

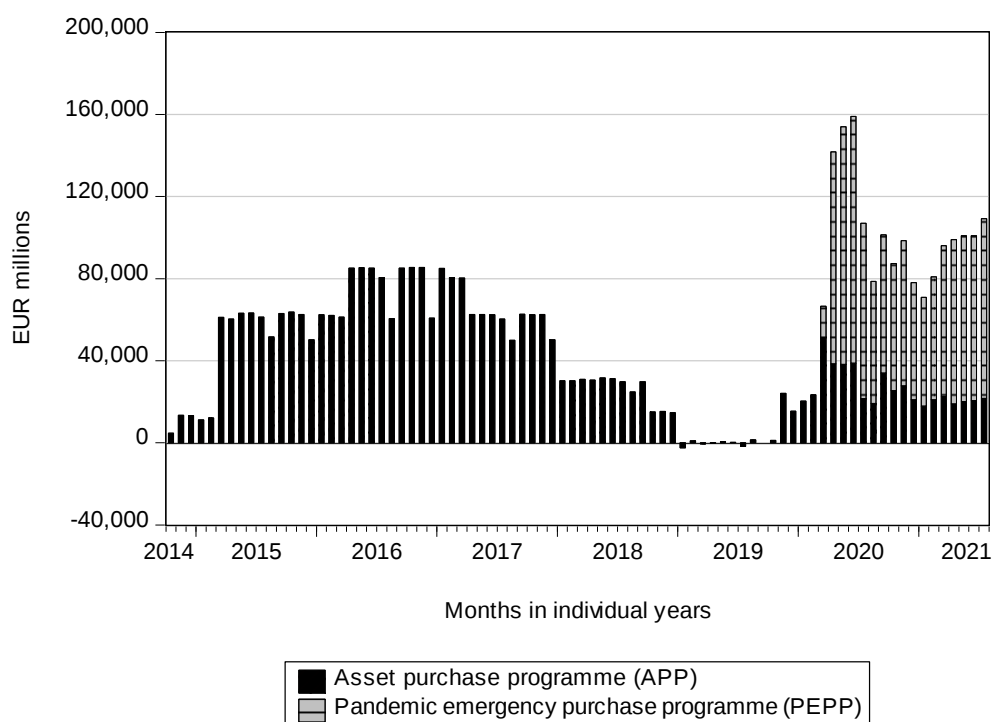
## SUPPLEMENTARY MATERIAL

**Table S1: Analysed economies and their characteristics**

| Group | Country (Abb.)      | Trade openness |     | Exchange rate volatility |                |     | Financial integration |     |
|-------|---------------------|----------------|-----|--------------------------|----------------|-----|-----------------------|-----|
|       |                     | %              |     | Regime                   | Volatility (%) |     | %                     |     |
|       |                     | GDP            | H/L |                          |                | H/L | GDP                   | H/L |
| NMOE  | Bulgaria (BG)       | 64.2           | H   | fixed                    | 0.2            | L   | -55.3                 | H   |
|       | Czech Republic (CZ) | 74.4           | H   | floating                 | 11.2           | H   | -28.8                 | L   |
|       | Hungary (HU)        | 82.2           | H   | floating                 | 10.0           | H   | -79.4                 | H   |
|       | Croatia (HR)        | 52             | L   | fixed                    | 1.8            | L   | -66.9                 | H   |
| NMCE  | Poland (PL)         | 55.5           | L   | floating                 | 6.8            | L   | -52.6                 | H   |
|       | Romania (RO)        | 40.4           | L   | floating                 | 18.2           | H   | -45.1                 | H   |
|       | Denmark (DK)        | 58.3           | x   | fixed                    | 0.1            | L   | 20.4                  | L   |
| OME   | United Kingdom (UK) | 31.1           | x   | floating                 | 12.8           | H   | -11.5                 | L   |
|       | Sweden (SE)         | 47.7           | x   | floating                 | 6.4            | L   | -8.5                  | L   |
| Mean  |                     | 56.2           |     |                          | 7.5            |     | -36.4                 |     |

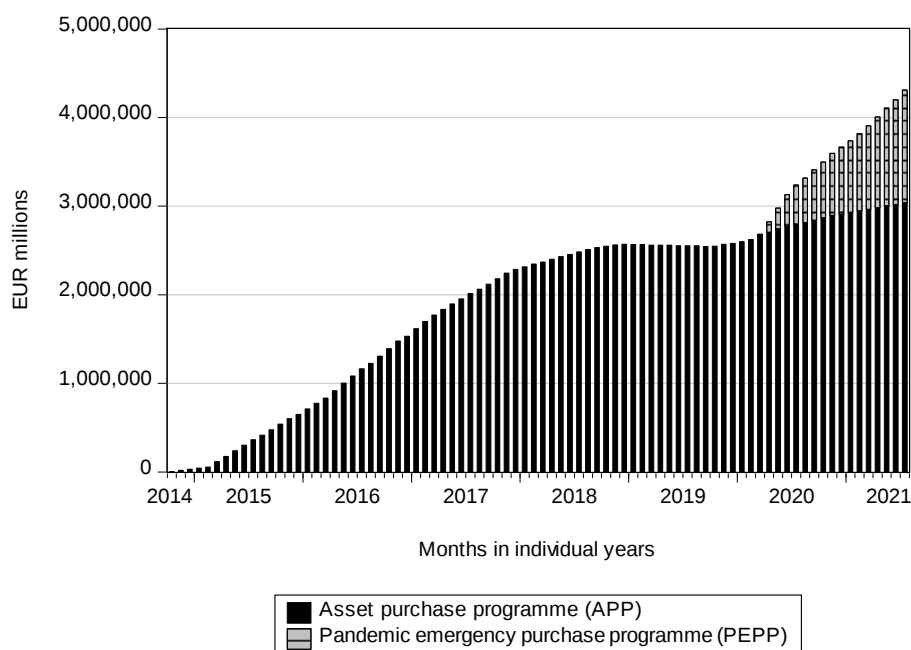
*Notes:* Economic openness is measured by the share of exports to GDP in 2019 according to Eurostat (2020). Exchange rate regime is based on the IMF de facto classification. Exchange rate volatility is calculated as the coefficient of variation (in percent) of the nominal exchange rate. We use The International Investment Position (IIP) by IMF to GDP ratio calculate financial integration. Countries with a value higher than the average of all countries are considered to have a high level (H). Countries with a low level (L) are those with a value lower than the average.

**Figure S1: ECB quantitative easing activity under the APP and PEPP programmes**



Note: In EUR millions, monthly values

**Figure S2: Cumulative quantitative easing by the European Central Bank under the APP and PEPP programmes**



Note: At amortised cost, in EUR millions, at month-end.

|                      | Financial crisis                                                            |                                                                                   | Sovereign debt crisis |                                                                   | Low-inflation recovery<br>(with lower bound constraint) |                                 |                         |                             | Pandemic era                                                                                                                                                                   |                                                                                                                                                                                                                                                                                        |                                                     |
|----------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------|---------------------------------------------------------|---------------------------------|-------------------------|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| Interest rate policy | +25bps<br>MRO:4.25%                                                         | -325bps<br>DFR:0.25%                                                              | +50bps<br>DFR:0.75%   | -75bps<br>DFR:0%                                                  | -20bps<br>DFR:<br>-0.20%                                | -20bps<br>DFR:<br>-0.40%        |                         | -10bps<br>DFR:<br>-0.50%    | Unchanged<br>DFR is negative                                                                                                                                                   |                                                                                                                                                                                                                                                                                        |                                                     |
| Credit operations    | Overnight FTOs<br>“Front-loading”<br>Maturity extension<br>Dec07<br>\$swaps | Oct08<br>FRFA<br>Expand. Collateral LTROs (6m)<br>\$ swaps<br>May09<br>LTROs (1y) |                       | Oct11<br>LTROs<br>Dec11<br>VLTRO I (3y)<br>Feb12<br>VLTRO II (3y) | Jun14<br>TLTRO I                                        | Mar16<br>TLTRO II               |                         | Mar7<br>TLTRO III           | <b>TLTRO III eased</b><br>Borrowing rate -25 to -75 bps (June2020 to June 2021)<br>borrowing allowance raised<br><b>Additional LTROs</b><br>Facilitating switch into TLTRO III | <b>TLTRO III eased further</b><br>Borrowing rate -50 to -100 bps (June 2020 to June 2021), depending on lending performance<br>Further easing of terms and conditions<br><b>PELTROs introduced</b><br>Interest rate of -25bps<br>Seven operations from May 2020, maturing by September |                                                     |
| Asset purchases      |                                                                             | May09<br>CBPP I                                                                   | May10<br>SMP I        | Aug11<br>SMP II<br>Oct11<br>CBPP II                               | Jun14<br>ABSPP<br>CBPP III                              | Dec15<br>APP I<br>Mar16<br>CSPP | Dec16<br>APP III (60bn) | Sep12<br>APP restart (20bn) | <b>APP expanded</b><br>Additional €120 billion in 2020, monthly                                                                                                                |                                                                                                                                                                                                                                                                                        | <b>PEPP expanded</b><br>Increase by €650 billion to |

|         |         |         |         |              |               |                  |                                                          |        |                                                                                                                                                                                                                                                                 |         |                                                                                                                                   |
|---------|---------|---------|---------|--------------|---------------|------------------|----------------------------------------------------------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------|
|         |         |         |         | Sep12<br>OMT | Jan15<br>PSPP | APP II<br>(80bn) | Oct17<br>APP<br>IV<br>(30bn)<br>Jun18<br>APP V<br>(15bn) |        | purchase of €20<br>billion and<br>reinvestments<br>NFC<br>commercial<br>paper made<br>eligible<br><b>PEPP</b><br><b>launched</b><br>€750 billion<br>envelope<br>Flexible<br>allocation<br>across time,<br>assets, countries<br>Wider<br>eligibility than<br>APP |         | €1,350 billion<br>and extension<br>by six months<br>until at least<br>June 2021<br>Reinvestments<br>at least until<br>end of 2022 |
| 08/2007 | 09/2008 | 05/2010 | 08/2011 | 06/2013      | 08/2015       | 12/2016          | 6/2018                                                   | 9/2019 | 03/2020                                                                                                                                                                                                                                                         | 04/2020 |                                                                                                                                   |

**Table S2: Overview of the implementation of the ECB's conventional and unconventional monetary policy since August 2007**

**Table S3: Correlation coefficients between GDP and IPI**

| Group | Country | Correlation coef. |
|-------|---------|-------------------|
|       | BG      | 0.646 ***         |
| NMOE  | CZ      | 0.450 ***         |
|       | HU      | 0.554 ***         |
|       | HR      | 0.875 ***         |
| NMCE  | PL      | 0.322 ***         |
|       | RO      | 0.516 ***         |
|       | DK      | 0.745 ***         |
| OME   | UK      | 0.410 ***         |
|       | SE      | 0.742 ***         |
|       | EA      | 0.889 ***         |

Note: Pearson correlation coefficient,  
\*\*\* represents 1% probability

**Table S4: ADF and KPSS unit root tests for variables in levels**

|           | BG      | CZ      | DK      | EA      | HR      | HU      | PL      | RO      | SE      | UK      |
|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| <i>y</i>  | -1.67   | -2.02   | -1.46   | -2.54   | -1.83   | -1.86   | -2.32   | -2.83   | -1.98   | -1.70   |
| <i>p</i>  | -0.68   | -1.65   | -0.16   | -1.84   | -0.40   | -1.24   | -1.34   | -3.07   | -1.56   | -2.07   |
| <i>i</i>  | -0.54   | -2.20   | -1.45   | -1.57   | -2.85*  | -1.28   | -       | -       | -1.88   | -1.63   |
| <i>R</i>  | -1.73   | -2.20   | -1.91   | -       | -3.57** | -3.28*  | -3.61** | -2.15   | -2.44   | -2.03   |
| <i>sr</i> | -       | -       | -       | 0.76    | -       | -       | -       | -       | -       | -       |
|           | BG      | CZ      | DK      | EA      | HR      | HU      | PL      | RO      | SE      | UK      |
| <i>y</i>  | 0.31*** | 0.19**  | 0.26*** | 0.15**  | 0.31*** | 0.20**  | 0.09    | 0.16**  | 0.17**  | 0.29*** |
| <i>p</i>  | 0.44*** | 0.2**   | 0.38*** | 0.43*** | 0.41*** | 0.40*** | 0.31*** | 0.45*** | 0.25*** | 0.22**  |
| <i>i</i>  | 1.23*** | 1.26*** | 1.48*** | 1.52*** | 1.33*** | 1.70*** | 1.36*** | 1.49*** | 1.49*** | 1.51*** |
| <i>R</i>  | 0.48*** | 0.40*** | 0.18**  | -       | 0.42*** | 0.43*** | 0.11    | 0.33*** | 0.16**  | 0.30*** |
| <i>sr</i> | -       | -       | -       | 1.73*** | -       | -       | -       | -       | -       | -       |

<sup>a</sup>  $H_0$  (ADF): There is a unit root

<sup>b</sup>  $H_0$  pro (KPSS): Variable is stationary

Notes: t-statistics for the ADF test and the LM-statistics for the KPSS test are reported at \* 10%, \*\* 5% and \*\*\* 1% level of significance. The time series for interest rates in Bulgaria is shortened to period from January 2000 to June 2018.

**Table S5: ADF and KPSS unit root tests for changes in variables (y-o-y)**

|           | BG     | CZ     | DK       | EA       | HR      | HU       | PL       | RO       | SE       | UK       |
|-----------|--------|--------|----------|----------|---------|----------|----------|----------|----------|----------|
| <i>y</i>  | -2.20  | -2.83* | -3.81*** | -3.79*** | -2.15   | -2.71**  | -3.65*** | -3.77*** | -3.69*** | -4.64*** |
| <i>p</i>  | -1.79  | -2.84* | -1.81    | -2.19    | -2.29   | -2.80*   | -2.61*   | -5.21*** | -1.95    | -2.52    |
| <i>i</i>  | -      | -      | -        | -        | -       | -        | -        | -        | -        | -        |
| <i>R</i>  | -1.69  | -2.75* | -2.22    | -        | -3.35** | -4.70*** | -3.56*** | -3.08*** | -3.25*** | -3.24*** |
| <i>sr</i> | -      | -      | -        | -        | -       | -        | -        | -        | -        | -        |
|           | BG     | CZ     | DK       | EA       | HR      | HU       | PL       | RO       | SE       | UK       |
| <i>y</i>  | 0.49** | 0.18   | 0.21     | 0.06     | 0.53**  | 0.14     | 0.09     | 0.06     | 0.08     | 0.15     |
| <i>p</i>  | 1.01** | 0.14   | 0.85***  | 0.72**   | 0.87**  | 1.11***  | 0.51*    | 1.36***  | 0.36**   | 0.24     |
| <i>i</i>  | -      | -      | -        | -        | -       | -        | -        | -        | -        | -        |
| <i>R</i>  | 0.98** | 0.25   | 0.18     | -        | 0.40*   | 0.47**   | 0.04     | 0.15     | 0.10     | 0.16     |
| <i>sr</i> | -      | -      | -        | -        | -       | -        | -        | -        | -        | -        |

<sup>a</sup>  $H_0$  (ADF): There is a unit root

<sup>b</sup>  $H_0$  pro (KPSS): Variable is stationary

Notes: t-statistics for the ADF test and the LM-statistics for the KPSS test are reported at \* 10%, \*\* 5% and \*\*\* 1% level of significance. We did not compute differences for interest rates and shadow rates.

**Table S6: ADF and KPSS unit root tests for changes in variables (m-o-m)**

|           | BG       | CZ       | DK       | EA       | HR       | HU       | PL       | RO       | SE       | UK       |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| <i>y</i>  | -20.2*** | -21.5*** | -15.6*** | -6.31*** | -21.8*** | -20.2*** | -19.5*** | -23.6*** | -21.2*** | -15.0*** |
| <i>p</i>  | -9.72*** | -12.7*** | -14.1*** | -2.52    | -13.6*** | -7.01*** | -9.14*** | -4.11*** | -14.5*** | -12.5*** |
| <i>i</i>  | -        | -        | -        | -        | -        | -        | -        | -        | -        | -        |
| <i>R</i>  | -11.3*** | -12.6*** | -5.78*** | -        | -12.8*** | -11.7*** | -10.6*** | -11.6*** | -13.2*** | -12.8*** |
| <i>sr</i> | -        | -        | -        | -        | -        | -        | -        | -        | -        | -        |
|           | BG       | CZ       | DK       | EA       | HR       | HU       | PL       | RO       | SE       | UK       |
| <i>y</i>  | 0.54**   | 0.18     | 0.12     | 0.07     | 0.25     | 0.13     | 0.07     | 0.04     | 0.09     | 0.09     |
| <i>p</i>  | 1.02***  | 0.11     | 0.94***  | 0.57**   | 0.95***  | 1.09***  | 0.50**   | 1.40***  | 0.31     | 0.25     |
| <i>i</i>  | -        | -        | -        | -        | -        | -        | -        | -        | -        | -        |
| <i>R</i>  | 0.98***  | 0.16     | 0.12     | -        | 0.36*    | 0.18     | 0.04     | 0.19     | 0.07     | 0.14     |
| <i>sr</i> | -        | -        | -        | -        | -        | -        | -        | -        | -        | -        |

<sup>a</sup>  $H_0$  (ADF): There is a unit root

<sup>b</sup>  $H_0$  pro (KPSS): Variable is stationary

Notes: t-statistics for the ADF test and the LM-statistics for the KPSS test are reported at \* 10%, \*\* 5% and \*\*\* 1% level of significance. We did not compute differences for interest rates and shadow rates.

**Table S7: Moduli of roots of a characteristic polynomial for individual models**

| Modul | BG    | CZ    | DK    | HR    | HU    | PL    | RO    | SE    | UK    |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| M1    | 0.976 | 0.996 | 0.964 | 0.975 | 0.989 | 0.985 | 0.976 | 0.975 | 0.996 |
| M2    | 0.976 | 0.972 | 0.964 | 0.963 | 0.967 | 0.964 | 0.960 | 0.975 | 0.971 |
| M3    | 0.953 | 0.956 | 0.944 | 0.897 | 0.906 | 0.964 | 0.952 | 0.954 | 0.943 |
| M4    | 0.953 | 0.956 | 0.944 | 0.897 | 0.906 | 0.952 | 0.952 | 0.925 | 0.943 |
| M5    | 0.872 | 0.916 | 0.814 | 0.897 | 0.899 | 0.914 | 0.844 | 0.925 | 0.935 |
| M6    | 0.872 | 0.916 | 0.752 | 0.799 | 0.899 | 0.914 | 0.844 | 0.875 | 0.935 |
| M7    | 0.633 | 0.672 | 0.752 | 0.771 | 0.754 | 0.776 | 0.758 | 0.676 | 0.659 |
| M8    | 0.618 | 0.536 | 0.584 | 0.474 | 0.650 | 0.551 | 0.620 | 0.611 | 0.412 |
| M9    | 0.386 | 0.536 | 0.584 | 0.474 | 0.303 | 0.373 | 0.427 | 0.204 | 0.412 |
| M10   | 0.386 | 0.343 | 0.385 | 0.377 | 0.303 | 0.330 | 0.346 | 0.271 | 0.216 |
| M11   | 0.289 | 0.277 | 0.343 | 0.284 | 0.287 | 0.330 | 0.140 | 0.198 | 0.216 |
| M12   | 0.242 | 0.245 | 0.226 | 0.095 | 0.287 | 0.324 | 0.183 | 0.114 | 0.140 |
| M13   | 0.242 | 0.245 | 0.072 | 0.095 | 0.107 | 0.324 | 0.145 | 0.114 | 0.120 |
| M14   | 0.003 | 0.078 | 0.070 | 0.020 | 0.036 | 0.035 | 0.145 | 0.014 | 0.120 |

Note: A value less than 1 indicates that the model is stable.

**Table S8: Lag selection criteria**

|    | FPE | AIC | SC | HQ |
|----|-----|-----|----|----|
| BG | 2   | 2   | 1  | 2  |
| CZ | 2   | 2   | 2  | 2  |
| DK | 2   | 2   | 2  | 2  |
| HR | 2   | 2   | 1  | 2  |
| HU | 2   | 2   | 1  | 2  |
| PL | 6   | 6   | 2  | 2  |
| RO | 2   | 2   | 2  | 2  |
| SE | 4   | 4   | 1  | 2  |
| UK | 2   | 2   | 1  | 2  |

Note: The values indicate the selected lags of the model according to individual information criterion

**Table S9: Summary of the results**

|                                  | BG | CZ | H<br>U | HR | PL | RO | D<br>K | U<br>K | S<br>E |
|----------------------------------|----|----|--------|----|----|----|--------|--------|--------|
| <hr/>                            |    |    |        |    |    |    |        |        |        |
| (a) Whole sample (interest rate) |    |    |        |    |    |    |        |        |        |
| Output ( $y$ )                   | –  | –  | –      |    | –  |    | –      | –      | –      |
| Price level ( $p$ )              |    | –  |        |    |    |    | –      | –      |        |
| Interest rate ( $i$ )            |    |    |        |    |    |    | +      | +      | +      |
| Real exchange rate ( $e$ )       |    |    | –      | –  |    |    | –      |        | –      |
| <hr/>                            |    |    |        |    |    |    |        |        |        |
| (b) Whole sample (shadow rate)   |    |    |        |    |    |    |        |        |        |
| Output ( $y$ )                   | –  | –  | –      | –  | –  | –  | –      | –      | –      |
| Price level ( $p$ )              | –  | –  | –      | –  | –  | –  | –      | –      | –      |
| Interest rate ( $i$ )            | –  | –  |        |    | –  | –  |        |        |        |
| Real exchange rate ( $e$ )       | +  | +  |        |    | +  |    | –      |        | –      |
| <hr/>                            |    |    |        |    |    |    |        |        |        |
| (c) 2001M01-2008M8               |    |    |        |    |    |    |        |        |        |
| Output ( $y$ )                   | –  | –  | –      |    | –  | –  |        | –      | –      |
| Price level ( $p$ )              | +  | +  |        | +  |    | +  | +      | +      | +      |
| Interest rate ( $i$ )            | +  |    |        | –  | –  |    | +      | +      | +      |
| Real exchange rate ( $e$ )       | –  |    | –      | –  | +  |    | –      |        |        |
| <hr/>                            |    |    |        |    |    |    |        |        |        |
| (d) 2008M09-2020M02              |    |    |        |    |    |    |        |        |        |
| Output ( $y$ )                   | –  | –  | –      | –  | –  | –  | –      | –      | –      |
| Price level ( $p$ )              | –  | –  | –      | –  | –  | –  | –      | –      | –      |
| Interest rate ( $i$ )            |    | –  |        | –  | –  | –  |        | –      |        |
| Real exchange rate ( $e$ )       |    | +  | –      | –  | +  |    | –      |        | –      |
| <hr/>                            |    |    |        |    |    |    |        |        |        |
| (c*) 2001M01-2008M8              |    |    |        |    |    |    |        |        |        |
| Output ( $y$ )                   | –  | –  | –      | –  | –  | –  | –      | –      | –      |
| Price level ( $p$ )              | –  | –  | –      | –  |    |    | –      | –      | +      |
| Interest rate ( $i$ )            | +  |    | –      | –  | –  |    | +      | +      | +      |
| Real exchange rate ( $e$ )       | +  | +  | –      | –  |    | +  | –      | –      | –      |

*Note:* The symbols (+, -) indicate the sign of the impulse-response analysis. We report only statistically significant peaks in the response to a foreign exchange shock (ea). Due to the small number of observations and bias in the results for model (c), we modified the sign restrictions (c\*). We applied an additional restriction on the evolution of the price level in the EA (-) after monetary tightening in the first three months. However, the restriction is still consistent with economic theory and does not invalidate the analysis of monetary policy spillovers.