Title: Econometrics Project

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Present a case in support of closing the gender pay gap in the UK. Discuss how a change in the average hourly wage rate of women will affect GDP, while ensuring that the results of your econometric work are valid.

2386 words

Executive summary

This project will focus on regression analysis, determining how closing the Gender Pay Gap (GPG), through a change in the average hourly wage rate of women will affect GDP, providing valid econometric results that will give insights into GDP and GPG trend relationships. Initially, the project discusses how a female over-representation in lower-paid jobs and under-representation in higher-paid careers, due to unpaid traditional care is not allowing optimal GDP growth, which would be reached by transmuting unpaid care into paid care, augmenting economical profits. Subsequentially, quantitative data is analysed to determine the effects of the reduction in GPG through an increase in the average hourly wage rate of female workers.

Standard OLS estimates are obtained through a classic linear regression model (CLRM), and the null hypothesis which states that reducing GPG would lead to an increase in the rate of GDP growth is confirmed by an autoregressive distributed lag model, computed following autocorrelation, unit root, cointegration, and heteroscedasticity tests.

Finally, policy recommendations are provided to ease the transition from unpaid care to paid care employment, boost women's employment, and stabilise their wages compared with their male counterparts.

Introduction

GPG is mainly caused by an over-presentation of women in lower-paid jobs and under-presentation in higher-paid careers because they choose lower-paying jobs to care for their families (Kim, 2013). A decrease in GPG influences economic development, as a higher number of women would be subtracted from the gendered activity of unpaid care that sustains GDP growth, substituting them with a paid care workforce, through ‘‘forced saving”, which would increase the production of human capital such as education, thus increasing labour capacities and enabling capitalists to increase their profits not only in the short-run, as more women enter the paid workforce, further augmenting economic output, but also in the long-run, as a mostly specialised future workforce would increase the profit share (Braunstein at al., 2011). The UK recognised the need for a more inclusive and egalitarian wage system in the 1990s, focusing on getting any member of households into employment through policies that allowed women to dissociate from their caring roles (de Henau & Himmelweit, 2013). Closing the GPG, though an increase in women’s average hourly wage rate will lead to productivity growth, creating savings, essential for investments and subsequential economic growth.

Data and methodology

The dataset for this project was obtained from the National Accounts of the UK, published by the Organisation for Economic Cooperation and Development (OECD). The available sample for the project consists of 215 observations, divide into 5 categories of 43 observations each, representing the total wage of males after tax (WBR_M), the total wage of females after tax (WBR_F) the total working hours of males (E_M), the total working hours of females (E_F), and total profits after tax (*PPR)*. The project reports how a change in the average hourly wage rate of women will affect GDP, through regression analysis, the technique used to analyse the data. The coefficients of the regression are estimated by Ordinary Least Squares (OLS).

It is necessary to determine:

(1) The average hourly wages of males (AHW_M) and females (AHW_F), respectively $\frac{WBR_M\ after\ tax}{E_M}$ and $\frac{WBR_F\ after\ tax}{E_F}$

(2) which consents the calculation of the GPG, through: $\frac{(AHW_M - AHW_F)}{AHW_M}$

(3) and of the GDP, expressed by (AHW_M)(E_M) + (AHW_F)(E_F) + *PPR*

(4) Given that $AHW_F = AHW_M(1 - \mathrm{GPG})$, adding variables in natural logs, by generating linearised variables, lead to the formulation of a mathematical model and a subsequent regression analysis equation:

$$ln(GDP) = ln(AHW_M) - ln(GPG) + ln(E_F) + ln(WBR_M) + ln(PPR)$$

$$ln(GDP) = \beta_0 + \beta_1 ln(AHW_M) + \beta_2 ln(GPG) + \beta_3 ln(E_F) + \beta_4 ln(WBR_M) + \beta_5 ln(PPR)$$

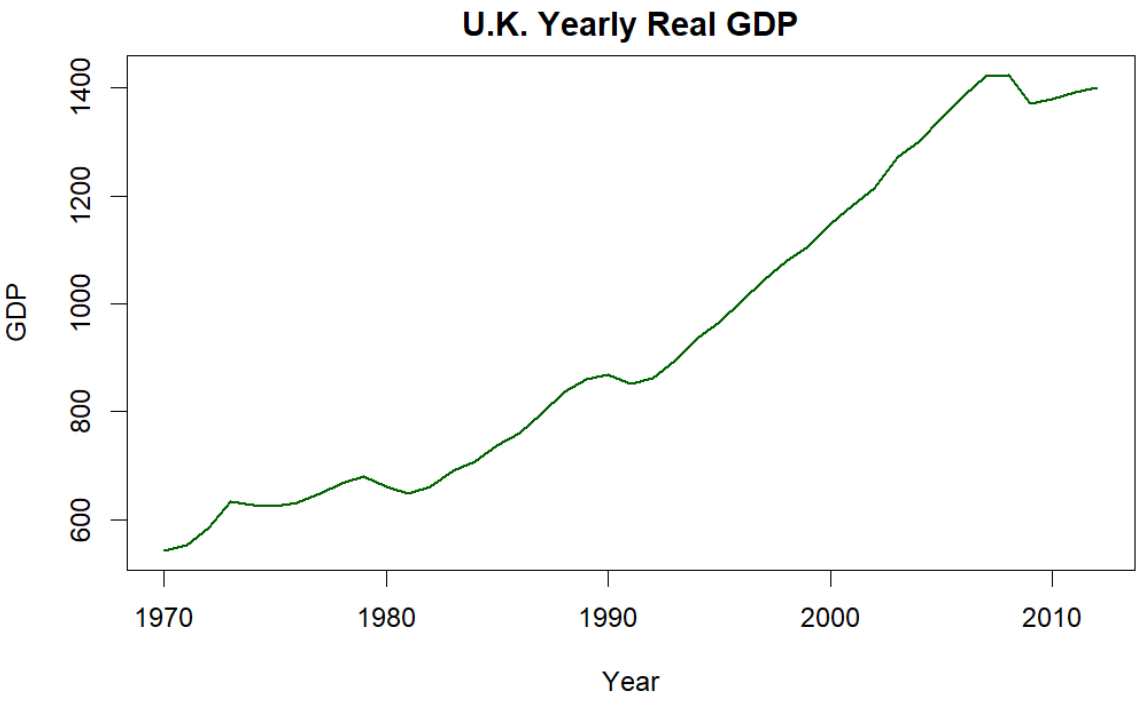
Time series analysis is used to show growth patterns between GDP and GPG. The hypotheses for the project are:

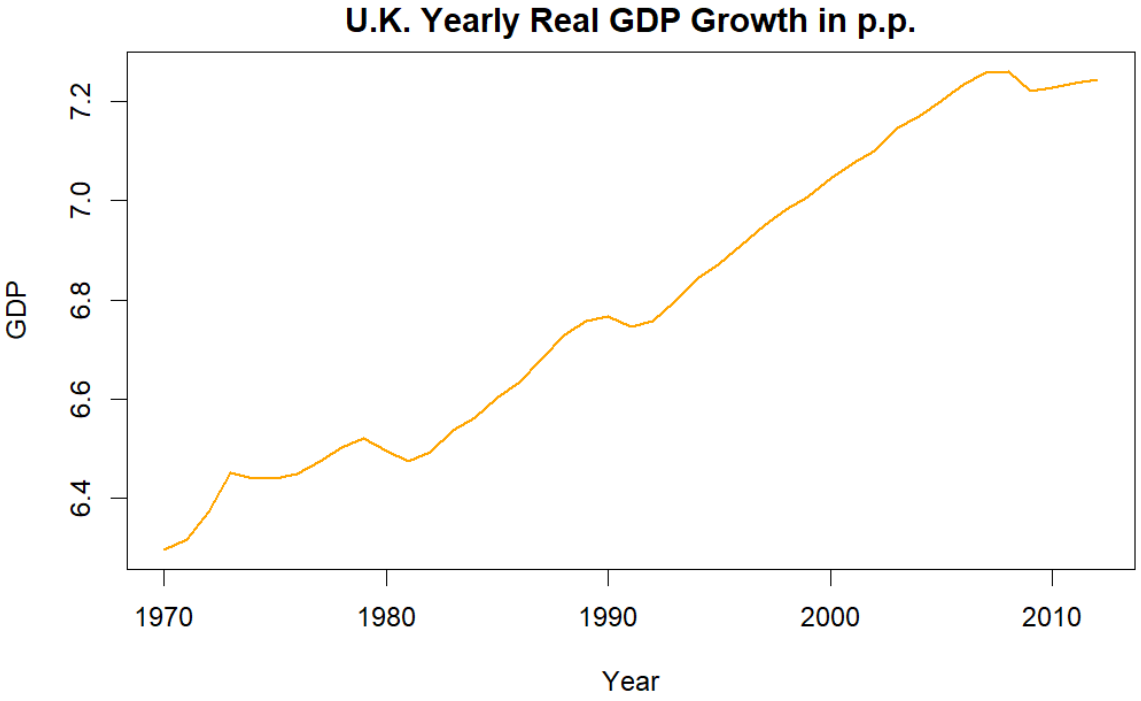
H_0: decreasing the GPG, by increasing the AHW_F leads to an increase in GDP

H_1: decreasing the GPG, by increasing the AHW_F does not lead to an increase in GDP

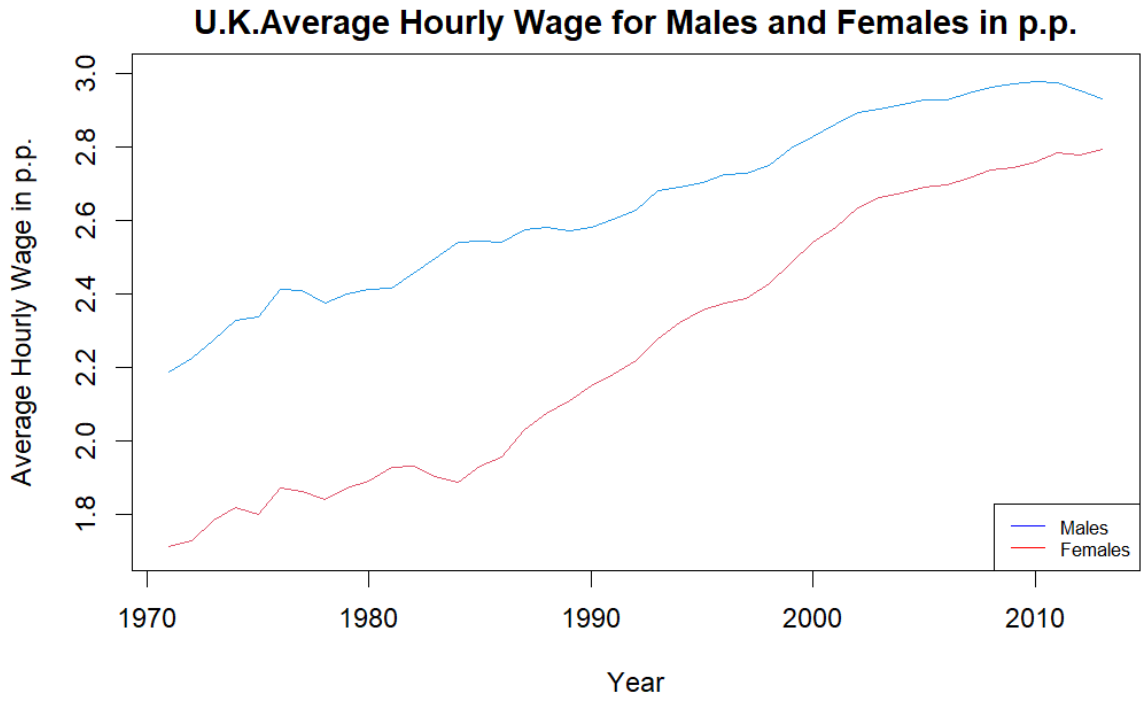
GDP, AHW_M, AHW_F, GPG, E_F, and E_M Plots

GDP has experienced a growth trend since 1970, and it has grown drastically from 861.053 £mln in 1992 to 1400.529 £mln in 2012.

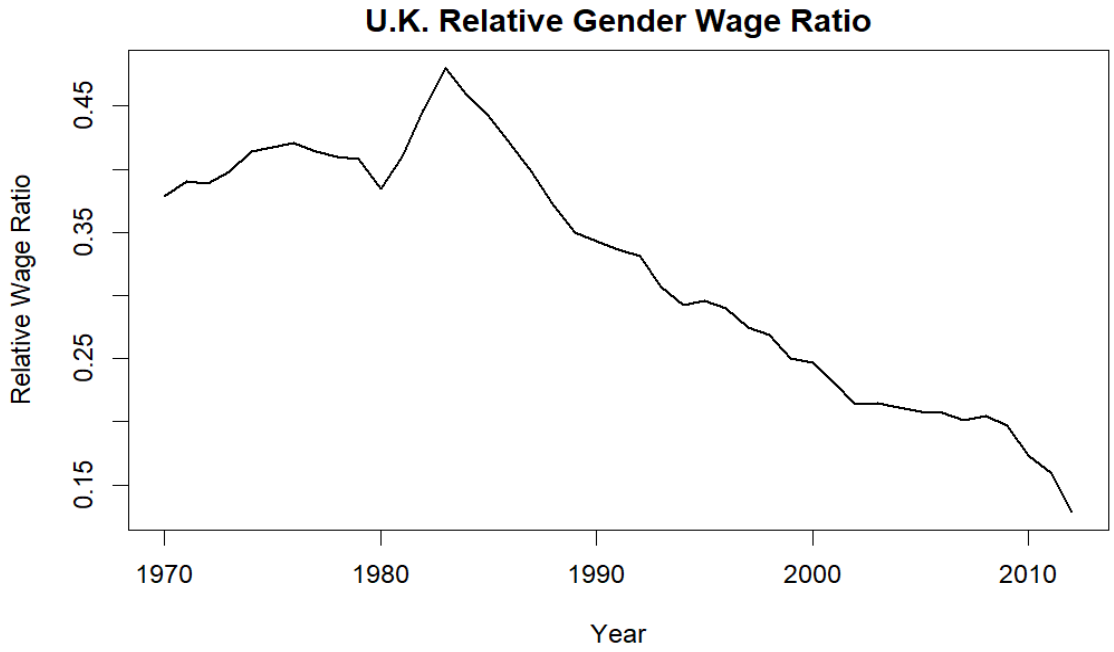




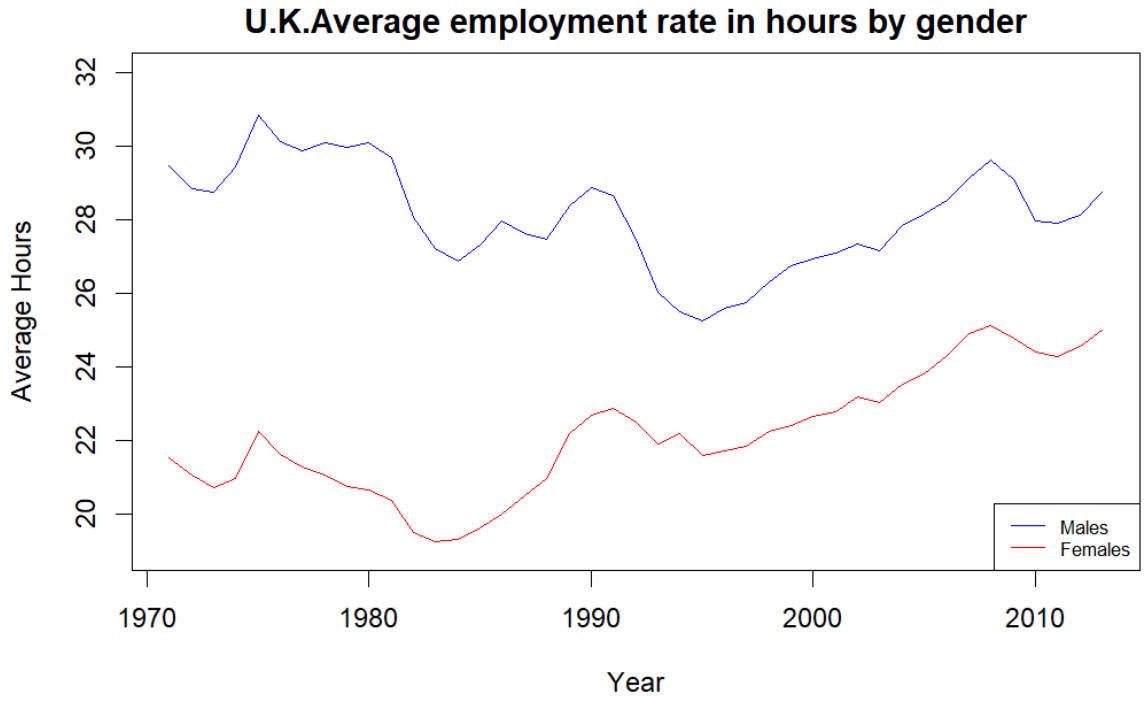
AHW_F and AHW_M have overall been growing steadily since 1970, in particular in the 1990s, suggesting a correlation with the trend of GDP. Furthermore, from the 2000s the rate of growth of females was higher than the rate of growth of males with the latter declining in 2010, suggesting a reduction in GPG.



GDP seems to be inversely related to GPG that has decreased from 33.2% to 12.8% from 1992 to 2012 due to fiscal policies, aimed at reducing GPG. Indeed, GPG growth rate experienced a negative trend between 1985 and 2012 with a significant slump in 2008.



Average employment rate in hours for females and males suggests a reduction in GPG, which considering GDP growth hints at a possible correlation between the two variables.



As it can inferred from the plots, there is a graphical indication of the presence of a unit root in every variable in levels as the respective means of the stochastic process appear to be

decreasing and not reverting over time. Furthermore, the plot suggests cointegration as the series follow a similar trend, inverse in the case of GDP and GPG.

Regression analysis

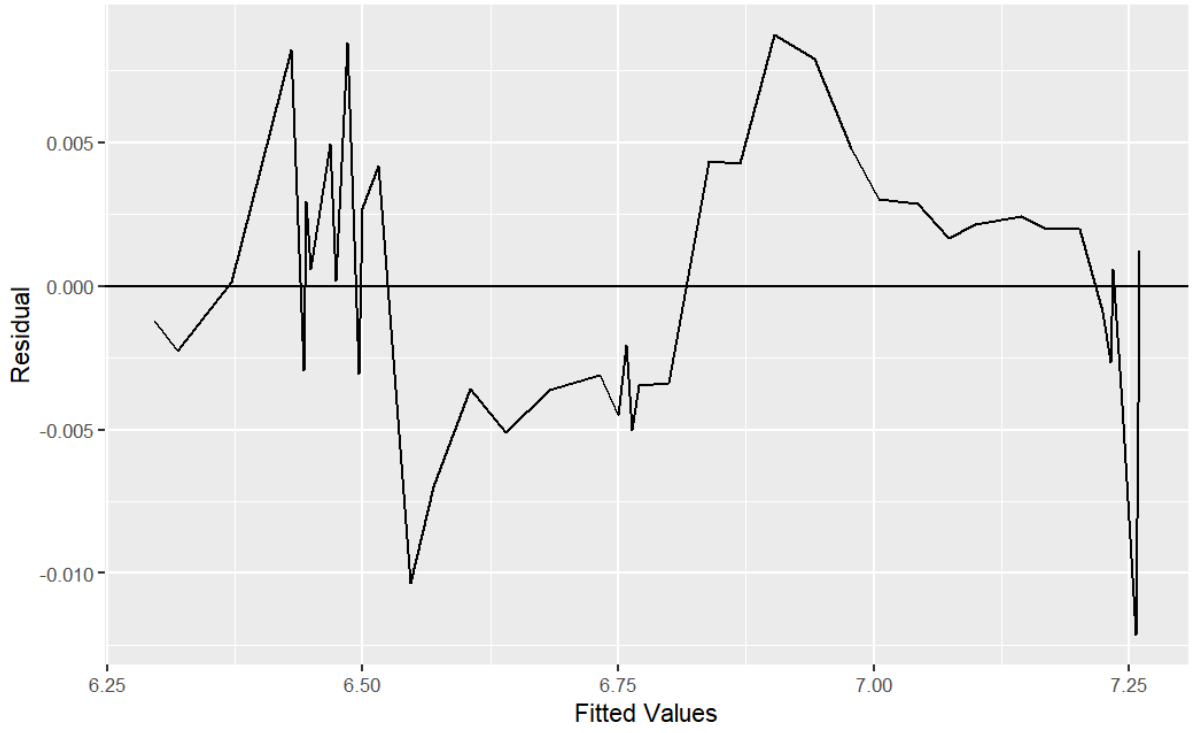
The project relies on statistical tests to determine the presence of unit roots, autocorrelation, heteroskedasticity, and cointegration.

According to the Gauss-Markov theorem, for the OLS to be BLUE, the CLRM assumptions of linearity on parameters, random sampling, zero conditional mean of errors, no perfect multicollinearity and homoscedasticity need to be respected to guarantee the unbiasedness and efficiency of the OLS estimators and estimates.

The normality in the residuals assumption about the error term is desirable for conducting statistical inference with non-linear estimators. If the test results indicate biased OLS estimates, an ARDL model will be applied to provide the required adjustments necessary to obtain coefficients coherent with the assumptions of efficiency, which will be represented in a regression table.

<u>OLS regression on levels</u>

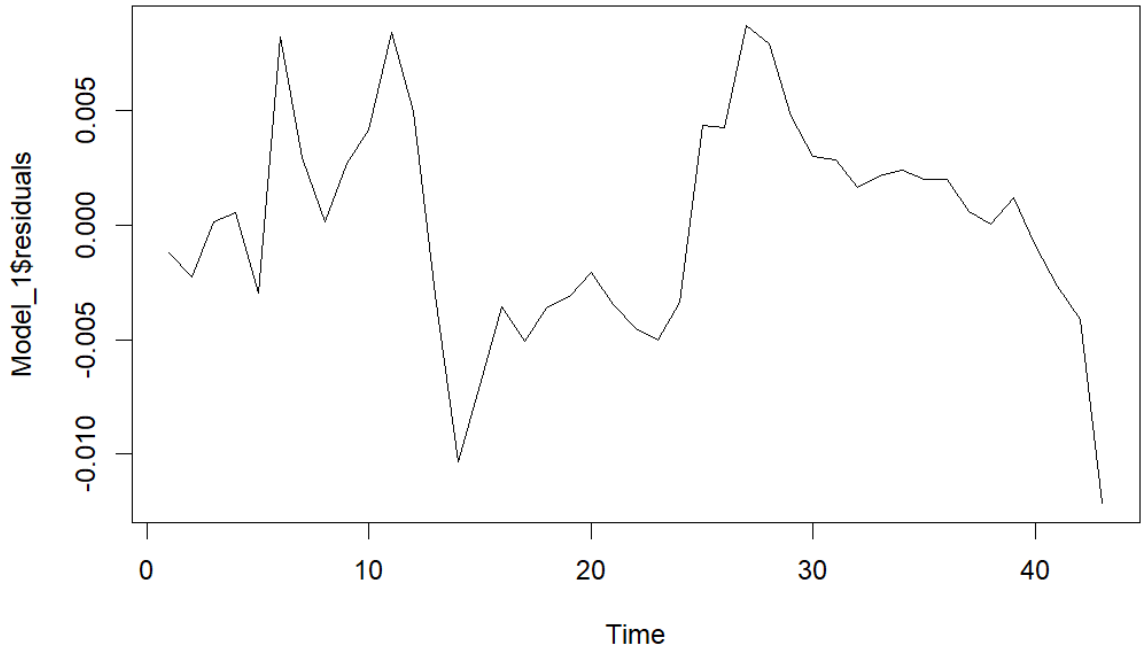
An OLS regression analysis model is constructed and a plot of residuals of the model is obtained and shown below.



A serial correlation diagnostic check is performed on the model. The Durbin-Watson (DW) test is used to examine first-order autocorrelation, which implies a consecutive serial correlation between the error terms of the dependent variable with its own lagged values. Autocorrelation, caused by the omission of influential variables or inclusion of non-influential variables, impacts on the consistency and unbiasedness of the model, affecting its variance and standard errors, which in turn affect the value of the statistical tests (Asteriou & Hall, 2016).

```
 lag Autocorrelation D-W Statistic p-value
   1       0.6248308     0.5889792       0
 Alternative hypothesis: rho != 0
```

According to the DW test statistic of 0.589, the null hypothesis of no autocorrelation is rejected, indicating a positive serial correlation between GDP and GPG, shown by the dispersion of the residuals in test plots. The R2 of the regression is larger than the DW statistic, suggesting that the results could be affected by spurious regression. The DW test gives further insights on the inversely proportional relationship between GDP and GPG. The corresponding residuals plot is shown below.



Unit root tests

The presence of a unit root indicates non-stationarity in the time-series which could lead to spurious regression and the OLS estimation of the regression yielding misleading, incorrect results (Koop, 2013). The null hypothesis of non-stationarity is tested against the hypothesis of stationarity. According to the latter, the time series is a stochastic process with mean and variance being constant over time and the covariance between two time periods depending only on their lag. Whereas according to the former, the mean and variance are not constant over time and the covariance between two time periods depends on the actual time it is computed.

Augmented Dickey Fuller (ADF)

Ho: residuals have a unit root and therefore the series is not stationary.

```
Value of test-statistic is: -1.6064 2.5418 2.0025

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.15 -3.50 -3.18
phi2  7.02  5.13  4.31
phi3  9.31  6.73  5.61
```

According to the Augmented Dickey Fuller (ADF) test with time trend and Akaike Information Criteria (used to select the optimal maximum number of lags), The test statistic of GDP is -1.61 which is less negative than the critical value at the 5% significance level (-3.50). Therefore, Ho cannot be rejected.

```
Value of test-statistic is: -2.013 2.3304 2.2199

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.15 -3.50 -3.18
phi2  7.02  5.13  4.31
phi3  9.31  6.73  5.61
```

The test statistic of AHW_M is -2.01 which is less negative than the critical value at the 5% significance level (-3.50). Therefore, Ho cannot be rejected.

```
Value of test-statistic is: -2.0902 4.6461 6.9203

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.15 -3.50 -3.18
phi2  7.02  5.13  4.31
phi3  9.31  6.73  5.61
```

The test statistic of GPG is -2.09 which is less negative than the critical value at the 5% significance level (-3.50). Therefore, Ho cannot be rejected.

```
Value of test-statistic is: -4.0724 6.297 8.3671

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.15 -3.50 -3.18
phi2  7.02  5.13  4.31
phi3  9.31  6.73  5.61
```

The test statistic of E_F is -4.07 which is more negative than the critical value at the 5% significance level (-3.50) but less negative than the critical value at the 1% level (-4.15). Therefore, Ho cannot be rejected only at the 1%.

```
Value of test-statistic is: -2.9156 3.2712 4.4415

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.15 -3.50 -3.18
phi2  7.02  5.13  4.31
phi3  9.31  6.73  5.61
```

The test statistic of WBR_M is -2.92 which is less negative than the critical value at the 5% significance level (-3.50). Therefore, Ho cannot be rejected.

```
Value of test-statistic is: 1.7062 2.8534 4.2654

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.15 -3.50 -3.18
phi2  7.02  5.13  4.31
phi3  9.31  6.73  5.61
```

The test statistic of PPR is 1.71 which is less negative than the critical value at the 5% significance level (-3.50). Therefore, Ho cannot be rejected.

Overall, Ho cannot be rejected for every variable at the 1% significance level, ADF results are compared to the results of the Phillips-Perron (PP) test.

Phillips-Perron (PP) test

```
        Phillips-Perron Unit Root Test

data:  LogGDP
Dickey-Fuller Z(t_alpha) = -1.7901, Truncation lag parameter = 3, p-value = 0.6566
alternative hypothesis: stationary


        Phillips-Perron Unit Root Test

data:  ln_AHW_M
Dickey-Fuller Z(t_alpha) = -1.6723, Truncation lag parameter = 3, p-value = 0.7032
alternative hypothesis: stationary


        Phillips-Perron Unit Root Test

data:  ln_G_W_Gap
Dickey-Fuller Z(t_alpha) = -0.99199, Truncation lag parameter = 3, p-value = 0.9279
alternative hypothesis: stationary


        Phillips-Perron Unit Root Test

data:  ln_E_F
Dickey-Fuller Z(t_alpha) = -2.2964, Truncation lag parameter = 3, p-value = 0.4566
alternative hypothesis: stationary


        Phillips-Perron Unit Root Test

data:  ln_WBR_M
Dickey-Fuller Z(t_alpha) = -2.0583, Truncation lag parameter = 3, p-value = 0.5507
alternative hypothesis: stationary


        Phillips-Perron Unit Root Test

data:  ln_PPR.after.tax
Dickey-Fuller Z(t_alpha) = -2.7393, Truncation lag parameter = 3, p-value = 0.2817
alternative hypothesis: stationary
```

Ho: residuals have a unit root.

The Phillips-Perron (PP) test provides a more accurate indication than the ADF test on the presence of unit roots by adjusting for type II errors. If the time-series are non-stationary, the test results would not be reliable and cannot be included in the regression analysis. However, if the variables are cointegrated, regression can be carried out even in the presence of spurious regression (Koop, 2013, p.175).

The PP tests confirm the results of the ADF tests, as the p value > 0.05 in every case, hence the null hypothesis of non-stationarity cannot be rejected for any variable. The results are shown above.

Cointegration tests

As mentioned before, to account for the problem of spurious regression when a non-stationary series regresses on another nonstationary series, a cointegration test is required. According to cointegration, the trend of the error terms of the two variables cancels each other out, leading to a common trend.

Johansen test

Ho: no cointegration vector.

According to the trace test, the test statistic 44.03 is greater than the critical value 19.96 at the 5% significance level. Ho is rejected at the 5% significance level as there is evidence of 4 cointegrating vectors. The MaxEigen version confirms the results of the previous Johansen test as there is evidence of at least 4 cointegrating vectors. Hence, spurious regression will not affect the validity of the results.

```
Values of teststatistic and critical values of test:

           test 10pct   5pct   1pct
r <= 5 |   9.17  7.52   9.24  12.97
r <= 4 |  44.03 17.85  19.96  24.60
r <= 3 |  95.34 32.00  34.91  41.07
r <= 2 | 155.84 49.65  53.12  60.16
r <= 1 | 260.07 71.86  76.07  84.45
r = 0  | 390.61 97.18 102.14 111.01
```

```
Values of teststatistic and critical values of test:

           test 10pct  5pct  1pct
r <= 5 |   9.17  7.52  9.24 12.97
r <= 4 |  34.86 13.75 15.67 20.20
r <= 3 |  51.31 19.77 22.00 26.81
r <= 2 |  60.51 25.56 28.14 33.24
r <= 1 | 104.23 31.66 34.40 39.79
r = 0  | 130.54 37.45 40.30 46.82
```

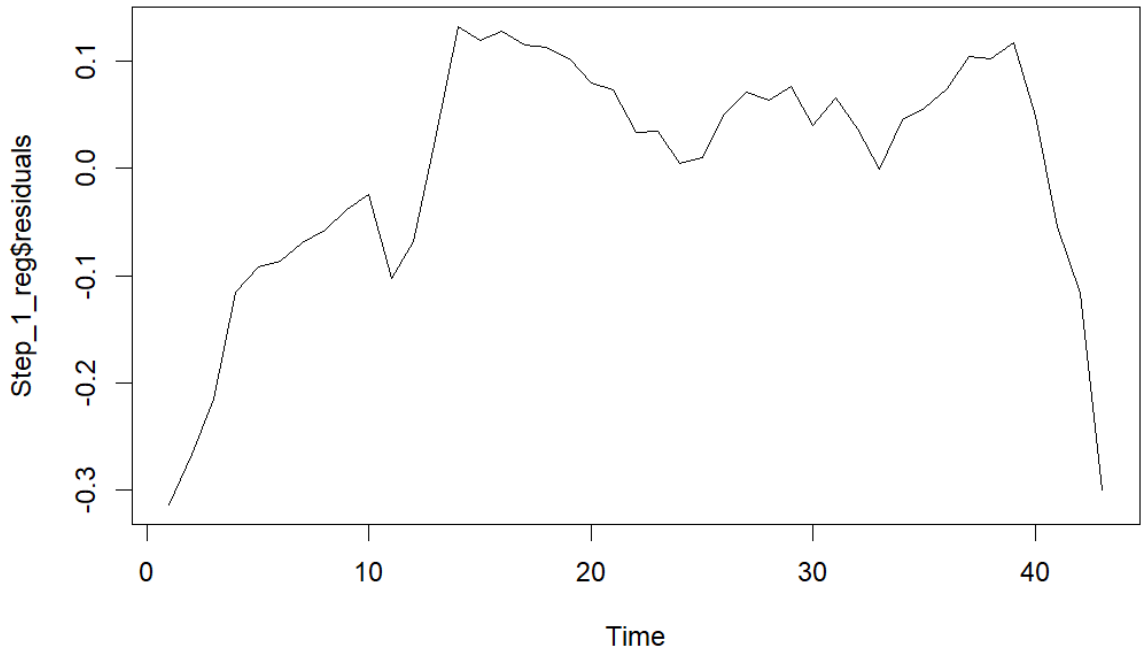
Engle-Granger test

Ho: no cointegration vector.

```
Value of test-statistic is: -1.3735

Critical values for test statistics:
      1pct  5pct 10pct
tau1 -2.62 -1.95 -1.61
```

The test, based on the ADF unit-root test, contradicts the results of the Johansen tests, indeed the test statistic is -1.37 which is less negative than the critical value at the 5% significance level (-1.95). Therefore, Ho cannot be rejected. However, the Johansen test is more reliable than the Engle-Granger test and therefore it will be assumed that GDP and GPG are cointegrated in levels at the 5% significance level. The residuals plot is shown below.



Regression on first differences

The variables seem to be autocorrelated and cointegrated. The next step of the project will be to create a new regression model in first differences to account for unit roots and accurately calculate the effects of the changes in the independent variables on the dependent variable.

The model is tested for autocorrelation and heteroscedasticity through the ADF test and Breusch-Pagan test respectively. Finally, the Newey West test allows to account for autocorrelation and heteroscedasticity, creating a regression model with adjusted coefficients.

```
        studentized Breusch-Pagan test

data:  regression_fo_diff
BP = 5.4419, df = 5, p-value = 0.3644
```

Heteroskedasticity implies that the variance of the error term is not constant in each observation but dependent on unobserved effects. According to the Breusch-Pagan test which runs an auxiliary regression of the squared residuals on the independent variables, the null hypothesis of no heteroskedasticity cannot be rejected, as the p value 0.3644 > 0.05. The CLRM assumption of homoscedasticity is not violated, and the estimation results are efficient.

```
        Durbin-Watson test

data:  regression_fo_diff
DW = 1.5974, p-value = 0.04867
alternative hypothesis: true autocorrelation is greater than 0
```

The Durbin-Watson test on the residuals of the model was conducted, confirming the autocorrelation trend of the time series, indeed the p value 0.04867 < 0.05, hence the null hypothesis of no autocorrelation is rejected.

<u>The ARDL model</u>

Finally, an autoregressive distributed lag (ARDL) model is constructed to estimate dynamic causal effects, including the lagged terms of the independent variable into the regression equation, and control for autocorrelation, improving the fit of the model, including autoregressive components such as the lags of the dependent variable as explanatory variables into it. Furthermore, the model allows to stationarise the variables that present non-stationary trends.

According to the results, by increasing the GPG by 1% in time t, the GDP in time t+1 decreases by -0.095%, thus decreasing the GPG by -1% would lead to an increase of the GDP by 0.095%. The interpretation of the ARDL indicates a failure to rejecting the null hypothesis of the project, as a decrease in the GPG would cause an increase in GDP, thus economic growth.

	Dependent variable:	
	ln_GDP	L(GDP_Diff)
	OLS	*dynamic linear*
	(1)	(2)
ln_AHW_M	0.316***	
	(0.026)	
ln_G_W_Gap	-0.082***	
	(0.007)	
ln_E_F	0.348***	
	(0.029)	
ln_WBR_M	0.373***	
	(0.023)	
ln_PPR.after.tax	0.305***	
	(0.009)	
L(AHW_M_Diff)		0.284***
		(0.052)
L(G_W_Gap_Diff)		-0.095***
		(0.013)
L(E_F_Diff)		0.269***
		(0.047)
L(WBR_M_Diff)		0.439***
		(0.044)
L(PPR_Diff)		0.301***
		(0.009)
Constant	0.833***	-0.001
	(0.087)	(0.001)
Observations	43	42
R^2	1.000	0.978
Adjusted R^2	1.000	0.975
Residual Std. Error	0.005 (df = 37)	0.004 (df = 36)
F Statistic	32,769.540*** (df = 5; 37)	321.712*** (df = 5; 36)
Note:		*p<0.1; **p<0.05; ***p<0.01

Conclusion and policy recommendations

It can be validly inferred from our results that decreasing the GPG, by increasing AHW_F leads to economic development, represented by GDP growth. following this research's conclusions, policies such as childcare schemes (free part-time pre-school education), efficient parental leave, 48-hour maximum working week, and tax-benefit systems should be constructed and implemented, in favour of easing access to women in the workforce, as the short work life expectancy of women represents a rational response to anticipated discrimination in the labour market, preventing women to progress in their careers due to occupational barriers, subsequentially impacting on the GPG (Oaxaca, 1973). Policies, easing job entry to women should be complemented by government interventions on the recruitment process of businesses, deficient in their representation of women throughout their departments, leading to a change in the gender composition in the workplace that reflects UK demography. Thanks to government representation, women would finally be able to rebalance the determination process of the market wage, which due to cultural and traditional influences has mostly been in favour of men (Kim, 2000). Indirect gender discrimination by financial institutions, caused by the GPG, makes it more difficult for women to borrow and save large amounts, rending them dependable to men, reinforcing cultural norms, which in turn, causes them to be more risk-averse than men, stemming from their role as providers for the household (van Staveren, 2010). Therefore, policies, easing loan requirements for women would provide a strong foundation for their individuality and independence, changing traditional family norms and decreasing their risk-aversity, leading to higher female labour force participation, which is associated with increases in human capacities production (Braunstein, 2011).

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