6)
b. Output gap
Jašová, M., Moessner, R., & Takáts, E. (2020). Domestic and global output gaps as inflation drivers: What does the Phillips curve tell?. Economic Modelling, 87, 238-253.

Coming to output gap: The authors compare the domestic and global output gaps across regions and time. They use different indicators and filtering approaches to do that. Using the macroeconomic data for India and the USA, please replicate the similar results for India using the same set of variables and linear regression. Please submit a report in about 300 words, excluding tables and figures.

Answer:

In this question we first collect data on a quarterly basis on real GDP series, expected inflation, CPI, and NEER estimates for India, we also collect data for crude oil prices, same as done by the author of the paper. We also collect data for the USA real GDP series and real Global weighted average GDP data in quarterly terms.

For CPI, expected inflation (we couldn't find the data for expected inflation, so we have assumed adaptive expectations in the model, thus inflation expectations equal inflation values of the last year), we had yearly and monthly data respectively; and we changed its frequency to quarters:

Calculations:
(1) For inflation expectations, we had yearly data, which we converted into quarterly data using compounding, such that quarterly values when compounded, result in equal final inflation at the end of the year;
(2) For CPI points, we had monthly data, we took an average of 3 months and used it in place of quarterly data.). We got NEER data with quarterly frequency for both countries.

Furthermore, we calculate the domestic output gap for India, the output gap for the USA and the global output gap using the Hodrick-Prescott filtering method in Excel, taking the smoothness parameter as 1600 given our data is on a quarterly basis.

We tried to conduct 4 regressions taking inspiration from the given paper :
1. For the full sample period (1996Q1-2022Q4)
2. For the pre-crisis period (1996Q1-2008Q2)
3. For the post-crisis period including the crisis quarters (2008Q3-2022Q4)
4. For the post-crisis period excluding the crisis quarters (2009Q3-2022Q4).

Regression equation considered as given in the paper :

$$\pi_{it} = \alpha_i + \rho E_t \pi_{it+1} + \delta \pi_{it-1} + \varphi y_{it}^d + \lambda y_t^g + \theta \pi_t^{oil} - \sum_{j=0}^{3} \gamma_j \Delta NEER_{it-j}$$

$$- \sum_{k=0}^{3} \mu_k \Delta NEER_{it-k}^2 - \sum_{l=0}^{3} \nu_l \Delta NEER_{it-l}^3 + \varepsilon_{it}$$

Dependent variable: CPI
Independent variables: Indian Output Gap, Global Output Gap, Expected Inflation India, Crude Oil Prices, NEER India (linear) estimate, NEER Quadratic estimates, NEER cubic estimates.

Full sample period (1996Q1-2022Q4)

Through this regression we get to know from the significance value of F that our model is reliable as our value for F is less than 0.05 (as per 95% confidence interval) which shows we reject the null hypothesis and not all coefficient values are equal to 0. Furthermore from the small adjusted R square value we can say that the association between our dependent variable i.e. CPI and all the other independent variables considered is not strong enough.

Regression Statistics	
Multiple R	0.500465452
R Square	0.250465669
Adjusted R Square	0.197468292
Standard Error	0.014029009
Observations	107

ANOVA					
	df	SS	MS	F	Significance F
Regression	7	0.006510973	0.000930139	4.726001232	0.0001308
Residual	99	0.019484497	0.000196813		
Total	106	0.02599547			

Here from the table below we can see the p-values and find that only two estimates i.e. for crude oil prices and NEER estimates have a significant effect on the CPI of India. Crude oil prices both in the case of 95% significance level and 90% significance level have a significant effect as the p-value is less than 0.05 for that. And for NEER estimates it is significant only for 90% confidence interval as the p-value is less than 0.1. All other variables have coefficient values nearly equal to 0 as their p values are greater than 0.1 so we do not reject null in those cases.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 90.0%	Upper 90.0%
Intercept	-0.000151419	0.001517699	-0.099768554	0.920729826	-0.003162863	0.002860026	-0.002671393	0.00236856
INDIA OUTPUT GAP	-1.49666E-06	1.55389E-06	-0.963167508	0.337810218	-4.57992E-06	1.5866E-06	-4.07673E-06	1.0834E-06
GLOBAL OUTPUT GAP	5.6035E-08	2.09855E-07	0.267017033	0.790011473	-3.60364E-07	4.72434E-07	-2.92407E-07	4.0448E-07
EXPECTED INFLATION INDIA (LOG DIFFERENCES Q ON Q)	0.000442753	0.002210553	0.20029039	0.841664348	-0.003943464	0.004828969	-0.00322763	0.00411314
CRUDE OIL PRICES	0.019907353	0.006629061	3.003042567	0.003384404	0.006753858	0.033060849	0.008900519	0.03091419
NEER ESTIMATE	0.227620363	0.122699637	1.855102162	0.066557306	-0.015842338	0.471083063	0.02389097	0.43134976
QUADRATIC NEER ESTIMATE	-0.034117171	0.139997964	-0.24369762	0.807969301	-0.311903504	0.243669162	-0.266568552	0.19833421
CUBIC NEER ESTIMATE	-0.066008369	0.052076896	-1.267517339	0.207943628	-0.169340228	0.037323491	-0.152476386	0.02045965

Pre-Crisis period (1996Q1-2008Q2)

Through this regression we get to know from the significance value of F, that our model is reliable as our value for F is less than 0.05 (as per 95% confidence interval) which shows we reject the null hypothesis and not all coefficient values are equal to 0. Furthermore from the small adjusted R square value we can say that the association between our dependent variable i.e. CPI and all the other independent variables considered is not strong enough.

Regression Statistics	
Multiple R	0.592068844
R Square	0.350545516
Adjusted R Square	0.239663043
Standard Error	0.01313342
Observations	49

ANOVA	df	SS	MS	F	Significance F
Regression	7	0.003817115	0.000545302	3.161415026	0.009117328
Residual	41	0.007071955	0.000172487		
Total	48	0.01088907			

Here from the table below we can see the p-values and find that only two estimates i.e. for crude oil prices and NEER estimates have a significant effect on the CPI of India. Crude oil prices and NEER estimates both in the case of 95% significance level and 90% significance level have a significant effect as p-value is less than 0.05. All other variables have coefficient values nearly equal to 0 as their p values are greater than 0.1 so we do not reject null in those cases.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 90.0%	Upper 90.0%
Intercept	-0.002084394	0.002114674	-0.985681358	0.330070854	-0.006355064	0.002186276	-0.00564313	0.001474343
INDIA OUTPUT GAP	-1.3456E-06	1.1895E-05	-0.113123029	0.910485112	-2.5368E-05	2.26768E-05	-2.1363E-05	1.86722E-05
GLOBAL OUTPUT GAP	-3.41902E-07	3.81734E-07	-0.895654091	0.375666077	-1.11283E-06	4.29026E-07	-9.8431E-07	3.0051E-07
EXPECTED INFLATION INDIA (LOG DIFFERENCES Q ON Q)	0.003867649	0.002902385	1.332576246	0.190029905	-0.001993836	0.009729134	-0.00101671	0.008752009
CRUDE OIL PRICES	0.032098083	0.013977679	2.296381401	0.026837095	0.003869587	0.06032658	0.008575354	0.055620813
NEER ESTIMATE	0.398307995	0.176917463	2.251377499	0.029784723	0.04101593	0.755600059	0.100577489	0.696038501
QUADRATIC NEER ESTIMATE	0.111805017	0.204914377	0.545618219	0.58828484	-0.302027962	0.525637997	-0.23304088	0.456650915
CUBIC NEER ESTIMATE	-0.027122708	0.077164823	-0.351490582	0.72702034	-0.182960229	0.128714812	-0.15698169	0.102736274

Post-crisis including crisis quarters (2008Q3-2022Q4)

Through this regression we get to know from the significance value of F that our model is reliable as our value for F is less than 0.05 (as per 95% confidence interval) which shows we reject the null hypothesis and not all coefficient values are equal to 0. Furthermore from the small adjusted R square value we can say that the association between our dependent variable i.e. CPI and all the other independent variables considered is not strong enough.

Regression Statistics	
Multiple R	0.494295298
R Square	0.244327841
Adjusted R Square	0.136374676
Standard Error	0.015198824
Observations	57

ANOVA					
	df	SS	MS	F	Significance F
Regression	7	0.003659785	0.000522826	2.263276301	0.044490858
Residual	49	0.011319208	0.000231004		
Total	56	0.014978993			

Here from the table below we can see the p-values and find that only one estimate i.e. for crude oil prices has a significant effect on the CPI of India. Crude oil prices estimate in the case 90% significance level has a significant effect as p-value is less than 0.1. For 95% significance level the p-value is slightly greater than 0.05. All other variables have coefficient values as 0 as their p values are greater than 0.1 so we do not reject null in those cases.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 90.0%	Upper 90.0%
Intercept	0.001231733	0.002257215	0.545686947	0.587756916	-0.003304311	0.005767777	-0.002552603	0.005016069
INDIA OUTPUT GAP	-7.68123E-07	1.73692E-06	-0.442233129	0.660266379	-4.25859E-06	2.72235E-06	-3.68016E-06	2.14391E-06
GLOBAL OUTPUT GAP	2.04433E-07	2.67969E-07	0.762900139	0.44918029	-3.3407E-07	7.42937E-07	-2.4483E-07	6.53697E-07
EXPECTED INFLATION INDIA (LOG DIFFERENCES Q ON Q)	-0.002810026	0.003464696	-0.8110455	0.421261637	-0.009772593	0.004152541	-0.008618765	0.002998713
CRUDE OIL PRICES	0.017107842	0.008626248	1.983230984	0.052960705	-0.000227252	0.034442936	0.002645498	0.031570185
NEER ESTIMATE	0.113138619	0.177615322	0.636986823	0.527098406	-0.243792733	0.470069971	-0.184642507	0.410919745
QUADRATIC NEER ESTIMATE	-0.114426651	0.200209604	-0.571534275	0.570250052	-0.516762914	0.287909612	-0.450088242	0.22123494
CUBIC NEER ESTIMATE	-0.085550437	0.073473631	-1.164369264	0.249912296	-0.233201226	0.062100352	-0.208732718	0.037631844

Post-crisis Excluding crisis Quarters (2009Q3-2022Q4)

Through this regression we get to know from the significance value of F, that our model is not reliable as our value for F is greater than 0.05 (as per 95% confidence interval) which shows we do not reject the null hypothesis and all coefficient values are equal to 0. Furthermore from the small adjusted R square value we can say that the association between our dependent variable i.e. CPI and all the other independent variables considered is not strong enough.

Regression Statistics	
Multiple R	0.475403723
R Square	0.226008699
Adjusted R Square	0.105610053
Standard Error	0.015035884
Observations	53

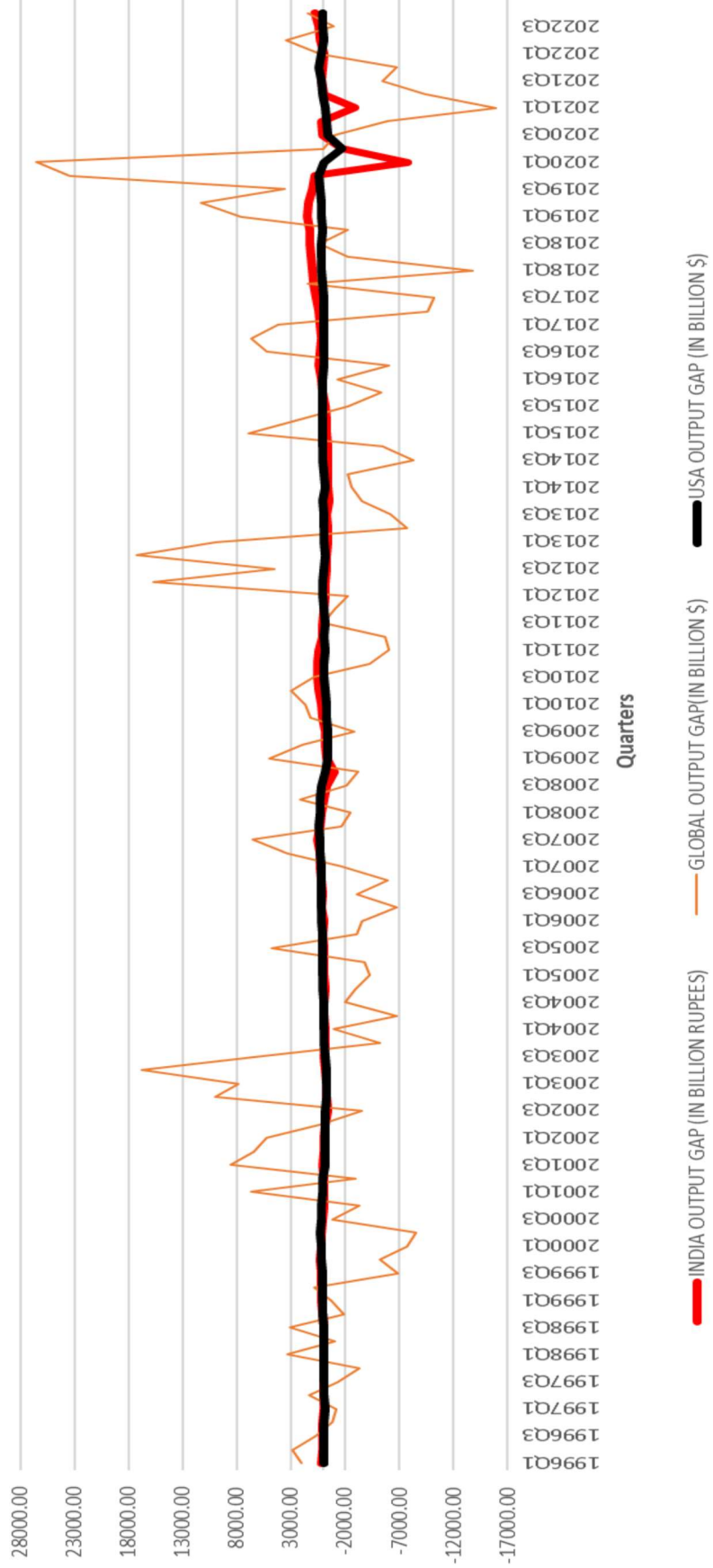| ANOVA					
	df	SS	MS	F	Significance F
Regression	7	0.002970705	0.000424386	1.877169765	0.095875548
Residual	45	0.010173502	0.000226078		
Total	52	0.013144207			

From the below table, we can see that all p values are greater than 0.1 and so none of the variables have a significant impact on CPI for India in this case.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 90.0%	Upper 90.0%
Intercept	0.00076631	0.002294987	0.333905949	0.740001626	-0.003856032	0.005388651	-0.003087954	0.004620574
INDIA OUTPUT GAP	-1.8011E-07	1.73957E-06	-0.103536858	0.917996959	-3.68378E-06	3.32356E-06	-3.10159E-06	2.74137E-06
GLOBAL OUTPUT GAP	2.66241E-07	2.68714E-07	0.990797672	0.327082281	-2.74976E-07	8.07458E-07	-1.85044E-07	7.17526E-07
EXPECTED INFLATION INDIA (LOG DIFFERENCES Q ON Q)	-0.003863692	0.0035003	-1.103817307	0.27554013	-0.010913658	0.003186274	-0.009742192	0.002014808
CRUDE OIL PRICES	0.013889006	0.009353884	1.484838375	0.144558563	-0.004950684	0.032728695	-0.001820163	0.029598175
NEER ESTIMATE	0.099991917	0.186253234	0.536860034	0.594008888	-0.275141352	0.475125186	-0.212806865	0.4127907
QUADRATIC NEER ESTIMATE	-0.113918274	0.212544681	-0.535973298	0.594616539	-0.542005236	0.314168689	-0.470871633	0.243035086
CUBIC NEER ESTIMATE	-0.081225619	0.077844035	-1.043440505	0.302317594	-0.238011553	0.075560315	-0.211959023	0.049507785

From the above regression we can see that for the case of India in the Pre-crisis period and the full sample period only crude oil prices and NEER estimates have some effect on the CPI of India and not any of the other variables. Also, we can see that the effect of all the variables including the Indian and global output gaps, crude oil prices and NEER estimates declines as we move towards the post-crisis period and in the post-crisis period they seem to have no effect on the CPI of India.

OUTPUT GAP

Quarters

Legend:
- INDIA OUTPUT GAP (IN BILLION RUPEES)
- GLOBAL OUTPUT GAP(IN BILLION $)
- USA OUTPUT GAP (IN BILLION $)

Y-axis values:
- 28000.00
- 23000.00
- 18000.00
- 13000.00
- 8000.00
- 3000.00
- -2000.00
- -7000.00
- -12000.00
- -17000.00

X-axis values (Quarters):
1996Q1, 1996Q3, 1997Q1, 1997Q3, 1998Q1, 1998Q3, 1999Q1, 1999Q3, 2000Q1, 2000Q3, 2001Q1, 2001Q3, 2002Q1, 2002Q3, 2003Q1, 2003Q3, 2004Q1, 2004Q3, 2005Q1, 2005Q3, 2006Q1, 2006Q3, 2007Q1, 2007Q3, 2008Q1, 2008Q3, 2009Q1, 2009Q3, 2010Q1, 2010Q3, 2011Q1, 2011Q3, 2012Q1, 2012Q3, 2013Q1, 2013Q3, 2014Q1, 2014Q3, 2015Q1, 2015Q3, 2016Q1, 2016Q3, 2017Q1, 2017Q3, 2018Q1, 2018Q3, 2019Q1, 2019Q3, 2020Q1, 2020Q3, 2021Q1, 2021Q3, 2022Q1, 2022Q3

From the graph we can see that for most of the period from 1996 to 2022, India's output gap is well within the range indicating that it is actually producing as per its potential. But one can see during FY09, FY16, and FY22 there is a negative output gap. These are periods of extreme financial stress caused by the Global Financial Crisis, the Indian Banking Crisis and the COVID-19 pandemic. One can also notice that after each of these crises, there is a recovery period where the Indian economy overperformed. When seen in comparison with the USA output gap we can see that USA's output gap has been little more stable than that of India and in comparison with global output gap trend both USA and India have had a much more stable output gap trend.

Sources used:
1) India: CPI, NEER, GDP per capita, Real GDP https://www.bis.org/
2) Global GDP (Adjusted and weighted), Indian Inflation data: https://www.macrotrends.net/
3) Related files and calculations are stored in the zip folder shared