COLLEGIUM OF ECONOMIC ANALYSIS
WORKING PAPER SERIES

Quantitative Easing During the COVID-19 Pandemic: A Cross-Country Study

Maciej Stefański

SGH KAE Working Papers Series Number: 2023/088 June 2023

Quantitative Easing During the COVID-19 Pandemic: A Cross-Country Study

Maciej Stefański

SGH Warsaw School of Economics and EY Economic Analysis Team[1]

June 2023

Abstract

This paper estimates the financial market and macroeconomic effects of central bank asset purchases (quantitative easing, QE) in 16 economies which have launched asset purchases for the first time in response to the COVID-19 pandemic. We opt for regression-based methods rather than event studies, which enable us to estimate the effects of QE on government bond yields and stock prices over the first year of the pandemic rather than only at the time of the programme announcement. These estimates are inputted into Bayesian vector autoregressive models using Structural Scenario Analysis to obtain the effects on GDP and inflation. Contrary to most of the previous literature, we find that QE has a strong and robust impact on stock prices (raising them by 40% on average), but only a muted and on average neutral impact on bond yields. This translates into usually positive, but rather muted and often statistically insignificant impact on GDP of 0.4% on average and an insignificant impact on prices. Analysing the cross-country differences in the results we find that QE tends to be more effective in countries with more credible monetary and fiscal policies, which suggests that it is a useful tool primarily in advanced economies.

Keywords: unconventional monetary policy, large-scale asset purchases, QE, GDP, inflation, stock prices, government bond yields, credibility, comparative study.

JEL: E52, E58.

[1] The views expressed in this paper belong to the author only and do not necessarily reflect the views of the institutions he is affiliated with. E-mail address: maciej.stefanski@doktorant.sgh.waw.pl

1. Introduction

Following the outbreak of the COVID-19 pandemic, large-scale asset purchases, commonly referred to as quantitative easing (QE), became the instrument of choice for central banks across the globe. Amid a secular downward trend in interest rates and given the magnitude of the pandemic shock, conventional interest rate cuts did not provide enough policy accommodation in advanced and some emerging market economies. Facing the zero lower bound (ZLB) and seemingly encouraged by the previous experience of major central banks, central banks of those economies turned to QE. Several emerging market central banks well away from the ZLB also launched asset purchases, aiming at supporting bond market functioning and helping governments finance unprecedented anti-crisis fiscal measures. As a result, while only 6 central banks utilised QE at some point before the pandemic, as many as 40 launched asset purchases after its outbreak (Fratto et al. 2021).

The majority of the pre-pandemic literature finds quantitative easing to be effective, i.e. to improve financial conditions and increase economic activity and inflation (Kuttner 2018, Papadamou et al. 2020, Hertel et al. 2022). However, the estimates tend to be highly uncertain and dependent on the method, assumptions, sample, economic conditions and country. Moreover, Stefanski (2022) finds that in the US, quantitative easing is transmitted to the real economy mostly via stock prices, putting into question the effectiveness of QE in countries with shallower capital markets.

For these reasons it seems interesting to investigate whether the results obtained thus far in the literature, mostly for major economies (the US, UK, euro area and Japan), can be generalised to smaller and/or less developed countries, which began to conduct quantitative easing during the pandemic. Furthermore, the adoption of quantitative easing by a larger number countries makes it possible to conduct a comparative study of QE, i.e. to study to what extent the effectiveness of QE depends on country and programme characteristics.

This paper aims to do exactly that by studying 16 advanced and emerging market economies, which have launched quantitative easing for the first time during the COVID-19 pandemic[2]. As the time series of the pandemic QE remain short, we opt for a two-stage approach, somewhat similar to the first empirical studies of QE conducted during the global financial crisis (Kapetanios et al. 2012, Baumeister and Benati 2013). Thus, we first estimate the impact of QE on financial variables (government bond yields and stock prices) and then input these estimates into a vector autoregressive (VAR) model to obtain the impact of QE on macroeconomic variables (GDP and inflation). We conclude this analysis with a comparative study of QE, investigating to what extent the financial market and macroeconomic effects of QE depend on country and QE programme characteristics.

[2] The sample includes Australia, Canada, Chile, Colombia, Costa Rica, Croatia, Iceland, India, Israel, Korea, New Zealand, Poland, Romania, South Africa, Thailand, and Turkey.

To be more specific, in the first stage, we construct country-specific autoregressive distributed lag (ARDL) models for government bond yields and stock prices on a pre-pandemic sample and interpret forecast errors obtained from these models as the effects of QE. While this approach has its drawbacks (see section 3.1.1 and section 6 for a discussion), we prefer it over an alternative of event studies for two main reasons: firstly, ARDL models allow for the estimation of the effects over a longer timeframe; secondly, in the pandemic QE setting, event studies are challenging to conduct as QE announcements often took place outside of the trading hours, were vague and happened at the time of unprecedented market volatility.

In the second stage, we estimate country-specific Bayesian VAR models, which include – but are not limited to – GDP, inflation, government bond yields and stock prices. These models are then combined with the estimates from the first stage to obtain the effects of QE on GDP and inflation with the assistance of structural scenario analysis (SSA) of Antolin-Diaz et al. (2021) by imposing the estimated effects of QE on bond yields and stock prices into the paths of impulse response functions. By inputting out-of-model estimates of financial market impact of QE into VAR models, we follow Kapetanios et al. (2012), Baumeister and Benati (2013) and Churm et al. (2021); however, we add to their approaches by inputting a path of shocks rather than one-period shocks and taking into account both bond yields and stock prices rather than only bond yields.

The Bayesian VAR models are estimated on a pre-pandemic sample using stochastic search variable selection (SSVS) prior of George et al. (2008), which allows for efficient shrinkage in the relatively small samples considered here. The use of SSA requires the identification of shocks that move government bond yields and stock prices – we identify a shock to expected interest rates/risk premium and a shock to expected economic activity using a mixture of sign and zero restrictions in the spirit of Arias et al. (2018).

Finally, in the third part of the paper, we make a tentative attempt at a comparative study of QE by studying simple correlations between the effects of QE (on bond yields, stocks prices, GDP and inflation) and country characteristics (such as GDP per capita, stock market capitalisation, government bond market size, proxies for monetary and fiscal policy credibility), the severity of the pandemic (containment measures, cases and deaths) and the characteristics of the QE programme (the scale of purchases, whether the size of purchases was announced, what securities were purchased etc.).

We find that pandemic QE programmes tend to have a relatively strong positive impact on stock prices, with QE increasing stock prices by 40% at peak on average. The effects are positive and statistically significant at a 10% level in 12 out of 16 analysed countries, and in 7 of these countries the peak impact exceeds 40%. At the same time, the impact on long-term government bond yields tends to be more muted and less clear-cut in terms of the sign. The effect is statistically significant, negative and economically meaningful (at least 2.1 pp at peak) in only 4 of the analysed countries (Israel, Croatia, Poland, Romania). Elsewhere the impact is either not statistically significant (5 cases), marginally significant and positive (4 cases) or significant and positive (2 cases). As a result, the average peak impact of QE on bond yields is estimated to be positive (0.3 pp).

There seem to be two explanations for the muted and often counterintuitive impact of QE on bond yields and – at the same time – strong impact on stock prices. Firstly, the signalling effect – i.e. QE not only lowers expected interest rates and/or risk premia, reducing bond yields and propping stock prices, but also improves expectations about future economic activity, cancelling out the impact on bond yields and further increasing stock prices. Secondly, the lack of credibility of many – especially emerging market – governments. The QE's effect on bond yields is positively correlated with pre-pandemic inflation (a proxy for monetary policy credibility) and negatively correlated with government balance and credit rating, i.e. the lower the inflation, the higher the rating and the lower the government deficit, the more negative the response of bond yields to QE. Thus, in less credible countries QE seems to be viewed as a way of debt monetisation, which supports fiscal profligacy and increases the risk of high inflation in the future, leading to an increase in expected future interest rates and/or term premium. At the same time, the issue of credibility seems to be playing much less of a role in the stock market.

The QE effects on bond yields and stock prices translate into a positive, but relatively muted and often statistically insignificant impact on GDP, amounting to 0.37% on average at peak. The results are positive and statistically significant for 5 countries (Iceland, Israel, New Zealand, Romania and South Africa), with the strongest peak impact of 4% in New Zealand. For other countries the point estimates either tend to be positive, but not statistically significant (5 cases), are very close to zero (3 cases) or are negative (3 cases). The impact on CPI, in turn, is statistically insignificant in most cases, though point estimates suggest a muted positive impact in 6 countries, with the average cross-country impact of 0.24%. The lack of the response of prices is a by-product of weak or non-existing reaction of prices to financial conditions and – indirectly – economic activity, which suggests that Phillips curves in the analysed economies are relatively flat.

Further analysis of the results reveals that characteristics of QE programmes, such as types of securities purchased, announcement of the expected size of purchases, the duration of purchases and finally, the actual size of purchases, are not correlated with the effectiveness of QE. Hence, it appears that quantitative easing operates primarily through announcement effects, specifically via the signalling channel, rather than actual purchases. The critical factor seems to be the presence of the central bank in the market and its ability to intervene if necessary, while the specifics of central bank communication and the programme's structure seem to have a lesser impact. Moreover, the size of the bond or stock markets does not appear to significantly influence the effectiveness of QE transmission.

The results have numerous policy implications. Since QE tends to be effective only in relatively credible countries, it seems to be more suitable for advanced than emerging market economies. Having said that, the impact of QE is highly heterogeneous across countries and quite sensitive to the method of estimation, making the effects of asset purchases highly uncertain also in relatively credible advanced economies. Thus, even the advanced economy central banks should continue to view interest rates, whose impact on the economy is much better established, as a primary monetary policy tool, resorting to QE only if further monetary policy expansion is needed at the effective lower bound. Finally, since the effects of QE do not seem to increase significantly with the increase in the scale of purchases, purchasing securities on a discretionary basis, when warranted by market conditions and ultimately on a smaller scale, may be a more cost-effective and less market-distortionary way of conducting QE than making large-scale, pre-announced purchases on a regular basis.

We contribute to the literature on quantitative easing in several ways. Firstly, we use a novel approach to studying the financial market impact of QE[3] and arrive at a somewhat different results than previously used event studies, i.e. we find the QE's impact on stock prices to be stronger than on bond yields. Secondly, we refine the two-stage approach to estimating macroeconomic effects of QE used previously by Kapetanios et al. (2012), Baumeister and Benati (2013) and Churm et al. (2021) by taking into account a path of shocks (rather than one-period shocks) and shocks to stock prices on top of bond yields. Thirdly, we attempt to conduct a comparative study of QE, which, to the best of our knowledge, has not been carried out previously in terms of macroeconomic impact. Our analysis suggests that QE appears to be more effective in countries with higher monetary and fiscal policy credibility. Finally, we obtain estimates of macroeconomic effects of QE for several countries for which such estimates – to our knowledge – have not yet been available.

The remainder of the paper is structured as follows. Section 2 briefly reviews the literature on quantitative easing – both pre-pandemic and pandemic - and describes the quantitative easing programmes in studied countries. Section 3 describes the first stage of the analysis, i.e. the estimation of the financial market effects of QE, including the empirical framework, the data, the baseline results and the robustness checks. Section 4 describes the second stage of the analysis, i.e. the macroeconomic effects of QE, in a similar manner, while Section 5 presents the attempt at a comparative study of QE. Finally, Section 6 sums up the results and concludes.

[3] Churm et al. (2021) come closest to our approach by regressing government bond yields on principal components obtained from a dozen of foreign bond yields; we take into account not only foreign bond yields, but also other financial market and macroeconomic variables, both domestic and foreign.

2. Literature review and pandemic QE programmes

In this section we briefly review both the rich literature on pre-pandemic QE programmes in major economies (the US, UK, euro area and Japan) and the literature on pandemic QE in the countries studied in this paper. We also briefly describe the modalities of pandemic QE programmes conducted by studied central banks.

2.1 Pre-pandemic QE – literature review

The empirical literature assessing the effectiveness of pre-pandemic QE programmes is rich and mostly shows that asset purchases improve financial conditions and have a positive impact on economic activity and inflation (Kuttner 2018, Papadamou et al. 2020, Hertel et al. 2022). However, the estimates tend to be highly uncertain and dependent on the method, assumptions, sample, economic conditions and country.

In the first years of QE, when time series remained relatively short, the studies of QE investigated mostly the response of asset prices within a short time window around the QE announcement, utilising the event study method. First studies of this kind indicated that QE was effective, i.e. bond yields fell, exchange rate depreciated and stock prices increased following QE-related announcements (Gagnon et al. 2011, Joyce et al. 2011, Krishnamurthy and Vissing-Jorgensen 2011, Lam 2011, Meaning and Zhu 2011, Christensen and Rudebusch 2012, Joyce and Tong 2012, Rosa 2012, Ueda 2012, Bauer and Rudebusch 2014, Rogers et al. 2014, Altavilla et al. 2015, Fukunaga et al. 2015, Andrade et al. 2016, Urbschat and Watzka 2020). However, these results were driven by the first QE announcements made at the height of the global financial crisis. The following announcements are found to have had smaller impact on asset prices, perhaps because they were to a large extent expected. Some studies even indicate that if the effects of all monetary policy announcements made during the QE period are summed, the effect of QE on bond yields is close to zero (Greenlaw et al. 2018). It is also not entirely clear whether these on impact, financial market responses persist over a longer period of time – there is some evidence that they may fade relatively fast (Wright 2012).

Given short time series, the effects of QE on GDP and inflation were initially studied using two-step approaches, in which shocks to long-term interest rates estimated with event studies are inputted into structural or VAR models (Chung et al. 2012, Kapetanios et al. 2012, Baumeister and Benati 2013, Engen et al. 2015, Churm et al. 2018, Liu et al. 2019) – this strand of literature is most closely related to this study. Papers using the two-step approach find moderately positive impact on economic activity and inflation – unemployment in the US was about 1.5 pp lower and inflation 0.7-1 pp higher thanks to QE (Chung et al. 2012, Baumeister and Benati 2013, Engen et al. 2015). The assumption that asset purchases affect economic activity only via long-term rates constitutes a weakness of this strand of literature, however. To address this issue, we refine this approach by also accounting for the impact on stock prices, in addition to bond yields. By utilising a regression-based method to estimate the financial market effects of QE, we are also able to impose a multi-period QE shock rather than a one-period shock that is usually obtained from event studies.

The macroeconomic effects of QE have also been studied using dynamic stochastic general equilibrium (DSGE) models (Chen et al. 2012, Gertler and Karadi 2013, Falagiarda 2014, Andrade et al. 2016, Sahuc 2016, Hohberger et al. 2019) and VAR models with QE shocks identified inside the model (Schenkelberg and Watzka 2013, Garcia Pascual and Wieladek 2016, Haldane et al. 2016, Weale and Wieladek 2016, Hesse et al. 2018, Hayashi and Koeda 2019, Kim et al. 2020, Breitenlechner et al. 2021). Estimates obtained from DSGE models range from small (0.1-0.3% rise in GDP following sizeable QE programmes; Chen et al. 2012, Sahuc 2016, Hohberger et al. 2019) to sizeable (1% rise in GDP following US QE2 alone; Gertler and Karadi 2013) depending on the mechanism via which QE affects long-term interest rates and the method of model estimation or calibration. The results obtained from VAR models also vary depending on the method of shock identification (larger effects tend to found using high-frequency identification than sign restrictions or Cholesky decomposition) and country (with larger effects found for the US and the UK than the euro area and Japan). There is also some evidence that the effects of QE decline over the following rounds of asset purchases and/or with improving financial conditions (Haldane et al. 2016, Hesse et al. 2018).

2.2 Pandemic QE programmes – description

The size, operational details, the scope and stated goals of the pandemic QE programmes differed widely across countries, and so did central bank communication regarding QE. Table 1 summarises the modalities of pandemic QE programmes for studied central banks (i.e. central banks that launched QE for the first time during the pandemic).

Some central banks – mostly in advanced economies - followed practices established by major central banks during the pre-pandemic QE programmes and announced the total scale and/or monthly/weekly scale of purchases (e.g. Australia, Canada, Iceland, Israel, New Zealand). Some other central banks – primarily in emerging markets – were somewhat more cryptic and limited themselves to stating they would conduct "large-scale" purchases, or simply purchases (e.g. Poland, Romania, South Africa). There were also central banks that did not announce they were launching an asset purchase programme, but rather stated the intention to buy a given amount of securities shortly before the auction or announced the purchase had just taken place (e.g. India, Croatia). Finally, as a second central bank after the Bank of Japan, the Reserve Bank of Australia set a price (yield) target rather than a quantity target for 3-year government bonds – the policy referred to as yield curve targeting (YCT) or yield curve control (YCC).

Table 1. Summary of pandemic QE programmes

Country	Purchased securities	Realised scale (% of 2019 GDP)	YCT	Total size announced?	Monthly size announced?	Duration (months)
Australia	Central and local government bonds	17.1	Yes	Yes	Yes	23
Canada	Central and local government bonds (including inflation-linked), mortgage bonds, bankers' acceptances, commercial paper, corporate bonds	17.0	No	No	Yes	19
Iceland	Central government bonds	0.8	No	Yes	No	16
Israel	Central government bonds (including inflation-linked), corporate bonds	6.0	No	Yes	No	21
Korea	Central government bonds	0.9	No	No	No	16
New Zealand	Central and local government bonds (including inflation-linked)	17.1	No	Yes	Yes	17
Chile	Bank bonds	2.9	No	Yes	No	10
Colombia	Central government bonds, bank bonds	1.7	No	Yes	No	3
Costa Rica	Central government bonds	0.01	No	Yes	No	14
Croatia	Central government bonds	4.9	No	No	No	5
India	Central government bonds	-	No	Yes	-	-
Poland	Central government and government-guaranteed bonds	6.3	No	No	No	21
Romania	Central government bonds	0.5	No	No	No	5
South Africa	Central government bonds	-	No	No	No	-
Thailand	Central government bonds, corporate bonds	0.9	No	Yes	No	1
Turkey	Central government bonds	1.7	No	No	No	5

Source: own compilation based on Fratto et al. (2021) and central bank websites.

Most central banks placed a significant emphasis on the operational details of their quantitative easing (QE) programs during the COVID-19 pandemic. They disclosed the days of the week on which auctions to buy securities would take place, the types of securities to be purchased on each day, and their maturities. The information provided tended to be more detailed than in the case of major central banks before the pandemic, even for some of the central banks that did not announce the total scale of purchases (e.g. Poland). The focus on operational details was probably mandated by the fact that virtually all purchases were made using auctions (unlike in the case of ECB, for example) and thus some operational details must have been released at least shortly before the auction. Central banks were also likely to err on the side of caution and preferred to give too much rather than too little information given the scale of the market turmoil at the height of the pandemic and the novelty of the instrument in their jurisdictions. By being transparent, they also aimed to dispel any potential accusations that QE was a form of monetary financing of government deficits.

All but one central bank purchased government bonds – the only exception was Chile, whose central bank was formally prohibited from purchasing government securities. However, the types of government securities varied quite widely across countries – the most commonly security purchased were central government fixed-coupon government bonds (i.e. with maturity of at least 1 year), but some central banks purchased also variable-rate and inflation-linked securities (e.g. Canada, New Zealand, Israel), government bills, local government securities (e.g. Australia, New Zealand, Canada) or government-guaranteed securities (e.g. Poland). On top of government securities, several central banks purchased private securities – the scope of Canada's QE programme was broadest comprising of bankers' acceptances, commercial paper, corporate bonds and mortgage bonds. Corporate bonds were also purchased by the central banks of Israel and Thailand, while the central banks of Chile and Colombia purchased bank bonds.

The stated goals of the QE programmes also varied across countries. Some central banks stressed that purchases are aimed solely at preserving the functioning of the markets and improving market liquidity (e.g. Korea, South Africa). The Reserve Bank of South Africa went to great length in explaining that such purchases do not constitute a QE programme. These central banks tended not to announce a total scale of purchases but rather intervene whenever tensions arose. Other central banks, while also usually stating the goal of supporting market liquidity, mentioned more directly or indirectly that asset purchases constitute a form of monetary expansion, which is supposed to support economic activity during the pandemic and thus contribute to the attainment of the inflation target in the medium term (e.g. Australia, Canada, Israel, New Zealand, Chile, Poland). These central banks tended to be more decisive in their communication and announced the (sizeable) scale of purchases or at least stated that purchases would be conducted regularly and on a large (though undefined) scale (Poland). Finally, some central banks also mentioned more or less directly that asset purchases are supposed to increase the fiscal space in the times of dwindling revenues and ballooning expenditures as tax cuts, furlough schemes and other forms of government transfers were needed to avoid large-scale bankruptcies and employment losses during pandemic lockdowns.

The goals and other modalities of pandemic QE programmes were reflected in the size of actual purchases and the duration of the programmes, which also varied widely across countries. Several central banks (Colombia, Romania, Thailand, Turkey) purchased securities worth no more than 2% of GDP and effectively ended purchases after less than half a year from the launch (even if the programmes were not officially terminated). A few other central banks purchased similarly small amount of securities, but continued with the programmes through the second and third COVID-19 waves until mid-2021 (Iceland, Korea, Costa Rica). On the other side of the spectrum were central banks of Australia, Canada and New Zealand, which purchased securities at a relatively fast pace from the onset of the programmes and continued with large-scale purchases – even if the pace slowed down somewhat – until the second half of 2021. In these countries, the total amount of securities purchased reached 17% of GDP – not far off amounts purchased by the major central banks[4]. The central banks of Israel, Croatia and Poland ended up somewhere in between at 4.8-6.3% of GDP as purchases were relatively large (though not as large as in major economies) in the first few months, but petered out later on, even if in the case of Israel and Poland the programmes continued until mid or late 2021.

In section 5 we find little to no correlation between the above-mentioned modalities of QE programmes and their impact on financial and macroeconomic variables, suggesting that programme characteristics mattered little – if at all – for the effectiveness of QE.

2.3 Pandemic QE – literature review

The literature on pandemic QE programmes is already quite rich, even though little time has passed since the onset of the pandemic crisis. However, it comprises mostly of event studies, investigating the impact of QE announcements on asset prices. On top of that, a few papers investigate implementation effects, i.e. the impact of actual purchases of government bonds on their yields. Studies of macroeconomic impact of QE are rare.

Rebucci et al. (2022), Fratto et al. (2021), Ha and Hanlon (2021), Sever et al. (2020) and Arslan et al. (2020) conduct cross-country event studies of QE announcements in advanced and/or emerging market economies, while Arena et al. (2021) focus on European emerging markets. Among country-specific studies, Finlay et al. (2022) conduct an event study of government bond purchases in Australia, while Arora et al. (2021) investigate Canada's QE.

These studies tend to find that QE announcements on average lowered government bond yields, though estimated average effects differ quite widely across studies (from approx. 10 to 100 bp) and country-specific estimates are even more heterogenous, with some evidence that the impact tends to be stronger in emerging markets than advanced economies. In addition, most studies find positive impact on stock prices and negative on corporate bond yields, though these results are less robust than for government bond yields. Finally, most studies find that QE does not lead to exchange rate depreciation.

[4] The ECB and the Fed purchased securities worth 20.2% and 21.8% of 2019 GDP, respectively.

These findings do not fully align with our results of strong impact on stock prices and muted impact on government bond yields, suggesting that on-impact effects – studied by the previous literature - differ from longer-term effects studied in this paper. The effects on bond yields seem to fade pretty quickly, in line with previous evidence for the US (Wright 2012, Hanson et al. 2021). In contrast, the effects on stock prices seem to increase over time.

Fratto et al. (2021) and Ha and Hanlon (2021) also check whether QE programme and country characteristics had an impact on the results and reach somewhat contradictory conclusions. While Fratto et al. (2021) find some evidence that the effects of QE are stronger in more credible countries, Ha and Hanlon (2021) find stronger impact on bond yields in countries with higher inflation, higher bond yields, higher inflation expectations and higher CDS spreads, i.e. in less credible countries. Both studies find that a larger scale of purchases is not associated with stronger impact on financial assets, though – in line with our findings.

Another strand of literature studies the effects of the announcements regarding Fed's corporate bond purchase programmes (D'Amico et al. 2020, Gilchrist et al. 2020, Haddad et al. 2021, Nozawa and Qiu 2021), finding that they led to a decline in yields and spreads, improvement in liquidity and increased issuance. In turn, Agur (2022) investigates the impact of unconventional monetary policies announced during the pandemic on inflation expectations, finding no impact.

Several studies investigate the implementation effects of QE, i.e. the impact of actual government bond purchases on their yields, in a similar fashion to pre-pandemic studies such as D'Amico and King (2013). Bernardini and De Nicola (2020) study the effects of ECB purchases on Italian bonds, Finlay et al. (2022) investigate Australia and Arora et al. (2021) Canada. All these studies find that actual purchases lower bond yields, but the effect is temporary, vanishing after just a few days. Having said that, Bernardini and De Nicola (2020) find that implementation effects tend to be stronger in periods of elevated market stress. In a related study, Vissing-Jorgensen (2021) argues that actual purchases of Treasuries by the Fed during the peak of pandemic crisis had a stronger impact on government bond yields than announcements. Finally, Bernardini and Conti (2021) study the impact of both announcements and actual purchases under ECB's PEPP within a single VAR model, finding a negative impact across the yield curve and a positive impact on stock prices, but with announcements providing the bulk of the effect.

Studies of macroeconomic effects of QE include Akkaya et al. (2023) and Garcia et al. (2022), who use DSGE models to study the QE programmes in Sweden and Chile, respectively. Both find a very modest impact – pandemic-era central bank asset purchases are estimated to have increased GDP and inflation by 0.1% in Sweden and even less than that in Chile. To our knowledge, the only other study investigating macroeconomic effects of pandemic QE is Hertel et al. (2022) for Poland, who estimate the impact of QE on the shadow interest rate and the exchange rate and input these estimates into a large-scale structural model to find that Polish QE increased GDP and the price level by 0.6-0.7%.

Against this background, our contribution to the literature on pandemic QE is manifold. Firstly, we use a novel approach to studying the financial market impact of QE and arrive at a somewhat different results than previously used event studies, i.e. we find the QE's impact on stock prices to be stronger than on bond yields. Secondly, we obtain estimates of macroeconomic effects of QE, which has been hardly done so far for the studied countries. Thirdly, we attempt to conduct a comparative study of QE, which, to the best of our knowledge, has not been carried out previously in terms of macroeconomic impact. Our analysis suggests that QE appears to be more effective in countries with higher monetary and fiscal policy credibility.

3. Financial market impact of QE

3.1 Empirical framework

The impact of QE on financial variables has usually been estimated using event studies (see e.g. Gagnon et al. 2011, Joyce et al. 2011, Krishnamurthy and Vissing-Jorgensen 2011, Andrade et al. 2016), i.e. by tracing down the change in prices/yields in the short window around the central bank announcement. While this strategy worked relatively well for QE announced in major economies during the global financial crisis[5], for several reasons it is less effective for pandemic QE programmes outside of the major economies. Firstly, central banks often deliberately made their announcements outside of the trading hours to avoid exacerbating market volatility; and due to an unprecedented pace of events, the price change the following morning can hardly be regarded as a reaction to the announcement. Secondly, in contrast to the major economies before (and during) the pandemic, central bank announcements – especially in emerging market economies - were often vague and did not specify the expected size of the purchases nor their timeline. Under these circumstances, it is unrealistic to expect the immediate financial market reaction to fully reflect the economic impact of a yet largely unknown policy. Finally, the pace of events at the peak of the pandemic crisis was so high that even in a short window around the announcement, price changes could have been easily influenced by other news and factors.

One can also have more general reservations about the event study methodology – it is unclear whether the short-term reaction of financial markets fully reflects the impact of policy on financial variables. The short-term reaction may underestimate the effect if market players need time to "digest" the news or are unable to fully anticipate the effects of the policy – which may be true especially if this policy had not been used before. On the other hand, the short-term reaction may also overestimate the impact due to financial market

[5] Even though it was more effective for initial announcements than subsequent rounds of QE, which were often anticipated and thus financial market reactions tended to be more muted and may have underestimated the effects.

overshooting. Indeed, some studies indicate that the effects of QE and other shocks on long-term interest rates tend to dissipate relatively fast (Wright 2012, Hanson et al. 2021).

For these reasons, we opt for estimating the financial market impact of QE using a regression-based method. On a pre-pandemic sample, we estimate country-specific autoregressive distributed lag (ARDL) models for long-term government bond yields and stock prices that take into account domestic economic conditions, fiscal policy and financial conditions abroad. Subsequently, for the pandemic period, we generate model-implied values for bond yields and stock prices, using actual outcomes of explanatory variables. We interpret the difference between actual financial prices and model-obtained values as the effect of QE.

The advantage of this approach is that it allows for an estimation of the effect of QE not only at one point in time (the moment of policy announcement), but over a longer timeframe. The most important drawback is the assumption that the pandemic does not lead to a structural change, i.e. does not alter the relationship between economic, fiscal and external variables and the dependent variable (bond yields or stock prices). Moreover, it is assumed that the pandemic affects dependent variables only via the variables included in the model, i.e. it does not have a direct impact on bond yields and stock prices.

In the following subsections the specifications for bond yields and stock prices are derived and discussed in more detail.

3.1.1 Government bond yields

Long-term government bond yields can be decomposed into current short-term interest rate, expected short-term interest rates over the maturity period, and the term premium (Adrian et al. 2013):

$$l_{t,T} = \alpha_1 r_t + \alpha_2 E_t \overline{r_{t+1,T}} + tp_{t,T} \quad (1)$$

Where $l_{t,T}$ is a yield at time t on a government bond maturing in time T, r_t is the short-term interest rate at time t, $\overline{r_{t+1,T}}$ is an average short-term interest rate between periods t+1 and T, $tp_{t,T}$ is a term premium at time t on a government bond maturing at time T.

Small open economy central banks are often assumed to set the short-term interest rate according to the following Taylor rule:

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 \pi_t + \beta_3 gap_t + \beta_4 r_t^f + \varepsilon_t \quad (2)$$

Where π_t is inflation, gap_t is an indicator of economic activity, r_t^f are central bank policy rates abroad, and ε_t is a monetary policy shock. The rule acknowledges two crucial factors: firstly, the tendency for policy adjustments to occur gradually, and secondly, the significant impact of global financial conditions on small open economies.

After moving equation (2) forward in time by T periods, substituting for lagged interest rate T times and simplifying the resultant expression, the expected short-term interest rate can be expressed as follows:

$$E_t\overline{r_{t+1,T}} = \gamma_0 + \gamma_1 r_{t-1} + \gamma_2 \pi_t + \gamma_3 E_t\overline{\pi_{t+1,T}} + \gamma_4 gap_t + \gamma_5 E_t\overline{gap_{t+1,T}} + \gamma_6 r_t^f + \gamma_7 E_t\overline{r_{t+1,T}^f} \quad (3)$$

i.e. as a function of current and expected inflation, economic activity and interest rates abroad as well as lagged domestic interest rate.

In a small open economy, the term premium can be expressed as a function of the risk premium ($rp_{t,T}$) and term premia abroad ($tp_{t,T}^f$). There is also likely to be a certain amount of persistence in the term premium, reflected by the lagged term.

$$tp_{t,T} = \delta_0 + \delta_1 tp_{t-1,T-1} + \delta_2 rp_{t,T} + \delta_3 tp_{t,T}^f + \epsilon_t \quad (4)$$

The key drivers of risk premium are likely to be the country-specific risk of default (cr_t) and the global risk appetite (ra_t^f):

$$rp_{t,T} = \theta_0 + \theta_1 cr_t + \theta_2 ra_t^f + \eta_t \quad (5)$$

Plugging (3), (4) and (5) into (1) and regrouping we get the following expression:

$$\begin{aligned} l_{t,T} = {} & (\alpha_2\gamma_0 + \delta_0 + \delta_2\theta_0) + \alpha_1 r_t + \alpha_2\gamma_2\pi_t + \alpha_2\gamma_4 gap_t + (\alpha_2\gamma_6 r_t^f + \alpha_2\gamma_7 E_t\overline{r_{t+1,T}^f} + \delta_3 tp_{t,T}^f) \\ & + \left(\alpha_2\gamma_1 r_{t-1} + \alpha_2\gamma_3 E_t\overline{\pi_{t+1,T}} + \alpha_2\gamma_5 E_t\overline{gap_{t+1,T}} + \delta_1 tp_{t-1,T-1}\right) + \delta_2\theta_1 cr_t \\ & + \delta_2\theta_2 ra_t^f + (\epsilon_t + \delta_2\eta_t) \end{aligned} \quad (6)$$

The first term is an intercept influenced by the natural rate of interest and time-invariant components of term and risk premium, likely reflecting slowly changing structural factors such as the relative level of economic development. It is followed by current short-term interest rates, inflation and output. The next term comprises of current and expected short-term interest rates abroad as well as foreign term premia and thus is approximately[6] equal to bond yields abroad. It is followed by a term comprising of lagged domestic short-term interest rates and term premium as well as expected inflation and output gap, and thus resembles lagged domestic bond yield[7]. Finally, there are terms describing the sovereign credit risk and global risk appetite and an error term.

Inspired by the above analysis, the following econometric specification is separately estimated for each country:

---

[6] How close this is to an actual equality depends on specific model parameters, which we do not discuss here in detail.

[7] This resemblance is not direct (expectations are one period ahead, foreign interest rates are excluded), so one could argue that it would be better to use the parts of this term as separate explanatory variables. In practice, however, while measures of inflation and economic conditions expectations exist, they are not easily available for a sufficiently long period and at sufficiently high frequency (preferably monthly) for a relatively broad range of countries considered here. On top of that, they suffer from severe measurement issues (these are usually either expectations of professional forecasters, which not necessarily reflect expectations of businesses, consumers and market players, or qualitative survey-based measures). Finally, from a purely econometric perspective, government bond yields tend to be persistent, so the inclusion of a lagged term seems warranted.

$$l_t = \tau_0 + \sum_{i=1}^{3} \tau_i l_{t-i} + \tau_4 r_t + \tau_5 \pi_t + \tau_6 gap_t + \tau_7 l_t^f + \tau_8 cr_t + \tau_9 ra_t^f + \tau_{10} t + \omega_t \quad (7)$$

The error term ω_t reflects not only unobserved factors ϵ_t and η_t, but also the measurement error, i.e. the potential imprecise equality of terms in equations (6) and (7). The model allows for deterministic trend to control for slowly moving structural change, e.g. in the natural rate of interest. It also allows for more than one lag of the bond yield (3 in the baseline specification, which is chosen based on the model fit of a fixed effects panel model). The models are estimated with ordinary least squares (OLS) on monthly data, with the sample ending in February 2020.

The detailed description of the data is provided in the data subsection 3.2. Let us only briefly mention here that we usually use 10-year government bond yields as an dependent variable, HP-filtered retail sales are utilised as a proxy for economic activity, the foreign sector is proxied by the US, Germany and in some cases Japan, credit risk is proxied by general government debt to GDP and deficit to GDP ratios, and the global risk appetite is approximated by VIX.

The model of this kind can also be interpreted in terms of Bayesian updating – government bond yields depend on expectations regarding future short-term interest rates, and thus expectations regarding economic conditions. These expectations are updated as news emerge, including after releases of macroeconomic data. Thus, long-term interest rates can be thought of as a combination of past long rates (prior) and current conditions.

Equation (7) may suffer from endogeneity – explanatory variables are likely to be correlated with the error term since some determinants of the long-term rates, such as expected interest rates and economic conditions, are partially captured by the error term. Equation (7) may also suffer from reverse causality as financial conditions influence economic conditions, though this is likely to be less problematic as this influence typically occurs with a lag. However, the aim of this model is not to study causal relationships, but to merely describe the data. Thus, the feature that the variables present in the model capture some of the variability driven by variables not included in the model (e.g. because of measurement issues) may be viewed as desirable – at least as long as the correlation with omitted variables remains stable over time.

The effect of QE in month *t*, starting in March 2020 and ending as dictated by data availability at the time of data gathering (usually either in March or June 2021), is estimated as a difference between the actual government bond yield in month *t* and the government bond yield predicted recursively by the model, using the actual outcomes of (exogenous) right-hand side variables other than the lagged bond yield:

$$\widehat{QE}_t = l_t - \widehat{l_t}$$

$$\widehat{l_t} = \tau_0 + \sum_{i=1}^{3} \tau_i \widehat{l_{t-\iota}} + \tau_4 r_t + \tau_5 \pi_t + \tau_6 gap_t + \tau_7 l_t^f + \tau_8 cr_t + \tau_9 ra_t^f + \tau_{10} t \quad (8)$$

The QE's impact on bond yields is assessed to be statistically significant if in any month t the bond yield lies outside of the "forecast" confidence band at a given significance level (10% is used as a benchmark).

Such an estimate is correct up to usual forecast error if:

- the relationship between bond yields and their economic determinants captured by explanatory variables remained unchanged during the pandemic, i.e. parameters τ did not change;
- QE is the only source of "abnormal" shock to bond yields, i.e. the pandemic or other policies did not have a direct impact (other than via explanatory variables included in the model) on bond yields.

These assumptions are admittedly strong, but not completely unrealistic. While the pandemic has had a profound effect on the economy, it did not change the bond pricing models, and thus the relationship with the main economic determinants of bond prices is likely to have remained broadly unchanged. Moreover, while the spread of the disease may have had a direct impact on bond prices at the peak of the pandemic, the majority of the impact is likely to have still come via the effect of the pandemic containment measures and voluntary social distancing on economic activity, inflation and short-term interest rates, which are captured by the model.

3.1.2 Stock prices

Stock prices are equal to a present value of expected future pay-offs, i.e. dividends:

$$s_t = E_t \sum_{i=0}^{\infty} \frac{d_{t+i}}{\prod_{s=0}^{i}(1 + i_{t+s})} \quad (9)$$

Where s_t is the stock price at time t, d_t is a dividend on that stock paid out at time t, and i_t is a relevant one-period discount rate.

Dividends can be expressed as a product of the dividend payout ratio dpr_t and firm profits p_t, while the discount rate can be decomposed into (risk-free) short-term interest rate r_t and the (equity) risk premium erp_t:

$$s_t = E_t \sum_{i=0}^{\infty} \frac{dpr_{t+i}p_{t+i}}{\prod_{s=0}^{i}(1 + r_{t+s} + erp_{t+s})} \quad (10)$$

On a macroeconomic level, profits can be expressed as a product of the (time-changing) profit share ps_t and nominal GDP, which can be further decomposed into real GDP y_t and the price index cpi_t:

$$s_t = E_t \sum_{i=0}^{\infty} \frac{dpr_{t+i}ps_{t+i}y_{t+i}cpi_{t+i}}{\prod_{s=0}^{i}(1 + r_{t+s} + erp_{t+s})} \quad (11)$$

Thus, stock prices depend on expected economic conditions, inflation, interest rates and risk premia at all maturities. As it depends on largely unobservable expectations, equation (11) cannot be estimated in practice, however. To make it more practical, we average over expectations in a similar fashion as in the previous section and take logs:

$$\begin{aligned}\ln s_t = {} & \mu_0 \ln E_t \overline{dpr_{t,\infty}} + \mu_1 \ln E_t \overline{ps_{t,\infty}} + \mu_2 \ln y_t + \mu_3 \ln E_t \overline{y_{t+1,\infty}} + \mu_4 \ln cpi_t \\ & + \mu_5 \ln E_t \overline{cpi_{t,\infty}} - \mu_6 \ln(1 + r_t) - \mu_7 \ln E_t\left(1 + \overline{r_{t+1,\infty}}\right) - \mu_8 \ln(1 + erp_t) \\ & - \mu_9 \ln E_t\left(1 + \overline{erp_{t+1,T}}\right) + \vartheta_t\end{aligned} \quad (12)$$

Where hats denote averages over periods between the points in time indicated in subscripts (as in the previous subsection) and ϑ_t is an error of approximation.

Furthermore, using the approximation that $\ln(1 + r_t) \approx r_t$ and equation (1), one arrives at the following expression:

$$\begin{aligned}\ln s_t = {} & \mu_2 \ln y_t + \mu_4 \ln cpi_t \\ & + \left(\mu_0 \ln E_t \overline{dpr_{t,\infty}} + \mu_1 \ln E_t \overline{ps_{t,\infty}} + \mu_3 \ln E_t \overline{y_{t+1,\infty}} + \mu_5 \ln E_t \overline{cpi_{t,\infty}} \right. \\ & \left. - \mu_9 \overline{erp_{t+1,T}}\right) - \mu_{10} l_t - \mu_8 erp_t + \mu_{11} tp_t + \vartheta_t\end{aligned} \quad (13)$$

Therefore, stock prices depend on the current and expected economic conditions and the price level, expected dividend payout ratio, expected profit share, long-term interest rates, current and expected equity risk premium and the term premium. The data on dividend payout ratio, profit share, expected economic conditions and expected inflation is not easily accessible for a relatively wide range countries studied here at a sufficiently high frequency (preferably monthly). Thus, we explain the term in brackets by past stock prices and deterministic components (constant and trend). The equity risk premium less bond term premium component is explained by global risk appetite, country-specific risk premium and stock prices abroad.

As a result, the following equation is estimated separately for each country:

$$\begin{aligned}\ln s_t = {} & \mu_{12} + \sum_{i=1}^{5} \mu_{12+i} \ln s_{t-i} + \mu_2 \ln y_t + \mu_4 \ln cpi_t - \mu_{10} l_t - \mu_{18} ra_t^f + \mu_{19} cr_t + \mu_{20} s_t^f \\ & + \mu_{21} t + \varphi_t\end{aligned} \quad (14)$$

Similarly to the specification for government bond yields, the models are estimated with ordinary least squares (OLS) on monthly data, with the sample ending in February 2020. The model includes 5 lags of stock prices - this number is chosen based on the data fit of a fixed effects panel model.

Stock prices are measured by equity indices available over a sufficiently long timeframe, preferably market-wide total return indices. As GDP data is usually available only in quarterly frequency, economic conditions are described by retail sales seasonally adjusted indices. Similarly as in the previous subsection, 10-year government bond yields are used as a measure of long-term interest rates, VIX is used as a measure of global risk appetite, and country-specific risk is proxied by general government debt to GDP ratio. Finally, major stock market indices from the US, Germany, China and Japan are used as proxies for stock prices abroad, though only Chinese Shanghai Composite enters the baseline specification. The data is described in more detail in the data subsection 3.2.

Analogically to government bond yields, the effect of QE in month t, starting in March 2020, is estimated as a difference between the log of actual stock prices in month t and the log of stock prices predicted recursively by the model, using the actual outcomes of (exogenous) right-hand side variables other than the lagged stock prices and government bond yields. In the latter case, fitted values from the specifications for government bond yields are used. Thus, it is taken into account that QE may influence stock prices indirectly via bond yields.

$$\widehat{QE}_t = \ln s_t - \widehat{\ln s_t}$$

$$\widehat{\ln s_t} = \mu_{12} + \sum_{i=1}^{5} \mu_{12+i} \widehat{\ln s_{t-i}} + \mu_2 \ln y_t + \mu_4 \ln cpi_t - \mu_{10} \hat{l}_t - \mu_{18} ra_t^f + \mu_{19} cr_t + \mu_{20} s_t^f + \mu_{21} t \quad (15)$$

The QE's impact on stock prices is assessed to be statistically significant if in any month t the log of stock prices lies outside of the "forecast" confidence band at a given significance level (10% is used as a benchmark).

3.2 Sample and data

Countries that meet the following three criteria have been included in the sample:

- Central banks of those countries conducted QE during the COVID-19 pandemic, with QE defined as balance-sheet-increasing, large-scale outright purchases of domestic currency-denominated long-term securities in the secondary market for reasons other than steering short-term interest rates (Hertel et al. 2022);
- QE was not conducted before the COVID-19 pandemic (otherwise, the identification strategy would not be appropriate);
- Data on long-term government bond yields, stock prices and explanatory variables is available for the time of the pandemic and a sufficiently long period beforehand.

Based on the information provided in the Fratto et al. (2021) paper and on central bank websites, 28 countries have been judged to have conducted QE during the COVID-19 pandemic. Some of the countries listed by Fratto et al. (2021)[8] are excluded as these countries either only made legal changes to allow for QE in the future (Brazil), conducted funding-for-lending type of schemes (China), did not buy securities outright (Mexico) or no confirmation of purchases has been found on central bank websites. Six of these 28 countries – Japan, the US, the UK, the euro area, Sweden and Hungary[9] - conducted QE before the pandemic and thus have been excluded from the sample. Six more countries have been excluded due to insufficient data availability: Philippines, Angola, Bolivia, Ghana, Papua New Guinea, and Uganda. This has left a sample of 16 countries: Australia, Canada, Iceland, Israel, Korea, and New Zealand among advanced economies as well as Chile, Costa Rica, Colombia, Croatia,

[8] They list 35 countries, even though major economies (the US, UK, euro area and Japan) are excluded.
[9] The central bank of Hungary conducted a programme of mortgage bond purchases in 2018.

India, Poland, Romania, South Africa, Thailand, and Turkey among emerging market economies.

Table 2. Data used in the government bond yield specification

Economic meaning	Definition	Data sources	Additional comments
Long-term interest rate	10-year government bond yield	Bloomberg, OECD, Eurostat, IMF	
Output gap	HP-filtered retail sales (baseline), year-on-year retail sales (for Chile), HP-filtered industrial production (for Croatia)	Bloomberg, OECD, Eurostat, IMF, Banco Central de Chile, Bank of Thailand, own calculations	For HP filter, lambda is set to 129600 Seasonally adjusted data Interpolated for New Zealand, India and Costa Rica
Inflation	CPI YoY	Bloomberg, OECD, Eurostat, Banco Central de Chile, Croatian National Bank, own calculations	Interpolated for Australia and New Zealand
Short-term interest rate	Central bank policy rate	Bloomberg, BIS, OECD, Banco Central de Chile	
Government bond yields abroad	10-year government bond yield in the US and Germany (baseline) and Japan (for Australia, Korea, New Zealand and Thailand)	Bloomberg	
Credit risk	• General government debt to GDP ratio • General government deficit to GDP ratio, 3-month moving average	Bloomberg, Eurostat, BIS, IMF, OECD, Australian Department of Finance, Statistics Canada, Banco Central de Chile, DIPRES, Banco de la Republica, Colombian Ministry of Finance and Public Credit, Costa Rican Ministry of Finance, Croatian National Bank, Statistics Iceland, Israel Central Bureau of Statistics, Israel Ministry of Finance, Korea Ministry of Planning and Finance, Bank of Thailand, Central Bank of Turkey	If data for general government not available at monthly frequency: • Data for central government if available in monthly frequency and showing similar trends to the GG data • Interpolated quarterly data otherwise. Debt and deficit data is divided by interpolated data on nominal GDP. Seasonally adjusted.
Global risk appetite	VIX	Bloomberg	

Table 3. Data used in the stock prices specification

Economic meaning	Definition	Data sources	Additional comments
Stock prices	Stock price index[10]	Bloomberg, OECD, stooq.pl	Preferably market-wide and total return, subject to data availability
Economic activity	Retail sales (baseline), industrial production (for India, Israel and Poland)	Bloomberg, OECD, Eurostat, IMF, Banco Central de Chile, Bank of Thailand	Seasonally adjusted Interpolated for New Zealand, India and Costa Rica
Price level	CPI	Bloomberg, OECD, Eurostat, Banco Central de Chile, Croatian National Bank, own calculations	Seasonally adjusted, interpolated for Australia and New Zealand
Long-term interest rate	10-year government bond yield	Bloomberg, OECD, Eurostat, IMF	
Stock prices abroad	Shanghai Composite (baseline), Nikkei 225 (for India), DAX (for Poland), S&P 500 total return (for Romania)	Bloomberg	
Country-specific risk	General government debt to GDP ratio	Bloomberg, Eurostat, BIS, IMF, OECD, Australian Department of Finance, Statistics Canada, Banco Central de Chile, Banco de la Republica, Costa Rican Ministry of Finance, Croatian National Bank, Statistics Iceland, Israel Central Bureau of Statistics, Korea Ministry of Planning and Finance, Bank of Thailand, Central Bank of Turkey	If data for general government debt not available at monthly frequency: • Data for central government if available in monthly frequency and showing similar trends to the GG data • Interpolated quarterly data otherwise. Debt data is divided by interpolated data on nominal GDP. Seasonally adjusted.
Global risk appetite	VIX	Bloomberg	

Monthly data is used, with the sample generally starting in January 1999 and ending in February 2020 for the model estimation sample and in July 2021 for the sample over which

[10] Australia: S&P/ASX 200 Gross Total Return, Canada: S&P/TSX Composite Total Return, Israel: TA-125, Korea: KOSPI, New Zealand: S&P/NZX All, Chile: S&P CLX IPSA, Croatia: CROBEX, India: SENSEX, Poland: WIG, Romania: BET, South Africa: FTSE/JSE Africa All Share, Thailand: SET, Iceland and Colombia: per OECD data, Turkey: BIST 100 Net Total Return, Costa Rica: BCT Corp Stock Market Index.

the effects of QE are estimated; country-specific samples may differ due to data availability, though. Even when data is available, we have chosen not to extend the sample before 1999 in order to estimate the models on relatively recent data.

Table 2 and Table 3 summarise the data used in the government bond yield and stock price specifications, respectively.

Data is compiled from various sources – Bloomberg, international databases and national sources, as indicated in the tables – to ensure as broad data coverage as possible.

Economic activity and output gap are measured with retail sales and industrial production – variables commonly available at monthly frequency (with some exceptions indicated in the tables), as opposed to GDP data. In case of output gap, we test both HP-filtered gaps and year-on-year growth rates. Panel fixed effects regressions show that only retail sales (HP-filtered in the case of output gap) are statistically significant (at every conventional significance level), thus only retail sales are included in the baseline specification. However, if industrial production is statistically significant on a country-specific level, it is added to the country-specific regression, as indicated in the tables.

General government debt and deficit to GDP ratios are used as proxies for credit risk and country-specific risk, though only debt enters the regression for stock prices per data fit of the panel fixed effects model. In this case, there is often a trade-off between data frequency and coverage - in many cases, only central government data is available in monthly frequency. Central government data is used only if it aligns well with the trends visible in the (quarterly) general government data. Otherwise, interpolated general government is used. For deficit, 3-month moving average is used as monthly data tends to be very volatile.

Global risk appetite is approximated by VIX, i.e. option-implied volatility of the S&P 500 stock market index in the US – a commonly used proxy for risk appetite not only in the US stock market, but global financial markets in general. Government bond yields and stock prices abroad are approximated by data for the US, Germany (for the lack of appropriate euro-area-wide data), Japan and, in the case of stock prices, China. However, only US and German bond yields and Chinese stock prices enter the baseline specifications for bond yields and stocks, respectively, per the data fit of the fixed effects panel regression. Similarly as in the case of economic activity measures, if other measures of foreign bond yields and stock prices are statistically significant on a country-specific level, they are added to a respective regression.

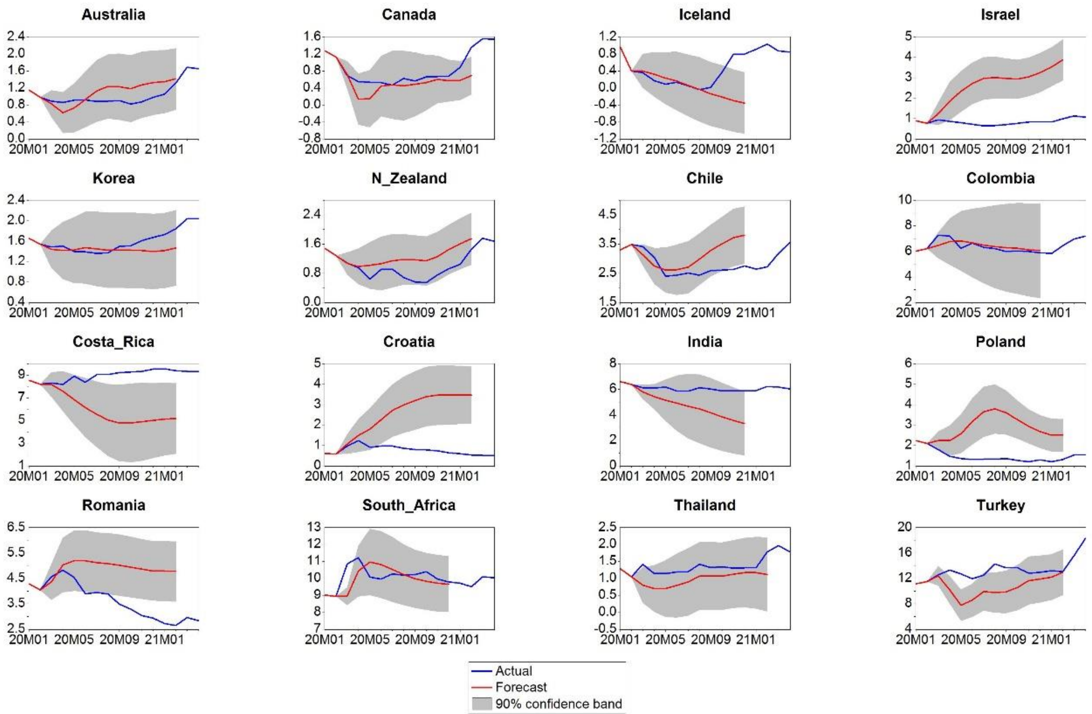
3.3 Baseline results

3.3.1 Government bond yields

For the sake of space, the results of country-specific regressions are presented in the Appendix A. It is worth noting that these regressions have a high explanatory power, with the R-squared in the 96-99% range, bar a few exceptions (Costa Rica, South Africa and Thailand). However, parameter estimates exhibit substantial variation across countries and frequently lack statistical significance, sometimes even showing unexpected signs, despite being significant and displaying the expected signs when estimated using the panel model.

The implied bond yields obtained from those regressions together with confidence bands are plotted against actual bond yields in Figure 1.

Figure 1. Actual vs. forecast government bond yields



For 5 countries (Australia, Korea, Colombia, New Zealand, India) the impact of QE on bond yields is not statistically significant at a 10% significance level, i.e. the realised bond yield never exceeds the forecast confidence band. For 5 more countries (Canada, Iceland, Chile, South Africa, Thailand), the effect is technically statistically significant, but bond yields fall out of confidence band only for a couple of months and by a relatively small margin. Moreover, for all of these countries but Chile, QE is estimated to have led to an increase in bond yields – against the expectations.

Finally, for the 6 remaining countries (Israel, Costa Rica, Croatia, Poland, Romania, and Turkey) the impact of QE is statistically significant throughout most of the studied period and economically meaningful, with peak effect ranging from 2.1 pp in Romania to 4.9 pp in Turkey. However, in Costa Rica and Turkey QE is estimated to have increased bond yields.

Thus, only in 4 countries (Israel, Croatia, Poland, Romania) QE led to a statistically significant and economically relevant (of 2.1-3 pp) decline in bond yields.

Hence, the results do not entirely corroborate the findings from most of the pre-pandemic literature, which indicate that quantitative easing leads to a reduction in bond yields (e.g. Gagnon et al. 2011, Joyce et al. 2011, Krishnamurthy and Vissing-Jorgensen 2011, Andrade et al. 2016). However, this is not the only paper to find little or no impact of QE on bond yields – Greenlaw et al. (2018) and Stefanski (2022) arrive at a similar conclusion studying the US economy and using event study and VAR methods, respectively.

Why would QE have no impact on bond yields, at least for most of the studied countries? QE can affect bond yields only if the bond market is segmented or various bonds are imperfect substitutes, i.e. agents prefer to hold bonds of certain maturities (Harrison 2012, Vayanos and Vila 2021). This would imply that for most of the studied countries, the degree of market segmentation is low, as estimated for the US by Chen et al. (2012).

But this is unlikely to be the whole story. The degree of market segmentation is likely to decrease with the size and the sophistication of the market. Thus, it may explain why QE has no statistically significant impact on bond yields in advanced and relatively large markets such as Australia, Canada or Korea, but less so in emerging market or small countries. And why would QE increase bond yields in some countries? In emerging market economies, it may lead to an increase in country-specific risk premium. QE may be viewed as a way of debt monetisation, which supports fiscal profligacy and increases the risk of high inflation in the future, especially in the countries with lower monetary policy credibility. The latter may explain why QE is estimated to have raised bond yields in Turkey, where the central bank has been under heavy political influence.

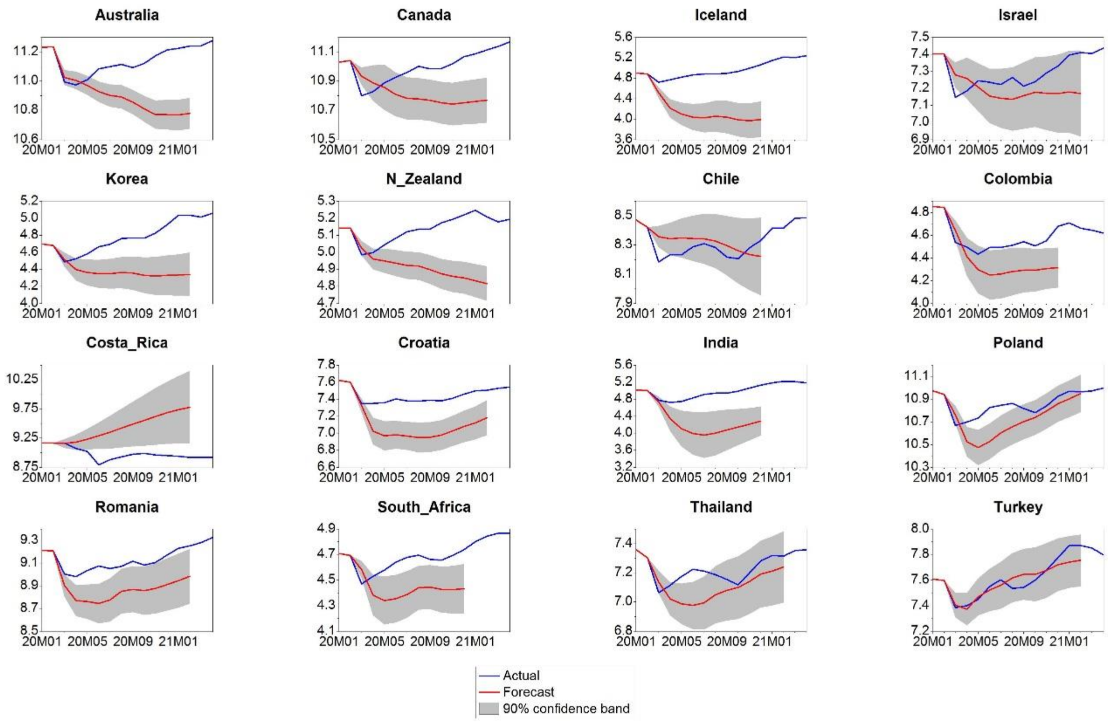
We test these hypotheses, as well as other potential drivers of variance in the effects of QE across countries, in Section 5. The analysis provided there shows that while market sophistication is not correlated with QE effectiveness, suggesting little role of bond market segmentation, monetary and fiscal policy credibility indeed seem to matter, with QE increasing bond yields in least credible countries and reducing them in most credible economies.

3.3.2 Stock prices

The results of country-specific regressions are presented in the Table A. 3 of the Appendix A. These regressions have an even higher explanatory power than in the case of government bond yields, with the R-squared in all but one cases (Romania) exceeding 98%. Similar to the government bond yield regressions, parameter estimates exhibit substantial variation across countries, with only the impact of the VIX being consistent and statistically significant across countries.

The implied logarithms of stock prices obtained from those regressions together with confidence bands are plotted against actual log stock prices in Figure 2.

Figure 2. Actual vs. forecast log stock prices



The conclusions are very different from those for bond yields – the impact of QE on stock prices is estimated to be statistically significant at a 10% level in all but one country (Turkey). In 12 countries, the impact is positive (the exceptions are Israel, Chile, and Costa Rica), and in 7 of those countries (Australia, Canada, Iceland, Korea, New Zealand, Croatia, and India), the impact is very strong both in statistical and economic terms. At peak, stock prices in those 7 countries are estimated to be from 34 to 107 log points higher than implied by the model, which translates into an impact of 40% to 190%, with the strongest impact estimated in Iceland.

The results line up with those of Stefanski (2022), who finds that pre-pandemic QE in the US was transmitted to the real economy mostly via stock prices. But why would QE have such a strong impact on stock prices when it has little to no impact on bond yields? The strong response of stock prices cannot be explained by the portfolio rebalancing channel or a decline in the discount rate, as when the impact on bond yields is low, the rebalancing away from them towards other assets should be low as well.

Instead, QE may be leading to a reduction in risk premia, propping up prices of risky assets. But, as it is discussed above, the weak (or even positive in some cases) response of bond yields to QE in emerging markets may be related to a an increase in risk premia, if QE is seen as a first step to debt monetisation, increasing the risk of high inflation in countries with relatively low monetary policy credibility. However, these concerns may play less of role for stock prices, as equity premium is not equal to the bond market term premium, though the two premia are interrelated. In line with this interrelation, the two countries that see an increase in bond yields following QE – Costa Rica and Turkey – do not see an increase in stock prices. At the same time, countries that saw a pronounced decline in bond yields (Israel, Croatia, Poland, Romania) do not necessarily stand out as those with the largest impact on stock prices.

An important caveat should be noted here – the model "forecast" error may be influenced by the unique character of the pandemic crisis. After the first months of the pandemic (when stock prices fell largely in line with model expectations), it became quite clear that economies are likely to rebound relatively quickly when pandemic containment measures are lifted, and thus a prolonged economic depression is rather unlikely. The rebound was also supported by generous job retention schemes and other fiscal policy support, which may not be fully captured by the model. This is likely to have boosted stock prices beyond by what was implied by current economic conditions. Thus, the estimates of QE's effect on stock prices presented here should be treated as an upper bound to the actual impact of QE.

3.4 Robustness and method checks

3.4.1 Robustness checks

We conduct two robustness checks: run single-country regressions using all considered variables[11] and estimate the baseline specification on panel data. In the latter case, fixed effects estimator is used as the bias on lagged dependent variables can be safely ignored given the length of the panel (254 periods). The panel data model is, on the one hand, unlikely to be warranted given large cross-country differences in estimated parameters (see Appendix A). On the other hand, however, a substantial increase in the degrees of freedom significantly decreases the variance of estimated parameters, which may outweigh the effects of the bias resulting from the assumption of equal parameters across countries.

The model-implied values of government bond yields and stock prices obtained from these alternative specifications, together with their 90% confidence bands, are plotted against the baseline estimates and actual outcomes in Figure 3 and Figure 4, respectively.

[11] Meaning that year-on-year retail sales, HP-filtered and YoY industrial production as well as Japanese bond yields are added to the government bond yield specifications for all countries, while general government deficit to GDP ratio, industrial production and major-economy stock price indices (from the US, Germany and Japan) are added to the stock price specifications. For Iceland, industrial production is not included due to data unavailability (as the industrial production index has not been published since early 2018).

Figure 3. Actual vs. forecast government bond yields: baseline specification and robustness checks

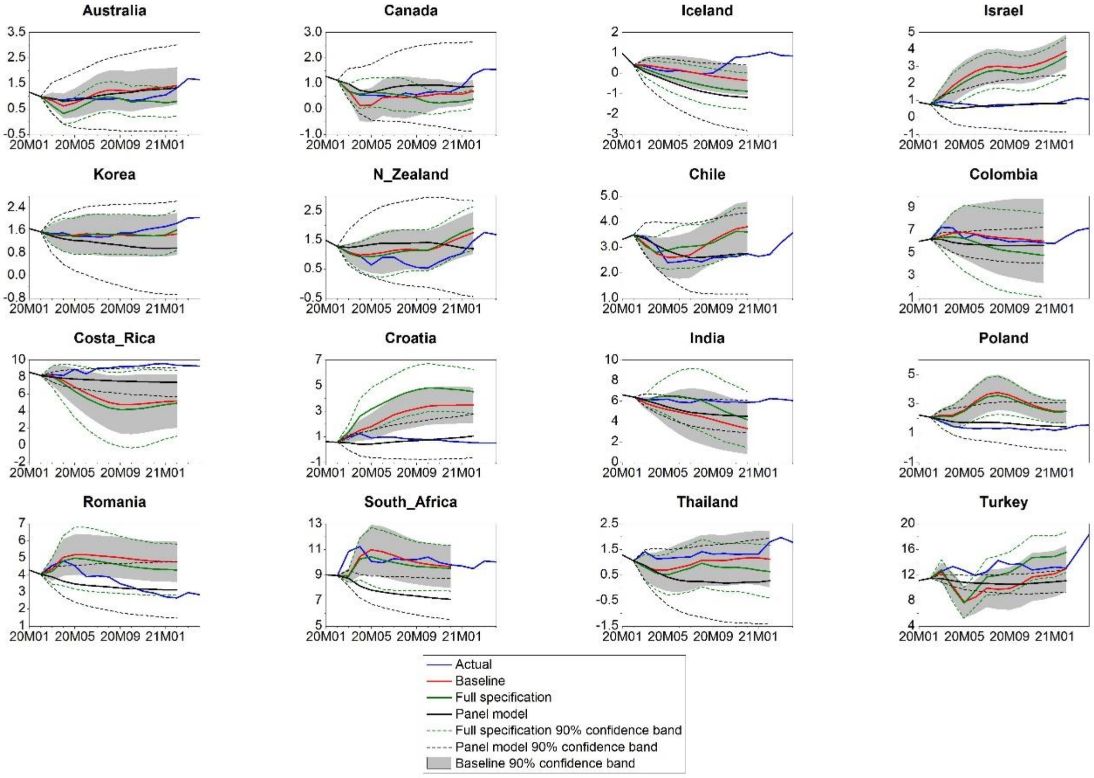
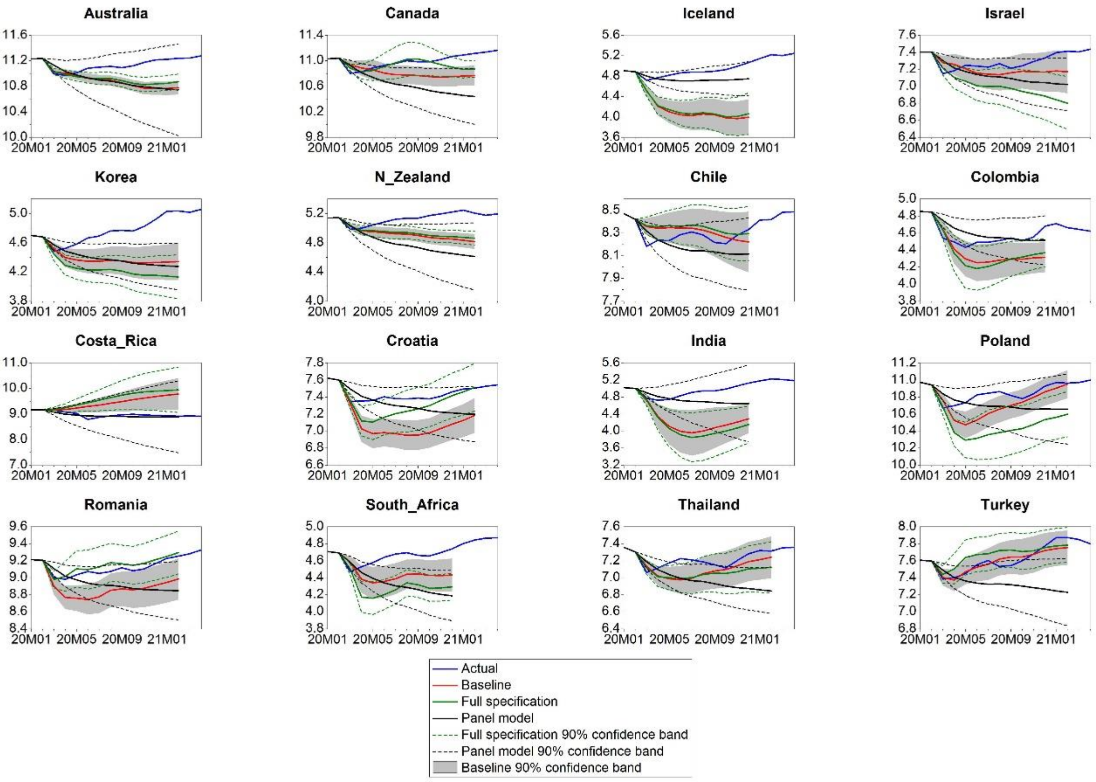


Figure 4. Actual vs. forecast log stock prices: baseline specification and robustness checks



For government bond yields, the results obtained from the full specification tend to be close to the baseline. The point estimates from the panel model in most cases are also quite close to the baseline, though in some cases confidence bands are much wider. Countries with a highly statistically significant impact of QE in the baseline (Israel, Costa Rica, Croatia, Poland, Romania) are an exception – the results of the panel model are much closer to the actual outcome, making the results no longer statistically significant, with the exception of Costa Rica. For South Africa, the results of the panel model also differ significantly from baseline, but in the other direction – in this case, QE has a statistically significant, but positive impact on the bond yields. This largely stems from the fact that in the panel data specification, model-implied bond yields react much more weakly to economic conditions and thus change by much less relative to the end of the pre-pandemic sample.

While the results of the panel data model should be interpreted cautiously, they do provide two valuable insights. Firstly, they confirm that for most countries, the impact of quantitative easing on bond yields is not statistically significant. Secondly, they suggest that the baseline results may overestimate the impact of QE for those countries where the baseline results do show statistical significance.

For stock prices, the inclusion of additional variables has a meaningful impact on the results in some cases (Canada, Israel, Croatia, Poland, Romania, South Africa). Panel data estimates tend to be more persistent than the baseline, reacting to economic conditions with a longer lag; in most cases, they differ substantially from the baseline. As a result, only in Korea, New Zealand and South Africa, the impact of QE on stock prices remains consistently statistically significant and positive across specifications. Said that, if panel data estimates are not considered – which is warranted given that the assumption of equal parameters across countries does not hold - the impact of QE is positive and statistically significant throughout most of the pandemic period across the baseline and full specifications also for 6 other countries (Australia, Iceland, Colombia, Croatia, India, Poland).

3.4.2 Method checks

Given that our method of identification may be seen as controversial, on top of the more standard robustness checks presented in the previous subsection, we conduct what may be referred to as "method checks". In the first of these checks, we test how well the model "forecasts" bond yields and stock prices in the pre-pandemic sample, i.e. how often these forecasts fall out of the 90% confidence bands despite there being no QE. In the second check we test whether actual bond yields and stock prices diverge from model-implied values for Czechia – one of the few advanced or higher-income emerging market economies which did not conduct QE.

In-sample forecasts

The bond yield and stock prices models are estimated on 51 samples ending from December 2014 to February 2019, with the models simulated for 12 months ahead in each case (this is effectively equal to forecasting horizon in the main sample, which starts in March 2020 and usually ends in February 2021). We then compute how often these forecasts fall out of the 90% confidence band. The expectation is that they should fall out of the confidence band about 10% of the time, per the definition of the confidence band, and that large deviations from the confidence band should be very rare.

Table 4 and Table 5 present how often model simulations fall out of the 90% confidence band for the government bond yield and stock prices specifications, respectively. The "runperiods" column treats each period of each simulation individually, the "runs" column counts simulations for which actual values fall out of the confidence band for at least one period and the "high significance runs" column counts simulations for which actual values fall out of the confidence band for at least half of the periods (i.e. six). Figure 5 and Figure 6 show in-sample simulations for the government bond yields and stock prices, respectively.

Table 4. The percentage of government bond yield in-sample simulations that fall out of the 90% confidence band

	Runperiods	Runs	High significance runs (>=0.5 periods significant)
Australia	15.8	29.4	17.6
Canada	42.5	100	41.2
Iceland	5.7	41.2	0.0
Israel	4.6	13.7	3.9
Korea	1.0	7.8	0.0
New Zealand	73.2	100	88.2
Chile	15.0	49	13.7
Colombia	5.6	17.6	3.9
Croatia	10.5	27.5	13.7
India	13.9	29.4	15.7
Poland	2.9	29.4	0.0
Romania	0.0	0.0	0.0
South Africa	19.3	49	17.6
Thailand	0.5	3.9	0.0
Turkey	32.4	78.4	35.3
Costa Rica	21.9	60.8	15.7

For the government bond yields, for all countries but three the percentage of single run-periods falling out of the 90% confidence band stands between 0% and 22% and thus is broadly in line with expectations. The number of simulations for which at least one period is outside the confidence band is understandably larger, but for most countries still does not exceed 30%, with 50% exceeded for only 4 countries. Finally, the confidence band is exceeded for at least half of the periods in less than 18% of simulations for all countries but the same 3 outliers.

These three outliers are Canada, for whom the model underestimates bond yields over 2017-19, New Zealand, for whom bond yields are consistently overestimated, and Turkey. The latter is not very surprising given rising inflation and macrofinancial volatility over the studied period. For Canada and New Zealand, the effects of QE are not estimated to be statistically significant, and for Turkey (as well as Costa Rica), QE is estimated to have increased bond yields. Thus, the relatively weak performance of the models for these three countries does not seem to have a big influence on the conclusions of this paper (or at least, it does not increase the number of countries for whom QE is assessed to reduce bond yields in a statistically significant fashion).

Figure 5. In-sample simulations of the government bond yields

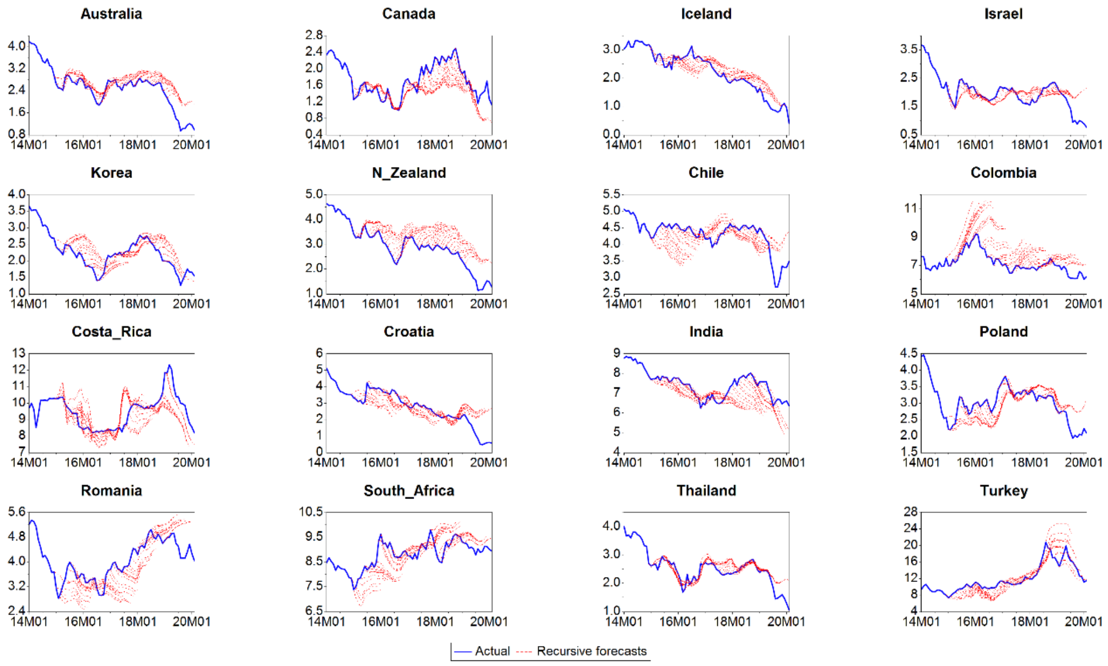
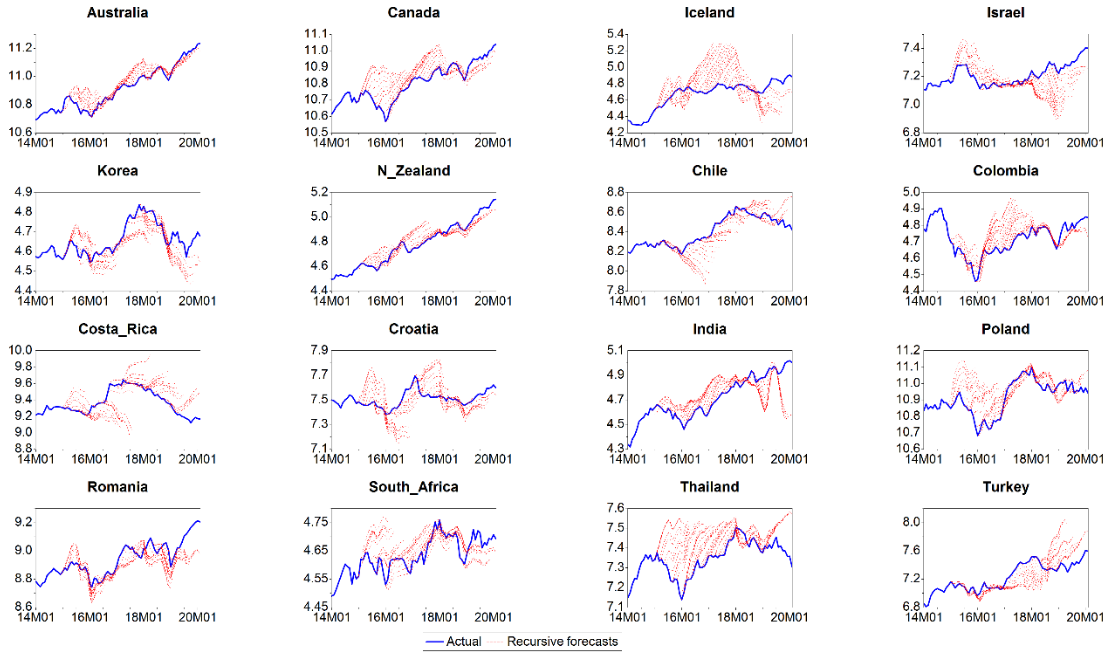


Table 5. The percentage of stock price in-sample simulations that fall out of the 90% confidence band

	Runperiods	Runs	High significance runs (>=0.5 periods significant)
Australia	24.8	45.1	27.5
Canada	17.6	45.1	15.7
Iceland	35.8	72.5	43.1
Israel	22.4	43.1	25.5
Korea	0.5	5.9	0
New Zealand	20.4	45.1	21.6
Chile	15	41.2	13.7
Colombia	8.2	27.5	5.9
Croatia	11.4	25.5	11.8
India	26.8	74.5	21.6
Poland	15.5	23.5	21.6
Romania	18.5	72.5	11.8
South Africa	2.1	9.8	0
Thailand	21.6	41.2	23.5
Turkey	49.8	94.1	51
Costa Rica	17.3	37.3	19.6

In contrast, for countries with positive and highly statistically significant impact of QE (Israel, Croatia, Poland, Romania), the performance of the models is high – the percentage of run-periods outside of the 90% confidence band and runs with at least half of the periods outside of the confidence band is lower than 15% (excluding Croatia, it is even below 5%). However, largest divergences tend to happen towards the end of the sample and in the opposite direction of estimated effects of QE, which may point to a potential overestimation of the effects of QE, if similar non-QE-generated forecast errors took place also during the pandemic.

Figure 6. In-sample simulations of stock prices

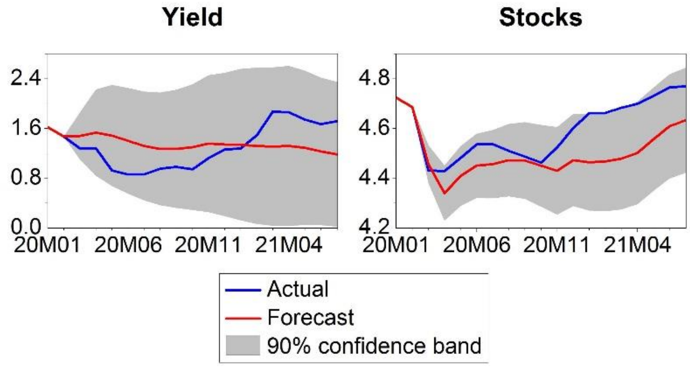


For stock prices, the conclusions are overall similar. For most countries, the performance of the model is relatively good – the number of run-periods outside the 90% confidence band and the number of simulations with at least half of the periods outside the confidence band is below 30%. The two exceptions are Iceland and once again Turkey. The impact of QE on Icelandic stock prices has been found to be extremely high, the highest in the studied sample of countries – the results of this method check indicate that this strong impact should be treated with a lot of caution. For most of the other countries, the relatively good in-sample performance of the model supports the finding that QE has had a relatively strong, positive impact on stock prices.

Czechia

We run analogous government bond yield and stock price models for Czechia, which did not launch QE despite reaching the effective lower bound and its peers (such as Poland and Hungary) conducting asset purchases. The results of this exercise are presented in Figure 7.

Figure 7. Actual vs. forecast government bond yields and log stock prices in Czechia



Bond yields do not diverge from the forecast by more than 60 bp and fall well into the 90% confidence band. Actual stock prices tend to exceed simulated values, with divergence of up to 20%, but also do not fall out of the 90% confidence band. Even though one should not rely overly on the results for one country, these results support our assumption that divergences of bond yields and stock prices from the forecast may be interpreted as the effects of QE. This evidence is quite strong especially given that Czechia's Central European peers – Poland, Romania and Croatia – are among the countries with largest divergences of bond yields and stock prices from forecasts.

4. Macroeconomic effects of QE

4.1 Empirical framework

To estimate the macroeconomic effects of QE, we begin by estimating country-specific VAR models, which include – but are not limited to – GDP, inflation, government bond yields and stock prices. In the next steps we identify shocks that move bond yields and stock prices and impose the estimated financial market effects of QE from the first stage of the analysis onto the paths of impulse response functions. In this way, we obtain the effects of QE on GDP and inflation.

As the VAR models do not directly account for QE, they are estimated on a pre-pandemic sample. Given relatively small samples (as quarterly data is used and the sample begins not earlier than in 1999), we use Bayesian methods and a stochastic search variable selection (SSVS) prior of George et al. (2008), which allows for efficient, data-based shrinkage.

We identify shocks that move government bond yields and stock prices using a mixture of sign and zero restrictions in the spirit of Arias et al. (2018). This allows us to both account for a lag in the impact of financial conditions on macroeconomic aggregates – as enabled by zero restrictions – and a co-movement of financial variables – as enabled by sign restrictions. We identify a shock to expected interest rates/risk premium, when stock prices and bond yields move in the opposite directions, and a shock to expected economic activity, when bond yields and stock prices move in the same direction.

The estimated financial market effects of QE is imposed onto the paths of impulse response functions using Structural Scenario Analysis (SSA) of Antolin-Diaz et al. (2021). This approach allows for the computation of conditional forecasts or impulse response functions by introducing predefined paths for specific variables, with the deviations from unconditional forecasts driven by selected shocks. Consequently, we calculate the impulse response functions by imposing the predetermined paths for bond yields and stock prices, driven by the aforementioned shocks related to expected interest rates/risk premium and expected economic conditions.

By inputting out-of-model estimates of financial market impact of QE into VAR models, we follow Kapetanios et al. (2012), Baumeister and Benati (2013) and Churm et al. (2021); however, we add to the approaches proposed by these papers by inputting a path of shocks rather than one-period shocks and taking into account both bond yields and stock prices rather than only bond yields.

The empirical framework is discussed in more detail in the subsections below.

4.1.1 BVAR with SSVS prior

For each of the 16 countries we estimate a VAR model with exogenous variables of the following form:

$$Y_t = \delta_0 + \sum_{k=1}^{2} A_k Y_{t-k} + \sum_{l=0}^{2} \beta_l gdp_{t-l}^{f} + BX_t + \delta_1 t + \varepsilon_t,\ \varepsilon_t \sim N(0, \Sigma) \qquad (16)$$

where Y_t is a vector of endogenous variables at time t, gdp_t^f is export-weighted GDP abroad, X_t is a vector of other exogenous variables, and ε_t is a vector of residuals, which is assumed to be normally distributed with variance-covariance matrix Σ. A_k are matrices of coefficients associated with lag k, B is a matrix of coefficients, β_l is a vector of coefficients associated with lag l, δ_0 is a vector of constants and δ_1 is a vector of coefficients associated with the time trend.

The baseline model includes 6 endogenous variables (GDP, CPI, general government debt to GDP ratio, central bank policy rate, 10-year government bond yield and a stock market index), 5 exogenous variables (export-weighted GDP abroad, VIX, US and German 10-year government bond yields and S&P 500 total return index) and a deterministic trend.

GDP and CPI are the key macroeconomic variables of interest. Given the aim of identifying shocks that move stock prices and bond yields, we also include other key determinants of these variables as discussed in the first part of the analysis: short-term interest rates and public debt among endogenous variables and VIX as well as bond yields and stock prices abroad among exogenous variables. On top of that, we include export-weighted GDP abroad as a key driver of GDP in small open economies studied here. The data used is described in detail in section 4.2.

Given relatively small samples, which call for parsimonious models, we do not include further drivers of GDP and inflation as well as bond yields and stock prices in other major economies. In subsection 4.4.1, we find the results are largely robust to the inclusion of some other variables (unemployment, exchange rate, stock prices and bond yields in other major economies, global food and energy prices). Similarly for the sake of parsimony, the models are estimated using 2 lags for endogenous variables and GDP abroad. Financial market exogenous variables enter only contemporaneously as they are likely to have an immediate impact on domestic financial variables.

The above model is estimated using Bayesian methods and the stochastic search variable selection (SSVS) prior of George et al. (2008). The use of Bayesian methods with an informative prior helps to shrink the model in small samples and thus improve its forecasting properties. However, in structural analysis there is risk that tight priors could dominate the information coming from the data. The SSVS prior significantly reduces this risk as the procedure is data-based.

The idea behind SSVS is simple – if the initial parameter estimate is close to 0, the prior is tight, effectively restricting the parameter to 0; if the initial estimate is far from zero, prior is non-informative, and thus the parameter is estimated freely[12].

Hence, SSVS is a hierarchical prior such that:

$$\alpha_i|\gamma_i \sim (1-\gamma_i)N(0,\tau_1) + \gamma_i N(0,\tau_2) \tag{17}$$

$$\gamma_i \sim Bernoulli(\pi) \tag{18}$$

where α_i is an element of a vector of model parameters $\alpha = [\delta_0^1, \dots, \delta_0^6, A_1^{1,1}, \dots, A_2^{6,6}, \beta_1^1, \dots, B^{1,1}, \dots, \delta_1^1, \dots]$ and γ_i is a dummy variable, which takes either 0 or 1 depending on whether the initial estimate of a parameter α_i is close to zero or not.

3 hyperparameters (τ_1, τ_2 and π) need to be set. τ_1 takes a low value, effectively restricting the parameter estimate to 0. τ_2 is high, letting the parameter be estimated freely. π is the parameter of the Bernoulli density which sets how often the parameter is allowed to be estimated freely. τ_1 is set to 0.1 times the standard deviation of the ordinary least squares (OLS) parameter estimate, τ_2 to 10 times that standard deviation, and π is set to the non-informative 0.5.

A very similar SSVS prior is set for the variance-covariance matrix Σ. An upper triangular matrix Ψ satisfying $\Sigma^{-1} = \Psi'\Psi$ is considered. The prior for the upper diagonal elements of matrix Ψ grouped in the vector η is analogous to the prior for parameters α:

$$\eta_{ij}|\omega_{ij} \sim \left(1-\omega_{ij}\right)N(0,\kappa_1) + \omega_{ij}N(0,\kappa_2) \tag{19}$$

[12] The initial estimate is drawn around the OLS estimate using the Gibbs sampler. See e.g. Koop and Korobilis (2010) for the more detailed description of the procedure.

$$\omega_{ij} \sim Bernoulli(q) \tag{20}$$

where η_{ij} is the element of vector η corresponding to i-th row and j-th column of matrix Ψ and ω_{ij} is a dummy variable.

Diagonal elements of matrix Ψ grouped in the vector ψ take the Gamma prior:

$$\psi_{ii}^2 \sim Gamma(\beta_1, \beta_2) \tag{21}$$

Hyperparameters κ_1, κ_2 and q are set to 0.1, 6 and 0.5, respectively. Gamma density hyperparameters β_1 and β_2 are both set to the default non-informative value of 0.01.

The joint posterior of a model with the SSVS prior is not of a known form, thus Gibbs sampling is required. For conditional posteriors and the Gibbs sampling setup, see George et al. (2008) or Korobilis (2008). The results are obtained using adopted Matlab codes provided by Koop and Korobilis (2010) and are based on 2000 iterations of the Gibbs sampler with 1000 burn-in.

The robustness of the baseline results to the choice of the prior is tested in subsection 4.4.4. While the estimates tend to change quite significantly depending on what prior is used, for countries with highest impact of QE on GDP in the baseline specification the results are largely robust.

4.1.2 Shock identification with sign and zero restrictions

We identify shocks by the means of sign and zero restrictions in the spirit of Arias et al. (2018), which combine the "traditional" zero restrictions (as in the Cholesky decomposition) of no contemporaneous impact of an identified shock on selected variables, with sign restrictions, i.e. the assumption that an identified shock has a positive or negative impact on a given variable for a selected number of periods following the shock. This enables us to account both for customary lags in the transmission of financial variables to the real economy as well as contemporaneous comovement of financial variables. We use adopted Matlab codes provided by Breitenlechner et al. (2019). For technical details of the procedure see either Arias et al. (2018) or Breitenlechner et al. (2019).

We identify two shocks that are of primary interest:

- an expected interest rates and/or risk premium shock, which has a positive impact on government bond yields, a negative impact on stock prices and no contemporaneous impact on GDP, inflation, public debt[13] or central bank policy rate,
- and a shock to expected economic conditions, which has a positive impact on both bond yields and stock prices and no contemporaneous impact on the 4 remaining variables[14].

[13] For economies with a typical profile of government bond maturities, bond yields have only a lagged impact on debt servicing costs and thus deficit and debt.

These two shocks capture a large group of sources of movements in bond yields and stock prices which do not stem from contemporaneous changes in economic conditions, fiscal policy and conventional monetary policy. These two shocks are likely to capture the vast majority of QE transmission channels discussed in the literature – the price, portfolio rebalancing and the risk premium channel are bundled in the expected interest rate/risk premium channel, as they all lead to a decline in bond yields and an increase in stock prices, while the signalling and information channels are captured by both shocks as they lead to a decline in expected interest rates, but may also have a positive or negative (if revealing negative information about the state of the economy) impact on expectations regarding future economic conditions.

While this is not strictly necessary for our purposes, in the baseline specification we also identify a conventional monetary policy shock, which increases policy rates and bond yields, lowers stock prices and has no contemporaneous impact on GDP, inflation and public debt. The sign restrictions are imposed over the first two quarters (i.e. on impact and in the following quarter). Per standard practice, the residual 3 shocks are normalised with a sign restriction on the impact response of each of the 3 slowly-moving variables (Giacomini and Kitagawa 2021). The baseline identification strategy is summarised in Table 6.

Table 6. Baseline shock identification strategy

	GDP	CPI	Public debt	Policy rate	Gov. bond yield	Stock prices
Expected interest rates/ risk premium	0	0	0	0	+	-
Expected economic conditions	0	0	0	0	+	+
Conventional monetary policy	0	0	0	+	+	-

The robustness of the baseline results to the various zero and sign restrictions identification schemes and identification by Cholesky decomposition is tested in subsection 4.4.3. In most cases, the baseline results are robust to changes in identification schemes – the qualitative conclusions remain unchanged the estimated impact of QE on GDP and CPI usually varies by relatively little across identification schemes.

4.1.3 Structural scenario analysis

The reaction of GDP and inflation to QE is obtained by imposing the estimated reactions of government bond yields and stock prices to QE from the first stage of the analysis onto the paths of impulse response functions calculated from the VAR model described above. This is done by the means of structural scenario analysis (SSA) as described by Antolin-Diaz et al.

[14] One could argue that monetary policy may contemporaneously react to the developments in the financial markets, and in particular to shocks to expected economic conditions. The robustness of the baseline results to such an identification strategy is tested in subsection 4.4.3.

(2021). Structural scenario analysis is a formal procedure of obtaining conditional forecasts or scenarios such that imposed paths for selected variables are driven by a selected subset of structural shocks. In our case, we impose paths for bond yields and stock prices, which are driven by shocks to expected interest rates/risk premium and expected economic activity, described in the previous subsection.

SSA is different from a "classic" conditional forecasting of Waggoner and Zha (1999), which uses reduced-form shocks and hence does not specify what is the source of the deviation of the conditional forecast from the unconditional mean. As such, SSA and conditional forecasting of Waggoner and Zha (1999) answer distinctly different questions – conditional forecasting shows under which conditions the given scenario is most likely to materialise, while SSA shows how studied variables respond to a given set of shocks. In practice the difference between these approaches may be very large – in the case of conventional monetary policy under the scenario of low (below the unconditional forecast) interest rates, conditional forecasting is likely to result in a low path of economic activity and inflation (because this is when central banks set low interest rates), while with SSA (if driven by monetary policy shocks) one is likely to obtain a high path of economic activity and inflation (because low interest rates stimulate economic activity and inflation).

In our case, we are interested in finding out what happens when bond yields and stock prices change due to QE, rather than finding out under which macroeconomic conditions a given path of bond yields and stock prices is obtained. Thus, SSA, with the scenarios driven by the shocks as described above, is the appropriate approach.

To formally define SSA in our setting, let us denote the distribution of the deviation of the conditional forecast from the unconditional mean (or the distribution of the impulse response to a set of shocks) as below:

$$y_{t+1,t+h} \sim N(\mu_y, \Sigma_y) \tag{22}$$

where $y_{t+1,t+h} = [y'_{t+1}, y'_{t+2}, \dots, y'_{t+h}]'$ denotes deviations of future values of endogenous variables from the unconditional forecast, μ_y is the mean of the distribution of $y_{t+1,t+h}$ and Σ_y is the associated variance-covariance matrix.

Assuming the structural parameters of the VAR are known, the deviation of the conditional forecast from the unconditional mean is given by the following equation:

$$y_{t+1,t+h} = M'\epsilon_{t+1,t+h} \tag{23}$$

where matrix M reflects impulse responses to a standard one-period shock and is a function of the structural VAR parameters, while $\epsilon_{t+1,t+h} = [\epsilon'_{t+1}, \epsilon'_{t+2}, \dots, \epsilon'_{t+h}]'$ denotes future structural shocks.

SSA describes how to obtain $y_{t+1,t+h}$ subject to constraints on the paths of a subset of the endogenous variables represented by

$$\bar{C}y_{t+1,t+h} = \bar{C}M'\epsilon_{t+1,t+h} \sim N(\bar{f}_{t+1,t+h}, \bar{\Omega}_f) \tag{24}$$

and subject to constraints on structural shocks represented by

$$\Psi\epsilon_{t+1,t+h} \sim N(g_{t+1,t+h}, \Omega_g) \tag{25}$$

where $\bar{C}$ is a selection matrix selecting the constrained endogenous variables, $\bar{f}_{t+1,t+h}$ is a vector specifying the paths of restricted endogenous variables, $\bar{\Omega}_f$ is a variance-covariance matrix describing uncertainty around these paths, Ψ is a selection matrix selecting the constrained shocks, $g_{t+1,t+h}$ is a vector specifying the paths for the constrained shocks and Ω_g is a variance-covariance matrix specifying uncertainty around these paths.

In our case, $\bar{C}$ selects government bond yields and stock prices, $\bar{f}_{t+1,t+h}$ is equal to the estimates of the impact of QE on bond yields and stock prices obtained from the first stage of the analysis, $\bar{\Omega}_f$ includes variances of these estimates (equal to variances of forecasts from the first stage), Ψ selects shocks other than those to expected interest rates/risk premium and expected economic activity, $g_{t+1,t+h}$ sets these shocks to zero with zero uncertainty specified in Ω_g.

To obtain $y_{t+1,t+h}$ - in our case, impulse responses to QE - one needs to find $\epsilon_{t+1,t+h}$ for the unconstrained shocks. Let us define the distribution of $\epsilon_{t+1,t+h}$ as follows:

$$\epsilon_{t+1,t+h} \sim N(\mu_\epsilon, \Sigma_\epsilon) \tag{26}$$

Where μ_ϵ and Σ_ϵ denote the mean and variance of the future structural shocks, respectively.

The solutions for μ_ϵ and Σ_ϵ are given by the following equations:

$$\mu_\epsilon = D^* f_{t+1,t+h} \tag{27}$$

$$\Sigma_\epsilon = D^*\Omega_f D^{*\prime} + (I - D^*DD'D^{*\prime}) \tag{28}$$

Where D^* is the Moore-Penrose inverse of $D = [M\bar{C}', \Psi']'$, $f_{t+1,t+h} = [\bar{f}'_{t+1,t+h}, g'_{t+1,t+h}]'$ and $\Omega_f = diag(\bar{\Omega}_f, \Omega_g)$.

Combing equation (23) with (27) and (28), one obtains the solutions for μ_y and Σ_y – i.e. the final result:

$$\mu_y = M'D^* f_{t+1,t+h} \tag{29}$$

$$\Sigma_y = M'M - M'D^*(\Omega_f - DD')D^{*\prime}M \tag{30}$$

For the derivation of the above equations, see Antolin-Diaz et al. (2021) or Appendix C of Breitenlechner et al. (2022).

4.2 Sample and data

VAR models are estimated on quarterly data, with the sample starting no earlier than in 1999 Q1 and ending in 2019 Q4, for the same 16 countries as in the first stage of the analysis[15]. As mentioned above, the baseline model includes 6 endogenous variables (GDP, CPI, general government debt to GDP ratio, central bank policy rate, 10-year government bond yield and a stock market index) and 5 exogenous variables (export-weighted GDP abroad, VIX, US and German 10-year government bond yields and S&P 500 total return index).

Table 7. Data used in VAR models

Definition	Data sources	Additional comments
Log GDP in constant prices	OECD, Eurostat, National Economic and Social Development Council of Thailand	Seasonally adjusted
Log CPI	Bloomberg, OECD, Eurostat, Banco Central de Chile, Croatian National Bank	Seasonally adjusted
General government debt to GDP ratio	Bloomberg, Eurostat, BIS, IMF, OECD, Australian Department of Finance, Statistics Canada, Banco Central de Chile, Banco de la Republica, Costa Rican Ministry of Finance, Croatian National Bank, Statistics Iceland, Israel Central Bureau of Statistics, Korea Ministry of Planning and Finance, Bank of Thailand, Central Bank of Turkey	Seasonally adjusted
Central bank policy rate	Bloomberg, BIS, OECD, Banco Central de Chile	
10-year government bond yield	Bloomberg, OECD, Eurostat, IMF	
Log stock price index[16]	Bloomberg, OECD, stooq.pl	Preferably market-wide and total return, subject to data availability
Log of export-weighted GDP abroad	Oxford Economics, Bloomberg, WITS, own calculations	Seasonally adjusted, index computed from quarterly growth rates
VIX	Bloomberg	
10-year government bond yield in the US and Germany	Bloomberg	
S&P 500 total return	Bloomberg	

[15] Australia, Canada, Iceland, Israel, Korea, and New Zealand among advanced economies as well as Chile, Costa Rica, Colombia, Croatia, India, Poland, Romania, South Africa, Thailand, and Turkey among emerging market economies.

[16] Australia: S&P/ASX 200 Gross Total Return, Canada: S&P/TSX Composite Total Return, Israel: TA-125, Korea: KOSPI, New Zealand: S&P/NZX All, Chile: S&P CLX IPSA, Croatia: CROBEX, India: SENSEX, Poland: WIG, Romania: BET, South Africa: FTSE/JSE Africa All Share, Thailand: SET, Iceland and Colombia: per OECD data, Turkey: BIST 100 Net Total Return, Costa Rica: BCT Corp Stock Market Index.

Non-stationary variables (GDP, CPI, stock prices, foreign GDP, S&P 500) are expressed in logarithms. We thus estimate the model in (log-)levels, per standard practice in the monetary VAR literature (e.g. Sims 1980, Litterman 1986, Eichenbaum and Evans 1995, Bernanke and Mihov 1998, Christiano et al. 1999, Uhlig 2005, Bańbura et al. 2010, Gertler and Karadi 2015). Specifications in levels are usually preferred as they may better capture long-run relationships among variables, with no need to explicitly account for cointegration. Although concerns about spurious correlation in nonstationary VARs have been common, Sims et al. (1990) have alleviated these concerns by demonstrating the consistency of parameter estimates in such VARs.

Most of the variables overlap with those used in the first stage of the analysis. Thus, the same data is used as in the first stage, with quarterly averages computed from monthly data. The exceptions are data on domestic and foreign GDP – domestic GDP is sourced mostly from the OECD, while data on foreign GDP is computed using GDP data combined from various sources and export data from World Bank's World Integrated Trade Solution (WITS) database. The data definitions and sources are listed in Table 7.

4.3 Baseline results

The estimated median responses of GDP and CPI to QE together with 68% Bayesian credible sets are plotted in Figure 8 and Figure 9, respectively.

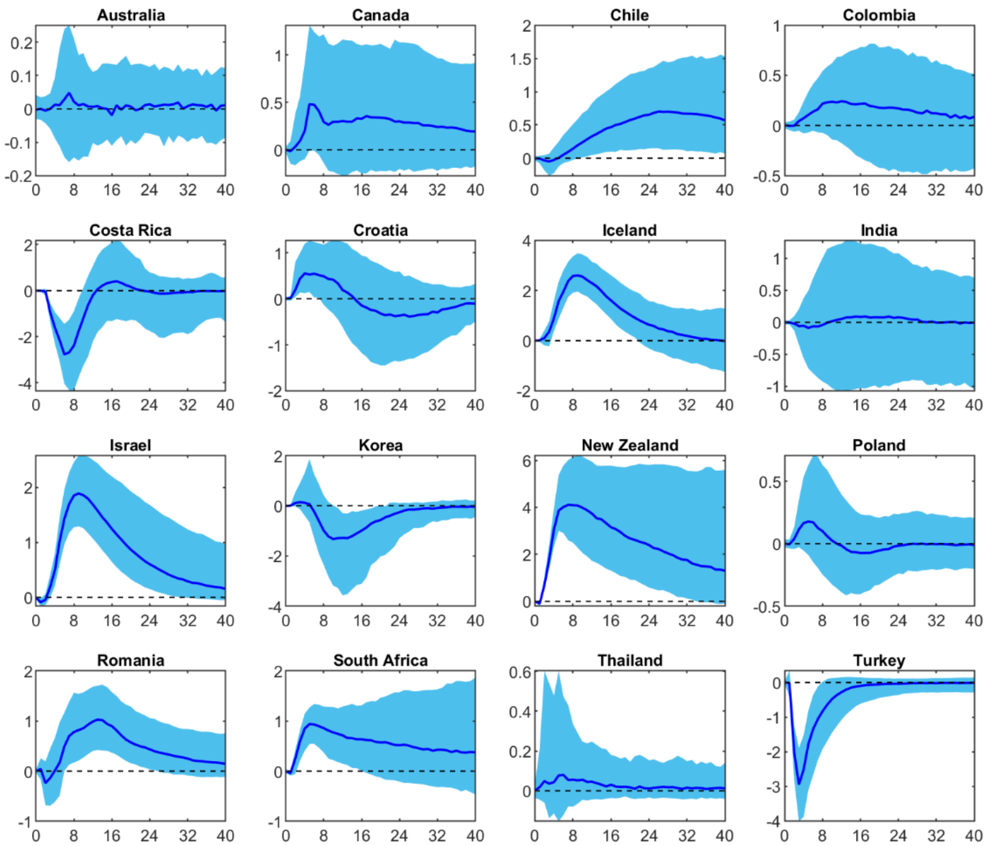
The impact on GDP is positive and relatively sizeable, with the 68% credible set well above 0 for at least 10 quarters, for 5 countries: Iceland, Israel, New Zealand, Romania and South Africa, with the effect of QE ranging from close to 1% in Romania and South Africa to 4% in New Zealand. The transmission of QE in these countries tends to be relatively quick, with the peak effect achieved after 5-9 quarters from the outbreak of the pandemic, Romania being the exception.

For 5 further countries: Canada, Chile, Colombia, Croatia and Poland, the median impact on GDP is positive, but 68% credible sets either always contain zero or exceed zero only slightly or only for a few quarters. Median estimates point to a relatively modest impact of 0.2-0.7%. For the 6 remaining countries, the estimates are either essentially zero (Australia, India, Thailand) or negative (Costa Rica, Korea, Turkey). In Costa Rica and Turkey, this negative impact is sizeable (2.8-3.0% at peak) and highly statistically significant, reflecting the estimates from the first stage of the analysis (positive impact of QE on bond yields in both countries and negative impact on stock prices in Costa Rica).

The impact on CPI tends to be more muted than on GDP – there is no country with a strongly significant impact. For 6 countries (Canada, Croatia, India, Israel, Poland, South Africa) median responses are positive, ranging from a mere 0.13% at peak in Canada to 1.9%

in India. For Colombia, Korea and Romania the median responses are negative, and for the remaining 7 countries they hardly move away from zero.

Figure 8. The estimated impact of QE on GDP (in percentage)

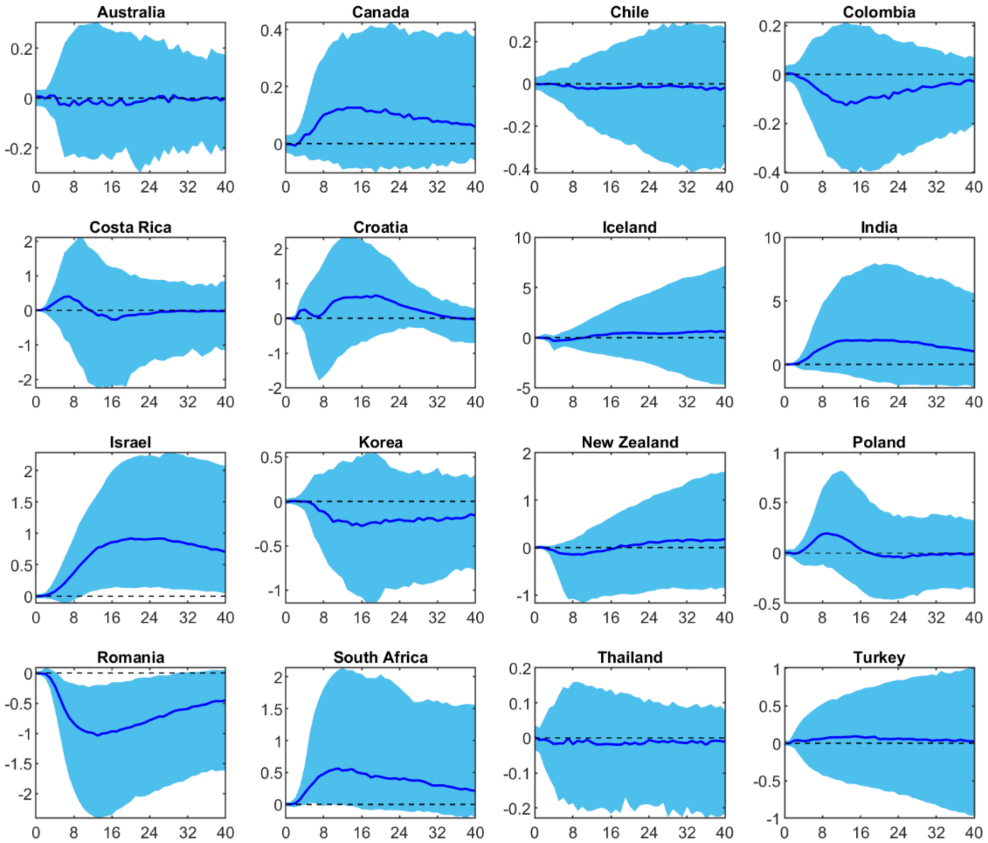


Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the pandemic outbreak.

How can these results be explained? They are a combination of, on the one hand, the impact of QE on stock prices and long-term interest rates as described in Section 3.3, and, on the other hand, the estimated impact of shocks to expected interest rates/risk premium and expected economic activity on GDP and CPI. The responses of government bond yields, stock prices, GDP and CPI to shocks to expected interest rates/risk premium and expected economic activity are shown and briefly described in Appendix B.

Table 8 summarises all the key results, i.e. the estimated peak impact of QE on long-term interest rates and stock prices, the impact of the two key identified shocks on GDP and CPI and finally the resultant impact of QE on GDP and CPI, in the form of a heat map. The green colour signals "expected" results, i.e. QE lowering bond yields and increasing stock prices, GDP and CPI; a positive shock to expected interest rates/risk premium lowering GDP and CPI; and a positive shock to expected economic activity increasing GDP and CPI. The red colour signals the opposite results.

Figure 9. The estimated impact of QE on CPI (in percentage)



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the pandemic outbreak.

As discussed in Section 3, QE tends to have a strong positive impact on stock prices, while the impact on bond yields is on average counterintuitively positive. The latter result is not solely driven by the two outliers (Turkey and Costa Rica) as the median estimate is also positive. A positive shock to expected interest rates/risk premium, which raises bond yields and increases stock prices, tends to lower GDP, but has little to no effect on prices. A positive shock to expected economic activity on average has little impact on both GDP and CPI, though for GDP, country-specific estimates range from positive to negative, while for CPI they cluster closer to zero.

Bearing this in mind, in the "average country" the model interprets the QE shock as a combination of a negative shock to expected interest rates/risk premium, which raises stock prices and lowers bond yields, and a positive shock to economic activity, which cancels out the negative impact of the former shock on bond yields while further propping stock prices. As such, pandemic QE programmes tended to increase GDP by 0.3-0.4% at peak and had no statistically significant impact on prices, though point estimates are also on average positive.

Table 8. The peak impacts of QE, expected interest rates/risk premium and expected economic activity shocks on bond yields, stock prices, GDP and inflation

	QE on bond yields	QE on stock prices	Expected interest rates/risk premium* shock on GDP	Expected interest rates/risk premium* shock on CPI	Expected economic activity** shock on GDP	Expected economic activity** shock on CPI	QE on GDP	QE on CPI
Australia	-0.4	58.7	-0.03	0.01	-0.02	-0.01	0.05	-0.03
Canada	0.66	41	0.37	-0.08	0.4	0.04	0.48	0.13
Chile	-1.09	-16	-0.63	0.04	-0.52	0.03	0.7	-0.02
Colombia	0.78	43.9	-0.15	0.06	0.02	-0.02	0.24	-0.13
Costa Rica	4.55	-57.7	-0.31	0.04	0.28	0.01	-2.77	0.4
Croatia	-2.95	54.5	-0.18	-0.28	-0.33	0.53	0.55	0.66
Iceland	1.16	191.9	-0.46	-1.61	0.24	-0.17	2.61	0.65
India	2.57	158.6	-0.04	-0.18	-0.01	0.2	0.09	1.9
Israel	-2.89	27.2	-0.97	-0.43	0.38	0.08	1.89	0.92
Korea	0.38	101	-0.15	0.02	-0.17	-0.03	-1.33	-0.28
New Zealand	-0.6	51.1	-1.35	0.05	0.76	0.02	4.1	-0.15
Poland	-2.46	34.8	0.19	0.21	-0.11	-0.15	0.18	0.19
Romania	-2.12	39.1	-0.44	0.45	0.67	0.2	1.03	-1.04
South Africa	1.9	35.8	-0.33	-0.09	0.22	0.21	0.93	0.56
Thailand	0.67	28.2	0.14	-0.02	0.06	-0.01	0.08	-0.02
Turkey	4.93	13.9	-0.61	-0.01	-0.84	0.04	-2.95	0.09
Average	**0.32**	**50.4**	**-0.31**	**-0.11**	**0.06**	**0.06**	**0.37**	**0.24**
Median	**0.52**	**40.1**	**-0.25**	**0.00**	**0.04**	**0.03**	**0.36**	**0.11**

Percentage points for bond yields, percentage for stock prices, GDP and CPI.

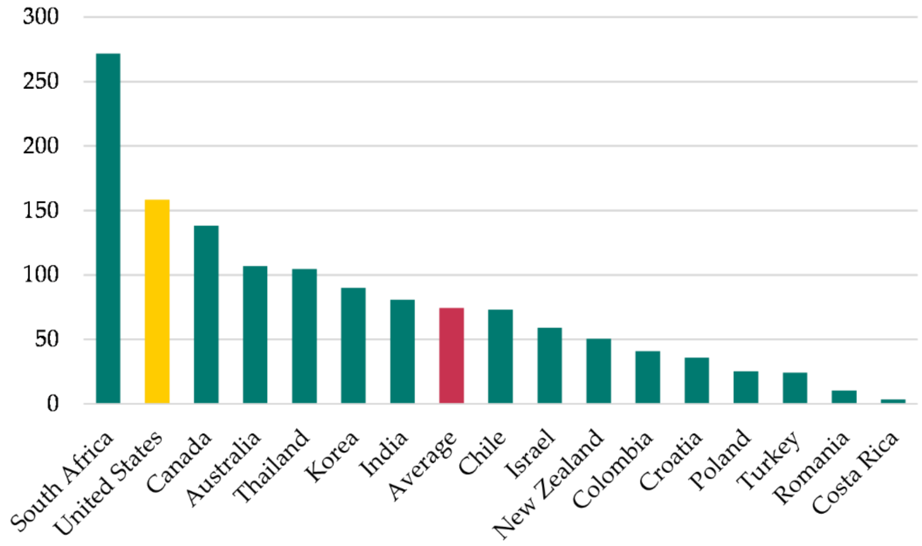
** Response to expected interest rates/risk premium shock which increases bond yields by 1 pp.*

*** Response to expected economic activity shock which increases stock prices by 10%.*

Economically, QE seems to be lowering expected interest rates and risk premia, while at the same time improving expectations about future economic activity. These two forces together pull up stock prices significantly, but largely cancel each other out when it comes to the impact on bond yields. This results in a positive impact on GDP and little to no impact on prices. The overall impact is rather muted, which may be related to a relatively limited role played by stock markets in most of the analysed economies (Figure 10). The lack of the response of prices is a by-product of weak or non-existing reaction of prices to financial conditions and – indirectly – economic activity, which suggests that Phillips curves in the analysed economies are relatively flat.

Said that, results vary widely across countries. Israel is the only economy which shows results consistently in line with expectations, i.e. the impact of QE and the two key identified shocks show expected signs and are in most cases statistically significant. In Croatia and New Zealand the results are also largely as expected. In other countries, financial conditions have virtually none (esp. Australia) or a counterintuitive (esp. Poland) impact on macroeconomic conditions and/or QE has a counterintuitive impact on financial conditions (esp. Costa Rica and Turkey), which results in a muted or inconsistent with expectations impact of QE on GDP and CPI. The drivers of some of these differences in the results are further investigated in Section 5, pointing to the importance of monetary and fiscal policy credibility in explaining the counterintuitive impact of QE on bond yields and thus GDP and inflation.

Figure 10. Stock market capitalisation at the end of 2019 (% of GDP)



Source: World Bank Databank.

4.4 Robustness checks

The robustness of the baseline results has been investigated by including additional endogenous and exogenous variables, changing the number of lags in the VAR model, amending the method and assumptions behind the shock identification, and changing the Bayesian VAR prior.

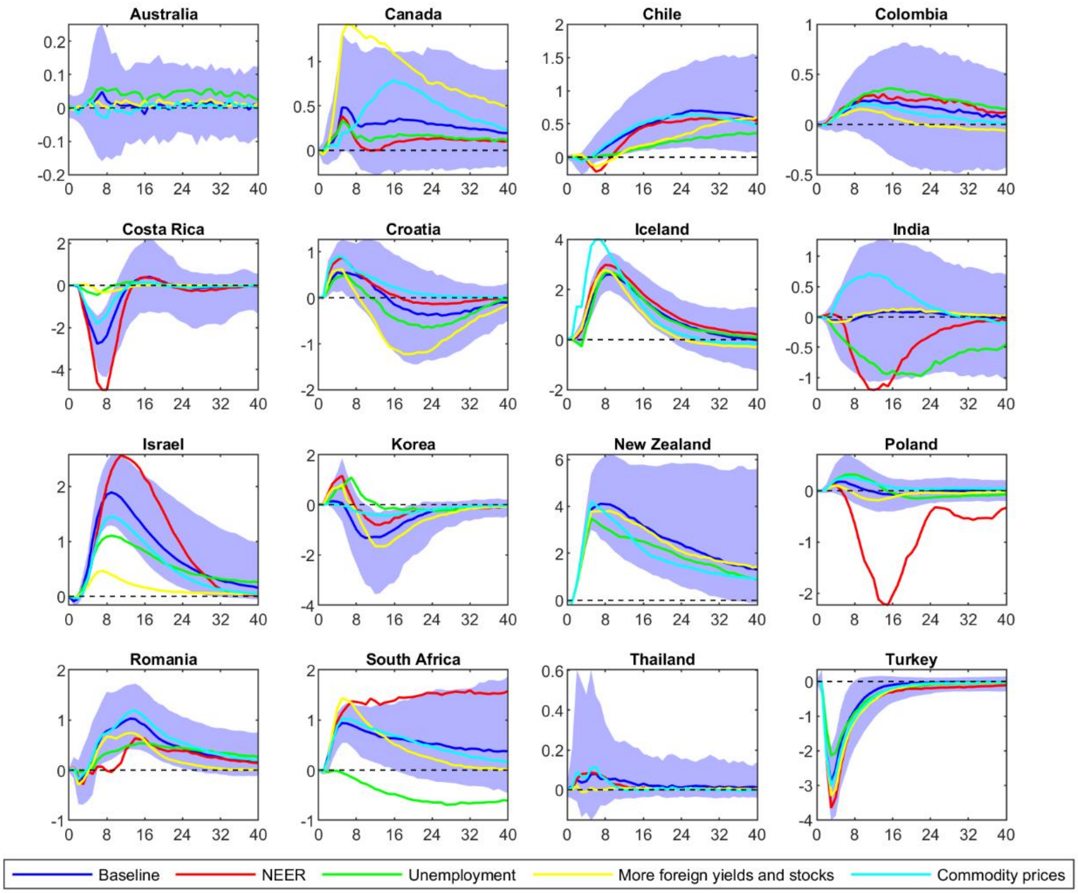
The baseline results are in most cases robust to the inclusion of additional variables and amending the shock identification. The number of lags tends to have somewhat more impact on the estimates, but does not alter the qualitative conclusions. The choice of the prior has most impact on the results, but for countries with strongest effects of QE on GDP, the results remain broadly unchanged.

4.4.1 Variables

We have tested 4 alternative VAR specifications: with either unemployment or nominal effective exchange rate (NEER) as an additional endogenous variable or either additional government bond yields and stock price indices abroad (in the US, Germany, Japan and China, if not yet included) or global food and energy commodities prices as additional exogenous variables.

Being a proxy for output gap, unemployment may help to single out movements in GDP caused by productivity shocks and thus help to identify the effects of financial conditions on GDP. Most of the economies studied in this paper are classified as small open, and thus the exchange rate may have a significant effect on both economic activity and inflation. Including further measures of financial conditions abroad may potentially help to identify domestic shocks to risk premium/expected interest rates and expected economic activity. Finally, commodity prices may be an important driver of inflation, helping to identify the effects of financial conditions on CPI.

Figure 11. The estimated impact of QE on GDP (in percentage): specifications with additional variables



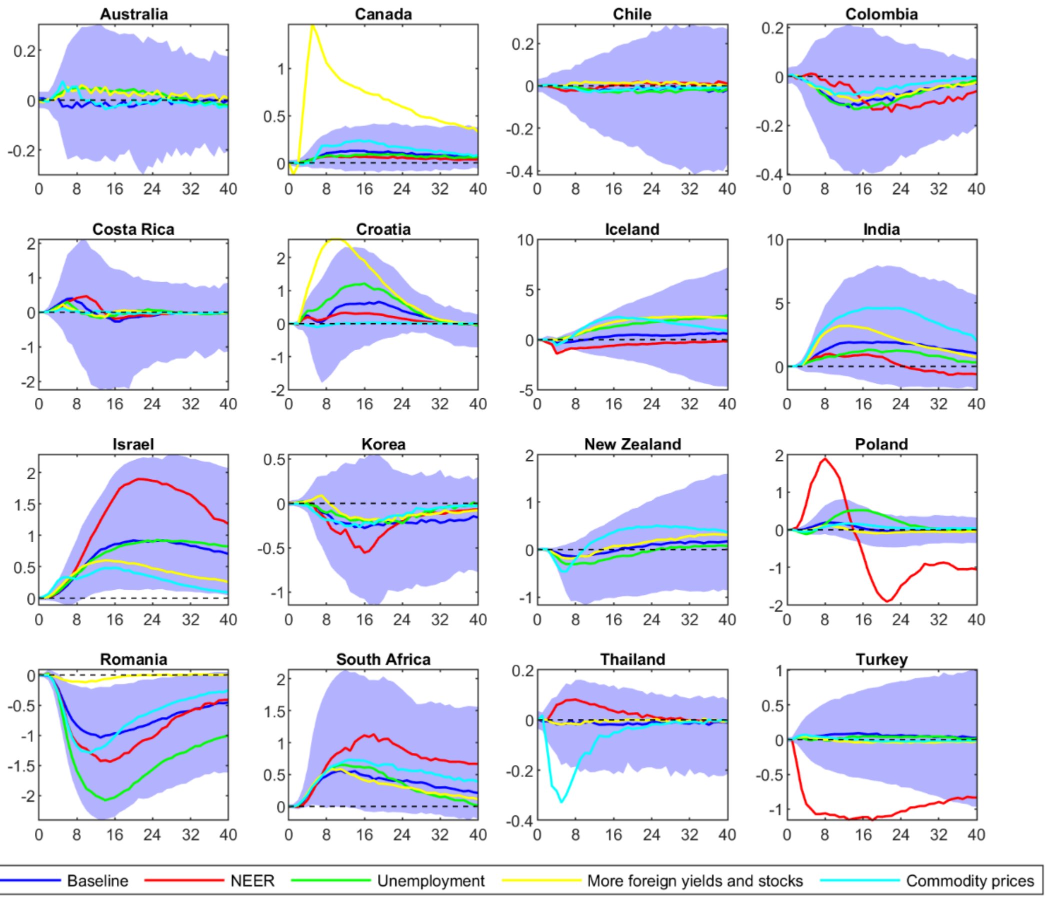
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets in the baseline specification. On horizontal axis: quarters since the pandemic outbreak.

The data on unemployment comes mostly from the IMF's International Finance Statistics, augmented by national sources. The data on NEER is from the BIS with the exception of Costa Rica, for whom the US dollar exchange rate is used. The data on bond yields and stock prices abroad comes from Bloomberg and is the same as used in the first stage of the analysis (see subsection 3.2). Finally, the data on global food and energy prices is from the IMF Primary Commodity Prices database.

The impact of QE on GDP and CPI obtained from alternative specifications is compared with the baseline estimates in Figure 11 and Figure 12, respectively[17].

The impact on GDP differs somewhat across specifications, but in most cases it remains within the 68% credible set of the baseline specification and the baseline results remain qualitatively robust – i.e. whenever the impact is statistically significant in the baseline, the sign of the peak impact remains unchanged across all specifications, though the size of the impact tends to differ somewhat; whenever the impact is not significant in the baseline, it tends to remain relatively close to zero in the alternative specifications.

Figure 12. The estimated impact of QE on CPI (in percentage): specifications with additional variables



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets in the baseline specification. On horizontal axis: quarters since the pandemic outbreak.

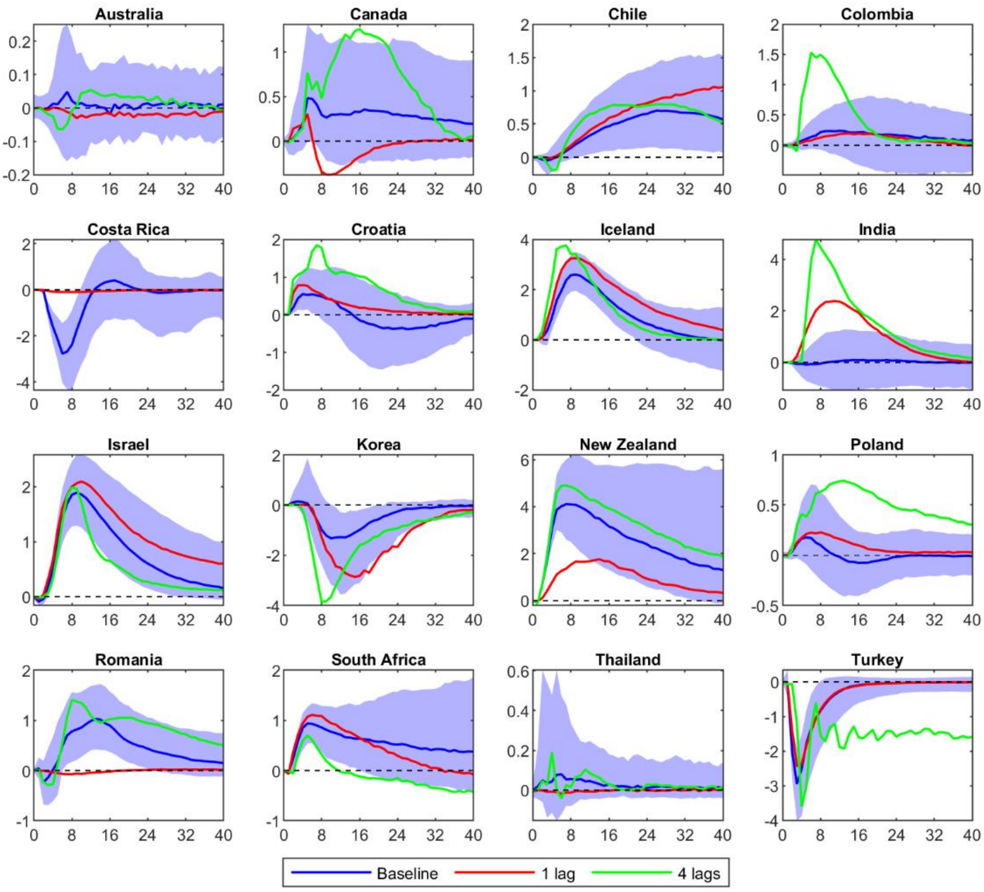
[17] For some country-specification combinations, the variance-covariance matrix of impulse responses to QE Σ_y is not positive-definite even after adding a small number to the diagonal (up to 0.001), making it impossible to draw the impulse response. Thus, the results for these country-specification combinations are not shown (specifications with NEER for Australia and New Zealand and with unemployment for Thailand).

The two countries with least robust results are Costa Rica (though the impact always remains negative, it varies widely in size) and India, with the impact varying from negative to positive. For Costa Rica, this is not unexpected as this country has the shortest sample (starting only in 2011). Other notable exceptions include the specification with additional bond yields and stock prices abroad for Canada and Israel, which suggest that the impact of QE is significantly stronger and weaker, respectively; the specification with NEER for Poland, which points to a strongly negative impact of QE on GDP; and the specification with unemployment for South Africa, which points to negative impact, unlike other specifications.

The results for CPI are more robust, i.e. they remain insignificant and close to zero across most specifications and countries. The specifications with additional financial variables abroad and NEER generate a few divergences from this rule – in this former case for Canada, Croatia and Romania, and in the latter case for Poland and Turkey.

4.4.2 Lags

Figure 13. The estimated impact of QE on GDP (in percentage): specifications with varying number of lags

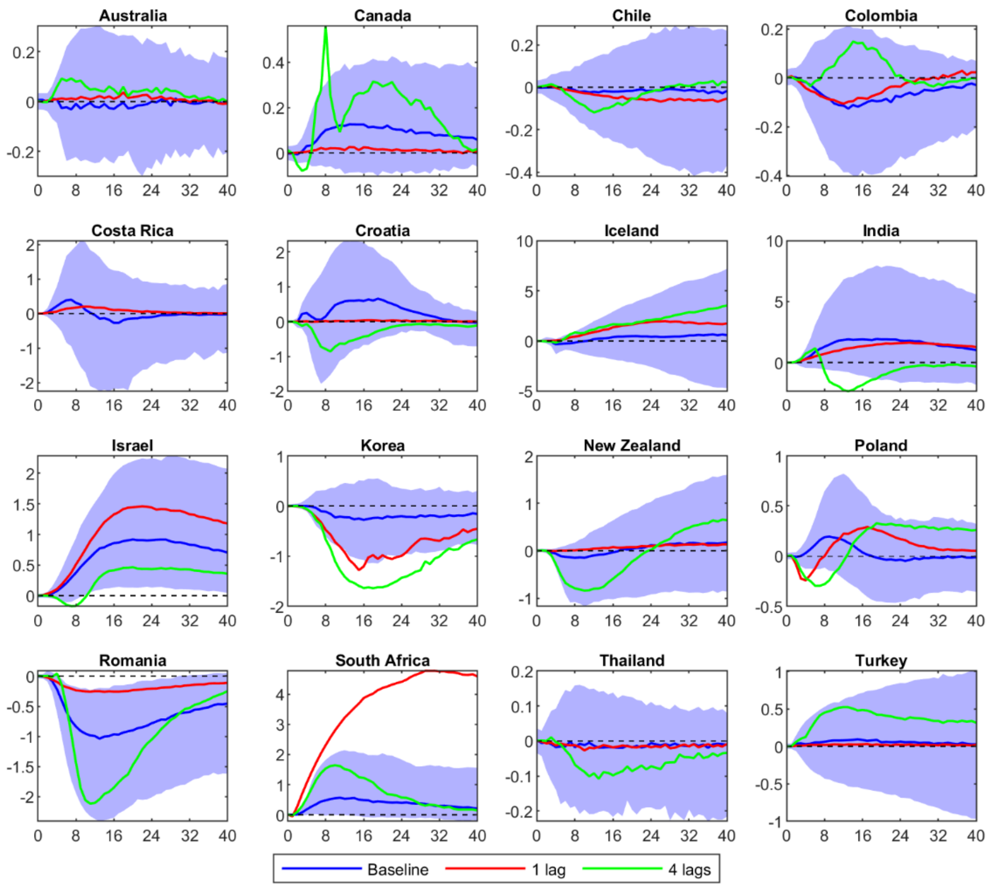


Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets in the baseline specification. On horizontal axis: quarters since the pandemic outbreak.

The robustness of the baseline results to the number of lags of endogenous variables in the VAR model is tested by estimating models with 1 and 4 lags, as opposed to 2 lags in the baseline specification. The estimated impact of QE on GDP and CPI in the baseline and alternative specifications is compared in Figure 13 and Figure 14, respectively[18].

For most countries, the impact on GDP is qualitatively and often quantitatively similar across specifications. The exceptions are Canada, Colombia, Costa Rica, India, Poland and Romania, especially for the specification with 4 lags, which tends to shows much stronger effects of QE. This is not entirely surprising given that in the specification with 4 lags, the number of parameters is high relative to the sample size (33 parameters in samples of up to 84 observations).

Figure 14. The estimated impact of QE on CPI (in percentage): specifications with additional variables



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets in the baseline specification. On horizontal axis: quarters since the pandemic outbreak.

The estimated impact on CPI quantitatively varies across specifications, but the qualitative conclusion remains unchanged in most cases – QE has no statistically significant effect on prices for most countries, with Israel, Romania and South Africa as notable exceptions. The

[18] For the same reason as in the previous robustness check, the results for the specification with 4 lags for Costa Rica are not shown (see the previous footnote).

latter country shows a particularly strong divergence in results for the specification with 1 lag, when the effect of QE is estimated to be much stronger. Similar as in the case of GDP, the results obtained from the specification with 4 lags often diverge from the baseline, but the qualitative conclusion remains unchanged in most cases.

4.4.3 Shock identification

We consider three alternative shock identification schemes:

- Cholesky decomposition, in which variables are ordered in the following way: GDP, CPI, public debt, central bank interest rate, government bond yield, stock prices.
- Sign and zero restrictions with a full set of shocks, i.e. on the top of the 3 already identified shocks, we identify shocks to demand, supply and fiscal policy.
- Sign and zero restrictions with amended definition of the shock to expected economic activity, which is now assumed to have a positive impact central bank interest rates.

The alternative shock identification strategies are summarised in Table 9.

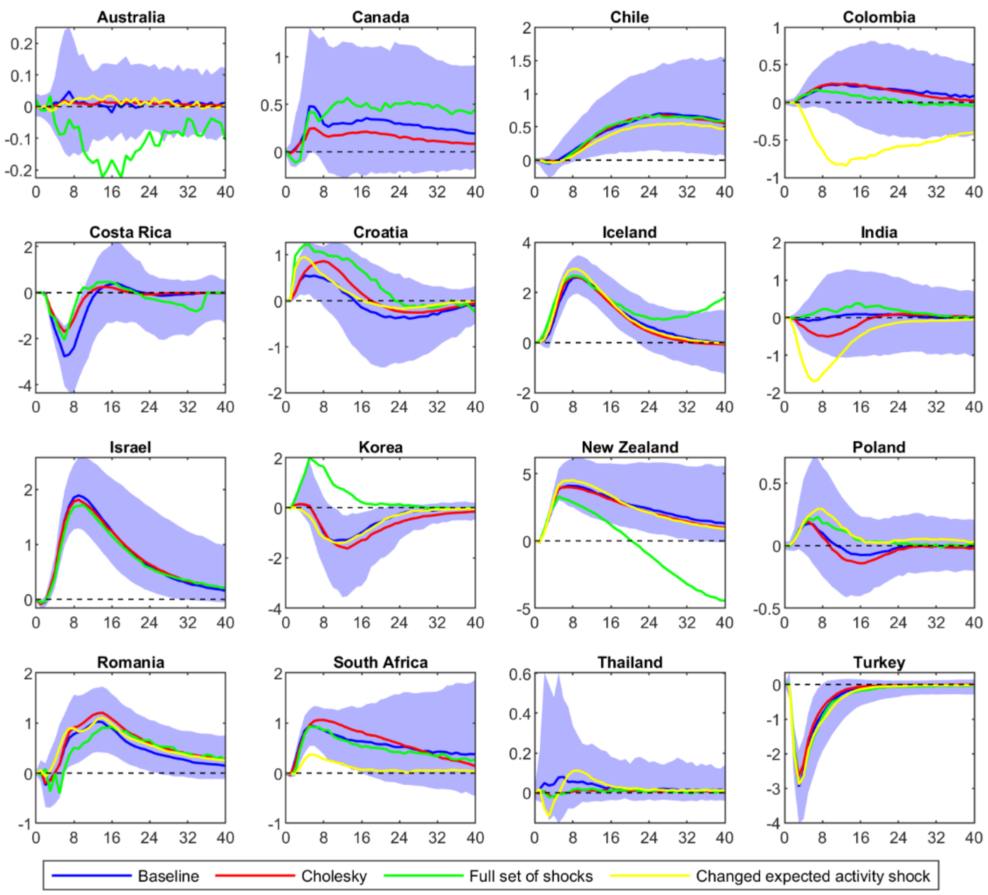
Table 9. Alternative shock identification strategies

	GDP	**CPI**	**Public debt**	**Policy rate**	**Gov. bond yield**	**Stock prices**
Cholesky decomposition						
Demand	1	NR	NR	NR	NR	NR
Supply	0	1	NR	NR	NR	NR
Fiscal policy	0	0	1	NR	NR	NR
Conventional monetary policy	0	0	0	1	NR	NR
Expected interest rates/ risk premium	0	0	0	0	1	NR
Expected economic conditions	0	0	0	0	0	1
Full set of shocks						
Demand	+	+	-	+	+	+
Supply	-	+	NR	NR	NR	NR
Fiscal policy	+	+	+	+	+	+
Conventional monetary policy	0	0	0	+	+	-
Expected interest rates/ risk premium	0	0	0	0	+	-
Expected economic conditions	0	0	0	0	+	+
Changed expected activity shock						
Conventional monetary policy	0	0	0	+	+	-
Expected interest rates/ risk premium	0	0	0	0	+	-
Expected economic conditions	0	0	0	+	+	+

In the Cholesky decomposition, relative to the baseline identification scheme, the shock to risk premium/expected interest rates has an unrestricted impact on stock prices, while the shock to expected economic activity has no contemporaneous impact on bond yields. While these assumptions are unlikely to hold, we provide the results for the Cholesky decomposition for the sake of completeness, as this is often the default way of identifying shocks by practitioners.

On the top of previously identified monetary policy shock, Cholesky decomposition identifies all the 3 remaining shocks, which are dubbed as shocks to demand, supply and fiscal policy. The identification of these shocks reflects the assumption that public debt reacts contemporaneously to economic activity and inflation (via tax revenue and automatic stabilisers), while economic activity has a contemporaneous effect on prices, but prices have no contemporaneous impact on activity. Admittedly, these identification assumptions also seem unrealistic, as fiscal policy is likely to have an immediate impact on GDP, while both demand and supply are likely to have contemporaneous impact on demand and prices.

Figure 15. The estimated impact of QE on GDP (in percentage): various shock identification schemes

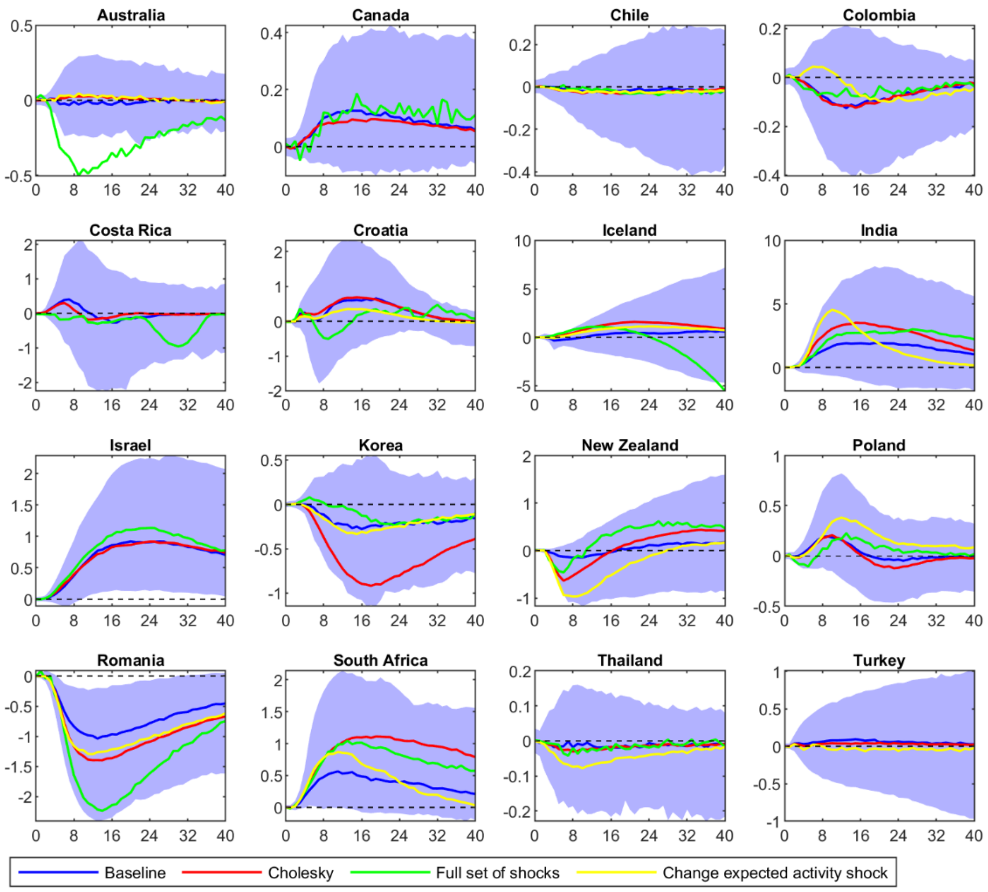


Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets in the baseline specification. On horizontal axis: quarters since the pandemic outbreak.

In the second alternative identification scheme we identify the three additional shocks mentioned above via sign restrictions, while the approach to identifying the two main shocks of interest and the monetary policy shock remains unchanged from baseline. Given that the 3 baseline shocks are identified assuming zero restrictions on GDP, CPI and public debt, the identification of 3 additional shocks is not strictly necessary, but it may help to eliminate parameter draws for which these 3 remaining shocks have unrealistic effects on the economy, and thus eliminate unlikely parameter estimates from the set of considered models.

A positive demand shock is assumed to have an immediate positive impact on GDP and CPI as is usually assumed (even though prices are often found to respond with a lag to economic conditions). The central bank is also assumed to react immediately to improved economic conditions, and so do government bond yields and stock prices. Faced with higher tax revenue and lower spending on automatic stabilisers, public debt declines.

Figure 16. The estimated impact of QE on CPI (in percentage): various shock identification schemes



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets in the baseline specification. On horizontal axis: quarters since the pandemic outbreak.

A positive supply shock raises prices and lowers economic activity, while having an ambiguous impact on the remaining variables – with lower activity and higher prices having opposite effects on interest rates, (nominal) stock prices and government deficit. Finally, a positive fiscal policy shock raises government deficit and thus debt, propping up economic activity and prices. Better economic outlook increases bond yields and stock prices and sparks an immediate monetary policy reaction.

In the third alternative shock identification scheme we make only one change relative to the baseline – we assume that the central bank reacts immediately to a change in expectations regarding economic activity.

The estimated impact of QE on GDP and CPI is compared across various identification schemes in Figure 15 and Figure 16, respectively.

In most cases, the baseline results are robust to changes in identification schemes – the qualitative conclusions remain unchanged the estimated impact of QE on GDP and CPI usually varies by relatively little across identification schemes. There are a few exceptions, though – with full set of shocks, QE is estimated to have a negative impact on GDP and CPI in Australia (against no impact in other schemes) and positive impact on GDP in Korea (against negative effect in other schemes); with changed expected activity shock, QE is estimated to have a negative impact on GDP in Colombia (against positive median estimates in other schemes) and a much more muted impact on GDP in South Africa; for India, the impact of QE on GDP varies quite significantly across specifications.

4.4.4 Prior

We test the robustness of the results with respect to the choice of the prior by estimating the models using a diffuse (uninformative) prior and independent Normal-Wishart prior with the Minnesota structure.

The diffuse prior does not affect the posterior. In our case it is equivalent to specifying the prior as equal to ordinary least squares (OLS) estimates or not specifying the prior at all. With diffuse prior, parameters are drawn around the OLS estimates. Thus, the diffuse prior can be interpreted as a Bayesian equivalent to OLS estimation.

The Minnesota prior has originally been proposed by Doan et al. (1984) and Litterman (1986) and is the most often used prior in the Bayesian VAR literature. It models variables as random walks and assumes that own lags are more important than lags of other variables and earlier lags are more important than further lags. Originally the prior was applied assuming a fixed, diagonal variance covariance matrix Σ, estimated separately. Independent Normal-Wishart prior allows to impose the Minnesota prior on model parameters without fixing Σ.

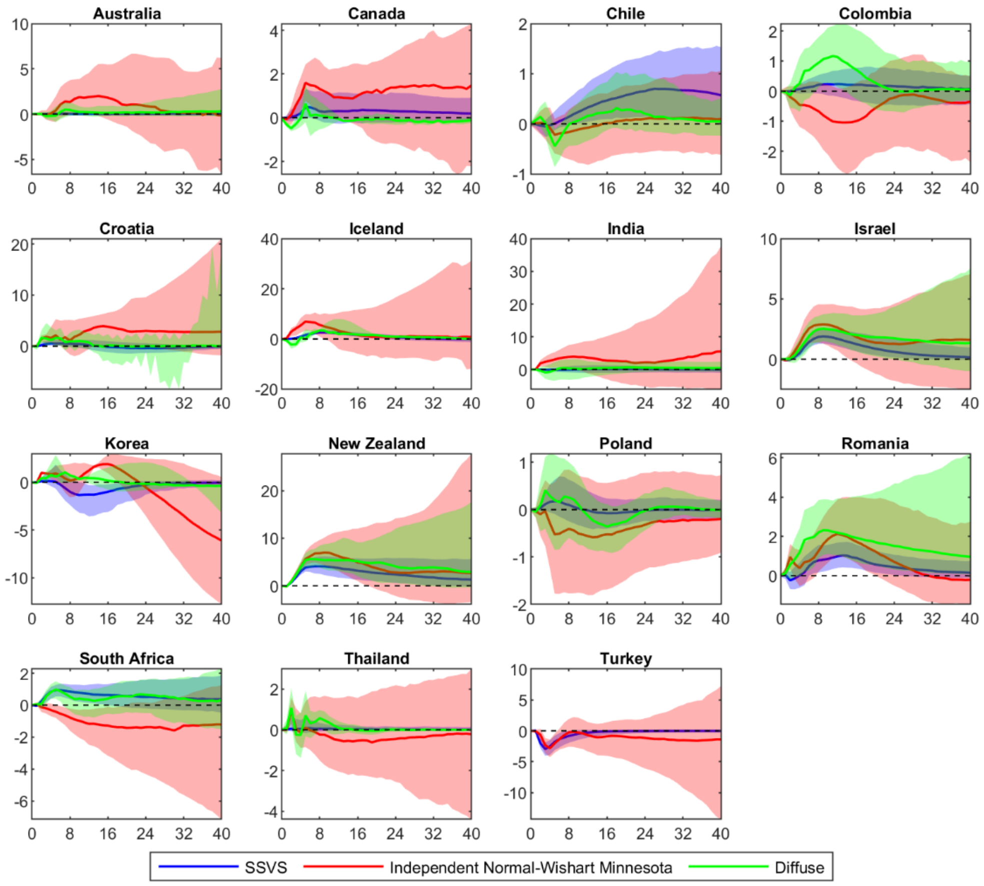
Formally, independent Normal-Wishart prior is a prior such that:

$$\alpha \sim N(\underline{\alpha}, \underline{V}) \tag{31}$$

$$\Sigma^{-1} \sim W(\underline{S}^{-1}, \underline{v}) \tag{32}$$

α and Σ are as defined in subsection 4.1.1.

Figure 17. The estimated impact of QE on GDP (in percentage): various priors



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the pandemic outbreak.

$\underline{\alpha}$ and $\underline{V}$ are set up in the spirit of the Minnesota prior:

$$\underline{\alpha} = \begin{cases} 1 \text{ for parameters on first own lags of nonstationary variables (GDP, CPI, stock prices)} \\ 0.9 \text{ for parameters on first own lags of stationary variables (public debt, policy rates, bond yields)} \\ 0 \text{ for other parameters} \end{cases}$$

$$\underline{V}_{i,jj} = \begin{cases} \dfrac{\underline{\alpha}_1 \sigma_{ii}^2}{p^{\underline{\alpha}_4} \sigma_{jj}^2} \text{ for parameters on lags of endogenous variables} \\ \underline{\alpha}_1 \underline{\alpha}_3 \sigma_{ii}^2 \text{ for parameters on exogenous variables} \end{cases}$$

where $\underline{V}_{i,jj}$ are diagonal elements of matrix $\underline{V}$ associated with the equation explaining variable i and coefficients on explanatory variable j, p is the lag order, $\underline{\alpha}_1, \underline{\alpha}_3$ and $\underline{\alpha}_4$ are prior hyperparameters and σ_{ii}^2 is the variance of residuals from the autoregressive model estimated for variable i.

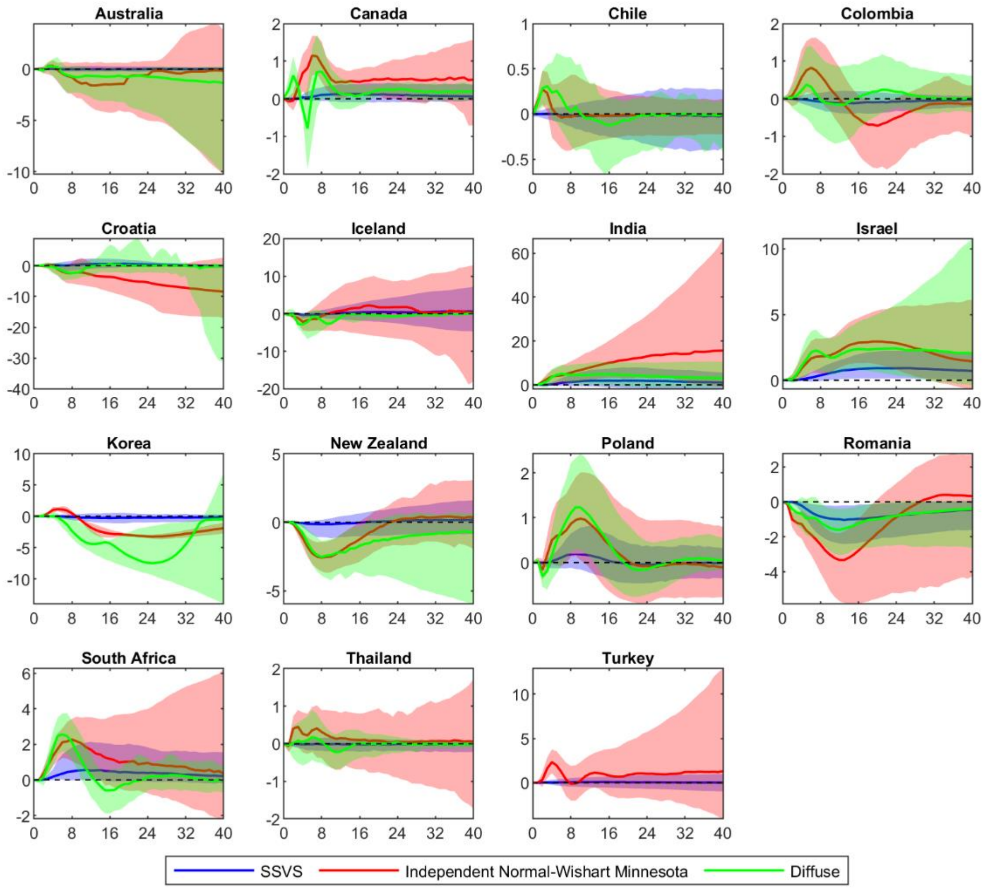
We choose the following values for hyperparameters: $\underline{\alpha}_1 = 0.2, \underline{\alpha}_3 = 100$ and $\underline{\alpha}_4 = 2$. The values for $\underline{\alpha}_1$ and $\underline{\alpha}_4$ are largely standard, while the value for $\underline{\alpha}_3$ is relatively high, which lets the parameters on exogenous variables (including deterministic components) to be freely estimated.

Finally, per standard practice, $\underline{\nu}$ is set to the number of endogenous variables plus two (in our case 8) and $\underline{S}$ is a diagonal matrix with σ_{ii}^2 on the diagonal.

For more details on independent Normal-Wishart prior, see e.g. Koop and Korobilis (2010).

The impact of QE on GDP and CPI under various priors is presented in Figure 17 and Figure 18, respectively[19].

Figure 18. The estimated impact of QE on CPI (in percentage): various priors



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the pandemic outbreak.

The first thing to note is that estimates obtained using the Minnesota prior have much wider Bayesian credible sets. The estimates tend to change quite significantly depending on what

[19] Similar as in other robustness checks, the results for some country-specification combinations are not shown as the variance-covariance matrix of impulse responses to QE Σ_y is not positive-definite even after adding a small number to the diagonal (up to 0.001), making it impossible to draw the impulse response.

prior is used. However, it is worth noting that for countries with highest impact of QE on GDP in the baseline specification the results are largely robust with respect to the prior used (Israel, New Zealand, Romania, to lesser extent Iceland; this also includes negative impact in Turkey). For other countries, where the impact was marginally statistically significant or insignificant, the results vary significantly across priors, suggesting that there are no strong arguments to reject the null hypothesis of no impact of QE on GDP.

As regards the impact on inflation, the alternative priors tend to show stronger median impact than the baseline SSVS, with 68% credible bands following outside of zero – this is the case in Canada, Chile, India, Israel, Poland and South Africa (which show positive impact) as well as Korea, New Zealand and Romania (which show negative impact). Thus, the baseline result of no impact of QE on inflation may be regarded as a conservative estimate.

5. Drivers of cross-country differences

The estimation of QE effects for 16 countries enables us to make a first attempt at a comparative study of QE, i.e. to investigate to what extent the effects of QE depend on the modalities of the QE programme, country characteristics and the severity of the pandemic. The sample of 16 countries is very small, however, and does not enable us to conduct a fully-fledged econometric analysis. Thus, we stop at studying pairwise correlations between measures of QE effectiveness and explanatory variables and drawing some tentative conclusions.

5.1 Data

As dependent variables, we use peak impact of QE on government bond yields, stock prices, GDP and CPI as presented in Table 8. As explanatory variables we use characteristics of QE programmes, largely as laid out in Table 1, as well as country characteristics and variables describing the severity of the pandemic reported in Table 10. To describe what assets were purchased we use two dummy variables indicating whether sovereign bonds were purchased and whether private securities were purchased. The size of QE is measured either in relation to GDP as in Table 1 or relative to general government debt.

Among country characteristics we include the size of the government bond market and the stock market proxied with general government debt and stock market capitalisation, respectively. A larger bond and stock market can make it more difficult for the central bank to exert influence, yet it may also result in a more pronounced response of macroeconomic variables to fluctuations in bond yields and stock prices. We also include several measures that proxy for country and monetary policy credibility since under low credibility, QE may be perceived as a gateway to monetary financing of government deficits, potentially leading to an opposite than otherwise expected impact of QE on bond yields, stock prices and GDP. These proxies include government credit rating, inflation before the pandemic (10-year and 5-year average as well as the value at the end of 2019, either in absolute terms and relative to central bank inflation target), GDP per capita in purchasing power parity terms and general government deficit before the pandemic.

Table 10. Potential drivers of differences in QE effectiveness across countries – country characteristics and measures of the severity of the pandemic

Variable	Definition	Data source
Debt	General government gross debt, percentage of GDP, in 2019	IMF World Economic Outlook
Stock market cap	Stock market capitalisation, percentage of GDP, in 2019	World Bank World Development Indicators
Rating	Average long-term sovereign credit rating of S&P, Moody's and Fitch at the time of the pandemic outbreak, translated into a numerical value, taking values from 1 to 24, where 1 is D in S&P's scale and 24 is AAA	Own compilation and calculations based on Trading Economics
Inflation	6 various definitions: average CPI inflation over 2010-19, over 2015-19 or inflation at the end of 2019, in each case either in absolute terms or relative to central bank inflation target	IMF World Economic Outlook
GDP per capita	GDP per capita in purchasing power parity at current prices in 2019	IMF World Economic Outlook
Government balance	General government net lending, percentage of GDP, in 2019	IMF World Economic Outlook
Covid cases	Either the average number of daily new cases per million of population over March 2020-February 2021 or the maximum number of 7-day moving average new daily cases over the same period	Our World in Data
Covid deaths	Either the average number of daily deaths per million of population over March 2020 - February 2021 or the maximum number of 7-day moving average daily deaths over the same period	Our World in Data
Stringency index	Either average stringency index over March 2020 - February 2021 or maximum stringency index over the same period	Our World in Data

As measures of the severity of the pandemic we use the most common measures, i.e. daily new cases and deaths, scaled by total population, and the stringency index. We calculate either the averaged value over the first year of the pandemic, which broadly matches our sample, or the maximum value over the same period.

5.2 Results

Table 11 presents the correlations between estimated effects of QE and potential drivers of cross-country differences in these estimates.

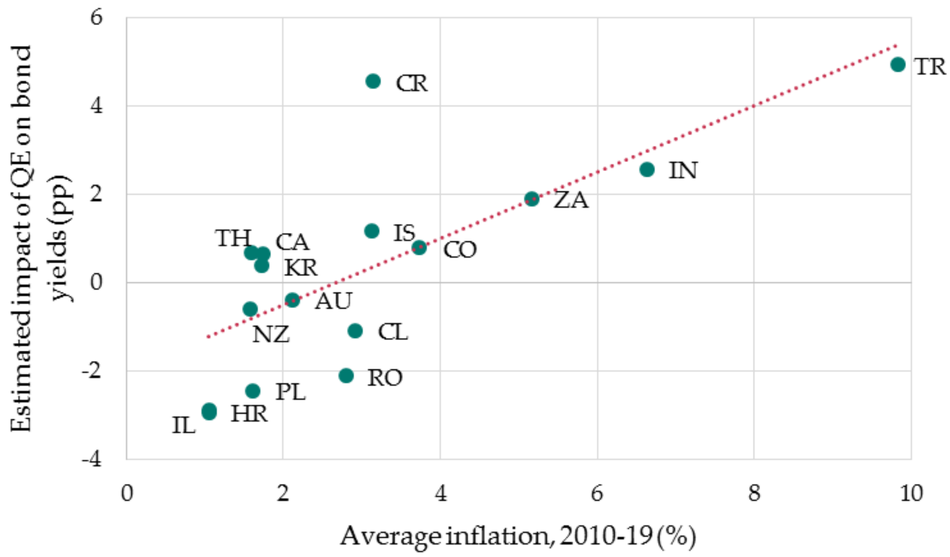
Table 11. Correlation of estimated effects of QE with their potential drivers

	Effect of QE on:			
Explanatory variable	**Bond yields**	**Stock prices**	**GDP**	**CPI**
Debt	0.06	0.38	0.06	0.62
Government balance	-0.49	0.14	0.24	-0.30
GDP per capita	-0.31	0.29	0.34	-0.25
Inflation 10Y average	0.74	0.07	-0.46	0.25
Inflation 10Y average minus target	0.72	0.15	-0.46	0.27
Inflation 5Y average	0.66	-0.04	-0.43	0.07
Inflation 5Y average minus target	0.58	-0.02	-0.40	0.00
Inflation end of 2019	0.53	0.02	-0.41	0.11
Inflation end of 2019 minus target	0.40	0.05	-0.36	0.04
Duration of QE	-0.20	0.19	0.24	0.31
Monthly size announced	-0.06	0.07	0.33	-0.16
Private securities purchased	-0.20	-0.30	0.12	-0.07
Rating	-0.48	0.27	0.52	-0.17
QE size (% of GDP)	-0.24	0.03	0.41	0.03
QE size (% of debt)	-0.22	0.01	0.51	-0.08
Sovereign bonds purchased	0.16	0.30	-0.05	0.11
Stock market cap	0.12	0.20	0.19	0.19
Total size announced	0.10	0.07	0.27	0.28
YCT	-0.08	0.04	-0.05	-0.11
Covid cases per population	-0.38	-0.40	-0.03	0.11
Covid deaths per population	-0.42	-0.41	-0.03	-0.14
Average stringency index	0.16	-0.30	-0.42	0.17
Max weekly Covid cases per population	-0.54	-0.28	0.07	0.13
Max weekly Covid deaths per population	-0.53	-0.23	0.08	0.01
Max stringency index	-0.30	-0.28	0.08	0.19
Covid cases per population	-0.38	-0.40	-0.03	0.11

Notes: shades of green denote statistical significance at 1%, 5% and 10% level, going from the darkest to the lightest, respectively.

The strongest relationship, significant at a 1% level, runs between long-term average inflation and the impact of QE on bond yields, with higher inflation associated with a more positive (i.e. more counterintuitive) response of bond yields to QE. The relationship is depicted in Figure 19 - 3 countries with average 10-year inflation above 4% (South Africa, India and Turkey) stand out, all with positive impact of QE on bond yields. However, the positive relationship holds even when these 3 countries are excluded (while correlation declines, the relationship becomes even steeper). Consistent with this relationship, higher inflation also tends to be associated with weaker impact of QE on GDP. At the same time, there is no correlation with the reaction of stock prices and the correlation with the reaction of CPI tends to be positive, though not statistically significant.

Figure 19. Correlation between 10-year average inflation and the estimated peak impact of QE on government bond yields

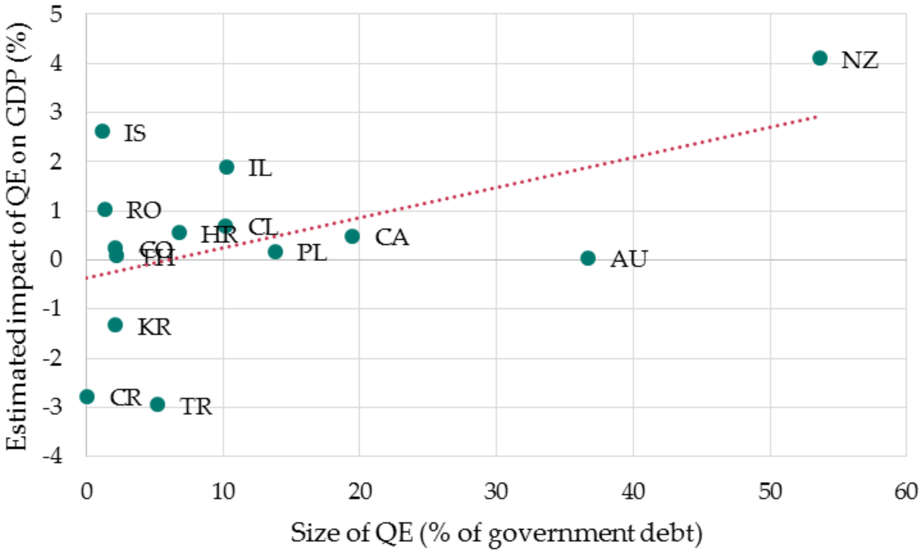


The results thus seem to be consistent with the hypothesis that in countries with less credible monetary policy, as epitomised by higher inflation, QE is seen as a risk to price stability, or even a way of concealed debt monetisation. This makes monetary policy even less credible, leading to an increase in long-term interest rates, which has a negative impact on economic activity. At the same time, inflation does not decline as inflation expectations increase and/or exchange rate depreciates due to an increase in risk premium.

In accordance with the above-described hypothesis, sovereign credit rating tends to be negatively correlated with the reaction of bond yields to QE (i.e. the higher the rating, the more negative the bond yield reaction) and positively correlated with the reaction of GDP to QE. However, this relationship is somewhat more tenuous and driven primarily by 2 countries with the lowest rating and, at the same time, most positive bond yield reaction and most negative GDP reaction: Turkey and Costa Rica. This may suggest that the effectiveness of QE may be more influenced by monetary policy credibility than by fiscal policy credibility.

Somewhat surprisingly, there seems to be little correlation between the amount of securities purchased and the effects of QE – while this correlation is statistically significant at a 10% level for the impact on GDP (Figure 20), this relationship is driven solely by outliers: New Zealand for the linear relationship and Costa Rica if logarithmic relationship is considered instead. Thus, it seems that QE works mostly via announcement effects (i.e. via the signalling channel) rather than through actual purchases – the mere presence of the central bank in the market, its ability to intervene if needed, seems to be the decisive factor.

Figure 20. Correlation between the amount of purchased assets and the estimated peak impact of QE on GDP



Other characteristics of QE programmes – how long QE was conducted, whether total or monthly sizes of purchases were announced, whether private securities were purchased, or yield curve was targeted – are not correlated with estimated impact of QE, suggesting that the modalities of QE programmes and central bank communication regarding QE play little to no role in QE effectiveness.

The size of the bond market is not correlated with the estimated impact of QE bond yields, suggesting that a relatively large bond market does not necessarily mean that central banks have to purchase more debt. At the same time, however, the QE reduces bond yields more if government deficit is smaller (Figure 21). Thus, while the total stock of debt does not seem to matter, current financing needs are correlated with QE effectiveness. This supports the notion that flow effects of QE (central bank purchases in relation to active market supply and demand) matter more than stock effects (cumulative purchases in relation to total stock of securities).

Another significant correlation is a positive one between government debt and QE's impact on inflation. This relationship, given the simultaneous lack of a connection between government debt and the effects on bond yields or GDP, may be interpreted in line with the credibility hypothesis proposed earlier. In highly-indebted countries, QE may be perceived as a form of concealed debt monetisation, leading to an increase in inflation expectations and, consequently, inflation.

Looking at the measures of the severity of the pandemic, government bond yields tend to be lower in countries with more Covid cases and deaths, especially when peak cases and deaths are considered (Figure 22). Stock prices also tend to be lower in countries struck harder by the pandemic, though this correlation is not statistically significant. At the same time, the macroeconomic impact of QE is not correlated with the severity of the pandemic – probably because the effects on bond yields and stock prices largely cancel each other out and/or the impact of financial conditions on the economy is weaker in countries most affected by the pandemic. The results suggest two possibilities: either quantitative easing (QE) is more effective during periods of heightened economic stress, as suggested by previous literature, or the pandemic directly influenced bond yields through channels not captured by the variables included in the stage 1 models.

Figure 21. Correlation between government balance and the estimated peak impact of QE on bond yields

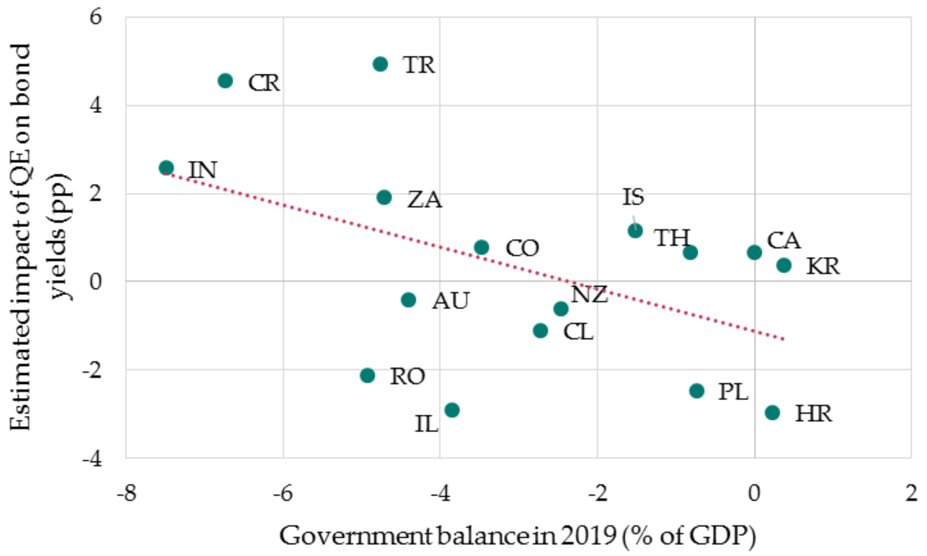
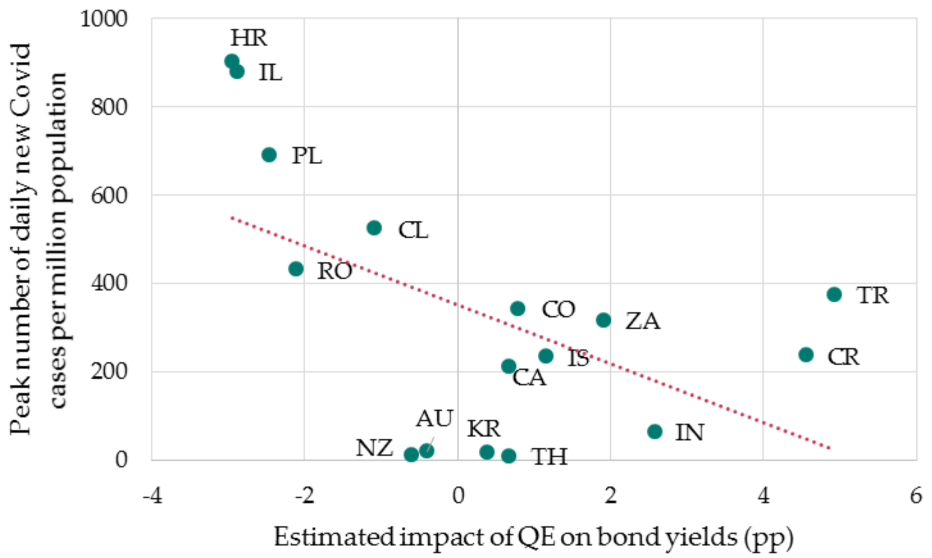


Figure 22. Correlation between peak number of Covid cases and the estimated peak impact of QE on bond yields



Finally, it is worth mentioning that the size of the stock market is correlated with the response to QE of neither stock prices nor macroeconomic variables.

Summing up this section, QE seems to work as expected only in countries with sufficient monetary policy credibility. At the same time, the characteristics of financial markets and the modalities of QE programmes, including the scale of purchases, seem to have little to no effect on QE effectiveness. However, these conclusion need to be taken with a grain of a salt, given that they are based on pairwise correlations and thus are subject to omitted variable bias, which may inflate some relationships and conceal other.

6. Discussion, caveats and conclusion

The paper finds that pandemic QE programmes tend to have a relatively strong positive impact on stock prices, with QE increasing stock prices by 40% at peak on average. The effects are positive and statistically significant at a 10% level in 12 out of 16 analysed countries, and in 7 of these countries the peak impact exceeds 40%. At the same time, the effects on long-term government bond yields tend to be more muted and less clear-cut in terms of the sign. The effect is statistically significant, negative and economically meaningful (at least 2.1 pp at peak) in only 4 of the analysed countries (Israel, Croatia, Poland, Romania). Elsewhere the impact is either not statistically significant (5 cases), marginally significant and positive (4 cases) or significant and positive (2 cases). As a result, the average peak impact of QE on bond yields is estimated to be positive (0.3 pp).

There seem to be two explanations for the muted and often counterintuitive impact of QE on bond yields and – at the same time – strong impact on stock prices. Firstly, the signalling effect – i.e. QE not only lowers expected interest rates and/or risk premia, reducing bond yields and propping stock prices, but also improves expectations about future economic activity, cancelling out the impact on bond yields and further increasing stock prices. Secondly, the lack of credibility of many – especially emerging market – governments. The QE’s effect on bond yields is positively correlated with pre-pandemic inflation (a proxy for monetary policy credibility) and negatively correlated with government balance and credit rating, i.e. the lower the inflation, the higher the rating and the lower the government deficit, the more negative the response of bond yields to QE. Thus, in less credible countries QE seems to be viewed as a way of debt monetisation, which supports fiscal profligacy and increases the risk of high inflation in the future, leading to an increase in expected future interest rates and/or term premium. At the same time, the issue of credibility seems to be playing much less of a role in the stock market.

The strong positive response of stock prices and neutral – on average – response of bond yields to QE translates into a positive, but relatively muted and often statistically insignificant impact on GDP, amounting to 0.37% on average at peak. The results are positive and statistically significant for 5 countries (Iceland, Israel, New Zealand, Romania and South Africa), with the strongest peak impact of 4% in New Zealand. For other countries the point estimates either tend to be positive, but are not statistically significant (5 cases), are very close to zero (3 cases) or are negative (3 cases). The impact on CPI, in turn, is statistically insignificant in most cases, though point estimates suggest a muted positive impact in 6 countries, with the average cross-country impact of 0.24%. The lack of the response of prices is a by-product of weak or non-existing reaction of prices to financial conditions and – indirectly – economic activity, which suggests that Phillips curves in the analysed economies are relatively flat.

Further analysis of the results reveals that characteristics of QE programmes, such as types of securities purchased, announcement of the expected size of purchases, the duration of purchases and finally, the actual size of purchases, are not correlated with the effectiveness of QE. Hence, it appears that quantitative easing operates primarily through announcement effects, specifically via the signalling channel, rather than actual purchases. The critical factor seems to be the presence of the central bank in the market and its ability to intervene if necessary, while the specifics of central bank communication and the program's structure seem to have a lesser impact. Moreover, the size of the bond or stock markets does not appear to significantly influence the effectiveness of QE transmission.

The results have numerous policy implications. Since QE tends to be effective only in relatively credible countries, it seems to be more suitable for advanced than emerging market economies. Having said that, the impact of QE is highly heterogeneous across countries and quite sensitive to the method of estimation, making the effects of asset purchases highly uncertain also in relatively credible advanced economies. Thus, even the advanced economy central banks should continue to view interest rates, whose impact on the economy is much better established, as a primary monetary policy tool, resorting to QE only if further monetary policy expansion is needed at the effective lower bound. Finally, since the effects of QE do not seem to increase significantly with the increase in the scale of purchases, purchasing securities on a discretionary basis, when warranted by market conditions and ultimately on a smaller scale, may be a more cost-effective and less market-distortionary way of conducting QE than making large-scale, pre-announced purchases on a regular basis.

The above-formulated conclusions come at numerous caveats, however. First and foremost, the identification of QE effects on bond yields and stock prices is based on several, admittedly quite strong, assumptions. The relationship between bond yields, stock prices and their economic determinants is assumed to have remained unchanged during the pandemic, i.e. past and present values of explanatory variables are assumed to capture expectations about interest rates, inflation and economic activity equally well during the pandemic than before it. That may be a particularly problematic assumption for stock prices - after the first months of the pandemic, it became quite clear that economies are likely to rebound relatively quickly when pandemic containment measures are lifted, which may have boosted stock prices beyond what was implied by current economic conditions. Moreover, QE is assumed to be the only source of an "abnormal" shock to bond yields and stock prices, i.e. the pandemic, other unconventional monetary policies (forward guidance, credit easing policies) or announced, but not yet implemented fiscal policies did not have a direct impact (other than via explanatory variables included in the model) on bond yields or stock prices. Against this background, the results presented in this paper should be considered as an upper estimate of the actual effects of QE as they likely encompass the impacts of other unconventional monetary policies and potentially even fiscal policies.

The QE's impact on macroeconomic variables is obtained via the effects on bond yields and stock prices. While this constitutes an upgrade on the previous literature, which takes only bond yields into account, another potentially important financial variable – especially for small open economies – is omitted: the exchange rate. While attempts have been made to use an analogous approach to single out the effects of QE on the exchange rate, these models have proven to be unsuccessful in explaining a sufficient degree of exchange rate variability to effectively use them to estimate the effects of QE. The estimates of macroeconomic effects are also subject to the same caveat as the financial market effects, i.e. they are obtained under the assumption that the relationships among main macroeconomic and financial variables have not changed during the pandemic. And as regards the analysis of the drivers of cross-country differences in the results, it is based on mere correlations obtained from a very small sample and thus may not imply causation.

For all the above reasons, the results presented in this paper have to be interpreted with caution. As such, they also call for further research. As time series grow longer, financial market and macroeconomic effects of pandemic QE may potentially be studied within a single model. However, identification will continue to be extremely difficult given the number of policy measures introduced at the same time both domestically and abroad, the direct effects of the pandemic and the following spike in inflation across the globe. Future research would also be advised to investigate further the reasons for a relatively strong response of stock prices to QE amid a relatively muted response of bond yields. Finally, more study is needed to pin down the determinants of cross-country differences in QE effectiveness, including confirming (or rejecting) the importance of monetary and fiscal policy credibility.

References

Adrian, T., Crump, R. K., & Moench, E. (2013). *Pricing the Term Structure with Linear Regressions*. Journal of Financial Economics, 110(1), 110-138.

Agur, I. (2022). *Government Finance by Central Banks and Inflation Expectations at the Onset of the COVID Pandemic.* Applied Economics Letters, 1-6.

Akkaya, Y., Belfrage, C. J., Di Casola, P., & Strid, I. (2023). Effects of Foreign and Domestic Central Bank Government Bond Purchases in a Small Open Economy DSGE Model: Evidence from Sweden before and during the Coronavirus Pandemic. Sveriges Riksbank Working Paper, 421.

Altavilla, C., Carboni, G., & Motto, R. (2015). *Asset Purchase Programmes and Financial Markets: Lessons from the Euro Area*. ECB Working Paper, 1864.

Andrade, P., Breckenfelder, J., De Fiore, F., Karadi, P., & Tristani, O. (2016). *The ECB's Asset Purchase Programme: an Early Assessment.* ECB Working Paper, 1956.

Antolin-Diaz, J., Petrella, I., & Rubio-Ramírez, J. F. (2021). *Structural Scenario Analysis with SVARs*. Journal of Monetary Economics, 117, 798-815.

Arena, M. M., Bems, M. R., Ilahi, M. N., Lee, M. J., Lindquist, W., & Lybek, M. T. (2021). *Asset Purchase Programs in European Emerging Markets*. IMF European Department, DP/2021/021.

Arias, J. E., Rubio-Ramírez, J. F., & Waggoner, D. F. (2018). *Inference Based on Structural Vector Autoregressions Identified with Sign and Zero Restrictions: Theory and Applications*. Econometrica, 86(2), 685-720.

Arora, R., Gungor, S., Nesrallah, J., Ouellet Leblanc, G., & Witmer, J. (2021). *The Impact of the Bank of Canada's Government Bond Purchase Program*. Bank of Canada Staff Analytical Note, 2021-23.

Arslan, Y., Drehmann, M., & Hofmann, B. (2020). *Central Bank Bond Purchases in Emerging Market Economies*. BIS Bulletin, 20.

Bańbura, M., Giannone, D., & Reichlin, L. (2010). *Large Bayesian Vector Auto Regressions*. Journal of Applied Econometrics, 25(1), 71-92.

Bauer, M., & Rudebusch, G. D. (2014). *The Signaling Channel for Federal Reserve Bond Purchases*. International Journal of Central Banking, 10(3), 233-289.

Baumeister, C., & Benati, L. (2013). *Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound*. International Journal of Central Banking, 9(2), 165-212.

Bernanke, B. S., & Mihov, I. (1998). *Measuring Monetary Policy.* The Quarterly Journal of Economics, 113(3), 869-902.

Bernardini, M., & Conti, A. (2021). *Assessing the Flexible Implementation of the ECB's Pandemic Asset Purchases*. Banca d'Italia Covid-19 Note.

Bernardini, M., & De Nicola, A. (2020). *The Market Stabilization Role of Central Bank Asset Purchases: High-Frequency Evidence from the COVID-19 Crisis*. Bank of Italy Temi di Discussione (Working Paper), 1310.

Breitenlechner, M., Geiger, M., & Sindermann, F. (2019). *ZeroSignVAR: A Zero and Sign Restriction Algorithm Implemented in MATLAB*.

Breitenlechner, M., Georgiadis, G., & Schumann, B. (2022). *What Goes Around Comes Around: How Large Are Spillbacks from US Monetary Policy?* Journal of Monetary Economics, 131, 45-60.

Breitenlechner, M., Gründler, D., & Scharler, J. (2021). *Unconventional Monetary Policy Announcements and Information Shocks in the US.* Journal of Macroeconomics, 67, 103283.

Chen, H., Cúrdia, V., & Ferrero, A. (2012). *The Macroeconomic Effects of Large-Scale Asset Purchase Programmes.* The Economic Journal, 122(564), F289-F315.

Christensen, J. H., & Rudebusch, G. D. (2012). *The Response of Interest Rates to US and UK Quantitative Easing.* The Economic Journal, 122(564), F385-F414.

Christiano, L. J., Eichenbaum, M., & Evans, C. L. (1999). *Monetary Policy Shocks: What Have we Learned and to What End?* Handbook of macroeconomics, 1, 65-148.

Chung, H., Laforte, J. P., Reifschneider, D., & Williams, J. C. (2012). *Have We Underestimated the Likelihood and Severity of Zero Lower Bound Events?*. Journal of Money, Credit and Banking, 44, 47-82.

Churm, R., Joyce, M., Kapetanios, G., & Theodoridis, K. (2021). *Unconventional Monetary Policies and the Macroeconomy: The Impact of the UK's QE2 and Funding for Lending Scheme*. The Quarterly Review of Economics and Finance, 80, 721-736.

D'Amico, S., & King, T. B. (2013). *Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply*. Journal of Financial Economics, 108(2), 425-448.

D'Amico, S., Kurakula, V., & Lee, S. (2020). *Impacts of the Fed Corporate Credit Facilities through the Lenses of ETFs and CDX.* Federal Reserve Bank of Chicago Working Paper, 2020-14.

Doan, T., Litterman, R., & Sims, C. (1984). *Forecasting and Conditional Projection Using Realistic Prior Distributions.* Econometric Reviews, 3(1), 1-100.

Eichenbaum, M., & Evans, C. L. (1995). *Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates.* The Quarterly Journal of Economics, 110(4), 975-1009.

Engen, E. M., Laubach, T., & Reifschneider, D. (2015). *The Macroeconomic Effects of the Federal Reserve's Unconventional Monetary Policies.* Finance and Economics Discussion Series, 2015-005.

Falagiarda, M. (2014). *Evaluating Quantitative Easing: a DSGE Approach.* International Journal of Monetary Economics and Finance, 7(4), 302-327.

Finlay, R., Titkov, D., & Xiang, M. (2022). *The Yield and Market Function Effects of the Reserve Bank of Australia's Bond Purchases.* Reserve Bank of Australia Research Discussion Paper, 2022-02.

Fratto, C., Vannier, B. H., Mircheva, M., de Padua, D., & Ward, M. H. P. (2021). *Unconventional Monetary Policies in Emerging Markets and Frontier Countries*. IMF Working Papers, 2021/014.

Fukunaga, I., Kato, N., & Koeda, J. (2015). *Maturity Structure and Supply Factors in Japanese Government Bond Markets.* Monetary and Economic Studies, 33, 45-96.

Gagnon, J., Raskin, M., Remache, J., & Sack, B. (2011). *The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases.* International Journal of Central Banking, 7(1), 3-43.

García, B., González, M., Guarda, S., & Paillacar, M. (2022). *Unconventional credit policies during crises: A structural analysis of the Chilean experience during the COVID-19 pandemic*. Central Bank of Chile Working Paper, 954.

Garcia Pascual, A. I., & Wieladek, T. (2016). *The European Central Bank's QE: A New Hope.* CESifo Working Paper, 594.

George, E. I., Sun, D., & Ni, S. (2008). *Bayesian Stochastic Search for VAR Model Restrictions.* Journal of Econometrics, 142(1), 553-580.

Gertler, M., & Karadi, P. (2013). *QE 1 vs. 2 vs. 3...: A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool.* International Journal of Central Banking, 9(S1), 5-53.

Gertler, M., & Karadi, P. (2015). *Monetary Policy Surprises, Credit Costs, and Economic Activity.* American Economic Journal: Macroeconomics, 7(1), 44-76.

Giacomini, R., & Kitagawa, T. (2021). *Robust Bayesian Inference for Set-Identified Models.* Econometrica, 89(4), 1519-1556.

Gilchrist, S., Wei, B., Yue, V. Z., & Zakrajšek, E. (2020*). The Fed Takes on Corporate Credit Risk: An Analysis of the Efficacy of the SMCCF.* NBER Working Paper, 27809.

Greenlaw, D., Hamilton, J. D., Harris, E., & West, K. D. (2018). *A Skeptical View of the Impact of the Fed's Balance Sheet*. NBER Working Paper Series, 24687.

Ha, J., & Kindberg-Hanlon, G. (2021). *Financial Market Effects of Asset Purchase Programs in Emerging Markets: An Early Assessment*.

Haddad, V., Moreira, A., & Muir, T. (2021). *When Selling Becomes Viral: Disruptions in Debt Markets in the COVID-19 Crisis and the Fed's Response.* The Review of Financial Studies, 34(11), 5309-5351.

Haldane, A., Roberts-Sklar, M., Young, C., & Wieladek, T. (2016). *QE: the Story so Far*. CEPR Discussion Paper, DP11691.

Hanson, S. G., Lucca, D. O., & Wright, J. H. (2021). *Rate-amplifying Demand and the Excess Sensitivity of Long-term Rates.* The Quarterly Journal of Economics, 136(3), 1719-1781.

Harrison, R. (2012). *Asset Purchase Policy at the Effective Lower Bound for Interest Rates*. Bank of England Working Paper, 444.

Hayashi, F., & Koeda, J. (2019). *Exiting from Quantitative Easing*. Quantitative Economics, 10(3), 1069-1107.

Hertel, K., Humanicki, M., Kitala, M., Kleszcz, T., Kuziemska-Pawlak, K., Mućk, J., Rybaczyk, B., & Stefański, M. (2022). *The Impact on the Polish Economy of the Structural Open Market Operations Programme Conducted by NBP*. NBP Working Paper, 343.

Hesse, H., Hofmann, B., & Weber, J. M. (2018). *The Macroeconomic Effects of Asset Purchases Revisited*. Journal of Macroeconomics, 58, 115-138.

Hohberger, S., Priftis, R., & Vogel, L. (2019). *The Macroeconomic Effects of Quantitative Easing in the Euro Area: Evidence from an Estimated DSGE Model*. Journal of Economic Dynamics and Control, 108, 103756.

Joyce, M. A., Lasaosa, A., Stevens, I., & Tong, M. (2011). *The Financial Market Impact of Quantitative Easing in the United Kingdom*. International Journal of Central Banking, 7(3), 113-161.

Joyce, M. A., & Tong, M. (2012). *QE and the Gilt Market: a Disaggregated Analysis*. The Economic Journal, 122(564), F348-F384.

Kapetanios, G., Mumtaz, H., Stevens, I., & Theodoridis, K. (2012). *Assessing the Economy-Wide Effects of Quantitative Easing*. The Economic Journal, 122(564), F316-F347.

Kim, K., Laubach, T., & Wei, M. (2020). *Macroeconomic Effects of Large-Scale Asset Purchases: New Evidence.* Finance and Economics Discussion Series, 2020-047.

Koop, G., & Korobilis, D. (2010). *Bayesian Multivariate Time Series Methods for Empirical Macroeconomics.* Foundations and Trends in Econometrics, 3(4), 267-358.

Korobilis, D. (2008). *Forecasting in Vector Autoregressions with Many Predictors*. Advances in Econometrics, 23, 403-431.

Krishnamurthy, A., & Vissing-Jorgensen, A. (2011). *The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy*. Brookings Papers on Economic Activity, 2, 215-287.

Kuttner, K. N. (2018). *Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond.* Journal of Economic Perspectives, 32(4), 121-146.

Lam, W. R. (2011). *Bank of Japan's Monetary Easing Measures: Are They Powerful and Comprehensive?*. IMF Working Paper, 11/264.

Litterman, R. B. (1986). *Forecasting with Bayesian Vector Autoregressions — Five Years of Experience.* Journal of Business & Economic Statistics, 4(1), 25-38.

Liu, P., Theodoridis, K., Mumtaz, H., & Zanetti, F. (2019). *Changing Macroeconomic Dynamics at the Zero Lower Bound.* Journal of Business & Economic Statistics, 37(3), 391-404.

Meaning, J., & Zhu, F. (2011). *The Impact of Recent Central Bank Asset Purchase Programmes*. BIS Quarterly Review, December 2011, 73-83.

Nozawa, Y., & Qiu, Y. (2021). *Corporate Bond Market Reactions to Quantitative Easing during the COVID-19 Pandemic.* Journal of Banking & Finance, 133, 106153.

Papadamou, S., Siriopoulos, C., & Kyriazis, N. A. (2020). *A Survey of Empirical Findings on Unconventional Central Bank Policies.* Journal of Economic Studies, 47(7), 1533-1577.

Rebucci, A., Hartley, J. S., & Jiménez, D. (2022). *An Event Study of COVID-19 Central Bank Quantitative Easing in Advanced and Emerging Economies*. In Essays in Honor of M. Hashem Pesaran: Prediction and Macro Modeling, 43, 291-322. Emerald Publishing Limited.

Rogers, J. H., Scotti, C., & Wright, J. H. (2014). *Evaluating Asset-Market Effects of Unconventional Monetary Policy: a Multi-Country Review*. Economic Policy, 29(80), 749-799.

Rosa, C. (2012). *How 'Unconventional' Are Large-Scale Asset Purchases? The Impact of Monetary Policy on Asset Prices*. FRB of New York Staff Report, 560.

Sahuc, J. G. (2016). *The ECB's Asset Purchase Programme: A Model-Based Evaluation*. Economics Letters, 145, 136-140.

Schenkelberg, H., & Watzka, S. (2013). *Real Effects of Quantitative Easing at the Zero Lower Bound: Structural VAR-Based Evidence from Japan*. Journal of International Money and Finance, 33, 327-357.

Sever, C., Goel, R., Drakopoulos, D., & Papageorgiou, E. (2020). *Effects of Emerging Market Asset Purchase Program Announcements on Financial Markets during the COVID-19 Pandemic*. IMF Working Paper, 292.

Sims, C. A. (1980). *Macroeconomics and Reality*. Econometrica: journal of the Econometric Society, 1-48.

Sims, C. A., Stock, J. H., & Watson, M. W. (1990). *Inference in Linear Time Series Models with some Unit Roots.* Econometrica: Journal of the Econometric Society, 113-144.

Stefański, M. (2022). *Macroeconomic Effects and Transmission Channels of Quantitative Easing.* Economic Modelling, 114, 105943.

Ueda, K. (2012). *The Effectiveness of Non-Traditional Monetary Policy Measures: The Case of the Bank of Japan*. The Japanese Economic Review, 63(1), 1-22.

Uhlig, H. (2005). *What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure*. Journal of Monetary Economics, 52(2), 381-419.

Urbschat, F., & Watzka, S. (2020). *Quantitative Easing in the Euro Area – An Event Study Approach*. The Quarterly Review of Economics and Finance, 77, 14-36.

Vayanos, D., & Vila, J. L. (2021). *A Preferred-Habitat Model of the Term Structure of Interest Rates*. Econometrica, 89(1), 77-112.

Vissing-Jorgensen, A. (2021). *The Treasury Market in Spring 2020 and the Response of the Federal Reserve.* Journal of Monetary Economics, 124, 19-47.

Waggoner, D. F., & Zha, T. (1999). *Conditional Forecasts in Dynamic Multivariate Models.* Review of Economics and Statistics, 81(4), 639-651.

Weale, M., & Wieladek, T. (2016). *What are the Macroeconomic Effects of Asset Purchases?.* Journal of Monetary Economics, 79, 81-93.

Wright, J. H. (2012). *What Does Monetary Policy Do to Long-term Interest Rates at the Zero Lower Bound?* The Economic Journal, 122(564), F447-F466.

Appendix

A. Stage 1 regression results

Table A. 1. Results of the government bond yield regressions

	AUSTRALIA	CANADA	CHILE	CROATIA	COLOMBIA	COSTA RICA	ICELAND	INDIA
YIELD(-1)	0.9248	0.5799	1.0747	1.1147	0.9310	0.8774	0.6894	0.8080
	(0.0671)**	(0.0717)**	(0.0814)**	(0.0800)**	(0.0719)**	(0.1106)**	(0.0763)**	(0.0632)**
YIELD(-2)	-0.2002	-0.0641	-0.4398	-0.3507	-0.1657	-0.2005	0.0555	0.2479
	(0.0892)*	(0.0758)	(0.1141)**	(0.1167)**	(0.0970)	(0.1493)	(0.0918)	(0.0807)**
YIELD(-3)	0.0429	0.1359	0.1621	0.1111	0.0877	0.0344	0.0181	-0.1712
	(0.0612)	(0.0575)*	(0.0796)*	(0.0742)	(0.0714)	(0.1013)	(0.0705)	(0.0649)**
CPI_YOY	-0.0147	0.0279	0.0230	-0.0115	0.1644	-0.0263	-0.0263	0.0056
	(0.0154)	(0.0152)	(0.0114)*	(0.0167)	(0.0561)**	(0.0390)	(0.0136)	(0.0091)
DEBT_GDP	-0.0067	0.0061	-0.0067	0.0074	0.0205	-0.0187	0.0052	-0.0260
	(0.0039)	(0.0023)**	(0.0089)	(0.0041)	(0.0142)	(0.0325)	(0.0013)**	(0.0086)**
DEFICIT_GDP_MA	-0.0038	-0.0015	-0.0111	-0.0288	0.0408	0.0446	0.0177	-0.0114
	(0.0057)	(0.0133)	(0.0105)	(0.0134)*	(0.0295)	(0.0622)	(0.0086)*	(0.0109)
SALES_HP	1.3328	1.4486			-0.4543	-1.1739	-0.4808	-0.9114
	(0.9200)	(0.7768)			(1.4697)	(2.5293)	(0.5064)	(1.2086)
RATE	-0.0373	-0.0331	-0.0231	0.0436	-0.1052	0.2296	0.0663	-0.0088
	(0.0236)	(0.0176)	(0.0180)	(0.0172)*	(0.0440)*	(0.0653)**	(0.0163)**	(0.0281)
VIX	-0.0078	-0.0034	-0.0094	0.0087	-0.0002	0.0144	0.0011	-0.0077
	(0.0018)**	(0.0016)*	(0.0029)**	(0.0034)*	(0.0058)	(0.0117)	(0.0028)	(0.0030)*
YIELD_DE	0.2205	0.0956	0.2432	0.0778	0.3072	-0.7051	-0.0357	-0.0069
	(0.0467)**	(0.0423)*	(0.0651)**	(0.0934)	(0.1404)*	(0.2311)**	(0.0609)	(0.0640)
YIELD_US	0.0316	0.2280	-0.0599	-0.0189	0.0457	0.4073	0.1263	0.1191
	(0.0296)	(0.0367)**	(0.0530)	(0.0718)	(0.1193)	(0.1678)*	(0.0538)*	(0.0600)*
@TREND	0.0015	-0.0020	0.0027	-0.0014	0.0019	-0.0065	-0.0009	-0.0004
	(0.0006)**	(0.0008)*	(0.0022)	(0.0017)	(0.0028)	(0.0107)	(0.0010)	(0.0014)
C	0.4575	-0.0264	0.5677	-0.1405	-0.6035	3.8089	-0.3056	2.4678
	(0.1931)*	(0.3156)	(0.3599)	(0.4770)	(0.6720)	(1.0778)**	(0.2731)	(0.9373)**
YIELD_JP	0.1313							
	(0.0619)*							
SALES_YOY			0.0080					
			(0.0045)					
IND_PROD_HP				1.5324				
				(0.7645)*				
Observations:	251	251	148	168	203	85	191	251
R-squared:	0.9885	0.9884	0.9742	0.9854	0.9662	0.8980	0.9714	0.9643

* statistically significant at a 5% level; ** at 1% level.

Table A. 2. Results of the government bond yield regressions (cont.)

	ISRAEL	KOREA	NEW ZEALAND	POLAND	ROMANIA	SOUTH AFRICA	THAILAND	TURKEY
YIELD(-1)	0.9717 (0.0709)**	1.0677 (0.0689)**	0.9856 (0.0641)**	1.1271 (0.0650)**	0.7915 (0.0770)**	1.0747 (0.0744)**	0.6736 (0.0702)**	0.9391 (0.0802)**
YIELD(-2)	-0.4401 (0.0921)**	-0.3712 (0.0966)**	-0.3218 (0.0880)**	-0.3555 (0.0952)**	-0.0400 (0.0990)	-0.3863 (0.1066)**	-0.0029 (0.0840)	-0.4261 (0.1041)**
YIELD(-3)	0.1126 (0.0610)	0.1244 (0.0651)	0.1690 (0.0588)**	-0.0246 (0.0596)	0.0212 (0.0750)	0.0983 (0.0747)	-0.0552 (0.0638)	0.2294 (0.0700)**
CPI_YOY	0.0838 (0.0147)**	-0.0010 (0.0190)	-0.0354 (0.0129)**	0.0326 (0.0124)**	-0.0043 (0.0180)	-0.0100 (0.0196)	0.0175 (0.0146)	0.0888 (0.0333)**
DEBT_GDP	0.0551 (0.0106)**	0.0115 (0.0136)	0.0016 (0.0037)	0.0222 (0.0063)**	-0.0145 (0.0155)	0.0123 (0.0111)	-0.0267 (0.0180)	-0.0064 (0.0387)
DEFICIT_GDP_MA	0.0159 (0.0134)	0.0004 (0.0093)	0.0090 (0.0032)**	-0.0368 (0.0137)**	-0.0150 (0.0160)	0.0095 (0.0219)	-0.0513 (0.0184)**	-0.0820 (0.0539)
SALES_HP	0.2782 (0.9398)	0.8039 (0.6587)	-1.2721 (0.7273)	2.5658 (0.6523)**	-1.8762 (1.1720)	-2.0616 (0.9960)*	0.3918 (0.3815)	8.5158 (1.9152)**
RATE	0.1123 (0.0226)**	-0.0306 (0.0242)	-0.0156 (0.0130)	0.0858 (0.0167)**	0.1287 (0.0488)**	0.0329 (0.0293)	0.0077 (0.0329)	0.0451 (0.0338)
VIX	0.0019 (0.0030)	0.0011 (0.0026)	-0.0039 (0.0019)*	0.0039 (0.0026)	0.0036 (0.0050)	-0.0001 (0.0033)	-0.0102 (0.0033)**	0.0404 (0.0110)**
YIELD_DE	0.3330 (0.0782)**	0.1794 (0.0661)**	0.2222 (0.0455)**	0.0566 (0.0492)	0.1857 (0.1174)	0.1927 (0.0891)*	-0.1068 (0.0749)	-0.1523 (0.2115)
YIELD_US	-0.1539 (0.0562)**	0.0400 (0.0328)	0.0035 (0.0211)	0.1303 (0.0417)**	-0.0550 (0.1129)	0.0092 (0.0620)	0.1260 (0.0509)*	0.8245 (0.1831)**
@TREND	0.0066 (0.0022)**	-0.0009 (0.0019)	0.0020 (0.0008)**	0.0001 (0.0012)	0.0064 (0.0033)	0.0047 (0.0018)*	-0.0017 (0.0012)	0.0028 (0.0073)
C	-3.9464 (0.9652)**	0.0753 (0.2239)	-0.0103 (0.2761)	-1.0135 (0.4403)*	-0.2633 (0.7332)	0.0081 (0.4416)	1.8358 (0.6342)**	-1.4576 (2.2864)
YIELD_JP		0.0001 (0.0808)	0.1184 (0.0493)*				0.4626 (0.1154)**	
SALES_YOY								
IND_PROD_HP								
Observations:	228	230	251	247	176	189	219	168
R-squared:	0.9885	0.9850	0.9896	0.9919	0.9631	0.8690	0.9348	0.9645

* statistically significant at a 5% level; ** at 1% level.

Table A. 3. Results of the stock prices regressions

Eq Name:	AUSTRALIA	CANADA	CHILE	COLOMBIA	COSTA RICA	CROATIA	ICELAND	INDIA
LN_SHARES(-1)	0.7690 (0.0577)**	1.0652 (0.0644)**	0.9929 (0.0797)**	0.9069 (0.0652)**	1.0833 (0.1092)**	1.0556 (0.0695)**	1.2472 (0.0659)**	1.0591 (0.0641)**
LN_SHARES(-2)	-0.0708 (0.0760)	-0.2075 (0.0940)*	-0.1957 (0.1123)	-0.2648 (0.0912)**	-0.2941 (0.1548)	-0.3759 (0.1057)**	-0.5517 (0.1127)**	-0.3304 (0.0924)**
LN_SHARES(-3)	0.0419 (0.0757)	-0.0088 (0.0945)	0.1633 (0.1104)	0.1634 (0.0925)	0.1992 (0.1552)	0.1581 (0.1089)	0.2809 (0.1185)*	0.1991 (0.0922)*
LN_SHARES(-4)	-0.0141 (0.0749)	0.0223 (0.0928)	-0.0876 (0.1120)	-0.1801 (0.0903)*	-0.0333 (0.1516)	0.1221 (0.1043)	-0.1307 (0.1090)	-0.1590 (0.0897)
LN_SHARES(-5)	0.1306 (0.0505)*	0.0033 (0.0588)	0.1206 (0.0764)	0.1683 (0.0585)**	0.0149 (0.1003)	-0.1270 (0.0624)*	0.0754 (0.0605)	0.0321 (0.0595)
LN_CPI	-0.6175 (0.1528)**	-0.5798 (0.3581)	0.4450 (0.3374)	2.0870 (0.2561)**	0.2049 (0.2467)	0.1386 (0.1915)	-0.4889 (0.2984)	-0.2952 (0.1443)*
DEBT_GDP	-0.0070 (0.0009)**	-0.0011 (0.0006)*	-0.0031 (0.0016)	-0.0043 (0.0012)**	0.0017 (0.0035)	0.0003 (0.0010)	0.0003 (0.0007)	-0.0060 (0.0030)*
LN_SALES	-0.4075 (0.1054)**	-0.1290 (0.1331)	-0.0976 (0.0765)	0.2343 (0.1278)	0.1245 (0.1980)	0.5076 (0.1967)*	0.0732 (0.1373)	0.1721 (0.2443)
RATE	-0.0130 (0.0030)**	0.0014 (0.0028)	-0.0076 (0.0026)**	-0.0113 (0.0026)**	-0.0026 (0.0034)	0.0026 (0.0028)	0.0008 (0.0036)	-0.0106 (0.0037)**
YIELDF	-0.0032 (0.0033)	-0.0059 (0.0057)	-0.0138 (0.0085)	-0.0260 (0.0037)**	-0.0146 (0.0046)**	-0.0004 (0.0048)	-0.0066 (0.0104)	-0.0046 (0.0056)
VIX	-0.0041 (0.0003)**	-0.0027 (0.0004)**	-0.0021 (0.0006)**	-0.0030 (0.0005)**	-0.0009 (0.0008)	-0.0052 (0.0006)**	-0.0082 (0.0007)**	-0.0027 (0.0005)**
LN_SHCOMP	0.0538 (0.0079)**	0.0304 (0.0088)**	0.0051 (0.0133)	-0.0137 (0.0122)	-0.0386 (0.0254)	0.0665 (0.0167)**	0.0611 (0.0178)**	-0.0028 (0.0159)
@TREND	0.0038 (0.0006)**	0.0016 (0.0007)*	-0.0008 (0.0013)	-0.0074 (0.0010)**	-0.0012 (0.0010)	-0.0012 (0.0005)*	0.0008 (0.0014)	0.0004 (0.0023)
C	7.6639 (1.1610)**	4.3328 (1.8786)*	-1.2334 (1.5215)	-7.3747 (1.1500)**	-1.8058 (2.6829)	-1.9620 (1.3476)	2.4444 (1.7859)	-1.6463 (3.1247)
LN_IND_PROD								0.3733 (0.1501)*
LN_NIKKEI								0.0702 (0.0248)**
Observations:	249	249	171	206	96	171	192	249
R-squared:	0.9978	0.9951	0.9854	0.9955	0.9917	0.9844	0.9967	0.9968

* statistically significant at a 5% level; ** at 1% level.

Table A. 4. Results of the stock prices regressions (cont.)

Eq Name:	ISRAEL	KOREA	NEW ZEALAND	POLAND	ROMANIA	SOUTH AFRICA	THAILAND	TURKEY
LN_SHARES(-1)	1.0274 (0.0624)**	1.0881 (0.0667)**	0.9194 (0.0568)**	0.9612 (0.0649)**	0.8425 (0.0755)**	0.9896 (0.0638)**	0.9495 (0.0645)**	0.7918 (0.0729)**
LN_SHARES(-2)	-0.2165 (0.0911)*	-0.3352 (0.0993)**	-0.1834 (0.0785)*	-0.2629 (0.0909)**	-0.2636 (0.1003)**	-0.2110 (0.0906)*	-0.1547 (0.0898)	-0.1705 (0.0975)
LN_SHARES(-3)	0.0965 (0.0921)	0.1587 (0.1014)	0.0733 (0.0778)	0.1077 (0.0924)	0.1776 (0.1006)	0.0689 (0.0916)	0.0983 (0.0901)	0.1233 (0.0971)
LN_SHARES(-4)	-0.1872 (0.0895)*	-0.1025 (0.0980)	0.0944 (0.0762)	0.0438 (0.0900)	-0.1089 (0.0960)	-0.1155 (0.0903)	-0.0063 (0.0887)	-0.0238 (0.0948)
LN_SHARES(-5)	0.1571 (0.0579)**	0.0903 (0.0639)	-0.0060 (0.0531)	-0.0545 (0.0592)	0.0539 (0.0609)	0.1725 (0.0612)**	-0.0856 (0.0563)	-0.0044 (0.0627)
LN_CPI	-0.1462 (0.1510)	0.5615 (0.1890)**	-0.3329 (0.1691)	0.1459 (0.1334)	0.1808 (0.1717)	0.1013 (0.1636)	0.4095 (0.1237)**	0.4290 (0.1931)*
DEBT_GDP	0.0016 (0.0014)	-0.0001 (0.0027)	-0.0020 (0.0004)**	0.0033 (0.0013)*	-0.0063 (0.0027)*	-0.0001 (0.0008)	0.0000 (0.0026)	0.0018 (0.0025)
LN_SALES	-0.3733 (0.1150)**	0.1166 (0.1122)	0.0216 (0.0658)	0.4286 (0.1165)**	-0.1881 (0.1070)	0.2163 (0.1143)	0.1653 (0.0501)**	0.0092 (0.0867)
RATE	-0.0020 (0.0020)	-0.0134 (0.0064)*	-0.0027 (0.0024)	-0.0057 (0.0031)	-0.0192 (0.0049)**	-0.0045 (0.0017)*	-0.0054 (0.0041)	0.0035 (0.0018)
YIELDF	-0.0083 (0.0028)**	0.0122 (0.0057)*	-0.0140 (0.0034)**	-0.0127 (0.0049)**	0.0169 (0.0059)**	0.0002 (0.0032)	-0.0191 (0.0055)**	-0.0144 (0.0029)**
VIX	-0.0033 (0.0005)**	-0.0032 (0.0005)**	-0.0028 (0.0003)**	-0.0027 (0.0006)**	-0.0045 (0.0009)**	-0.0025 (0.0004)**	-0.0044 (0.0005)**	-0.0047 (0.0007)**
LN_SHCOMP	0.0451 (0.0134)**	0.0358 (0.0120)**	0.0045 (0.0057)	-0.0061 (0.0138)	0.0582 (0.0184)**	0.0286 (0.0105)**	0.0057 (0.0129)	0.0665 (0.0158)**
@TREND	0.0013 (0.0005)*	-0.0010 (0.0005)*	0.0005 (0.0004)	-0.0036 (0.0007)**	-0.0014 (0.0012)	-0.0007 (0.0010)	-0.0005 (0.0003)	-0.0010 (0.0015)
C	1.7671 (1.1535)	-2.6829 (0.8534)**	2.6942 (1.3350)*	-2.7807 (0.8478)**	0.1637 (0.8109)	-1.0429 (0.9326)	-1.1776 (0.5110)*	-0.5990 (0.8874)
LN_IND_PROD	0.1913 (0.0965)*			0.3800 (0.1483)*				
LN_DAX				0.1326 (0.0340)**				
LN_SPXT					0.3166 (0.0898)**			
Observations:	249	233	249	249	179	249	238	171
R-squared:	0.9935	0.9917	0.9945	0.9935	0.9787	0.9979	0.9948	0.9907

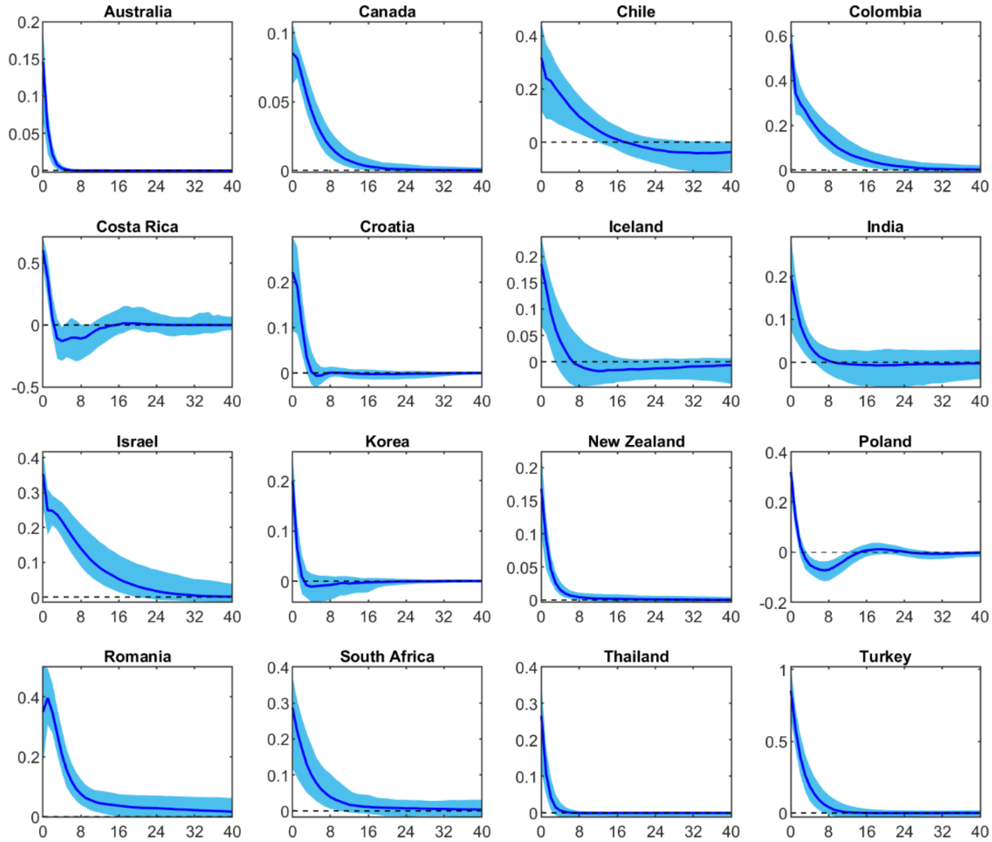
* statistically significant at a 5% level; ** at 1% level.

B. Impulse responses to shocks to expected interest rates/risk premia and expected economic activity

The shock to expected interest rates/risk premium which raises long-term interest rates and reduces stock prices has the expected, negative and statistically significant (i.e. with 68% Bayesian credible sets outside zero) impact on GDP for 9 countries (Chile, Colombia, Costa Rica, Croatia, Israel, New Zealand, Romania, South Africa, Turkey; Figure A. 3), with the strongest impact estimated for Israel and Turkey. For the remaining 7 countries the impact is not statistically significant, though for Australia, Iceland and Korea point estimates are negative, in line with expectations. The impact on prices is found to be much more muted with statistically insignificant effect for 13 out of 16 countries; for 9 of these, point estimates hardly diverge from zero (Figure A. 4). The exceptions for whom 68% credible Bayesian sets fall out of zero are Israel and Iceland with negative impacts and Romania with a counterintuitively positive effect.

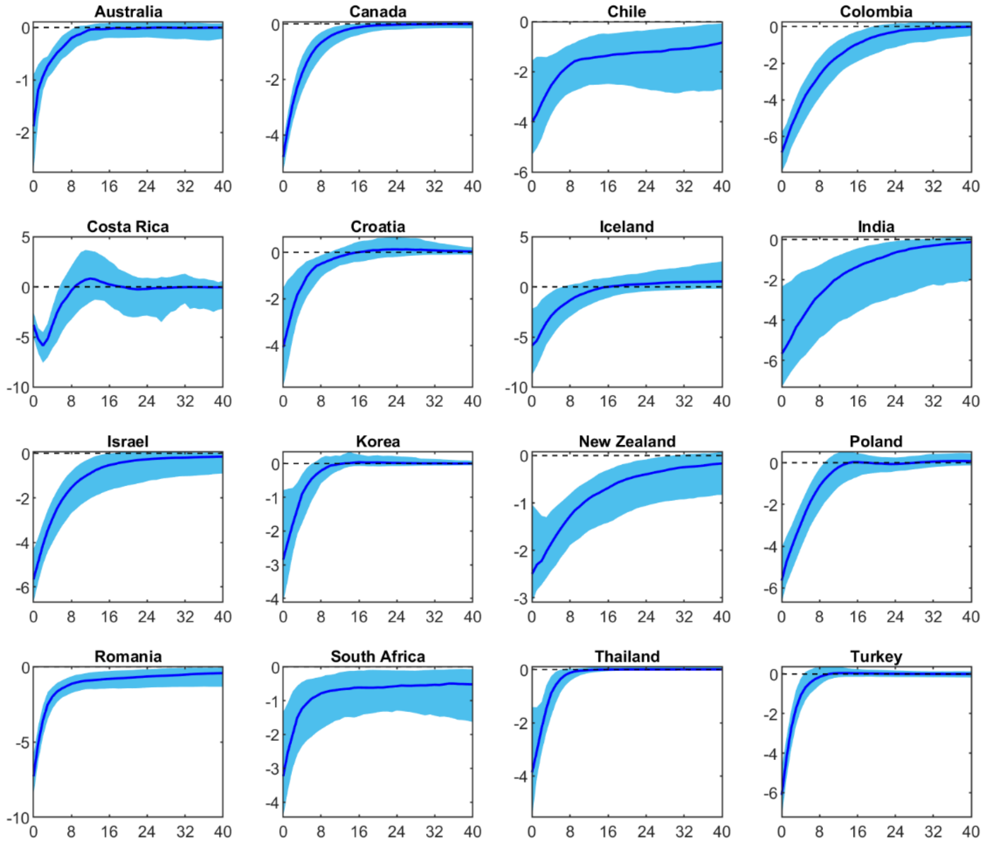
A positive shock to expected economic activity has a more mixed impact on GDP as it raises both bond yields and stock prices. There is a statistically significant positive effect for 6 countries (Croatia, Costa Rica, Iceland, Israel, New Zealand, South Africa) and statistically significant negative impact for 4 countries (Chile, Croatia, Korea, Turkey), with insignificant results for the remaining 6 (Figure A. 7). Similar as in the case of the shock to expected interest rates/risk premium, the impact on prices is more muted – statistically insignificant for 14 out of 16 countries, with the only exceptions being Croatia and Romania (with positive impact, though in the latter case marginally so; Figure A. 8).

Figure A. 1. Response of government bond yields to a one standard deviation shock to expected interest rates/risk premium (in percentage points)



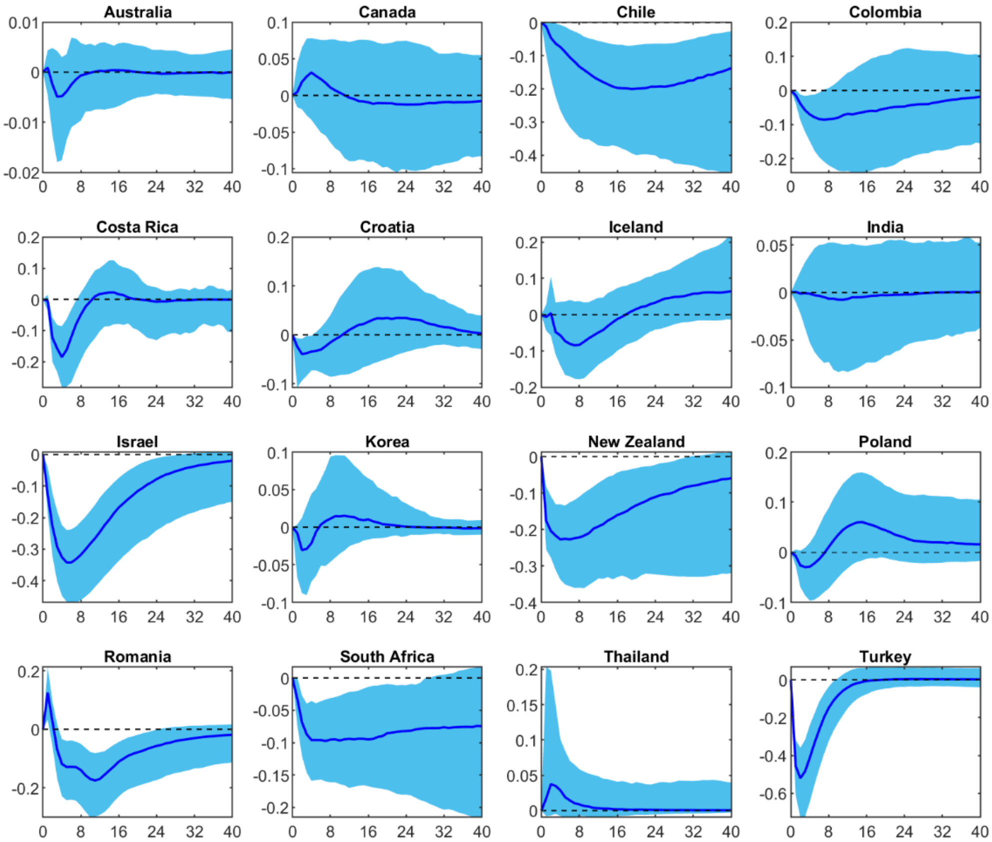
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 2. Response of stocks prices to a one standard deviation shock to expected interest rates/risk premium (in percentage)



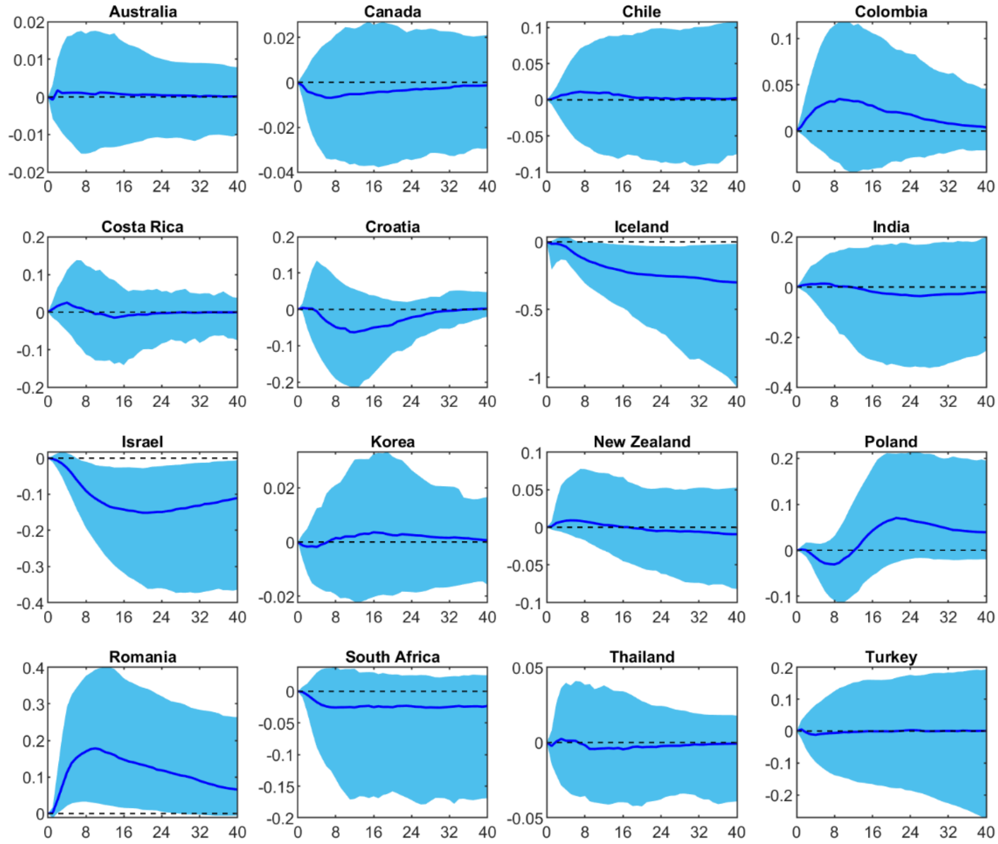
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 3. Response of GDP to a one standard deviation shock to expected interest rates/risk premia (in percentage)



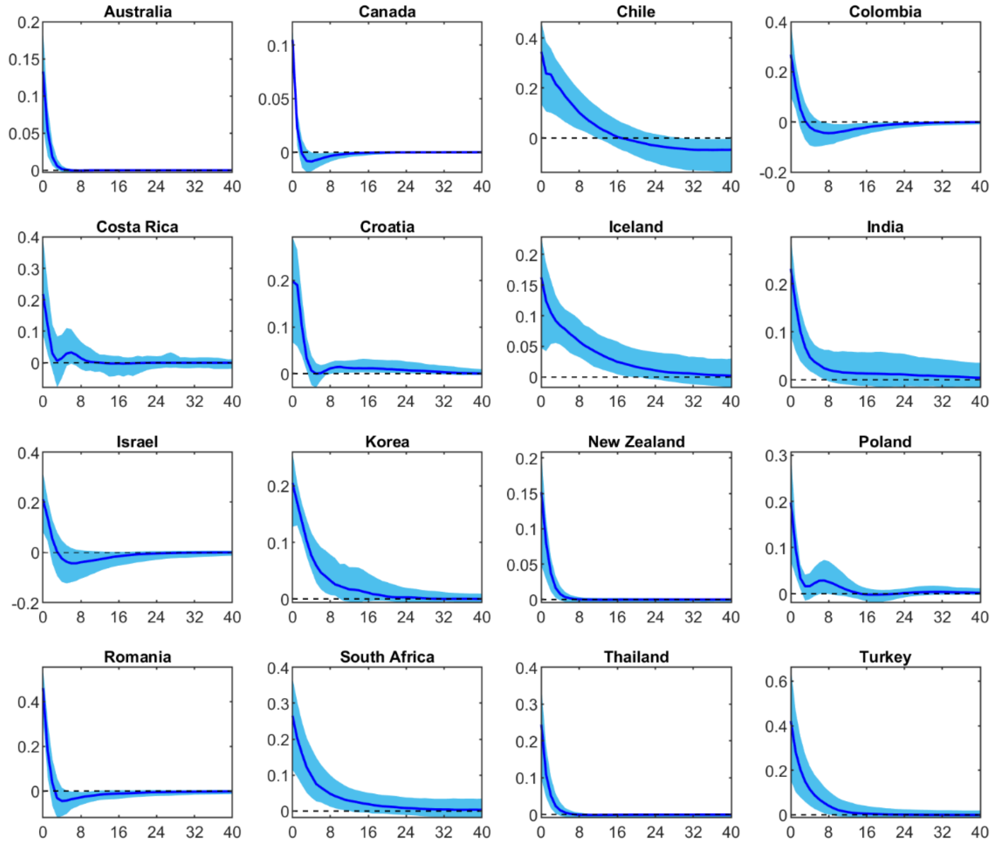
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 4. Response of CPI to a one standard deviation shock to expected interest rates/risk premia (in percentage)



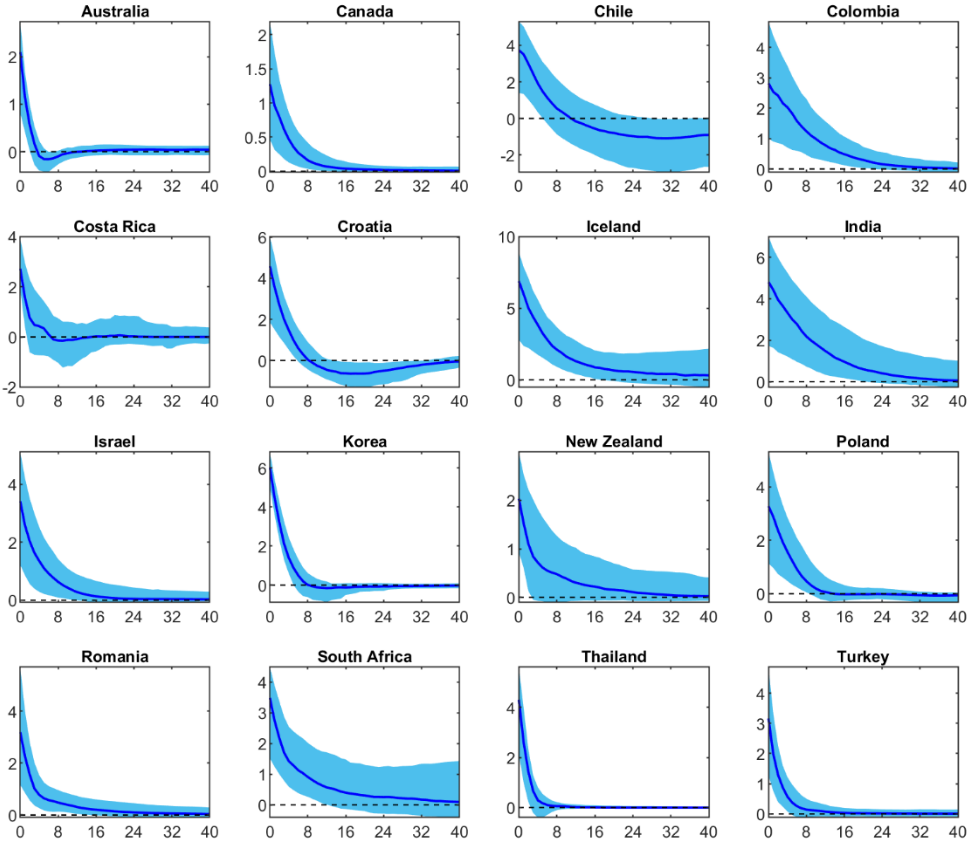
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 5. Response of government bond yields to a one standard deviation shock to expected economic activity (in percentage points)



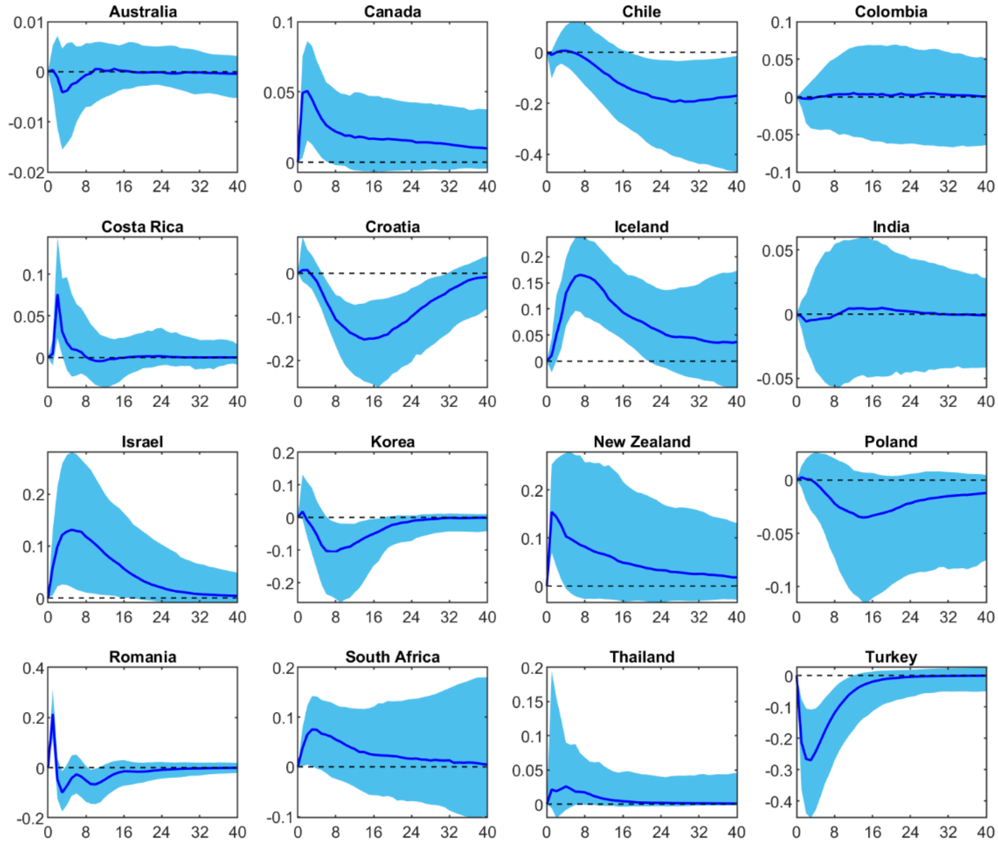
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 6. Response of stock prices to a one standard deviation shock to expected economic activity (in percentage)



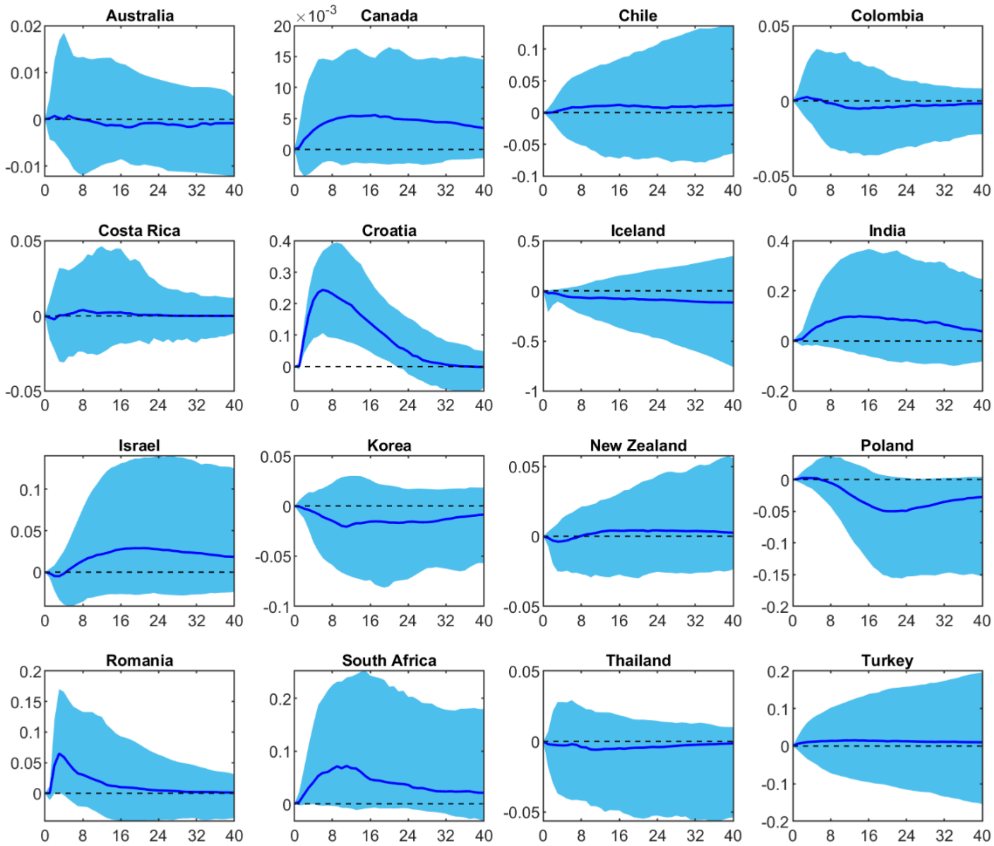
Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 7. Response of GDP to a one standard deviation shock to expected economic activity (in percentage)



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.

Figure A. 8. Response of CPI to a one standard deviation shock to expected economic activity (in percentage)



Lines indicate median impulse responses, shaded areas represent 68% Bayesian credible sets. On horizontal axis: quarters since the shock.