Determinants of Inflation in Denmark and a Panel Data analysis of Denmark and 4 other countries.

Section I: Introduction

Inflation is generally defined as the sustained rise in the general price level (Blanchard, Amighini, & Giavazzi, 2021, p. 577).

The negative effects of inflation are well documented. One such cost of inflation is the “shoe leather cost” (Mishkin & Posen, 1997, p. 3) – the extra cost needed to conduct day-to-day transactions rises to >1% of GDP when inflation rates rise above 100%. Another cost is that inflation induces overinvestment in the financial sector: as price instability increases, arbitrage opportunities grow (*ibid*, p. 4); the rise in the financial sector share of GDP increases by 1pp for every 10pp rise in inflation (English, 1999). This transfer of resources out of the productive sector can be “as large as a few percentage points of GDP and can even be seen at relatively low or moderate rates of inflation.” (Mishkin & Posen, 1997, p. 4) Inflation is passed onto the population not only through increased prices – which reduce the purchasing power of an individual’s income – but also through fiscal drag. Fiscal drag occurs when nominal income rises while real income and tax brackets remain frozen; as a result, income after tax decreases in real terms; Fischer (1994, p. 14) estimates that an inflation rate of 10% could put the social cost of fiscal drag at 2-3% of GNP.

Due to the misallocation of resources and damage to the standard of living caused by inflation, governments around the world have decided to specifically target low and stable inflation as a policy objective of their monetary authorities (Mishkin & Posen, 1997). To succeed, these monetary authorities must have a clear model for producing inflation forecasts (Masson, Savastano, & Sharma, 1997, p. 9), and must consequently understand the determinants of inflation. This paper will contribute to this understanding by estimating the relationship between inflation and past inflation, money supply, exchange rates, and global energy prices. I have chosen first to conduct a timeseries analysis of inflation, from Q1 2001 to Q4 2023, in Denmark, and then a panel data analysis of inflation in Denmark, Sweden, Iceland, Norway and the UK.

Section II will review existing evidence on the determinants of inflation and examine the models and specifications used. Section III will cover a timeseries summary and analysis of Denmark, estimating inflation as an ARMA model and then as an ARDL model. Section IV will cover a panel data analysis of inflation in the five countries. Section V will use a probit model to estimate the average marginal effects (AME) and marginal effects at average (MEA) of a change in energy price on the probability of a country achieving their inflation target.

Section II: Literature Review

Among economists, there are competing explanations for the fundamental causes of inflation. Friedman provides the well-known monetarist explanation where inflation is the result of money supply rising faster than output (Leeson & Palm, 2012, p. 3). This view is popular and the relationship between money supply growth and inflation has been examined by a number of studies.

Holod (2000) uses a VEC model to investigate the relationship between price level, exchange rate and money supply in Ukraine; a VEC rather than VAR model is used because evidence of cointegration between the variables exists at a 5% significance level. Holod (2000) finds that the influence of money supply on inflation is not very strong, which he explains is due to concurrent fluctuations in the money demand.

Lim & Sek (2015) explore panel data on 28 countries by estimating inflation as an ARDL model against money supply (M4) and a number of other regressors. In high inflation countries, every 1% increase in the money supply is found to induce a 0.77% increase in inflation, in the long-run. In low-inflation countries, increased money supply does not have a significant effect in the long-run and decreases inflation in the short-run in low inflation countries.

Money growth leads to inflation by increasing aggregate demand, known as demand-pull inflation. On the other hand, cost-push inflation, which follows a reduction in aggregate supply, has also been examined in the literature. Cost-push inflation is typically caused by high factor prices (Ellahi, 2017, p. 3). Global energy prices are one example of a variable which should have such an effect on factor prices, and this view is supported by existing evidence.

Jatuporn (2024) and Liang & Long (2018) both estimated the impacts of global oil price changes on CPI and PPI using ARDL and NARDL models to analyse Thailand and China, respectively. Both found evidence of cointegration using the bounds cointegration methodology introduced by Perasan at al. (2001). Both studies find that ARDL models do not find evidence of long-run effects of oil price shocks on inflation, however NARDL models can capture the effects at a 1% significance level. Jatuporn (2024) finds: +1% change in oil price led to +0.147% CPI change; -1% change in oil price led to -0.115% CPI change. Liang & Long (2018) did not find significant long-run effects due to a drop in oil prices, but found a +1% change in oil price led to a +0.143% CPI change.

Finally, there is also a lot of evidence examining the effects of a currency’s exchange rate on domestic prices. Movements in the exchange rate influence domestic prices through various channels, from direct effects on energy prices (discussed above) to indirect effects on import prices (Ha et al., 2019); this raises the price of inputs and thus the price of capital, reducing aggregate supply. The marginal effect of a 1% depreciation in the exchange rate on inflation is known as the exchange rate pass-through ratio (Ha et al., 2019, p. 271).

The exchange rate pass-through varies across countries and time (Ha, Kose, Ohnsorge, & Yilmazkuday, 2019, p. 284). Choudhri & Hakura (2001) estimated inflation as an ARDL model, using panel data of 71 countries. The explanatory variables were the nominal exchange rate and foreign CPI. No evidence of cointegration was found however the stationarity of the error term has not been settled (Choudhri & Hakura, 2001, p. 14). They find that the long-run pass-through rates in Denmark, Sweden, Norway, and the UK are 0.24, 0.03, 0.13, and 0.03, respectively – Iceland did not form part of the panel. They also determine that the main reason for cross-country variation in the pass-through rate is due to the different inflationary regimes between countries.

Section III: Timeseries variables, data and models

1. *Data sources*

The databases utilised are the IMF, OECD, Bank for International Statistics (BIS), and Federal Reserve Economic Data (FRED). CPI data was obtained from the IMF, money supply (M3) data from OECD, the exchange rate from BIS and global energy prices from FRED. The literature varies between using real effective exchange rates (Deniz, Tekce, & Yilmaz, 2016) and nominal effective exchange rates (Choudhri & Hakura, 2001; Campa & Goldberg, 2005) – in this paper I will use the nominal exchange rate following from Campa & Goldberg’s (2005) model where it is the nominal rate that influences decision-makers at the microlevel. Any monthly data was converted into quarterly data by taking the value for the last month of each quarter.

1. *Presenting and transforming the data*

Table I contains the summary statistics for Denmark in the studied period (2000:1-2023:4). This includes the consumer price index (cpi) in 2015=100, money supply aggregate M4 (m), nominal effective exchange rate index (xr) in 2020=100, and the global energy price index (gep) in 2016=100.

Table I

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Statistic | cpi | m | xr | gep |
| Mean | 94.527 | 1271726.000 | 96.050 | 153.268 |
| Median | 96.967 | 1394929.000 | 96.120 | 148.764 |
| S.D. | 10.845 | 377165.800 | 3.815 | 64.919 |
| Min | 75.429 | 507134.000 | 85.430 | 61.703 |
| Max | 117.867 | 1922206.000 | 103.240 | 350.124 |
| Obs | 96 | 96 | 96 | 96 |

Figure I represents the variables visually in the studied period (2000:1-2023:4).

Figure I

|  |  |
| --- | --- |
|  |  |
|  |  |

To reduce data variability and find elastic relationships (Jatuporn, 2024), all variables have been transformed into logarithmic functions (lcpi, lm, lxr, lgep).

1. *Stationarity Testing*

The Augmented Dickey-Fuller (ADF) test will be used to test for stationarity.

Each variable is first estimated as:

Where , is the number of lagged, differenced, dependent variables to include to eliminate serial correlation, is an array of variables that may or may not be added if the variable is exhibiting drifting or trending behaviour, and is a stochastic error term.

To find the value of , the Breusch-Godfrey (BG) test is used which to indicate how many lagged, differenced, dependent variables should be included to eliminate serial correlation. As all variables – other than – have non-zero means and appear to increase over time, they must be either: drift-stationary, trend-stationary, or a random walk with drift.

First, all variables – other than – are estimated using the ADF test **with a trend term** and then tested for serial correlation. is estimated with a drift term as it has a non-zero mean. Once was found[[1]](#footnote-1), an ADF test with lags and a trend (drift for ) term was estimated[[2]](#footnote-2). Table II displays the value of for each variable the BG test recommends to eliminate serial correlation, as well as the test statistic, 5% critical value and the MacKinnon approximate p-value from the ADF test.

Table II

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Lags (p) | Test statistic | 5% critical value | MacKinnon p-value |
|  | 5 | -2.131 | -3.460 | 0.5289 |
|  | 0 | -1.616 | -3.455 | 0.7861 |
|  | 3 | -3.271 | -3.458 | 0.0712 |
| \* | 1 | -2.743 | -1.662 | 0.0059\*\*\* |

\*

We do not accept the alternate hypothesis that are trend-stationary. We accept the alternate hypothesis that stationary with drift.

, and are then re-estimated using the ADF test **with a drift constant** and tested for serial correlation[[3]](#footnote-3). Table III contains the new , test statistic, 5% critical value and MacKinnon approximate p-value for this new estimation[[4]](#footnote-4).

Table III

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Lags (p) | Test statistic | 5% critical value | MacKinnon p-value |
|  | 5 | -0.286 | -1.663 | 0.3879 |
|  | 0 | -1.937 | -1.661 | 0.0279\*\* |
|  | 4 | -2.095 | -1.663 | 0.0196\*\* |

We accept the null hypothesis that is a random walk with drift, and accept the alternative hypothesis that and are drift-stationary processes due to their non-zero means.

As is non-stationary, it is differenced (=) and tested again for stationarity. As before, serial correlation[[5]](#footnote-5) is tested and then an ADF test is used[[6]](#footnote-6). As has a non-zero mean, tests are conducted using a **drift constant**. Results are shown in Table IV.

Table IV

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Lags (p) | Test statistic | 5% critical value | MacKinnon p-value |
|  | 4 | -4.114 | -1.663 | 0.0000\*\*\* |

We accept the alternate hypothesis that is drift-stationary.

1. *Estimating inflation as an ARMA model*

In order to determine values of *p* and *q*, I will be using the AIC and BIC up to a maximum of .

Exchange rate fluctuations:

* There is reason to believe that an exchange rate peg can help to lower inflation.

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# Appendix

## Appendix 1

Estimated using a foreach loop in Stata. The name of the variable, e.g., , is at the top of each section followed by the results of the BG test looking at 4 lags of the error term, up to a maximum of 5 lags in the ADF test. Each variable section is then followed by a dashed line to indicate the next variable’s estimation has begun. Output has been split into two columns to reduce pagination. The ADF test includes a **trend term**.

. foreach v of varlist lcpi lm lxr lgep {

2. display "`v'"

3. display "Lags: 0"

4. quietly regress D.`v' L.`v' trend

5. estat bgodfrey, lags(1/4) nomiss0

6. forvalues lags = 1/5 {

7. display "Lags: `lags'"

8. quietly regress D.`v' L(1/`lags')D.`v' L.`v' trend

9. estat bgodfrey, lags(1/4) nomiss0

10. }

11. display "\*-----------------\*"

12. }

lcpi

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 15.522 1 0.0001

2 | 16.469 2 0.0003

3 | 18.263 3 0.0004

4 | 28.871 4 0.0000

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.112 1 0.7378

2 | 2.358 2 0.3076

3 | 15.398 3 0.0015

4 | 22.773 4 0.0001

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 2.284 1 0.1307

2 | 15.294 2 0.0005

3 | 14.431 3 0.0024

4 | 21.716 4 0.0002

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 13.099 1 0.0003

2 | 20.590 2 0.0000

3 | 19.580 3 0.0002

4 | 19.510 4 0.0006

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 10.241 1 0.0014

2 | 9.600 2 0.0082

3 | 9.516 3 0.0232

4 | 13.602 4 0.0087

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.712 1 0.3989

2 | 0.758 2 0.6844

3 | 4.798 3 0.1872

4 | 5.159 4 0.2714

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

lm

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 2.513 1 0.1129

2 | 3.532 2 0.1710

3 | 3.916 3 0.2707

4 | 4.498 4 0.3428

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 1.045 1 0.3065

2 | 1.908 2 0.3851

3 | 2.318 3 0.5091

4 | 2.432 4 0.6568

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.487 1 0.4852

2 | 0.954 2 0.6205

3 | 1.118 3 0.7728

4 | 1.954 4 0.7442

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.674 1 0.4115

2 | 0.680 2 0.7117

3 | 1.444 3 0.6953

4 | 2.043 4 0.7278

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.048 1 0.8259

2 | 0.884 2 0.6429

3 | 2.181 3 0.5358

4 | 7.039 4 0.1338

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.815 1 0.3668

2 | 1.882 2 0.3903

3 | 6.664 3 0.0834

4 | 7.755 4 0.1010

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

lxr

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.349 1 0.5548

2 | 1.141 2 0.5654

3 | 7.332 3 0.0620

4 | 10.069 4 0.0393

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.524 1 0.4692

2 | 6.704 2 0.0350

3 | 9.631 3 0.0220

4 | 8.957 4 0.0622

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 6.436 1 0.0112

2 | 9.533 2 0.0085

3 | 10.641 3 0.0138

4 | 10.119 4 0.0385

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 3.419 1 0.0644

2 | 6.294 2 0.0430

3 | 6.598 3 0.0859

4 | 9.300 4 0.0540

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 3.080 1 0.0792

2 | 3.800 2 0.1496

3 | 7.488 3 0.0579

4 | 8.155 4 0.0861

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 1.058 1 0.3036

2 | 3.835 2 0.1470

3 | 4.354 3 0.2257

4 | 4.601 4 0.3308

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

lgep

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 14.588 1 0.0001

2 | 14.576 2 0.0007

3 | 14.406 3 0.0024

4 | 14.619 4 0.0056

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.261 1 0.6093

2 | 0.293 2 0.8636

3 | 0.235 3 0.9718

4 | 0.340 4 0.9871

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.039 1 0.8443

2 | 0.099 2 0.9517

3 | 0.266 3 0.9664

4 | 0.548 4 0.9687

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.050 1 0.8237

2 | 0.200 2 0.9049

3 | 0.441 3 0.9316

4 | 1.328 4 0.8566

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.104 1 0.7469

2 | 0.271 2 0.8732

3 | 0.899 3 0.8257

4 | 0.923 4 0.9213

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.123 1 0.7254

2 | 0.876 2 0.6452

3 | 1.435 3 0.6974

4 | 2.940 4 0.5679

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

## 

## Appendix 2

ADF test using trend term for and drift term for . Horizontal lines added to split output into variable sections.

. dfuller lcpi, lags(5) trend

Augmented Dickey–Fuller test for unit root

Variable: lcpi Number of obs = 90

Number of lags = 5

H0: Random walk with or without drift

Dickey–Fuller

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -2.131 -4.062 -3.460 -3.156

--------------------------------------------------------------

MacKinnon approximate p-value for Z(t) = 0.5289

. dfuller lm, trend

Dickey–Fuller test for unit root Number of obs = 95

Variable: lm Number of lags = 0

H0: Random walk with or without drift

Dickey–Fuller

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -1.616 -4.051 -3.455 -3.153

--------------------------------------------------------------

MacKinnon approximate p-value for Z(t) = 0.7861.

. dfuller lxr, lags(3) trend

Augmented Dickey–Fuller test for unit root

Variable: lxr Number of obs = 92

Number of lags = 3

H0: Random walk with or without drift

Dickey–Fuller

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -3.271 -4.058 -3.458 -3.155

--------------------------------------------------------------

MacKinnon approximate p-value for Z(t) = 0.0712.

. dfuller lgep, lags(1) drift

Augmented Dickey–Fuller test for unit root

Variable: lgep Number of obs = 94

Number of lags = 1

H0: Random walk with drift, d = 0

t-distribution

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -2.568 -2.368 -1.662 -1.291

--------------------------------------------------------------

p-value for Z(t) = 0.0059

Appendix 3

Estimated using a foreach loop in Stata. The name of the variable, e.g., , is at the top of each section followed by the results of the BG test looking at 4 lags of the error term, up to a maximum of 5 lags in the ADF test. Each variable section is then followed by a dashed line to indicate the next variable’s estimation has begun. Output has been columnated to reduce pagination. The ADF test includes a **drift term**

. foreach v of varlist lcpi lm lxr lgep {

2. display "`v'"

3. display "Lags: 0"

4. quietly regress D.`v' L.`v'

5. estat bgodfrey, lags(1/4) nomiss0

6. forvalues lags = 1/5 {

7. display "Lags: `lags'"

8. quietly regress D.`v' L(1/`lags')D.`v' L.`v'

9. estat bgodfrey, lags(1/4) nomiss0

10. }

11. display "\*-----------------\*"

12. }

lcpi

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 13.451 1 0.0002

2 | 14.315 2 0.0008

3 | 15.226 3 0.0016

4 | 21.778 4 0.0002

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.300 1 0.5839

2 | 1.331 2 0.5139

3 | 9.225 3 0.0264

4 | 22.072 4 0.0002

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.992 1 0.3193

2 | 8.887 2 0.0118

3 | 21.834 3 0.0001

4 | 21.661 4 0.0002

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 7.893 1 0.0050

2 | 20.768 2 0.0000

3 | 20.442 3 0.0001

4 | 20.547 4 0.0004

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 15.204 1 0.0001

2 | 15.393 2 0.0005

3 | 15.608 3 0.0014

4 | 18.000 4 0.0012

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 1.482 1 0.2235

2 | 1.910 2 0.3847

3 | 4.187 3 0.2420

4 | 5.560 4 0.2345

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

lm

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 2.122 1 0.1452

2 | 2.793 2 0.2474

3 | 3.303 3 0.3472

4 | 3.642 4 0.4566

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.715 1 0.3977

2 | 1.701 2 0.4272

3 | 1.824 3 0.6096

4 | 2.000 4 0.7357

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.674 1 0.4118

2 | 0.850 2 0.6538

3 | 1.059 3 0.7870

4 | 2.289 4 0.6827

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.398 1 0.5281

2 | 0.463 2 0.7934

3 | 1.657 3 0.6464

4 | 2.587 4 0.6292

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.115 1 0.7350

2 | 1.354 2 0.5082

3 | 2.863 3 0.4132

4 | 6.626 4 0.1570

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 1.232 1 0.2671

2 | 2.450 2 0.2938

3 | 6.109 3 0.1064

4 | 9.148 4 0.0575

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

lxr

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.143 1 0.7049

2 | 0.873 2 0.6464

3 | 5.573 3 0.1343

4 | 9.625 4 0.0472

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.484 1 0.4866

2 | 5.191 2 0.0746

3 | 9.390 3 0.0245

4 | 8.767 4 0.0672

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 4.962 1 0.0259

2 | 9.383 2 0.0092

3 | 11.411 3 0.0097

4 | 10.156 4 0.0379

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 4.735 1 0.0296

2 | 8.342 2 0.0154

3 | 8.134 3 0.0433

4 | 10.126 4 0.0384

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 3.883 1 0.0488

2 | 4.222 2 0.1211

3 | 7.269 3 0.0638

4 | 7.522 4 0.1107

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.713 1 0.3984

2 | 2.754 2 0.2523

3 | 2.880 3 0.4105

4 | 3.511 4 0.4762

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

lgep

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 13.833 1 0.0002

2 | 13.977 2 0.0009

3 | 13.824 3 0.0032

4 | 14.161 4 0.0068

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.466 1 0.4950

2 | 0.453 2 0.7972

3 | 0.350 3 0.9503

4 | 0.449 4 0.9783

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.004 1 0.9503

2 | 0.076 2 0.9625

3 | 0.277 3 0.9642

4 | 0.451 4 0.9781

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.058 1 0.8101

2 | 0.249 2 0.8831

3 | 0.401 3 0.9400

4 | 1.012 4 0.9080

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.153 1 0.6956

2 | 0.275 2 0.8714

3 | 0.972 3 0.8080

4 | 1.621 4 0.8051

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.096 1 0.7564

2 | 0.839 2 0.6572

3 | 1.488 3 0.6850

4 | 3.106 4 0.5402

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

Appendix 4

ADF test using drift term for . Horizontal lines added to split output into variable sections.

. dfuller lcpi, lags(5) drift

Augmented Dickey–Fuller test for unit root

Variable: lcpi Number of obs = 90

Number of lags = 5

H0: Random walk with drift, d = 0

t-distribution

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -0.286 -2.372 -1.663 -1.292

--------------------------------------------------------------

p-value for Z(t) = 0.3879

. dfuller lm, drift

Dickey–Fuller test for unit root Number of obs = 95

Variable: lm Number of lags = 0

H0: Random walk with drift, d = 0

t-distribution

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -1.937 -2.367 -1.661 -1.291

--------------------------------------------------------------

p-value for Z(t) = 0.0279

. dfuller lxr, lags(4) drift

Augmented Dickey–Fuller test for unit root

Variable: lxr Number of obs = 91

Number of lags = 4

H0: Random walk with drift, d = 0

t-distribution

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -2.095 -2.371 -1.663 -1.292

--------------------------------------------------------------

p-value for Z(t) = 0.0196

Appendix 5

Estimated using a foreach loop in Stata. The ADF test includes a **drift term**

. foreach v of varlist D.lcpi {

2. display "`v'"

3. display "Lags: 0"

4. quietly regress D.`v' L.`v'

5. estat bgodfrey, lags(1/4) nomiss0

6. forvalues lags = 1/5 {

7. display "Lags: `lags'"

8. quietly regress D.`v' L(1/`lags')D.`v' L.`v'

9. estat bgodfrey, lags(1/4) nomiss0

10. }

11. display "\*-----------------\*"

12. }

D.lcpi

Lags: 0

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.261 1 0.6092

2 | 1.283 2 0.5265

3 | 8.876 3 0.0310

4 | 22.001 4 0.0002

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 1

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.920 1 0.3374

2 | 8.535 2 0.0140

3 | 21.670 3 0.0001

4 | 21.553 4 0.0002

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 2

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 7.627 1 0.0058

2 | 20.688 2 0.0000

3 | 20.412 3 0.0001

4 | 20.398 4 0.0004

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 3

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 15.287 1 0.0001

2 | 15.647 2 0.0004

3 | 15.757 3 0.0013

4 | 18.242 4 0.0011

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 4

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 1.411 1 0.2348

2 | 1.737 2 0.4197

3 | 4.249 3 0.2358

4 | 5.497 4 0.2400

---------------------------------------------------------------------------

H0: no serial correlation

Lags: 5

Breusch–Godfrey LM test for autocorrelation

---------------------------------------------------------------------------

lags(p) | chi2 df Prob > chi2

-------------+-------------------------------------------------------------

1 | 0.349 1 0.5547

2 | 3.125 2 0.2096

3 | 4.429 3 0.2187

4 | 5.378 4 0.2507

---------------------------------------------------------------------------

H0: no serial correlation

\*-----------------\*

Appendix 6

ADF test using drift term for .

. dfuller d.lcpi, lags(4) drift

Augmented Dickey–Fuller test for unit root

Variable: D.lcpi Number of obs = 90

Number of lags = 4

H0: Random walk with drift, d = 0

t-distribution

Test -------- critical value ---------

statistic 1% 5% 10%

--------------------------------------------------------------

Z(t) -4.114 -2.372 -1.663 -1.292

--------------------------------------------------------------

p-value for Z(t) = 0.0000

1. Appendix 1 [↑](#footnote-ref-1)
2. Appendix 2 [↑](#footnote-ref-2)
3. Appendix 3 [↑](#footnote-ref-3)
4. Appendix 4 [↑](#footnote-ref-4)
5. [↑](#footnote-ref-5)
6. [↑](#footnote-ref-6)