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Spillover effects of the European Central Bank's Expanded Asset Purchase Program to non-eurozone countries in Central and Eastern Europe

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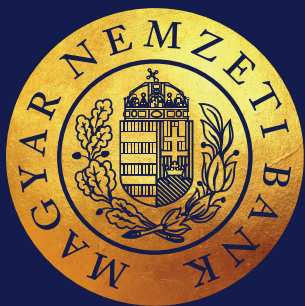
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MARK ANTAL | LORANT KASZAB

SPILOVER EFFECTS OF THE EUROPEAN CENTRAL BANK'S EXPANDED ASSET PURCHASE PROGRAM TO NON-EUROZONE COUNTRIES IN CENTRAL AND EASTERN EUROPE

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The views expressed are those of the authors' and do not necessarily reflect the official view of the Central Bank of Hungary (Magyar Nemzeti Bank).

MNB Occasional Papers 2021/140

Spillover Effects of the European Central Bank's Expanded Asset Purchase Program to Non-eurozone Countries in Central and Eastern Europe

(Az Európai Központi Bank eszközvásárlási programjainak spillover hatásai a közép-kelet-európai országokra)

Written by Mark Antal *, Lorant Kaszab ** ***

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Abstract

For a panel of six Central and Eastern European countries outside the eurozone (Bulgaria, Croatia, Czechia, Hungary, Poland and Romania) we estimate the spillover effects of the European Central Bank's Expanded Asset Purchase Program (APP) on exchange rates, equity prices, government bond yields of various maturities, and CDS spreads. We find that the most pronounced spillovers induced sovereign bond yields to drop by around 1-6 basis points in a two-day time window in response to the Public Sector Purchase Program (PSPP) announcements.

JEL: E51, E32, E44, F45, F47.

Keywords: ordinary least squares estimation, panel data, unconventional monetary policy.

Összefoglaló

Az Európai Központi Bank eszközvásárlási programjának spillover hatásait becsüljük hat, eurozónán kívüli közép-kelet-európai ország (Bulgária, Csehország, Horvátország, Lengyelország, Magyarország, Románia) mintáján az valutaárfolyamokra, a részvény és kötvényhozamokra (több lejáraton), és a kockázati felárakra. Azt találjuk, hogy a PSPP program hatására átlagosan 1-6 bázisponttal csökkentek a kötvényhozamok a bejelentést követő napon.

1 Introduction

In response to the recent financial crises the European Central Bank (ECB) implemented unconventional monetary policy (UMP) to stimulate economic growth and guide inflation back to the target rate of close to but below two percent after the base rate reached its zero lower bound. Initial programs included the first covered-bond purchase program (CBPP) in 2009 and the Securities Market Program (SMP) in 2010. From 2011 the ECB offered funding to banks for appropriate collateral (with haircuts) under the Long-term Refinancing Operations Program (LTRO). In 2014 the ECB implemented the third CBPP program (CBPP3) and the Asset-backed Securities Purchase Program (ABSPP). The Public Sector Purchase Program (PSPP) which is part of the expanded Asset Purchase Program (APP) induced the greatest rise in the balance sheet of the ECB so far (see Figure (1)). Over 2015-2017 the assets purchased under the PSPP amounted to about 15 per cent of the eurozone's GDP on average per quarter (see Figure (2)). The Corporate Sector Purchase Program (CSPP) was launched in March 2016. Figure (3) shows that the introduction of CBPP3 and ABSPP in 2014 and the launch of the PSPP in 2015 reinforced the downward trend in the sovereign bond yields of CEE countries.¹ The figure also shows that the CSPP program had more limited effects on the yields.

Unconventional monetary policies in the US and the eurozone had strong spillovers effects which were more studied in the US (Aizenman et al. (2014), Anaya et al. (2017), Chen et al. (2014), Gagnon et al. (2011), Tillmann (2016)) but less in the eurozone. Several papers found that ECB asset purchases decreased long-term bond yields in eurozone countries. For instance, Afonso and Kazimi (2018) find significant reduction in the 10-year yield spread using a panel of 10 euro area countries over 1999 January and 2016 July. In line with the literature they find that the reduction in the sovereign long-term bond yields of several eurozone periphery countries (Greece, Italy, Portugal and Spain) was higher than in the core countries such as France and Germany. However, somewhat less focus has been devoted to the spillover effects on Central and Eastern European (CEE) countries.

This paper, on the one hand, contributes to the empirical literature by exploring the effects of 19 more recent APP announcements (including PSPP announcements as well as the major CSPP announcements) focusing on exchange rates, stock exchange yields, government bond yields of various maturities, and credit default swaps (CDS) on a panel of six CEE countries (Bulgaria, Croatia, the Czech Republic, Hungary, Poland, and Romania) between 01/01/2014 and 02/28/2017 in a two-day time-window. We apply an impulse event approach through ordinary least squares regressions with numerous control variables included. Our paper also covers the later announcements related to the PSPP (following the first announcement on 22 January 2015), and more importantly we assess the impact stemming from the major CSPP announcements starting from March 2016. Further, our paper differentiates among the effects of individual programs within the expanded APP. The expanded APP on its mature period consisted of four operating programs that are different in terms of magnitude and purchasable universe as well.

Our results from the panel regressions show that the cumulative spillover effect after all nineteen APP events is very limited for CEE countries. In particular, APP induced a statistically significant reduction in the government bond yields with maturities ranging from one to five years by two basis points on average one day after the APP announcements. We consider two-day time windows for impulse events to allow for a one-day delay for the impacts to materialise. The underlying reasoning is that the press conferences revealing monetary policy announcements take place at 2.30 PM CET at the ECB, only a few hours from close of business. As peripheral markets are considered to be less liquid, it is justifiable to account for some delay until spillovers transmit. We intend to control for confounding factors stemming from economic events of the subsequent days by including macroeconomic events and economic surprise indices.

We also consider a break-down of the expanded APP into subprograms and find that the PSPP shocks affect all asset classes except for equity prices. Specifically, PSPP decreases the bond yields and CDS spreads of the CEE countries by two to four basis points across maturities. The PSPP is also associated with a small but statistically significant appreciation of the exchange rates of the relevant² CEE countries by 0.74 percent on average relative to the euro. Literature suggests that purchases as impulse

¹ In the interest of space we only plot the 5-year yields but similar declining pattern can be observed for the one-, three-, and ten-year maturities as well.

² The Czech koruna and the Bulgarian lev have been excluded from this regression as the former was capped at 27 korunas per euro from November 2013 till April 2017, whereas the latter is pegged to the euro at a 1.95583 leva per euro rate.

events carry limited information and it is only the first day of purchases at best that may have a significant effect on asset prices (Andrade et al. 2016). In line with these findings, we include a variable for the first days of program implementations but identify only limited impacts.

On the other hand, we attempt to identify some of the relevant transmission channels, through which ECB monetary policies affect financial markets outside the currency area.³ In particular, we consider how measures of volatility and inflation are affected by APP announcements. Our regressions mainly capture the confidence and signaling channel although the literature also pointed to the importance of other channels such as the exchange rate channel or the portfolio rebalancing channel through which spillovers can occur. The confidence channel identifies the benign effects of the APP on market volatility while the signaling channel aims to capture the positive reaction of inflation i.e. guiding inflation and inflation expectations back to the target.

We are closely related to Georgiadis and Gräb (2016) and Falagiarda et al. (2015) whose sample end in February 2015. In particular, Georgiadis and Gräb (2016) investigated the impacts of 14 APP-related events between September 2014 and February 2015, and considered 39 trading partners of the eurozone. They found that there were statistically significant spillovers to non-euro area European Union (EU) countries in terms of exchange rates, equity prices, and government bond yields.⁴ Falagiarda et al. (2015) examined how selected UMP events of the ECB spilled over to CEE non-euro area EU countries. More specifically, they assessed the effects in response to SMP, OMT, and PSPP shocks on the Czech Republic, Hungary, Poland, and Romania over the 2007-2015 period. Their research showed that the spillovers from the SMP were the most pronounced whereas those of the OMT and the PSPP were more muted. The latter two studies, however, do not include the more recent developments in the ECB's policy measures: neither are the latest news about PSPP included, nor the introduction of the corporate sector purchase program (CSPP).

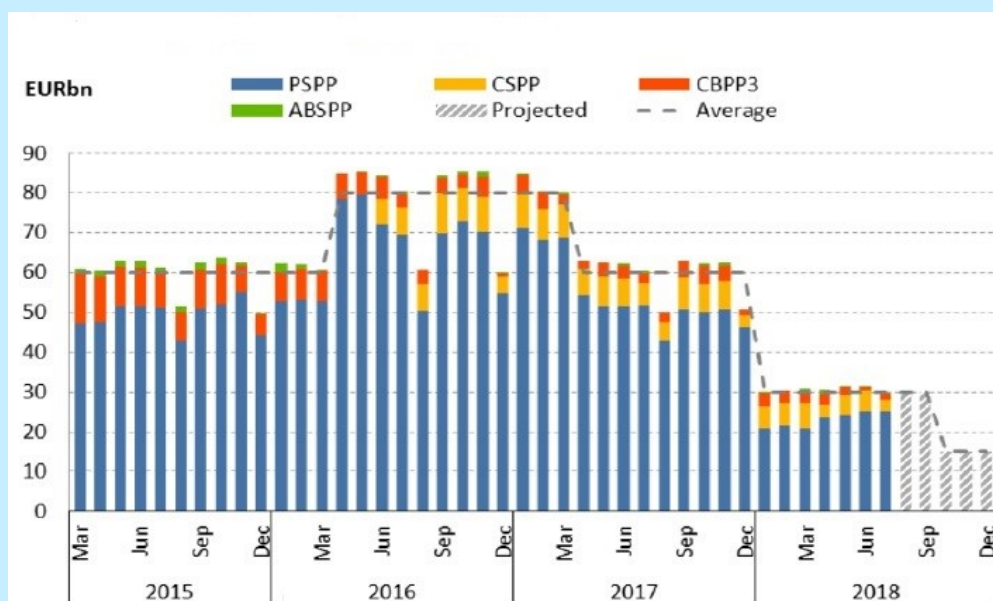
We are also related to the literature which aims to measure the spillover effects from the programs of the Fed and the ECB to several groups of countries. These papers use the shadow interest rate to capture the effects of unconventional policies at the zero lower bound. Feldkircher et al. (2017), Potjagailo (2017) and Hajek and Horvath (2018) use Bayesian global VAR model and study the spillover effects of ECB's unconventional monetary policy proxied by the shadow nominal interest rate. The papers by Hajek and Horvath (2016) as well as Horvath and Voslarova (2017) also consider spillover effects to non-eurozone countries but their samples end in 2014. Different from our paper De Santis (2020) uses market news to identify monetary policy shocks (asset purchases) but focuses on the euro area exclusively.

The structure of the paper is as follows: section 2.1 discusses the data, the outcome and explanatory variables used in the regressions. Section 2.2 reviews panel regression models applied and results from the regressions between asset yields, exchange rates, CDS spreads and APP announcements. Section 2.3 consider time-series regressions to measure the confidence and signalling channels of the APP. Finally, we conclude.

³ The analysis in this paper does not cover terminated programs within the APP such as the SMP, OMT, CBPP, and CBPP2, as those were implemented in very different economic cycles. Further, we do not elaborate on the impact of program implementation as literature suggests that the surprise element of purchases is limited and declines beyond the first day of purchases.

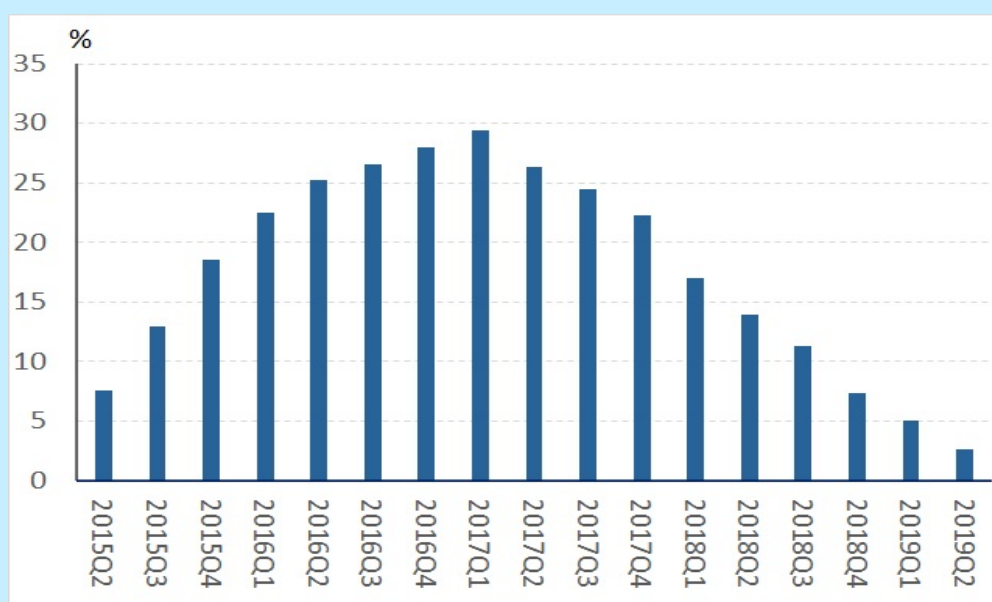
⁴ Note that although the authors included CEE countries among others, their primary focus was on world-wide effects, hence they do not differentiate among CEE countries.

Figure 1
Expanded Asset Purchases by programme



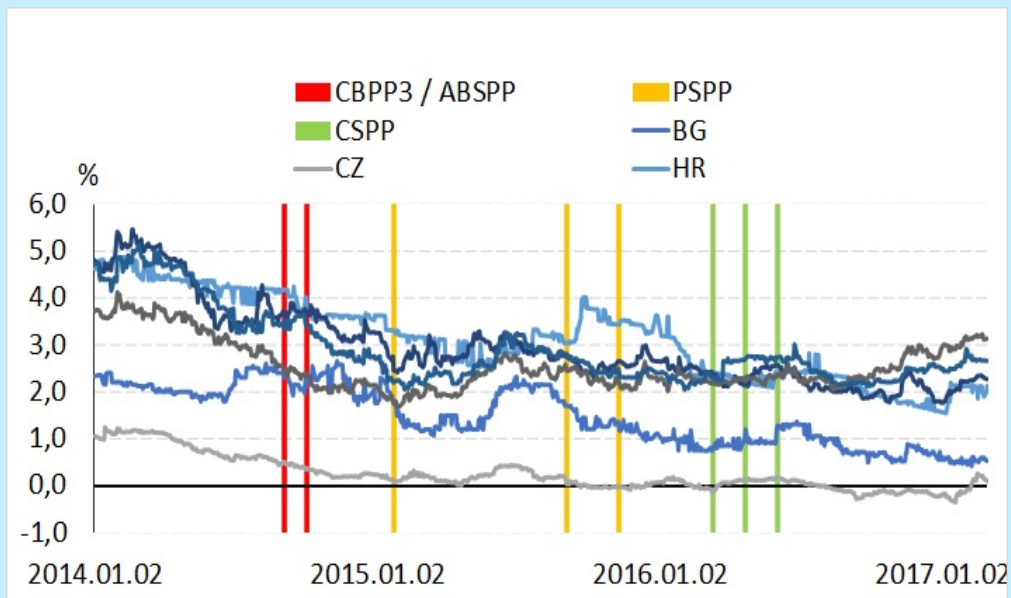
Source: ECB. CBPP3 is the third Covered Bond Purchase Program. ABSPP is the Asset-backed Securities Purchase Program. PSPP is the Public Sector Purchase Program. CSPP is the Corporate Sector Purchase Program.

Figure 2
Public Sector Purchases Programme as a fraction of euroarea GDP



Source: ECB and Eurostat

Figure 3
Sovereign bond yields and program announcements of the ECB



Notes: Each yield refers to annualised benchmark bond yields expressed in percent.

2 Model and data

We use an event-study approach similar to Falagiarda et al. (2015), Fratzscher et al. (2014), and Georgiadis and Gräb (2016) whereby we measure the effect of APP-related events (dummies) on financial indicators (see the subsections 'Outcome variables', 'Impulse events' and 'Control variables' below for a detailed description of the outcome and explanatory variables used in the regressions). Specifically, we consider simple ordinary least squares (OLS) regressions with daily data frequency in panel as well as time-series setups in line with the literature listed above. The main argument for the OLS is that the interpretation of results is straightforward. However, OLS poses limits on the robustness of the results due to the strong assumptions of the framework which we discuss below.

2.1 DATA DESCRIPTION

We retrieved daily data on asset prices via Thomson Reuters Eikon for the period between 01/01/2014 and 02/28/2017. For the complete list of financial time-series with more detailed description, refer to Appendix A. We consider either a panel or time-series framework. In the panel framework, non-trading days were dropped by default which led to a strongly balanced dataset over 812 days and 6 countries. Concerning the time series analyses, the applied estimator requires regularly spaced data, hence the length of the series varied across asset classes, ranging between 600 and 800 observations. For each series, the number of observations is indicated at the bottom of the output tables.

There are possible caveats related to the use of daily data frequency which a number of studies avoid by using high-frequency data. For instance, Ghysels et al. (2014) evaluate the effects of SMP using high-frequency intraday data in fifteen-minute time windows. The use of high-frequency data helps to identify the intervention in question and helps to avoid the endogeneity problem that might arise because the ECB applies SMP to offset another market impact that had previously affected asset prices. For instance, the ECB may also intervene to prevent the excessive increase of bond yields on the same day when the shock appears. If the intervention perfectly offsets the preceding market shock, the overall effect of the SMP intervention is zero when working with daily or weekly data. Whereas using time windows of a couple of minutes, one can identify the direct and immediate effect of the intervention.

Swanson (2011) applies high-frequency methodology⁵ to analyze the effects of six Federal Reserve Operation Twist announcements⁶. Besides addressing the endogeneity issue, their method can offset the long-term government bond yields' sensitivity to expectations about main macroeconomic aggregates such as the expectations about future inflation. Further, one can rule out that a third confounding shock distorts the results since a confounding shock is unlikely to occur within the exact same fifteen-minute time window.

We opt to work with daily data nevertheless, because the above concerns do not apply to the present study for the following reasons. First, there is no endogeneity issue since we deal with non-euro area countries and it is unlikely that the ECB would implement policies in response to developments in one of these countries. Second, we include control variables for macroeconomic announcements and other economic surprises occurring on the days of the announcements. Thus, we can avoid the confounding effect of other events. Third, the ECB has consistently articulated that its only target measure is inflation and does not maintain other goals with respect to exchange rate, bond yield, etc.

Furthermore, our event-study approach is subject to the caveat that it is built upon the strong assumption that markets are efficient. Although the depth of markets is not deterministic in terms of the realization of spillovers (Georgiadis and Gräb (2016)), markets of the periphery, non-eurozone countries are likely to be less efficient than the core countries of the EU, hence

⁵ See, e. g. Altavilla et al. (2019) for a recent application of tick-data on the effect of the ECB monetary policy announcements on the yield curve.

⁶ In the Operation Twist, the Fed rebalances the amount of short versus long-term government bonds in its portfolio depending on its goal. Hence, depending on its target yield curve the Fed purchases maturities whose yields it aims to reduce and vice versa. Swanson finds that the impacts of QE and Operation Twist are similar in magnitude.

wider event windows are more favorable. Since our interest is in the international spillover effects, transmission lags can take longer than 15 to 60 minutes, hence daily data is suitable for such analyses (Falagiarda et al. (2015)). The following three subsections discuss the outcome and explanatory variables, respectively.

2.1.1 OUTCOME VARIABLES

We uncover whether APP-related events affected financial indicators (outcome variables) such as bond yields of various maturities, stock market indices, exchange rates and CDS spreads outside the eurozone. For bilateral euro exchange rates and main stock market indices we observe percentage changes between daily close prices. Regarding exchange rates, we exclude the Czech koruna and the Bulgarian lev since the former was capped at 27 korunas per euro from November 2013 till April 2017, whereas the latter is pegged to the euro at a 1.95583 leva per euro rate. Equity prices are represented by the main stock exchange indices of each country, hence the impact on daily returns of SOFIX, CRBEX, PX, BUX, WIG, and BETI are measured.

As for government bond yields, we consider benchmark bonds which are sufficiently liquid and, thus, comparable on a day-to-day basis. Bond yields are measured in basis point changes of daily close prices. CDS spreads serve as a mark-up on the risk of a country's default risk, hence an important component of countries' debt financing. We retrieved data on the most commonly referred 5-year spreads and calculated daily basis point changes. Due to the transformations above, the Phillips-Perron test shows that neither of the series contain unit root and, hence, data is considered to be stationary.

We construct data and run time-series regressions to identify the confidence and the signaling channels of unconventional monetary policy. When identifying these channels, numerous studies look at the values of assets that are linked to some sort of market performance measure (Falagiarda et al. (2015), Fratzscher et al. (2014), Georgiadis and Gräb (2016)). Regarding the confidence channel, stock market volatility gauges the riskiness of the market and, thus, a eurozone volatility index is suitable to identify the relevance of the channel. The signaling channel is closely related to inflation expectations and, therefore, inflation-linked assets that are traded large-scale can be good indicators of the channel. The lack of a volatility index and inflation-linked assets in the periphery of the EU makes it difficult to identify the relevant channels.

If the market of these inflation-linked assets existed, they would probably be highly and positively correlated with those in euro area markets due to the increasing degree of financial integration of peripheral EU countries (Falagiarda et al. 2015); hence, we consider the following two assets. The VSTOXX index (V2TX) represents the volatility of the Euro Stoxx 50 Index which is one of the leading indices of the euro area, covering 50 blue-chip shares from 11 countries⁷.

The Amundi ETF Euro Inflation UCITS exchange-traded fund incorporated in the Paris Stock Exchange (CI3.PA) tracks the Markit iBoxx Euro Inflation-linked Index, and, therefore, it is a representative of inflation-linked government bonds of several eurozone countries. According to the Bloomberg, the price of a unit of the ETF is approximately equal to the Markit iBoxx Euro Inflation Linked Index in Euros⁸. Similar to the case of other equity prices, we take the daily returns on these assets to have stationary time series.

2.1.2 IMPULSE EVENTS

The main explanatory variables of the analysis are daily event dummies, taking the value of one on announcement days and zero elsewhere. We consider nineteen days when significant APP-related events took place: primarily, remarkable press releases or press conferences with Q&A sessions about the announcement of new programs or substantial modification of the running programs.

The first days of the asset purchase events are also included as a separate variable (see *Purchase* in regression (2) and (3)) since the start of the PSPP was found to be associated with statistically significant asset price changes in the eurozone. In particular, Andrade et al. (2016) found that the first day of PSPP purchases revealed new information on the program, and, thus, implied statistically significant changes in asset prices. Hence, we take the first days of executions for each program as APP-related events. For the full list of APP-related events, refer to table (5) in the Appendix.

⁷ For more detail, see: <https://www.stoxx.com/index-details?symbol=V2TX>; accessed on May 5, 2017.

⁸ For more detail, see: <https://www.bloomberg.com/quote/CI3:FP>; accessed on May 5, 2017.

Without specific selection criteria, the sampling of impulse events may leave room for manipulation of the results. Hence, we opt to include all press releases and press conferences⁹ announced on the ECB's website that were related to any of the four programs within the expanded APP between 01/01/2014 and 02/28/2017. By doing so, we avoid to arbitrarily judge the significance of the announcements. However, when clustering events with respect to their targeted program, we consider only the most remarkable announcements per program, hence we manage to grasp the obvious differences among shocks in terms of economic relevance.

2.1.3 CONTROL VARIABLES

To ensure that the effects of the impulse events show the true impact on the financial markets in question, one must control for other factors potentially distorting the results. First, we include the effects of macroeconomic releases occurring on APP event days, accessed from the Trading Economics Calendar¹⁰. Only one of these events is a monetary policy decision: the National Bank of Poland maintained its base rate at the previous 1.5 percent level on June 8, 2016 which was in accordance with market consensus; hence, we rule out any distortion stemming from the announcement. The set of macroeconomic releases are standardized to have zero mean and unit variance.

Citigroup Economic Surprise Indices (CESI) control for the surprise element of economic events occurring on the days of the APP announcements. Indices were retrieved for three regions that may be relevant in the context of the study: the euro area, the US, and CEMEA (Central Europe, Middle East, and Africa) countries. The index is a standardized measure of data surprises derived from the difference of actual releases and Bloomberg median forecasts¹¹. It is calculated daily in a rolling three-month window, and the relevance of the considered events is weighted in terms of their impact on foreign exchange (forex) markets – the bigger the impact, the higher the weight. A positive CESI implies that the released data was above market consensus, meaning that economists were on average less optimistic than the actual outcome would have suggested; and vice versa for negative values. To avoid unit root, we consider the first differences of daily CESI values.

When carrying out panel estimation, it is plausible to take into account time-invariant characteristics by adding country fixed effects. By doing so, we offset variation in the outcome variables occurring due to the properties of a specific market.

2.2 THE DESCRIPTION OF THE MODELS USED IN ESTIMATION

The OLS regression framework is built upon strong assumptions regarding the error term and the regressors, which we discuss below. Strict exogeneity implies that there is no two-way relationship between the left and the right-hand side variables. Practically, explanatory variables must be exogenous in the sense that they do not occur due to parallel shocks. We rule out that the APP interventions take place in response to asset price variation in CEE financial markets.

The independent errors assumption requires independence between residuals and a third variable outside the model. The existence of such a global factor that determines asset price variation in all six countries are not captured by the model is ruled out due to the inclusion of economic surprise indices.

The basic OLS framework assumes no autocorrelation and homoscedasticity of the error term. Serial correlation can be offset by considering returns or daily differences as these are independent of preceding values. Homoskedasticity holds if error variance is the same across observations, implying that market volatility is constant over time. Hence, OLS could not account for estimation errors in preceding forecasts which may distort estimates in case of structural breaks. The Breusch-Pagan test did not find heteroskedasticity in the residuals of the estimated models. Further, the period between 2014 and 2017 was relatively stable in comparison with the preceding years and did not exhibit major structural breaks in terms of market volatility (see Figure (4)) and, thus, parameter estimates can be considered reliable.

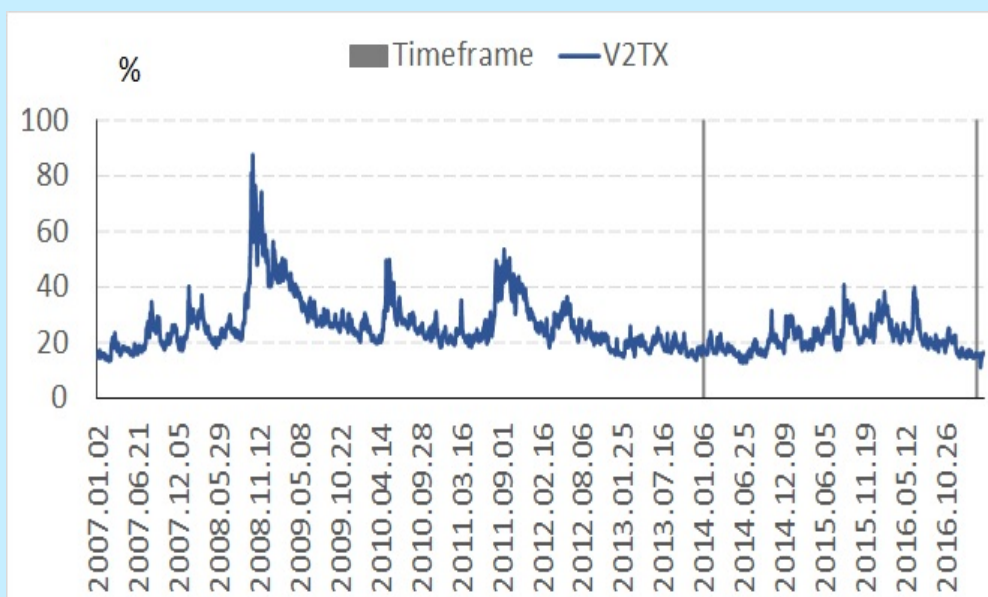
The next two subsections consider i) the effects of all APP-events as well as ii) the effects of the sub-programs in panel frameworks, respectively. In the last subsection we consider a time-series framework to measure the confidence and signalling channels of the APP.

⁹ To cross-check our results we have also run placebo regressions with random announcement dates but we did not obtain significant results (available upon request).

¹⁰ For more detail, see: <http://www.tradingeconomics.com/calendar?g=world#>; accessed on April 26, 2017.

¹¹ For more detail, see: <http://www.businessinsider.com/citi-economic-surprise-index-2013-12?IR=T>; accessed on April 12, 2017.

Figure 4
Eurozone volatility over 2007-2017



2.2.1 CUMULATIVE EFFECTS OF ALL APP EVENTS

We aim to measure overall (or cumulative) effects of all APP announcement on foreign exchange rates, equity indices, government bond yields, and CDS spreads in six peripheral EU countries outside the common currency area with the following regression:

$$\Delta y_{t,i}^j = FE_i^j + \sum_{a=1}^A \sum_{k=0}^1 (\beta_a^j APP_{a,t-k}) + \sum_{u=1}^U (\gamma_u^j CESI_{u,t}) + \delta^j Macro_{i,t} + u_{i,t}^j \quad (1)$$

where

$country_i \in \{\text{Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania}\}$

$y_j \in \{\text{FX, equity index, bond yields, CDS spread}\}$

Regression (1) is a panel OLS regression with robust standard errors, including six countries over more than three years. The outcome variables are bilateral euro exchange rates vis-a-vis country i 's currency, the main stock market index of country i , 1, 3, 5, 10-year benchmark government bond yields of country i , and 5-year CDS spreads of country i . The main explanatory variable is the overall impact of nineteen APP announcements over the 01/01/2014 – 02/28/2017 period. The APP_a , $t - k$ impulse dummy equals 1 on days when APP events took place and $a \in A$ where A is the full set of nineteen APP events as indicated in Appendix A. We consider two-day event windows to make sure that the impacts are identified even in case of lags in the transmission. Consequently, $k \in \{0, 1\}$ represents the number of lags, hence impulse events are measured on the days of the announcements (at time t) as well as the subsequent days.

In regression (1) we control for confounding factors such as country-specific characteristics, macroeconomic announcements, and other world economic surprises occurring on the days of the APP events. Hence, standardized macroeconomic data releases (see variable $Macro_i$ in regression (1)) are added occurring on the days of the APP events where the full set of releases has zero mean and unit variance. Economic surprises from the world economy are taken into account in the form of Citigroup Economic

Table 1
The effects of cumulated APP announcements

	FX	Equity	10-year bond	5-year bond	3-year bond	1-year bond	CDS spread
Macroeconomic data releases	-0.00270 (0.534)	-0.00653 (0.382)	-1.323 (0.535)	0.154 (0.877)	1.133 (0.095)	0.234 (0.631)	0.283 (0.435)
CESI CEMEA	-0.00830 (0.130)	-0.0126 (0.235)	-0.574 (0.092)	-0.591 (0.101)	-0.583 (0.089)	-0.271 (0.122)	-0.225 (0.236)
CESI EUR	-0.00649 (0.131)	-0.00998 (0.233)	-0.458 (0.088)	-0.418 (0.138)	-0.413 (0.129)	-0.201 (0.147)	-0.144 (0.329)
CESI USD	0.00263 (0.132)	0.00419 (0.220)	0.179 (0.113)	0.244* (0.040)	0.178 (0.128)	0.0828 (0.169)	0.0668 (0.266)
All APP events	-0.00210 (0.662)	-0.00187 (0.803)	0.526 (0.499)	0.747 (0.316)	0.546 (0.487)	-1.044 (0.198)	0.0392 (0.844)
First lag of all APP events	0.000895 (0.798)	0.00270 (0.628)	-0.945 (0.175)	-2.099* (0.034)	-2.012* (0.016)	-1.276* (0.049)	-0.361 (0.109)
Constant	0.00196 (0.353)	0.00277 (0.413)	-0.0211 (0.947)	-0.0342 (0.934)	0.205 (0.645)	0.166 (0.757)	0.0755 (0.484)
Observations	4565	4387	4215	4281	4308	4030	4556
F	0.457	0.299	0.729	1.549	1.580	1.040	1.071

Notes: *p*-values in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Outcome and control variables are described in detail in the main text, here we provide the unit of measurement for outcome variables. FX is daily percentage change in the exchange rate of four CEE currencies (HRK, HUF, PLN and RON). 1 year -10 year bond refers to daily basis point changes in benchmark government bond yields. 5-year CDS is the daily basis point change of CDS spreads for six CEE countries. Equity is the daily percentage change in the stock exchange close prices of six CEE countries.

Surprise Indices where $u \in U$ and U is the set of indices calculated for three regions: CEMEA countries (*CESI CEMEA*), eurozone (*CESI EUR*), and the US (*CESI USD*) (see variable *CESI_u* regression 1 as well as table 1). Finally, country fixed effects FE_i control for time-invariant characteristics of the respective economies. Results in table (1) show that the contemporaneous effects are not significant. However, benchmark bond yields with maturity 1, 3 and 5 years have declined significantly (by 1-2 basis points on average) the day after the APP announcements (see the row 'the first lag of APP ann.').

2.2.2 DISCUSSION OF THE RESULTS

This section aims to put empirical findings into a broader context and evaluate the economic significance of the results compared to the literature.

Based on the results from the panel regression one can see that equity prices, euro vis-a-vis national currency exchange rates, and CDS spreads remained seemingly unaffected with high confidence in response to the cumulative effect of nineteen APP events whereas there appears to be a slight negative trend in government bond yields. This result is somewhat inconsistent with those of Fratzscher et al. (2014) and Georgiadis and Gräb (2016) who found that non-euro area EU financial markets responded with increasing equity prices, slightly depreciating currencies, and declining government bond yields. On the one hand, Georgiadis and Gräb's primary focus was global financial market spillovers across 39 trading partners of the euro area and patterns within non-euro area EU countries is unknown, hence those results are not necessarily applicable to the CEE countries considered here. On the other hand, Fratzscher et al. considered the 2007-2012 period and announcements of early ECB UMPs which was a different macroeconomic environment in terms of market mood and volatility.

Although Georgiadis and Gräb (2016) found that global exchange rate spillovers were significant, those to non-euro area EU countries were less remarkable (1.8 percent versus 8.4 percent against the US dollar). In comparison with its world-wide performance, the euro depreciated much less against non-euro area EU currencies, which indicates strong co-movement between the euro and national currencies in the EU. Not only is it consistent with van den End et al.'s (2015) expectation that the euro depreciation would be the main driver of achieving ECB's stated goals, but also suggests that there is a deeper integration between the eurozone and non-euro area EU countries versus the eurozone and the rest of the global economy.

Falagiarda et al. (2015) concentrate on CEE countries and draw similar conclusions to our study. In particular, they find that sovereign bond yields decrease while stock market indices, exchange rates, and CDS spreads remain unchanged over the 2007-2015 period. Effects across different programs, however, varied greatly: their overall results suggest that spillovers from SMP turned out to be the most robust whereas those of OMT and PSPP events were limited. The phenomenon that latter programs were less sound may stem from two factors. First, the environment in which the programs were introduced might have been different in terms of market mood, uncertainty, and expectations, briefly captured by volatility. In a more volatile or high-yield environment, the introduction of an expansionary program was likely to make greater impact; see the aftermath of Draghi's "whatever it takes" speech in London. Second, the latter programs may have contained less surprise element in the sense that markets had already priced in the long-run maintenance of UMPs as if it had functioned as forward guidance. The period under consideration in our study was different from the early years of ECB UMPs with respect to both factors. Hence, our results can be taken consistent with the findings of other studies finding that earlier programs had larger effects than the latter ones. The next subsection considers the effects from the announcement of each program within the APP and confirms the results in this section.

2.2.3 SUB-PROGRAM EFFECTS OF THE APP

We also consider the impact of sub-programs within the APP to the same panel of CEE countries¹² using the following regression:

$$\begin{aligned} \Delta y_{i,t}^j = & FE_{i,t}^j + \sum_{b=1}^B \sum_{k=0}^1 (\beta_{1,b}^j CBAB_{b,t-k}) + \sum_{c=1}^C \sum_{k=0}^1 (\beta_{2,c}^j PSPP_{c,t-k}) \\ & + \sum_{d=1}^D \sum_{k=0}^1 (\beta_{3,d}^j CSPP_{d,t-k}) + \sum_{e=1}^E \sum_{k=0}^1 (\beta_{4,e}^j Purchase_{e,t-k}) \\ & + \sum_{u=1}^U (\gamma_u^j CESI_{u,t}) + \delta^j Macro_{i,t} + u_{i,t}^j \end{aligned} \quad (2)$$

with

$$\begin{aligned} country_i \in & \{\text{Bulgaria, Croatia, Czech Republic, Hungary,} \\ & \text{Poland, Romania}\} \\ y_j \in & \{\text{FX, equity index, bond yields, CDS spread}\} \end{aligned}$$

In regression (2) the impulse dummies are considered in clusters depending on which APP program was targeted by the respective events so that we can differentiate among programs of the APP. The notation is mostly analogous to regression (1) with the modification that the full sets of program events are now subsets of all APP events: b, c, d, and e denote the most remarkable CBPP3 and ABSPP events together¹³, as well as PSPP¹⁴, CSPP¹⁵, and purchase¹⁶ events, respectively. Control variables are the

¹² Note that our [online appendix](#) contains time-series regressions for the effects of the APP programs on individual CEE countries. The time-series regressions with the sub-programs display great variety of the effects across countries.

¹³ CBPP3 and ABSPP announcements are considered together under variable CBAB; represented by event 2 and 3 in the Appendix.

¹⁴ Variable PSPP is represented by event 7, 9, and 11 in the Appendix.

¹⁵ Variable CSPP is represented by event 13, 14, and 15 in the Appendix.

¹⁶ Variable Purchase is represented by event 4, 6, 8, and 16 in the Appendix.

same as those of the baseline model: macroeconomic data releases and Citigroup Economic Surprise Indices (CESI). The results in table (2)¹⁷ reveal the same pattern as in the previous regression: PSPP announcements lead to a decline in bond yields (about 2-4 basis points) with a delay of one day. The euro depreciated against four national currencies (HRK, HUF, PLN and RON) by 0.74 per cent on average in response to PSPP announcements (see first column in table (2)). The 5-year CDS spread decreased by 0.7 basis points in response to PSPP (see the last column).

Overall we find that it is the PSPP which can be mainly associated with the decline in the yields of CEE countries. We have further shown that the asset purchases also lead to a decline in CDS spreads and an appreciation of the national exchange rates relative to euro in those countries where the currency was not pegged. In the next section we turn our attention to some of the channels through which the APP must have affected the yields of assets, CDS spreads, stock indices, exchange rates and inflation.

2.3 TRANSMISSION CHANNEL ANALYSIS

The literature on unconventional monetary policy lists several channels through which asset purchases affected macroeconomic indicators. Here we emphasize and measure the confidence channel (a reduction in uncertainty) and the signalling channel (raising inflationary expectations such that they are consistent with the inflation target). We explore the transmission channels through which the APP affected the economy with the following regression:

$$\begin{aligned} \Delta y_t^j = & \alpha^j + \sum_{b=1}^B \sum_{k=0}^1 \left(\beta_{1,b}^j CBAB_{b,t-k} \right) + \sum_{c=1}^C \sum_{k=0}^1 \left(\beta_{2,c}^j PSPP_{c,t-k} \right) \\ & + \sum_{d=1}^D \sum_{k=0}^1 \left(\beta_{3,d}^j CSPP_{d,t-k} \right) + \sum_{e=1}^E \sum_{k=0}^1 \left(\beta_{4,e}^j Purchase_{e,t-k} \right) \\ & + \gamma^j CESIEUR_t + \gamma^j CESIUSD_t \\ & + \delta^j Macro_t + u_t^j \end{aligned} \quad (3)$$

where

$$outcome_j \in \{\text{volatility index, Amundi inflation-indexed asset}\}$$

As opposed to the previous two regressions, equation (3) is a time series framework where the outcome variables are described as follows. The VSTOXX volatility index captures changes in uncertainty (confidence channel) while the Amundi ETF inflation-linked index can be broadly interpreted as an indicator of inflation or inflationary expectations (signalling channel).

The relevant control variables are the Citigroup Economic Surprise Indices calculated for the eurozone as well as for the US. The former is used because of the assets in question are traded in stock exchanges of the euro area whereas the latter is included due to the influential role of the US on the financial market.

We apply the Newey-West estimator with seven lags since those are robust to heteroskedasticity as well as autocorrelation. Impulse dummies are those of equation (2), hence the regression measures the effect of APP-related events clustered per program on eurozone volatility and inflation expectations. We also include a constant (α^j) in the estimation.

Table (3) presents how volatility and inflation-linked assets responded to program announcements (control variables not shown). On the subsequent days of CBPP3 and ABSPS announcements, the return on the euro area volatility index (VSTOXX) decreased by 5.8 percent, implying that eurozone volatility, hence uncertainty decreased in response to the shocks. The result is statistically significant with 99.9 percent confidence. On the following days of PSPP events, returns on the Amundi ETF increased by

¹⁷ Note that the estimate for the CESI USD control variable (included in the previous table) is not reported in the sub-program table because of space constraint but is available upon request. The estimate for CESI USD is not statistically significant.

Table 2
The effects of APP subprograms

	FX	Equity	10-year bond	5-year bond	3-year bond	1-year bond	CDS
Macroeconomic data releases	-0.00255 (0.556)	-0.00787 (0.301)	-1.106 (0.529)	0.0380 (0.970)	0.944 (0.216)	0.0699 (0.931)	0.369 (0.237)
CESI CEMEA	-0.00839 (0.130)	-0.0127 (0.235)	-0.582 (0.092)	-0.595 (0.103)	-0.590 (0.089)	-0.278 (0.116)	-0.227 (0.237)
CESI EUR	-0.00650 (0.131)	-0.01000 (0.233)	-0.455 (0.090)	-0.415 (0.142)	-0.411 (0.131)	-0.200 (0.148)	-0.144 (0.329)
ABSPP and CBPP3 ann.	0.0167 (0.148)	0.0234 (0.309)	-0.0901 (0.964)	-1.574 (0.406)	-0.902 (0.745)	-3.321 (0.325)	0.655 (0.207)
First lag of ABSPP and CBPP3 ann.	0.0210 (0.312)	0.0329 (0.363)	0.571 (0.803)	-0.519 (0.876)	-1.670 (0.751)	0.515 (0.552)	0.410 (0.488)
PSPP announcements	-0.00744* (0.040)	0.00282 (0.610)	-3.804 (0.091)	-1.553 (0.290)	-0.901 (0.608)	-3.972* (0.038)	-0.710** (0.006)
First lag of PSPP ann.	0.00439 (0.411)	0.00816 (0.447)	-2.514* (0.049)	-4.936** (0.004)	-4.429** (0.003)	1.083 (0.468)	-0.326 (0.567)
CSPP announcements	-0.0105 (0.205)	-0.0152 (0.317)	-1.146 (0.378)	0.430 (0.718)	0.489 (0.651)	0.707 (0.691)	-0.247 (0.380)
First lag of CSPP announcements	-0.0275 (0.170)	-0.0396 (0.278)	-1.548 (0.302)	-0.359 (0.842)	-2.110 (0.223)	-2.185 (0.239)	-1.473 (0.058)
Purchase events	-0.0483 (0.161)	-0.0744 (0.246)	-3.451 (0.185)	-2.436 (0.363)	-3.840 (0.126)	-4.323* (0.037)	-0.951 (0.466)
First lag of purchase events	0.0106 (0.316)	0.0142 (0.451)	-0.989 (0.452)	-1.324 (0.492)	0.594 (0.503)	-0.491 (0.743)	0.567 (0.329)
Constant	0.00219 (0.320)	0.00317 (0.377)	0.0190 (0.952)	-0.0237 (0.955)	0.210 (0.637)	0.150 (0.779)	0.0769 (0.484)
Observations	4565	4387	4215	4281	4308	4030	4556
F-test	0.438	0.672	0.850	1.618	1.333	0.899	1.305

Notes: *p*-values in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Outcome and control variables are described in detail in the main text, here we provide the unit of measurement for outcome variables. FX is daily percentage change in the exchange rate of four CEE currencies (HRK, HUF, PLN and RON). 1 year -10 year bond refers to daily basis point changes in benchmark government bond yields. 5-year CDS is the daily basis point change of CDS spreads for six CEE countries. Equity is the daily percentage change in the stock exchange close prices of six CEE countries.

Table 3
Test for transmission channels

	VSTOXX	Amundi ETF
CBPP3 and ABSPP	0.0359 (0.468)	0.000758 (0.796)
First lag of CBAB	-0.0579*** (0.000)	0.00119 (0.578)
PSPP	-0.0586 (0.231)	0.00526 (0.173)
First lag of PSPP	0.0588 (0.169)	0.00386*** (0.000)
CSPP	-0.00368 (0.790)	-0.00211* (0.017)
First lag of CSPP	-0.0440 (0.296)	0.00199 (0.180)
Purchase event	-0.00103 (0.953)	0.00191* (0.019)
First lag of purchase event	0.00910 (0.820)	0.00272* (0.011)
Observations	788	788
F-test	77.11	4.166

Notes: *p*-values in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Outcome and control variables are defined in the main text, VSTOXX is yield on the euro area volatility index in percent. Amundi ETF is the daily yield on euro inflation-linked index.

approximately 0.4 percent at the 0.001 significance level which signals a raise in inflation expectations (measured by Amundi inflation-indexed asset yield). Surprisingly, CSPP was associated with a negative 0.2 percent effect on the return of the inflation-indexed asset. Purchase days and the subsequent days both saw statistically significant raise in inflation expectations, the Amundi ETF return increased by 0.2 and 0.3 percent, respectively. Recently, Rieth et al. (2016) as well as Gambetti and Musso (2017) also argued that the APP raised HICP inflation and inflation expectations successfully.

Overall we have shown that it is the confidence channel through which asset purchases have mitigated macroeconomic and financial risks and enabled banks and governments to reduce loans rates as well as the yields on financial assets. The signalling channel of APP reinforced the expectations of the agents about loose monetary policy (persistently low interest rates) and help guide back inflation close to its target level. In line with the existing literature we find that the confidence and signalling channels have more limited impact outside the eurozone.

3 Conclusion

Earlier studies on European Central Bank's asset purchase programs considered the effects on the eurozone. Although some papers explored spillover effects to CEE countries, these studies did not include the more recent announcements about the recalibration of the PSPP as well as the announcement on the introduction of the CSPP. Considering a panel of CEE countries we show that the expanded asset purchase program of the European Central Bank had positive spillover effects in terms of reducing long-term bond yields in CEE countries. Our panel regression estimates indicate a reduction of about 1-6 basis points in the yields of non-eurozone CEE countries which is somewhat smaller than the estimates by Georgiadis and Gräb (2016) who used a wider set of non-eurozone countries (including, e.g. Sweden, Denmark and the UK).

Future research, on the empirical side, should focus on the estimation of the portfolio rebalancing channel which is one of the main channel through which APP exerted affect on the economy. On the theoretical side one would be able to understand the mechanisms behind our empirical findings by using a dynamic general equilibrium model including global banks whose behaviour are significantly affected by policies of the ECB. The latter is challenging because commercial banks in Hungary hold negligible fraction of their assets in eurozone government bonds which were purchased by the ECB under the PSPP.

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4 Appendix

Table 4

Data Retrieved from Thomson Reuters

Asset	Thomson Reuters Eikon symbol	Quoted price
Bilateral euro exchange rates	EURBGN, EURHRK, EURCZK, EURHUF, EURPLN, EURRON	Bid close
Stock market indices	SOFIX; CRBEX; PX; BUX; WIG; BETI	Trade close
1-year benchmark government bond yields	BG1YT=RR; HR1YT=RR; CZ1YT=RR; HU1YT=RR; PL1YT=RR; RO1YT=RR	Bid yield close
3-year benchmark government bond yields	BG3YT=RR; HR3YT=RR; CZ3YT=RR; HU3YT=RR; PL3YT=RR; RO3YT=RR	Bid yield close
5-year benchmark government bond yields	BG5YT=RR; HR5YT=RR; CZ5YT=RR; HU5YT=RR; PL5YT=RR; RO5YT=RR	Bid yield close
10-year benchmark government bond yields	BG10YT=RR; HR10YT=RR; CZ10YT=RR; HU10YT=RR; PL10YT=RR; RO10YT=RR	Bid yield close
5-year sovereign CDS spreads	BGGV5YUSAC=R; HRGV5YUSAC=R; CZGV5YUSAC=R; HUGV5YUSAC=R; PLGV5YUSAC=R; ROGV5YUSAC=R;	Mid spread close
Euro area volatility index (VSTOXX)	V2TX	Trade close
Euro inflation-linked index (Amundi ETF Euro Inflation UCITS ETF)	CI3.PA	Trade close
Citigroup Economic Surprise Indices	CESIUSD; CESIEUR; CESICMEA	Trade close

Table 5**Appendix A: List of APP-related events**

Nr.	Date (M/D/Y)	Event description	Event type	Related program(s)
1	06/05/2014	Intensification of preparatory work related to outright purchases in the ABS market	Press release and press conference	ABSPP
2	09/04/2014	ECB reveals CBPP3 and ABSPP	Press conference	CBPP3, ABSPP
3	10/02/2014	ECB announces operational details of CBPP3 and ABSPP	Press release and press conference	CBPP3, ABSPP
4	10/20/2014	Commencement of CBPP3	Purchase event	CBPP3
5	10/30/2014	ECB appoints executing asset managers for ABSPP	Press release	ABSPP
6	11/21/2014	Commencement of ABSPP	Purchase event	ABSPP
7	01/22/2015	ECB announces expanded asset purchase program	Press release and press conference	PSPP
8	03/09/2015	ECB announces the purchases of euro-denominated public securities	Purchase event	PSPP
9	09/03/2015	Governing Council decides to increase issue share limit of PSPP	Press conference	PSPP
10	09/23/2015	ECB adjusts purchase process in ABSPP	Press release	ABSPP
11	11/09/2015	Increase in PSPP issue share limit enlarges purchasable universe	Press release	PSPP
12	12/03/2015	ECB decides to reinvest principal payments, include new securities in PSPP, and extend APP till the end of March 2017 or beyond if necessary	Press conference	APP, PSPP
13	03/10/2016	ECB adds CSPP to APP, expands monthly purchases from 60 billion euros to 80 billion euros, and announces minor adjustment to PSPP	Press release and press conference	CSPP, APP
14	04/21/2016	ECB announces details of CSPP	Press release	CSPP
15	06/02/2016	ECB announces operational details of CSPP	Press release	CSPP
16	06/08/2016	Commencement of CSPP	Purchase event	CSPP
17	12/08/2016	ECB decides to extend the APP till the end of December 2017 at a reduced 60 billion euro of monthly purchases as of April 2017. Additional adjustments to PSPP (cash collateral in securities lending, YTM below DFR allowed, lower band of maturity range extended to 1 year)	Press release and press conference	APP, PSPP
18	12/15/2016	ECB adjusts purchase process in ABSPP	Press release	ABSPP
19	01/19/2017	ECB reveals further details on the purchases of assets with yields below the deposit facility rate under PSPP	Press release and press conference	PSPP

Source: <https://www.ecb.europa.eu/press/html/index.en.html>

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