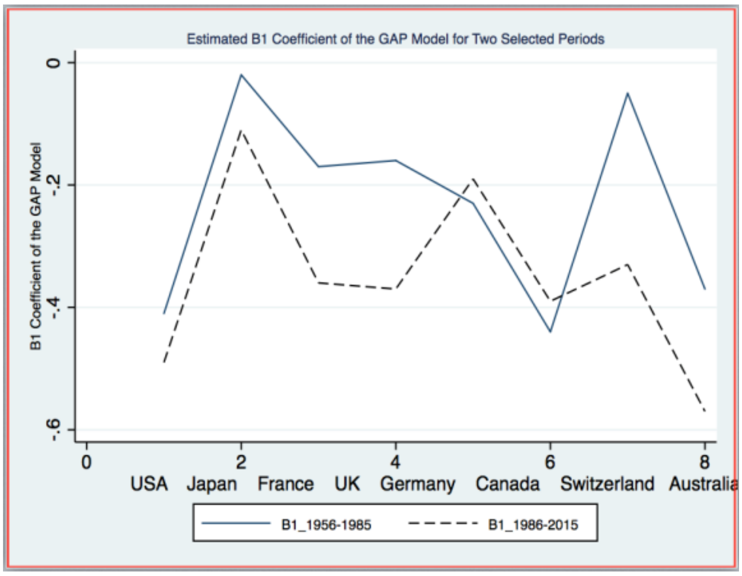
Graph 9: βo of the first- difference model



Graph10: β_1 of the first-difference Model



Graph 11: Estimated β Coefficient of the GAP Model



Graph 12: Response of Unemployment Rate to GDP Growth: Panel data