# Spillovers from the European Central Bank's Expanded Asset Purchase Program to Non-Euro Area Financial Markets in Central and Eastern Europe

by

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### Abstract

I carry out empirical analysis on how the European Central Bank's expanded asset purchase program (APP) spilled over to selected financial markets in Central and Eastern European countries outside the eurozone. I consider the impulses of remarkable APP announcements, potentially affecting exchange rates, equity prices, government bond yields with various maturities, and CDS spreads. I differentiate among programs within the APP and find that the most pronounced spillovers induced sovereign bond yields to drop in response to public securities purchase program (PSPP) announcements. Additionally to the existing literature, I assess the impacts after corporate sector purchase program (CSPP) events, and conclude that they were associated with slight increases in government bond yields in four out of the six observed countries.

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### List of abbreviations

ABSPP: Asset-Backed Securities Purchase Program APP: Asset Purchase Program CBPP3: Third Covered Bond Purchase Program CSPP: Corporate Sector Purchase Program ECB: European Central Bank OMT: Outright Monetary Transactions PSPP: Public Sector Purchase Program QE: Quantitative Easing SMP: Securities Market Program UMP: Unconventional Monetary Policy

### **1. Introduction**

The asset purchase program (APP) of the European Central Bank (ECB) has been a major breakthrough in the monetary policy of the eurozone. The fundamental German hegemony in European monetary policy has traditionally resulted in monetary discipline, hence the ECB was hesitant to follow suit of its counterparties in monetary easing in the wake of the crisis. Later however, Frankfurt also adapted monetary measures beyond base rate policy and other standard policy tools. Initial programs included the first covered-bond purchase program (CBPP) in 2009 and the Securities Market Program (SMP) in 2010 which were the first signs of a shift towards unconventional monetary policy (UMP). Although these programs were much smaller scale than those within the expanded APP, they signaled the revision of eurozone monetary policy and their magnification led to commitment towards quantitative easing (QE) in its Anglo-Saxon sense.

QE programs of the Federal Reserve (Fed) generally have very significant spillover effects which has been studied by numerous research papers (Aizenman et al. 2014, Canova 2005, Chen et al. 2014, Gagnon et al. 2011). The QE of the ECB at this point is a relatively new development, one that is constantly evolving as ECB leaves monetary discipline behind. Literature dealing with the spillover effects of these policies is relatively narrow compared to those in the United States (US), and particularly, with little focus on Central and Eastern European (CEE) countries. 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.<sup>1</sup> Falagiarda et al. (2015) examined how selected UMP events of the ECB spilled over to CEE non-euro area EU countries. More

<sup>&</sup>lt;sup>1</sup> Note that although the authors included CEE countries among others, their primary focus was on worldwide effects, hence they do not show the effects on CEE countries explicitly.

specifically, they assessed the effects in response to SMP, Outright Monetary Transactions (OMT), and public sector purchase program (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 expanded APP program today consists of four operating programs that are different in terms of magnitude and purchasable universe as well. The papers above however do not include the more recent developments in the ECB's policy considerations: neither are the latest news about PSPP included, nor the introduction of the corporate sector purchase program (CSPP). Also, existing literature do not differentiate between the effects of individual programs within the expanded APP.

Hence the goal of my research is twofold: first, I wish to measure the overall effect of selected events across six CEE countries in the EU but outside the eurozone. Secondly, I intent to uncover whether different programs were associated with different impacts across countries. Additionally, I try to identify the relevant transmission channels, through which ECB monetary policies affect financial markets outside the currency area. I apply an impulse event approach through simple OLS regressions with numerous control variables included, in accordance with the above mentioned two papers. I consider nineteen APP-related events between 01/01/2014 and 02/28/2017 and investigate whether financial markets saw significant spillovers in a two-day time window. I am after impacts on exchange rates, equity prices, government bond yields with various maturities, and CDS (credit default swap) spreads in Bulgaria, Croatia, the Czech Republic, Hungary, Poland, and Romania.

My results show that the cumulative spillover effect after all nineteen APP events is very limited. Equity prices, exchanges rates, and CDS spreads remain essentially unaffected, whereas government bond yields see a muted but statistically significant negative effect in response to APP announcements. Clustering events with respect to their targeted programs shows various patterns of spillover effects across countries and programs as well. However, there is a clear tendency regarding PSPP shocks which turn out to affect all asset classes except for equity prices. Spillovers from PSPP announcements to sovereign bond yields with different maturities are particularly robust and consistent across countries. Additionally to the existing literature, I also assess the spillovers from the CSPP. Although results are not highly robust across countries, four out of six countries experience increases in government bond yields in response to CSPP announcements. Since bond yields seem to be the most exposed to APP shocks, spillovers occur primarily through the portfolio rebalance channel.

The analysis 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. Also, I do not wish to analyze the effects after the execution of purchases, since literature suggests that the surprise element of purchases, if exists at all, is very limited and hard to identify.<sup>2</sup>

The structure of the paper is as follows: the next section discusses the special properties and relevant transmission channels of the programs involved in the APP. Section 3 reviews the applied methodological details of the analysis. In Section 4 and 5, I elaborate on and discuss the economic significance of my results in the context of other scholars' findings. Finally, Section 6 concludes.

<sup>&</sup>lt;sup>2</sup> Andrade et al. (2016) found that the first day of PSPP purchases indeed revealed new information on the program, and thus implied statistically significant changes in asset prices. Hence, I take the first days of executions for each program as APP-related events.

#### 2. About the APP

The APP can be thought of as a special case of open market operations which is implemented by central banks on a daily basis even in normal times. The main difference is that these large-scale outright purchases are aiming to implicate expansionary monetary measures when base rate policy is not sufficient anymore. The ECB follows inflation targeting, meaning that its one and ultimate responsibility is to maintain inflation below but close to 2 percent. Hence, the ECB carries out essentially all its operations in the name of fulfilling the inflation rate mandate.

As the eurozone started to leave the debt crisis behind in 2013, it had to face low economic growth which also brought along declining inflation rates, far from the two-percent target. The ECB thus, interpreted the introduction of the APP as an act to follow its mandate and prevent low inflation. Within the APP the ECB buys public as well as private debt instruments and by holding these assets, it provides additional liquidity, maintains market confidence and signals its commitment to raise inflation expectations.

Regarding the effects of the APP within the euro area Van den End et al. (2015) identify four relevant transmission channels: bank lending channel, signaling channel, portfolio rebalance channel, and exchange rate channel. The authors expect the exchange rate channel to be the main driver of achieving stated goals of the ECB. Their supposed mechanism is that the depreciation of the euro would raise inflation expectations closer to the two-percent target rate as well as enhance economic growth in the euro area.

Impacts of the APP in the eurozone were indeed substantial. In terms of microeconomic results, government bond yields dropped by 13 basis points in response to the announcement of the PSPP and the implementation day saw an additional 14-basis-point decrease on average across bonds of various maturities (Andrade et al. 2014). Regarding macroeconomic effects, the same

authors found that the program contributed with a 40-basis-point increase in inflation and 1.1 percent increase in output compared to the counterfactual scenario. It is also notable that researchers typically found non-standard ECB measures to be of similar effect size as standard ones (Andrade et al. 2014, Georgiadis and Gräb 2016).

#### 2.1. Programs within the expanded APP

The term "expanded" was introduced in conjunction with the PSPP in January 22, 2015. As part of the expanded APP, average monthly net purchases reached  $\notin$ 60 billion from March 2015 till March 2016 then later  $\notin$ 80 billion from April 2016 till April 2017. As of April 2017, the program continues at the original  $\notin$ 60 billion pace until December 2017 and beyond if necessary. Expanded APP today covers the CBPP3, ABSPP, PSPP, and CSPP, although the CBPP3 and ABSPP were introduced before it was referred to as the expanded APP. Terminated APP programs, such as the SMP, OMT, and previous versions of CBPP are not covered in present study.

#### 2.1.1. Third covered bond purchase program

Covered bonds are debt securities that are backed by other (typically highly rated) loans. These instruments are issued by companies with high credit ratings, hence bear very low risk. The aim of the program is to "enhance the functioning of the monetary policy transmission mechanism, supports financing conditions in the euro area, facilitates credit provision to the real economy and generates positive spillovers to other markets" as stated by the ECB.<sup>3</sup> In spring 2017, the CBPP3 represented the second biggest holding within all APP programs, however monthly purchases had been decreasing ever since the introduction of the PSPP (ECB 2017).

<sup>&</sup>lt;sup>3</sup> For more detail, see: https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html; accessed on May 3, 2017.

#### 2.1.2. Asset-backed securities purchase program

Asset-backed securities are debt instruments secured by a pool of financial assets as collaterals. ABS's are essentially securitized loans, hence substitutes for corporate debt papers, meaning that banks can sell them to raise funds which then can be credited to other participants of the economy. The ABSPP thus incentivizes lending to the real economy which "further ease[s] funding and credit conditions and help the transmission of monetary policy" – according to the ECB.<sup>4</sup> Monthly net purchases of ABSPP turned negative in spring 2017, and its overall weight had also become the lowest of the four (ECB 2017).

#### 2.1.3. Public sector purchase program

Within the PSPP, the ECB buys central government bonds from the euro area with maturities between 2 to 30 years on the secondary markets, but similar instruments issued by recognized agencies, local governments, and multilateral development banks are also in the purchasable universe of assets. Since national central banks of the euro area are the main shareholders of the ECB, gains and losses through the operation of the ECB are passed on to these institutions per their so-called capital key.<sup>5</sup> Purchases under the PSPP are primarily conducted by national central banks, thus they bear most of the burden from potential losses, and only 20 percent of the risk is pooled. These settings aim to mitigate moral hazard issues and incentivize national governments not to postpone structural adjustments and budgetary discipline. The PSPP can be considered QE in its purest form, targeting to further ease monetary policy in the shadow of deflationary pressure.

<sup>&</sup>lt;sup>4</sup> For more detail, see: https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html; accessed on May 3, 2017.

<sup>&</sup>lt;sup>5</sup> The capital key is calculated to all EU member states based on their population and GDP, but those not in the currency area are obliged to pay only 3.75 percent of their respective amount. More on capital key and risk sharing under QE can be read in van den End et al. (2015).

The PSPP is unquestionably the most remarkable program of the four: net monthly purchases were typically above  $\notin$ 50 billion but sometimes close to  $\notin$ 80 billion. PSPP holdings in spring 2017 reached  $\notin$ 1500 billion, and it consistently represented around 80 percent of the APP portfolio (ECB 2017).

#### 2.1.4. Corporate sector purchase program

Under the CSPP, the ECB buys euro-denominated bonds of non-financial corporations from both in the primary and the secondary markets. The purchasable universe is non-bank corporate bonds of a previously announced group of firms, with maturities between 6 months and 30 years. Purchases are carried out by six national central banks and purchase amount and portfolio weights are unknown to stem speculation. Hence, the goal of the program is not to ease the financing of individual companies, but to "further strengthen the pass-through of the Eurosystem's asset purchases to the financing conditions of the real economy" (ECB 2016, 20).

Net monthly purchases varied between  $\notin 6$  to  $\notin 10$  billion since its commencement in June 2016, hence it became the program with the second highest monthly purchases. In terms of holdings, it was below that of the CBPP3 in spring 2017, but as said, its weight had been firmly increasing month by month (ECB 2017).

#### 2.2. Transmission channels of the APP

This section discusses the role of transmission channels through which monetary policy and especially asset purchase decisions by central banks spill over to financial markets different from that of the central bank. It is worth mentioning that there is no widely accepted view on the transmission channels of asset purchases and these mechanisms are continuously subject to further research outside the scope of present study. There exists a view according to which purchases themselves do not affect the markets at all since all available information has already been priced in, and the expected return after an asset is immediately adjusted to the information released (Curdia and Woodford 2011). Although studies have found evidence on the relevance of purchases as well (Andrade et al. 2016, Fratzscher et al. 2014), here I primarily focus on the announcements and not the execution of purchases, since, presumably, announcements possess more surprise element.

#### 2.2.1. Confidence channel

Expansionary central bank interventions may induce better market mood and higher confidence in the sense that financial markets face increasing and more stable demand, hence uncertainty decreases. Lower uncertainty implies lower risk premia and increasing demand for assets formerly considered risky, which together boost financial markets.

Falagiarda et al. (2015) argue that the international spillover from the euro area to the periphery can be twofold. On the one hand, improved confidence in the euro area may suggest that market participants are more willing to invest in markets outside the currency area too, which would mean capital flow into non-euro area countries. On the other hand, assets in CEE countries can be reassessed as riskier relative to those in the currency area which may result in capital outflows and negative effects on peripheral markets. Confidence channel can be appropriately captured by option implied volatility indices that track the volatility of an established market index.

#### 2.2.2. Portfolio rebalance channel

A central bank asset purchase intervention can generate two effects that potentially imply portfolio rebalancing: as mentioned above risk premia may decline and/or central banks may crowd out other market participants. As a result of the two, investors seek to substitute assets in domestic or foreign markets to offset the decreasing risk premia of benchmark assets and hence maintain the yields in line with their risk appetite. In the current setup, this would materialize in declining yields in euro-

area markets which incentivizes investors to change the composition of portfolios by increasing the weight of assets from CEE countries. The increasing demand for assets from CEE countries would ultimately drive down their yields.<sup>6</sup>

#### 2.2.3. Signaling channel

Asset purchases can function as forward guidance in the sense that the central bank is willing to keep interest rates low in the long run. Andrade et al. (2016) argue that an asset purchase program can be even more credible than forward guidance by interest rate policy when the central bank holds a large magnitude of long-term assets on its balance sheet. The assets are sensitive to interest rate changes which ultimately makes the central bank itself exposed to just that, hence low interest rates are more likely to be longer-lasting. Consequently, when the ECB signals that it is committed to large-scale asset purchases, it foreshadows low interest rates and increasing inflation expectations until that adjusts to the target level below but close 2 percent over the medium term. Falagiarda et al. (2015) assert that the underlying mechanisms of cross-border effects are similar to those of the portfolio rebalance channel. Namely, that the interest rate environment in the euro area lowers, therefore funds may seek for assets in CEE markets. Good indicators of the signaling channel are the indices that follow the performance of inflation-linked government bonds in the eurozone.

<sup>&</sup>lt;sup>6</sup> The channel could be empirically specified by daily bond and equity flows, but such data was not accessible at the time of the research. Hence, I wish to determine the relevance of the channel through theoretical reasoning, as well as identify as part of the residuum beyond the other two channels.

#### 3. Model and data

I consider simple ordinary least squares (OLS) models with daily data frequency in time series as well as panel setups, similarly to other studies in the topic (Falagiarda et al. 2015 and Georgiadis and Gräb 2016). The main argument for OLS models it that the interpretation of results is straightforward, however there may occur pitfalls that limit the robustness of the result due to the basic assumptions of the framework. I discuss the possible limitations of the OLS method in Section 3.2.

#### **3.1. Data description**

One crucial consideration in impulse event assessment is data frequency which is up to consideration depending on the type of effect aimed to be identified. Ghysels et al. (2014) evaluate the SMP using high-frequency intraday data with fifteen-minute time windows. The reason for the methodology is the so-called endogeneity problem, the phenomenon that the ECB applies SMP to offset another market impact that had previously affected asset prices. For instance, the ECB may intervene to prevent the excessive increase of bond yields on the same day as the shock appears. If the intervention perfectly offsets the preceding market shock, the overall effect of the SMP intervention is zero (or even positive if the intervention is of smaller magnitude than the shock itself) when working with daily or weekly data. Whereas, if using time windows of a couple of minutes, one can identify the direct and immediate effect of the intervention.

Swanson (2011) applies similar high-frequency methodology to analyze the effects of six Federal Reserve Operation Twist announcements.<sup>7</sup> Aside from addressing the endogeneity issue, the method can be effective because long-term government bond yields can be very sensitive to the

<sup>&</sup>lt;sup>7</sup> In an Operation Twist, the Fed rebalances short versus long-term government bonds in its portfolio depending on its goal: purchases the one whose yield they want to bring down and sells the other. Swanson finds that the impacts of QE and Operation Twist are similar in magnitude.

main macroeconomic expectations, say inflation. Also, one can rule out that a third confounding shock distorts the results since it is unlikely to occur within the exact same fifteen-minute time window.

Similarly to Falagiarda et al. (2015), Fratzscher et al. (2014), and Georgiadis and Gräb (2016), I opt to work with daily data nevertheless, because the above concerns do not apply to present study. There is no endogeneity issue since I deal with non-euro area countries and it is unlikely that the ECB would implement policies in answer to developments in one of these countries. Also, I include a control variable for macroeconomic announcements, thus government bond yield sensitivity is not an issue in this sense. Concerning confounding factors, I control for other economic surprises occurring on the same days as the announcements. Moreover, the event-study approach is built upon a strong assumption, namely 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 are likely to be less efficient than those in the centrum of the EU, hence wider event windows are more favorable. Since I am after 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).

Daily data on asset prices was retrieved via Thomson Reuters Eikon for the period between 01/01/2014 and 02/28/2017. For the complete list of assets with more detailed description, refer to Appendix A. 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 required 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.

#### **3.1.1.** Outcome variables

The ultimate goal of the study is to uncover whether APP-related events are associated with changes in financial markets outside the eurozone. I observe percentage changes between daily close prices in bilateral euro exchange rates and main stock market indices. Regarding exchange rates, I exclude the Czech koruna and the Bulgarian lev since the former was capped at 27 korunas per euro since 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, I consider benchmark bonds since these are very liquid assets and easily comparable between days; I am after basis point changes in 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. I retrieved data on the most commonly referred 5-year spreads and calculated daily basis point changes. Due the transformations above, the Phillips-Perron test shows that neither of the series contain unit root, hence ca be considered stationary.

When identifying the relevant transmission 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, thus a eurozone volatility index is suitable to identify the relevance of the channel. As described above, the signaling channel is closely related to inflation expectations which is why inflation-linked assets that are traded large-scale can be good indicators of the channel. However, the lack of volatility index and inflation-linked assets in the periphery of the EU might be problematic in the sense that it makes it harder to identify the relevant channels. Then again, if the market of these 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, I consider the two assets below. 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 countries.<sup>8</sup> 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, hence is a representative of inflation-linked government bonds of several eurozone countries. According to Bloomberg, the price of a unit in the ETF is approximately equal to the Markit iBoxx Euro Inflation Linked Index in Euros.<sup>9</sup> Like in case of other equity prices, I take the daily returns on these assets to have stationary time series.

#### 3.1.2. Impulse events

The main explanatory variables of the analysis are the daily event dummies, taking value one on announcements days and zero elsewhere. I 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 purchases are also included since the start of the PSPP was found to be associated with statistically significant asset price changes in the eurozone (Andrade et al. 2016). For the full list of APP-related events, refer to Appendix B.

Without specific selection criteria, the sampling of impulse events may leave room for manipulation of the results. Hence, I opt to include all press releases and press conferences announced on the ECB's media site that were related to any of the four programs within the expanded APP between 01/01/2014 and 02/28/2017. By doing so, I avoid to arbitrarily judge the significance of the announcements. However, when clustering events with respect to their targeted

<sup>&</sup>lt;sup>8</sup> For more detail, see: https://www.stoxx.com/index-details?symbol=V2TX; accessed on May 5, 2017.

<sup>&</sup>lt;sup>9</sup> For more detail, see: https://www.bloomberg.com/quote/CI3:FP; accessed on May 5, 2017.

program, I consider only the most remarkable announcements per program (as shown in Section 3.2.2), hence I manage to grasp the obvious differences among shocks in terms of economic relevance.

#### **3.1.3.** Control variables

To make sure 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, I include the effects of macroeconomic releases occurring on APP event days, accessed from the Trading Economics Calendar.<sup>10</sup> 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 it is unlikely to cause much of a bias on the respective day. 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 are 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 forecasts.<sup>11</sup> 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, I consider the first differences of daily CESI values.

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

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

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

#### **3.2. Model description**

As mentioned above, the OLS framework is built upon strong assumptions which entails limitations in terms of economic substance which I 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. This is essentially the same problem as what was grasped by the high-frequency studies referred in Section 3.1. As discussed there, it is highly unlikely that an APP intervention takes 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 prices in all six countries and not captured by the model is very unlikely due to the inclusion of economic surprise indices.

No linear dependence suggests that there should be no multicollinearity among the righthand side variables. Any of the explanatory variables should not be linearly expressed by another regressor of the model. Variables on the right-hand side are either binary shock events or standardized values of economic surprises, hence their linear prediction can be ruled out.

The spherical errors assumption entails no autocorrelation and homoscedasticity of error terms. Serial correlation can be offset by considering returns instead of prices: the return on an asset on a given day is much less likely to depend on the returns of the previous days compared to the correspondence between prices in subsequent days. Homoscedasticity holds if error variance is the same across observations, implying that market volatility is constant over time. Hence, OLS do not account for estimation errors in preceding forecasts which may become an issue in case of structural breaks. The period between 2014 and 2017 was relatively stable in comparison with the preceding years and did not experience major structural breaks (see Figure 1 in Appendix C), thus parameter estimates can be considered reliable.

#### **3.2.1. Baseline model**

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

Equation 1 – Baseline model

country  $i \in \{Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania\}$ outcome  $j \in \{FX, equity index, bond yields, CDS spread\}$ 

Regression 1 aims to measure effects of APP announcement on four financial markets indicated by foreign exchange rates, equity indices, government bond yields, and CDS spreads in six peripheral EU countries outside the common currency area. The model unfolds the overall effect of all APP announcements while controlling for confounding factors such as country-specific characteristics, macroeconomic announcements, and other world economic surprises occurring on the days of the APP events.

In the regression, I consider an OLS panel analysis with robust standard errors, including six countries over more than three years. The outcome variables are bilateral euro exchange rates vis-à-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*<sub>*a,t-k*</sub> 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 B. I 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. To control for confounding factors, I add standardized macroeconomic data releases (*Macroi*) 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 Surprise Indices (*CESI*<sub>*u,i*</sub>) where  $u \in U$  and U is the set of indices calculated for three regions: CEMEA countries, eurozone, and the US. Finally, country fixed effects *FE*<sub>*i*</sub> control for time-invariant characteristics of the respective economies.

#### **3.2.2.** Program impact analysis

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

Equation 2 – Model for program impacts

outcome  $j \in \{FX, equity index, bond yields, CDS spread\}$ 

As opposed to Equation 1, in Regression 2 I consider a time series framework to measure the individual impacts of programs across countries. I apply the above model for the same group of CEE countries over the same period as in case of the baseline model. I apply Newey West estimators with seven lags since those are robust to heteroskedasticity as well as autocorrelation. The impulse dummies are considered in clusters depending on which APP program was targeted by the respective events so that I 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 together<sup>12</sup>, as well as PSPP<sup>13</sup>, CSPP<sup>14</sup>, and purchase<sup>15</sup> events, respectively. Control variables are the same as those of the baseline model: macroeconomic data releases and Citigroup Economic Surprise Indices.

#### 3.2.3. Transmission channel analysis

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

Equation 3 – Model for transmission channels

outcome  $j \in \{volatility, inflation\}$ 

Similarly to Regression 2, Equation 3 is a time series analysis considering the returns of two financial assets representing the transmission channels through which changes have possibly occurred in the aforementioned financial markets. 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. I consider the following main transmission channels:

<sup>&</sup>lt;sup>12</sup> CBPP3 and ABSPP announcements are considered together under variable *CBAB*; represented by event 2 and 3 as denoted in Appendix B.

<sup>&</sup>lt;sup>13</sup> Variable *PSPP* is represented by event 7, 9, and 11 as denoted in Appendix B.

<sup>&</sup>lt;sup>14</sup> Variable *CSPP* is represented by event 13, 14, and 15 as denoted in Appendix B.

<sup>&</sup>lt;sup>15</sup> Variable *Purchase* is represented by event 4, 6, 8, and 16 as denoted in Appendix B.

confidence channel identified by the volatility index of the EURO STOXX 50 bundle and signaling channel identified by euro inflation-linked government bonds underlying the Amundi ETF.<sup>16</sup> The relevant control variables are again the Citigroup Economic Surprise Indices, but here the ones calculated on the eurozone as well as the US; the former because the assets in question are traded in stock exchanges of the euro area whereas the latter due to the influential role of the US.

<sup>&</sup>lt;sup>16</sup> As discussed before, the relevance of the portfolio rebalance channel would be assessed theoretically.

#### 4. Results

The aim of the analysis was to identify whether there exist statistically significant spillover effects from the ECB's APP announcements to the financial markets of non-euro area EU countries in Central and Eastern Europe. I considered the impact of nineteen APP-related events on forex, equity, and bond markets as well as CDS spreads between 2014 and early 2017. The approach was fundamentally in accordance with the existing literature with the difference that the observed time frame had not been covered yet. My results are mostly consistent with that of other authors, but also shows new directions in the development of APP spillover effects.

#### 4.1. Baseline model

When measuring the cumulative effects of all APP-related shocks, there was no statistically significant spillover to any of the financial markets on the day of the announcements, as indicated by Table 1 (country fixed effects not shown). This finding suggests that the observed financial markets in all six countries on average did not react to the announcements and other events in questions. On the subsequent days of the events, denoted by the "First lag of all APP" however, there seems to be a spillover effect on bond yields. 1, 3, and 5-year benchmark government bond yields decreased by 1, 2 and 2 basis points, respectively, significant at 95 percent confidence level. On the following days of the events, there seems to be a negative effect regarding 10-year bonds and CDS spreads as well, although statistically insignificant. National currencies of the four relevant countries and main stock exchange indices remained entirely unaffected by APP events.

Considering all events across all markets, my results do not show strong spillover effects of ECB announcements to CEE countries. There is a muted association between APP events and government bond yields but these occur only on the subsequent days of the announcements and effects are low in magnitude. It must be taken into account, however that there has been a tendency

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
Macro	-0.00270	-0.00653	-1.323	0.154	1.133	0.234	0.283
	(0.534)	(0.382)	(0.535)	(0.877)	(0.095)	(0.631)	(0.435)
CESI CEMEA	-0.00830	-0.0126	-0 574	-0 591	-0 583	-0 271	-0 225
	(0.130)	(0.235)	(0.092)	(0.101)	(0.089)	(0.122)	(0.225)
	(0.150)	(0.233)	(0.0)2)	(0.101)	(0.007)	(0.122)	(0.230)
CESI EUR	-0.00649	-0.00998	-0.458	-0.418	-0.413	-0.201	-0.144
	(0.131)	(0.233)	(0.088)	(0.138)	(0.129)	(0.147)	(0.329)
CESI USD	0.00263	0.00419	0.179	$0.244^{*}$	0.178	0.0828	0.0668
	(0.132)	(0.220)	(0.113)	(0.040)	(0.128)	(0.169)	(0.266)
All APP	-0.00210	-0.00187	0.526	0.747	0.546	-1.044	0.0392
	(0.662)	(0.803)	(0.499)	(0.316)	(0.487)	(0.198)	(0.844)
Einst log of all ADD	0.000805	0.00270	0.045	2 000*	2.012*	1 776*	0.261
FIRST TAG OF ALL APP	0.000893	(0.628)	-0.943	-2.099	-2.012	-1.270	-0.501
	(0.798)	(0.028)	(0.175)	(0.034)	(0.010)	(0.049)	(0.109)
Observations	4565	4387	4215	4281	4308	4030	4556
	0 457	0.200	0 7 2 0	1 5/19	1 580	1.040	1 071

Table 1 – Cumulative effects of all APP events across all six countries

towards less and less pronounced spillovers since the beginning of ECB UMPs. Falagiarda et al. (2015) considered the period between 2007 and 2015 and their results suggested that the early ECB programs had been more remarkable in terms of spillovers to CEE countries than the latter ones. This trend seems to live on when the most recent developments of the APP are also involved in the analysis.

#### **4.2. Program impact analysis**

This section discusses how the most remarkable events of one type of program affected an individual country. APP events are grouped such that variables represent event types, and their effects are indicated in output Tables 4-9 (control variables not shown), as seen in Appendix C.

#### 4.2.1. Bulgaria

The most remarkable results are those related to the announcements of the CBPP3 and the ABSPP. In response to these events, 3 and 5-year benchmark sovereign bond yields dropped by 15 and 12 basis points, respectively, both significant with 99.9 percent confidence. A statistically less robust but still significant 11 basis point decrease in yields was present for the 1-year government bond yield. The first lag of these events was associated with an additional almost 2 basis point drop in 1-year government bond yields and a 0.6 percent decrease in the SOFIX stock exchange index. The latter is not consistent with my a priori assumption, namely that outright purchase shocks boost equity prices, although in response to CSPP announcements equity returns indeed increased by 0.5 percent. There also appeared a slightly significant 4 and 5 basis-point increase in 3 and 5-year government bond yields on the days of CSPP events.

#### 4.2.2. Croatia

Results show the least pronounced and statistically least significant spillovers in case of Croatia. There was only one slightly statistically significant and very muted association between one of the event types and any of the benchmark sovereign bonds: 1-year yields dropped by 1 basis point in response to CBPP3 and ABSPP announcements. Other spillovers tended to negatively affect equity returns, although with low significance and magnitude.

#### 4.2.3. Czech Republic

Similarly to Croatia, equity market reactions in the Czech Republic were economically inconsistent: in response to CBPP3 and ABSPP announcements returns dropped by 1 percent whereas they increased by the same amount on PSPP event days; both statistically significant with 99.9 percent confidence. After the days of PSPP announcements, 3 and 5-year benchmark government bond yields decreased by 9 and 6 basis points, respectively.

#### 4.2.4. Hungary

There were two highly significant spillovers to Hungarian financial markets. First, CBPP3 and ABSPP announcements were associated with a 5-basis-point drop in 5-year benchmark government bond yields, significant at the 0.01 level. Secondly, PSPP announcements were followed by an almost 2 percent increase in equity prices, significant with 99.9 percent confidence. Interestingly, on the days of the same group of events, 1-year government bond yields decreased whereas 5-year government bond yields increased by 5 and 6 basis points, respectively. Like in case of Bulgaria, CSPP events were associated with 4 and 3-basis-point increases in 1 and 10-year sovereign bond yields, significant at the 0.05 level.

#### **4.2.5.** Poland

The most pronounced association in Poland occurred in response to PSPP announcements. The subsequent days of the PSPP announcements saw a drop of 7, 8, and 9 basis point drop in 3, 5, and 10-year benchmark government bond yields, significant with 99.9 percent confidence. The same assets experienced highly significant increases of a few basis points in response to CSPP

announcements, which suggests a similar tendency to Bulgaria and Hungary. Purchase events were followed by a 4-basis-point decrease in 3 and 5-year government bond yields.

#### 4.2.6. Romania

Interestingly, almost all the statistically significant associations between impulse events and outcome variables were seen at 5 and 10-year government bond yields in case of Romania. In response to CBPP3 and ABSPP announcements, 10-year benchmark sovereign yields decreased by 8 basis points, statistically significant at the 0.001 level. The aftermath of the PSPP shocks saw an increase as well as a decrease in 5-year government bond yields, which together left the yields essentially unchanged. Similarly to Bulgaria, Hungary, and Poland, CSPP events were again associated with increases in sovereign bond yields, this time by 1 and 5 basis points. After the days of purchases, 5 and 10-year Romanian government bond yields experienced a 5-basis-point drop, statistically significant with 99.9 and 99 percent confidence.

#### **4.3.** Transmission channel analysis

Table 2 presents how volatility and inflation-linked assets responded to program announcements (control variables not shown). On the subsequent days of CBPP3 and ABSPP announcements, the return on the VSTOXX index 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 approximately 0.4 percent at the 0.001 significance level which signals a raise in inflation expectations. 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.

	VSTOXX	Amundi ETF
CBPP3 and ABSPP	0.0359	0.000758
	(0.468)	(0.796)
First lag of CBAB	-0.0579***	0.00119
U	(0.000)	(0.578)
PSPP	-0.0586	0.00526
	(0.231)	(0.173)
First lag of PSPP	0.0588	$0.00386^{***}$
6	(0.169)	(0.000)
CSPP	-0.00368	-0.00211*
	(0.790)	(0.017)
First lag of CSPP	-0.0440	0.00199
C	(0.296)	(0.180)
Purchases	-0.00103	$0.00191^{*}$
	(0.953)	(0.019)
First lag of purchases	0.00910	$0.00272^{*}$
	(0.820)	(0.011)
Observations	788	788
	77 11	1 166

Table 2 – Test for transmission channels

### **5.** Discussion

This section aims to put empirical findings into a broader context. Below I evaluate the economic significance of the results as well compare those to findings of other scholars.

#### 5.1. Baseline model

Equity prices, euro vis-à-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 slightly 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 is clearly a different era in terms of market mood and volatility.

Although Georgiadis and Gräb (2016) found that global exchange rate spillovers were sound, 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 the 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) assumption that 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 are EU countries versus the eurozone and the rest of the global economy.

Falagiarda et al. (2015) who concentrate on CEE countries drew similar conclusions to present study: the authors found sovereign bond yields to decrease while stock market indices, exchange rates, and CDS spreads remained 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 proceed 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 grasped 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. Secondly, 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 present study was different from the early years of ECB UMPs with respect to both factors. Hence, my results can be seen consistent with the findings of other researchers in the sense that it carries on an existing trend. Then again, patterns across countries and programs varied greatly, which I discuss in the section below.

#### **5.2. Program impact analysis**

My results show that there were several statistically significant but economically somewhat inconsistent associations between impulse events and financial market developments. Having results on six countries however helps to draw the overall conclusions from individual outcomes. If tendencies are similar across most of the countries, there is likely to be a not solely statistically, but also economically significant association between impulse events and results.

As verification, I consider a panel model characterized by Equation 4 (as seen in Appendix C), which shares similar properties to Equation 2. The panel framework can make the results of the time series analyses more credible, since in case the same statistically significant associations occurred across multiple countries, that would suggest the presence of the same mechanism in the region. The possibility that another, non-ECB development moved financial markets in all six countries can be ruled out with high confidence. Hence, the results of the panel framework, as presented in Table 2, serves as a robustness check of the findings from the time series analyses.

Although the announcement of the CBPP3 and the ABSPP induced highly robust and significant drops in government bond yields (Bulgaria, Hungary, and Romania), it did not transfer into significant association in the panel framework. The bottom line is that some of the countries experienced spillovers through the announcements of the two programs whereas others remained unaffected.

Among all programs, spillovers from the PSPP seem to be the most robust and consistent across countries. Except for equity prices, every instrument saw statistically significant spillovers either on the days of PSPP events or on those following the shocks. Again, patterns varied across countries as described in Section 4.2, but the panel model uncovers clear tendencies: the euro depreciated and government bond yields as well as CDS spreads dropped. The euro on average depreciated by 0.75 percent against the four national currencies not capped or pegged to the euro, on days when PSPP announcements took place. This result is closer to what Georgiadis and Gräb (2016) found about euro depreciation against non-euro area EU currencies (1.8 percent). Also on announcement days, CDS spreads and 1-year benchmark government bond yields experienced 0.7 and 4-basis-point decreases, respectively. 3, 5, and 10-year government bond yields dropped by 4.5, 5, and 2.5 basis points, respectively on subsequent days. Although effects on CDS spreads are negligible, those on government bond yields seem substantial. Bond yields with different maturities

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	0.0167	0.0234	-0.0901	-1.574	-0.902	-3.321	0.655
	(0.148)	(0.309)	(0.964)	(0.406)	(0.745)	(0.325)	(0.207)
First lag of CBAB	0.0210	0.0329	0.571	-0.519	-1.670	0.515	0.410
	(0.312)	(0.363)	(0.803)	(0.876)	(0.751)	(0.552)	(0.488)
PSPP	-0.00744*	0.00282	-3.804	-1.553	-0.901	$-3.972^{*}$	$-0.710^{**}$
	(0.040)	(0.610)	(0.091)	(0.290)	(0.608)	(0.038)	(0.006)
First lag of PSPP	0.00439	0.00816	$-2.514^{*}$	-4.936**	-4.429**	1.083	-0.326
	(0.411)	(0.447)	(0.049)	(0.004)	(0.003)	(0.468)	(0.567)
CSPP	-0.0105	-0.0152	-1.146	0.430	0.489	0.707	-0.247
	(0.205)	(0.317)	(0.378)	(0.718)	(0.651)	(0.691)	(0.380)
First lag of CSPP	-0.0275	-0.0396	-1.548	-0.359	-2.110	-2.185	-1.473
	(0.170)	(0.278)	(0.302)	(0.842)	(0.223)	(0.239)	(0.058)
						*	
Purchase	-0.0483	-0.0744	-3.451	-2.436	-3.840	-4.323**	-0.951
	(0.161)	(0.246)	(0.185)	(0.363)	(0.126)	(0.037)	(0.466)
First lag of purchase	0.0106	0.0142	-0.989	-1.324	0.594	-0.491	0.567
Co	(0.316)	(0.451)	(0.452)	(0.492)	(0.503)	(0.743)	(0.329)
eTD							
Observations	4565	4387	4215	4281	4308	4030	4556
F	0.438	0.672	0.850	1.618	1.333	0.899	1.305

Table 3 – Effects by programs, panel

appear to consistently change in the same direction in response to PSPP announcements, hence the impact is likely to uncover some sort of true economic mechanism. These results are also in accordance with Falagiarda et al.'s (2015) findings: basis point changes in their model varied between 1 and 5, depending on country and bond maturity. Although the magnitude of changes is muted and does not reach those of domestic monetary policy decisions (Falagiarda et al. 2015), results can be considered robust.

Similar conclusion applies to the CSPP but in the opposite direction. Some of the countries saw increases in government bond yields (Bulgaria, Hungary, Poland, and Romania), whereas the effect stayed insignificant in the panel framework. Although initial intuition about outright purchases would have implied a negative effect on bond yields, the positive effect is also justifiable. With the introduction of the CSPP, corporate securities might have become substitutes of emerging market government bonds. Investors had decided to shift their purchases towards corporate debt instruments which made CEE sovereign bonds less attractive and ultimately increased yields. It is worth noting that the effect was not consistent across countries: different countries experienced different impacts with various magnitudes.

It is also notable that days on which the execution of programs started were associated with a 4-basis-point drop in 1-year government bond yields. There seems to be a negative impact on bond yields with longer maturities as well, but those are statistically insignificant. Andrade et al. (2016) found that the first days of PSPP purchases revealed new information on the program's maturity coverage such that it caused substantial asset price changes. Overall, the first days of purchases had a weak effect on bond yields, and although the start of PSPP might have induced robust asset price changes, the cumulative impact after the commencement of all programs is negligible.

#### 5.3. Transmission channel analysis

As discussed above, it was sovereign bond yields that were primarily affected by the APP and particularly PSPP announcements. In this case, the relevant channel of transmission can be assumed to be the portfolio rebalance channel (Falagiarda et al. 2015, Georgiadis and Gräb 2016.). Although there is no empirical result on the significance of the portfolio rebalance channel, it is very likely that the channel played an important role in the transmission of spillovers from ECB's APP decisions to non-euro area CEE countries. Government bonds in the eurozone experienced a more pronounced decline in yields (Andrade et al. 2016) which incentivized investors to revise the composition of their portfolio and search for substitutes in order to maintain returns. The increasing demand for peripheral sovereign bonds ultimately drove down yields.

Falagiarda et al. (2015) also argue that in setups described by Lucas's (1978) model, asset prices may react to shocks even without actual transactions taking place. Hence, the ECB announcements might have spilled over based solely on the information content of the shocks, even before investors initiated actual rebalancing of their portfolio.

Although their relevance in terms of spillovers may be lower, there is empirical evidence on the presence of the other two transmission channels as well. It cannot be ruled out that the confidence and signaling channels also induced asset price spillovers to non-euro area CEE countries (Falagiarda et al. 2015).

CBPP3 and ABSPP announcements induced decrease in eurozone volatility, hence their relevant transmission channel was the confidence channel. Although other authors did not test the transmission channels of these particular events, this result seems to be consistent with the literature. Fratzscher et al. (2014) who observed early developments in the ECB's outright purchases found that the main channel of transmission was the confidence channel. It is plausible

to assume that CBPP3 and ABSPP carry on this legacy: the announcements of these programs implied lessening volatility in the eurozone. The overall decline in volatility suggests decrease in uncertainty, hence the demand for assets, previously considered riskier, increased. Unlike Georgiadis and Gräb (2016), I found that equity prices which are most likely to be affected by the confidence channel, generally remained unchanged in response to APP announcements. Yet again, due to the ever-increasing integration of the CEE region and the eurozone, volatility and uncertainty can be assumed to be positively correlated between the two (Falagiarda et al. 2015), thus the transmission channel is likely to have played a significant role, even though it did not transfer into changes in asset prices.

On the subsequent days of PSPP announcements, returns on the ETF that replicates the Markit iBoxx Euro Inflation Linked Index, increased with high statistical significance which suggests the relevance of the signaling channel. Preceding programs, such as the CBPP3 and the ABSPP were indeed found to make smaller impacts on inflation expectations (Rieth and Gehrt 2016). Consequently, the introduction of the PSPP was a more robust tool in stemming further decline of inflation expectations. This robustness carried over to CEE countries as well, since PSPP events were associated with significant asset price changes. Besides Rieth and Gehrt (2016), other researchers also found PSPP to come into effect through the signaling channel (Andrade et al. 2016, Falagiarda et al 2015). On a different note, the relevance of the portfolio rebalance channel, although not empirically verified, cannot be ignored for the reasons discussed above.

In response to CSPP events and the commencement of purchases, changes in inflation expectations turned out to be neither highly significant, nor robust. The effects of CSPP and purchase shocks on the assets were blurry, similarly to the asset price changes they were associated with. Overall, inflation expectations reacted moderately to these shocks, but their spillover effect remains unclear nevertheless.

### 6. Conclusion

I observed the spillover effects to six CEE countries after nineteen APP-related ECB events. I considered the changes of seven financial instruments: exchange rates, equity prices, bond yields with four different maturities, and CDS spreads. I applied an impulse event methodology first, to identify the overall effect of the announcements, then to measure their impact program-by-program across countries. I also identified the three relevant transmission channels through which the countries in consideration might have been affected.

I found that the cumulative effect of the events was mostly insignificant, although there was a moderate decrease in government bond yields. When clustering events according to their related programs, changes in asset prices varied greatly across programs and countries. There was a clear tendency however, namely that PSPP events were the most pronounced in terms of inducing changes in asset prices. PSPP events affected all asset classes except for equity prices, but their impact on government bond yields turned out to be the most remarkable. My results are mostly consistent with the findings of other researchers, especially those of Falagiarda et al. (2015). Assessing the spillovers from the CSPP was a new addition to the existing literature. Although there was no unambiguous correspondence across countries and asset classes, four out of six countries shared similarities with respect to government bond yields in response to CSPP announcements. Somewhat surprisingly, yields moderately increased in Bulgaria, Hungary, Poland, and Romania. Since government bond yields experienced the most pronounced impacts, spillovers are likely to have occurred through the portfolio rebalance channel.

Limitations arose due to numerous factors around model design. Although the observed period did not see excessive variation in market uncertainty, the OLS model would not be capable of handling periods of different volatility if the analysis covered a longer time span. Regarding the selection of shocks, even though impulse events were collected based on objective criteria, their relevance was subject to arbitrary judgement. Future research may involve a more sophisticated differentiation process across impulse events.

As the ECB shows intent to lessen its outright purchases, it opens new directions for further research. Studies found that market reactions on Fed tapering were of significantly higher magnitude than QE announcements (Falagiarda et al. 2015), hence similar comparison could be made about ECB shocks, once Frankfurt shows full commitment to toning down its expanded APP.

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## Appendix A: Retrieved data from Thomson Reuters Eikon

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

## Appendix B: List of APP-related events

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

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

## Appendix C: Additional figures, equations, and output tables



*Figure 1 – Eurozone volatility over the past decade* 

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

Equation 4 – Panel model for program impacts

 $country i \in \{Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania\}$ 

outcome  $j \in \{FX, equity index, bond yields, CDS spread\}$ 

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	N/A	0.00578	-5.016	-11.89***	-15.04***	-11.19*	0.739
		(0.143)	(0.117)	(0.000)	(0.000)	(0.038)	(0.147)
First lag of CBAB	N/A	-0.00621***	1.904	9.086	11.68	-1.793**	-0.888
		(0.000)	(0.176)	(0.107)	(0.155)	(0.001)	(0.134)
PSPP	N/A	0.00468	-3.332	0.604	2.446	-4.630	-0.532
		(0.373)	(0.247)	(0.816)	(0.619)	(0.488)	(0.210)
First lag of PSPP	N/A	0.00179	-1.084	-2.600	-5.437	7.459	0.504
		(0.363)	(0.241)	(0.324)	(0.124)	(0.312)	(0.691)
CSPP	N/A	$0.00540^{**}$	-3.524	$4.762^{*}$	$4.307^{*}$	2.176	-0.0578
		(0.005)	(0.230)	(0.021)	(0.039)	(0.611)	(0.730)
First lag of CSPP	N/A	0.000195	-0.114	7.956	-4.104	1.901	-0.730
		(0.947)	(0.965)	(0.134)	(0.424)	(0.130)	(0.301)
Purchase	N/A	-0.00848	-0.374	4.329	6.170	-18.40	0.394
		(0.217)	(0.933)	(0.290)	(0.121)	(0.178)	(0.625)
u							
First lag of purchase	N/A	0.00186	2.396	2.512	8.583	26.64	-1.318
Coll		(0.564)	(0.358)	(0.313)	(0.276)	(0.291)	(0.212)
eTD							
Observations 🖹	N/A	659	659	659	659	636	659
F	N/A	6.334	3.634	20.19	6.141	13.42	4.817

Table 4 – Effects by programs, Bulgaria

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	0.000120	0.00134	1.086	-0.359	-0.795	-1.340*	-0.991
	(0.658)	(0.230)	(0.909)	(0.852)	(0.587)	(0.040)	(0.645)
First lag of CBAB	0.000657	$-0.00187^{*}$	5.881	-13.15	-24.55	0.165	0.0830
	(0.096)	(0.039)	(0.172)	(0.174)	(0.170)	(0.098)	(0.649)
PSPP	0.000334	-0.00252	-4.374	0.943	1.447	1.559	3.045
	(0.749)	(0.552)	(0.343)	(0.691)	(0.392)	(0.102)	(0.382)
First lag of PSPP	0.00172	-0.00414***	2.845	0.141	0.130	-0.536	-3.597
	(0.195)	(0.002)	(0.165)	(0.688)	(0.773)	(0.369)	(0.111)
CCDD	0.00100*	0.000552	1 270	2 600	1.062	1 020	0.219
CSPP	-0.00109	0.000552	-1.379	3.000	1.002	-1.808	0.218
	(0.043)	(0.447)	(0.141)	(0.298)	(0.534)	(0.258)	(0.085)
First lag of CSPP	-0.000174	-0.00149	0 298	-2.362	-1 984	0.0446	-1 550
This hag of Corr	(0.359)	(0.250)	(0.667)	(0.313)	(0.086)	(0.759)	(0.157)
	(0.000))	(0.200)	(0.007)	(0.010)	(0.000)	(01103)	(01207)
Purchase	0.000426	0.000266	0.839	3.688	-0.386	-0.557	1.067
	(0.305)	(0.781)	(0.562)	(0.223)	(0.765)	(0.258)	(0.780)
Ę	. ,	· · · ·		. ,		. ,	
First lag of purchase	-0.000197	$-0.00252^{*}$	-3.045	-6.644	0.217	0.173	2.118
Coll	(0.548)	(0.039)	(0.353)	(0.278)	(0.727)	(0.850)	(0.239)
eTD							
Observations	748	748	748	748	748	748	748
F	3.680	10.39	2.079	1.323	1.391	3.806	1.474

Table 5 – Effects by programs, Croatia

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	N/A	-0.0125***	-0.416	0.851	0.919	-0.598	0.0375
		(0.000)	(0.825)	(0.382)	(0.537)	(0.325)	(0.499)
First lag of CBAB	N/A	$0.00377^{*}$	0.413	-1.028	0.0333	-0.165	0.0577
		(0.011)	(0.366)	(0.572)	(0.900)	(0.447)	(0.147)
PSPP	N/A	0.0105***	4.083	-0.141	1.778	-1.138	-0.156
		(0.000)	(0.143)	(0.923)	(0.194)	(0.092)	(0.258)
				de de de			
First lag of PSPP	N/A	-0.00128	-2.566	-5.646***	-8.601**	0.0339	0.212
		(0.768)	(0.148)	(0.000)	(0.004)	(0.857)	(0.122)
CODD		0.00416	1 070	1 0 1 4	0 (10	0.0005	0.00700
CSPP	N/A	0.00416	-1.378	-1.314	-0.612	0.0996	0.00723
		(0.112)	(0.065)	(0.389)	(0.162)	(0.430)	(0.816)
First lag of CSDD	NI/A	0.00174	0 565	1 673	1 961	2 010	0.0860
Flist lag of CSFF	$\mathbf{N}/\mathbf{A}$	(0.738)	(0.505)	(0.281)	(0.117)	-3.019	(0.0809)
		(0.738)	(0.081)	(0.201)	(0.117)	(0.223)	(0.077)
Purchase	N/A	-0.00633	-0.482	0.0561	0.395	-1.094	0.152
		(0.320)	(0.199)	(0.906)	(0.558)	(0.217)	(0.114)
-		(0.020)	(01222)	(01) 00)	(0.000)	(0.217)	(0111)
First lag of purchase	N/A	-0.000721	-1.189	-0.994	-0.0402	0.166	-0.109
		(0.887)	(0.060)	(0.096)	(0.930)	(0.377)	(0.317)
D CL		× /	× /	```	× /	× /	` '
Observations 🖹	N/A	750	750	750	750	600	750
F	N/A	36.88	4.307	7.722	1.606	1.190	1.592

Table 6 – Effects by programs, Czech Republic

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	-0.000928	-0.00227	0.192	-5.306**	-3.421	0.482	-0.529
	(0.360)	(0.785)	(0.603)	(0.002)	(0.261)	(0.055)	(0.657)
First lag of CBAB	0.000255	0.00358	-4.380	2.454	2.875	-0.110	-0.315
	(0.427)	(0.141)	(0.250)	(0.102)	(0.063)	(0.875)	(0.488)
PSPP	-0.00340	$0.0184^{***}$	2.916	$6.069^{*}$	0.564	$-4.862^{*}$	-0.259
	(0.152)	(0.000)	(0.601)	(0.031)	(0.891)	(0.030)	(0.573)
First lag of PSPP	-0.00239	-0.00105	-12.19	-10.75	-2.779	-1.390	-2.791
	(0.336)	(0.832)	(0.274)	(0.183)	(0.557)	(0.369)	(0.166)
C ( ) )	<b>-</b>		0.10.4	1.001		1	0 <b>1 -</b> 0
CSPP	0.00197	-0.00182	-3.436	-1.801	-2.323	-1.873	0.179
	(0.380)	(0.629)	(0.371)	(0.403)	(0.198)	(0.542)	(0.143)
	0.00157	0.000011	0.074*	0.460	0.554	4 101*	1 000
First lag of CSPP	-0.00157	0.000811	3.374	0.468	0.554	4.191	-1.090
	(0.357)	(0.883)	(0.031)	(0.511)	(0.493)	(0.023)	(0.070)
Durahaaa	0.000472	0.00405	0.295	1.072	1 270	0.280	0 697
Fulchase	(0.744)	-0.00493	(0.046)	-1.073	-1.379	(0.380)	(0.215)
	(0.744)	(0.242)	(0.940)	(0.838)	(0.798)	(0.077)	(0.213)
First lag of purchase	0.00214	-0.00278	-0.0178	3 4 1 0	2 436	0 291	1 378
	(0.246)	(0.543)	(0.997)	(0.535)	(0.406)	(0.192)	(0.352)
C B	(0.240)	(0.5+5)	(0.777)	(0.333)	(0.+00)	(0.172)	(0.332)
Observations P	766	766	766	766	766	690	766
F 5	10.27	7.610	2.157	15.78	4.417	3.905	0.986
-	10.27	/.010	2.107	101/0		21202	0.200

Table 7 – Effects by programs, Hungary

	Foreign	Equity	BPS change				
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	-0.000913	-0.000272	$0.570^{*}$	-0.191	1.853	-1.958	-0.578
	(0.157)	(0.973)	(0.048)	(0.959)	(0.538)	(0.735)	(0.164)
First lag of CBAB	0.000645	$0.00281^{*}$	-2.943	0.134	-2.276	-0.0849	$0.171^{*}$
	(0.787)	(0.038)	(0.527)	(0.930)	(0.444)	(0.975)	(0.034)
							*
PSPP	-0.00310	-0.000212	5.266	4.382	1.238	0.266	-0.587*
	(0.452)	(0.978)	(0.469)	(0.549)	(0.787)	(0.908)	(0.016)
			***	~ ~ ***	***		
First lag of PSPP	-0.00423	0.000624	-8.788	-8.564	-6.810	-1.178	0.491
	(0.257)	(0.749)	(0.000)	(0.000)	(0.000)	(0.169)	(0.442)
CSPD	0.00532	0.00106	2 534**	2 573***	3 0/11***	-0.0597	-0.00275
CSIT	(0.00552)	(0.523)	2.334	2.373	(0,000)	(0.074)	-0.00273
	(0.090)	(0.323)	(0.008)	(0.000)	(0.000)	(0.974)	(0.939)
First lag of CSPP	0.000297	0.00826	-0.00511	-0.507	-0.267	-1.277	-0.357
U	(0.951)	(0.064)	(0.999)	(0.820)	(0.856)	(0.271)	(0.226)
Purchase	-0.00299	0.00148	-0.160	-3.694*	-3.861***	-1.924	0.243
	(0.080)	(0.487)	(0.970)	(0.036)	(0.000)	(0.101)	(0.218)
u							
First lag of purchase	0.00233	-0.00304	-0.707	0.344	0.759	-0.510	-0.177
Coll	(0.348)	(0.580)	(0.384)	(0.388)	(0.061)	(0.552)	(0.305)
eTD							
Observations $\overline{\mathbb{R}}$	765	765	765	765	765	763	765
F	2.484	2.825	9.229	6.595	43.91	1.008	16.12

Table 8 – Effects by programs, Poland

	Foreign	Equity	BPS change	BPS change	BPS change	BPS change	BPS change
	exchange rate	returns on	in 10-year	in 5-year	in 3-year	in 1-year	in 5-year
	percentage	stock market	government	government	government	government	CDS
	changes	indices	bond yields	bond yields	bond yields	bond yields	spreads
CBPP3 and ABSPP	0.000421	-0.00341	-8.245***	-0.307	-0.881	5.538	$0.983^{*}$
	(0.505)	(0.199)	(0.000)	(0.938)	(0.917)	(0.138)	(0.018)
First lag of CBAB	0.000317	0.000144	-4.217	-9.511	-2.461	-1.574	0.0859
	(0.354)	(0.919)	(0.286)	(0.208)	(0.372)	(0.066)	(0.198)
				<u>ب</u>			
PSPP	-0.00113	-0.000219	-2.307	$4.198^{*}$	-0.335	-3.719	0.336
	(0.436)	(0.916)	(0.546)	(0.023)	(0.788)	(0.272)	(0.554)
				**			
First lag of PSPP	-0.00139	0.000345	-5.972	-3.371	-4.084	-1.216	-0.359
	(0.223)	(0.708)	(0.151)	(0.006)	(0.342)	(0.456)	(0.610)
CCDD	0.000490	0.000002	4.007**	0.0269	0.0240	10.64	0.295
CSPP	0.000489	-0.000803	4.807	0.0308	-0.0349	10.04	0.285
	(0.367)	(0.753)	(0.008)	(0.984)	(0.956)	(0.182)	(0.263)
First lag of CSPP	0.000178	-0.00122	-2 410	1 196*	1 924	-9 642	-0.648
Thist hag of Corr	(0.742)	(0.438)	(0.241)	(0.030)	(0.335)	(0.184)	(0.349)
	(0.712)	(0.150)	(0.211)	(0.050)	(0.555)	(0.101)	(0.517)
Purchase	-0.000258	0.00172	3.004	4.113	0.476	-0.00809	-0.608
	(0.370)	(0.475)	(0.083)	(0.256)	(0.832)	(0.996)	(0.353)
q	~ /		× ,		× /		× ,
First lag of purchase	0.000237	-0.00414	-5.058**	$-5.470^{***}$	-2.175	5.122	-0.155
Colli	(0.598)	(0.519)	(0.005)	(0.001)	(0.279)	(0.054)	(0.827)
CL.							
Observations E	765	765	765	765	765	765	765
F	2.728	2.157	42.80	3.500	1.323	1.966	1.704

Table 9 – Effects by programs, Romania