Essays in International Finance and Macroeconomics

by

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To Cristiana: all that begins with you brings out the best in me.

To Mom and Dad: all the best in me began with you.

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ABSTRACT

This thesis contains three essays in international finance and macroeconomics, which investigate flight-to-safety episodes and their interactions with crises, macroeconomic conditions, fiscal and monetary policy, and bond markets.

The first chapter tackles three questions directly relating to flight-to-safety events and the safe-assets phenomenon. First, can we measure demand for safe assets on a continuum? Second, can we tell what sovereign bonds investors consider safe, and whether the safety of a bond can experience changes (or switches) over time? And third, what are the macro and fiscal dynamics associated with higher safe-assets demand and with safety switches? To answer these questions, I construct a text-based index from newspaper mentions, the FLY, to measure global demand for safe assets. The FLY picks up relevant flight-to-safety episodes and the global savings glut, is priced in the cross-section of sovereign bond returns, and predicts declines in the natural interest rate. I then estimate time-varying loadings on the FLY for many sovereign bonds and use these to identify switches in a bond's safety. Safety switches are associated with sizable movements in macroeconomic variables: positive switches (i.e. becoming safe) are associated with expansions, increases in government spending, and higher debt; conversely, negative switches (i.e. becoming risky) are associated with contractions, decreases in government spending, and lower debt with a shorter maturity structure. The results are driven by advanced economies in the post-global-savings-glut period and are not fully accounted for by credit ratings and crisis periods.

The second and third chapters look at a recent period of crisis and flight to safety, the onset of the Covid-19 pandemic, and shift the focus in two other directions: first, from fiscal policy to monetary policy; and second, from sovereign to municipal bonds. More specifically, the second chapter, joint with Kathryn M.E. Dominguez, looks at unconventional monetary policy, in the form of large-scale sovereign debt purchases and the communication strategy that was used to announce them, during the pandemic. We examine whether open-ended, or "whatever-it-takes", announcements had larger effects than announcements with explicit limits on scale, focusing on government bond markets and exchange rates. We find that on average a central bank's first whatever-it-takes announcement lowers 10-year bond yields by an additional 47 basis points relative to size-limited announcements. Our results for yields hold for both advanced and emerging economies, while exchange rates go in opposing

directions, likely due to the strong flight-to-safety dynamics at play, muting their response when we group all countries together.

The third chapter, joint with Dmitriy Stolyarov, Linda L. Tesar, and Matthew Wilson, investigates pricing anomalies in the US municipal bond market during the flight to safety and liquidity, the dash for cash, that occurred at the onset of the pandemic. Municipal bonds were not considered safe during these period, but their relative perceived safety also experienced a substantial reordering, with a persistent re-ranking of their risk premia during the early months of the pandemic. Conventional factor bond pricing models do not adequately capture these yield dynamics, and neither do added state-level pandemic controls. Instead, we find that during March-September 2020, factors constructed from portfolios sorted on state-level Covid characteristics are the only ones with significant risk premia. A state's risk premium during Covid depends not on the situation within the state but on the distribution of pandemic intensity across all states.

CHAPTER 1

Safety Switches: The Macroeconomic Consequences of Time-Varying Asset Safety

I Introduction

Safe assets are one of the cornerstones of the international financial system: they are the fundamental instrument through which a variety of economic agents can save, insure against adverse shocks, and store value during difficult times, while benefitting from the liquidity benefits and collateral value that holding these assets typically entails. Because of the central position safe assets have in the architecture of the world economy, the safety of an asset, be it true or perceived, is a phenomenon with far-reaching implications. On a global level, the increased hunger for safe assets caused by the global savings glut and the ensuing shortage of safe assets have contributed to lower interest rates and large imbalances, and remain a source of global economic fragility. At a country level, from the point of view of a government issuing sovereign debt, whether that debt is perceived as safe or risky is a crucial distinction: it can make the difference between favorable or adverse financial conditions, between having additional fiscal space for spending or being constrained in the ability to use fiscal policy, especially during crises. For all these reasons, safe assets are an important area of research that has received increasing attention over the last years. Thinking about these issues from an empirical perspective, however, requires some fundamental precondition: having a way to measure exactly when safe assets are in demand, and being able to tell what assets are safe at a given point in time. During flight-to-safety events, and if the set of safe assets changes, we should expect repercussions, both globally and at the level of the individual countries involved in the change. These are the questions that this paper is after: what is the set of global safe assets? Can we measure global demand for these safe assets precisely, and identify whether, at a business-cycle frequency, an asset that was considered safe can experience a "switch" and become risky, and vice versa? And do these *safety switches* have relevant macroeconomic consequences?

Addressing these questions, I show that, over time, the perceived safety of an asset can exhibit short-to-medium-term fluctuations, and these fluctuations have significant real implications, especially for governments and their fiscal policy. To detect fluctuations in safety, I construct a text-based index from newspaper mentions, the FLY, to measure global demand for safe assets. The index picks up relevant flight-to-safety episodes, is priced in the cross-section of sovereign bond returns, and predicts declines in the natural interest rate. I then identify switches in a bond's safety, or "safety switches", through changes in the sign and significance of its correlation with the FLY. I find that positive safety switches (i.e. becoming safe) are associated with expansions and increases in government spending, while negative switches (i.e. becoming risky) are associated with contractions and decreases in government spending. In addition, debt grows after a positive switch; conversely, following a negative switch, debt falls and its maturity structure shortens.

The paper begins by presenting a theoretical framework to explain the sources of an asset's safety and come up with a definition of safety that can be taken to the data. In the literature, a safe asset is generally defined as follows: it is an asset with low risk and high liquidity, used by investors to balance their portfolios and as collateral; because of these features, a safe asset will be particularly sought after during times of turmoil − namely, during flight-to-safety episodes. The model speaks to all the aspects of this definition, showing that the safety of a sovereign bond is driven by a combination of factors: country fundamentals, non-pecuniary benefits from holding the bond (which relate to the liquidity and collateral aspects of the definition), and the volatilities of idiosyncratic and country-specific risk (which relate to the low-risk and portfolio-balancing aspects of the definition). Because safety originates from this bundle of characteristics, which are potentially time-varying, safety is a time-varying phenomenon. In addition, because not all of these characteristics are perfectly observable in the data, measuring safety by relying only on some variables (such as convenience yields, which only capture the non-pecuniary benefits component of safety) can give a potentially incomplete picture. On the other hand, the model also points to a solution: the safety of an asset can be simply inferred from its correlation with global safe assets demand. This relates directly to the last aspect of the definition of safe assets mentioned above − namely, that they are sought after during flight-to-safety episodes.

Starting from this observation, the paper develops a two-step empirical procedure to identify which bonds markets consider safe at any given point in time. In the first step, I construct a novel index aimed exclusively at measuring global demand for safe assets. I call this the flight-to-safety index, or, more concisely, FLY. To construct the index, I build on the approach and methods of Baker et al. (2016) and Hassan et al. (2019). I use academic papers related to safe assets and flights to safety to construct a library of safe-assets-related terms.

I then count the articles in financial newspapers that mention these terms, weighted by their frequency in the library, to obtain the FLY. The FLY is one of the key contributions of the paper: it measures demand for safety on a continuum, and effectively captures important events that we would intuitively associate with flight-to-safety episodes, such as the Russian debt default, the subprime mortgage meltdown and financial crisis, the US debt downgrade, the European debt crisis, Brexit, and Covid, among others. The FLY is correlated with the Chicago Board Options Exchange (CBOE) Volatility Index (VIX), but the correlation is low, and the FLY distinctly highlights dates that stand out less when looking at the VIX, such as the European debt crisis, Brexit, and the 2019 global bond rally. Moreover, the FLY exhibits a distinct positive trend starting in the 2000's, consistent with the global saving glut phenomenon: this is apparent when comparing the FLY with an estimate of R^*, and is confirmed by a VAR analysis that shows how innovations in the FLY foreshadow sizable declines in the natural interest rate.

In the second step of my empirical procedure, I estimate correlations (or, more precisely, loadings) of different bonds on the FLY index. I apply this procedure to a large dataset covering many sovereign bonds of several maturities from both advanced and emerging economies. I first estimate fixed loadings over the whole sample: this approach points to a plausible set of global safe assets, which can be clearly identified even though their negative-market-beta qualities are potentially unstable due to changing stock-bond correlations. Moreover, I use these loadings to run a set of cross-section Fama-MacBeth regressions that show how safety is priced in the cross-section, providing evidence of a safety premium.

I then estimate a time-varying version of the loadings, in order to assess how the safety of different bonds changes over time. I identify switches in a bond's safety as changes in the sign and statistical significance of its loading on the FLY index. Following the reasoning outlined earlier, a bond will be safe if its returns are positively correlated with the FLY, risky if they are negatively correlated, and "neutral" if they are uncorrelated. Therefore, a positive switch happens when a bond becomes safe, i.e. its correlation with the FLY goes from negative or not significant to positive and significant. Conversely, a negative switch happens when a bond becomes risky, i.e. its correlation with the FLY goes from positive or not significant to negative and significant.

I find that safety switches are frequent and fairly distributed over time and across countries. I provide descriptive evidence on the macroeconomic dynamics associated with these switches. I find that positive switches (i.e. becoming safe) are associated with increases in government spending and economic expansions. On the other hand, negative switches (i.e. becoming risky) are associated with contractions and declines in government spending. Positive switches are also associated with an increase in debt, while negative switches are associated with a decrease in debt and a shortening of its maturity structure.

Finally, I repeat the estimation in different subsamples and carry out some robustness checks. Taken together, these show that the importance of safety switches for macroeconomic dynamics is attributable to advanced economies in the period following the global savings glut, as results are not significant for emerging economies and in the pre-2003 period. In addition, results remain valid when controlling for credit ratings and when excluding the global financial crisis, the euro debt crisis, and the Covid-19 period, suggesting that safety switches are able to capture distinct fluctuations beyond those that can be explained by crisis periods and rating levels or changes.

The rest of the paper is structured as follows: the remainder of this section reviews the literature; section II presents a theoretical framework for thinking about safety that motivates the FLY index and the empirical methodology; section III describes the construction of the FLY index and evaluates its behavior over time and in comparison to the VIX and to natural interest rates; section IV shows the estimation of fixed factor loadings on the FLY and some asset pricing implication of safety; section V describes the estimation of time-varying loadings on the FLY and how safety switches are identified from there; section VI discusses the behavior of macroeconomic variables around switches; section VII concludes.

Related literature A rich and deep literature has analyzed many aspects of safe assets. One area of research has focused on understanding what exactly makes an asset "safe". For instance, on the theoretical side, He et al. (2016b, 2019) show that fundamentals, investors' beliefs, and coordination play a role in determining what assets are safe. Brunnermeier et al. (2022a) present a framework for thinking about safety as a feature of sovereign bonds emerging from the possibility of re-trading them dynamically to offset idiosyncratic shocks. On the empirical side, Habib et al. (2020) find that a limited set of fundamentals (related to inertia, institutional quality, and debt) are the key determinants of government yield movements in periods of high risk-aversion (measured by the VIX), and can therefore be thought of as safe asset fundamentals.

A number of papers have focused on exactly identifying which assets are safe, and on quantifying the convenience yields they carry. These include Gorton et al. (2012), who analyze the behavior of the so-called safe-asset share, i.e. the share of US assets that are "safe"; Krishnamurthy and Vissing-Jørgensen (2012) and Christensen and Mirkov (2022), who quantify the convenience yield earned by US Treasuries and Swiss bonds respectively; Diamond and Van Tassel (2023), who extend the estimation of convenience yields to ten G-11 countries; and Cuevas (2023), who looks at convenience yields in emerging economies.

Another strand of the literature has studied the implications of safety for fiscal policy, debt, and macroeconomic conditions. Caballero and Farhi (2013, 2018), and Caballero et al. (2016a, 2017, 2021a) explore the important global macroeconomic consequences of a shortage of safe assets and present their implications for policy in a world at the zero lower bound. Gourinchas and Rey (2016) explore these issues with an eye to smaller economies and to the euro area. Zhengyang et al. (2018, 2021) explore the effects of the safety of US Treasuries on the dollar exchange rate. Van Binsbergen et al. (2022) show that monetary policy reduces this convenience yield, especially in times of crisis. Brunnermeier et al. (2022a) explain how governments can extract seignorage revenues by taking advantage of the safe-asset status of their bonds. Aizenman et al. (2019a) study how shortages of safe assets affect international reserves.

A common starting point in the literature described so far is the distinction between a set of assets that are always safe and a set of assets that are not. In such a setup, safety is therefore a largely cross-sectional phenomenon: some assets are safe, some are not, and these are essentially permanent features. Some exceptions include Christensen and Mirkov (2022), Diamond and Van Tassel (2023), and Cuevas (2023), who empirically estimate time-varying convenience yields for Switzerland and a number of other advanced and emerging economies, finding evidence of noticeable oscillations; Mota (2021), who focuses on US corporate bonds, showing that they provide a form of safety benefits and that variations in safety premia have an impact on investment decisions; and Brunnermeier et al. (2022b), who theoretically characterize the potential for gaining and losing the safe asset status as a transition between different equilibria in a framework where bond prices have a bubble term.

My main contribution to the rich literature outlined above is a stronger focus on the time-varying dimension of safety. To do so, I use a tripartite classification, whereby each sovereign bond can be considered safe, neutral, or risky, depending on how its price correlates with the FLY. Safety switches happen when the bond moves from one category to another. To the best of my knowledge, this is the first work to present a methodology for identifying and characterizing safety switches systematically and consistently in a large panel of sovereign bonds. Similarly, to the best of my knowledge, this is also the first paper that empirically assesses the macroeconomic dynamics associated with these switches.

A separate literature has worked on measuring and identifying the global financial cycle, risk-on/risk-off events, and uncertainty shocks, as well as assessing their global implications. Some examples include the work of Akinci et al. (2022), Miranda-Agrippino and Rey (2021), and Kekrel and Lenel (2021). Some authors have given particular attention to the isolation and identification of flight-to-safety episodes specifically, for instance Baele et al. (2020). My main contribution in this respect is the creation of the FLY index, which not only provides an independent indicator of flight-to-safety episodes, but also captures variations in demand for safety on a continuum, allowing the analysis to extend outside of the individual flight-to-safety events. The usefulness of the index is confirmed by the fact that it picks up relevant episodes, is consistent with the global savings glut, it foreshadows declines in natural interest rates, and is priced in the cross-section of sovereign bond returns.

Finally, this work also relates to the many contributions in the use of text- and news-based data for measuring uncertainty, sentiment, economic activity. These include, among others, the measure of sentiment during recessions by García (2013); the Economic Policy Uncertainty (EPU) index by Baker et al. (2016); the Daily News Sentiment Index published by the Federal Reserve Bank of San Francisco, based on Shapiro et al. (2020); and the local and global news sentiment indicators by Fraiberger et al. (2021). I follow a methodology similar to Hassan et al. (2019) to construct a library of terms related to safe assets that I can then search in newspapers, in order to construct an index aimed specifically at measuring demand for safe assets and flight-to-safety episodes.

II Theoretical framework

I present a theoretical framework with two main objectives in mind: explaining where the safety of an asset originates from, and come up with a definition of safety based on concepts and variables that can be measured empirically, directly or indirectly, so that it can be taken to the data. The model is a version of the one by Brunnermeier et al. (2022a), with two main extensions: I include time-varying utility benefits from holding safe bonds, and I expand the model to many countries with additional country-specific sources of risk.

The model has intentionally many ingredients, as the aim is not to fully solve it, but to derive analytical expressions that can point us to the drivers of time-varying demand for safety and how to use it to identify safe bonds. The first key ingredient is the presence of non-diversifiable idiosyncratic risk: this is one driver of the safety of bonds, because it makes them valuable as a way to insure against idiosyncratic shocks. The second key ingredient is the afore-mentioned time-varying utility of holding safe bonds: this is needed to generate convenience yields, which are another feature of safe assets that captures their attractiveness. The third key ingredient is non-diversifiable country-specific risk, which will negatively affect the safety of bonds and potentially make them behave as risky assets.

While having these many ingredients makes the model more complicated, it serves a few purposes. On the negative side, by pointing to many different potential drivers of safety, the model shows that measuring safety by individually relying on observable elements like convenience yields, the VIX, or fundamentals can give an incomplete picture: as the model will show, these variables are bundled together in determining safety, and relying on one of them without the others may not be the perfect approach. In addition, the model also suggests that measuring demand for safe assets directly in the data is quite difficult due to the many unobservable elements. On the positive side, however, the model shows that, if demand for safe assets can be measured at least indirectly, it can provide a more complete way of measuring safety in the data than relying on the individual variables mentioned above.

II.1 Setup

Time is continuous with an infinite horizon. There is a continuum of countries $j \in (0,1)$. In each country, there is a continuum of agents $i \in (0,1)$. To improve readability, I will always use i as a subscript and j as a superscript, so that x^j_{it} refers to the value of variable x for agent i in country j at time t. For bond variables, I will use two superscripts: the first identifies the country of the bond holder, and the second identified the country that issued the bond. Therefore, $b^{j,j'}_{it}$, for instance, denotes the holdings by agent i in country j of the bond issued by country j'.

II.1.1 Production

There is one consumption good, produced by each agent using a linear production technology $y_{it} = a_t k^j_{it}$. Productivity a_t is common across agents and countries, but capital is agent-specific. Each agent operates their own k^j_{it} by choosing investment ι^j_{it}. In addition, agents also face idiosyncratic capital quality shocks, $\tilde{\sigma}_t \mathrm{d}\widetilde{Z}^j_{it}$, where the tildes are used to denote the fact that the variables are idiosyncratic. Each agent's capital then evolves as

$$\frac{\mathrm{d}k^j_{it}}{k^j_{it}} = \Big(\Phi(\iota^j_{it}) - \delta\Big)\mathrm{d}t + \tilde{\sigma}_t \mathrm{d}\widetilde{Z}^j_{it} \ , \tag{1.1}$$

where $\Phi(\iota_{it}) = \frac{1}{\phi}\ln(1+\phi\iota_{it})$ is a function capturing capital adjustment costs and δ is the depreciation rate. The shocks follow an idiosyncratic Brownian motion $\widetilde{Z}^j_{it}$, but their volatility $\tilde{\sigma}_t$ is the same for all agents and all countries at each point in time. Note that this common global volatility is also potentially time-varying, and follows its own exogenous process.

II.1.2 Preferences

Following Krishnamurthy and Vissing-Jørgensen (2012), Di Tella (2020), and Mota (2021), among others, I assume that agents experience non-pecuniary benefits from holding safe assets.[1] More specifically, each bond j' is characterized by a certain degree of time-varying

[1] A safety premium can be generated by either having safety in the utility, as in this case, or by including a term associated with safety in the budget constraint. The former approach is the one used, for instance, by

safety benefits, $v_t^{j'}$, so that holding an amount $b_{it}^{j,j'}$ provides an overall safety benefit of $v_t^{j'} \ln b_{it}^{j,j'}$. Utility is then given by

$$U_{i0}^j = \mathbb{E}\left[\int_0^\infty e^{-\rho t}\Big\{\ln c_{it}^j + \int_0^1 v_t^{j'} \ln b_{it}^{j,j'} \mathrm{d}j\Big\}\right] , \tag{1.2}$$

where ρ is the discount factor and c_{it}^j is consumption. The equilibrium will be expressed in terms of consumption as a fraction of net worth, $\hat{c}_{it}^j = \frac{c_{it}^j}{n_{it}^j}$, as this will be symmetric across all agents.

II.1.3 Government

A government in each country issues nominal sovereign bonds and taxes firms to fund government spending. The face value of outstanding nominal debt of country j is B_t^j, and the nominal interest paid by the bond is i_t^j. Both are exogenous. The face value in particular evolves according to an exogenous process, which is characterized by a growth rate $\mu_t^{B,j}$:

$$\frac{\mathrm{d}B_t^j}{B_t^j} = \mu_t^{B,j} \mathrm{d}t . \tag{1.3}$$

Real spending needs are also exogenous and given by $gK_t^j \mathrm{d}t$, where $K_t^j = \int k_{it}^j \mathrm{d}i$ is total capital in the country and g is a parameter relating spending to a fraction of that capital. The nominal government budget constraint is given by

$$i_t^j B_t^j + P_t^j g K_t^j = \mu_t^{B,j} B_t^j + P_t^j \tau_t^j a_t K_t^j , \tag{1.4}$$

where P_t^j is the price level. In other words, the government faces nominal liabilities in the form of nominal interest payments on existing debt and nominal government spending needs, and pays for them with new nominal debt issuance and taxes. Note that since i_t^j, g, and $\mu_t^{B,j}$ are exogenous, τ_t^j adjusts to balance the constraint.

Krishnamurthy and Vissing-Jørgensen (2012), Di Tella (2020), and Mota (2021); it is similar to widely used money-in-the-utility formulations and can be interpreted as capturing non-pecuniary convenience benefits in the form of utility derived from holding safe assets. The latter approach is used, for instance, by Liu et al. (2019) and Choi et al. (2022). If the safety term is on the left-hand side of the budget constraint, it can be interpreted as a measure of the transaction costs associated with bond trading, with safer bonds being more liquid and thus having lower transaction costs. If the term is on the right-hand side of the budget constraint, it can be seen as the pecuniary value of holding safe assets, associated, for example, to the possibility of using them as collateral to finance other investments. All these ways of introducing a safety premium vary in terms of their interpretation but generally lead to similar first-order conditions and implications.

II.1.4 Net worth

Agents can trade bonds from any country j', choosing a corresponding portfolio weight $\theta_{it}^{j,j'}$ for each. Crucially, however, there is a friction that makes risk sharing incomplete: agents face a "home-bias" constraint, so that they must hold a fraction $\hbar \in (0,1]$ of their bond investments in domestic bonds, resulting in exposure to country-specific risk that they cannot diversify. Effectively, agents are therefore going to choose how much to invest in their own domestic bonds, $\theta_{it}^{j,j}$, and how much to invest in a diversified portfolio of bonds from all countries, $\theta_{it}^{\bar{B},j}$. The home bias constraint can then be written as

$$\theta_{it}^{j,j} = \hbar(\theta_{it}^{j,j} + \theta_{it}^{\bar{B},j}) = \hbar \Theta_{it}^{j} \ , \tag{1.5}$$

where $\Theta_{it}^{j} = \theta_{it}^{j,j} + \theta_{it}^{B,j}$ is the total share of their wealth that agents invest in bonds, which equals the sum of the domestic bond investments and the diversified portfolio. As a result of the home-bias constraint, some of the country-specific risk faced by agents cannot be diversified.

Differently from bonds, agents can only trade capital within their country. More specifically, they can invest a fraction $\theta_{it}^{K,j}$ of their net worth n_{it}^{j} in their own capital, but they can also trade equity, by issuing claims $\theta_{it}^{E,j}$ on their capital and buying a diversified portfolio of claims on other agents' capital within the country. For capital, too, there is a fundamental friction that prevents perfect diversification: agents face a skin-in-the-game constraint, so that they have to retain ownership of a fraction $\chi \in (0,1]$ of their capital and thus they cannot issue equity claims on it. More specifically,

$$\theta_{it}^{E,j} \leq (1-\chi)\theta_{it}^{K,j} \ . \tag{1.6}$$

Similarly to the home-bias constraint, the skin-in-the-game constraint creates a situation where some of the idiosyncratic risk faced by agents cannot be diversified. The two non-diversifiable types of risk will create forces pushing the safety of bonds in opposite directions.

Agents earn a return from each of their investments: $\mathrm{d}r_t^{B,j}$ from their holdings of domestic bonds from their own country; $\mathrm{d}r_t^{\bar{B}}$ from their investment in the diversified bond portfolio; $\mathrm{d}r_{it}^{K,j}$ from their capital; $\mathrm{d}r_{it}^{E,j}$ from issuing equity; and $\mathrm{d}\bar{r}_t^{E,j}$ from investing in a diversified equity portfolio. Overall, each agent's net worth evolves according to their consumption and the returns that they earn on each of these investments, proportionally to the corresponding portfolio weights,[2]

$$\frac{\mathrm{d}n_{it}^j}{n_{it}^j} = -\frac{c_{it}^j}{n_{it}^j} + \theta_{it}^{j,j}\mathrm{d}r_t^{B,j} + \theta_{it}^{\bar{B},j}\mathrm{d}r_t^{\bar{B}} + \theta_{it}^{K,j}\mathrm{d}r_{it}^{K,j} - \theta_{it}^{E,j}\mathrm{d}r_{it}^{E,j} + \theta_{it}^{\bar{E},j}\mathrm{d}\bar{r}_t^{E,j} \ . \tag{1.7}$$

In addition, the portfolio weights must add up to 1:

$$\theta_{it}^{j,j} + \theta_{it}^{\bar{B},j} + \theta_{it}^{K,j} - \theta_{it}^{E,j} + \theta_{it}^{\bar{E},j} = 1 \ . \tag{1.8}$$

II.1.5 Exogenous processes

In addition to government debt, other exogenous variables include productivity, volatility of idiosyncratic risk, nominal interest rates, and convenience benefits. The processes for productivity, a_t, and for the volatility of idiosyncratic shocks, $\tilde{\sigma}_t$ (which can be related to the VIX), are assumed to take the form of generic Ito processes driven by the global Brownian motion Z_t:

$$\frac{\mathrm{d}a_t}{a_t} = \mu_t^a \mathrm{d}t + \sigma_t^a \mathrm{d}Z_t \ , \tag{1.9}$$

$$\frac{\mathrm{d}\tilde{\sigma}_t}{\tilde{\sigma}_t} = \mu_t^{\tilde{\sigma}} \mathrm{d}t + \sigma_t^{\tilde{\sigma}} \mathrm{d}Z_t \ . \tag{1.10}$$

Conversely, the nominal interest rate on each country's bonds, i_t^j, and the convenience benefits that it generates, v_t^j, are assumed to be driven by country-specific Brownian motions $\tilde{W}_t^j$:

$$\frac{\mathrm{d}i_t^j}{i_t^j} = \mu_t^{i,j} \mathrm{d}t + \tilde{\omega}_t^i \mathrm{d}\widetilde{W}_t^j \ , \tag{1.11}$$

$$\frac{\mathrm{d}v_t^j}{v_t^j} = \mu_t^{v,j} \mathrm{d}t + \tilde{\omega}_t^v \mathrm{d}\widetilde{W}_t^j \ . \tag{1.12}$$

Note the use of tildes, as in the case of the idiosyncratic Brownian motions for each agent's capital, $\widetilde{Z}_{it}^j$: like those shocks, the country-specific shocks are also idiosyncratic, but over countries instead of agents, and they will thus wash out in the diversified bond portfolio.

II.2 Prices and returns

The returns entering individuals' net worth process are driven by exogenous processes, fundamentals, and asset prices. Let $q_t^{K,j}$ denote the market price of capital in country j. For convenience, we will work with a scaled version of the real value of bond holdings, which

[2] Note that $\theta_{it}^E > 0$: the negative sign in front of it makes it explicit that it represents an issuance.

expresses them as a fraction of capital in the issuing country:

$$q_t^{B,j'} = \frac{B_t^{j'}/P_t^{j'}}{K_t^{j'}} \ . \tag{1.13}$$

Before deriving processes for returns, we postulate generic Ito processes for capital and bond prices

$$\frac{\mathrm{d}q_t^{B,j'}}{q_t^{B,j'}} = \mu_t^{q^B,j'}\mathrm{d}t + \sigma_t^{q^B,j'}\mathrm{d}Z_t + \tilde{\omega}_t^{q^B}\mathrm{d}\widetilde{W}_t^{j'} \ ,$$

$$\frac{\mathrm{d}q_t^{K,j}}{q_t^{K,j}} = \mu_t^{q^K,j}\mathrm{d}t + \sigma_t^{q^K,j}\mathrm{d}Z_t \ .$$

Notice the price of capital only depends on global shocks, as idiosyncratic shocks wash out in the aggregate, but the price of bonds depends both on global and country-specific shocks.

We can now write the return on bonds issued by j' , which is going to be given by the interest it pays plus the change in the value debt:

$$\begin{aligned}
\mathrm{d}r_t^{B,j'} &= i_t^{j'}\mathrm{d}t + \frac{\mathrm{d}(1/P_t^{j'})}{1/P_t^{j'}} = i_t^{j'}\mathrm{d}t + \frac{\mathrm{d}(q_t^{B,j'}K_t^{j'}/B_t^{j'})}{q_t^{B,j'}K_t^{j'}/B_t^{j'}} \\
&= \left[\Phi(\iota_{it}^{j'}) - \delta + \mu_t^{q^B,j'} - \check{\mu}_t^{B,j'}\right]\mathrm{d}t + \sigma_t^{q^B,j'}\mathrm{d}Z_t + \tilde{\omega}_t^{q^B}\mathrm{d}\widetilde{W}_t^{j'} \ ,
\end{aligned} \tag{1.14}$$

where $\check{\mu}_t^{B,j'} = \mu_t^{B,j'} - i_t^{j'}$,the second equality uses (1.13), and the last equality uses Ito's Lemma. Investors can also invest in a diversified bond portfolio, with return

$$\mathrm{d}r_t^{\bar{B}} = \int \mathrm{d}r_t^{B,j'}\mathrm{d}j' \ . \tag{1.15}$$

For capital, the return is agent-specific and given by output net of taxes and investment, plus the change in the value of capital:

$$\begin{aligned}
\mathrm{d}r_{it}^{K,j} &= \frac{(1-\tau_t^j)a_t - \iota_{it}^j}{q_t^{K,j}} + \frac{\mathrm{d}(q_t^{K,j}k_{it}^j)}{q_t^{K,j}k_{it}^j} \\
&= \left[\frac{(1-\tau_t^j)a_t - \iota_{it}^j}{q_t^{K,j}} + \Phi(\iota_{it}^j) - \delta + \mu_t^{q,K,j}\right]\mathrm{d}t + \sigma_t^{q^K,j}\mathrm{d}Z_t + \tilde{\sigma}_t\mathrm{d}\widetilde{Z}_{it} \ .
\end{aligned} \tag{1.16}$$

As for equity claims, they are identical to capital in terms of risk, but potentially different in terms of expected return, which will be determined in equilibrium, due to the possibility of diversification

$$\mathrm{d}r_{it}^{E,j} = \mathbb{E}_t\big[\mathrm{d}r_{it}^{E,j}\big] + \sigma_t^{q^K,j}\mathrm{d}Z_t + \tilde{\sigma}_t\mathrm{d}\widetilde{Z}_{it} \ . \tag{1.17}$$

The return on the diversified equity portfolio is then given by

$$\mathrm{d}\bar{r}_t^{E,j} = \int \mathrm{d}r_{it}^{E,j} \mathrm{d}i \ . \tag{1.18}$$

II.3 Equilibrium

I define a symmetric competitive equilibrium. The equilibrium is symmetric across agents within each country, but not across countries, i.e. we can drop the i subscripts. Further assumptions can be made on the exogenous processes to also make it symmetric across countries, but I stick to the general case.

Definition 1 *A symmetric competitive equilibrium is a set of*

- *price processes* $\left\{q_t^{B,j}, q_t^{K,j}, \mathbb{E}_t\left[dr_{it}^{E,j}\right]\right\}_{t\geq 0,\ j\in(0,1)}$
- *consumption (as a share of net worth) and investment choices* $\left\{\hat{c}_t^j, \iota_t^j\right\}_{t\geq 0,\ j\in(0,1)}$ *portfolio weights* $\left\{\theta_t^{j,j}, \theta_t^{\bar{B},j}, \theta_t^{K,j}, \theta_t^{E,j}, \theta_t^{\bar{E},j}\right\}_{t\geq 0,\ j\in(0,1)}$
- *taxes* $\left\{\tau_t^j\right\}_{t\geq 0,\ j\in(0,1)}$ *and aggregate capital* $\left\{K_t^j\right\}_{t\geq 0,\ j\in(0,1)}$

s.t., *given initial conditions and exogenous processes,*

- *aggregate capital obeys the LOM:* $dK_t^j = \left(\Phi_t^j(\iota_t^j) - \delta\right) dt \ \forall j$
- *taxes satisfy the government budget constraint:* $g_t^j K_t^j - \tau_t^j a_t K_t^j = \breve{\mu}_t^{B,j} q_t^{B,j} K_t^j \ \forall j$
- *consumption, investment, and portfolio weights max.* (1.2) $\forall i, j$ *with* $\mathbb{E}_t\left[dr_{it}^{E,j}\right] = \mathbb{E}_t\left[dr_t^{E,j}\right]$
- *goods markets clear:* $C_t^j + g_t^j K_t^j + \iota_t K_t^j = a_t K_t^j \ \forall j$
- *asset markets clear:* $\theta_t^{j,j} = \frac{q_t^{B,j} K_t^j}{N_t^j} \ \forall j;\ \theta_t^{K,j} = \frac{q_t^{Kj} K_t^j}{N_t^j} \ \forall j;\ \theta_t^{E,j} = \theta_t^{\bar{E},j} \ \forall j$

II.4 Bond prices and safe assets demand

First-order conditions and some algebra show that the price of a bond is given by

$$q_t^{B,j} = \theta_t^{j,j} \frac{1 + \phi(a_t - g)}{1 - \theta_t^j + \phi\rho} \ . \tag{1.19}$$

In other words, the price of the bond goes up in proportion to the demand for that bond by its domestic buyers, $\theta_t^{j,j}$. Since everyone else buys the bond as part of a perfectly diversified portfolio, the domestic buyers are the key drivers of demand due their home bias. What drives this demand in turn? Further derivations involving the first-order conditions for portfolio shares and various calculations with Ito's lemma lead to the following stochastic differential equation for the demand for a bond j:

$$\frac{\mathbb{E}_t[\mathrm{d}\theta_t^{j,j}]}{\theta_t^{j,j}}\frac{1+\hbar}{\hbar} = \frac{\rho}{1-\theta_t^j} + \check{\mu}_t^{B,j}\left(1+\frac{\hbar\theta_t^j}{1-\theta_t^j}\right) - (1-\theta_t^j)\chi^2\tilde{\sigma}_t^2 + (\theta_t^j)^2\hbar^2(\tilde{\omega}_t^{q^B})^2 - \frac{\rho v_t^j}{\hbar\theta_t^j} \ . \quad (1.20)$$

This equation cannot be solved analytically, but on its own it is informative enough for us, as it summarizes all the drivers of safe assets demand. The term on the left denotes the expected growth in the share of wealth invested in the asset, which is directly related to its demand. It can be read similarly to an expected return: in the same way a *lower* expected return implies a *higher* price today, similarly a *lower* expected growth in demand implies a *higher* demand right now.

What drives this demand? If idiosyncratic risk were absent ($\tilde{\sigma}_t = 0$) or perfectly diversifiable ($\chi = 0$), country-specific risk were absent ($\tilde{\omega}_t^{q^B} = 0$), and there were no convenience yields ($v_t^j = 0$), then demand would be driven only by debt growth net of interest payments. However, the presence of all these additional terms means that demand deviates from that baseline.[3] Two of the variables make bonds more desirable, boosting their safety: the presence of idiosyncratic capital risk makes bonds desirable because agents can buy them to insure against idiosyncratic shocks, with the possibility of liquidating them if needed; the presence of convenience yields means that agents receive non-pecuniary benefits from holding bonds, which generates an additional safety motive. The other variable makes bonds less desirable: the bonds' exposures to their own country-specific risk decreases their safety and makes them risky, which reduces their attractiveness. Whether a bond is safe or risky overall depends on the relative magnitudes of these terms. It seems natural, then, to use these quantities to define safety.

II.5 Defining safety

In light of (1.20) and its implications, let

$$\mathcal{S}_t^j = (1-\theta_t^j)^2\chi^2\tilde{\sigma}_t^2 - (\theta_t^j)^2\hbar^2(\tilde{\omega}_t^{q^B})^2 + \frac{\rho v_t^j}{\hbar\theta_t^j} \ . \quad (1.21)$$

This is the key quantity determining whether a bond is safe or risky relative to a baseline where all the causes of safety and riskiness (convenience yields and idiosyncratic, aggregate, and country-specific risk) are absent. When $\mathcal{S}_t^j$ is positive, one can think of it as the "safety boost" in demand a bond experiences; conversely, it turns into a "riskiness drag" when it is

[3]Note that, without home bias ($\hbar = 0$), everyone in every country would just hold the diversified bond portfolio, which would perfectly insure from both idiosyncratic risk and country-specific risk.

negative. I therefore adopt the following definition

Definition 2

$$A\ bond\ \mathrm{j}\ is \begin{cases} \text{safe} & if \quad \mathcal{S}_t^j > 0\ , \\ \text{neutral} & if \quad \mathcal{S}_t^j = 0\ , \\ \text{risky} & if \quad \mathcal{S}_t^j < 0\ . \end{cases}$$

Note that safety is a time-varying phenomenon in this setup: a bond can switch between categories depending on how $\mathcal{S}_t^j$ moves.

A problem that immediately arises is that this definition is not easily applicable in the data. The volatility of idiosyncratic risk can be mapped into the VIX, and the convenience yields can be measured using corporate bonds, but it would be misleading to rely only on them as we do not know the portfolio weights and the aggregate and country-specific risk terms. At this point, prices can be helpful. The $\mathcal{S}_t^j$ term maps directly into a premium when it is positive, and into a discount when it is negative. Since returns are observable, we can then use them to identify safe assets: an asset would be safe if its price goes up because $\mathcal{S}_t^j > 0$, risky if its price goes down because $\mathcal{S}_t^j < 0$, and neutral otherwise. However, this would still require observing $\mathcal{S}_t^j$ at the individual asset level. We could look at the behavior of $\breve{\mu}_t^{B,j}$, but in reality there might be other factors driving prices, especially at high frequency, so that would not be sufficient.

While relying on the value of $\mathcal{S}_t^j$ cannot help us, switching to an aggregate can: even if it cannot be measured directly, a global aggregate could be measured indirectly in the data through proxies. I therefore define global demand for safe assets as an aggregate of the global demand for all assets with a positive $\mathcal{S}_t^j$.

Definition 3 *The share of global wealth invested in safe assets, θ_t^S, is the sum of all global portfolio shares allocated to bonds with a positive $\mathcal{S}_t^j$, weighted by the wealth of the corresponding country relative to the world, i.e.*

$$\theta_t^S = \int \frac{N_t^j}{N_t} \theta_t^{j,j} \cdot \mathbb{1}_{\{\mathcal{S}_t^j \geq 0\}} \mathrm{d}j\ .$$

Here, $N_t^j = \int n_{it}^j \mathrm{d}j$ and $N_t = \int N_t^j \mathrm{d}j$. This object is directly related to demand for safe assets in equilibrium. Now, whenever a bond is safe, changes in demand for that bond will be counted as part of the change in θ_t^S. Conversely, whenever a bond is risky, it will be counted as part of $\theta_t^T - \theta_t^S$, where $\theta_t^T = \int \frac{N_t^j}{N_t} \theta_t^{j,j} \mathrm{d}j$ is the total share of global wealth invested in all bonds. We can then look at the behavior of bond prices in relation to this aggregate quantity to identify safe and risky bonds.

Definition 4 *A bond* j *is* safe *if its price (realized return) is positively correlated with global demand for safe assets, i.e.*

$$\beta_t^{r^{B,j},\theta^S} = \frac{\mathbb{C}\mathrm{ov}\left(\frac{\mathrm{d}r_t^{B,j}}{r_t^{B,j}}, \frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right)}{\mathbb{V}\left[\frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right]} > 0 \ .$$

Similarly, a bond j *is* risky *if its price (realized return) is negatively correlated with global demand for safe assets, i.e.*

$$\beta_t^{r^{B,j},\theta^S} = \frac{\mathbb{C}\mathrm{ov}\left(\frac{\mathrm{d}r_t^{B,j}}{r_t^{B,j}}, \frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right)}{\mathbb{V}\left[\frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right]} < 0 \ .$$

Lastly, a bond j *is* neutral *if its price (realized return) is uncorrelated with global demand for safe assets, i.e.*

$$\beta_t^{r^{B,j},\theta^S} = \frac{\mathbb{C}\mathrm{ov}\left(\frac{\mathrm{d}r_t^{B,j}}{r_t^{B,j}}, \frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right)}{\mathbb{V}\left[\frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right]} = 0 \ .$$

This is the most intuitive definition one can think of: an asset is safe if it behaves as a safe asset, i.e. it is sought after when investors are looking for safety, and thus its price increases − or, in other words, its price goes up during flight-to-safety episodes. It is a pragmatic and operational definition that has the advantage of finally relating safety to two variables that can be observed in the data: prices (or returns) can be observed directly; global demand for safe assets is hard to measure directly as defined in the model, given the number of unobservables needed to compute it, but it can be measured indirectly in an effective way by constructing an index that tracks investor demand for safe assets through news. This will be the objective of the next section.

Note that I have used a beta notation for the definition: this is to prepare the ground for bringing the definition to the data. Of course, $\beta_t^{r^{B,j},\theta^S}$ has the same sign as $\mathbb{C}\mathrm{ov}\left(\frac{\mathrm{d}r_t^{B,j}}{r_t^{B,j}}, \frac{\mathrm{d}\theta_t^S}{\theta_t^S}\right)$, but it has a more immediate interpretation as a factor loading of the kind that are usually estimated by time-series regressions of returns on factors in empirical asset pricing. Indeed, $\beta_t^{r^{B,j},\theta^S}$ will be interpretable as a "beta" in those terms, and will be estimated from a similar setup, although it will be time-varying.

This definition of safety does not exactly coincide with the one given by Brunnermeier et al. (2022a): in their paper, an asset is defined as safe if it is a "good friend", i.e. it serves as a safe haven after adverse aggregate shocks. In practice, this means that the relevant covariance is the one between the bond's return and an individual's (or an aggregate) stochastic discount factor. Such a definition is also very intuitive, and points directly at the key feature that we typically associate with safe assets. However, it comes with some caveats. First, it relies on the assumption that the volatility of idiosyncratic risk is countercyclical, i.e. it goes up in recessions and falls in expansions. While this is a reasonable and realistic assumption, it also abstracts away from the possibility that idiosyncratic risk can rise "in the background" in normal times as well. An example of this might be the 2019 bond rally: this was a period were investors started hoarding safe bonds while the stock market was doing well and general economic conditions were stable. I will touch upon this event again later in the paper. For the moment, the bond rally is an example of a kind of flight-to-safety episode that occurred outside of a recessionary period. If investors seek safe assets outside of recessions, we want to use that information to identify which assets are safe, but a definition based on the assumption of countercyclical idiosyncratic risk is not able to pick that up. In any case, assuming countercyclical idiosyncratic risk in the model, global demand for safe assets always rises in recessions, so that definition 4 and the good-friend definition lead to the same conclusion.

A second, related caveat is that the good friend definition relies heavily on the volatility of idiosyncratic risk as a driver of safety. As all bonds are characterized by their capability of protecting agents against idiosyncratic capital risk, this definition would have a harder time capturing differences in safety between different bonds in a model with many countries as in this case. The introduction of heterogeneous convenience benefits from holding different bonds would help in that respect, but would likely still require an assumption about their countercyclicality to fit the good-friend definition. Given these consideration, I choose to define safety based on the covariance of bond prices with global demand for safe assets, instead of the covariance with the stochastic discount factor, because it is, arguably, equally intuitive, but more flexible in terms of accommodating heterogeneity and information about safety coming from non-recessionary periods; moreover, global demand for safe assets can be measured indirectly in the data independently from prices, while this is harder to do for the stochastic discount factor.

II.6 Takeaways from the model

We can summarize the takeaway from the model in three points

1. the safety of an asset depends on its fundamentals, the volatility of idiosyncratic risk, exposure to aggregate and country-specific risk, convenience benefits, and exogenous shocks, inasmuch as these enter the processes driving all the previous factors;
2. the safety of an asset can vary over time;

3. the safety of an asset can be be identified from its correlation with global safe assets demand.

The first and second takeaway will help us in setting up and putting structure on the empirical framework that will be used to identify safety switches in the data. Before we can do that, however, we have to deal with the third takeaway: we need a way to measure global safe assets demand. The model suggests that this is hard, if not impossible, to do directly, due to all the unobservable variables involved. However, it is possible to measure it indirectly, through news. This will be the focus of the next section.

III The FLY index

I use newspaper articles to construct a FLight-to-safetY index, or, more concisely, FLY, aimed at measuring changes in demand for safe assets. News are a natural way of measuring demand for safe assets since, generally, whenever there is a flight-to-safety episode or an increased desire for safe assets, financial media will pick it up and mention it in the news, with little to no delay. The construction of the index requires two steps. First, one needs to come up with a library of terms related to safe assets: these must be terms that are specific enough to discussions about safe assets that they are likely to appear distinctively in financial media when demand for safety rises. Then, the actual search happens: the terms are searched one by one, the number of articles that mention them are counted, and the results are aggregated into the index. Finally, we can assess how the index performs relative to other existing measures.

III.1 Libraries

I consider two safe-assets libraries, and therefore come up with two versions of the index. The first library, which I call the benchmark or simple library $\mathscr{L}^0$, is simply a set of bigrams that I hand-pick because they are intuitively related to safe assets and flight to safety:

$$\mathscr{L}^0 = \{\text{“safe asset”},\ \text{“flight safety”},\ \text{“flight quality”}\}\ .$$

The second library, which I call the full library $\mathscr{L}$, is constructed as follows. To create a list of relevant terms related to safe assets, I first download all working papers from the National Bureau of Economic Research (NBER) that contain terms from the simple library $\mathscr{L}^0$ in their abstract.[4] I did not look for mentions of those terms in the title only, since I consider

[4] I did this in November 2021, so I do not account for new papers that were added since then.

that too restrictive (a paper might well be related to safe assets without mentioning them in the title); similarly, I did not look for mentions in the full body of the paper, since that would have been too loose (a paper might well be about an entirely different topic but might briefly mention an application to safe assets). I chose to look at NBER working papers because they have a consistent format, they are freely accessible, they reflect a large variety of fields, and they include unpublished work that nonetheless can contain relevant vocabulary related to safe assets.

I end up with a total of 56 papers, which are listed in Table A.1 in the appendix. I take the main body of each paper and merge them all together into a single document; I remove headers, footers, and numbers; and I tokenize the text, lemmatize and stem the words, and erase punctuation and stop words. I then create a list of all the bigrams that are present in the document. I manually remove from the list all those bigrams that are evidently very common in economic research but are not useful for newspaper searches (for instance, "euler equation" or "statistically significant").

I thus end up with a temporary safe-assets library $\widetilde{\mathscr{L}} = \{b_k\}$, consisting of a list of all the bigrams from the selected 56 NBER papers. Each bigram b_k is characterized by its count, $n_k(\widetilde{\mathscr{L}})$, defined as the number of times the bigram b_k appears in the NBER papers. Denoting by $N(\widetilde{\mathscr{L}})$ the total number of bigrams contained in the NBER papers, one can also define the relative frequency of each bigram $f_k(\widetilde{\mathscr{L}}) = n_k(\widetilde{\mathscr{L}})/N(\widetilde{\mathscr{L}})$.

To construct the final library $\mathscr{L}$, an extra step is required. I carry out the exact same textual analysis on the eighth edition of Greg Mankiw's *Principles of Economics* (Mankiw, 2017),[5] thus creating another library of bigrams, $\mathscr{L}^{econ} = \{b_k\}$, each characterized by its count in the book $n_k(\mathscr{L}^{econ})$. The total number of bigrams in Mankiw's book is given by $N(\mathscr{L}^{econ})$. I call this the economic library, and, due to the introductory but detailed nature of the book and its coverage of many topics, I take it as a benchmark of the vocabulary used in economics and of the prevalence of different terms in economic discourse. The top 100 bigrams in the economics library are summarized in the wordcloud in Fig. A.1 in the appendix.

The purpose of the economic library is to help identify which bigrams in the 56 NBER papers appear often because they are really strongly related to safe assets, as opposed to those that appear often because they are simply very common in the economic vocabulary.

[5] I choose the eighth edition of Mankiw's textbook because it is a more recent version of a textbook that has been around since 1997 and has been widely used to teach introductory economics since then. As such, the book hopefully contains a widely representative synthesis of the general vocabulary, lexicon, and jargon used in economics in the last 25 years – the same years that constitute a majority of my sample. As a university textbook, its language should be specialized enough that it is entirely specific to economics, but given its introductory nature, it should also be representative of economic terminology used by the general population and more specifically by financial newspapers.

For instance, a top bigram in the NBER papers would be "interest rate"; however, the appearance of such a bigram in a newspaper article would hardly be informative about a flight-to-safety episode, given how generally ubiquitous the bigram is in economics.

To construct my final full safe-assets library, I therefore weigh the frequency of bigrams from the NBER papers based on their prevalence in Mankiw's book as follows:

$$f_k^{weight} = f_k\big(\widetilde{\mathscr{L}}\big)\ \frac{N\big(\mathscr{L}^{econ}\big)}{1 + n_k\big(\mathscr{L}^{econ}\big)}\ .$$

This works as a kind of signal-to-noise ratio: bigrams that are rare in Mankiw's book but prevalent in the NBER papers receive a higher weight, as they are likely the most informative about flight-to-safety. Lastly, I keep the bigrams with the 100 largest frequencies:[6]

$$\mathscr{L} = \big\{b_k \bigm| rank\big(f_k^{weight}\big) \leq 100\big\}\ ,$$

and I renormalize the frequencies accordingly

$$f_k(\mathscr{L}) = \frac{f_k^{weight}}{\sum_{k=1}^{100} f_k^{weight}}\ .$$

The resulting bigrams are listed in Table A.2 and summarized by the word cloud in Fig. 1.1.

III.2 Search

I search for mentions of the bigrams in the Financial Times and The Wall Street Journal. Due to their coverage and circulation, these two newspapers should arguably capture all global flight-to-safety episodes. Since I search for mentions through Factiva and I do not have direct access to the full underlying text of all the articles, I manually carry out a reverse-stemming and reverse-lemmatizing procedure to account for relevant variations of each bigram. For instance, in the case of the bigram "safe asset", I adjust the search to account for variations such as "safe assets", "safer asset", "safer assets", "safest asset", "safest assets". In the case of a bigram like "flight safety", instead, I account for all conjugations of the verb "fly".[7]

[6] The decision to focus on the first 100 bigrams is due to constraints in actually searching for mentions on Factiva, which is very time consuming. Arguably, however, focusing on the top 100 bigrams is not a problem, since the remaining terms have relative frequencies of less than 0.025% and their contribution to the index would be negligible.

[7] I decide not to use the wildcard search function available in Factiva to avoid including unrelated terms in the mentions count. For instance, in the above example, searching for both "flight" and "flying" would require using the notation "fl?*" in Factiva: these would allow for the the presence of both "i" and "y" in the third character and would account for different word endings. However, this would obviously also capture a

Figure 1.1: Wordcloud summarizing the relative importance of the bigrams in the full safe-assets library

Note: The figure shows the list of 100 bigrams that form the full safe-assets library, $\mathscr{L}$; the size of each bigram k is proportional to its frequency $f_k(\mathscr{L})$; the construction of the library and frequencies is described in section III.1; the list of bigrams can also be found in Table A.2.

Finally, I ensure the search accounts for occurrences of the two elements of each bigram appearing within three words from each other. Therefore, when searching for the bigram "flight safety" I also find all articles containing "flight to safety" (or any other word other than "to" in between); the same is true for all the variations of the bigram (e.g. "fly safety", "flying safety", etc.).

For each bigram b_k from either the simple or the full library, the result of the search is the daily count of articles that contain the terms of the bigram or their variations within three words of each other. Let A_{kt} be the set of all articles a_t published in day t that mention bigram k, i.e.

$$A_{kt} = \left\{ a_t \mid b_k \in a_t \right\} .$$

In the case of the simple library, all bigrams are equally weighted, so the total number of relevant mentions in a day is simply the total number of articles that mention any of the

myriad other unrelated words, such as "flow", "flag", "floor", or "Florida". Similarly, using "saf*" to search for "safe", "safer", and "safest" would also capture words like "safari". This could dramatically contaminate the results. For consistency, I then stick to manually accounting for word variants also with bigrams for which the wildcard search would plausibly work without such risks.

bigrams, avoiding repetitions:

$$M_t^0 = \left| \bigcup_{k|b_k \in \mathscr{L}^0} A_{kt} \right| ,$$

where the notations $\bigcup$ and $\left| \cdot \right|$ refer to union and cardinality, respectively. In the case of the full library, instead, articles that mention more frequent terms should receive a higher weight, so the total number of mentions is a frequency-weighted sum:

$$M_t = \sum_{k|b_k \in \mathscr{L}} f_k(\mathscr{L}) \left| A_{kt} \right| ,$$

where $\left| \cdot \right|$ again denotes cardinality. Note repeated articles are included in this case because they receive different weights each time they are counted.

I finally normalize the number of mentions by the total number of articles published in the corresponding period

$$m_t^0 = \frac{M_t^0}{\text{total \# of articles}_t} ,$$

$$m_t = \frac{M_t}{\text{total \# of articles}_t} ,$$

and lastly standardize these measures to obtain the simple and the full FLY indices

$$FLY_t^0 = 100 \cdot \frac{m_t^0 - \overline{m}^0}{\sigma(m_t^0)} ,$$

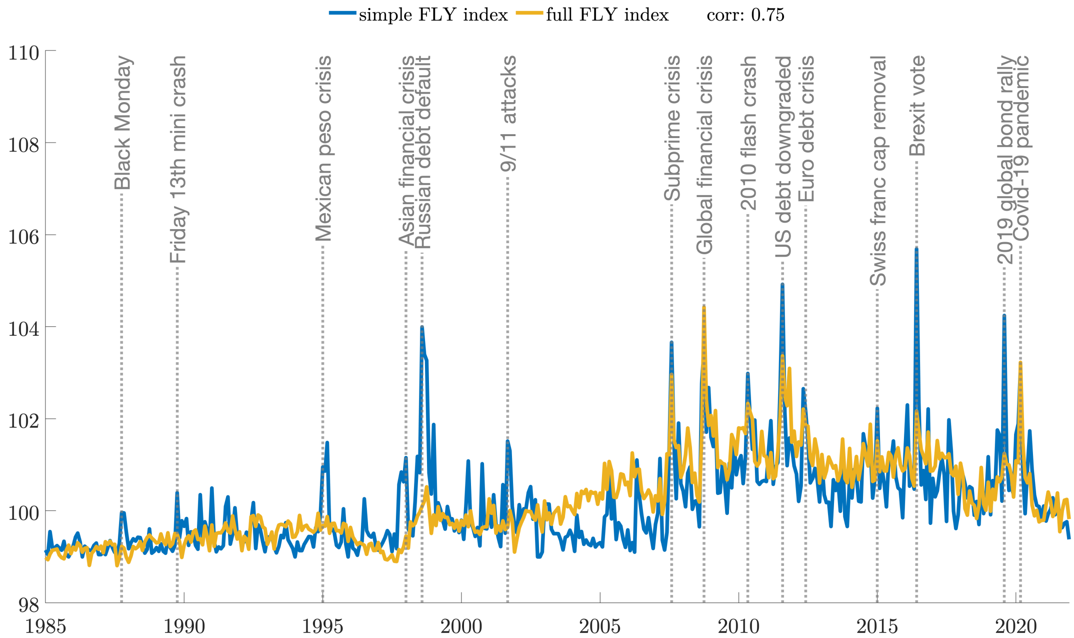
$$FLY_t = 100 \cdot \frac{m_t - \overline{m}}{\sigma(m_t)} .$$

Monthly and quarterly versions of the indices are constructed in the exact same way, simply letting t denote a month or quarter instead of a day.

III.3 Evaluating the index

The resulting monthly versions of the indices constructed according to the above procedure are shown in Fig. 1.2. As the figure shows, the indices exhibit a considerable degree of variation and do a good job at capturing important events that we would intuitively associate with flight-to-safety episodes. The indices are correlated, as expected, though the simple version of the index exhibits somewhat more pronounced spikes, due to its sensitivity to fewer key terms compared to the full index. Both indices spike at the Russian debt default, the subprime mortgage meltdown and financial crisis, the US debt downgrade, the European debt crisis, Brexit, and Covid, among other events.

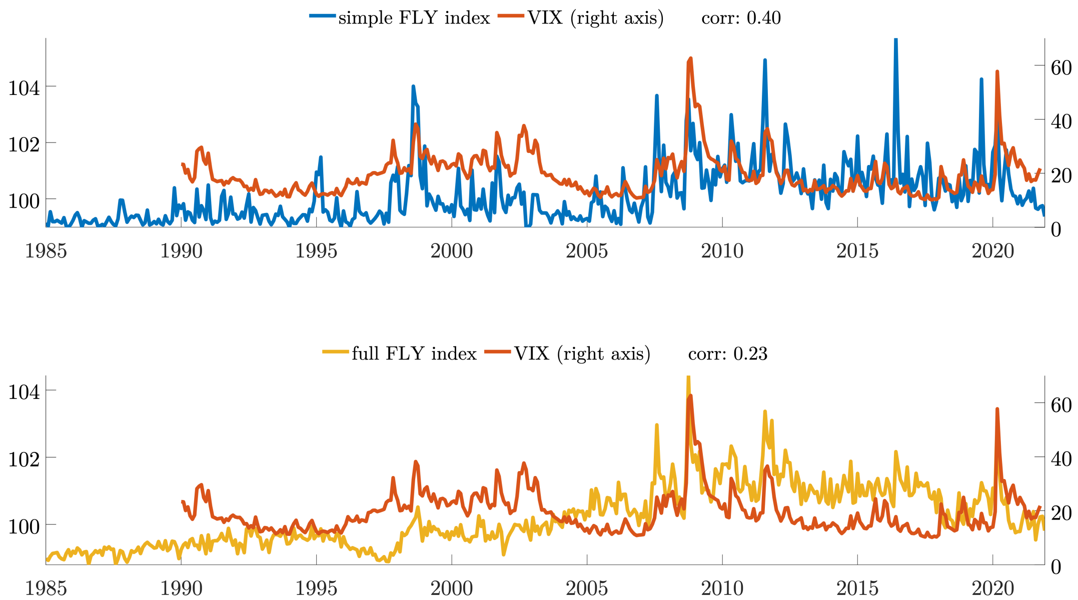
Figure 1.2: Simple FLY index and Full FLY index comparison, with highlighted relevant events



Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$; vertical lines highlight major global events that coincide with spikes in the indices; details on the construction of the FLY are described in section III.1; the correlation between the two versions of the index is shown at the top of the graph; the frequency is monthly.

Importantly, not all these events, which we can associate with flight-to-safety episodes, were accompanied by market downturns. Cases in points include the Swiss central bank's removal of its cap on the franc and the global bond rally that occurred in 2019. This confirms the importance of measuring demand for safety separately from market returns. Moreover, the indices distinctly capture or give different emphasis to dates that stand out less when looking at the Chicago Board Options Exchange (CBOE) Volatility Index (VIX), which is traditionally the variable of choice when looking at uncertainty and demand for safe assets. Indeed, while both FLY indices are correlated with the VIX, that correlation is relatively low. Understandably, being a measure of expected volatility in the US stock market, the VIX largely misses or gives little importance to events like the the European debt crisis, Brexit, and the 2019 global bond rally, but also the initial subprime meltdown that preceded the financial crisis. Furthermore, through the lens of the model, we can think back to the volatility of idiosyncratic risk, $\tilde{\sigma}_t$, and to the global demand for safe assets, θ_t^S: the VIX maps into the former, while the FLY maps into the latter. The model suggests that $\tilde{\sigma}_t$ is a key driver of θ_t^S, but far from the only one: this is consistent with what the plots show for the VIX and the FLY.[8]

Figure 1.3: Simple FLY index and Full FLY index compared with the VIX

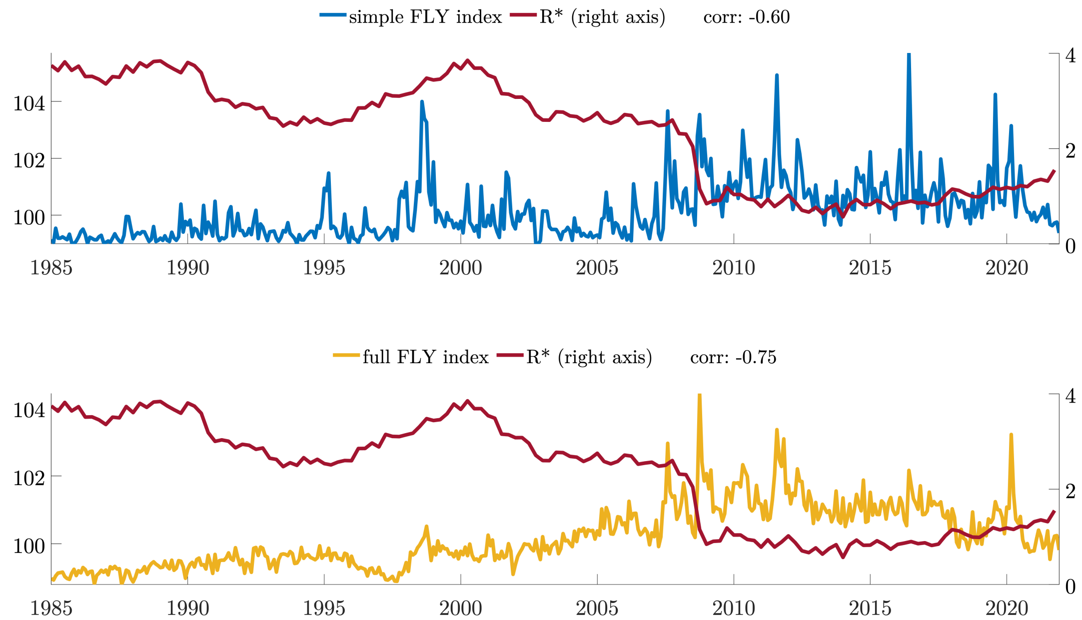


Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to the VIX (with units on the right axis); details on the construction of the FLY are described in section III.1; the VIX is from the CBOE; the correlation between each version of the index and the VIX is shown at the top of each graph; the frequency is monthly.

Another feature that the FLY indices exhibit and that the VIX does not capture is a distinct positive trend starting in the 2000's. This is consistent with the global saving glut phenomenon, whereby the global supply of savings increased considerably starting around 2003, and correspondingly the demand for safe assets also got permanently higher. The ability of the FLY index to capture this trend makes it potentially useful to also think about other phenomena related to the global savings glut, such as the decline in global interest rates. This is apparent, for instance, when comparing the indices against an estimate of R^* for the United States, as shown in Fig. 1.4. For these reasons, I will focus my main analysis on the post-2003 period, where safe-assets dynamics are expected to be particularly relevant due to the global savings glut, and I will then compare this with the pre-2003 period.

[8]Additional figures in the appendix (Figg. A.2-A.6) provide further comparisons of the two FLY indices with the Economic Policy Uncertainty (EPU) index by Baker et al. (2016), the Global Financial Factor (GFF) computed by Miranda-Agrippino and Rey (2021), and the price of gold.

Figure 1.4: Simple FLY index and Full FLY index compared with R^*



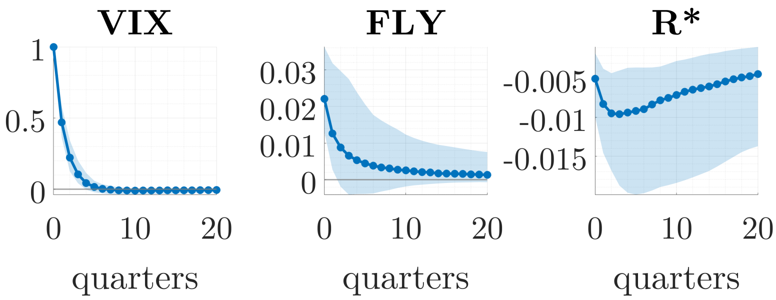
Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to an estimate of R^* (in %, with units on the right axis); details on the construction of the FLY are described in section III.1; the estimate of R^* is from Holston et al. (2023); the correlation between each version of the index and R^* is shown at the top of each graph; the frequency is monthly.

To further investigate the relationship of the FLY to the VIX and to natural interest rates, I use a VAR with the full FLY index, the VIX, and the estimate of R^* for the US plotted above. Specifically, we want to better assess two ideas: first, that the VIX is one of the components driving the FLY, but does not fully explain its fluctuations; and second, that the FLY can capture phenomena like the global savings glut, and generally that the hunger for safe assets that it measures can be associated with declines in natural interest rates. For this reason, I use the following ordering for the VAR: VIX first, FLY second, and R^* last. I then plot impulse responses to innovations in the VIX and the FLY, identified via Cholesky decomposition. The results are plotted in Figg. 1.5-1.6.

The results corroborate both stories. As Fig. 1.5 shows, an innovation in the VIX foreshadows both an increase in the FLY and a decline in R^*: this makes sense, as it suggests an increase in volatility generates a precautionary motive for demanding more safe assets and saving more, thus lowering the natural interest rate. However, as Fig. 1.5 shows, there are also innovations in the FLY that are not driven by volatility and are thus unrelated to the VIX, which in fact does not respond to them. These innovations still matter greatly for the natural interest rate, which indeed declines considerably. For reference, since the

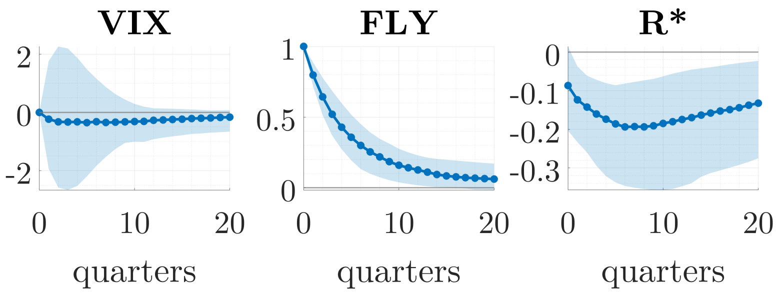
FLY is standardized, a unitary shock corresponds to a one standard deviation shock; this corresponds, for instance, to about a quarter of the increase that can be observed in the FLY at the height of the financial crisis, and, as the figure shows, it foreshadows an up to 20 basis points decline in the natural interest rate.

Figure 1.5: Impulse responses to a VIX innovation



Note: the figure plots the impulse response functions in response to an orthogonalized VIX shock, obtained via Cholesky decomposition in a VAR with VIX, FLY, and R^*, in that ordering; the lag is 1 and was selected according to the Akaike information criterion; shaded areas denote 90% confidence intervals; the VIX is from the CBOE; the estimate of R^* is from Holston et al. (2023).

Figure 1.6: Impulse responses to a FLY innovation



Note: the figure plots the impulse response functions in response to an orthogonalized FLY shock, obtained via Cholesky decomposition in a VAR with VIX, FLY, and R^*, in that ordering; the lag is 1 and was selected according to the Akaike information criterion; shaded areas denote 90% confidence intervals; the VIX is from the CBOE; the estimate of R^* is from Holston et al. (2023).

IV Safety with fixed factor loadings

Before allowing for safety to change over time, as a first assessment of its importance across countries, I start by assuming that it is constant. I describe here the data that I will use for both this section and the next one, where safety is allowed to be time-varying. After describing the data, I briefly show some takeaways and asset pricing implications of constant safety.

IV.1 Data

I download data on local-currency-denominated sovereign bond yields from Bloomberg for a total of 43 countries, covering maturities between 3 months and 10 years. The countries include 25 advanced economies and 18 emerging economies, according to country groupings from the International Monetary Fund. For 8 countries, foreign-currency-denominated bond yields are also available. The panel is unbalanced, but the oldest data dates to 1991. A summary of the available data is provided in Table A.3.

Since I have data on yields and not prices or total returns, I use the following approximation, based on Tuckman and Serrat (2011), to compute returns R_t^j from yields y_t^j:[9]

$$R_t^j = y_{t-1}^j - D_t^j(y_t^j - y_{t-1}^j) + \frac{1}{2}C_t^j(y_t^j - y_{t-1}^j)^2 \ , \tag{1.22}$$

where D_t and C_t are the duration and the convexity of the bond, respectively. These are in turn approximated as

$$D_t^j = \frac{1}{y_t^j}\left[1 - \frac{1}{(1+\frac{1}{2}y_t^j)^{2m_t^j}}\right] , \tag{1.23}$$

$$C_t^j = \frac{2}{y_t^j}D_t^j - \frac{2m_t^j}{y_t^j(1+\frac{1}{2}y_t^j)^{2m_t^j+1}} , \tag{1.24}$$

where m is the number of years until maturity. I then take the return on the US 1-month T-bills as the risk free return to compute excess returns. Given the presence of a heterogeneous group of countries, some of which have structurally more volatile yields, I standardize the excess returns in each country by their standard deviation. The resulting standardized excess returns for each country are then given by

$$R_t^{e,j} = \frac{R_t^j - R_t^F}{\mathbb{V}[R_t^j - R_t^F]^{\frac{1}{2}}} \ .$$

To further reduce the effect of outliers, I finally winsorize this object at the 1st and 99th percentiles.

[9]These approximations are required because the exact composition of coupons and weights for the bonds making up each index are not known, otherwise total returns could be computed precisely. The approximations hold for par bonds that are not subject to default. This does not apply to all bonds, of course, but the resulting approximation has been shown to be accurate when compared with total return series, when these are available − see Swinkels (2019). An alternative is to simply use the change in yields instead of approximating the returns.

IV.2 Safety rankings and stock-bond correlations

One first thing that comes to mind when thinking about safe assets is that their safety can be characterized as having a negative market beta, and thus they are a good store of value during market downturns. While that is one of the desirable characteristics of safe assets, it is also true that the correlation between stocks and sovereign bonds is not always negative, and has in fact changed sign over time. In addition, as suggested by the model, there can be drivers behind the demand for safe assets that are not necessarily associated to market downturns − for instance, the volatility of idiosyncratic risk might go up without a contraction. I assess these ideas by running a set of time series regressions: using monthly data, I run

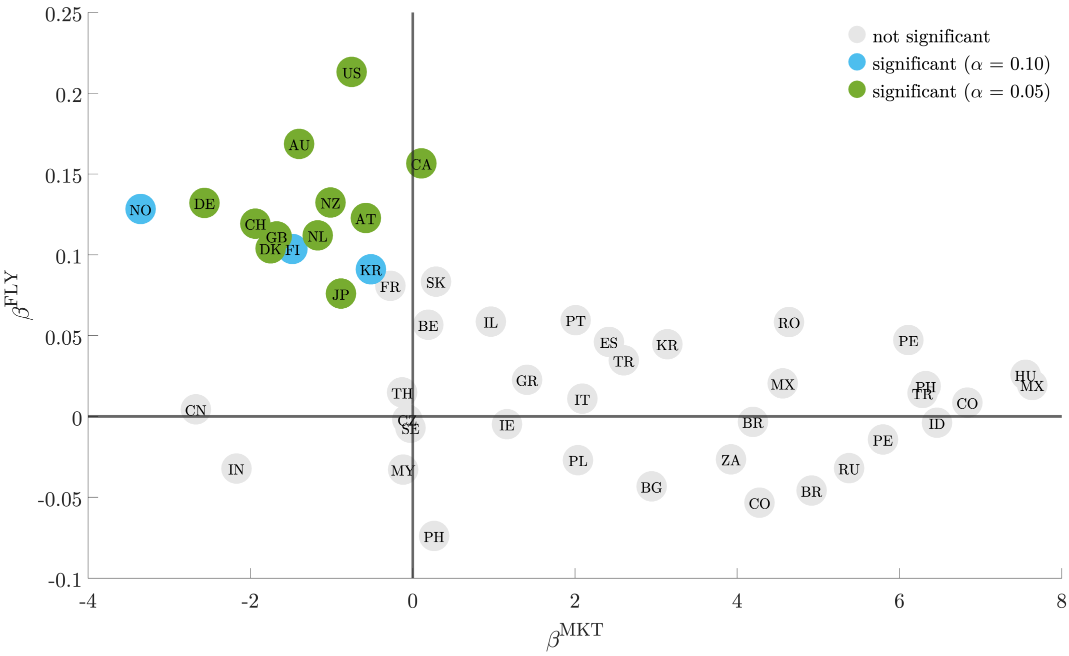
$$R_t^{e,j} = \gamma^j + \beta^{M,j} R_t^{e,M} + \beta^{FLY,j} FLY_t^{\Delta} + \eta_t^j \quad , \qquad \forall j \; . \tag{1.25}$$

In general, the relevant stochastic discount factor for pricing bonds should ideally be the one of a hypothetical global investor that accounts for the majority of international sovereign bond trading. Given the prevalence of investors from advanced economies in this context, I therefore use value-weighted total excess stock market returns on advanced economies to measure $R_t^{e,M}$ from Kenneth French's website. Here FLY_t^{Δ} is the percentage change in the full FLY index (for the rest of the paper, when I mention the FLY I will always be referring to its full version unless otherwise stated).

If we think back to definition 4, $\beta^{FLY,j}$ maps into the $\beta^{r^{B,j},\theta^S}$ we had defined there, after controlling for the market, and its sign is informative about whether an asset is safe, neutral, or risky. By assuming $\beta^{FLY,j}$ to be fixed, the resulting estimates should give us an idea of which bonds, on average over the whole sample, behave as safe assets, which ones behave as risky assets, and which ones are neutral. Fig. 1.8 shows a scatterplot of the factor loadings on the market ($\beta^{M,j}$) and on the FLY index ($\beta^{FLY,j}$) for 10Y bonds, using data from 1991 to 2021. A few things stand out. First, and not surprisingly, the US sits at the top with the largest loading on safety, confirming its undisputed status as a global safe asset. Maybe a bit more surprisingly, a number of other countries rank just after the US and display positive and significant safety betas. In fact, this method indicates a whole set of safe assets, sitting in the second quadrant, with a negative market beta and a positive safety beta. The members of this group are relatively usual suspects, comprising countries traditionally considered to be safe havens. Remaining countries all appear to be neutral, and none seems to be explicitly risky overall.[10]

[10]Fig. A.7 in the appendix replicates the same plot when only data up to 2019 is included, i.e. excluding the Covid-19 period. The results are very similar.

Figure 1.7: Scatterplot of factor loadings on the global market factor and on the FLY index, 10Y sovereign bonds, 1991-2021



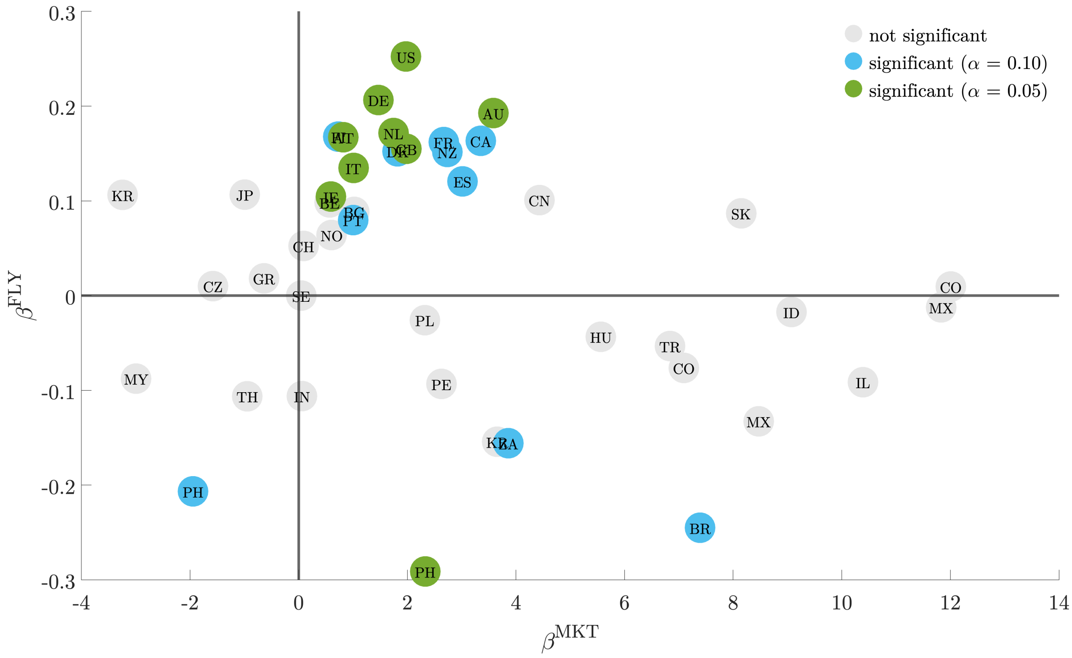
Note: each bubble corresponds to a 10Y bond index j; the ISO-2 code of the corresponding country is reported inside the bubble; the associated x-axis value is the estimated $\hat{\beta}^{M,j}$ from running regression (1.25) for bond index j in the period from 1991 to 2021, using monthly data; similarly, the associated y-axis value is the estimated $\hat{\beta}^{FLY,j}$ from the same regression; countries may appear twice if there are both local- and foreign-currency denominated bond indices; statistical significance for $\hat{\beta}^{FLY,j}$ is indicated by different colors, as reported in the legend; significance for $\hat{\beta}^{MKT,j}$ is not reported.

Fig. 1.8 presents the same results, but only using data from 1991 to 2007. A few more things stand out by comparing it to Fig. 1.8. First, all the safe assets now sit in the first quadrant, with a positive safety beta and a positive market beta. This relates to the issue of defining safety as having a negative market beta: the picture suggests that it would be restrictive, since the covariance between bonds and the market can switch sign, and indeed it has in the past, as emphasized by a number of authors – among others, Viceira (2012), Campbell et al. (2017), and Song (2017). In fact, the figures generalize to many countries the common finding that the stock-bond correlation in the US changed sign around the turn of the millennium. This, however, does not necessarily compromise the safe-asset qualities of these sovereign bonds, provided that they still do co-move positively with a separately-measured demand for safety.

The other thing one can immediately notice is how the composition of the safe asset basket was different pre-2007 compared to what we see using the whole sample. Most notably, Spain

(ES), Ireland (IE), Italy (IT), and Portugal (PT) all had a positive safety beta before 2007. Not surprisingly, extending the sample to include the financial crisis and the Euro debt crisis, their safety disappears. This is, of course, a good sanity check that covariances with the FLY line up with our intuition, but it also highlights a crucial point: safety can oscillate and switch over time. The next question, then, is how to capture these safety switches.

Figure 1.8: Scatterplot of factor loadings on the global market factor and on the FLY index, 10Y sovereign bonds, 1991-2007



Note: each bubble corresponds to a 10Y bond index j; the ISO-2 code of the corresponding country is reported inside the bubble; the associated x-axis value is the estimated $\hat{\beta}^{M,j}$ from running regression (1.25) for bond index j in the period from 1991 to 2007, using monthly data; similarly, the associated y-axis value is the estimated $\hat{\beta}^{FLY,j}$ from the same regression; countries may appear twice if there are both local- and foreign-currency denominated bond indices; statistical significance for $\hat{\beta}^{FLY,j}$ is indicated by different colors, as reported in the legend; significance for $\hat{\beta}^{MKT,j}$ is not reported.

IV.3 Safety and the cross-section of returns

Before moving to time-varying factor loadings, a natural followup to the previous section is using the fixed loadings estimated above to test whether there is evidence of a safety premium. I therefore follow the Fama and MacBeth (1973a) procedure: after the set of time series regressions run in IV.2, I then run a set of cross-sectional regressions:

$$R_t^{e,j} = \varsigma_t + \lambda_t^M \hat{\beta}^{M,j} + \lambda_t^{FLY} \hat{\beta}^{FLY,j} + \alpha_t^j \quad , \qquad \forall t \ . \tag{1.26}$$

Again, I use value-weighted total excess stock market returns on advanced economies to measure $R_t^{e,M}$.

Table 1.1: Fama-MacBeth risk premia

R^M(AE)	0.015	0.012	0.013	0.010
	(0.020)	(0.023)	(0.019)	(0.022)
FLY	-1.216^{**}	-1.479^{**}	-1.122^{*}	-1.311^{**}
	(0.599)	(0.668)	(0.612)	(0.631)
R^M(EM)		0.009		-12.949
		(0.028)		(8.419)
VIX			-12.335	0.010
			(7.515)	(0.026)
maturity	-0.014^{**}	-0.012^{**}	-0.015^{**}	-0.014^{**}
	(0.006)	(0.006)	(0.006)	(0.006)
avg. adj. R2	0.192	0.232	0.209	0.244

Note: the table reports, in the first column, the estimated $\hat{\lambda}^M = \frac{1}{T}\sum_t \hat{\lambda}_t^M$ and $\hat{\lambda}^{FLY} = \frac{1}{T}\sum_t \hat{\lambda}_t^{FLY}$; $\hat{\lambda}_t^M$ and $\hat{\lambda}_t^{FLY}$, in turn, are obtained by running regression (1.25) for each bond j, and then running regression (1.26) for each month t, controlling for maturity, and using value-weighted total excess stock market returns in advanced economies to measure $R_t^{e,M}$; the other columns show the same estimates when additionally controlling for value-weighted total excess stock market returns in emerging economies and for the VIX; standard errors are heteroskedasticity- and autocorrelation-consistent and are adjusted according to the Shanken (1992) correction for generated regressors.

I also consider three other specifications, by further including the VIX and value-weighted total excess stock market returns on emerging economies. The inclusion of the VIX is to confirm if the FLY index has distinct explanatory power that the VIX does not account for. The inclusion of portfolio returns from emerging economies is to assess if the relevant pricing kernel is indeed accounted for by a market portfolio based on advanced economies only. Finally, for all specifications, I control for maturity directly in the cross-sectional regressions because I don't have bond-specific outstanding amounts to compute a value-weighted portfolio mimicking the behavior of a hypothetical duration factor.

If safety is priced in the cross-section, we expect λ_t^{FLY} to be different from zero on average, and specifically, if there is a safety premium, it should have a negative sign $-$ the opposite of a risk premium.[11] In line with the Fama-MacBeth approach, I use $\hat{\lambda}^{FLY} = \frac{1}{T}\sum_t \hat{\lambda}_t^{FLY}$ to test this. The results are reported in Table 1.1. Unmistakably, there is robust evidence of a safety premium across specifications.

V Safety with time-varying factor loadings

The previous section highlighted an example of safety switches that can be identified by splitting the sample and looking at how the safety beta changes across smaller subsamples. However, to really identify safety switches, we want to take this reasoning to an extreme. Thinking back about the model and definition 4 again, safety was defined by the sign of $\beta_t^{r^{B,j},\theta^S}$, and it changed over time as $\beta_t^{r^{B,j},\theta^S}$ fluctuated, driven by all the variables driving demand for safe assets: fundamentals, idiosyncratic risk, and the non-fundamental drivers of convenience yields and bond exposures to aggregate and country-specific risk. Connecting back to that reasoning, I allow for $\beta_t^{FLY,j}$ to change period-to-period.

V.1 Time-varying safety estimation

I impose the following general structure on the process that drives $\beta_t^{FLY,j}$:

$$\beta_{t+1}^{FLY,j} = (1-\rho^j)\bar{\beta}^{FLY,j} + \rho^j \beta_t^{FLY,j} + \varepsilon_{t+1}^{FLY,j} \ . \tag{1.27}$$

Intuitively, the safety of an asset fluctuates around a long-run average ($(1-\rho^j)\bar{\beta}^{FLY,j}$), has some degree of persistence ($\rho^j \beta_t^{FLY,j}$), and is subject to shocks ($\varepsilon_{t+1}^{FLY,j}$).[12]

Recovering the full path of $\beta_t^{FLY,j}$ now requires setting up a Kalman filter estimation in which the coefficients correspond to the unobservable time-varying state variables. This is similar to the conditional CAPM estimation used in Adrian and Franzoni (2009). Assuming a similar simple autoregressive process for the intercept, the resulting Kalman filter formulation can be written in state-space form as

$$R_{t+1}^{e,j} = \gamma_{t+1}^j + \beta_{t+1}^{FLY,j} FLY_t^{\Delta} + \eta_{t+1}^j \ , \tag{1.28}$$

[11]The vocabulary is somewhat confusing, due to the fact that the risk premium usually refers to a premium required by investors on expected returns, which amounts to a required discount on the price; conversely, the safety premium refers to a premium that investors are willing to pay on the price, which amounts to allowing a discount on the expected return, i.e. a convenience yield. To make them comparable, one could talk about a risk premium and a safety discount.

[12]This is likely the most general specification for this process. Alternatively, one could put further structure on the process and allow it to be also influenced by fundamentals, such as fiscal space and macroeconomic variables. Results are qualitatively similar.

$$\gamma_{t+1}^{j} = (1-\rho^{\gamma,j})A^{j} + \rho^{\gamma,j}\gamma_{t}^{j} + \varepsilon_{t+1}^{\gamma,j} \ , \tag{1.29}$$

$$\beta_{t+1}^{FLY,j} = (1-\rho^{FLY,j})B^{FLY,j} + \rho^{FLY,j}\beta_{t}^{FLY,j} + \varepsilon_{t+1}^{FLY,j} \ , \tag{1.30}$$

where once again FLY_t^{Δ} is the percentage change in the full FLY index.[13] I run the filter using quarterly data, since the ultimate goal is assessing the dynamics of quarterly macroeconomic variables around switches, and thus using quarterly data at this stage avoids the problem of temporal aggregation when it comes to defining switches in the next section.

Fig. 1.9 shows the resulting path of $\hat{\beta}_t^{FLY,j}$ for a selection of countries, with 90% confidence intervals. Areas shaded in green indicate periods in which the loading on the FLY was positive and significant. These can be thought of as periods in which the bond behaved as a safe asset. Conversely, areas shaded in red indicate periods in which the loading was negative and significant. These can be thought of as periods in which the bond behaved as a risky asset. Unshaded areas are periods in which the coefficient is not significant, and the bond is "neutral" with respect to the FLY, i.e. it does not behave as a safe asset earning a safety premium, but also does not behave as a risky asset experiencing sell-offs during flight-to-safety episodes.

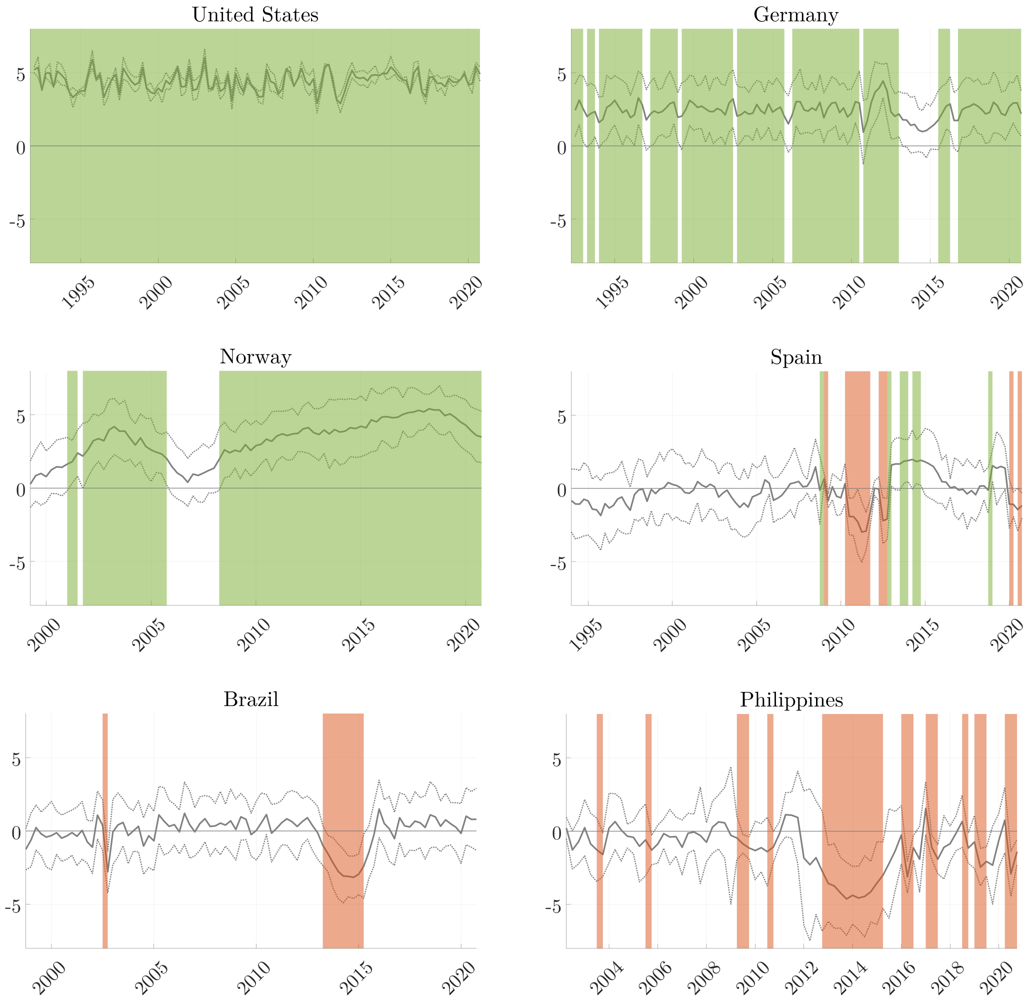
There are some countries, like the United States, that are always safe. There are others, like Germany and Norway, that are never risky, but switch in and out of enjoying a safety status. Spain, on the other hand, is an example of a country whose bonds behaved as both safe and risky assets in different periods. As we would expect, the loading turned decisively negative during the euro debt crisis; later, however, Mario Draghi's "whatever it takes" and the European Central Bank's quantitative easing program switched the country back into having a positive loading. The country then benefitted positively from the global bond rally in 2019, but suffered again with the onset of Covid.

Brazil and the Philippines are examples of countries that are mostly neutral, but sometimes switch in and out of being risky. Some of these switches can be attributed to specific events, such as the Brazilian debt crisis in 2002 and economic crisis in 2014, or the investor scare that happened in 2016 in the Philippines following a number of antagonistic statements against the US and China made by the newly elected president.[14]

[13] Note that the filter is estimating $\beta_t^{FLY,j}$ without controlling for the market, differently from the previous section. In that case, the point was illustrating the difference between safety and negative market beta, and emphasizing the distinct explanatory power of the FLY and the presence of a safety premium in the cross-section even when controlling for the market. This estimation, instead, takes the model more seriously, one could say, since the model suggests that, if the FLY is a valid measure of demand for safe assets, then the safety of a bond should be given by its unconditional return correlation with the FLY. In other words, that should also account for what the market is doing, and for whatever negative-beta quality the bond may also have.

[14] See, for instance, Choudhury (2016).

Figure 1.9: Estimated time-varying loadings on the FLY index, selected countries



Note: the dark gray line plots the estimated $\hat{\beta}_t^{FLY,j}$ obtained by running the Kalman filter (1.28)-(1.30) for the 10Y bond index j of each country; in the presence of multiple 10Y bond indices for a country (due to local and foreign currency denomination), the longest series is plotted; the dotted gray lines denote 90% confidence intervals; green shaded areas highlight periods when the coefficient is positive and significant; red shaded areas highlight periods when the coefficient is negative and significant.

V.2 Finding safety switches

In line with definition 4, I identify switches in a country's safety through changes in the sign and statistical significance of its bonds' loading on the FLY. I focus specifically on the β^{FLY} of short-term, 3-month bonds, which are generally the most traded for safety and liquidity purposes.[15] More specifically, country j experiences a positive safety switch in quarter t ($\text{switch}^{+}_{j,t} = 1$) if

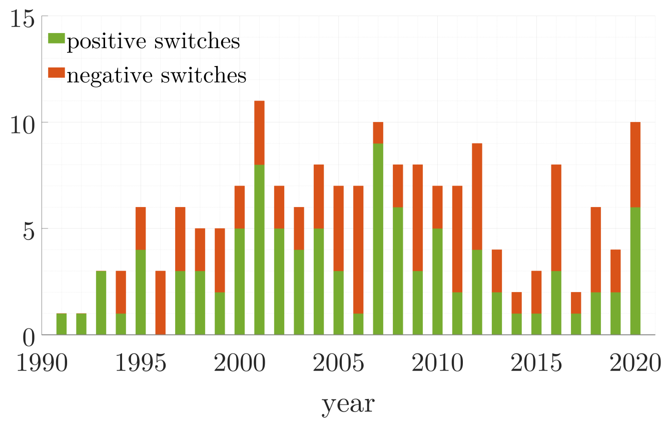
- $\hat{\beta}^{FLY}$ is *positive and significant* in quarter t and
- $\hat{\beta}^{FLY}$ was *negative or not significant* in quarter $t-1$.

Similarly, country i experiences a negative safety switch in quarter t ($\text{switch}^{-}_{j,t} = 1$) if

- $\hat{\beta}^{FLY}$ is *negative and significant* in quarter t and
- $\hat{\beta}^{FLY}$ was *positive or not significant* in quarter $t-1$.

Fig. 1.10 shows the resulting total number of switches by year. Switches appear to be fairly distributed over time. The biggest concentration of positive switches happens during the early 2000s, probably following the emergence of the global savings glut and the creation of the euro area. Many positive switches then occur again during the financial crisis, the euro debt crisis, and Covid, although many switches also occur outside of these crisis periods. Negative switches also occur frequently outside of crisis periods, although larger occurrences are concentrated around the Great Recession, the euro debt crisis, and Covid.

Figure 1.10: Total number of positive and negative safety switches each year



Note: the figure plots the total number of positive and negative switches occurring each year across all countries.

[15] Alternatively, one could look at the coefficients across all maturities and define switches by averaging or aggregating across them. The results are similar with that approach.

VI Macroeconomic dynamics around safety switches

At this point, we have a panel of positive and negative safety switches. I collect additional data on GDP, consumption, investment, and government spending from the International Monetary Fund; on debt as a share of GDP from the IMF-World Bank Public Sector Debt database; and on average debt maturity and ratings from the World Bank Fiscal Space Database.[16] I then run the following local projections for y equal to GDP, consumption, investment, and government spending

$$100 \cdot \frac{y_{j,t+h} - y_{j,t-1}}{y_{j,t-1}} = \delta_i + \delta_t + \lambda_h \cdot \text{switch}^s_{j,t} + \mu_h \cdot 100 \cdot \frac{y_{j,t-1} - y_{j,t-2}}{y_{j,t-2}} + u_{j,t+h} \ , \tag{1.31}$$

and the following local projections for y equal to total debt-to-GDP ratios (in %) and average debt maturity (in years)

$$y_{j,t+h} - y_{j,t-1} = \delta_i + \delta_t + \lambda_h \cdot \text{switch}^s_{j,t} + \mu_h \cdot (y_{j,t-1} - y_{j,t-2}) + u_{j,t+h} \ . \tag{1.32}$$

The horizons are $h = 0, 1, \ldots 20$. Here, $s \in \{+, -\}$, i.e. the regression is run separately for positive and negative safety switches. Notice the presence of country and time fixed effects and a control for the lagged value of the dependent variable. Following the discussion in Section III.3, I focus my baseline analysis on the post-2003 period when the global savings glut made safe-assets dynamics particularly relevant, and in advanced economies, which were the ones most directly impacted by the phenomenon. I later show results for the 1991-2003 period and for emerging economies.

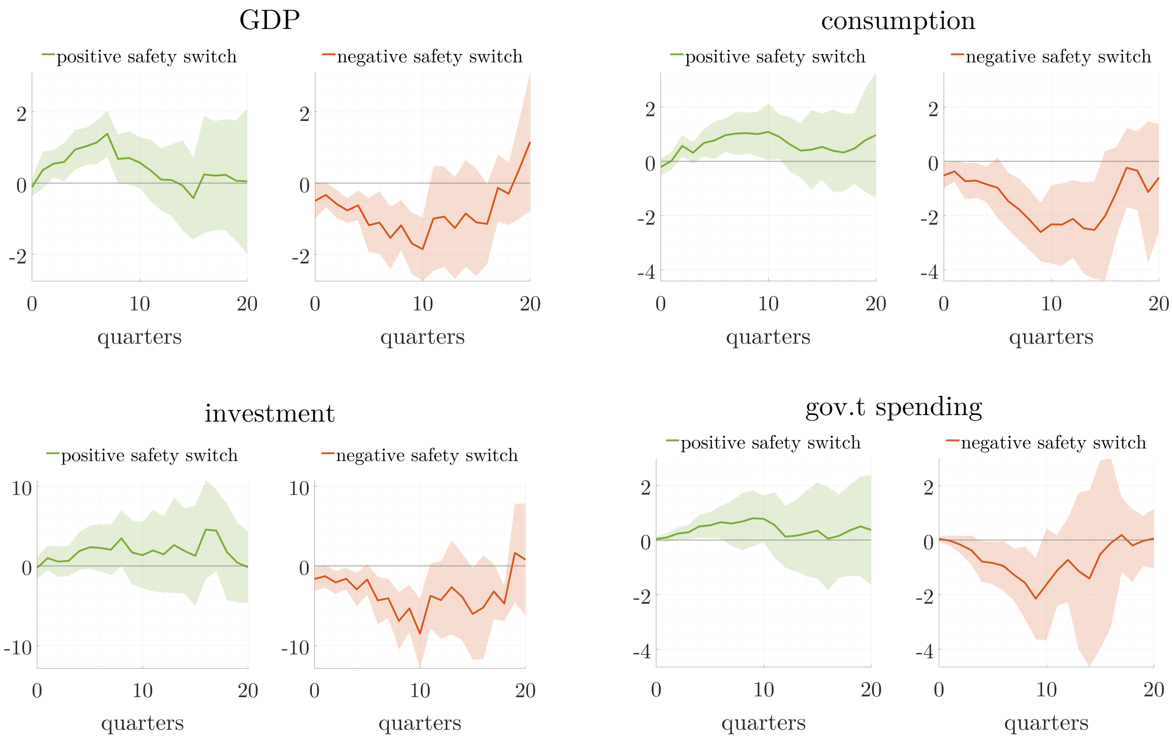
Fig. 1.11 shows the resulting local projections for GDP and its components. Safety switches are associated with sizable movements in macroeconomic variables. Positive switches (in green) are associated with expansions in consumption and GDP and increases in government spending over the short term. The story is different for negative switches (in red). Consumption, investment, and GDP all contract considerably, and government spending falls by as much as 2 percent over the medium term.

Fig. 1.12 shows the local projections for the debt-to-GDP ratio and the average maturity of debt. The behavior of debt-to-GDP is opposite: positive safety switches are associated with a short-term increase in debt, probably as countries take advantage of their newly-gained safe status to borrow more cheaply and finance their expanded spending; conversely, negative switches are associated with a longer-term decrease in debt, as countries contract their spending and reduce their borrowing to avoid exacerbating the negative effects of their novel riskiness.

[16] Further details can be found in Kose et al. (2022); I use the 2021 version of the data.

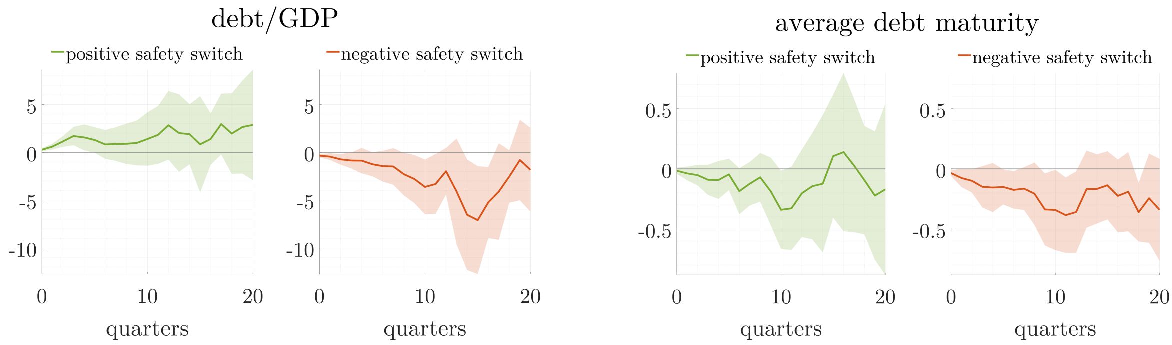
The maturity structure seems to get shorter in both cases, though results are not quite significant for positive switches. For negative switches, the average debt maturity decreases by up to about 5-6 months. For reference, the average maturity over the sample is about 8 years. A potential story behind this result is that the cheapness of short-term debt outweighs the insurance benefits of long-term debt in the trade-off the government faces when adjusting the maturity structure of its debt in response to a switch. In particular, after a negative switch, the cost of borrowing increases across maturities, but short-term debt is still the cheapest option. Moreover, being advanced economies, rollover risk is probably less of a concern in this case. As a result, governments that want to reduce their debt but still need to borrow will do the borrowing via short-term debt and will do the debt reduction through the long-term margin. The result is a tilting of the maturity structure towards shorter maturities.

Figure 1.11: Macroeconomic dynamics after safety switches: positive switch to safe (green) and negative switch to risky (red)



Note: dark green lines plot the estimated $\hat{\lambda}_h$ obtained by running regression (1.31) for positive switches (i.e. $s = +$); dark red lines plot the estimated $\hat{\lambda}_h$ obtained by running the same regressions for negative switches (i.e. $s = -$); shaded areas denote 90% confidence intervals; standard errors for the confidence intervals are Driscoll-Kraay.

Figure 1.12: Debt dynamics after safety switches: positive switch to safe (green) and negative switch to risky (red)



Note: dark green lines plot the estimated $\hat{\lambda}_h$ obtained by running regression (1.32) for positive switches (i.e. $s = +$); dark red lines plot the estimated $\hat{\lambda}_h$ obtained by running the same regressions for negative switches (i.e. $s = -$); shaded areas denote 90% confidence intervals; standard errors for the confidence intervals are Driscoll-Kraay.

VI.1 Alternative samples and robustness

The baseline analysis focused on safety switches in the post-global-savings-glut period in advanced economies. I repeat the analysis for the pre-2003 period and for emerging economies, and then controlling for credit ratings (both level and change) and dropping crisis periods. The results for GDP and government spending are summarized in Table 1.2. One thing that is immediately apparent is that, in line with our earlier intuition, the macroeconomic relevance of safety switches does indeed appear to be a phenomenon strictly related to the global savings glut in advanced economies, seeing as the coefficients are not significant for the pre-2003 period and for emerging economies. One point worth noting, for the pre-2003 estimates, is that the sample only begins in 1991, due to the availability of the Bloomberg bond data that was used to define safety switches in the first place. As a result, the finding do not necessarily generalize to the pre-1991 period as well, since that is not covered in this analysis. It may be that they are just specific to the 1990s.

The table also shows that the magnitude and significance of the results are not affected when controlling for ratings. This suggests that safety switches pick up distinctive dynamics that are not fully captured by ratings alone. There are a few reasons why credit ratings might not be able to fully capture all the switches. First of all, ratings focus on default risk for long-term debt, whereas the switches are isolated by relying on the behavior of short-term debt prices. Switches might also be short-lived, while ratings might be updated with considerable delays, so that by the time the agency decides to change the rating, there is no reason to do so anymore. The lag in rating changes is an issue that has been raised often, most recently in response to Fitch's downgrade of US debt in August 2023.[17] The US downgrade also provides a complementary example to the above graphs: while the plots show that changes in ratings are not a necessary condition for switches, Fitch's downgrade shows that they are not a sufficient condition either, since the US status as a safe asset appeared unaffected by the event, at least for the time being.[18] Finally, there might be a degree of discretion, biases, and political considerations that further affect the timing of and decision to change ratings, especially when it comes to downgrades.[19]

Table 1.2: GDP dynamics ($h = 4$) around safety switches, different samples and robustness

	GDP		**gov.t spending**	
	positive switch	negative switch	positive switch	negative switch
Baseline	0.93^{***} (0.34)	-0.84^{***} (0.27)	0.50^{*} (0.26)	-0.79^{*} (0.46)
N	979	979	979	979
Pre-2003	-0.14 (0.21)	-0.66 (0.46)	0.05 (0.31)	-0.12 (0.38)
N	638	638	596	596
Emerging economies	0.31 (0.37)	-0.52 (0.62)	0.37 (0.81)	0.12 (0.72)
N	557	557	551	551
Controlling for rating	0.87^{***} (0.36)	-0.67^{***} (0.27)	0.44^{*} (0.26)	-0.75^{*} (0.40)
N	978	978	978	978
Dropping crises	0.78^{***} (0.28)	-0.57^{**} (0.27)	0.21^{***} (0.08)	-0.35^{*} (0.20)
N	671	671	671	671

Note: The table reports the estimated $\hat{\lambda}_h$ obtained by running regression (1.32) for GDP for positive ($s = +$) and negative ($s = -$) switches, at a selected horizon and with different samples and specifications. *, **,*** indicate significance at 10%, 5% and 1%, respectively.

Lastly, the table shows that the results are not entirely driven by crisis periods. When dropping the financial crisis, the euro debt crisis, and Covid, the coefficients definitely get smaller in magnitude, and those for government spending in particular get more than halved. Still, they remain significant: this suggests that, while some of the macroeconomic fluctuations picked up by the switches are those associated with these periods of turmoil, there are

[17]For instance, US Treasury Secretary Janet Yellen called the downgrade "arbitrary and based on outdated data" (Barbuscia 2023).

[18]Treasury Assistant Secretary for Financial Markets Josh Frost said: "We see limited or no impact on yields or prices" (McCormick 2023).

[19]See, for instance, Kiff et al. (2010).

still important switches outside of these downturns periods and the corresponding dynamics are not unique to periods of crisis.

VII Conclusion

This paper presents a model for thinking about sovereign safety and for defining it in a way that can be taken to the data. It introduces a novel, news-based index of global demand for safe assets, the FLY, which picks up relevant flight-to-safety episodes and the global savings glut, is priced in the cross-section of sovereign bond returns, and predicts movements in the natural interest rate. It then proposes a methodology that exploits the FLY to identify switches in a bond's safety through changes in the sign and significance of its loading on the index. Safety switches are common and are associated with sizable movements in macroeconomic variables: positive switches (i.e. becoming safe) are associated with expansions, increases in government spending, and higher debt; conversely, negative switches (i.e. becoming risky) are associated with contractions, decreases in government spending, and lower debt with a shorter maturity structure. These results are attributable to advanced economies in the post-global- savings-glut period and they cannot be explained by credit ratings or crises periods alone.

The findings have potentially relevant policy implications. The relationship between the FLY and the natural interest rate and the presence of a safety premium in the cross-section of global sovereign bond returns highlight the impact that worldwide savings patterns and hunger for safe assets can have for international interest rates, bond markets, and the financial system as a whole. At the country level, the shortening of debt maturity in response to negative switches, in particular, suggests potential consequences for countries' fragility, so it might be in the interest of the government to build buffers of long term debt when the conditions allow it outside of switching periods. Symmetrically, positive switches do seem to provide additional fiscal space that the government uses to finance more spending. Exploiting the benefits of positive switches productively seems desirable, but should not come at the cost of eroding the fiscal situation of the country, as that could ultimately prove detrimental if the safe-asset status is lost again – something poorer fiscal fundamentals might also directly contribute to.

CHAPTER 2

Whatever-It-Takes Policymaking During the Pandemic

with Kathryn M.E. Dominguez

I Introduction

Former ECB President Mario Draghi is credited with resolving the euro crisis based on his promise to do whatever-it-takes to preserve the euro. In September 2022, the Bank of England echoed the phrase in its announcement that it would purchase long-dated UK government bonds on whatever scale necessary to restore orderly conditions in the gilt market. Likewise, during both the global financial crisis and the pandemic, many central banks established facilities to restore market liquidity and support aggregate demand with an explicitly open-ended set of provisions.[1] Would market reactions to these policy announcements have been as strong in the absence of this ramping up in scale and communication strategy? This paper examines this question by testing whether the whatever-it-takes asset purchase policies announced during the pandemic had larger effects than those with explicit limits on scale.

Central banks across the globe introduced extraordinary policies to address the unprecedented circumstances experienced during the global pandemic. This project categorizes these central bank pandemic-related policy announcements as whatever-it-takes or limited in scale, based on the texts of the announcement press releases, post-announcement press-conference statements, and news coverage of the announcements in the financial press. Documenting the accompanying post-announcement news is important, because it often clarifies central bank intentions. In some cases central bank press releases indicate an open-ended commitment, but subsequent statements suggest that there are significant limits to their firepower.[2]

[1]Examples of these types of facilities are described in detail in Buiter et al. (2023).

[2]In some cases central banks may be intentionally fuzzy because fiscal backstop limits are unclear, in other cases central banks themselves may not know how long they will be willing to do whatever-it-takes. Other potential constraints arise if the country prioritizes exchange rate stability or if central bank solvency

In yet other situations, central banks announce size-limited policies, but the size is so unprecedented that markets consider the announcement as a whatever-it-takes moment.

This paper examines market reactions to pandemic-related monetary policy announcements involving asset purchases by a wide array of central banks over the period March 2020 through December 2021. We ask which announcements had the largest impact and whether the way that policies were communicated to the market mattered. In the midst of the financial and economic turmoil it seems likely that countries were influenced by the types of policies and announcements made by other countries, which we describe as peer-pressure-induced policy. Countries are also influenced by the severity of the impacts of the pandemic on domestic economic conditions, which we describe as desperate-times[3] policy. We control for these potential foreign country spillovers and own-country pressures in the analysis and distinguish the impacts of whatever-it-takes announcements relative to similar, but size-limited, policy announcements. Importantly, we measure the effects of the announcement, not the implementation of the policy. In many cases, the size of the ultimate asset purchases was far lower than what markets anticipated based on asset price reactions at the time of announcement. An extreme example of this comes from Draghi's now-famous speech in 2012, which resulted in the creation of the Outright Monetary Transaction facility (OMT) that was never tapped.[4]

Our empirical strategy involves using a combination of event study, propensity score matching, and local projection methods to measure the short-term effects of pandemic-related central bank policy announcements on exchange rates and sovereign bond yields. We find evidence that expansionary whatever-it-takes policies during the pandemic have stronger effects on asset prices than do size-limited announcements, suggesting that communication of potential policy scale matters. We also find that subsequent whatever-it-takes announcements have little additional impact, suggesting that markets already priced in these policies at the time of the initial announcement. On average a central bank's first whatever-it-takes announcement lowers 10-year bond yields by an additional 47 basis points relative to size-limited announcements. Our results for yields hold for both advanced and emerging economies, while exchange rates go in opposing directions, muting their response when we

is in question.

[3]The expression "desperate times call for desperate measures" is attributed to Hippocrates.

[4]Draghi's speech where he used the phrase "whatever it takes," but did not provide any specific policy announcement, was on 26 July 2012. Policy specifics followed in two announcements outlining the terms of the Outright Monetary Transactions (OMT) facility, which allowed the ECB to purchase 1-3 year maturity Eurozone sovereign bonds subject to EFSF/ESM conditionality. The OMT was introduced on 2 August and technical details were released on 6 September. Market reaction to the three 2012 announcements is described in Krishnamurthy et al. (2018), the average yield response across Eurozone countries was between 34 and 63 basis points. No asset purchases were ever made using the OMT, so it is an extreme example of a pure announcement effect.

group all countries together.

Background and Related Literature China was the first country to lockdown cities in January 2020 in order to reduce the spread of Covid-19 transmission. Numerous other countries followed suit, along with issuing travel bans. The World Health Organization declared Covid-19 a global pandemic on 11 March 2020. By the end of March 2020, over half of the world's population was under some form of stay-at-home mandate. Many businesses were forced to close down, and global economic activity fell sharply. Reactions in the financial markets were immediate and severe: corporate spreads surged, equity prices tumbled, and implied volatilities for a wide range of assets jumped dramatically. Businesses and households around the globe dashed-for-cash as confidence in the financial sector plummeted. Governments responded to the crisis with a range of health-related and fiscal policy announcements, with the underlying objective of providing citizens with resources to cushion the impacts of a sudden reduction in economic activity. Likewise, central banks around the globe announced expansionary monetary policies to support aggregate demand and restore the smooth functioning of financial markets.

The Bank of Canada, the European Central Bank, the Bank of Mexico, and the Federal Reserve were the first in a long line of central banks that announced expansions of asset-purchasing facilities to help stabilize financial markets on 12 March 2020.[5] In most cases, advanced economy central banks had used quantitative easing (QE) measures during and in the aftermath of the global financial crisis in 2008, and had continued to expand their balance sheets in the years prior to the pandemic. The pandemic-related central bank announcements were, as a consequence, not introducing new policy tools; they were instead emphasizing the greatly expanded potential size of the interventions they would be willing to take to counteract the negative impacts of the pandemic on financial markets. In many cases, the announcement was not just that the size of operations would increase, but that they could increase by an open-ended amount.

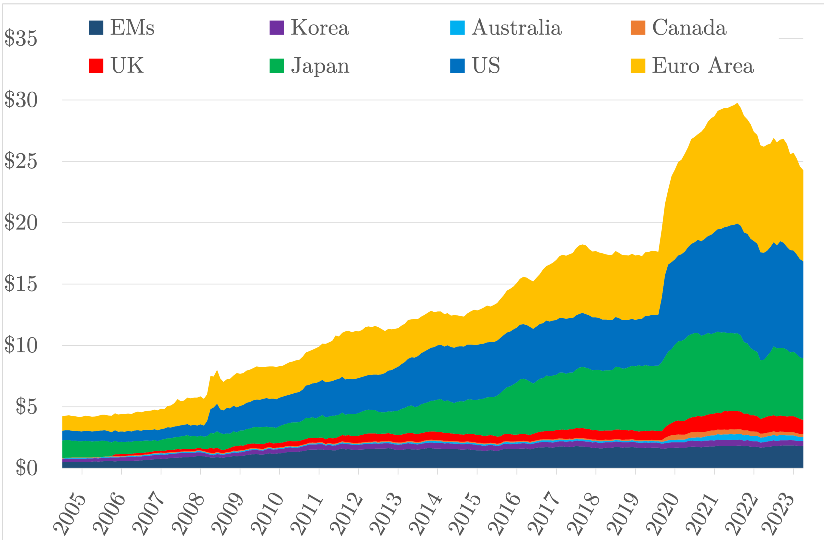
In emerging markets, only the central banks of Hungary and Colombia had pre-existing asset purchasing programs prior to the pandemic, so in the rest of the cases these programs were established for the first time in reaction to the extraordinary circumstances brought about by the pandemic. The central banks of Brazil and Chile needed changes to the legal framework from their legislative branches to allow them to purchase public debt. As was

[5]The Bank of Canada announced the expansion of various programs over multiple days in March 2020. The first time the press release stated purchases would be open-ended was on 27 March, but news reports suggest that it was the first BoC announcement on 12 March that was considered its first whatever-it-takes moment. Arora et al. (2021) only study the announcement on 27 March and find that it reduced Government of Canada bond yields by 10 to 15 basis points.

the case for many of the advanced economies, programs in emerging economies included purchases of private sector assets and well as government bonds, public agency assets and provincial and municipal bonds.

Central banks did not just say that they would purchase assets, they did so on an unprecedented scale. Figure 2.1 shows the dramatic increase in central bank balance sheets during the pandemic. The Bank of Japan's assets as a percent of GDP (103% in 2019) expanded by 21% between 2020 and 2021; the Federal Reserve (by 22%) and the ECB (by 33%) also greatly increased the size of their balance sheets as a result of pandemic-era operations. Emerging market (EM) countries did not expand on the same scale. Among EMs the central banks of Hungary, the Philippines and Poland saw the largest expansion of assets at around 6% of 2019 GDP over the two year period. Many central banks also expanded the range of assets they were willing to purchase, including corporate bonds, commercial paper and asset-backed securities, though the largest share of purchases were government securities.

Figure 2.1: Assets on Central Bank Balance Sheets (Trillions of US$)



Source: Country Central Banks.

Measuring the impacts of monetary policy is always complicated by the fact that economic conditions typically drive policy changes. Central banks do not randomly announce policy changes and this is likely to be especially the case for whatever-it-takes announcements: central banks 'go big' in times of crisis. An important reason to emphasize the open-ended size of an intervention is presumably because a similar, but size-limited, intervention might not be large enough to restore confidence.[6]

[6]Haddad et al. (2023) consider the possibility that all policy announcements have a whatever-it-takes

Most of the whatever-it-takes monetary policy announcements in this time period involved asset purchasing facilities that allowed central banks to expand their balance sheets with a wide array of assets. The first of these announcements by the Federal Reserve on March 15, 2020 stated that the objective was "to support the smooth functioning of markets for Treasury securities and agency mortgage-backed securities that are central to the flow of credit to households and businesses," (Federal Reserve, 2020).[7] In a related set of actions, the Federal Reserve announced a number of other (size limited) measures expanding access to the discount window, intraday credit, bank capital and liquidity buffers, reserve requirements and dollar liquidity swap line arrangements.[8] The package of announcements seems to have been designed to shock-and-awe market participants in order to restore confidence in financial markets as well as provide aggregate demand stimulus by resuming quantitative easing (QE).[9]

Monetary policies, including QE policies, can impact asset prices through at least two channels: by changing expectations through the signaling channel; and through liquidity and portfolio balance effects, in models that allow for financial and goods market frictions.[10] Examples of models in which QE can affect interest rates and exchange rates include Woodford (2012), Farhi and Gabaix (2016), Gourinchas et al. (2022) and Greenwood et al. (2020).[11] In these models, the signaling channel can operate on expected values of forward looking asset prices at the time of a policy announcement. No actual asset purchases are needed in order for changes in expectations to impact market prices. All that is needed is some form

element because market participants view policies as state-contingent, expecting more support in bad states. They suggest that large announcement impacts incorporate a "policy put" that reflects the expectation that additional interventions will be made if economic conditions worsen. Our study tests whether policy announcements that are explicitly limited in size differ from those that are perceived as open-ended, and find evidence that the distinction matters, suggesting that the policy put is not fully priced.

[7]https://www.federalreserve.gov/newsevents/pressreleases/monetary20200315a.htm

[8]Countries that relied heavily on dollar funding were especially hard hit by the global fall in dollar liquidity in March 2020. The Federal Reserve responded to this stress in the dollar market by reopening swap lines with an expanded list of countries and establishing the FIMA Repo Facility for countries without access to swap lines. This allowed central banks to obtain dollars by pledging US Treasuries as collateral. Countries with standing swap lines with the US include: Canada, Euro area, Japan, UK and Switzerland. The expanded list of countries that were given access to swap lines included: Australia, Brazil, Korea, Mexico, Singapore, Sweden, Denmark, New Zealand and Norway.

[9]English et al. (2022) note that along with the unprecedented size of many of the pandemic-era asset-purchase programs, the speed at which these purchases were made is also notable. They provide the example of the Bank of England which purchased bonds in 2020 at almost twice the pace as in the initial phase of QE in 2008.

[10]Bhattarai and Neely (2022) provide a comprehensive survey of macro models where QE and other unconventional monetary policies, regardless of size, have no impact, as well as what assumptions are needed for these policies to matter. Likewise, Borio and Zabai (2018) describe the range of unconventional monetary measures that central banks have taken, and what we know about their influence on financial conditions and the macro-economy. These papers, however, do not distinguish whatever-it-takes QE from size-limited QE policies.

[11]In Dedola et al. (2021) expansionary relative QE shocks exacerbate limits to arbitrage in foreign exchange markets by widening CIP deviations.

of friction that allows the announcement to provide new market-relevant information. In contrast, the liquidity and portfolio balance channels require actual asset purchases. Central banks can reduce liquidity premia on bonds by reducing the risk that bonds will be difficult to sell. Asset purchases can also impact the prices of specific bonds by changing the quantity and composition of private asset holdings. Asset purchase programs tend to reduce exposure to credit risk as central banks exchange safer assets for private sector holdings of riskier assets.

Studies of announcements of size-limited QE measures prior to the pandemic find that they are often associated with significant depreciations of the currency of the announcing central bank and declines in bond yields. The first QE announcement by the Federal Reserve on 25 November 2008 led the dollar to depreciate by approximately 4% (Greenwood et al. 2020) and for average declines in yields of around 40 basis points (Gagnon et al. 2011). The European Central Bank's size-limited securities market program (SMP) announcement on 10 May 2010 led to an average decline in yields (across the Eurozone countries) of 190 basis points (Krishnamurthy et al. 2018).[12] The Bank of England's 4 March 2009 size-limited QE announcement led to a 100 basis point decline in the 10-year Gilt yield. Few developing countries used QE prior to the pandemic, so we do not have similar estimates for comparison. Rebucci et al. (2022) examine the pandemic-era QE announcements and find that one-day impact effects were larger for emerging market QE announcements than for advanced countries. They find a statistically significant overall average one-day decline of 23 basis points on 10-year yields, with the largest impact coming from the Romanian announcement on 20 March 2020 that led to a 150 basis points decline.

Dedola et al. (2021) examine the longer term effects of QE on bilateral exchange rates, emphasizing the need to take into account the relative QE actions of the two relevant central banks. They use the announcements of QE measures as instruments for changes in relative central bank balance sheets and find that a typical QE announcement by either the Federal Reserve or the ECB led to a persistent exchange rate depreciation of around 7%. Importantly, in their approach, the focus is on actual relative changes in central bank balance sheets. Whatever-it-takes announcements that do not result in asset purchases, like the original one by Draghi, cannot be examined in their framework.

The impact of policy changes during the pandemic was also likely to be influenced by Covid-19 fundamentals. Davis and Zlate (2022) find that Covid-19 infection rates − which differed in timing and intensity across countries − affected the sensitivity of exchange rates

[12] The ECB's first explicit QE program, the Public Sector Purchase Programme (PSPP), was announced on 22 January 2015. Along with the 2010 SMP, in 2009 and 2011 the ECB announced covered bond purchase programmes, and in 2012 it established the Outright Monetary Transactions programme, but none of these were officially described as QE facilities by the ECB.

and capital flows to the global financial cycle[13] and explain a larger share of cross country heterogeneity in the early months of the pandemic than traditional macroeconomic fundamentals. During the pandemic, measures of the global financial cycle fell sharply, most currencies depreciated relative to the U.S. dollar and capital flows fell across the board, but they fell by more for countries and during episodes with larger increases in Covid cases.

Figure 2.2 plots three trade-weighted dollar exchange rate indices: a broad one based on the dollar exchange rate against all major US trading partners, and then two narrower indices based on subsets of the same currencies, separating advanced economies and emerging markets. Vertical lines denote announcements of open-ended sovereign bond purchases made by the Federal Reserve, identified according to our methodology. The plot shows that the dollar appreciated sharply against all currencies in the early days of the pandemic, but the appreciation was steeper with respect to emerging market currencies. The steepest period of dollar appreciation coincided with the bulk of the Fed's initial whatever-it-takes announcements (along with announcements of a number of other facilities). As investors were dashing for cash, and especially for dollars, in this period, it is hard to disentangle the flight-to-safety dynamics from the concomitant announcement of open-ended asset purchases. It seems likely that the announcements reinforced the dollar's safe status (a point we will come back to later). Subsequent Fed announcements seem to be associated with both appreciations and depreciations.

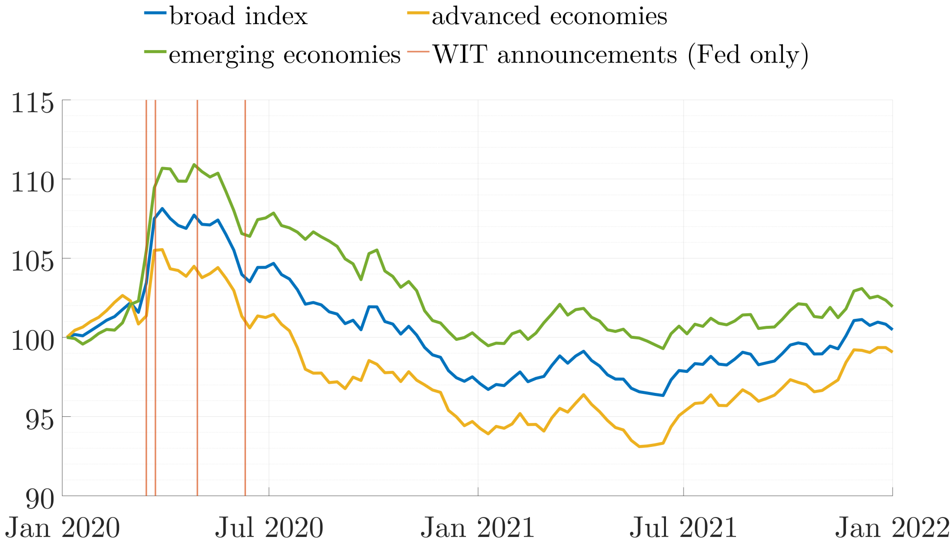
Figure 2.3 plots an index capturing the global behavior of 10-year sovereign bond yields. We construct this as an average of the 10-year sovereign bond yields of the countries in our dataset of central bank announcements, weighted by their 2019 PPP GDP.[14] Vertical red lines mark all whatever-it-takes asset-purchase announcements involving sovereign bonds made by central banks around the world, identified according to our methodology. A quick glance at the plot immediately reveals the spike in global yields at the beginning of March 2020, and a clustering of whatever-it-takes announcements crowding the same weeks. Yields peak on 24 March and then start declining, the day after the Fed unleashed its bazooka[15] involving four asset-purchase facilities in what newspapers named "Jerome Powell's whatever-it-takes moment". Notable downward movements in the yield index are punctuated by many other

[13]The global financial cycle is estimated in Miranda-Agrippino and Rey (2020) as a common component in a wide sample of advanced and emerging market asset prices at a monthly frequency.

[14]We drop Chile, India, and the Philippines, for which local-currency 10Y yields are not available for this period. For the euro area, we include Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal, and Slovakia.

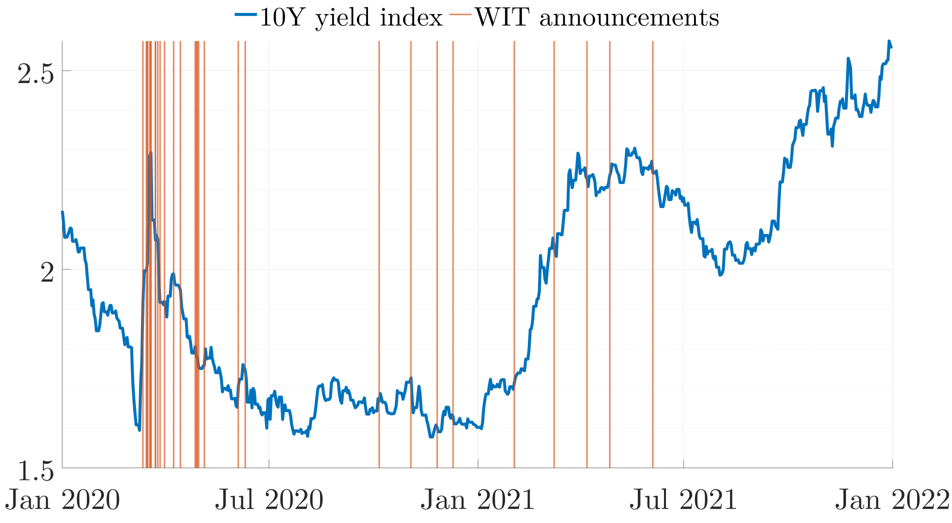
[15]The word is an extension of bazoo, a slang term for "mouth" or "boastful talk" (1877), which is probably from Dutch bazuin "trumpet." The Fed announcement included expanding the QE program to include purchases of commercial MBS, establishing two new facilities (the Primary Market Corporate Credit Facility and the Secondary Market Corporate Credit Facility), reestablishing the Term Asset-Backed Securities Loan Facility (TALF), along with expansions of other facilities.

Figure 2.2: Figure 2a: USD exchange rate indices



Source: Federal Reserve Bank of St Louis; announcement data from Cantú et al. (2021), classification as whatever-it-takes (WIT) by authors based on central bank press release and subsequent news coverage.

Figure 2.3: Figure 2b: Global GDP-weighted 10-year yield index



Source: World Bank (GDP); Bloomberg (yields); announcement data from Cantú et al. (2021), classification as whatever-it-takes (WIT) by authors based on central bank press release and subsequent news coverage.

open-ended asset purchases announcements, including another WIT announcement by the Fed on 29 April, Christine Lagarde's own newspaper-coined whatever-it-takes moment on 4 June, and similar announcements in other countries that came later (for instance, Hungary on 6 October and Australia on 3 November). Of course, it was not just policy that mattered; improvements in the underlying global Covid situation also contributed to lowering yields. Yields later surged again in 2021, driven especially by the yields of advanced economies, as the outlook for recovery improved and inflation expectations rose. Whatever-it-takes announcements got sparser during this period and were concentrated in a handful of countries (Australia, Hungary, India, and Japan).

II Categorizing Announcements using Press Releases and Newspaper Reports

The pandemic-era central bank announcements used in our study are collected and described in Cantú et al. (2021). These authors created a database of policy measures together with links to accompanying press statements that provide the timing and details of each announcement. In some cases these press statements are explicit about the size and limited duration of the facility, and in others the language indicates that the central bank is prepared to intervene by as much, and for as long, as needed. In this section, we describe how we categorize the central bank sovereign bond asset-purchase announcements used in our empirical analysis.

Our study aims to distinguish the impacts of open-ended policies from those with explicit limits; therefore, along with using the information provided by each central bank at the time of an announcement in the press-release, as well as statements made in the post-announcement press conferences, we also use the Factiva search engine to understand how the financial media describe the announced policies.[16] There are cases where the press release suggests a size-limited policy announcement, but news reports describe the policy as unprecedented and expansive, often based on subsequent statements made during the post-announcement press conference. It seems likely that central banks purposely invoked constructive ambiguity in some of these cases in order to win over financial markets. This intentional ambiguity required us to take a narrative approach that involved reading both

[16] We filter the Factiva search on each announcement day to include articles in global and local news sources that include the terms "asset*" and "purchas*" within 3 words, "monetary policy", "central bank", and the country's name or the central bank's name when it does not contain the country's name (e.g., the Fed or the Riksbank). Our search window goes from the day of the announcement out one week to ensure that all relevant articles reporting on the announcement are included. Central Bank announcement dates are from Cantú et al. (2021).

the press releases and the accompanying news reports to ultimately code each announcement as limited or open-ended, rather than rely on an algorithmic method or text analysis.

Two instructive examples of the difficulty of categorizing policies include two of the ECB and Fed's announcements in March 2020. The European Central Bank's 18 March 2020 announcement of the Pandemic Emergency Purchase Programme (PEPP) included the size and duration of the program (€750 billion until the end of 2020), along with the statement, "The Governing Council will do everything necessary within its mandate. The Governing Council is fully prepared to increase the size of its asset purchase programmes and adjust their composition, by as much as necessary and for as long as needed." [17] We categorize this announcement as open-ended based on this expansive description of the program, even though an explicit size was also announced. Likewise, the Federal Reserve FOMC press release on 15 March 2020 states that "it will increase its holdings of Treasury securities by at least $500 billion and its holdings of agency mortgage-backed securities by at least $200 billion." [18] At the press conference directly after the FOMC meeting, Chair Powell clarified that the $500 billion is a floor, but there is no ceiling. This whatever-it-takes clarification was a central feature of the news coverage of the Fed's announcement and led us to classify it as open-ended.

We code announcements as open-ended in all cases where expansive language is included, potentially downward biasing our results. An example of this is the announcement by the Reserve Bank of Australia on 5 May 2020. In this case, the press release itself is a bit confusing. It states that the RBA "has scaled back the size and frequency of bond purchases, which to date have totaled around $50 billion. The Bank is prepared to scale-up these purchases again and will do whatever is necessary to ensure bond markets remain functional and to achieve the yield target for 3-year AGS [Australian Government Securities]." [19] The news coverage of this announcement focused on the fact that purchases were scaled back: the potential for reversing course and do "whatever is necessary", if needed, did not receive as much attention. Nevertheless, because the press-release language includes an open-ended promise we code the announcement as whatever-it-takes. Likewise, the Bank of England's 19 March 2020 announcement included a limit to how much would be purchased combined with language that they would "do what was necessary," leading us to classify it as open-ended. In robustness tests we check whether dropping ambiguous announcements matters and find no evidence that these announcements are driving results.

Central banks made 166 asset-purchase announcements over 96 days during the period

[17] https://www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr200318_1 3949d6f266.en.html

[18] https://www.federalreserve.gov/newsevents/pressreleases/monetary20200315a.htm

[19] https://www.rba.gov.au/media-releases/2020/mr-20-13.html

from March 2020 to December 2021. Of these announcements, 120 (72%) are coded as limited in size. Of the 46 open-ended announcements, 14 make explicit reference to the phrase whatever-it-takes either in the press-release, press-conference, or in the news coverage. Our analysis starts with the full range of central bank asset-purchase announcements, and then focuses just on announcements of sovereign bond purchases (which reduces the total number of announcements to 105 over 73 days). In our full sample of announcements there are 23 dates on which multiple central banks made announcements and 26 dates on which the same central bank made multiple announcements. Our daily analysis is unable to disentangle the impacts of specific announcements on these dates, though we do test whether financial market reactions on dates with multiple announcements are larger than impacts on dates with a single announcement.

Table 2.1 lists the 22 central banks that announced asset-purchasing programs during the pandemic, the date of their first announcement, the total number of announcements made by each central bank, and the percent of these announcements that we code as open-ended in scale. In our empirical work we compare the exchange rate and bond market reactions to the announcements that are explicitly size-limited to those that are open-ended.[20] We also group announcements in four additional ways. First, we narrow the announcements to those involving purchases of sovereign bonds in order to focus on similar policies across countries. Second, we look at advanced economy announcements separately from those made by emerging market countries. In asset pricing models, only shocks, whether exogenous or the surprise component of policy news, should lead to market reactions. Information that is expected will already be priced by markets. In the case of advanced economy pandemic-related asset-purchase announcements, some part of the information is likely to have been expected by markets, based on their actions during the 2008 financial crisis and the wide use of QE in the subsequent years. Few central banks in emerging market countries had previously used QE policies, so their pandemic-related asset-purchase announcements were likely to have been more surprising. Third, we look at the first whatever-it-takes announcement separately from subsequent open-ended announcements, and do the same for the first size-limited announcement. The first announcement at the start of the pandemic is likely to have more of a surprise-factor than succeeding announcements. Bernanke (2020) and Haddad et al. (2023) also find that the initial announcements of QE by the Federal Reserve and the ECB had larger effects on asset prices than did succeeding announcements.[21] Fourth,

[20] Our robustness tests exclude the announcements that are ambiguous, either because they include limits in the press release, or because the news reports suggest markets are skeptical that the policy is open-ended. Results are qualitatively the same when we exclude all ambiguous announcements at once, as well as one at a time, indicating that none of these announcements are driving the results.

[21] Vissing-Jørgensen (2021) studies the effects of the Federal Reserve March 2020 announcements as well

Table 2.1: Central Bank Asset-Purchase Announcements

Country	**Date of First Announcement**	**Number of Announcements**	**No. Open-ended**	**% Open-ended**
Canada	12/03/20	23	3	13%
Euro Area	12/03/20	13	6	46%
United States	12/03/20	25	11	44%
Mexico	12/03/20	2	0	0%
Japan	13/03/20	11	4	36%
Israel	15/03/20	4	0	0%
Sweden	16/03/20	7	1	14%
Poland	16/03/20	2	2	100%
Chile	16/03/20	9	0	0%
United Kingdom	17/03/20	7	2	29%
India	18/03/20	6	2	33%
Australia	19/03/20	9	6	67%
Korea	19/03/20	7	0	0%
Romania	20/03/20	1	0	0%
Thailand	22/03/20	2	0	0%
Colombia	23/03/20	4	2	50%
New Zealand	23/03/20	5	0	0%
South Africa	25/03/20	1	1	100%
Turkey	31/03/20	2	1	50%
Indonesia	01/04/20	3	0	0%
Hungary	07/04/20	22	5	23%
Philippines	10/04/20	1	0	0%
Total		166	46	28%

Source: Announcement data from Cantú et al. (2021), classification as open-ended by authors based on central bank press release and subsequent news coverage.

we distinguish those announcements that literally use the phrase "whatever-it-takes" in describing the policy either in the press release, the post-announcement press conference, or in the news coverage of the announcement.

as actual asset purchases on high frequency data from Treasury futures. She finds a causal link from asset purchases, not announcements, to yield declines and suggests that the severe liquidity needs of sectors that were heavy sellers of Treasuries required large actual purchases to stabilize the market. Swanson (2021) also takes a high-frequency (30 min) approach to identify the immediate causal effect of asset-purchase announcements on a broad set of asset prices in the pre-pandemic period and finds impacts that are significant and comparable to those of conventional monetary policy.

Table 2.2: First Open-ended Sovereign Bond Purchase Program, Announcement Dates by Country

Advanced Economies	**Date**	**Announcement**
Bank of Canada	12/03/20	Expansion of Bond Buyback Program
Federal Reserve Board	15/03/20	Asset Purchase Program
Bank of Japan	16/03/20	Government Bond Purchases
European Central Bank	18/03/20	Pandemic Emergency Purchase Program (PEPP)
Bank of England	19/03/20	Government Bond Purchases
Reserve Bank of Australia	19/03/20	Government bond purchases
Sveriges Riksbank	26/11/20	Asset Purchase Program
Emerging Economies		
National Bank of Poland	16/03/20	Treasury Bond Purchases
Central Bank of Colombia	23/03/20	Government Bond Purchases
South African Reserve Bank	25/03/20	Government Security Purchases
Central Bank of the Republic of Turkey	31/03/20	Government Domestic Debt Securities (GDDS)
Hungarian National Bank	28/04/20	Government Security Purchase Program
Central Bank of India	07/04/21	Government Security Purchases

Source: Announcement data from Cantú et al. (2021), classification as open-ended by authors based on central bank press release and subsequent news coverage.

Our main set of empirical analyses uses daily data. We use US dollar exchange rates from the Bank for International Settlements online statistics, which in turn are sourced from the ECB and the Federal Reserve.[22] Exchange rates are measured between 13:15 and 17:00 GMT. For the US, we look at the exchange rate against the euro. All exchange rates are quoted so that an increase corresponds to an appreciation. Local-currency-denominated sovereign bond yields are from Bloomberg, covering maturities between 3 months and 10 years. We focus on results for the 10-year yield in the main text, but results for other maturities are contained in the appendix. Daily Covid-19 cases are from the World Health Organization.[23] The daily Economic Policy Uncertainty (EPU) index is computed by Baker et al. (2016).[24] Central bank announcements are from Cantú et al. (2021).[25] We provide a robustness test of our daily results by focusing on intraday impacts of ECB announcements using tick-data described in Altavilla et al. (2019).

[22] https://www.bis.org/statistics/xrusd.htm?m=2675
[23] https://covid19.who.int/data
[24] https://www.policyuncertainty.com/index.html
[25] https://www.bis.org/publ/work934.htm

III Event Study Analysis

During the pandemic, governments and central banks announced policy changes to address the negative impacts of business closures and financial market turmoil.[26] In some cases, the announcements were explicitly open-ended. In many other cases, announced new facilities included specific size and time limits. Market reactions to these different types of announcements are likely to differ.

If we start with an initial price of an asset, p_0 at time 0, it should reflect the expected value of the asset in the next period, so that: $p_0 = \mathbb{E}[p_1]$. If a size-limited asset-purchase policy is announced at time 0, this tells the market that the central bank will purchase a quantity Q of the asset by a specific date. To keep things simple, let that policy end-date be time 1 and assume that M is the known price impact of a Q-sized purchase of the asset. This suggests that the post-announcement price of the asset at time 1 is $p_1^A = p_1(1 + MQ)$ and at time 0 it is $p_0^A = \mathbb{E}[p_1](1 + MQ)$.[27] It is straightforward from this to relate the change in the asset price before and after the announcement, $\frac{p_0^A - p_0}{p_0}$, to MQ.

In the case of an open-ended policy announcement where Q is not defined, the post-announcement price will be based on an expectation of Q. Our setup allows for the possibility that policymakers decline to explicitly define Q so that this market expectation will exceed the Q that would have been announced in normal times. In Haddad et al. (2023), all announcements are modeled as conditional promises, so that markets expect policymakers to scale-up policy by an additional amount Q^* if economic conditions deteriorate in time 1 (which is equivalent to the asset price falling below a cutoff value p^*). The post-announcement price at time 0 in this setting includes the baseline case with a known Q (and M), and an additional term multiplied by MQ^* that includes the expected probability that $p_1 \leq p^*$:

$$P_0^A = \mathbb{E}[p_1] + \mathbb{E}[p_1]MQ + \mathbb{E}[p_1 \cdot \mathbb{1}_{\{p_1 \leq p*\}}]MQ^* \ . \tag{2.1}$$

In our setup, the post-announcement asset price change for announcements that are limited in size and scope should be based on the information policymakers provide about Q and views about M. The size of the post-announcement asset price change after whatever-it-takes announcements are less clear-cut, but we will test whether it exceeds the size of the Q-baseline case. In the case of central bank asset purchases, credibility is likely to be higher than it will be for some other government policies, given that central banks have the unique

[26] Bergant and Forbes (2022) examine how countries decide on specific policy packages, looking at a wide array of policies, including fiscal, monetary, foreign exchange intervention and macroprudential regulation. Interestingly, they find that use of one of these types of policies did not affect a country's use of the other policies.

[27] This notation is the similar to what is used in Haddad et al. (2023).

ability to expand their balance sheets when they choose to do so.[28]

The first step of our analysis is an assessment of the effectiveness of the first whatever-it-takes (we will sometimes abbreviate "whatever it takes" with "WIT" going forward) and the first size-limited announcements. We do this with an event study framework, and specifically with a two-way fixed effect estimator in a staggered dynamic difference-in-differences specification. The choice to focus only on the first announcement is somewhat determined by the event study setup. On the one hand, this methodology is effective for gauging the effect of a single treatment or event, even if it is staggered. On the other hand, however, the shortcoming of the event study approach via this diff-in-diff specification is that it is more appropriate in settings where each group is treated once, and it is not suitable for a situation with repeated treatments, as we have in our case. Indeed, most central banks made several consecutive announcements, and often they were closely timed to each other. As a result, most countries were treated multiple times, and there was no clear "switching off" of the previous treatment before the next one is introduced, so that they effectively overlapped and cumulated, making estimation difficult. For this reason, we limit our event-study analysis only to the first announcement, and we consider this the only treatment experienced by each country. We will expand our analysis to the full set of announcements in the section on the local projections approach to the diff-in-diff analysis.

We begin with an examination of the effects of open-ended sovereign bond purchase announcements on our two outcome variables, exchange rates and yields, around a 15-day window.[29] We measure the impact of the first whatever-it-takes and size-limited announcements by the central banks listed in Table 2.2 on the dollar bilateral rate for non-US announcements and the euro-USD bilateral rate for Federal Reserve announcements as well as own-country

[28]Central banks have the unique ability to create domestic base money, but they cannot create foreign currency legal tender. This means that counties with fixed exchange rates may be subject to greater constraints on their ability to do whatever-it-takes, for fear of triggering a run on the currency. It is also the case that central bank's solvency can be at risk if they suffer substantial losses from intervention-related operations, suggesting that balance sheet exposure and restricted access to fiscal support may also influence the credibility of a whatever-it-takes pronouncement.

[29]Blotevogel et al. (2022) expand the event study specification to include pre-announcement expectations (based on survey data) and post-announcement implementation effects (based on actual asset purchases). In an examination of Euro Area announcements during the pandemic they find large announcement effects, some evidence of pre-announcement expectation effects, and weak implementation effects. These results are in keeping with the larger literature that finds the largest asset pricing effects at the time of announcement.

10-year sovereign yields.[30] Our specification for the exchange rate is as follows:

$$100 \cdot \ln FX_{i,t} = \alpha_i + \alpha_t + \sum_{s=-15}^{-2} \beta_s D_{i,t,s} + \sum_{s=0}^{15} \beta_s D_{i,t,s} + \mathbf{X}_{i,t}\boldsymbol{\gamma} + \varepsilon_{i,t} \ , \tag{2.2}$$

so that the units of the dependent variable correspond to percentages. The specification is similar for the yields, except the dependent variable is in basis points:

$$y_{i,t} = \alpha_i + \alpha_t + \sum_{s=-15}^{-2} \beta_s D_{i,t,s} + \sum_{s=0}^{15} \beta_s D_{i,t,s} + \mathbf{X}_{i,t}\boldsymbol{\gamma} + \varepsilon_{i,t} \ . \tag{2.3}$$

Here, $D_{i,t,s}$ is a dummy variable, equaling 1 if, in period t, country i is s days away from its first whatever-it-takes or limited sovereign bond purchases announcement, and 0 otherwise. We cumulate lags and leads that are farther than 15 days away from the announcement, so that $D_{i,t,-15}$ and $D_{i,t,15}$ are equal to 1 if observation $\{i, t\}$ is 15 or more days earlier or later than the announcement, respectively. Treatment in this context occurs in period 0, and we examine how differences in the outcome variable between treated and untreated countries evolve pre- and post-announcement, relative to their value in the omitted base day, i.e. the day before the announcement. Although in past QE episodes asset prices reacted quickly to central bank announcements, the unusual circumstances of the pandemic may have made it more difficult for markets to process the information revealed in the asset-purchase announcements. This possibility led us to include additional post-announcement days in our estimation window. Importantly, 12 of the 13 first open-ended sovereign bond purchase announcements in our dataset took place in 2020. More specifically, as shown in Table 2.2, 11 of them occurred between March and April, and only two occurred later. As a result, we estimate the regressions using data from 2020 only, so as not to contaminate the control with observations from 2021 that are very distant from the treatment for most of the countries in our sample.

We include country and time-fixed effects as well as a set of control variables $\mathbf{X}_{i,t}$ that are available on a daily basis. Our regression controls capture global, foreign and domestic factors that may be driving policy announcements. These controls allow us to identify the unpredictable component of the policy announcement. We take into account peer effects by including prior whatever-it-takes announcements made by other central banks. The

[30] For the exchange rate, the euro area counts as one country. When looking at yields, we look at individual countries within the currency union: Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal, and Slovakia. For each of these countries, we therefore have the ECB announcements on the right-hand side, and the country's own yield on the left-hand side. The control variables are similarly aggregated and disaggregated depending on the specification.

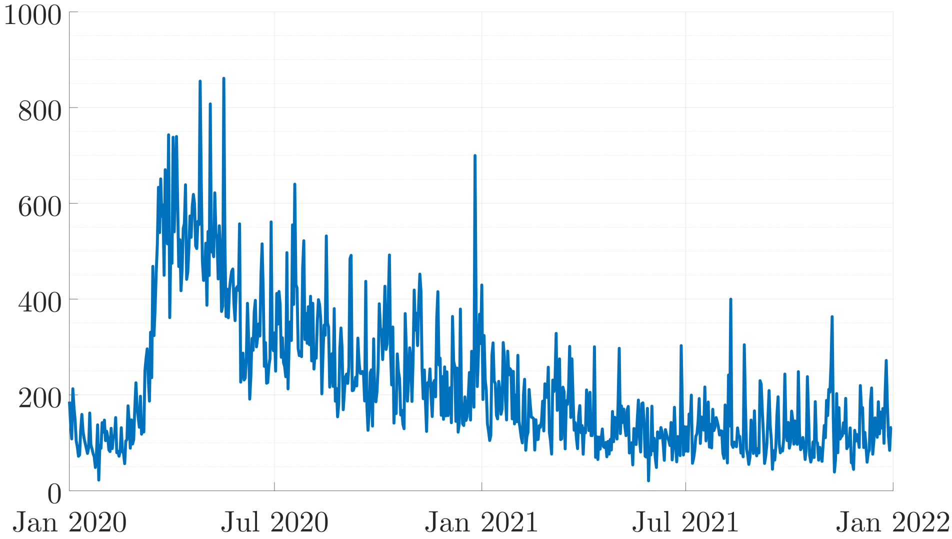
cumulative number of own-country Covid-19 cases is also included as an important economic barometer during the pandemic, and we separately include the global number of Covid-19 cases (excluding own-country cases) as an indicator of worldwide economic conditions. Finally, we include the number of own-country prior limited-size policy announcements. The larger the number of prior policy announcements, the more likely economic circumstances have continued to deteriorate, leading to more expansive (desperate-times) policy measures.

Figures 2.4-2.7 present an overview of the control variables. We begin by plotting the economic policy uncertainty (EPU) index introduced in Baker et al. (2016), which is based on counts of news articles that are related to policy uncertainty, and has been found to be a useful daily predictor of macroeconomic conditions. This is a single time series, so it gets absorbed by the time fixed effects when both are included, but we find either of these controls to be important to take account of the high degree of volatility and uncertainty experienced globally during this period. The Covid cases and cumulative announcements variables have a panel structure given that we include the own-country and rest-of-the-world measures separately. In the plots we provide a global aggregate to show their overall behavior during this period. The first announcements plot shows the steep increase in the number of open-ended announcements in the early days of the pandemic, which coincides with increases in Covid cases and rising uncertainty. Initially the number of WIT announcements grew faster than size-limited ones. In the summer of 2020, the pace of WIT announcements slowed down and eventually plateaued, at the same time the first Covid wave also flattened. Size-limited announcements continued steadily during this period as central banks kept up efforts to sustain the economy. A new wave of open-ended announcements came with the new wave of Covid cases in the fall of 2020. WIT announcements largely ended in the summer of 2021, while size-limited announcements continued through the end of 2021.

The second announcements figure does not explicitly plot variables that we use as controls, but since we focus on sovereign bond purchases announcements only, it shows how these were different from non-sovereign asset purchases. We call an announcement sovereign if at least one of the asset-purchase programs that were announced that day is directed at sovereign bonds. We call it non-sovereign if no sovereign programs were announced on that day. The yellow line corresponds to the sum of the red and green lines in the previous plot. The plot shows that most of the announcements were directed at purchasing sovereign bonds, rather than other assets such as corporate or municipal bonds. This is especially true between March and July of 2020, where sovereign announcements grow much faster than non-sovereign ones.

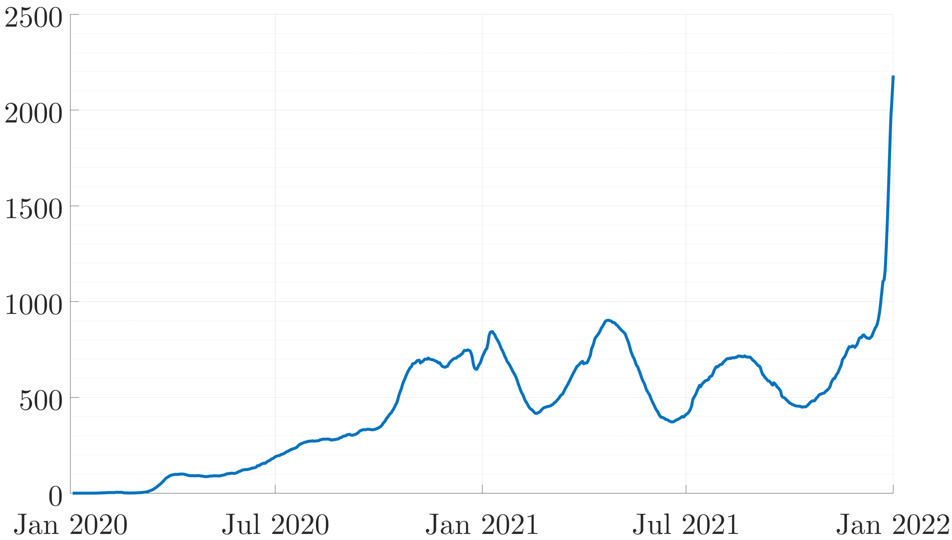
The event study approach focuses on the coefficients that capture the impact of each country's policy announcement on the exchange rate and sovereign yields, relative to the day immediately preceding the announcement. In the figures, the x-axis is measured in

Figure 2.4: Economic Policy Uncertainty Index



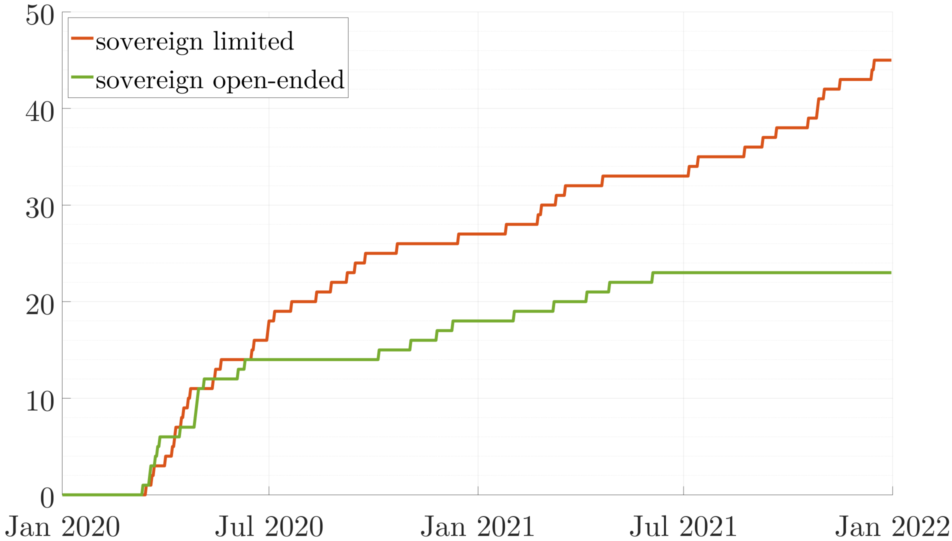
Source: Baker et al. (2016).

Figure 2.5: Number of New Covid-19 Cases Globally (thousands), Weekly MA



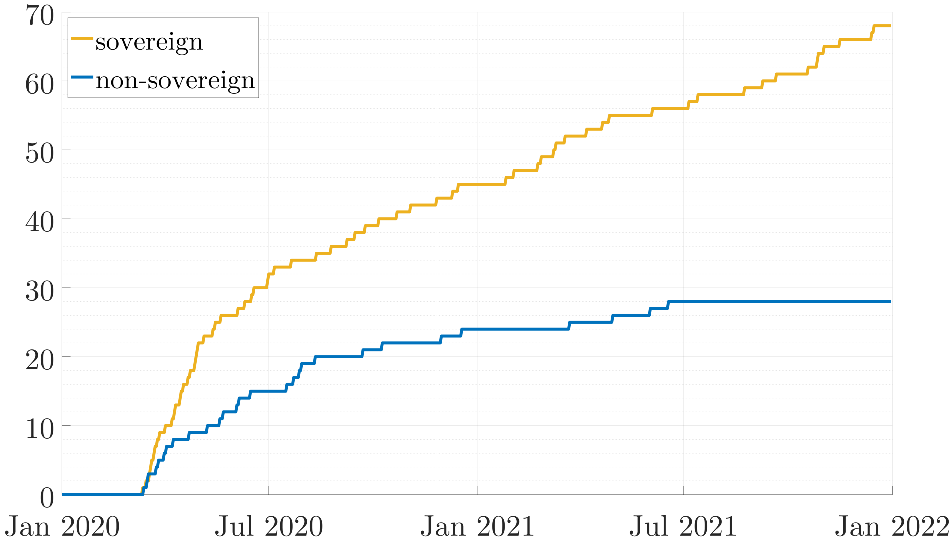
Source: World Health Organization.

Figure 2.6: Cumulative Number of Sovereign Bond Purchases Announcements



Source: Announcement data from Cantú et al. (2021), classification as open-ended by authors based on central bank press release and subsequent news coverage.

Figure 2.7: Cumulative Number of Asset Purchases Announcements

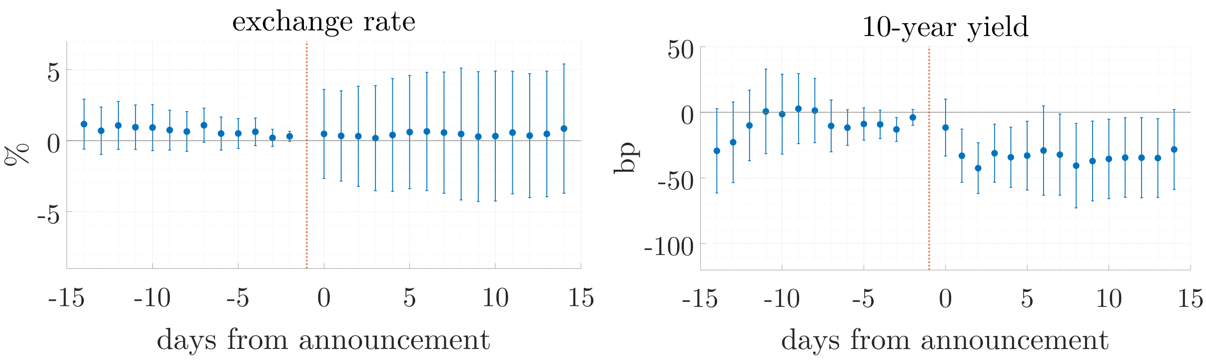


Source: Announcement data from Cantú et al. (2021), classification as sovereign and non-sovereign based on program description and central bank press release.

event time, so that for each central bank, the announcement of a new policy is aligned at time zero. The underlying assumption is that the time-zero event is the announced policy that changed what otherwise would have happened to the exchange rate or the sovereign yield. The y-axis shows the depreciation of the country's currency value relative to the dollar, or the change in the yield, before and after the announcement.

Figure 2.8 on the left shows that open-ended announcements had little impact on the exchange rate, although standard errors become considerably larger after the event. The same is true for the first size-limited announcement, where none of the coefficients are significant. One possibility is that these first announcements significantly moved exchange rates, but did so in different directions for different countries, so that the point estimates cancel out, but the standard errors get bigger. We will elaborate further on this point in the next section.

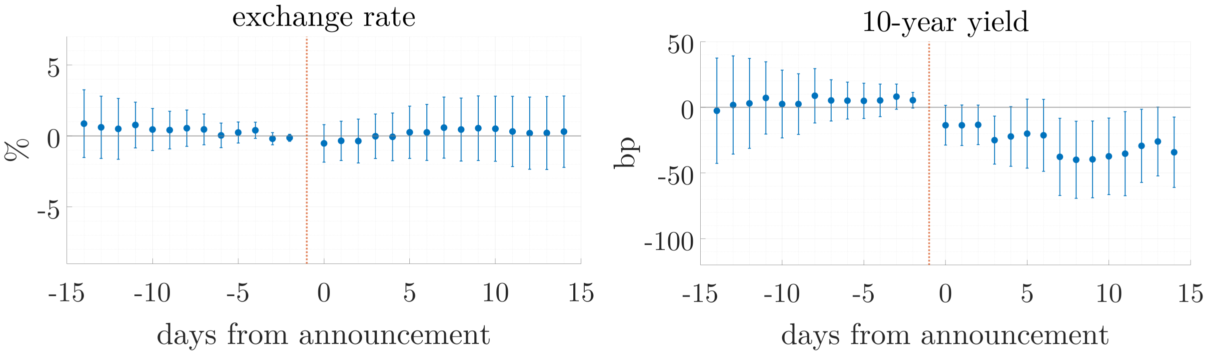
Figure 2.8: Event study (WIT)



Notes: Event studies are based on equations 2 and 3. In the charts the x-axis is measured in "event time." The first whatever-it-takes announcement for the countries listed in Table 2.2 is the "event". The y-axis shows depreciation against the dollar in percentages (on the left) or the change in the 10-year sovereign yield in basis points (on the right) relative to the day before the announcement. Dots indicate the coefficient estimates β_s, bars denote 90% confidence intervals. Regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by country.

The story is different for 10-year yields in Figure 2.8 on the right, where open-ended announcements appear to have strong and rapid effects leading to a persistent decrease of around 40-50 basis points. No pattern of increasing standard errors appears in this case. Our control variables are generally not statistically significant. Figure 2.9 shows the impact of the first size-limited announcement on 10-year yields, which shows little or no effect in the first week, but then the coefficient falls and gets closer to what we find for open-ended announcements. The takeaway from these event study plots seems to be that the first policy announcement impacted market expectations significantly, but only when it comes to yields, not for the exchange rate. This result, however, might hide some heterogeneity, which we will

Figure 2.9: Event study (size-limited)



Notes: Event studies are based on equations 2 and 3. In the charts the x-axis is measured in "event time." The first size-limited announcement for the countries listed in Table 2.2 is the "event". The y-axis shows depreciation against the dollar in percentages (on the left) or the change in the 10-year sovereign yield in basis points (on the right) relative to the day before the announcement. Dots indicate the coefficient estimates β_s*, bars denote 90% confidence intervals. Regressions include country and time fixed effects and the set of controls* $\mathbf{X}_{i,t}$*. Standard errors are clustered by country.*

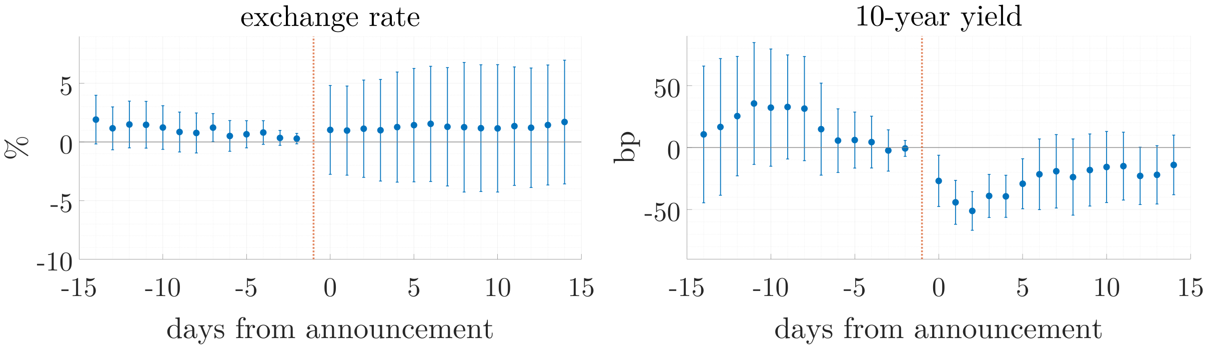
attempt to uncover in the next section, along with a broader comparison of the effectiveness of different policy announcements.

In our event study analysis of WIT announcements, our control sample includes all countries that did not make an open-ended announcement. One concern with this approach is selection bias: it may be that the countries that made WIT announcements differ in important ways from those who did not. In our context, it may be that some countries could not have credibly made open-ended policy promises because they have different monetary policy histories or different levels of financial market development. One way to address this potential selection bias in the control group is to use propensity score matching techniques to narrow our control group to countries that are more similar to each other ex-ante. We base our propensity scores on the behavior of the lagged values of our outcome variables (exchange rates and yields[31]) over 2019. Figure 2.10 shows that using nearest-neighbor[32] propensity score weights (allowing for ties) confirms our results for both exchange rates and yields. For yields, the effect of the announcement is about 50% larger on impact and immediately significant, and remains slightly larger for the next few days, although it then decreases, showing lower persistence relative to our baseline estimates.

[31]For yields, in addition to the 10-year yield, which is our main outcome variable, we also include 1-year and 5-year yields.

[32]We also used other alternative propensity weighting schemes (including nearest 3 neighbors and radius-matching using a range of "caliper" cutoffs) and found that results are comparable with the size of the standard errors not changing significantly.

Figure 2.10: Event study (WIT) with propensity score matching



Notes: Event studies are based on equations 2 and 3, estimated using propensity score weights. In the charts the x-axis is measured in "event time." The first whatever-it-takes announcement for the countries listed in Table 2.2 is the "event". The y-axis shows depreciation against the dollar in percentages (on the left) or the change in the 10-year sovereign yield in basis points (on the right) relative to the day before the announcement. Dots indicate the coefficient estimates β_s, bars denote 90% confidence intervals. Regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by country. The never-treated countries that act as controls (and their propensity score weights) are: Indonesia (0), South Korea (0), Mexico(3), New Zealand (1), Romania (15), and Thailand (3).

IV Local Projection Analysis

IV.1 Absolute effect of each kind of announcement

The event study and propensity score matching approaches can capture the impact of the announcements (or other forms of treatment) relative to appropriate controls, which in our case are countries and days in which no announcements are made. As long as the announcement is a surprise, and the control days are similar (exhibit parallel trends) to the pre-treatment days, an event study can identify the average announcement effect. In our setting, there are three additional complications: the timing of announcements differs across central banks; there are different types of announcements; and each central bank makes multiple announcements of each type. This suggests that impacts of the announcements may differ due to timing, heterogeneity in underlying policy, and potentially due to gradual learning about the announcements or a cumulation of their effects. In order to take into account these potential staggered, heterogeneous, repeated, and dynamic treatment effects we turn to the local projection methods described in Dube et al. (2023).

A critical issue in our setting is what days can be included in the non-treatment control group. Once a central bank announces a new asset purchasing policy, for how long should we consider the subsequent days to be part of the treatment? Our estimates will potentially be subject to bias if we include control days that are still being affected by an earlier announcement. In the language of event studies, this is described as an ‘unclean comparison’ and will be a source of negative weights bias in the event estimation. Alternatively, if we exclude all subsequent days after an announcement (the clean control condition), this would force us to exclude any subsequent announcements by the same central bank in the analysis and would result in very few eligible days for the control group. In some settings the control days from a distant time period could be used, but in our context we need days during the pandemic in order to be able to match pre-treatment outcome dynamics.

Our setting is one in which the treatment is not always absorbing, as the same central bank can (and often did) make multiple announcements. We would like to examine these subsequent announcements in our analysis. Our approach is therefore to report results using a partially cleaned (15- and 30-day) control group as well as those based on a fully-cleaned control group that excludes all subsequent days after each announcement.[33] In cases where central banks make subsequent announcements prior to the end of the (partial) cleaning period, we include the announcement and start-over with a new cleaning period.

We run the following regression for the exchange rate:

$$100 \cdot \frac{FX_{i,t+h} - FX_{i,t-1}}{FX_{i,t-1}} = \alpha_i + \alpha_t + \beta_h D_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \tag{2.4}$$

We run a similar regression for yields, using differences instead of cumulative percentage changes, and expressing the results in basis points:

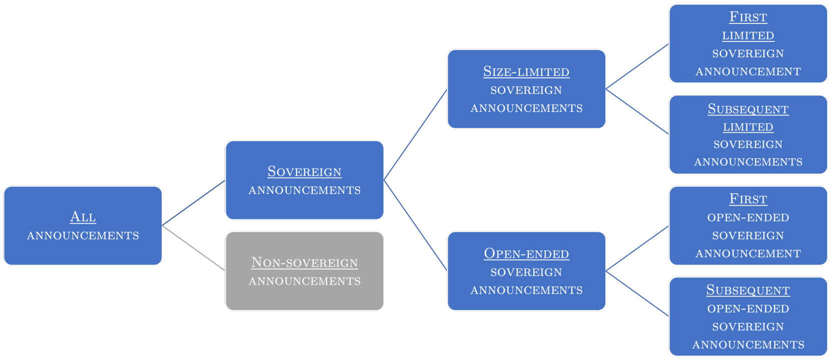
$$y_{i,t+h} - y_{i,t-1} = \alpha_i + \alpha_t + \beta_h D_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \tag{2.5}$$

We run the regression for $h = 0, 1, \ldots 15$ days. Here, $D_{i,t}$ is a dummy equal to 1 if the central bank of country i makes an announcement on day t, and 0 otherwise. Differently from the diff-in-diff methodology, the local projections approach is specifically designed to estimate impulse responses to a sequence of shocks, and our asset purchasing announcements resemble repeated, narratively-identified monetary policy shocks more than they do a single and isolated event or treatment. Therefore, we use our local projections approach to break down the effects of different types of announcements. Our empirical analysis starts with an initial assessment of market reactions to all 166 central bank asset-purchase announcements during the pandemic. We then narrow our announcements to those involving purchases of sovereign bonds, and split these announcements into those with size-limits and those we

[33]Dube et al. (2023) make clear that the only way to rule out negative weights bias is to fully clean controls (in our context exclude all days after an announcement), but at the cost of a reduction in the number of observations (in our case a severe reduction) which can reduce statistical power. They suggest a number of possible modifications of the clean control condition, including a version of the approach we take by limiting the horizon of treatment.

classify as whatever-it-takes. Finally, we look at responses to the first WIT and limited announcement (similar to the event study setup) as well as responses to the subsequent announcements, as outlined in the diagram below. We do not explicitly look at non-sovereign announcements, these are shown in grey in the diagram.

Figure 2.11: Overview of the different kinds of announcements considered in the analysis



In the local projection approach, covariates help to control for variation in treatment assignment (which in our context is the timing of central bank announcements). As was the case in our event study analysis, we include country and time fixed effects as well as the same set of controls $\mathbf{X}_{i,t}$ that help us identify the surprise component of the policy announcement. These controls are generally not statistically significant for short horizons, but are significant and appropriately signed for longer horizons across our local projection specifications, suggesting they may have contributed to driving yields with some lag, and might have influenced central bank decisions to intervene. For robustness, we also verify in the appendix that results are the same irrespective of whether the controls are included or excluded. Standard errors are clustered by date and plotted confidence intervals are at the 90% level. Similar to our findings in the event study section, our local projection analysis, as illustrated in Figure 2.12, which plots the β_h coefficients for the exchange rate regressions, shows that exchange rates against the dollar do not seem to respond to asset purchase announcements. The unresponsiveness of the exchange rate remains even after distinguishing between size-limited and WIT announcements, except in the case of the first size-limited announcement, which leads to a significant (though puzzlingly delayed) appreciation.

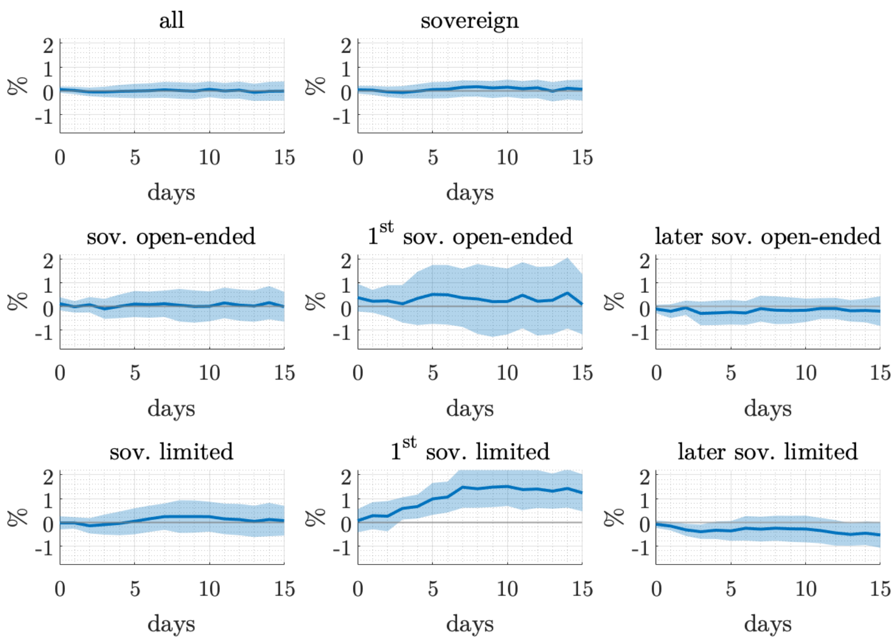
In order to interpret our local projection results, it is useful to start with the context in the foreign exchange and bond markets during the period under examination. In early 2020, global asset markets had already started to show signs of concern. The US yield curve inverted in late-February 2020, suggesting that investors had begun to worry about a potential crisis, driving short-term security yields up to compensate for the elevated risk. Connected to this, the U.S. dollar briefly lost value relative to a number of other currencies in late February.[34] As the potential worldwide severity of the pandemic started to be better understood, we saw a global dash for cash, as investor confidence in financial markets plummeted. The flight to safe cash, and especially dollar cash, reversed the earlier dollar slide; the broad U.S. dollar index appreciated by 7.5% between 6 March and the dollar's pandemic peak on 24 March. The combination of Federal Reserve swap line announcements on 15 March and 19 March, which reduced a perceived dollar shortage, together with its asset purchase announcements seem to have largely stabilized dollar bilateral rates through mid-May 2020.

The U.S. financial market and monetary policy context is critical to understanding how non-dollar currencies reacted to the asset purchase announcements made by the Federal Reserve and other central banks. The objectives of central bank policy announcements in the early days of the pandemic were twofold: to calm financial markets and provide aggregate demand stimulus. Policies that successfully calm financial markets should appreciate the domestic currency, while expansionary monetary policy (all else equal) should lead to domestic currency depreciation. Of course, during the pandemic all else was not equal. Central banks across the globe were all announcing similar policies at the same time. This meant that foreign exchange markets were responding to the relative strength of central bank policies and attempting to disentangle the effects of counteracting channels.

In light of these considerations, it is less surprising that exchange rates against the dollar do not seem to respond to asset purchase announcements. When we further separate the first WIT and size-limited announcements from the following ones, the point estimate is positive (i.e. an appreciation) on impact, but not significant. This lack of response can be attributed to the conflicting mechanisms through which asset purchases likely impacted exchange rates in this period. During the Covid period, the strong flight to safety dynamics likely kept exchange rates of safer countries strong. In this context, asset purchasing policies might actually have a positive effect on the exchange rate, due to their ability to enhance the perceived safety of the country as the central bank commits to doing whatever-it-takes to support its economy.

[34]This pattern of yield inversion and currency depreciation as a crisis materializes is described in Farhi and Gabaix (2016).

Figure 2.12: Response of Exchange Rate to Asset Purchases Announcements

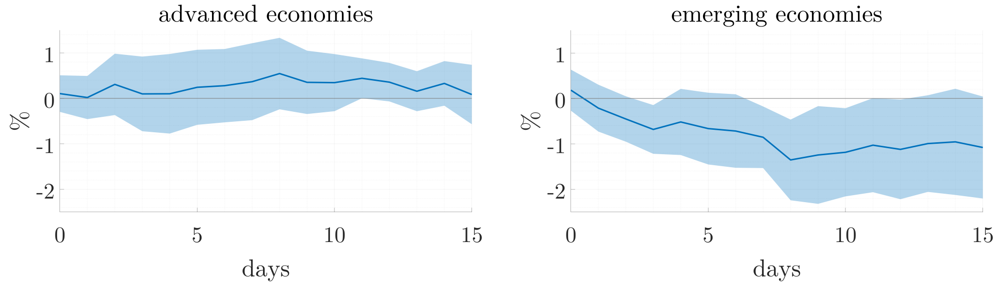


Notes: Local projections are based on equation 4 for each of the classifications of central bank asset purchase announcements (all, sovereign, open-ended, 1st open-ended, subsequent open-ended, limited, 1st limited, subsequent limited). In the charts the x-axis shows the days after the announcement and the y-axis shows the cumulative depreciation against the dollar relative to the day before the announcement, in percentages. Our clean control approach excludes 30 days after each announcement. Solid blue lines are the coefficient estimates β_h, shaded areas are 90% confidence intervals. Regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date.

This dual channel suggests distinguishing between advanced and emerging economies: dominance of one channel over the other is likely to differ between these groups. In emerging economies, which do not enjoy a safety status, the traditional channel should be at work, so that asset purchases lead to a depreciation. In advanced economies, by contrast, asset purchases might have boosted their perceived safety relative to other countries, thus making their assets more attractive for investors looking for safety in the midst of a risk-off period.

Figure 2.13 confirms that splitting our sample to examine advanced and emerging countries separately is important. It shows that open-ended asset purchasing announcements lead to no response, or a small appreciation, in advanced economies, but lead to a significant depreciation against the dollar in emerging economies. Pooling all the countries together masked this heterogeneity. We will come back to this point later.

Figure 2.13: Response of Exchange Rate to Open-ended Sovereign Bond Purchases Announcements, Differentiating Between Advanced and Emerging Economies

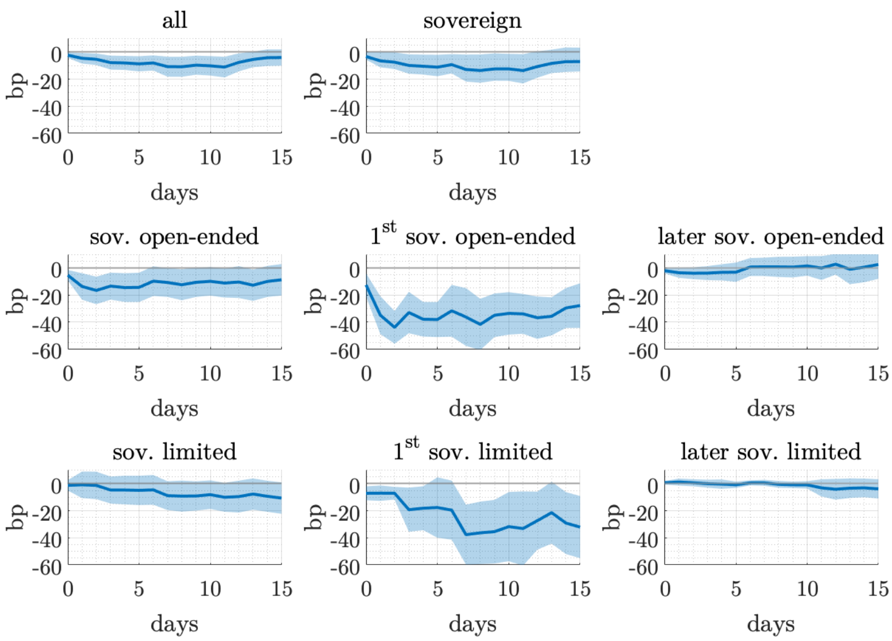


Notes: Local projections are based on equation 4 for open-ended central bank sovereign bond purchase announcements. The sample is split between advanced and emerging economies. In the charts the x-axis shows the days after the announcement and the y-axis shows the cumulative depreciation against the dollar relative to the day before the announcement, in percentages. Our clean control approach excludes 30 days after each announcement. Solid blue lines are the coefficient estimates β_h*, shaded areas are 90% confidence intervals. Regressions include country and time fixed effects and the set of controls* $\mathbf{X}_{i,t}$*. Standard errors are clustered by date.*

We find yields to be more responsive to announcements than exchange rates. Figure 2.14 shows the response of 10-year yields to all announcements, and then breaks it down between size-limited and open-ended, and between the first and the subsequent open-ended announcements. Results for the first two days following the announcements are also reported in Table 2.3. Our estimates suggest that asset purchase announcements change expectations and therefore prices, though the effect is modest, hovering between 5 and 10 basis points over the week following the announcement.

Breaking this down shows that there is an underlying heterogeneity in the effectiveness of different announcements: while size-limited announcements have, essentially, no effect, open-ended announcements push yields down by 15 basis points in the first two days and up to 20 basis points after a week. There is evidence of a "first announcement" effect, even with size-limited announcements, but the effect is much larger for first WIT announcements. The very first whatever-it-takes moment is most effective, lowering yields by 40 basis points, which roughly matches our estimate from the event study section; conversely subsequent WIT announcements have no impact. Consistent with what theory and intuition suggests, the real power of whatever-it-takes policy lies largely in its shock-and-awe effect when it is first announced. After the first WIT announcement, market participants update their expectations, and subsequent announcements seem to only reinforce the original commitment to do whatever is necessary. This may itself be important, as markets might otherwise react negatively if no further announcements are made.

Figure 2.14: Response of 10-Year Yield to Asset Purchases Announcements



Notes: Local projections are based on equation 5 for each of the classifications of central bank asset purchase announcements (all, sovereign, open-ended, 1st open-ended, subsequent open-ended, limited, 1st limited, subsequent limited). In the charts the x-axis shows the days after the announcement and the y-axis shows the cumulative change in the 10-year yield relative to the day before the announcement, in basis points. Our clean control approach excludes 30 days after each announcement. Solid blue lines are the coefficient estimates β_h, shaded areas are 90% confidence intervals. Regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date.

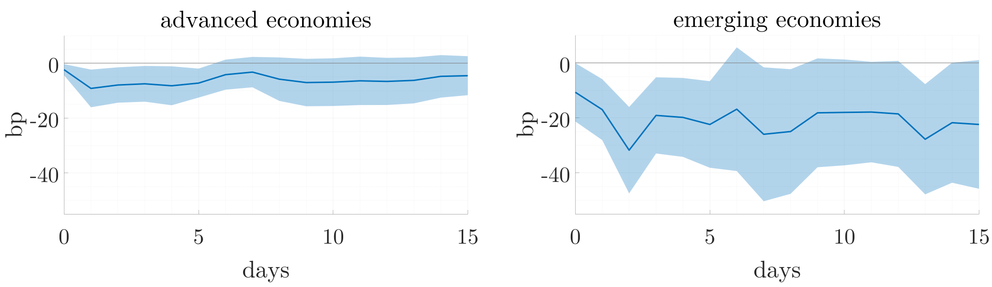
Finally, as we did for the exchange rate, we look at open-ended announcements by splitting the sample between advanced and emerging economies. The results are shown in Figure 2.15. Whatever-it-takes announcements appear particularly powerful in emerging economies, lowering yields by up to 30 basis points. The same does not appear to be true for advanced economies. The results we found for whatever-it-takes announcements in Figure 2.14, therefore, appear to be driven by emerging market countries rather than advanced economies. However, this sizable discrepancy in magnitudes between advanced and emerging economies might be related to the differences in volatilities, as yields are higher and more volatile in emerging economies, and thus looking at simple differences might mask how effective the announcements were in advanced economies. We will come back to this point later, when we consider what happens if yields are standardized by country using their volatility over this period, or if we look at percentage changes in yields instead of simple differences, to account for the lower base level in advanced economies.

Table 2.3: Local Projection Coefficients ($h = 1, 2$) for 10-Year Yields

Announcement	**1-day after:** $y_{i,t+1} - y_{t-1}$, in bp		**2-days after:** $y_{i,t+2} - y_{t-1}$, in bp	
All	-4.59^{*}	(2.38)	-5.32^{**}	(2.57)
Sovereign	-6.51^{**}	(2.88)	-7.46^{**}	(3.10)
Limited	-0.87	(5.94)	-1.29	(6.17)
1st limited	-7.05^{**}	(3.44)	-7.09^{**}	(2.85)
Later limited	1.18	(1.57)	0.64	(1.59)
Open-ended	-13.75^{**}	(5.94)	-16.65^{***}	(6.17)
1st open-ended	-34.93^{***}	(8.51)	-43.94^{***}	(7.33)
Later open-ended	-3.61	(2.28)	-3.95	(2.66)

Notes: The table shows the estimated coefficients β_h on central bank asset-purchase announcements for each of the six classifications of announcements (all, sovereign, limited, open-ended, 1st open-ended, and subsequent open-ended) over 1-day and 2-days for the 10-year yield local projection regression (equation 5). The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.

Figure 2.15: Response of 10-Year Yield to Open-ended Sovereign Bond Purchases Announcements, Differentiating Between Advanced and Emerging Economies



Notes: Local projections are based on equation 4 for open-ended central bank sovereign bond purchase announcements. The sample is split between advanced and emerging economies. In the charts the x-axis shows the days after the announcement and the y-axis shows the cumulative change in the 10-year yield relative to the day before the announcement, in basis points. Our clean control approach excludes 30 days after each announcement. Solid blue lines are the coefficient estimates β_h, shaded areas are 90% confidence intervals. Regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date.

IV.2 Relative efficacy of open-ended vs size-limited announcements

Our local projection analysis indicates that WIT announcements during the pandemic had significant impacts on financial markets, especially when we focus on the most surprising of these announcements. The figures show the absolute response of exchange rates and yields to WIT and size-limited announcements separately, but they do not allow us to measure differences in market reaction across announcement types. In order to test whether WIT announcement impacts are different than size-limited announcements, we use the following regression specification for the exchange rate:

$$100 \cdot \frac{FX_{i,t+h} - FX_{i,t-1}}{FX_{i,t-1}} = \alpha_i + \alpha_t + \beta_h WIT_{i,t} + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \tag{2.6}$$

Again, we run a similar regression for yields, using differences instead of cumulative percentage changes, and expressing the results in basis points:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i + \alpha_t + \beta_h WIT_{i,t} + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \tag{2.7}$$

In this specification, the coefficient on $WIT_{i,t}$, β_h, is an estimate of the average change in the dependent variable (the bp change in yields or the percentage change in the exchange rate) in reaction to a WIT announcement relative to the reference group of size-limited announcements. The variable $ALL_{i,t}$ includes the full set of sovereign bond purchase announcements, so that the reference (or omitted) category are the size-limited sovereign bond purchase announcements, and $\mathbf{X}_{i,t}$ includes our control variables.

Table 2.4 presents our baseline estimates of the impact of WIT announcements relative to size-limited announcements on the one- and two-day post-announcement percentage change in the exchange rate and changes in 3-month, one-year, five-year and ten-year bond yields. Consistent with the message from the event study and local projection analysis, the results show that WIT announcements had statistically significant larger (negative) impacts on yields relative to size-limited announcements, with the largest difference in impact being an additional 16 basis point fall in the two-day 10-year yields. Likewise, similar to our previous results, we do not find a statistically different impact of WIT announcements on exchange rates; neither type of announcement had an impact when we include the full set of sovereign bond announcements in the regression.

The results in Table 2.4 across yield maturities suggest that the largest relative impacts of WIT announcements are on 10-year bond yields, with much smaller relative effects for 1-year and 3-month yields. The finding that the relative impact is larger over a longer horizon, after

Table 2.4: Local Projection Coefficients ($h = 1, 2$) of Open-ended Relative to Limited Announcements for Exchange Rate and Yields

$h = 1$	FX	10Y	5Y	1Y	3M
Baseline (30 days cleaning)	0.06	-13.27^{**}	-13.73^{**}	-5.76^{*}	-5.68
	(0.16)	(6.54)	(6.77)	(3.25)	(3.67)
N	12364	14441	14441	14441	13859

$h = 2$	FX	10Y	5Y	1Y	3M
Baseline (30 days cleaning)	0.31	-15.87^{**}	-15.01^{*}	-6.48^{*}	-6.94^{*}
	(0.25)	(7.10)	(7.92)	(3.52)	(3.89)
N	12342	14415	14415	14415	13834

*Notes: The table shows the estimated coefficients β_h on open-ended asset-purchase announcements over 1-day and 2-days for the exchange rate (in %) and yield (in bp) local projection regressions (equations 6-7). The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.*

the announced asset-purchases would have long stopped, suggests that WIT policy may be affecting long-run expectations. The result may also follow from the underlying volatility distributions across maturities: there was more room for movement in longer maturity bond yields during the pandemic when short-term interest rates in many advanced countries were at the zero-lower-bound. In order to take this difference in underlying yield volatilities into account, we repeat our analysis using the percentage change in yields rather than simple differences. The results using this specification are reported in Table 2.5, and are even stronger than those reported in Table 2.4 for 10-year yields: the relative impact of WIT announcements remains more powerful. The results, however, are no longer significant for the other maturities.

Our next set of tests examine different groupings of WIT announcements (the first one versus subsequent ones, those that occurred on days when the central bank made other policy announcements versus days with just one asset-purchase policy announcement, those that occurred on days when other central banks also made asset-purchase policy announcements versus days when only one central bank made an announcement, those that literally used the phrase whatever-it-takes in the announcement versus those that made open-ended promises without using the WIT phrase) relative to size-limited announcements. The regression specification for each of these tests includes two types of WIT announcements ($WIT^1_{i,t}$ and $WIT^2_{i,t}$), with $WIT^1_{i,t}$ always defining the narrower category, the full set of announcements ($ALL_{i,t}$), and our control variables ($\mathbf{X}_{i,t}$). Again, the omitted category of announcements

Table 2.5: Local Projection Coefficients ($h = 1, 2$) of Open-ended Relative to Limited Announcements for Yields (% change)

$h = 1$

	10Y	**5Y**	**1Y**	**3M**
Baseline (30 days cleaning)	-25.51^{**}	63.02	-1.08	71.08
	(11.02)	(53.68)	(7.39)	(51.78)
N	14441	14441	14441	13859

$h = 2$

	10Y	**5Y**	**1Y**	**3M**
Baseline (30 days cleaning)	-29.74^{**}	66.80	-2.81	53.56
	(14.55)	(53.39)	(9.28)	(82.35)
N	14415	14415	14415	13834

Notes: The table shows the estimated coefficients β_h on open-ended asset-purchase announcements over 1-day and 2-days for the yield local projection regressions (equation 7), replacing the dependent variable with a percentage change instead of a simple difference. The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.

are the size-limited ones. We run, for the exchange rate :

$$100 \cdot \frac{FX_{i,t+h} - FX_{i,t-1}}{FX_{i,t-1}} = \alpha_i + \alpha_t + \beta_h^1 WIT_{i,t}^1 + \beta_h^2 WIT_{i,t}^2 + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ , \quad (2.8)$$

and, for yields:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i + \alpha_t + \beta_h^1 WIT_{i,t}^1 + \beta_h^2 WIT_{i,t}^2 + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \quad (2.9)$$

In addition, we also re-run regressions 6-7 by splitting the sample between advanced and emerging economies, and between the first months of the pandemic (from March to July 2020) and the later period (from August 2020 to December 2021). We present these results together with those for regressions 8-9 as they all amount to testing different groupings of WIT announcements.

Table 2.6 reports the estimated coefficient for each of the narrower groupings of WIT announcements on changes in 10-year yields and the percent change in the exchange rate. The top row shows our baseline case with all WIT announcements relative to size-limited ones (previously reported in Table 2.4), and each subsequent set of rows show the additional impact of a narrower grouping of WIT announcements relative to size-limited announcements. These results largely confirm our previous findings, especially for the two-day results. The first WIT announcement lowers yields by an additional 47 basis points relative to size-limited announcements. Likewise, days when multiple central banks made WIT announcements lowered yields by an additional 25 basis points relative to size-limited announcements, whereas on days when only one central bank made a WIT announcement the basis point difference fell to 11.

Interestingly, the days when the same central bank announced multiple policies were not statistically different from days with size-limited announcements, whereas days with just the WIT announcement significantly lowered relative yields by 18 basis points. Another surprising result came when we separated those announcements that literally used the whatever-it-takes phrase. In both these cases the likely explanation is that we had too few announcements that fit our narrower grouping of WIT announcements. As we found earlier, emerging economy WIT announcements lowered relative yields by the largest amount, almost 30 basis points, and WIT announcements in the first five months of the pandemic had the largest relative impact.

When looking at the exchange rate, we find at least some evidence, after two days, of the heterogeneity in response that we also found when looking at the absolute effect of WIT announcements: there is evidence of an additional appreciation in advanced economies, while the effect is not significant (though the point estimate is negative) in emerging economies. The opposing directions of the exchange rate responses might suggest that, at least to some extent, the muted response of the exchange rate when taking all countries together is actually due to the underlying heterogeneity in the response between different countries.

V Robustness

Our analysis so far has found strong evidence that financial markets react to what-ever-it-takes announcements, and that these reactions are statistically significantly stronger than those to size-limited announcements. We also find that grouping the WIT announcements in various ways increases the relative difference in market reaction. In this section we include a number of robustness checks, that examine whether our method of post-announcement "cleaning" matters, whether adding additional controls (specifically a lock-down stringency index which is available daily and across our sample of countries) matters, whether omitting controls matters, and finally whether the way in which we measure changes in our two outcome variables matter.

The results reported in Table 2.7 suggest that our findings that WIT announcements have larger impacts on bond markets than do to size-limited announcements are robust to a number of changes in our baseline regression specification. In our first set of robustness checks we examine whether reducing or expanding the number of post-announcement days

Table 2.6: Local Projection Coefficients ($h = 1, 2$) of Open-ended Relative to Limited Announcements for Exchange Rate and Yields, Different Announcement Groupings

	$h=1$		$h=2$	
	FX	**10Y**	**FX**	**10Y**
Baseline (30 days cleaning)	0.06	-13.27^{**}	0.31	-15.87^{**}
	(0.16)	(6.54)	(0.25)	(7.10)
N	12364	14441	12342	14415
1^{st} open-ended	0.35	-37.58^{***}	0.48	-47.17^{***}
	(0.27)	(9.21)	(0.41)	(9.65)
Subsequent open-ended	-0.15	-1.01	0.17	-0.62
	(0.22)	(2.78)	(0.26)	(3.05)
N	12364	14441	12342	14415
Multiple policies announced	0.20	-7.11	0.32	-6.61
	(0.35)	(5.83)	(0.37)	(5.69)
Only sovereign AP announced	0.04	-14.69^{*}	0.31	-18.03^{**}
	(0.19)	(7.72)	(0.28)	(8.45)
N	12364	14441	12342	14415
Other CB announcements	0.42	-20.26	0.36	-25.06^{*}
	(0.33)	(13.52)	(0.41)	(14.55)
No other CB announcements	-0.09	-9.19^{*}	0.28	-10.69^{*}
	(0.20)	(4.97)	(0.33)	(5.57)
N	12364	14441	12342	14415
Literal "whatever it takes"	0.34	-2.21	0.84^{*}	-3.83
	(0.45)	(3.18)	(0.47)	(4.11)
Not literal "whatever it takes"	-0.03	-16.94^{**}	0.13	-19.94^{**}
	(0.21)	(8.32)	(0.32)	(9.12)
N	12364	14441	12342	14415
Advanced economies	0.27	-5.93	0.83^{*}	-4.82
	(0.32)	(3.93)	(0.47)	(3.34)
N	5335	8745	5325	8727
Emerging economies	-0.13	-17.99^{**}	-0.42	-29.37^{***}
	(0.41)	(8.17)	(0.43)	(10.13)
N	7025	5690	7011	5680
Mar 2020 − Jul 2020	-0.03	-13.29	0.26	-17.03^{*}
	(0.21)	(8.79)	(0.35)	(9.58)
N	2032	2201	2029	2200
Aug 2020 − Dec 2021	0.20	-2.08	0.46	-2.64
	(0.29)	(1.92)	(0.38)	(2.11)
N	10332	12240	10313	12215

*Notes: The table shows the estimated coefficients β_h^1 and β_h^2 on open-ended asset-purchase announcements over 1-day and 2-days for the exchange rate (in %) and yield (in bp) local projection regressions (equations 8-9). For the last two blocks of comparisons, the coefficients are the β^h obtained by running 6-7 in subsamples. The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.*

that are excluded from our control group matters. In our original specification we excluded 30 days after each announcement from our control group. The first row in Table 2.7 reports results for specifications that exclude 15 days and the second row reports results based on a specification that drops all subsequent days from our control group after a central bank has made a whatever-it-takes announcement. The results for the specification with 15 days excluded are very similar to those in our baseline specification that excludes 30 days, whereas the β_h coefficient estimates in the specification that assumes all days subsequent to a WIT announcement are part of the treatment are three times larger than their counterparts in the partially-cleaned versions. Similar to our findings using propensity score matching, this suggests that a more narrow definition of our counterfactual leads to larger estimates of the relative impacts of WIT announcements.

Our next set of robustness checks examine the role of the control variables in our baseline specification. Along with our original set of control variables (country and time fixed effects, prior WIT announcements made by other central banks, the cumulative number of own country Covid-19 cases, the global number of Covid-19 cases excluding own-country cases, and own-country prior size-limited policy announcements) we add a lock-down stringency index to better take into account differences in economic activity across our sample of countries during the pandemic. We also drop all our controls in a second robustness specification. The results reported in Table 2.7 indicate that adding or subtracting controls has no measurable impact on our coefficients of interest.

Table 2.7: Local Projection Coefficients ($h = 1, 2$) of Open-ended Relative to Limited Announcements for Exchange Rate and Yields, Robustness

	$h=1$		$h=2$	
	FX	**10Y**	**FX**	**10Y**
15 days cleaning	0.04 (0.16)	-12.50^{**} (6.16)	0.22 (0.25)	-16.20^{**} (6.99)
N	13492	16484	13470	16456
Permanent cleaning	0.07 (0.38)	-36.18^{***} (12.04)	0.20 (0.57)	-46.54^{***} (10.88)
N	6939	4720	6917	4692
Additional control (stringency index)	0.06 (0.16)	-13.24^{**} (6.52)	0.31 (0.25)	-15.83^{**} (7.08)
N	12364	14441	12342	14415
No controls	0.06 (0.16)	-13.45^{**} (6.48)	0.29 (0.25)	-16.01^{**} (7.01)
N	12364	14441	12342	144415

Notes: The table shows the estimated coefficients β_h^1 and β_h^2 on open-ended asset-purchase announcements over 1-day and 2-days for the exchange rate (in %) and yield (in bp) local projection regressions (equations 6-7). The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.

Next we focus on the measurement of our outcome variables, the percentage change in the exchange rate and the change in sovereign bond yields. Among our sample of countries there is wide variation in the size and volatility of these changes. We attempt to control for this variation in two ways. First, we standardize our outcome variables in our regression specifications using own-volatility over the pandemic, so that $\widetilde{FX}_{i,t} = \frac{FX_{i,t}}{\sigma(FX_i)}$ and $\tilde{y}_{i,t} = \frac{y_{i,t}}{\sigma(y_i)}$. We then run, for the exchange rate,

$$100 \cdot \frac{\widetilde{FX}_{i,t+h} - \widetilde{FX}_{i,t-1}}{\widetilde{FX}_{i,t-1}} = \alpha_i + \alpha_t + \beta_h WIT_{i,t} + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ , \tag{2.10}$$

and, for yields,

$$\tilde{y}_{i,t+h} - \tilde{y}_{i,t-1} = \alpha_i + \alpha_t + \beta_h WIT_{i,t} + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \tag{2.11}$$

Second, for yields, we also use percentage changes rather than level changes:

$$\frac{y_{i,t+h} - y_{i,t-1}}{y_{i,t-1}} = \alpha_i + \alpha_t + \beta_h WIT_{i,t} + \theta_h ALL_{i,t} + \mathbf{X}_{i,t}\boldsymbol{\gamma_h} + \varepsilon_{i,t} \ . \tag{2.12}$$

Table 2.8 reports the estimated β_h coefficients in regression specifications that include these transformations in our outcome variables. The first set of estimates includes all countries in our sample, and the second two sets of estimates split the sample between advanced and emerging economies. When we standardize our outcome variables we find similar results to those in our baseline specification: WIT announcements have statistically significantly larger impacts on 10-year bond yields relative to size-limited announcements for all countries, advanced economies, and emerging economies, with the largest relative differences appearing in the emerging economies. Further, as we found in our baseline case, there are no significant differences in the impacts of WIT and size-limited announcements on standardized changes in exchange rates. In the second set of estimates, where we measure our 10-year yields in percentage changes, we find that advanced rather than emerging economies are driving the overall results. This transformation of the dependent variable matters; reducing the relative size of yield changes for emerging economies turns out to be consequential and suggests that the differences in results between emerging and advanced economies are less clear cut. These results confirm that the financial market impacts of WIT announcements are significantly larger than sized-limited announcements, but do not allow us to rank the relative strength of this result between advanced and emerging markets.

Another way we take volatility into account is to examine whether specific emerging market countries that experienced extreme movements in yields are driving our results. We do sensitivity tests for outliers by dropping one emerging economy at a time in the regression to see if there is one that makes a big difference. We compare the local projection coefficient on open-ended asset-purchase announcements over 1-day for all emerging economy 10-year yields in Table 2.6 (-17.99) to the same coefficient when we drop Poland (-13.89), Colombia (-20.21), Turkey (-16.31), Hungary (-25.59), and South Africa (-11.44). In each of these cases the coefficient value and statistical significance is very similar to what we find for the emerging economy group as a whole.

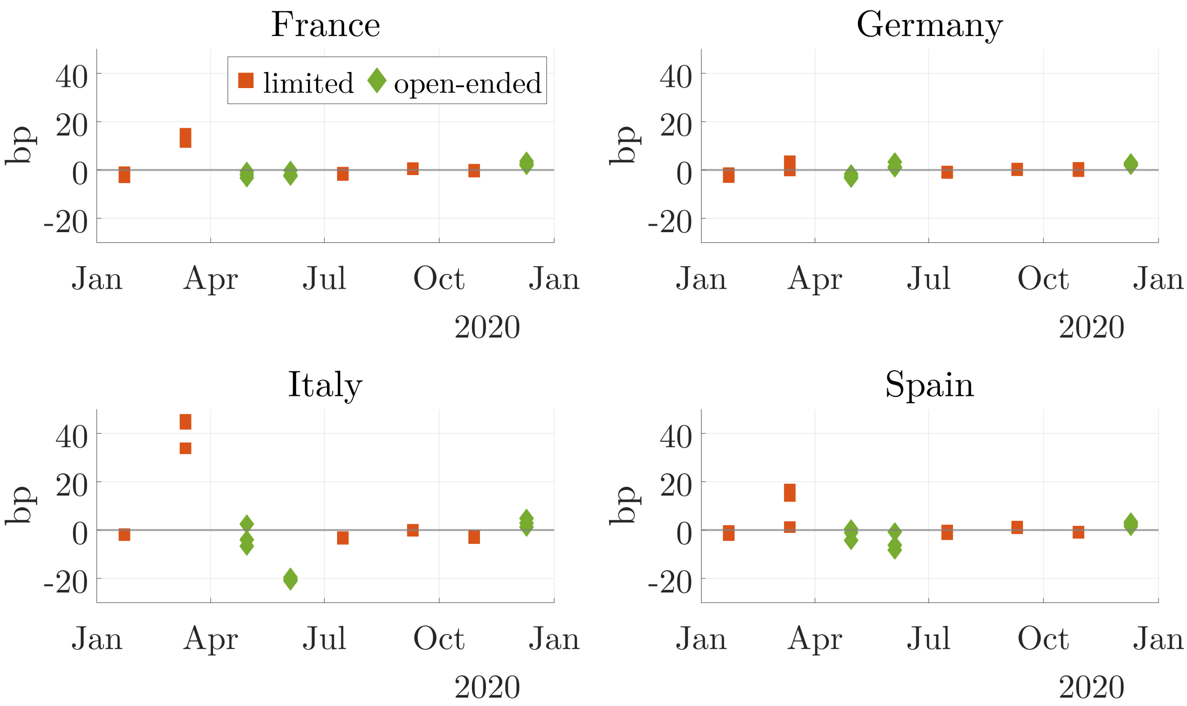
Table 2.8: Local Projection Coefficients ($h = 1, 2$) of Open-ended Relative to Limited Announcements for Exchange Rate and Yields, Results for Advanced and Emerging Economies for Different Specifications of the Dependent Variable

	$h = 1$		$h = 2$	
	FX	**10Y**	**FX**	**10Y**
Standardized Dep. Variable				
All countries	0.04 (0.25)	-148.08^{***} (52.87)	0.31 (0.33)	-136.17^{**} (56.63)
N	12364	14441	12342	14415
Advanced economies	0.30 (0.47)	-114.04^{**} (57.24)	0.90 (0.58)	-77.04^{*} (42.83)
N	5335	8745	5325	8727
Emerging economies	-0.23 (0.60)	-153.96^{**} (69.99)	-0.45 (0.53)	-161.24^{***} (51.05)
N	7025	5690	7011	5680
Dep. Variable in BP % Change				
All countries		-25.51^{**} (11.02)		-29.74^{**} (14.55)
N		14441		14415
Advanced economies		-24.30 (15.43)		-37.67 (24.96)
N		8745		8727
Emerging economies		-14.47 (21.33)		-7.58 (29.93)
N		5690		5680

Notes: The table shows the estimated coefficients β_h^1 and β_h^2 on open-ended asset-purchase announcements over 1-day and 2-days for the exchange rate (standardized %) and yield (standardized bp and bp %) local projection regressions (equations 10-12). The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.

Our final robustness check examines whether daily data are appropriate for our analysis. The concern this raises is that our results may be subject to omitted variable bias if other news that occurred on the same day as the announcements were the actual drivers of market reactions. In most cases it seems likely that a central bank announcement, especially one that promises whatever-it-takes actions, will be the critical market-relevant news on a given day, but as a robustness check we analyze a subset of the announcements over a narrower within-day window.

Figure 2.16: Change in 2-,5-, and 10-Year Yields (in bp) around Press Releases for ECB Asset Purchases Announcements

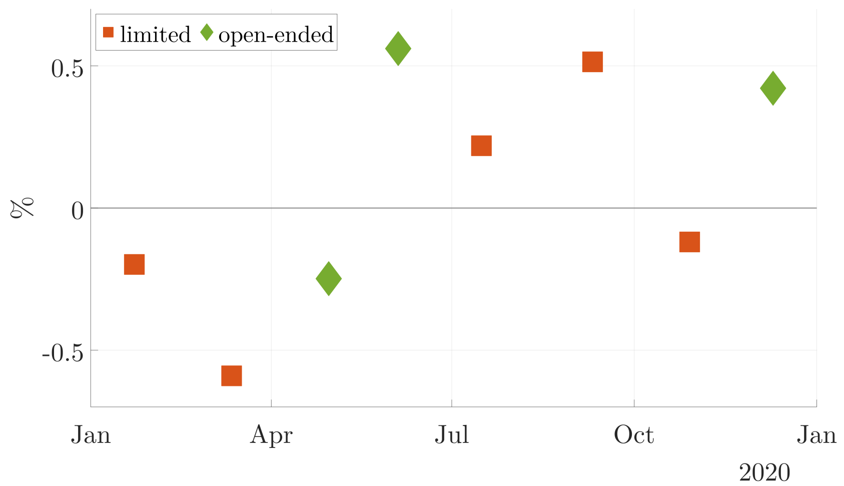


The figures plot the change in yields (in basis points) in the window around press releases by the European Central Bank. Specifically, the changes are computed by comparing the median quote from the window 15:40-15:50 CET, right after the press conference, to the median quote from the window 13:25-13:35 CET, right before the press release. Intraday changes are from Altavilla et al. (2019). Announcements are from Altavilla et al. (2019) and from Cantú et al. (2021), classification as open-ended by authors based on central bank press release and subsequent news coverage.

The Euro Area Monetary Policy Event-Study Database described in Altavilla et al. (2019) provides intraday asset price changes around a two-hour announcement window that starts with quotes immediately prior to ECB announcements and ends with quotes immediately after the end of the press-conference. All ECB Governing Council meeting decisions are announced with a press release at 13:45 Central European Time (CET), this is followed by a press conference starting at 14:30 CET that generally ends at 15:40 CET. The underlying tick data are from Thomson Reuters Tick History database, the data are discretized by using the last quote of each minute and calculating the median price over a ten minute interval from 13:25-13:35 CET for the pre-press-release quote, 14:00-14:10 CET for the post-press-release quote, 14:15-14:25 for the pre-press-conference quote, and 15:40-15:50 CET for the post-press-conference quote.

As was the case in our daily analysis, the underlying assumption is that the central bank announcements are not responding to asset price changes within the day, so that reverse causality is not a concern. From the results in Figures 2.16-2.17, one announcement appears particularly special: the one on 4 June 2020, after which newspapers wrote that "the ECB is in whatever-it-takes mode". This is especially apparent when looking at the yields of Italy and, to some extent, Spain. The other two announcements that we categorize as open-ended according to our methodology do not particularly stand out when looking at intraday data. Size-limited announcements, by contrast, are associated with either no movement or with increases in yields. When looking at the euro exchange rate against the dollar, the implications are less clear: the June announcement again stands out, but appreciations are also visible in association with some size-limited announcements.

Figure 2.17: Percentage Change in the Euro-Dollar Exchange Rate around Press Releases for ECB Asset Purchases Announcements



The figures plot the percentage change in the exchange rate in the window around press releases by the European Central Bank. Specifically, the changes are computed by comparing the median quote from the window 15:40-15:50 CET, right after the press conference, to the median quote from the window 13:25-13:35 CET, right before the press release. Intraday changes are from Altavilla et al. (2019). Announcements are from Altavilla et al. (2019) and from Cantú et al. (2021), classification as open-ended by authors based on central bank press release and subsequent news coverage.

Unfortunately, the monetary event window dataset does not include the ECB's first open-ended announcement on 18 March 2020, which did not follow a regularly scheduled ECB Governing Council meeting. The announcement was made at 6:00 pm CET (just before mid-day in New York). Vissing-Jorgensen (2021) lists the Federal Reserve announcement times in March and April 2020 (in Table 2.3). Interestingly, like the ECB, the Fed made its first open-ended policy announcement when most US financial markets were closed, at 5pm on a Sunday. Measuring within-day asset price reactions to these late-in-the-day announcements is unlikely to fully capture market responses in the same way as a scheduled announcement.

Data constraints limit our ability to analyze a larger set of announcements across central banks, but our results for the 8 ECB scheduled announcements suggest a high degree of heterogeneity in the within-day market reactions to both WIT and size-limited announcements. These results suggest that our larger sample of daily reactions include a wide range of impacts, which while providing significant average effects, may overstate the power of WIT announcements for some countries.

VI Conclusion

Central banks across the globe took aggressive action during the pandemic to restore confidence in financial markets and support economies. They both actively intervened and communicated their intervention to markets ex ante using announcements. This use of policy announcements to signal resolve and restore confidence was also used by many central banks during the 2008 crisis, and stands in marked contrast to the pre-1990s secrets-of-the-temple approach to monetary policy.[35]

In this paper we ask whether a subgroup of these monetary policy announcements, those that include a promise to intervene at a whatever-it-takes scale, are more effective than announcements that include size-limits. It is important to note that whatever-it-takes statements embody constructive ambiguity: they are inherently less transparent than announcements with explicit size and duration information. This form of purposeful policy vagueness allows for the possibility that no policy interventions will be taken if the announcement itself is all that it takes. It is also noteworthy that central banks rarely describe the criteria they will use to determine when their whatever-it-takes policy interventions will have accomplished their objective.

Along with the reduced transparency of open-ended operations, there are other downsides to whatever-it-takes policymaking. After a whatever-it-takes announcement is made, it may be harder to impress the market again. Our estimates indicate that subsequent open-ended announcements have less impact on asset prices. Whatever-it-takes announcements set a high bar, potentially leading to ever escalating market expectations for large-scale intervention. These types of announcements will also be counter-productive if they inadvertently heighten investors' fears that economic circumstances are even worse than was thought, or that more standard (size limited) policies are not up to the task. Markets may also worry that if central banks go 'too big,' they will have limited their options to address the next shock (Bergant

[35] Geraats (2002) and Blinder et al. (2008) provide excellent discussions of the costs and benefits of central bank transparency.

and Forbes, 2023). Finally, whatever-it-takes policies are likely to increase moral hazard. Large-scale asset purchases will inevitably increase incentives for risk taking by financial institutions that hold a high share of eligible securities.[36]

Peer pressure was likely a factor in the decisions of some central banks to announce whatever-it-takes policies during the pandemic. If other central banks are successfully restoring orderly financial market function with the use of whatever-it-takes policy, it would be difficult not to follow suit. It may also be the case that cross-country spillovers are likely to be less problematic if policy responses are synchronized. The global scope of the crisis also lessened the worry for central banks that markets would interpret their own aggressive actions as a sign that their economy was facing unusual difficulty.

The empirical analysis in this paper underscores the benefits of whatever-it-takes policies. Markets responded positively to these announcements during the pandemic, and this was especially the case for emerging economy central banks. Impacts on yields indicate that these announcements were successful in restoring confidence in financial markets and in reducing uncertainty and financial stress. In the early days of the pandemic there was a risk that the financial market turmoil would intensify, which would have led economies into much deeper recessions. It does not follow that central banks can rely on whatever-it-takes policy in future crises, but it is useful to understand the preemptive role they played in the pandemic.

[36] Acharya et al. (2019) describe the misallocation of credit that resulted from the announcement impacts of the ECB's OMT on weak European banks.

CHAPTER 3

Municipal Bonds During the Covid-19 Crisis: A Factor-Model Approach

with Dmitriy Stolyarov, Linda L. Tesar, and Matthew Wilson

I Introduction

The onset of the Covid-19 pandemic in early 2020 set off a unique period of disruption in financial markets in the United States and around the world. The S&P 500 index fell by 34 percent, and 10-year treasury yields had already dropped by over 75bp in January and February when the Fed began rate cuts in March. Bond markets were roiled, including the $4 trillion municipal sector. Municipal bonds experienced an unprecedented increase in yields. Between March 9 and March 20 of 2020, yield to maturity on the S&P Municipal Bond Index increased by 162 basis points.[1] In the same month, risk premia on bonds of individual states changed relative to each other March 2020, and these changes were persistent. The changes in the risk premia point to potentially new sources of risks emerging in the municipals markets. This paper's main contribution is to add to our understanding of the nature of these risks.

During periods of economic distress, it is common for investors to favor less risky and more liquid fixed-income assets. The yield spike for municipal bonds that occurred in March 2020 could have been driven by both liquidity and credit risk. Some early commentators believed that liquidity risks were dominant in March 2020 and that municipal bond fund outflows were related to liquidity concerns (Gillers and Banerji, 2020; Schuele and Shiner, 2020). However, liquidity risks were short lived compared to credit risks. Bi and Marsh (2022) study the effect of Federal Reserve policies in March and early April of 2020 and show that policy interventions mitigated liquidity risks whereas elevated credit risk was more enduring.

Early on, academics and portfolio managers alike pointed to restrictions on commercial

[1] The next highest spike over that short span was an increase of 73 basis points from November 19, 2015 to November 30, 2015.

activity, travel and social distancing policies as sources of credit risks for states (Clemens and Veuger, 2020; Galgano, 2020; Lennon et al., 2020; Li and Lu, 2020; Mukherjee, 2020). Consistent with this view, evidence in Baker et al. (2020) confirmed that pandemic restrictions were the primary drivers of stock price volatility. By contrast, early analysis in Bi et al. (2020) did not find strong evidence of a correlation between state-level credit risk proxies and municipal bond yields in Feb-Apr 2020. Apparently, state-level risk premia did not move in a way that one would expect given local pandemic trajectories and economic conditions. The question about the source of Covid-related risk in municipal bond prices therefore still remains.

The paper attempts to reconcile the evidence of credit risk in municipal bonds and the apparent lack of correlation between risk premia and state-level variables thought to capture these credit risks. We present evidence that the conventional pricing of municipal bonds broke down beginning in March 2020. The persistent reordering of risk premia by state is the clearest indication of this. Not surprisingly, a standard pricing model including 50-state factor portfolios and various controls performs poorly from March to May 2020, as standard bond pricing factors become insignificant. We extend earlier results to show that adding state-specific Covid-related variables does not consistently improve the explanatory power of the standard model. Importantly, we find no evidence that state-specific risk factors, such as the economic losses caused by lockdowns, the increase in underfunding risk of state pensions, and the risk of state health care expenditure, play a significant role. We then introduce a novel factor model for pricing state-level municipal bond portfolios that performs well before and after the first half of that year. As it turns out, the influence of pandemic conditions on muni prices is not intuitive or straightforward. A state's risk premium due to Covid depends not on the situation in the state itself but on the distribution of Covid intensity across all states. In other words, we find that the Covid risk in municipal bond pricing is best captured by the dispersion of extremely favorable relative to extremely unfavorable current pandemic impacts across states. We show that the municipal bond market disruption during the early pandemic period lasted for about 8 months, and during that time municipal debt pricing was influenced mostly by the cross-state distribution of the pandemic crisis.

Outline We motivate the paper by showing the unprecedented disruption of the muni market in response to the onset of the Covid-19 crisis in early 2020. In March 2020, yields on municipal bonds spiked and the distribution of relative yields across states experienced a significant reordering. Using a concept of "rank correlation," we show that state-level municipal bond indices shifted around the cross-sectional distribution to a much greater degree in the early days of the pandemic than is typical in historical data. These historically unique movements in the muni yield distribution motivate the paper's goal of investigating the pricing mechanism for municipal bonds in 2020.

We then formulate a pricing model for municipal bonds based on factor models that have been used elsewhere in the asset pricing literature. This pricing model uses portfolio-based factors, augmented with other macro variables, to explain state-level municipal bond index returns. The model is evaluated using a Fama-MacBeth two-step procedure that estimates each asset's factor loadings individually and backs out the aggregate risk premium assigned to each factor. We then augment the model with factors based on state-level Covid characteristics such as mobility, cases, and deaths.

We show that the model with conventional factors performs well in normal times and poorly during the period of disruption. In the first few months of the pandemic crisis, the standard factors are generally not significant for determining muni prices. We first attempt to explain this breakdown by adding the Covid-related variables into the pricing model. Own-state characteristics alone generate mixed results in explaining excess returns relative to the conventional model. By contrast, common factors that reflect the dynamics of the Covid pandemic at the macro level do explain muni risk premia from March 2020 to November 2020. By the end of 2020, the effect of pandemic-related factors wanes as the historical model reasserts itself and the municipal bond market returns to normal. We conclude that the disruptive effects of Covid-19 on municipal bond markets were powerful but short-lived, concurring with existing literature on the policy effects of Federal Reserve action and opening up avenues for interesting research into municipal bond pricing and financial markets during crises.

Related Literature This paper contributes to the municipal bond pricing literature along several dimensions, especially with respect to the Covid-19 pandemic. We show that returns on portfolios sorted by Covid variables influence municipal bond yields in the early days of the Covid-19 pandemic when standard bond pricing models break down in the face of a liquidity crisis. Some recent papers also investigate the relationship between local Covid situations and municipal bond yields. Odusami and Mansur (2022) find that a state-level Covid intensity measure is positively related with state-level muni index yields in panel data from 2020, while Tran and Uzmanoglu (2022) find similar effects of state-level Covid conditions on individual municipal bond trades. Li and Lu (2020) find that county-level cases, deaths, and emergency declarations increased yields and decreased issuance for municipal bonds on the primary market, imposing significant fiscal costs on local governments. Cusatis and Hoxha (2022) find that the relationship between munis and treasuries shifted during the pandemic, reflecting a flight from munis to treasuries. Wu and Ostroy (2021) show a sharp increase in transaction costs during the early days of the pandemic, and the same authors (Wu and Ostroy, 2022) also show how primary market pricing was affected.

These papers find evidence for a shift in the municipal bond market immediately after the onset of the pandemic, during which time the pandemic had a significant effect on municipal bond prices. We improve on the bond pricing model of Odusami and Mansur (2022) by introducing a novel factor-based model for municipal bonds and allowing state-level bond indices to respond differently to each factor. Our finding that the pricing model changed significantly in 2020 is consistent with Cusatis and Hoxha (2022), who find a shift in the relationship between munis and aggregate financial market variables at the beginning of the pandemic, consistent with a flight to treasuries. We build on that finding by more fully specifying a pricing model and showing a significant effect of Covid-specific factors on municipal bond prices, which also explain a large shift in relative bond prices. The temporary breakdown we find in the secondary market for munis is significant and corroborates the finding of Li and Lu (2020) that borrowing costs for state and local governments on the primary market increased in the early days of the pandemic. Our findings are consistent with Park et al. (2024), who show that a Covid factor was a significant determinant of stock returns.

In focusing on the initial phase of Covid's effect on municipal bond yields, we interact with recent papers studying the early days of the Covid crisis and the movements of muni yields. An early analysis from Bi et al. (2020) found that the spike in municipal bond yields in March 2020 was driven primarily by liquidity, rather than credit, concerns. Multiple papers have studied the effects of the Federal Reserve's Municipal Liquidity Facility (MLF) on the municipal bond market, finding that MLF increased liquidity, decreased yields, alleviated credit risk, and encouraged debt issuance; these papers include Haughwout et al. (2022), Bi and Marsh (2022), Fritsch et al. (2021), Bordo and Duca (2023), and Li and Lu (2020).

This paper also contributes to the broader literature on municipal bond pricing. One strand of this literature focuses on the effect of local economic characteristics on municipal bond yields; for example, Painter (2020) examines the effect of climate change exposure on munis. Yang (2019) and Gao et al. (2019) consider the effects of state bankruptcy policies on municipal bonds. Another strand of the literature seeks to identify the effect of ratings on individual bonds. Schwert (2017) finds that ratings influence spreads more that liquidity characteristics, and Adelino et al. (2017) exploit an exogenous ratings recalibration to identify the effect of ratings on yields. Other important papers in the municipal bond pricing literature include Harris and Piwowar (2006), Green et al. (2007), and Garrett et al. (2023).

Finally, the paper complements the evolving literature on the relationship between pandemic risk and asset prices. Baker et al. (2020) support this paper's finding that Covid was a unique event: they show that the stock market volatility in response to Covid far exceeded the stock market reaction to any other infectious disease outbreak over the previous 120 years. Another recent paper by Park et al. (2024) estimate significant risk premia for Covid factors constructed from firm-level and sector-level exposures to pandemic risk. Compared to studies of stock returns, the advantage of our research design is in using the linkage between municipal bond performance and state economic conditions and thus exploiting the variation in pandemic dynamics across states. The surprising finding is that own-state economic conditions do not have much effect on municipal debt prices whereas the cross-state distribution of pandemic intensity emerges as a significant source of risk.

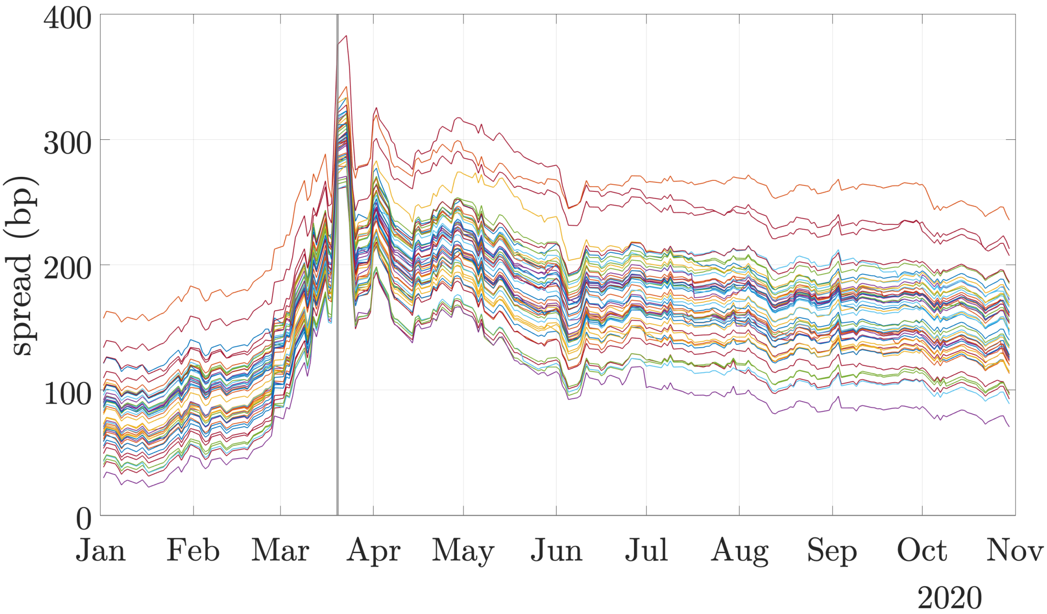
II Covid-19: An Unprecedented Event in Muni Markets

The onset of the coronavirus pandemic in early 2020 induced a disruption in bond markets due to a "dash for cash," in which even traditionally safe assets—including U.S. treasuries—experienced a rapid selloff.[2] The municipal bond market also experienced this selloff. On March 6, 2020, the S&P Municipal Bond index yielded a rate of 2.33%; by March 20, this rate had jumped 162 basis points to 3.95%. Liquidity concerns were rampant, and uncertainty around the course of the virus and the future of municipal finances drove investors to cash safety. Municipal bond funds, which owned almost $900 billion in munis at the end of 2019, raced to sell and the primary market for new municipal debt ground to a standstill.

The Federal Reserve took swift action to calm markets. On March 18 it announced a lending facility to backstop money market mutual funds, and on March 20 it announced that it would accept certain low-risk municipal bonds as collateral for these loans. On March 23, it expanded the range of municipal debt it would include. On April 9, the Fed unveiled the Municipal Liquidity Facility (MLF), which would purchase debt directly from U.S. states and large local governments, and which was expanded to include smaller government borrowers twice during the following two months. Congress also stepped in during this time, providing $340 billion in direct aid to state and local governments through the CARES act, and by providing general economic relief through other provisions such as the Paycheck Protection Program.

[2]Barone et al. (2022) documents that selling pressures on sovereign bonds were greater in March 2020 than during the global financial crisis of 2007-2008, and pressure on U.S. treasuries were greater than for other major economies. Haddad et al. (2021) show that investment-grade bonds moved more closely with high-yield bonds and equities than in previous crises, indicating an atypical event.

Figure 3.1: Impact of Covid-19 on State-Level Municipal Bond Spreads

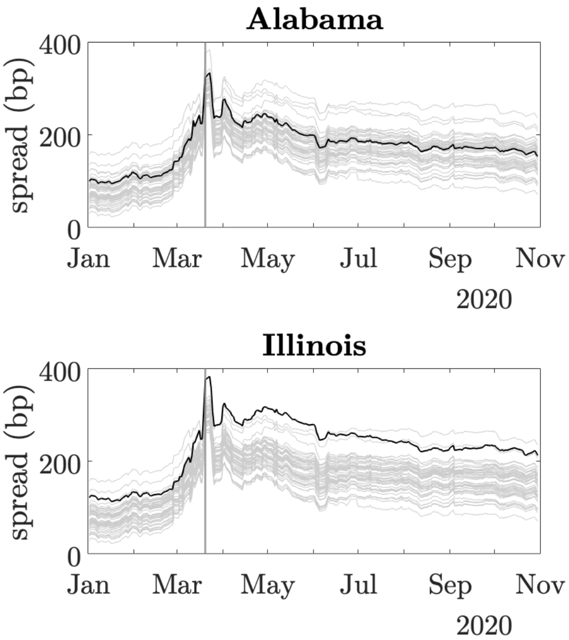


Note: *Each line represents the evolution of the spread between the constant-maturity yield on a 10-year Treasury and the yield-to-maturity (YTM) for an individual U.S. state's S&P Municipal Bond index during Jan 1-Oct 30, 2020. These indices include both state and local municipal bonds. The vertical line indicates the peak of YTM on the aggregate municipal bond index on March 20, 2020.*

Markets ultimately calmed, but municipal bonds behaved differently during the early weeks of the pandemic than ever before, both over time and relative to other munis. Figure 3.1 plots the yields of state-level S&P municipal bond spreads, with the 10-year treasury rate as the basis, to show this. Spreads began to spike in late February 2020, continuing their upward trajectory until the peak on March 20 (vertical line), the first day of signaling from the Fed that it was willing to support the muni market. While spreads came down from their peak in March, they remained volatile through May, after which volatility decreased and spreads stabilized throughout the rest of the year, though at higher levels than before the pandemic.

Most interesting for our purposes is that there was also a marked shift in *relative* bond yields: states did not remain in the same segment of the cross-sectional distribution of yields throughout this period. Figure 3.2 illustrates this phenomenon in four different states. New Jersey starts in the middle of the distribution and quickly moves to the top at the peak of the yield spike remaining near the top for the remainder of 2020. Connecticut moves from bottom to middle to mid-bottom, Illinois moves from the top end to the very top, and Alabama moves from the top to the middle. The reordering of state municipal bond risk premia during March 2020 was greater than in any other month in the history of the S&P indices.

Figure 3.2: Re-ordering of Municipal Bond Spreads Over 10-year Treasury Yields, Select States



Note: *Each line represents the evolution of the spread between the constant-maturity yield on a 10 year Treasury and the yield-to-maturity (YTM) for an individual U.S. state's S&P Municipal Bond index during Jan 1-Oct 30, 2020. These indices include both state and local municipal bonds. The vertical line indicates the peak of YTM on the aggregate municipal bond index on March 20, 2020. The dark line on each panel corresponds to the state index indicated in the panel title.*

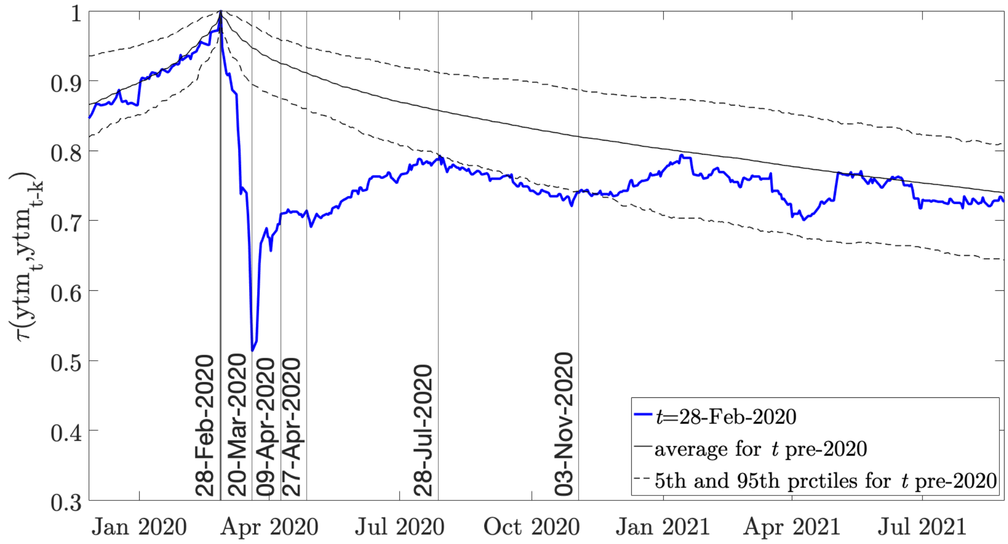
To be more precise about the shift in the ranking of bond yields, Figure 3.3 shows the evolution of the Kendall rank correlation coefficient, the blue line in the figure, commonly referred to as Kendall's τ coefficient.[3] Kendall's $\tau \in [-1, 1]$ measures the rank correlation of yields between the current date and a reference date. If the ranking is identical to the reference period, $\tau = 1$, and if the ranking is perfectly reversed from the reference period, $\tau = -1$.

The blue line on Figure 3.3 plots this τ measure in 2020 and 2021, which summarizes the relationship between the rankings of state-level municipal bond yields on a given date with the ranking as it stood on the reference date of February 28, 2020. On the reference date, τ is defined to be 1. As the time interval k widens, rank orderings shift and τ begins to fall.

[3] Kendall's τ is a measure of the agreement between the relative rankings of elements in a pair of vectors. If x and y are two vectors of size n, Kendall's τ is defined as $\tau(x, y) = \frac{2}{n(n-1)} \sum_{i<j} sgn(x_i - x_j) sgn(y_i - y_j)$.

The solid black line shows the historical average τ for a particular k based on data from 2014 to 2019, and the dotted black lines show the 5^{th} and 95^{th} percentiles of the distribution of τ as k increases.[4]

Figure 3.3: Rank Correlation of Municipal Yields in 2020



Note: *The blue line represents the Kendall's τ rank correlation measure for state municipal bond yields between a given date and the reference date, February 28, 2020. τ is equal to 1 if the ranking of states by yield is exactly the same as it was on the reference date, and equal to -1 if the ranking is perfectly opposite. The solid black line indicates the average evolution of τ from any given reference period, estimated on data from 2014 to 2019. The dashed black lines indicate the 5^{th} and 95^{th} percentiles. State yields are the YTM of the S&P state municipal bond indices. Kendall's τ is defined in Footnote 3. Vertical lines indicate significant dates in government policy related to the muni market in 2020.*

Before Feb 28, 2020, the rank correlation pattern is not far from its pre-pandemic average––the blue line closely follows the solid black line. Right after the Covid news, τ plummets to 0.5, well outside the 90 percent error band based on pre-2020 data. This indicates a sudden, substantial re-shuffling of yield rankings far outside the typical distribution. This anomaly persists until late July 2020; while τ gradually rises over the course of the summer of 2020, it remains outside the 90 percent interval until November 2020, when the ranking finally approaches what one would have predicted based on pre-Covid data. The figure also notes significant policy dates affecting municipal bonds. Clearly, the pandemic-induced liquidity

[4]For each date s, let $T_s(k) = \tau(y_s, y_{s+k})$ be the Kendall rank correlation function between YTM vectors y_s and y_{s+k}, $k = 0, \pm1, \pm2, ...$, and let $\bar{\tau}_k = (1/N)\sum_n T_n(k)$ be its average over time. By construction, $T_s(0) = \bar{\tau}_0 = 1$, all s. The blue line on Figure 3.3 shows $T_t(k)$ with t fixed at Feb 28, 2020. The black line superimposes $\bar{\tau}_k$ over the pre-Covid time period 2014-2019, centered around the same reference date Feb 28, 2020. The dashed lines show the 5^{th} and the 95^{th} percentiles among the values of $T_s(k)$ during 2014-2019.

crisis affected the cross-sectional distribution of municipal bond yields in a historically unique way, and this reshuffling of the market's assessment of bonds grouped by state was persistent for several months. It is this period of abnormal movement in relative yields that motivates the rest of the paper.

III A Factor Model of Municipal Bond Prices

While movements in the muni market in early 2020 were unique in history, the underlying causes of those movements are not obvious. One possibility is that market pricing of municipal bonds relative to other financial variables did not change, and the strange movements in munis simply reflected the unique reaction of the rest of financial markets to Covid news. In this case, we would not expect to see a significant impact of any additional pandemic-related variables on municipal bond yields. The other possibility is that the pricing of municipal bonds specifically changed at the onset of the pandemic, in which case pandemic-related variables may or may not influence municipal bond prices.

To evaluate whether the municipal bond market pricing mechanism changed significantly at the beginning of the pandemic, we introduce a novel factor pricing model for municipal bonds. Our selection of conventional factors is based on factor models from the finance literature which have been used to price the risk premia of government and corporate bonds. Examples include Israel et al. (2018), Bektiċ et al. (2020), Gava et al. (2020), and Dang et al. (2023). The only applications to municipal bonds that we are aware of are Sibears (2017) and Wang (2022), and they do not look at Covid. We apply these methods to municipal bond markets to obtain a robust model of municipal premia before and after the pandemic.

III.1 Fama-MacBeth Two-Step Estimation

The model relates the rate of return on an index of municipal bonds in state i on day t to N aggregate factors, defined by the vector $\mathbf{F}_t = [F_t^1, ..., F_t^N]$. Our estimation is based on the familiar two-step procedure introduced in Fama and MacBeth (1973b). For each muni index i we run the time series regression

$$r_{it}^e = \gamma_i + \mathbf{F}_t \beta_i + u_{it}, \tag{3.1}$$

where $r_{it}^e = r_{it} - r_t^F$ is the excess return of state i's return r_{it} over the risk-free return in the economy r_t^F. The vector $\beta_i = [\beta_i^1, ..., \beta_i^N]'$ contains the loadings of each of the aggregate factors on excess returns in state i. Each estimated $\hat{\beta}_i^n$ corresponds to the estimated factor loading of muni index i on factor n. Each vector $[\hat{\gamma}_i, \hat{\beta}_i]$ captures the estimated pricing model for excess returns in a state.

After estimating the individual state models, we perform a second step regression to recover the aggregate risk premia corresponding to each of the factors. We do this by running a series of cross-sectional regressions on each day t:

$$r_{it}^e = \lambda_t \hat{\beta}_i + \alpha_{it}, \tag{3.2}$$

where $\lambda_t = [\lambda_t^1, ..., \lambda_t^N]$ is the vector of time-t risk premia for each of the factors. We can then estimate the average risk premium for factor n along with its variance, given by

$$\hat{\lambda}^n = \frac{1}{T} \sum_t \hat{\lambda}_t^n; \tag{3.3}$$

$$\sigma^2(\hat{\lambda}^n) = \frac{1}{T^2} \sum_t (\hat{\lambda}_t^n - \hat{\lambda}^n)^2. \tag{3.4}$$

The average pricing error for municipal bond i and its variance are given by

$$\hat{\alpha}_i = \frac{1}{T} \sum_t \hat{\alpha}_{it}; \tag{3.5}$$

$$\sigma^2(\hat{\alpha}_i) = \frac{1}{T^2} \sum_t (\hat{\alpha}_{it} - \hat{\alpha}_i)^2. \tag{3.6}$$

We further apply the Shanken correction to the variances to account for the fact that the βs are estimated regressors.

III.2 Conventional and Unconventional Factors

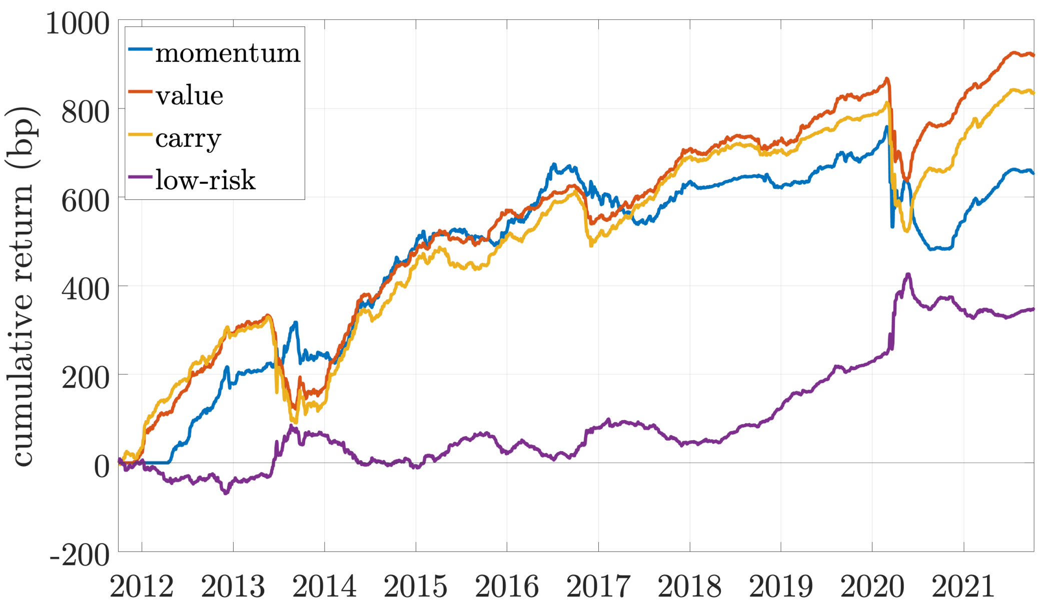
We consider two broad classes of factors to be included in the vector $\mathbf{F}_t$. The first class of factors are conventional, i.e., these are factors which have been used in other pricing models. The second class includes unconventional factors which attempt to capture features of the distribution of pandemic situations across states. These factors are included in the post-pandemic period to test whether Covid-19, aside from the national financial situation it induced, had any additional direct effect on risk premia.

III.2.1 Conventional Factors

Long-short factors. Our first four conventional factors are based on the distribution of municipal bond indices over four potential determinants of excess returns. These factors take some characteristic of an asset, sort the assets on that characteristic, and compute the hypothetical return of a zero net wealth portfolio which is long on the "top" quintile of the distribution and short on the "bottom" quintile. The return of this portfolio is intended to capture a broad sense of how the characteristic influences excess returns on average, and that return is what we call a "factor." The risk premium associated with the factor estimated in (3.2) indicates whether the factor plays a significant role in pricing the asset.

We consider four such portfolio-based factors constructed by sorting on conventional characteristics. The *carry* factor sorts on yield-to-worst, or lowest possible yield from buying and holding a callable bond until the earliest allowable prepayment date. The *value* factor sorts on real yield-to-maturity, or YTM minus the 10-year inflation expectation.[5] The *momentum* factor sorts on the trailing six-month return. Finally, *low-risk* is sorted on the volatility of the last 18 months of returns, and then weights the returns by the inverse of volatility.

Figure 3.4: Cumulative Returns on Long-Short Portfolios Mimicking Conventional Factors



Note: *Lines indicate the historical performance of portfolios based on the indicated factors for state municipal bond indices from S&P. A portfolio for each factor is long on the "top" quintile of the distribution and short on the "bottom" quintile. Details of this procedure are described in Section III.*

Figure 3.4 plots the cumulated returns of these four long-short portfolios over the sample period relative to the 3-month treasury yield. The momentum, value, and carry portfolios perform well throughout the pre-pandemic period, with the low-risk performance picking up starting in 2018. At the beginning of 2020, the first three factors perform poorly, with the low-risk portfolio increasing significantly. By 2021, the factors seem to resume their previous

[5]This expectation is the median 10-year ahead inflation from the Survey of Professional Forecasters.

paths. The paths of these portfolios lend further evidence to the claim that the onset of Covid induced an unprecedented shakeup in municipal bond markets.

Other macro factors. In addition to the long-short factors, we consider a set of macro factors that may also influence municipal bond prices. The first is the simple return to the *municipal bond market*, which captures the average performance of all municipal bonds. The second is the *slope* of the yield curve, represented by the spread between the 3-year and 3-month treasury rates. The third is *convexity*, or the spread between the 5-year and the average of the 2-year and 10-year treasury rates. Finally, we consider the *VIX*, which captures volatility in the stock market. These four additional factors are intended to capture the state of financial markets in general as they relate to the municipal bond market.

III.2.2 Unconventional Factors

The unique nature of the pandemic period suggests that some novel unconventional factors might have become relevant for pricing municipal bonds. For example, locations facing serious outbreaks of Covid-19 may have responded by increasing government spending and may have experienced large decreases in economics activity, affecting tax revenues. Both effects could influence the prices of municipal bonds. To investigate this possibility, we introduce four Covid-related characteristics intended to capture the pandemic situation in each state. We use these characteristics directly to examine their statistical relationship with pricing errors. We also use these characteristics to construct long-short sorted portfolios analogous to the conventional long-short factors and compute their effect on average risk premia.

The four pandemic-related variables are *mobility*, *cases*, *deaths*, and *ICU*. The mobility variable is an index of mobility within a state, which broadly captures the extent of shutdowns and voluntary social distancing. Cases and deaths record the number of estimated Covid cases and deaths at the state level. ICU records occupied beds in ICUs in a state. We define Covid *characteristics* by this set of variables with cases, deaths, and ICU in per capita terms, and we define Covid *factors* as the return of a long-short portfolio based on each variable.

III.3 Data and Samples

Our municipal bond data are at the state-day level. For each state, we use the total return index of municipal bonds available from S&P Global. These indices are constructed to represent a group of municipal bonds from an array of government entities, including state governments, local governments, and other entities such as utilities boards. The Covid characteristics and population at the state level are estimates from the Institute for Health

Metrics and Evaluation (IHME).[6] Data on daily treasury yields and the VIX are from the Federal Reserve Bank of St. Louis. Daily risk-free returns are computed from the total return index of 1-3 month Treasury bills, which is also obtained from the S&P500 fixed-income indices.

Start dates for the municipal bond indices vary across states; we begin our sample in January 2014 so that all states have equal numbers of observations in their pricing models. Our pre-pandemic model is estimated through the end of 2019.[7] Our pandemic sample begins on March 1, 2020, in step with data availability for the Covid characteristics. The pandemic sample ends on May 15, 2020, reflecting our focus on the earliest days of the pandemic.

IV The Factor Model and Covid-19

Applying the factor model as described above reveals three key facts about municipal bond pricing and the early pandemic period. First, conventional pricing models break down at the onset of the Covid-19 crisis, suggesting that unprecedented swings in the muni market are not fully explained by the pandemic's effect on the macroeconomy. Second, Covid-related variables were significantly related to the cross-section of municipal bond returns in the early days of the pandemic, though perhaps not in a simple and direct way. Third, the shakeup in muni markets was short-lived, and the pricing models returned to normal by the end of 2020. We now explore each of these three facts in turn.

IV.1 The Pricing Model Broke Down in 2020

Table 3.1 summarizes the average risk premia of the four long-short factors and other conventional factors during the pre-pandemic sample, reported in basis points.[8] The table includes eight different specifications of the model. Each factor's average estimated risk premium is of the expected sign in all specifications and significant in most specifications, except for *VIX*. Adding whole-market factors does not much affect the point estimates for risk premia on conventional factors and improves the overall fit of the model somewhat.

By contrast, Table 3.2 contains the risk premia for the same eight models estimated during the early days of the Covid pandemic. Specifically, the sample runs from March 1st to May 15th, the period corresponding to the most upheaval in relative yields as evidenced in

[6] IHME estimates were updated regularly through December 16, 2022. The data in this paper reflect the vintage from December 2020, which would not contain later revisions and presumably more accurately reflect the information available to investors in 2020.

[7] The appendix restricts the sample to rolling 3-month subperiods of the pre-pandemic sample.

[8] Specifically, the reported values are the average premia over time as calculated in 3.3 in basis point units.

Table 3.1: Conventional Factors Explain Cross-Sectional Returns in the Pre-Covid Period

Factor	All Factors	+ Market	+ Slope	+ Slope + Convexity	+ VIX	+ Market + Slope	+ Market + Slope + Convexity	+ Market + Slope + Convexity + VIX
				Long-Short Factors				
Momentum	138***	174***	157***	150***	141***	159***	152***	147*
	(0.034)	(0.017)	(0.020)	(0.030)	(0.035)	(0.038)	(0.052)	(0.061)
Value	182***	179***	177***	179***	178***	177***	179***	178***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Carry	152***	164***	155***	154***	159***	156***	154***	155***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low-risk	-62**	-39	-64**	-67**	-47*	-63**	-65**	-62*
	(0.025)	(0.176)	(0.026)	(0.027)	(0.099)	(0.047)	(0.046)	(0.062)
				Market Factors				
Market	-	527***	-	-	-	526***	526***	527***
		(0.000)				(0.001)	(0.001)	(0.001)
Slope	-	-	5680*	7785**	-	5424*	7542**	7771**
			(0.066)	(0.056)		(0.049)	(0.037)	(0.037)
Convexity	-	-	-	1045*	-	-	1016**	1010**
				(0.054)			(0.034)	(0.036)
VIX	-	-	-	-	-1943	-	-	-632
					(0.216)			(0.679)
Avg. Adj. R^2	0.22	0.26	0.25	0.26	0.24	0.28	0.29	0.30

Note: Values displayed are the average risk premia, in annualized basis points, for a given factor (row) in a given model (column), where models include different combinations of the market factors. Average risk premia for the factors are computed as described in Equation 3.3 of the text. Data are daily state municipal bond indices from S&P from 2014 to 2019. p-values for these estimates are in parentheses. *: $p \leq 0.1$; **: $p \leq 0.05$; ***: $p \leq 0.01$.

Figure 3.3. These results confirm the suggestive evidence in Section II that the municipal bond market transformed significantly in the early days of the pandemic. Furthermore, this transformation was not simply a function of aggregate market characteristics: the relationship between municipal bond prices and aggregate variables changed fundamentally in March 2020, in addition to the significant movements in the aggregate variables themselves.

None of the risk premia on the conventional muni factors are significant. Moreover, the value and carry portfolios had negative returns during the sample period (see Figures 3.4 and 3.5) which is reflected in the negative risk premia estimates. The conventional model attributes the aggregate yields spikes to movements in λ_t causing these estimates to have high variance and low significance. The often-significant risk premium on the slope factor points to the importance of aggregate movements for muni returns, and suggests the large shift in the model is not simply due to an increase in noise post-Covid.

In combination with the evidence in Figures 3.1-3.3, Tables 3.1 and 3.2 show that risk premia on municipal bonds were not calculated the same way in early 2020 as they were from 2014 to 2019.[9] The unprecedented changes in muni yields, both relative to treasuries

[9]The appendix shows that these results are not simply due to the smaller sample size of the pandemic period. Analysis of rolling 3-month samples leads to the conclusion that the pandemic period reflected

Table 3.2: Conventional Factors Fail to Explain Cross-Sectional Returns in the Covid Period

Factor	All Factors	+ Market	+ Slope	+ Slope + Convexity	+ VIX	+ Market + Slope	+ Market + Slope + Convexity	+ Market + Slope + Convexity + VIX
				Long-Short Factors				
Momentum	777	441	182	197	267	-159	-352	-227
	(0.562)	(0.734)	(0.899)	(0.893)	(0.851)	(0.907)	(0.808)	(0.879)
Value	-808	-853	-1017	-1022	-846	-1066	-1103	-1156
	(0.328)	(0.306)	(0.243)	(0.252)	(0.329)	(0.228)	(0.238)	(0.219)
Carry	-1323	-1430	-1478	-1418	-1368	-1590*	-1579	-1606
	(0.137)	(0.105)	(0.119)	(0.143)	(0.144)	(0.091)	(0.114)	(0.111)
Low-risk	1064	1002	1094	1048	1025	1028	922	962
	(0.141)	(0.166)	(0.156)	(0.185)	(0.177)	(0.187)	(0.262)	(0.248)
				Market Factors				
Market	-	-1768	-	-	-	-1837	-1841	-1793
		(-.794)				(0.800)	(0.810)	(0.818)
Slope	-	-	5337*	5447*	-	5806**	6276*	6095**
			(0.033)	(0.038)		(0.020)	(0.024)	(0.030)
Convexity	-	-	-	429	-	-	598	590
				(0.346)			(0.185)	(0.196)
VIX	-	-	-	-	822*	-	-	302
					(0.092)			(0.308)
Avg. Adj. R^2	0.23	0.27	0.26	0.30	0.26	0.32	0.34	0.37

Note: Values displayed are the average risk premia, in annualized basis points, for a given factor (row) in a given model (column), where models include different combinations of the market factors. Average risk premia for the factors are computed as described in Equation 3.3 of the text. Data are daily state municipal bond indices from S&P from March 1 to May 15, 2020. p-values for these estimates are in parentheses. *: $p \leq 0.1$; **: $p \leq 0.05$; ***: $p \leq 0.01$.

and relative to each other, cannot be explained by pricing models estimated from data prior to 2020. This fundamental change in estimated risk premia in the post-pandemic period suggests that Covid-related variables may need to be included in the pandemic pricing model.

IV.2 Pandemic Conditions Affected Relative Muni Yields

We examine the effects of the Covid variables on relative municipal bond prices in two ways. First, we take the pricing errors of the conventional factors in the early pandemic period and regress those errors on the Covid characteristics at the state level. This provides simple estimates of how the own-state pandemic situation affected municipal bond prices. Second, we include the long-short portfolio factors based on these Covid characteristics and compute their average risk premia during the pandemic period. This method captures more subtle and complicated ways in which the distribution of Covid outcomes across the country affects muni prices in individual states.

Effect of Covid characteristics on pricing errors. The pricing model using conventional factors breaks down in early 2020, resulting in a large unexplained portion of muni

unprecedented shifts in municipal bond pricing.

returns. If markets were considering the pandemic situation in a state when pricing bonds from that state, then the pricing errors from the conventional model u_{it} can be modeled as a function of the Covid characteristics within each state:

$$u_{it} = \beta_0 + \beta_1 * Mobility_{it} + \beta_2 * \frac{Cases_{it}}{pop_i} + \beta_3 * \frac{ICU_{it}}{pop_i} + \beta_4 * \frac{Deaths_{it}}{pop_i} + \nu_{it}. \tag{3.7}$$

Table 3.3 contains results from estimating this regression on errors generated from the eight different combinations of factors in the pricing model (3.1), with state fixed effects, standardized regressors, and standard errors clustered at the state level.

Table 3.3: Own-State Covid Characteristics Fail to Explain Pricing Errors

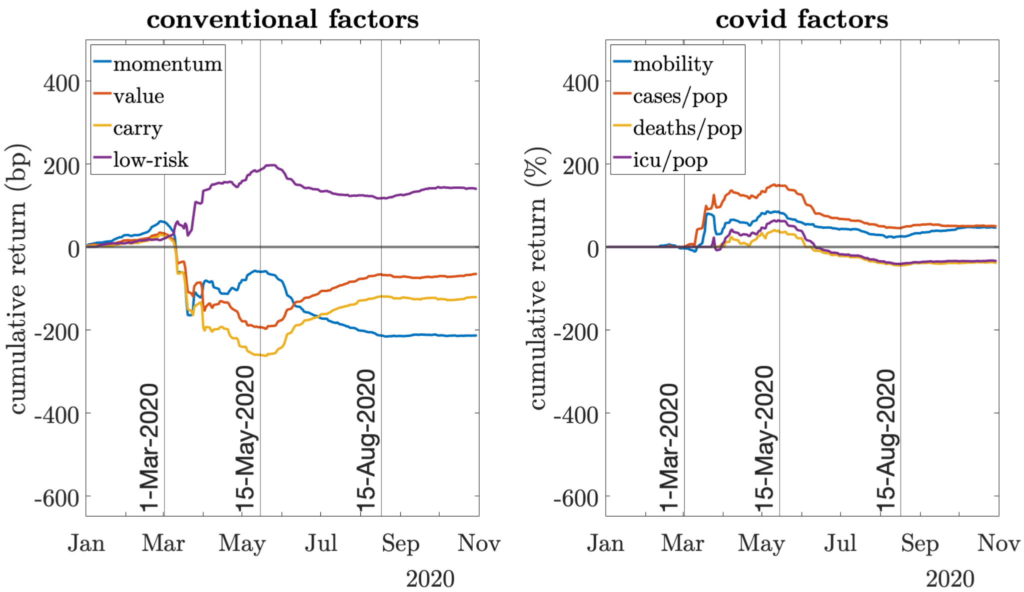
Factor	All Factors	+ Market	+ Slope	+ Slope + Convexity	+ VIX	+ Market + Slope	+ Market + Slope + Convexity	+ Market + Slope + Convexity + VIX
Mobility	33	38	17	19	18	22	20	30
	(0.610)	(0.531)	(0.778)	(0.753)	(0.755)	(0.698)	(0.726)	(0.542)
Cases / pop	186*	188*	163***	126	141*	165	132	108
	(0.038)	(0.097)	(0.049)	(0.158)	(0.026)	(0.115)	(0.199)	(0.191)
ICU beds / pop	36	48	33	69	35	46	62	65
	(0.840)	(0.728)	(0.847)	(0.677)	(0.867)	(0.716)	(0.602)	(0.649)
Deaths / pop	-36	-31	-42	-50	-50	-36	-41	-44
	(0.779)	(0.799)	(0.741)	(0.684)	(0.728)	(0.759)	(0.704)	(0.692)
Joint significance F-test								
F-statistic (p-value)	1.59 (0.78)	1.82 (0.14)	1.57 (0.20)	0.76 (0.56)	3.21 (0.02)	1.21 (0.32)	0.81 (0.53)	0.52 (0.72)

Note: Values are estimated coefficients from a regression of municipal bond pricing errors from (3.1) on own-state Covid characteristics. Each column corresponds to a distinct set of factors in (3.1). These regressions are described in Equation 3.7 in the text. Data are daily state municipal bond indices (S&P) and Covid characteristics (IHME) from March 1 to May 15, 2020. p-values for these estimates are in parentheses. *: $p \leq 0.1$; **: $p \leq 0.05$; ***: $p \leq 0.01$.

Most of the pandemic-related variables in a state are not statistically significantly related to unexplained muni returns within that state. The lone exception to this is Covid cases per capita, which shows up as positive and significant in half of the regressions, though only when fewer than six factors are included in the pricing model. Table 3.3 suggests that while some simple pandemic characteristics may be related to unexplained returns in early 2020, this relationship is not robust to pricing models. While own-state characteristics might fail to explain much of the remaining excess returns, it may be that we need to allow a more flexible relationship between the distribution of the pandemic situation and the distribution of municipal bond returns.

Average risk premia of Covid-based factors. To examine more fully the relationship between the state of Covid and lockdowns across states and the distribution of relative muni yields, we include our unconventional pandemic factors directly into the pricing model and compute the average risk premia of these factors. These factors are long-short factors corresponding to the return on a portfolio which is long on states with favorable Covid situations and short on states with unfavorable situations. Figure 3.5 compares the performance of these pandemic-based factors against the performance of the conventional factors we have analyzed thus far.

Figure 3.5: Cumulative Returns on Conventional and Covid-Based Factors



Note: *Lines indicate the historical performance of portfolios based on the indicated factors for state municipal bond indices from S&P, beginning in January 2020. The left panel includes four conventional factors, while the right panel shows factors based on state-level pandemic characteristics. A portfolio for each factor is long on the "top" quintile of the distribution and short on the "bottom" quintile. Details of this procedure are described in Section III. Vertical lines indicate the beginnings of the subperiods we analyze in Section IV.3.*

Figure 3.5 shows that the long-short Covid-based portfolios generated positive excess returns in the first few months of the pandemic, indicating that the distribution of pandemic situations had some relationship to the distribution of muni returns. At the same time, three of the four conventional factors performed poorly: the long-short portfolios declined in value during this period. Only the low-risk factor, based on past volatility, performed positively. A portfolio relying on traditional determinants of municipal bond returns would have performed badly during the early days of the pandemic relative to a portfolio based on indicators of state-level mobility and Covid spread.

Table 3.4 makes this point clear. This table displays the average risk premia for the eight models considered previously with the unconventional Covid factors added into each model. The risk premium on the *ICU* factor is significant across all 8 models, and the *Cases* factor is significant in most specifications.[10] *Deaths* is significant in two models, and it is close to significance in two more; *Mobility* is not significant in any model. Furthermore, the

[10]If *ICU* and *Deaths* are dropped for collinearity, *Cases* is significant in every model.

Table 3.4: Covid Factors Outperform Conventional Factors in Early 2020

Factor	All Factors	+ Market	+ Slope	+ Slope + Convexity	+ VIX	+ Market + Slope	+ Market + Slope + Convexity	+ Market + Slope + Convexity + VIX
				Long-Short Factors				
Momentum	1472	1519*	1438	1438	1396	1494*	1493*	1463
	(0.101)	(0.084)	(0.114)	(0.114)	(0.134)	(0.092)	(0.092)	(0.106)
Value	-867	-908	-919	-919	-950	-974	-974	-1008
	(0.383)	(0.357)	(0.350)	(0.350)	(0.331)	(0.313)	(0.313)	(0.290)
Carry	-1038	-1078	-1027	-1032	-1033	-1076	-1079	-1088
	(0.255)	(0.236)	(0.266)	(0.272)	(0.266)	(0.238)	(0.244)	(0.241)
Low-risk	763	757	807	811	781	803	805	793
	(0.164)	(0.167)	(0.147)	(0.140)	(0.163)	(0.146)	(0.140)	(0.146)
				Market Factors				
Market	-	-1857	-	-	-	-1859	-1859	-1860
		(0.749)				(0.749)	(0.749)	(0.751)
Slope	-	-	890	875	-	842	833	812
			(0.233)	(0.213)		(0.267)	(0.246)	(0.267)
Convexity	-	-	-	212	-	-	223	246
				(0.497)			(0.463)	(0.405)
VIX	-	-	-	-	-52	-	-	-47
					(0.496)			(0.532)
				Covid Factors				
Mobility	626	634	624	626	626	634	635	638
	(0.240)	(0.230)	(0.245)	(0.247)	(0.248)	(0.230)	(0.234)	(0.235)
Cases / pop	1006*	1005*	982*	991*	959	979*	986*	970
	(0.089)	(0.088)	(0.099)	(0.099)	(0.111)	(0.098)	(0.100)	(0.109)
ICU beds / pop	1109*	1076*	1077*	1079*	1069*	1034*	1035*	1023*
	(0.057)	(0.071)	(0.066)	(0.067)	(0.072)	(0.083)	(0.084)	(0.091)
Deaths / pop	1221*	1106	1203	1213	1271*	1059	1067	1106
	(0.097)	(0.154)	(0.105)	(0.105)	(0.089)	(0.173)	(0.176)	(0.166)
Avg. Adj. R^2	0.36	0.39	0.40	0.41	0.39	0.42	0.44	0.46

Note: Values displayed are the average risk premia, in annualized basis points, for a given factor (row) in a given model (column), where models include different combinations of the market factors. Average risk premia for the factors are computed as described in Equation 3.3 of the text. Data are daily state municipal bond indices from S&P from March 1 to May 15, 2020. Covid factors are from IHME. p-values for these estimates are in parentheses. *: $p \leq 0.1$; **: $p \leq 0.05$; ***: $p \leq 0.01$.

conventional factors are rarely significant determinants of muni returns: only the *Momentum* factor has even an occasional claim to significance. Note that the results presented so far are obtained by running the cross-sectional regressions without an intercept. The results in 3.5 show that, for key selected specifications, the conclusions are the same even when an intercept is included.

Overall, the results in this section suggest that pandemic-related variables at the state level did indeed have an influence on the level and distribution of municipal bond prices in early 2020. The unprecedented shakeup in this market was not solely a function of its relationship to other markets which were also roiled; new factors came into play as the pandemic spread. However, the relationship between the state of the pandemic across states and municipal yields in those states is not a simple matter of the own-state pandemic situation on a given day on average. States with a more favorable pandemic situation relative

Table 3.5: Results Remain the Same When Including Intercept

Factor	Long-Short Factors	Long-Short + Market Factors	Long-Short + Covid Factors	Long-Short + Market + Covid Factors
		Long-Short Factors		
Momentum	517	-405	1557*	1546*
	(0.692)	(0.781)	(0.055)	(0.054)
Value	-822	-1167	-992	-1108
	(0.319)	(0.214)	(0.226)	(0.159)
Carry	-1354	-1626	-1102	-1146
	(0.127)	(0.106)	(0.185)	(0.171)
Low-risk	894	823	551	599
	(0.226)	(0.334)	(0.288)	(0.269)
		Market Factors		
Market	-	-2487	-	-2821
		(.0750)		(0.435)
Slope	-	6012**	-	927
		(0.032)		(0.122)
Convexity	-	612	-	263
		(0.178)		(0.321)
VIX	-	291	-	4918
		(0.319)		(0.508)
		Covid Factors		
Mobility	-	-	704	705
			(0.127)	(0.123)
Cases / pop	-	-	1000*	965
			(0.093)	(0.114)
ICU beds / pop	-	-	1127**	1040*
			(0.048)	(0.076)
Deaths / pop	-	-	1287*	1149
			(0.066)	(0.129)
Intercept	1142	916	1533	1298
	(0.143)	(0.168)	(0.530)	(0.610)
Avg. Adj. R^2	0.23	0.38	0.40	0.51

Note: Values displayed are the average risk premia, in annualized basis points, for a given factor (row) in a given model (column), where models include different combinations of the market factors. Average risk premia for the factors are computed as described in Equation 3.3 of the text. Data are daily state municipal bond indices from S&P from March 1 to May 15, 2020. Covid factors are from IHME. p-values for these estimates are in parentheses. *: $p \leq 0.1$; **: $p \leq 0.05$; ***: $p \leq 0.01$.

to other states—–fewer cases, severe illnesses, and deaths—–did tend to have more favorable bond prices than states with worse situations, but the relationship of each state to this overall pattern was slightly different. The long-short Covid-based factors generated significant risk premia, suggesting that this effect was pronounced at the extremes of the distribution during the early Covid period.

IV.3 The Breakdown was Short-Lived

Figure 3.3 suggests that while the distribution of municipal bond yields experienced an unprecedented disruption in March 2020, the dynamics of this distribution returned to historical patterns by the end of that year. That figure along with Figure 3.5 suggests that there were three distinct periods in the post-pandemic behavior of municipal bonds. First, the March and April period saw extreme disruption in the distribution and strong performance of the Covid portfolios coupled with poor performance of the conventional factors. Second, an adjustment period occurred from mid-May to mid-August as the distribution of relative yields returned to normal and the factors reversed course gradually from their strong changes in the first period. Finally, the rest of 2020 witnesses a return of distributional dynamics to their historical ranges and a settling down of the portfolio-based factors to a place of stable performance.

Table 3.6: Pricing Model Returns to Normal by the End of 2020

Factor	March 1 - May 15	June 1 - August 15	September 1 - December 15
	Long-Short Factors		
Momentum	1472	-682***	15
	(0.101)	(0.009)	(0.805)
Value	-868	689***	164**
	(0.381)	(0.001)	(0.036)
Carry	-1039	803***	244**
	(0.254)	(0.002)	(0.018)
Low-risk	764	-267	51
	(0.164)	(0.149)	(0.654)
	Covid Factors		
Mobility	626	-255*	-86
	(0.239)	(0.081)	(0.241)
Cases / pop	1005*	-631***	-4
	(0.089)	(0.003)	(0.942)
ICU beds / pop	1107*	-519***	29
	(0.057)	(0.007)	(0.602)
Deaths / pop	1225*	-450**	13
	(0.093)	(0.034)	(0.816)
Avg. Adj. R^2	0.36	0.24	0.30

Note: Values displayed are the average risk premia, in annualized basis points, for a given factor (row) in the model without market factors, for three different subperiods of 2020 (column). Column 1 of this table corresponds to Column 1 of Table 3.4. Average risk premia for the factors are computed as described in Equation 3.3 of the text. Data are daily state municipal bond indices from S&P, and Covid factors are from IHME. p-values for these estimates are in parentheses. *: $p \leq 0.1$; **: $p \leq 0.05$; ***: $p \leq 0.01$..

An analysis of average risk premia for the eight portfolio-based factors—four conventional and four Covid-related—confirms the existence of these three distinct periods in the dynamics of muni returns throughout 2020. Table 3.6 shows the average risk premia on these eight factors for three distinct subperiods of 2020: March 1 through May 15, June 1 through August 15, and September 1 through December 15. The first subperiod reflects the first column of Table 3.4. In the second subperiod, the sign flips on all eight factors, significantly so for all but Low risk. The risk premia are negative on all of the Covid factors and the momentum factor, because the excess returns on them during the second subperiod are negative (see Figure 3.5). In the final period risk premia on pandemic factors are essentially zero and the premia on the conventional factors—–except for momentum, which is close to zero—–return to values in line with their pre-pandemic values (Column 1 of Table 3.1).

The risk premia in each of these subperiods reflects the dynamics present in Figures 3.3 and 3.5. The first two months of the Covid crisis reflect an initial panic and upheaval in financial markets. It is during this panic that Covid-related variables seem to be priced into the municipal market most strongly. In the middle of the year, the market corrected itself: distributional dynamics began to return to normal, the long-short portfolios reversed course, and risk premia on the portfolio-based factors flipped completely from their values early in the crisis. This correction continued until the dynamics of municipal bond prices had largely returned to their pre-crisis levels by the end of the year. While the pandemic had a profound effect on municipal markets, this effect only lasted for a short time.

V Conclusion

This paper examines the unique behavior of municipal yields during the Covid-19 crisis. We introduced a factor-based pricing model to the municipal bond market, and show that traditional factors failed to explain the large movements in relative muni yields in March 2020 and the following months. While the traditional factors broke down, factors based on the distribution of pandemic-related outcomes significantly explained muni prices, though the effect of the Covid situation on state-level yields is different across the distribution. Finally, the influence of these novel factors was short-lived, and the municipal market returned to normal after eight months.

The causes of this quick return to normalcy are a fruitful topic for research. Our results suggest that policy actions undertaken by the Federal Reserve were effective in calming municipal markets; this is the conclusion of papers such as Haughwout et al. (2022). Federal Reserve actions may not be the only cause, and further investigation into the reasons for the dynamics shown in this paper would lend valuable insights for pricing municipal bonds in times of acute financial crisis.

APPENDIX A

Appendix to Chapter 1

I Additional tables

Table A.1: NBER papers used to construct the safe assets library

Authors	Title	Date	JEL	Number
Ben Bernanke, Mark Gertler, Simon Gilchrist	THE FINANCIAL ACCELERATOR AND THE FLIGHT TO QUALITY	July 1994	N/A	4789
Clemens Sialm	STOCHASTIC TAXATION AND ASSET PRICING IN DYNAMIC GENERAL EQUILIBRIUM	October 2002	G1, H2, E4	9301
Harvey S. Rosen, Stephen Wu	PORTFOLIO CHOICE AND HEALTH STATUS	January 2003	G11, I19	9453
Anna Pavlova, Roberto Rigobon	WEALTH TRANSFERS, CONTAGION, AND PORTFOLIO CONSTRAINTS	June 2005	G12, G15, F31, F36	11440
Ricardo J. Caballero, Arvind Krishnamurthy	FINANCIAL SYSTEM RISK AND FLIGHT TO QUALITY	December 2005	E30, E44, E5, F34, G1, G22, G28	11834
Ricardo J. Caballero, Arvind Krishnamurthy	FLIGHT TO QUALITY AND COLLECTIVE RISK MANAGEMENT	March 2006	E30, E44, E5, F34, G1, G22, G28	12136
Ricardo J. Caballero, Arvind Krishnamurthy	COLLECTIVE RISK MANAGEMENT IN A FLIGHT TO QUALITY EPISODE	February 2007	E30, E44, E5, F34, G1, G21, G22, G28	12896
Markus K. Brunnermeier, Lasse Heje Pedersen	MARKET LIQUIDITY AND FUNDING LIQUIDITY	February 2007	G12, G21, G24	12939
William A. Brock, Charles F. Manski	COMPETITIVE LENDING WITH PARTIAL KNOWLEDGE OF LOAN REPAYMENT	October 2008, Revised July 2009	E43, G11, G18, H81	14378
Isil Erel, Brandon Julio, Woojin Kim, Michael Weisbach	MARKET CONDITIONS AND THE STRUCTURE OF SECURITIES	May 2009	E00, G01, G32	14952
John Y. Campbell, Robert J. Shiller, Luis M. Viceira	UNDERSTANDING INFLATION-INDEXED BOND MARKETS	May 2009	E43, E44, G12	15014
Stavros Panageas	BAILOUTS, THE INCENTIVE TO MANAGE RISK, AND FINANCIAL CRISES	June 2009	G01, G32, G33	15058
François Gourio	DISASTERS RISK AND BUSINESS CYCLES	October 2009	E32, E44, G12	15399
Oliver D. Hart, Luigi Zingales	INEFFICIENT PROVISION OF LIQUIDITY	August 2011	E41, E51, G21	17299
Carol Bertaut, Laurie Pounder DeMarco, Steven B. Kamin, Ralph W. Tryon	ABS INFLOWS TO THE UNITED STATES AND THE GLOBAL FINANCIAL CRISIS	August 2011	F3, G1	17350
Arvind Krishnamurthy, Annette Vissing-Jorgensen	THE EFFECTS OF QUANTITATIVE EASING ON INTEREST RATES: CHANNELS AND IMPLICATIONS FOR POLICY	October 2011	E4, E5, G01, G14, G18	17555

Ufuk Akcigit, Qingmin Liu	THE ROLE OF INFORMATION IN COMPETITIVE EXPERIMENTATION	November 2011, Revised November 2011	D83, D92, O31	17602
Veronica Guerrieri, Robert Shimer	DYNAMIC ADVERSE SELECTION: A THEORY OF ILLIQUIDITY, FIRE SALES, AND FLIGHT TO QUALITY	March 2012	D82, E44, G14	17876
Yongyang Cai, Kenneth L. Judd, Rong Xu	NUMERICAL SOLUTION OF DYNAMIC PORTFOLIO OPTIMIZATION WITH TRANSACTION COSTS	January 2013	C61, C63, G11	18709
Gary B. Gorton, Guillermo Ordoñez	THE SUPPLY AND DEMAND FOR SAFE ASSETS	January 2013, Revised April 2020	E0, E02, E2, E3, E32, E4, E41, G01, G12, G2	18732
Ricardo J. Caballero, Emmanuel Farhi	A MODEL OF THE SAFE ASSET MECHANISM (SAM): SAFETY TRAPS AND ECONOMIC POLICY	January 2013, Revised August 2013	E32, E4, E5, E52, E62, E63, F3, F33, F41, G01, G1, G28	18737
Ricardo J. Caballero, Emmanuel Farhi	THE SAFETY TRAP	February 2014, Revised January 2017	E0, E1, E5, E52	19927
Anil K. Kashyap, Dimitrios P. Tsomocos, Alexandros P. Vardoulakis	HOW DOES MACROPRUDENTIAL REGULATION CHANGE BANK CREDIT SUPPLY?	May 2014	E44, G01, G21, G28	20165
Alan Moreira, Alexi Savov	THE MACROECONOMICS OF SHADOW BANKING	July 2014	E44, E52, G01, G21, G23	20335
Robert J. Barro, Jesús Fernández-Villaverde, Oren Levintal, Andrew Mollerus	SAFE ASSETS	October 2014, Revised May 2017	G1, E0, E2	20652
Frédéric Boissay, Russell Cooper	THE COLLATERAL TRAP	November 2014, Revised March 2016	E44, E51, G21, G23	20703
Ricardo J. Caballero, Emmanuel Farhi, Pierre-Olivier Gourinchas	GLOBAL IMBALANCES AND POLICY WARS AT THE ZERO LOWER BOUND	October 2015, Revised January 2021	E0, F3, F4, G01	21670
Sebastian Edwards, Francis A. Longstaff, Alvaro Garcia Marin	THE U.S. DEBT RESTRUCTURING OF 1933: CONSEQUENCES AND LESSONS	November 2015	E43, E44, E65	21694
Shin-ichi Fukuda	STRONG STERLING POUND AND WEAK EUROPEAN CURRENCIES IN THE CRISES: EVIDENCE FROM COVERED INTEREST PARITY OF SECURED RATES	January 2016	F36, G12, G15	21938
Markus K. Brunnermeier, Luis Garicano, Philip Lane, Marco Pagano, Ricardo Reis, Tano Santos, David Thesmar, Stijn Van Nieuwerburgh, Dimitri Vayanos	THE SOVEREIGN-BANK DIABOLIC LOOP AND ESBIES	February 2016, Revised June 2016	E58, F34, G01, G15, G21, G23	21993
Zhiguo He, Arvind Krishnamurthy, Konstantin Milbradt	WHAT MAKES US GOVERNMENT BONDS SAFE ASSETS?	February 2016	E0, F0, F3, G0, G11	22017
Ricardo J. Caballero, Emmanuel Farhi, Pierre-Olivier Gourinchas	SAFE ASSET SCARCITY AND AGGREGATE DEMAND	February 2016	E0, F3, F4, G1	22044

Gary B. Gorton	THE HISTORY AND ECONOMICS OF SAFE ASSETS	April 2016	E3, E41, E42, E44, E5, G2	22210
Zhiguo He, Arvind Krishnamurthy, Konstantin Milbradt	A MODEL OF SAFE ASSET DETERMINATION	May 2016	E44, F33, G15, G28	22271
Jacob Boudoukh, Jordan Brooks, Matthew Richardson, Zhikai Xu	THE COMPLEXITY OF LIQUIDITY: THE EXTRAORDINARY CASE OF SOVEREIGN BONDS	August 2016	F3, G1, G12, G15	22576
Pierre-Olivier Gourinchas, Hélène Rey	REAL INTEREST RATES, IMBALANCES AND THE CURSE OF REGIONAL SAFE ASSET PROVIDERS AT THE ZERO LOWER BOUND	September 2016	E2, E4, F4	22618
Germán Gutiérrez, Thomas Philippon	INVESTMENT-LESS GROWTH: AN EMPIRICAL INVESTIGATION	December 2016, Revised January 2016	E22, G3	22897
Mark Egan, Stefan Lewellen, Adi Sunderam	THE CROSS SECTION OF BANK VALUE	March 2017, Revised July 2021	G2, G21	23291
Michael D. Bordo, Robert N. McCauley	TRIFFIN: DILEMMA OR MYTH?	January 2018	F32, F33, F34, F41, H63	24195
Zhengyang Jiang, Arvind Krishnamurthy, Hanno Lustig	FOREIGN SAFE ASSET DEMAND AND THE DOLLAR EXCHANGE RATE	March 2018, Revised in September 2020	G15	24439
Gita Gopinath, Jeremy C. Stein	BANKING, TRADE, AND THE MAKING OF A DOMINANT CURRENCY	April 2018	E0, F0, G0	24485
Marina Azzimonti, Pierre Yared	THE OPTIMAL PUBLIC AND PRIVATE PROVISION OF SAFE ASSETS	April 2018	E21, E25, E62, H21, H63	24534
Maarten Meeuwis, Jonathan A. Parker, Antoinette Schoar, Duncan I. Simester	BELIEF DISAGREEMENT AND PORTFOLIO CHOICE	September 2018, Revised June 2021	D14, D84, E71, G11, G12, G40	25108
Matthias Fleckenstein, Francis A. Longstaff	FLOATING RATE MONEY? THE STABILITY PREMIUM IN TREASURY FLOATING RATE NOTES	November 2018	G12, G18	25216
Markus K. Brunnermeier, Lunyang Huang	A GLOBAL SAFE ASSET FOR AND FROM EMERGING MARKET ECONOMIES	December 2018	E42, E43, F32, F33	25373
Gary Gorton, Toomas Laarits, Tyler Muir	1930: FIRST MODERN CRISIS	January 2019	E02, E3, G01	25452
Joshua Aizenman, Yin-Wong Cheung, Xingwang Qian	THE CURRENCY COMPOSITION OF INTERNATIONAL RESERVES, DEMAND FOR INTERNATIONAL RESERVES, AND GLOBAL SAFE ASSETS	June 2019	F15, F3, F31	25934
Jules H. van Binsbergen, William F. Diamond, Marco Grotteria	RISK-FREE INTEREST RATES	August 2019	E41, E43, E44, E52, E58, G12, G15	26138
Menzie D. Chinn, Hiro Ito	A REQUIEM FOR “BLAME IT ON BEIJING”: INTERPRETING ROTATING GLOBAL CURRENT ACCOUNT SURPLUSES	September 2019	F32, F41	26226

Carolin Pflueger, Emil Siriwardane, Adi Sunderam	FINANCIAL MARKET RISK PERCEPTIONS AND THE MACROECONOMY	September 2019	E03, E22, E44, G12	26290
Shai Bernstein, Richard R. Townsend, Ting Xu	FLIGHT TO SAFETY: HOW ECONOMIC DOWNTURNS AFFECT TALENT FLOWS TO STARTUPS	October 2020, Revised August 2021	E32, J22, J24, L26, M13	27907
Robert J. Barro	R MINUS G	October 2020, Revised June 2021	E21, G12, O4	28002
Susanto Basu, Giacomo Candian, Ryan Chahrour, Rosen Valchev	RISKY BUSINESS CYCLES	April 2021, Revised November 2021	E24, E32, G12	28693
J. Scott Davis, Eric van Wincoop	A THEORY OF THE GLOBAL FINANCIAL CYCLE	September 2021	F30, F40	29217
Rohan Kekre, Moritz Lenel	THE FLIGHT TO SAFETY AND INTERNATIONAL RISK SHARING	September 2021	E44, F44, G15	29238
Galina Hale, Luciana Juvenal	EXTERNAL BALANCE SHEETS AND THE COVID-19 CRISIS	September 2021	F32, F34, G15	29277

Table A.2: Bigrams used for the construction of the full index

safe asset	inflationindexed bond	wealth share
public debt	valuation effect	newly issue
convenience yield	market liquidity	euro crisis
risky asset	sterling pound	global riskaversion
flight quality	equity share	banking sector
risk premia	home foreign	asset provider
safety trap	treasury security	safe claim
risk premium	probability disaster	danish krone
basis point	financial autarky	portfolio share
asset position	hedge fund	perceive risk
treasury basis	commercial paper	liquidity provision
excess return	interbank market	bidask spread
demand safe	global imbalance	float rate
supply safe	term structure	value safe
safe debt	debt issuance	save glut
gold clause	libor basis	basis swap
private asset	domestic bond	external finance
deposit productivity	position safe	return equity
equity premium	safety shock	asset pricing
asset productivity	safe interest	fiscal capacity
bond yield	treasury note	collateral trap
periphery country	expect return	treasury bill
safe dollar	bond price	stock return
deposit rate	relative risk	risk perception
home bias	bond return	credit quality
term trade	treasury bond	treasury agency
riskfree rate	shortterm debt	rate note
sovereign debt	sovereign bond	corporate bond
cash flow	liquidity shock	debt issue
currency composition	risk free	collateral value
credit market	asset market	knightian uncertainty
treasury yield	asset return	riskaversion shock
real rate	bank value	
default risk	asset demand	

Table A.3: Summary of bond data

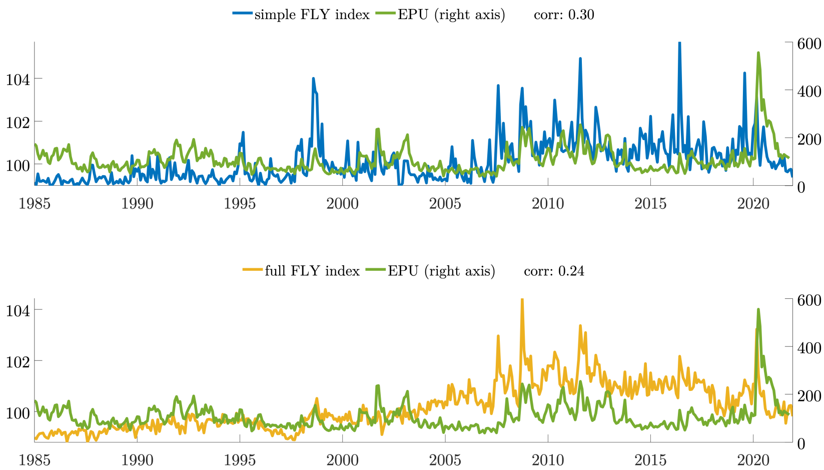
ISO 2 code	Country	IMF classification	Time available	Currencies available	Maturities available
AT	Austria	advanced	Jan-1995 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
AU	Australia	advanced	May-1991 : Dec-2021	AUD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
BE	Belgium	advanced	Jan-1995 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
BG	Bulgaria	emerging	Jul-2005 : Dec-2021	BGN	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
BR	Brazil	emerging	Apr-2007, Apr-1998 : Dec-2021	BRL, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
CA	Canada	advanced	Jul-1991 : Dec-2021	CAD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
CH	Switzerland	advanced	Mar-1994 : Dec-2021	CHF	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
CL	Chile	emerging	Nov-2005 : Dec-2021	CLP, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
CN	China	emerging	Apr-2003 : Dec-2021	CNY	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
CO	Colombia	emerging	Nov-2004, Jan-1998 : Dec-2021	COP, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
CZ	Czech Republic	advanced	Feb-1997 : Dec-2021	CZK	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
DE	Germany	advanced	Nov-1991 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
DK	Denmark	advanced	Mar-1994 : Dec-2021	DKK	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
ES	Spain	advanced	Jul-1993 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
FI	Finland	advanced	Oct-1998 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
FR	France	advanced	May-1992 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
GB	United Kingdom	advanced	May-1991 : Dec-2021	GBP	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
GR	Greece	advanced	Feb-2001 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
HU	Hungary	emerging	Feb-1999 : Dec-2021	HUF	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
ID	Indonesia	emerging	Aug-2003 : Dec-2021	IDR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
IE	Ireland	advanced	Mar-1994 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
IL	Israel	advanced	Apr-2005 : Dec-2021	ILS	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
IN	India	emerging	Dec-1998 : Dec-2021	INR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
IT	Italy	advanced	May-1997 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
JP	Japan	advanced	Oct-1992 : Dec-2021	JPY	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
KR	South Korea	advanced	Nov-2000, Jan-1998 : Dec-2021	KRW, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
MX	Mexico	emerging	Mar-2003, Jan-1998 : Dec-2021	MXN, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
MY	Malaysia	emerging	Oct-1999 : Dec-2021	MYR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
NL	Netherlands	advanced	May-1991 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
NO	Norway	advanced	Aug-1998 : Dec-2021	NOK	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
NZ	New Zealand	advanced	Apr-1992 : Dec-2021	NZD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
PE	Peru	emerging	Sep-2007, Mar-2006 : Dec-2021	PEN, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
PH	Philippines	emerging	Sep-2001, Jan-2001 : Dec-2021	PHP, USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
PL	Poland	emerging	Jun-1999 : Dec-2021	PLN	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
PT	Portugal	advanced	Jan-1995 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
RO	Romania	emerging	Dec-2010 : Dec-2021	RON	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
RU	Russia	emerging	Jul-2007 : Dec-2021	RUB	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
SE	Sweden	advanced	Mar-1994 : Dec-2021	SEK	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
SK	Slovakia	advanced	May-2003 : Dec-2021	EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
TH	Thailand	emerging	Jul-1999 : Dec-2021	THB	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
TR	Turkey	emerging	Jul-2010, Aug-2000 : Dec-2021	TRY, USD, EUR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
US	United States	advanced	May-1991 : Dec-2021	USD	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y
ZA	South Africa	emerging	Jan-1995 : Dec-2021	ZAR	3M, 1Y, 2Y, 3Y, 5Y, 7Y, 10Y

II Additional figures

Figure A.1: Wordcloud summarizing the relative frequency of the bigrams in Mankiw's *Principles of Economics*

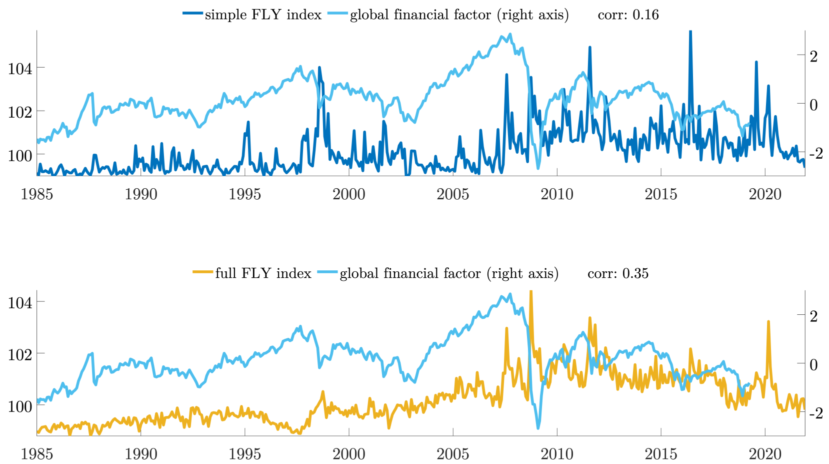
Note: The figure shows the list of the top 100 bigrams in the economics library, $\mathscr{L}^{econ}$, which is based on the eighth edition of Greg Mankiw's *Principles of Economics* (Mankiw, 2017); the size of each bigram k is proportional to its frequency $f_k(\mathscr{L}^{econ})$; the construction of the library and frequencies is described in section III.1.

Figure A.2: Simple FLY index and Full FLY index compared with the EPU



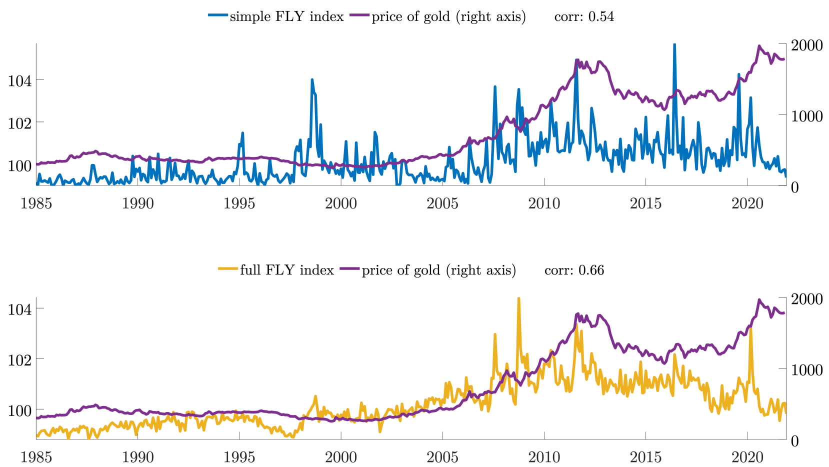
Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to the Economic Policy Uncertainty Index (EPU, with units on the right axis); details on the construction of the FLY are described in section III.1; the EPU is from Baker et al. (2016); the correlation between each version of the index and the EPU is shown at the top of each graph; the frequency is monthly.

Figure A.3: Simple FLY index and Full FLY index compared with the global financial factor



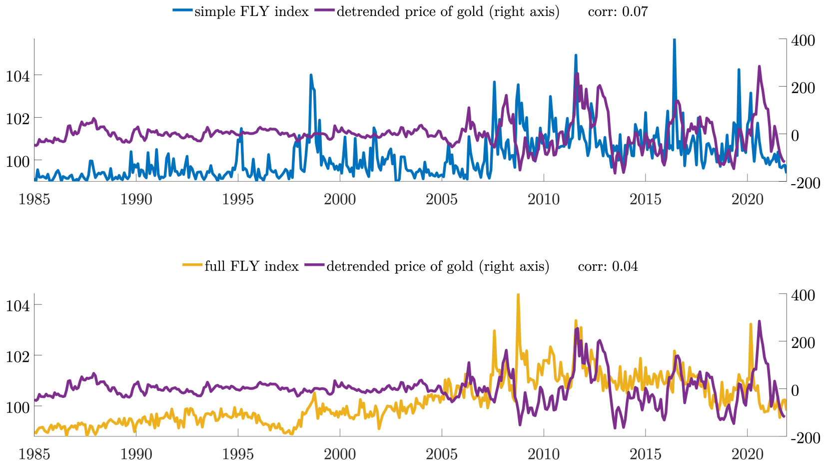
Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to the Global Financial Factor (GFF, with units on the right axis); details on the construction of the FLY are described in section III.1; the GFF is from Miranda-Agrippino and Rey (2021); the correlation between each version of the index and the GFF is shown at the top of each graph; the frequency is monthly.

Figure A.4: Simple FLY index and Full FLY index compared with the price of gold



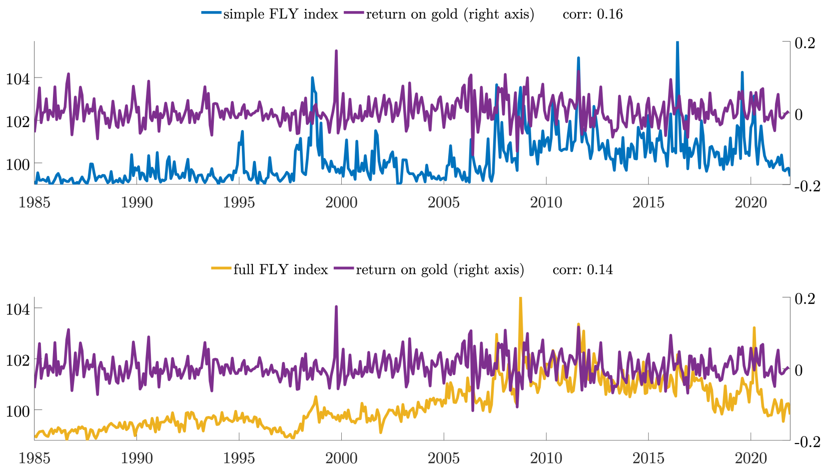
Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to the price of gold (with units on the right axis); details on the construction of the FLY are described in section III.1; the price of gold is from the Federal Reserve Economic Data; the correlation between each version of the index and the price of gold is shown at the top of each graph; the frequency is monthly.

Figure A.5: Simple FLY index and Full FLY index compared with the detrended price of gold



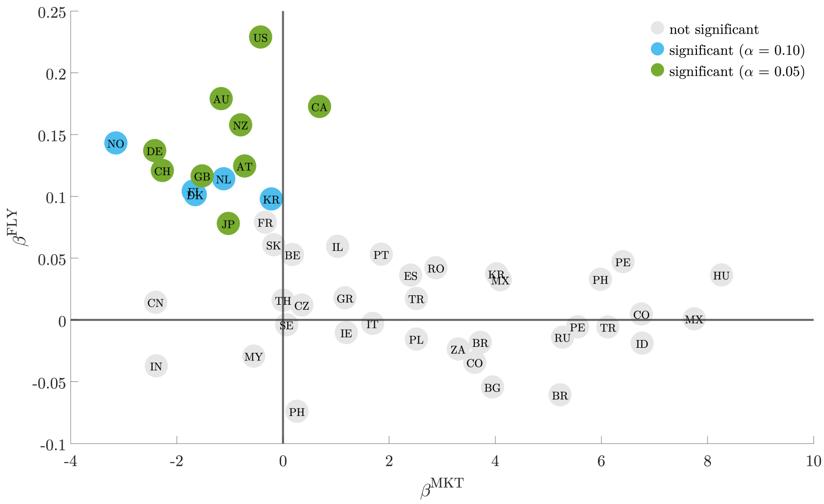
Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to the detrended (HP-filtered) price of gold (with units on the right axis); details on the construction of the FLY are described in section III.1; the price of gold is from the Federal Reserve Economic Data; the correlation between each version of the index and the detrended price of gold is shown at the top of each graph; the frequency is monthly.

Figure A.6: Simple FLY index and Full FLY index compared with the return of gold



Note: the figure plots the simple version of the FLY index, based on the simple safe assets library $\mathscr{L}^0$, and the full version of the FLY index, based on the full safe assets library $\mathscr{L}$, and compares each of them to the return of gold (with units on the right axis); details on the construction of the FLY are described in section III.1; the price of gold is from the Federal Reserve Economic Data; the correlation between each version of the index and the return of gold is shown at the top of each graph; the frequency is monthly.

Figure A.7: Scatterplot of factor loadings on the global market factor and on the FLY index, 10Y sovereign bonds, 1991-2019



Note: each bubble corresponds to a 10Y bond index j; the ISO-2 code of the corresponding country is reported inside the bubble; the associated x-axis value is the estimated $\hat{\beta}^{M,j}$ from running regression (1.25) for bond index j in the period from 1991 to 2019, using monthly data; similarly, the associated y-axis value is the estimated $\hat{\beta}^{FLY,j}$ from the same regression; countries may appear twice if there are both local- and foreign-currency denominated bond indices; statistical significance for $\hat{\beta}^{FLY,j}$ is indicated by different colors, as reported in the legend; significance for $\hat{\beta}^{MKT,j}$ is not reported.

III Model derivations

I follow the derivation in Brunnermeier et al. (2022a), adapted to accommodate the extensions involving multiple countries, country-specific risk, and time-varying convenience yields. First, let us recap the equations from the setup in the main text. On the production side, output is produced linearly from capital, $y_{it} = a_t k_{it}^j$, and the law of motion of individual capital is

$$\frac{\mathrm{d}k_{it}^j}{k_{it}^j} = \Big(\Phi(\iota_{it}^j) - \delta\Big)\mathrm{d}t + \tilde{\sigma}_t \mathrm{d}\widetilde{Z}_{it}^j \ , \tag{A.1}$$

where $\Phi(\iota_{it}) = \frac{1}{\phi}\ln(1+\phi\iota_{it})$. On the consumption side, preferences are given by

$$U_{i0}^j = \mathbb{E}\left[\int_0^\infty e^{-\rho t}\Big\{\ln c_{it}^j + \int_0^1 v_t^{j'} \ln b_{it}^{j,j'} \mathrm{d}j\Big\}\right] \ . \tag{A.2}$$

On the government side, nominal debt follows an exogenous process

$$\frac{\mathrm{d}B_t^j}{B_t^j} = \mu_t^{B,j}\mathrm{d}t \ , \tag{A.3}$$

and the government faces the budget constraint

$$i_t^j B_t^j + P_t^j g K_t^j = \mu_t^{B,j} B_t^j + P_t^j \tau_t^j a_t K_t^j \ . \tag{A.4}$$

We are going to focus on the price of capital and, for simplicity, scaled real value of bond holdings

$$q_t^{B,j'} = \frac{B_t^{j'}/P_t^{j'}}{K_t^{j'}} \ . \tag{A.5}$$

Bond and capital prices are assumed to follow standard Ito processes

$$\frac{\mathrm{d}q_t^{B,j'}}{q_t^{B,j'}} = \mu_t^{q^B,j'}\mathrm{d}t + \sigma_t^{q^B,j'}\mathrm{d}Z_t + \tilde{\omega}_t^{q^B}\mathrm{d}\widetilde{W}_t^j \ . \tag{A.6}$$

$$\frac{\mathrm{d}q_t^{K,j}}{q_t^{K,j}} = \mu_t^{q^K,j}\mathrm{d}t + \sigma_t^{q^K,j}\mathrm{d}Z_t \ . \tag{A.7}$$

Applying Ito's lemma, bond returns are given by

$$\begin{aligned}
\mathrm{d}r_t^{B,j'} &= i_t^{j'}\mathrm{d}t + \frac{\mathrm{d}(1/P_t^{j'})}{1/P_t^{j'}} = i_t^{j'}\mathrm{d}t + \frac{\mathrm{d}(q_t^{B,j'}K_t^{j'}/B_t^{j'})}{q_t^{B,j'}K_t^{j'}/B_t^{j'}} \\
&= \Big[\Phi(\iota_{it}^{j'}) - \delta + \mu_t^{q^B,j'} - \check{\mu}_t^{B,j'}\Big]\mathrm{d}t + \sigma_t^{q^B,j'}\mathrm{d}Z_t + \tilde{\omega}_t^{q^B}\mathrm{d}\widetilde{W}_t^{j'} \ ,
\end{aligned} \tag{A.8}$$

and the diversified bond portfolio return is

$$\begin{aligned}\mathrm{d}r_t^{\bar{B}} &= \int \mathrm{d}r_t^{B,j'}\mathrm{d}j' \\ &= \mathbb{E}_t\big[\mathrm{d}r_t^{\bar{B}}\big] + \left(\int \sigma_t^{q^B,j'}\mathrm{d}j'\right)\mathrm{d}Z_t \ . \end{aligned} \tag{A.9}$$

Similarly, the capital return is

$$\begin{aligned}\mathrm{d}r_{it}^{K,j} &= \frac{(1-\tau_t^j)a_t - \iota_{it}^j}{q_t^{K,j}} + \frac{\mathrm{d}(q_t^{K,j}k_{it}^j)}{q_t^{K,j}k_{it}^j} \\ &= \left[\frac{(1-\tau_t^j)a_t - \iota_{it}^j}{q_t^{K,j}} + \Phi(\iota_{it}^j) - \delta + \mu_t^{q^K,j}\right]\mathrm{d}t + \sigma_t^{q^K,j}\mathrm{d}Z_t + \tilde{\sigma}_t\mathrm{d}\widetilde{Z}_{it} \ . \end{aligned} \tag{A.10}$$

Finally, the equity return is

$$\mathrm{d}r_{it}^{E,j} = \mathbb{E}_t\big[\mathrm{d}r_{it}^{E,j}\big] + \sigma_t^{q^K,j}\mathrm{d}Z_t + \tilde{\sigma}_t\mathrm{d}\widetilde{Z}_{it} \ , \tag{A.11}$$

and the diversified equity portfolio return

$$\mathrm{d}\bar{r}_t^{E,j} = \int \mathrm{d}r_{it}^{E,j}\mathrm{d}i \ . \tag{A.12}$$

Net worth evolves as

$$\frac{\mathrm{d}n_{it}^j}{n_{it}^j} = -\frac{c_{it}^j}{n_{it}^j} + \theta_{it}^{j,j}\mathrm{d}r_t^{B,j} + \theta_{it}^{\bar{B},j}\mathrm{d}r_t^{\bar{B}} + \theta_{it}^{K,j}\mathrm{d}r_{it}^{K,j} - \theta_{it}^{E,j}\mathrm{d}r_{it}^{E,j} + \theta_{it}^{\bar{E},j}\mathrm{d}\bar{r}_t^{E,j} \ . \tag{A.13}$$

Portfolio choices are limited by two constraints: a home bias constraint

$$\theta_{it}^{j,j} = \hbar\big(\theta_{it}^{j,j} + \theta_{it}^{\bar{B},j}\big) = \hbar\vartheta_{it}^j \ , \tag{A.14}$$

and a skin-in-the-game constraint

$$\theta_{it}^{E,j} \leq (1-\chi)\theta_{it}^{K,j} \ . \tag{A.15}$$

The total portfolio weight on bonds is

$$\vartheta_{it}^j = \theta_{it}^{j,j} + \theta_{it}^{\bar{B},j} \ . \tag{A.16}$$

Portfolio weights must also add up to 1:

$$\theta_{it}^{j,j} + \theta_{it}^{\bar{B},j} + \theta_{it}^{K,j} - \theta_{it}^{E,j} + \theta_{it}^{\bar{E},j} = 1 \ . \tag{A.17}$$

Finally, productivity, volatility of idiosyncratic risk, nominal interest rates, and convenience benefits follow exogenous processes:

$$\frac{\mathrm{d}a_t}{a_t} = \mu_t^a \mathrm{d}t + \sigma_t^a \mathrm{d}Z_t \ , \tag{A.18}$$

$$\frac{\mathrm{d}\tilde{\sigma}_t}{\tilde{\sigma}_t} = \mu_t^{\tilde{\sigma}} \mathrm{d}t + \sigma_t^{\tilde{\sigma}} \mathrm{d}Z_t \ , \tag{A.19}$$

$$\frac{\mathrm{d}i_t^j}{i_t^j} = \mu_t^{i,j} \mathrm{d}t + \tilde{\omega}_t^i \mathrm{d}\widetilde{W}_t^j \ , \tag{A.20}$$

$$\frac{\mathrm{d}v_t^j}{v_t^j} = \mu_t^{v,j} \mathrm{d}t + \tilde{\omega}_t^v \mathrm{d}\widetilde{W}_t^j \ . \tag{A.21}$$

III.1 Hamiltonian

Before writing down the Hamiltonian, use the home bias constraint to rewrite the portfolio weights on domestic bonds and diversified bond portfolio as $\theta_{it}^{j,j} = \hbar \uptheta_{it}^j$ and $\theta_{it}^{\bar{B},j} = (1-\hbar)\uptheta_{it}^j$. In addition, use the fact that the portfolio weights have to sum up to one to get rid of the portfolio weight on the diversified bond portfolio. Finally, let $\bar{\sigma}_t^{q^B} = \int \sigma_t^{q^B,j'} \mathrm{d}j'$ and let $\bar{v}_t = \int v_t^{j'} \mathrm{d}j'$. Notice the non-pecuniary benefits from holding bonds can be split between the holding of domestic and diversified portfolio, and in the diversified portfolio each bond receives an equal infinitesimal weight, so that $\int v_t^{j'} \ln \theta_{it}^{j,j'} n_{it}^j \mathrm{d}j' = v_t^j \ln \theta_{it}^{j,j} n_{it}^j + \bar{v}_t \ln \theta_{it}^{\bar{B},j} n_{it}^j$. Therefore the Hamiltonian for the problem is

$$\begin{aligned}
\mathscr{H}_{it}^j = {} & e^{-\rho t} \ln c_{it}^j + e^{-\rho t} v_t^j \ln \hbar \uptheta_{it}^j n_{it}^j + e^{-\rho t} \bar{v}_t \ln(1-\hbar)\uptheta_{it}^j n_{it}^j + \xi_{it}^j \Bigg\{ - c_{it}{}^j \\
& + n_{it}^j \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} + n_{it}^j \hbar \uptheta_{it}^j \left(\frac{\mathbb{E}_t[\mathrm{d}r_t^{B,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} \right) + n_{it}^j \theta_{it}^{K,j} \left(\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{K,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} \right) \\
& - n_{it}^j \theta_{it}^{E,j} \left(\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{E,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} \right) + n_{it}^j \theta_{it}^{\bar{E},j} \left(\frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{E},j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} \right) \Bigg\} \\
& - \varsigma_{it}^j \xi_{it}^j n_{it}^j \left(\bar{\sigma}_t^{q^B} - \hbar \uptheta_{it}^j \big(\sigma_t^{q^B,j} - \bar{\sigma}_t^{q^B} \big) - \big(\theta_{it}^{K,j} - \theta_{it}^{E,j} + \theta_{it}^{\bar{E},j} \big) \big(\sigma_t^{q^K,j} - \bar{\sigma}_t^{q^B} \big) \right) \\
& - \tilde{\varsigma}_{it}^j \xi_{it}^j \big(\theta_{it}^{K,j} - \theta_{it}^{E,j} \big) \tilde{\sigma}_t - \tilde{\varpi}_{it}^j \xi_{it}^j n_{it}^j \hbar \uptheta_{it}^j \tilde{\omega}_t^{q^B} \ ,
\end{aligned}$$

where ξ_{it}^j is the costate (which corresponds to the stochastic discount factor), and $\varsigma_{it}\xi_{it}, \tilde{\varsigma}_{it}\xi_{it}$, and $\tilde{\varpi}_{it}\xi_{it}$ are its loadings on the Brownian motions $\mathrm{d}Z_t, \mathrm{d}\widetilde{Z}_{it}$, and $\mathrm{d}\widetilde{W}_t^j$, respectively. In addition, remember the skin-in-the game constraint when taking first-order conditions with respect to the capital and equity portfolio weights.

III.2 Deriving equilibrium prices and investment

FOCs for consumption and investment give

$$c_{it}^j = \rho n_{it}^j \ , \tag{A.22}$$

$$q_t^{K,j} = 1 + \phi \iota_t^j \ . \tag{A.23}$$

Aggregating consumption within each country gives

$$C_t^j = \rho N_t^j = \rho \frac{q_t^{K,j}}{1 - \vartheta_t^j} \ , \tag{A.24}$$

where $\vartheta_t^j = \int \vartheta_{it}^j \mathrm{d}i$ and we have used the fact that $q_t^{K,j} = \theta_t^{K,j} N_t^j = (1 - \vartheta_t^j) N_t^j$ because equity is in zero net supply and $\theta_t^{E,j} = \theta_t^{\bar{E},j}$.

Combining this with the investment FOC and substituting it into the goods market clearing condition gives

$$\rho \frac{1 + \phi \iota_t^j}{1 - \vartheta_t^j} + g + \iota_t^j = a_t \ . \tag{A.25}$$

Solving for ι_t^j gives

$$\iota_t^j = \frac{(1 - \vartheta_t^j)(a_t - g) - \rho}{1 - \vartheta_t^j + \phi\rho} \ . \tag{A.26}$$

Substituting this back into (A.23) gives

$$q_t^K = \left(1 - \vartheta_t^j\right) \frac{1 + \phi(a_t - g)}{1 - \vartheta_t^j + \phi\rho} \ . \tag{A.27}$$

By the definition of $\theta_t^{j,j}$

$$q_t^{B,j} = \frac{\theta_t^{j,j}}{1 - \vartheta_t^j} q_t^K \ , \tag{A.28}$$

so

$$q_t^{B,j} = \theta_t^{j,j} \frac{1 + \phi(a_t - g)}{1 - \vartheta_t^j + \phi\rho} \ . \tag{A.29}$$

Using the home bias constraint

$$q_t^{B,j} = \hbar \uptheta_t^j \frac{1+\phi(a_t - g)}{1-\uptheta_t^j + \phi\rho} \ . \tag{A.30}$$

III.3 Deriving the equilibrium process for asset demand

FOCs for portfolio shares give

$$\frac{\mathbb{E}_t[\mathrm{d}r_t^{B,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} = \varsigma_{it}^j\big(\sigma_t^{q^B,j} - \bar{\sigma}_t^{q^B}\big) + \tilde{\varpi}_{it}^j \tilde{\omega}_t^{q^B} - \frac{\rho v_t^j}{\hbar \uptheta_t^j} \ , \tag{A.31}$$

$$\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{K,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} = \varsigma_{it}^j\big(\sigma_t^{q^K,j} - \bar{\sigma}_t^{q^B}\big) + \tilde{\varsigma}_{it}^j \tilde{\sigma}_t - \ell_{it}^{\chi,j}(1-\chi) \ , \tag{A.32}$$

$$\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{E,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} = \varsigma_{it}^j\big(\sigma_t^{q^K,j} - \bar{\sigma}_t^{q^B}\big) + \tilde{\varsigma}_{it}^j \tilde{\sigma}_t - \ell_{it}^{\chi,j} \ , \tag{A.33}$$

$$\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{\bar{E},j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{B}}]}{\mathrm{d}t} = \varsigma_{it}^j\big(\sigma_t^{q^K,j} - \bar{\sigma}_t^{q^B}\big) \ , \tag{A.34}$$

where $\ell_{it}^{\chi,j}$ is the Lagrange multiplier on the skin-in-the-game constraint, and we have used the fact that $\xi_{it}^j = \frac{e^{-\rho t}}{\rho n_{it}^j}$. Since in equilibrium $\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{E,j}]}{\mathrm{d}t} = \frac{\mathbb{E}_t[\mathrm{d}r_t^{\bar{E},j}]}{\mathrm{d}t}$, the last two equations immediately imply

$$\ell_{it}^{\chi,j} = \tilde{\varsigma}_{it}^j \tilde{\sigma}_t \ , \tag{A.35}$$

meaning the skin-in-the-game constraint always binds, as the RHS of this equation is always strictly positive (as confirmed below). Since $\xi_{it}^j = \frac{e^{-\rho t}}{\rho n_{it}^j}$ we have that the loadings of the costate correspond to the loadings of net worth on each of the Brownian motions

$$\varsigma_{it}^j = \sigma_{it}^{n,j} = \theta_{it}^{j,j}\sigma_t^{q^B,j} + \theta_{it}^{\bar{B},j}\bar{\sigma}_t^{q^B} + (\theta_{it}^{K,j} - \theta_{it}^{E,j} + \theta_t^{\bar{E},j})\sigma_t^{q^K,j} \ , \tag{A.36}$$

$$\tilde{\varsigma}_{it}^j = \tilde{\sigma}_{it}^{n,j} = (\theta_{it}^{K,j} - \theta_{it}^{E,j})\tilde{\sigma}_t \ , \tag{A.37}$$

$$\tilde{\varpi}_{it}^j = \tilde{\omega}_{it}^{n,j} = \theta_{it}^{j,j}\tilde{\omega}_t^{q^B} \ . \tag{A.38}$$

Now use a few more conditions to simplify: because the skin-in-the-game constraint binds, $\theta_{it}^{E,j} = (1-\chi)\theta_{it}^{K,j}$; because the home-bias constraint binds, $\theta_{it}^{j,j} = \hbar\uptheta_t^j$; and in equilibrium, $\theta_{it}^{E,j} = \theta_t^{\bar{E},j}$ and $\theta_{it}^{K,j} = 1 - \uptheta_t^j$ as portfolio choices are symmetric. So we can rewrite the conditions as

$$\varsigma_{it}^j = \uptheta_t^j \hbar \sigma_t^{q^B,j} + \uptheta_t^j(1-\hbar)\bar{\sigma}_t^{q^B} + (1-\uptheta_t^j)\sigma_t^{q^K,j} \ , \tag{A.39}$$

$$\tilde{\varsigma}_{it}^j = (1-\uptheta_t^j)\chi\tilde{\sigma}_t \ , \tag{A.40}$$

$$\tilde{\varpi}_{it}^j = \uptheta_t^j \hbar \tilde{\omega}_t^{q^B} \ . \tag{A.41}$$

Now, we can take the difference between (A.10) and (A.8), and take the expectations of this difference to get:

$$\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{K,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{B,j}]}{\mathrm{d}t} = \frac{(1-\tau_t^j)a_t - \iota_t^j}{q_t^{K,j}} + \mu_t^{q^K,j} - \mu_t^{q^B,j} + \breve{\mu}_t^{B,j'} \ . \tag{A.42}$$

If instead we take the difference between (A.32) and (A.31), we get

$$\frac{\mathbb{E}_t[\mathrm{d}r_{it}^{K,j}]}{\mathrm{d}t} - \frac{\mathbb{E}_t[\mathrm{d}r_t^{B,j}]}{\mathrm{d}t} = \tilde{\varsigma}_{it}^j\tilde{\sigma}_t - \ell_{it}^{\chi,j}(1-\chi) - \varsigma_{it}^j\big(\sigma_t^{q^B,j} - \sigma_t^{q^K,j}\big) - \tilde{\varpi}_{it}^j\hbar\tilde{\omega}_t^{q^B} + \frac{\rho v_t^j}{\hbar\theta_t^j} \ . \tag{A.43}$$

Combining them, and substiting the expressions we derived for (A.35) and (A.39)-(A.41), we get

$$\begin{aligned}\frac{(1-\tau_t^j)a_t - \iota_t^j}{q_t^{K,j}} + \mu_t^{q^K,j} - \mu_t^{q^B,j} + \breve{\mu}_t^{B,j'} &= (1-\theta_t^j)\chi^2\tilde{\sigma}_t^2 \\ &- \Big[\theta_t^j\hbar\sigma_t^{q^B,j} + \theta_t^j(1-\hbar)\bar{\sigma}_t^{q^B} + (1-\theta_t^j)\sigma_t^{q^K,j}\Big]\big(\sigma_t^{q^B,j} - \sigma_t^{q^K,j}\big) \\ &- \theta_t^j\hbar(\tilde{\omega}_t^{q^B})^2 + \frac{\rho v_t^j}{\hbar\theta_t^j} \ . \end{aligned} \tag{A.44}$$

From the government budget constraint, $\tau_t^j = g - q_t^{B,j}\breve{\mu}_t^{B,j}$, and use $q_t^{K,j} = (1-\theta_t^j)N_t^j$ and $q_t^{B,j} = \hbar\theta_t^j N_t^j$ to rewrite the LHS as

$$\begin{aligned}\frac{(1-\tau_t^j)a_t - \iota_t^j}{q_t^{K,j}} + \mu_t^{q^K,j} - \mu_t^{q^B,j} + \breve{\mu}_t^{B,j'} &= \frac{a_t - g + q_t^{B,j}\breve{\mu}_t^{B,j} - \iota_t^j}{(1-\theta_t^j)N_t^j} + \mu_t^{q^K,j} - \mu_t^{q^B,j} + \breve{\mu}_t^{B,j'} \\ &= \frac{1}{1-\theta_t^j}\frac{a_t - g - \iota_t^j}{N_t^j} + \breve{\mu}_t^{B,j} + \frac{\hbar\theta_t^j}{1-\theta_t^j}\breve{\mu}_t^{B,j} + \mu_t^{q^K,j} - \mu_t^{q^B,j} \\ &= \frac{\rho}{1-\theta_t^j} + \breve{\mu}_t^{B,j}\frac{1-\theta_t^j + \hbar\theta_t^j}{1-\theta_t^j} + \mu_t^{q^K,j} - \mu_t^{q^B,j} \ , \end{aligned} \tag{A.45}$$

where the last equality follows from good market clearing and (A.24). Now, apply Ito's lemma to $1 - \theta_t^j = \frac{q_t^{K,j}}{N_t^j}$ and $\theta_t^{j,j} = \frac{q_t^{B,j}}{N_t^j}$ to obtain

$$-\mu_t^{\theta,j}/\hbar = \mu_t^{q^K,j} - \mu_t^{N,j} + (\sigma_t^{N,j})^2 - \sigma_t^{q^K,j}\sigma_t^{N,j} \ , \tag{A.46}$$

$$\mu_t^{\theta,j} = \mu_t^{q^B,j} - \mu_t^{N,j} + (\sigma_t^{N,j})^2 - \sigma_t^{q^B,j}\sigma_t^{N,j} + (\tilde{\omega}_t^N)^2 - \tilde{\omega}_t^{q^B}\tilde{\omega}_t^N \ . \tag{A.47}$$

Combine them to obtain an expression for $\mu_t^{q^K,j} - \mu_t^{q^B,j}$, use (A.41), and substitute the result into (A.45) to get

$$\frac{\rho}{1-\theta_t^j} + \breve{\mu}_t^{B,j}\frac{1-\theta_t^j+\hbar\theta_t^j}{1-\theta_t^j} - \mu_t^{\theta,j}\frac{1+\hbar}{\hbar} - \sigma_t^{N,j}(\sigma_t^{q^B,j} - \sigma_t^{q^K,j}) + (\theta_t^j)^2\hbar^2(\tilde{\omega}_t^{q^B})^2 - \theta_t^j\hbar(\tilde{\omega}_t^{q^B})^2\ . \tag{A.48}$$

Finally, replace this as the LHS of (A.44) and rearrange to get

$$\mu_t^{\theta,j}\frac{1+\hbar}{\hbar} = \frac{\rho}{1-\theta_t^j} + \breve{\mu}_t^{B,j}\left(1+\frac{\hbar\theta_t^j}{1-\theta_t^j}\right) - (1-\theta_t^j)\chi^2\tilde{\sigma}_t^2 + (\theta_t^j)^2\hbar^2(\tilde{\omega}_t^{q^B})^2 - \frac{\rho v_t^j}{\hbar\theta_t^j}\ . \tag{A.49}$$

Write $\mu_t^{\theta,j}$ as $\frac{\mathbb{E}_t[\mathrm{d}\theta_t^{j,j}]}{\theta_t^{j,j}}$ to obtain equation (1.20) in the main text.

APPENDIX B

Appendix to Chapter 2

Table B.1: Asset Purchase Announcements by Central Bank and Date

Central Bank	**Date**	**Type of Asset Purchase**	**Size**	**Sovereign Open-ended**	**Sovereign Limited**
Reserve Bank of Australia	19/03/20	Government bond purchases	Open-ended	✓	
	05/05/20	Government bond purchases	Open-ended	✓	
	03/11/20	Government bond purchases	Open-ended	✓	
	03/11/20	Government bond purchases	Open-ended	✓	
	03/11/20	Government bond purchases	Open-ended	✓	
	02/02/21	Government bond purchases	Open-ended	✓	
	06/07/21	Government bond purchases	4 billion weekly		✓
	06/07/21	Government bond purchases	4 billion weekly		✓
	02/11/21	Discontinument of Government bond purchases	Limited		✓
Bank of Canada	12/03/20	Expansion of Bond Buyback Program	Starting with 500 million	✓	
	13/03/20	Bankers' Acceptance Purchase Facility (BAPF)	Limited by min bank credit rating		
	16/03/20	Canada Mortgage Bond Purchase	$500 billion weekly		
	24/03/20	Provincial Money Market Purchase Program (PMMP)	40-percent purchase limit		
	27/03/20	Commercial Paper Purchase Progeam (CPPP)	Open-ended		
	27/03/20	Government securities purchases	Open-ended	✓	
	15/04/20	Provincial Bond Purchase Program (PBPP)	Up to 50 billion		
	15/04/20	Corporate Bond Purchase Program (CBPP)	Up to 10 billion		
	15/04/20	Treasury Purchases	40-percent purchase limit		✓
	20/05/20	Government securities purchases	Up to 100 million		✓
	03/06/20	Bankers' Acceptance Purchase Facility (BAPF)	Reduce frequency to bi-weekly		
	21/07/20	PMMP Securities Purchase	20-percent purchase limit		✓
	21/07/20	Treasury Purchases	20-percent purchase limit		✓
	21/07/20	Treasury Purchases	20-percent purchase limit		✓
	15/09/20	Provincial Money Market Purchase Program (PMMP)	10-percent purchase limit		
	15/09/20	Treasury Purchases	10-percent purchase limit		✓
	23/03/21	Commercial Paper Purchase Progeam (CPPP)	Limited		
	23/03/21	Provincial Bond Purchase Program (PBPP)	Limited		
	23/03/21	Corporate Bond Purchase Program (CBPP)	Limited		
	21/04/21	Government bond purchases	3 billion		✓
	30/04/21	Securities Repo Operations (SROs)	4,000 million		
	14/07/21	Bank Quantitative Easing Program (QE)	2 billion weekly		✓
	27/10/21	Bank Quantitative Easing Program (QE)	End QE, only replacing maturing bonds		✓
Central Bank of Chile	16/03/20	Bond Purchase Program	US$4 billion		✓
	19/03/20	Bank Purchase Program	Limited		
	31/03/20	Bank Purchase Program	US$5.5 billion		
	08/04/20	Bank Purchase Program	US$8 billion		

	16/06/20	Asset Purchase Program	US$8 billion		✓
	30/07/20	Cash Purchase Operations Program	US$10 billion		
	30/07/20	Bank Deposit Purchase Program	US$8 billion		
	24/09/20	Bank Deposit Purchase Program	US$6 billion		
	24/09/20	Asset Purchase Program	Limited		✓
Central Bank of Colombia	23/03/20	Government Bond Purchases	Expansion, as large as 2 trillion	✓	
	23/03/20	Purchase of Private Titles of Credit Establishments	10 trillion		
	14/04/20	Government Bond Purchases	Expansion, as large as 2 trillion	✓	
	15/05/20	Public Debt Swap	1,766 billion		✓
European Central Bank	12/03/20	Asset Purchase Program (APP)	120 billion		✓
	18/03/20	Corporate Sector Purchase Program (CSPP)	Open-ended		
	18/03/20	Pandemic Emergency Purchase Program (PEPP)	Open-ended	✓	
	30/04/20	Asset Purchase Program	Open-ended	✓	
	30/04/20	Pandemic Emergency Purchase Program (PEPP)	Open-ended	✓	
	04/06/20	Pandemic Emergency Purchase Program (PEPP)	Expanded by at least 600 billion euros	✓	
	22/09/20	Sustainability-linked bonds Purchases	Limited		
	22/09/20	Sustainability-linked bonds Purchases	Limited		
	10/12/20	Pandemic Emergency Purchase Program (PEPP)	Ongoing commitment, increase of 500 billion	✓	
	11/03/21	Pandemic Emergency Purchase Program (PEPP)	Limited		✓
	09/09/21	Pandemic Emergency Purchase Program (PEPP)	Limited		✓
	28/10/21	Pandemic Emergency Purchase Program (PEPP)	Limited		✓
	16/12/21	Pandemic Emergency Purchase Program (PEPP)	Limited		✓
Bank of England	17/03/20	Covid Corporate Financing Facility (CCFF)	Open-ended		
	19/03/20	Government Bond Purchases	Ongoing commitment, increase of 200 billion	✓	
	02/04/20	Corporate Bond Purchases	>10 billion		
	19/05/20	Covid Corporate Financing Facility (CCFF)	Limited		
	05/06/20	Corporate Bond Purchase Scheme (CBPS)	Limited		
	18/06/20	Government Bond Purchases	100 billion		✓
	18/06/20	Asset Purchase Facility: Gilt Purchases	Limited		✓
Hungarian National Bank	07/04/20	Government Security Purchase Program	Limited		✓
	07/04/20	Mortgage Bond Purchase Program	Limited		
	07/04/20	Bond Funding for Growth Scheme (BGS)	50 billion		✓
	28/04/20	Government Security Purchase Program	Open-ended	✓	
	28/04/20	Mortgage Bond Purchase Program	Open-ended		

	30/04/20	Government Security Purchase Program	Limited		✓
	30/04/20	Bond Funding for Growth Scheme (BGS)	Limited		✓
	21/07/20	Government Security Purchase Program	Limited		✓
	25/08/20	Government Security Purchase Program	Limited		✓
	22/09/20	Bond Funding for Growth Scheme (BGS)	Limited		✓
	06/10/20	Government Security Purchase Program	Open-ended	✓	
	26/01/21	Bond Funding for Growth Scheme (BGS)	Limited		✓
	26/01/21	Government Security Purchase Program	Limited		✓
	23/02/21	Government Security Purchase Program	Limited		✓
	09/03/21	Government Security Purchase Program	Open-ended	✓	
	27/04/21	Government Security Purchase Program	Open-ended	✓	
	24/08/21	Government Security Purchase Program	50 billion weekly		✓
	21/09/21	Government Security Purchase Program	40 billion weekly		✓
	19/10/21	Government Security Purchase Program	Limited		✓
	16/11/21	Government Security Purchase Program	Limited		✓
	14/12/21	Bond Funding for Growth Scheme (BGS)	Limited		✓
	14/12/21	Government Security Purchase Program	Limited		✓
Bank Indonesia	01/04/20	Government Security Purchase	Limited		✓
	18/06/20	Government Security Purchase	Limited		✓
	06/07/20	Government Security Purchase	40 billion		✓
Bank of Israel	15/03/20	Government Bond Purchases	Limited		✓
	23/03/20	Government Bond Purchases	50 billion		✓
	06/07/20	Corporate Bond Purchase Program	15 billion		
	22/10/20	Government Bond Purchases	35 billion		✓
Central Bank of India	18/03/20	Government Security Purchases	10,000 crores		✓
	20/03/20	Government Security Purchases	30,000 crores		✓
	23/04/20	Government Security Sales	10,000 crores		✓
	09/10/20	State Development Loans (SDLs)	Limited		
	07/04/21	Government Security Purchases	Open-ended	✓	
	04/06/21	Government Security Purchases	Open-ended	✓	
Bank of Japan	13/03/20	Government Bond Purchases	Limited		✓
	16/03/20	Government Bond Purchases	Open-ended	✓	
	16/03/20	Corporate Bond Purchases	<2 trillion yen		
	16/03/20	Stock Purchases	<12 trillion yen		
	27/04/20	Government Bond Purchases	Open-ended	✓	
	27/04/20	Corporate Bond Purchases	Open-ended		
	22/05/20	Corporate Bond Purchases	Limited		
	18/12/20	Corporate Bond Purchases	<20 trillion yen		

	19/03/21	Stock Purchases	<12 trillion yen		
	19/03/21	Government Bond Purchases	Limited		✓
	18/06/21	Corporate Bond Purchases	Open-ended		
Bank of Korea	19/03/20	Treasury Bond Purchases	1.5 trillion		✓
	09/04/20	Government Bond Purchases	1.5 trillion		✓
	20/05/20	Commercial Paper Purchase Program	10 trillion		
	30/06/20	Government Bond Purchases	1.5 trillion		✓
	17/07/20	Corporate Bond Purchases	8 trillion		
	08/09/20	Government Bond Purchases	5 trillion		✓
	26/02/21	Government Bond Purchases	7 trillion		✓
Bank of Mexico	12/03/20	Government Bond Swaps	40,000 million		✓
	21/04/20	Government Security Swaps	100 billion		✓
Reserve Bank of New Zealand	23/03/20	Large Scale Asset Purchase Program (LSAP)	30 billion		✓
	07/04/20	Large Scale Asset Purchase Program (LSAP)	3 billion		✓
	13/05/20	Large Scale Asset Purchase Program (LSAP)	60 billion		✓
	12/08/20	Large Scale Asset Purchase Program (LSAP)	100 billion		✓
	14/07/21	Large Scale Asset Purchase Program (LSAP)	Limited		✓
Bangko Sentral ng Pilipinas	10/04/20	Government Securities Purchase	1-hour daily window, selected bonds		✓
National Bank of Poland	16/03/20	Treasury Bond Purchases	Open-ended	✓	
	08/04/20	Government Securities Purchase	Open-ended	✓	
National Bank of Romania	20/03/20	Government Securities Purchase	Limited		✓
Sveriges Riksbank	16/03/20	Government Bond Purchases	300 billion		✓
	20/03/20	Covered Bonds Purchase	10 billion		
	26/03/20	Commercial Paper Purchase	4 billion		
	22/04/20	Municipal Bond-purchasing Program	15 billion		
	08/05/20	Commercial Paper Purchase	32 billion		
	01/07/20	Bond-purchasing Program	200 billion		✓
	26/11/20	Asset Purchase Program	Open-ended	✓	
Central Bank of Thailand	22/03/20	Government Bond Purchase Program	>100 billion		✓
	07/04/20	Corporate Bond Stabilization Fund	Limited		
Central Bank of Turkey	31/03/20	Government Domestic Debt Securities (GDDS) Sale	Open-ended	✓	
	17/04/20	Government Domestic Debt Securities (GDDS) Sale	Limited		✓
Federal Reserve Board	12/03/20	Treasury Bills Purchase	60 billion		✓
	13/03/20	Treasury Security Purchases	80 billion		✓
	15/03/20	Purchase of Securities	Open-ended	✓	
	17/03/20	Commercial Paper Funding Facility (CPFF)	10 billion		
	23/03/20	Purchase of Securities	Open-ended	✓	
	23/03/20	Commercial Paper Funding Facility (CPFF)	Open-ended		

	23/03/20	Primary Market Corporate Credit Facility (PMCCF)	Open-ended		
	23/03/20	Secondary Market Corporate Credit Facility (SMCCF)	Open-ended		
	09/04/20	Primary Market Corporate Credit Facility (PMCCF)	Open-ended		
	09/04/20	Secondary Market Corporate Credit Facility (SMCCF)	Open-ended		
	09/04/20	Municipal Liquidity Facility (MLF)	Open-ended		
	27/04/20	Municipal Liquidity Facility (MLF)	Limited		
	29/04/20	Purchase of Securities	Open-ended	✓	
	03/06/20	Municipal Liquidity Facility (MLF)	Limited		
	10/06/20	Purchase of Securities	Open-ended	✓	
	15/06/20	Secondary Market Corporate Credit Facility (SMCCF)	Open-ended		
	23/07/20	Emergency Lending Facilities	Limited		
	23/07/20	Emergency Lending Facilities	Limited		
	28/07/20	Extension of Lending Facilities	Limited		
	28/07/20	Extension of Lending Facilities	Limited		
	11/08/20	Municipal Liquidity Facility (MLF)	Limited		
	03/11/20	Purchase of Securities	15 billion		✓
	30/11/20	Extension of Lending Facilities	Limited		
	15/12/20	Purchase of Securities	30 billion		✓
	02/06/21	Secondary Market Corporate Credit Facility (SMCCF)	Limited		
South African Reserve Bank	25/03/20	Government Security Purchases	Open-ended	✓	

Source: Announcement data from Cantú et al. (2021), classification as open-ended by authors based on central bank press release and subsequent news coverage.

Table B.2: Local Projection Coefficients ($h = 1, 2$) for Yields of Different Maturities

1-day after:
$y_{i,t+1} - y_{t-1}$, in bp

Announcement	**10Y**		**5Y**		**1Y**		**3M**	
All	-4.59^{*}	(2.38)	-5.19^{**}	(2.42)	-2.81^{**}	(1.14)	-3.48^{***}	(1.29)
Sovereign	-6.51^{**}	(2.88)	-7.21^{**}	(2.94)	-3.75^{***}	(1.34)	-4.01^{***}	(1.52)
Limited	-0.87	(5.94)	-1.42	(6.18)	-0.84	(2.74)	-0.90	(3.11)
1^{st} limited	-7.05^{**}	(3.44)	-7.51^{**}	(3.19)	-1.04	(4.08)	-1.92	(5.26)
Later limited	1.18	(1.57)	0.58	(1.36)	-0.72	(1.05)	-0.54	(1.15)
Open-ended	-13.75^{**}	(5.94)	-15.12^{**}	(6.18)	-7.25^{***}	(2.74)	-7.06^{**}	(3.11)
1^{st} open-ended	-34.93^{***}	(8.51)	-36.69^{***}	(7.75)	-19.54^{***}	(6.80)	-20.38^{**}	(8.94)
Later open-ended	-3.61	(2.28)	-3.46^{*}	(2.08)	-1.72^{*}	(1.02)	-1.72	(1.44)

2-days after:
$y_{i,t+2} - y_{t-1}$, in bp

Announcement	**10Y**		**5Y**		**1Y**		**3M**	
All	-5.32^{**}	(2.57)	-5.30^{*}	(2.73)	-2.68^{**}	(1.19)	-3.44^{**}	(1.39)
Sovereign	-7.46^{**}	(3.10)	-7.12^{**}	(3.31)	-3.55^{***}	(1.37)	-4.02^{**}	(1.57)
Limited	-1.29	(6.17)	-0.81	(6.68)	-0.16	(2.70)	-0.27	(2.87)
1^{st} limited	-7.09^{**}	(2.85)	-6.00	(3.95)	-0.68	(4.06)	-1.48	(5.28)
Later limited	0.64	(1.59)	0.96	(1.51)	0.13	(1.21)	0.24	(1.30)
Open-ended	-16.65^{***}	(6.17)	-14.39^{**}	(6.68)	-6.80^{**}	(2.70)	-7.02^{**}	(2.87)
1^{st} open-ended	-43.94^{***}	(7.33)	-36.72^{***}	(12.20)	-16.12^{**}	(7.44)	-17.44^{**}	(8.61)
Later open-ended	-3.95	(2.66)	-4.25	(3.16)	-2.97^{**}	(1.43)	-3.34^{*}	(1.81)

Notes: The table shows the estimated coefficients β_h on central bank asset-purchase announcements for each of the eight classifications of announcements (all, sovereign, limited, 1^{st} limited, subsequent limited, open-ended, 1^{st} open-ended, and subsequent open-ended) over 1-day and 2-days for the yield local projection regression (equation 5) with different maturities. The regressions include country and time fixed effects and the set of controls $\mathbf{X}_{i,t}$. Standard errors are clustered by date and shown in parentheses. *, **,*** indicate significance at 10%, 5% and 1%, respectively.

Table B.3: Local Projection Coefficients ($h = 1, 2$) for 10-Yields, With and Without Controls

1-day after:
$y_{i,t+1} - y_{t-1}$, in bp

Announcement	**with controls**		**without controls**	
All	-4.59^{*}	(2.38)	-4.45^{*}	(2.38)
Sovereign	-6.51^{**}	(2.88)	-6.28^{**}	(2.87)
Limited	-0.87	(5.94)	-0.76	(5.91)
1st limited	-7.05^{**}	(3.44)	-6.89^{**}	(3.31)
Later limited	1.18	(1.57)	1.12	(1.59)
Open-ended	-13.75^{**}	(5.94)	-13.74^{**}	(5.91)
1st open-ended	-34.93^{***}	(8.51)	-34.81^{***}	(8.39)
Later open-ended	-3.61	(2.28)	-3.70	(2.30)

2-days after:
$y_{i,t+2} - y_{t-1}$, in bp

Announcement	**with controls**		**without controls**	
All	-5.32^{**}	(2.57)	-5.20^{**}	(2.55)
Sovereign	-7.46^{**}	(3.10)	-7.23^{**}	(3.07)
Limited	-1.29	(6.17)	-1.20	(6.15)
1st limited	-7.09^{**}	(2.85)	-6.85^{***}	(2.60)
Later limited	0.64	(1.59)	0.51	(1.60)
Open-ended	-16.65^{***}	(6.17)	-16.65^{***}	(6.15)
1st open-ended	-43.94^{***}	(7.33)	-43.77^{***}	(7.25)
Later open-ended	-3.95	(2.66)	-4.08	(2.68)

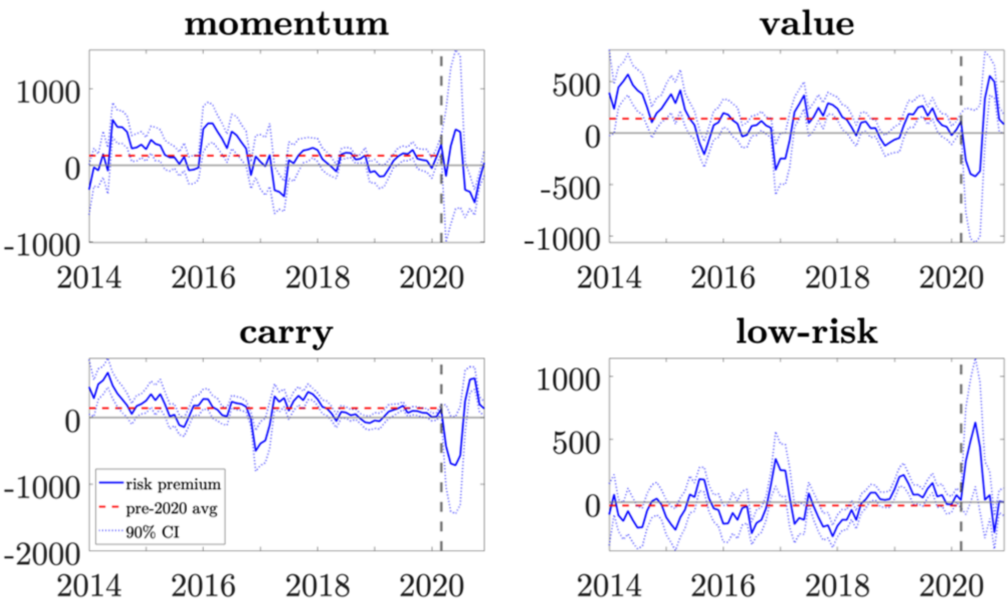
Notes: The table shows the estimated coefficients β_h on central bank asset-purchase announcements for each of the eight classifications of announcements (all, sovereign, limited, 1st limited, subsequent limited, open-ended, 1st open-ended, and subsequent open-ended) over 1-day and 2-days for the 10-year yield local projection regression (equation 5). The regressions include country and time fixed effects; controls $\mathbf{X}_{i,t}$ are included in one specification and excluded in the other. Standard errors are clustered by date and shown in parentheses. *, **, *** indicate significance at 10%, 5% and 1%, respectively.

APPENDIX C

Appendix to Chapter 3

Four-factor Bond Pricing Model for pre-Covid Subsamples In the body of the paper, we show that the conventional bond pricing model generates risk premia which are starkly different from those estimated in the pre-2020 sample. To examine whether such differences reflect a true anomaly given the smaller pandemic sample size, we re-estimate the model of column 1 in Table 3.1 for a series of rolling 3-month windows for comparison with the pandemic sample. Figure C.1 plots the results from these rolling estimations. While the 3-month risk premium estimates do fluctuate throughout the period from 2014 to 2019, March 2020 emerges as an outlier event for the distribution of each risk premium. Each factor experiences a record movement in both the average and variance of its risk premium across states.

Figure C.1: 3-Month Risk Premia $\hat{\lambda}^n$ for the Four-Factor Model



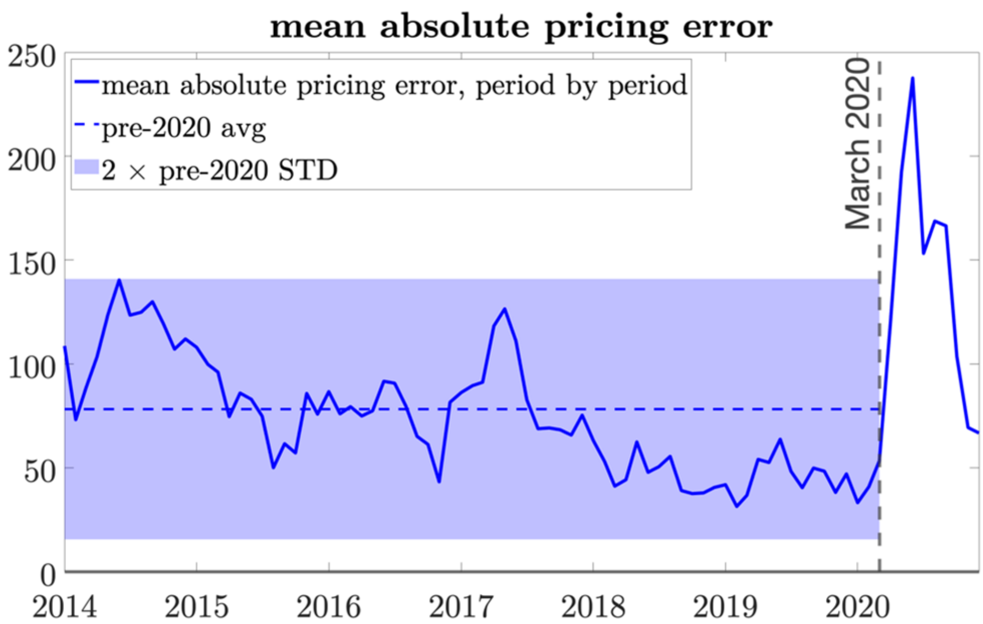
Note: *Solid blue lines indicate the average risk premia for each of the four conventional factors in the model of column 1 in Table 3.1. Each observation represents a model estimated on a sample consisting of the 3 prior months of data. Grey lines indicate the 90% confidence interval of risk premia during the 3-month window, and the dashed red lines indicate the averages for the full 2014-2019 sample.*

Additionally, we compute the average absolute pricing errors of the models across states for those rolling 3-month windows. Those pricing errors are obtained for a given window T as

$$\hat{\alpha}_T = \frac{1}{ST} \sum_i \sum_t |\hat{\alpha}_{it}| \,, \tag{C.1}$$

where $\hat{\alpha}_{it}$ is the model's error for a given state-day observation in the 3-month window ending at T. Figure C.2 plots the results, along with the pre-pandemic mean and 2-standard deviation band. Consistent with the results of the paper, March 2020 kicks off a period of abnormally large errors for the estimated state-level models. Taken together, the results from the 3-month rolling models suggest that the breakdown of the pricing model we identify in the paper is not simply a byproduct of the smaller sample size, and represents a true economic shift.

Figure C.2: 3-Month Average Pricing Errors $\hat{\alpha}_T$ for the Four-Factor Model



Note: *The solid blue line indicates the mean absolute pricing error (Equation C.1) for the model of column 1 in Table 3.1. Each observation represents a model estimated on a sample consisting of the 3 prior months of data. The dashed blue line indicates the mean for the full 2014-2019 sample, and the shaded area is the 2-standard deviation band around the average.*

BIBLIOGRAPHY

Acharya, V., T. Eisert, C. Eufinger, and C. Hirsh (2019): "Whatever It Takes: The Real Effects of Unconventional Monetary Policy," *The Review of Financial Studies*, 32, 3366–3411.

Adelino, M., I. Cunha, and M. A. Ferreira (2017): "The Economic Effects of Public Financing: Evidence from Municipal Bond Ratings Recalibration," *The Review of Financial Studies*.

Adrian, T. and F. Franzoni (2009): "Learning about Beta: Time-Varying Factor Loadings, Expected Returns, and the Conditional CAPM," *Journal of Empirical Finance*, 16, 537–556.

Aizenman, J., Y.-W. Cheung, and X. Qian (2019a): "The Currency Composition of International Reserves, Demand for International Reserves, and Global Safe Assets," *Journal of International Money and Finance*, 102.

——— (2019b): "The Currency Composition of International Reserves, Demand for International Reserves, and Global Safe Assets," Working Paper 25934, National Bureau of Economic Research.

Akcigit, U. and Q. Liu (2011): "The Role of Information in Competitive Experimentation," Working Paper 17602, National Bureau of Economic Research.

Akinci, O., Ş. Kalemli-Özcan, and A. Queralto (2022): "Uncertainty Shocks, Capital Flows, and International Risk Spillovers," Working Paper 30026, National Bureau of Economic Research.

Altavilla, C., L. Brugnolini, R. Gurkaynak, R. Motto, and G. Ragusa (2019): "Measuring Euro Area Monetary Policy," *Journal of Monetary Economics*, 108, 162–179.

Arora, R., S. Gungor, J. Nesrallah, G. O. Leblanc, and J. Witmer (2021): "The Impact of the Bank of Canada's Government Bond Purchase Program," Working paper, Bank of Canada.

Azzimonti, M. and P. Yared (2018): "The Optimal Public and Private Provision of Safe Assets," Working Paper 24534, National Bureau of Economic Research.

Baele, L., G. Bekaert, K. Inghelbrecht, and M. Wei (2020): "Flights to Safety," *Review of Financial Studies*, 33, 689–746.

Baker, S. R., N. Bloom, and S. J. Davis (2016): "Measuring Economic Policy Uncertainty," *Quarterly Journal of Economics*, 131, 1593–1636.

Baker, S. R., N. Bloom, S. J. Davis, K. Kost, M. Sammon, and T. Viratyosin (2020): "The Unprecedented Stock Market Reaction to COVID-19," *The Review of Asset Pricing Studies*.

Barbuscia, D. (2023): "Fitch Cuts US Credit Rating to AA+; Treasury Calls it 'arbitrary'," *Reuters*, https://www.reuters.com/markets/us/fitch-cuts-us-governments-aaa-credit-rating-by-one-notch-2023-08-01/, August 2.

Barone, J., A. Chaboud, A. Copeland, C. Kavoussi, F. Keane, and S. Searls (2022): "The Global Dash for Cash: Why Sovereign Bond Market Functioning Varied across Jurisdictions in March 2020," Staff Report 1010, Federal Reserve Bank of New York.

Barro, R. J. (2021): "r Minus g," Working Paper 28002, National Bureau of Economic Research.

Barro, R. J., J. Fernández-Villaverde, O. Levintal, and A. Mollerus (2017): "Safe Assets," Working Paper 20652, National Bureau of Economic Research.

Basu, S., G. Candian, R. Chahrour, and R. Valchev (2021): "Risky Business Cycles," Working Paper 28693, National Bureau of Economic Research.

Bektič, D., B. Hachenberg, and D. Schiereck (2020): "Factor-Based Investing in Government Bond Markets: a Survey of the Current State of Research," *Journal of Asset Management*.

Bergant, K. and K. Forbes (2022): "Policy Packages and Policy Space: Lessons from COVID-19," Discussion Paper 17699, CEPR.

Bernanke, B. (2020): "The New Tools of Monetary Policy," *American Economic Review*, 110, 943–83.

Bernanke, B., M. Gertler, and S. Gilchrist (1994): "The Financial Accelerator and the Flight to Quality," Working Paper 4789, National Bureau of Economic Research.

Bernstein, S., R. R. Townsend, and T. Xu (2021): "Flight to Safety: How Economic Downturns Affect Talent Flows to Startups," Working Paper 27907, National Bureau of Economic Research.

Bertaut, C., L. P. DeMarco, S. B. Kamin, and R. W. Tryon (2011): "ABS Inflows to the United States and the Global Financial Crisis," Working Paper 17350, National Bureau of Economic Research.

Bhattarai, S. and C. Neely (2022): "An Analysis of the Literature on International Unconventional Monetary Policy," *Journal of Economic Literature*, 60, 527–97.

Bi, H. and W. B. Marsh (2022): "What Did Policy Interventions Fix in the Municipal Bond Market - Liquidity or Credit?" Working Paper 20-19, Federal Reserve Bank of Kansas City.

Bi, H., W. B. Marsh, J. Dice, and C. Gulati (2020): "Understanding the Recent Rise in Municipal Bond Yields," Economic Bulletin (May), Federal Reserve Bank of Kansas City.

Blinder, A. S., M. Ehrmann, M. Fratzscher, J. de Haan, and D.-J. Jansen (2008): "Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence," *Journal of Economic Literature*, 46, 910–945.

Blotevogel, R., H. Gergely, and E. Vangelista (2022): "Asset Purchases and Sovereign Risk Premia in the Euro Area during the Pandemic," Working Paper 55, European Stability Mechanism.

Boissay, F. and R. Cooper (2016): "The Collateral Trap," Working Paper 20703, National Bureau of Economic Research.

Bordo, M. D. and J. V. Duca (2023): "How the new Fed Municipal Bond Facility Capped Municipal-Treasury Yield Spreads in the Covid-19 Recession," *Journal of The Japanese and International Economies*.

Bordo, M. D. and R. N. McCauley (2018): "Triffin: Dilemma or Myth?" Working Paper 24195, National Bureau of Economic Research.

Borio, C. and A. Zabai (2018): "Unconventional Monetary Policies: a Re-appraisal," in *Research Handbook on Central Banking*, ed. by P. Conti-Brown and R. Lastra, chap. 20, 398–444.

Boudoukh, J., J. Brooks, M. Richardson, and Z. Xu (2016): "The Complexity of Liquidity: The Extraordinary Case of Sovereign Bonds," Working Paper 22576, National Bureau of Economic Research.

Brock, W. A. and C. F. Manski (2009): "Competitive Lending with Partial Knowledge of Loan Repayment," Working Paper 14378, National Bureau of Economic Research.

Brunnermeier, M. K., L. Garicano, P. Lane, M. Pagano, R. Reis, T. Santos, D. Thesmar, S. Van Nieuwerburgh, and D. Vayanos (2016): "The Sovereign-Bank Diabolic Loop and ESBIES," Working Paper 21993, National Bureau of Economic Research.

Brunnermeier, M. K. and L. Huang (2018): "A Global Safe Asset for and from Emerging Market Economies," Working Paper 25373, National Bureau of Economic Research.

Brunnermeier, M. K., S. Merkel, and Y. Sannikov (2022a): "Debt as Safe Asset," Working Paper 29626, National Bureau of Economic Research.

——— (2022b): "The Fiscal Theory of Price Level with a Bubble," Working Paper 27116, National Bureau of Economic Research.

Brunnermeier, M. K. and L. H. Pedersen (2007): "Market Liquidity and Funding Liquidity," Working Paper 12939, National Bureau of Economic Research.

Buiter, W., S. Cecchetti, K. Dominguez, and A. Sanchez-Serrano (2023): "Stabilising Financial Markets: Lending and Market Making as a Last Resort," Reports of the Advisory Scientific Committee 13, European Systemic Risk Board.

Caballero, R. J. and E. Farhi (2013): "A Model of the Safe Asset Mechanism (SAM): Safety Traps and Economic Policy," Working Paper 18737, National Bureau of Economic Research.

——— (2017): "The Safety Trap," Working Paper 19927, National Bureau of Economic Research.

——— (2018): "The Safety Trap," *Review of Economic Studies*, 85, 223–274.

Caballero, R. J., E. Farhi, and P.-O. Gourinchas (2016a): "Safe Asset Scarcity and Aggregate Demand," *American Economic Review*, 106, 513–518.

——— (2016b): "Safe Asset Scarcity and Aggregate Demand," Working Paper 22044, National Bureau of Economic Research.

——— (2017): "The Safe Assets Shortage Conundrum," *Journal of Economic Perspectives*, 31, 29.46.

——— (2021a): "Global Imbalances and Policy Wars at the Zero Lower Bound," *Review of Economic Studies*, 88, 2570–2621.

——— (2021b): "Global Imbalances and Policy Wars at the Zero Lower Bound," Working Paper 21670, National Bureau of Economic Research.

Caballero, R. J. and A. Krishnamurthy (2005): "Financial System Risk and Flight to Quality," Working Paper 11834, National Bureau of Economic Research.

——— (2006): "Flight to Quality and Collective Risk Management," Working Paper 12136, National Bureau of Economic Research.

——— (2007): "Collective Risk Management in a Flight to Quality Episode," Working Paper 12896, National Bureau of Economic Research.

Cai, Y., K. L. Judd, and R. Xu (2013): "Numerical Solution of Dynamic Portfolio Optimization with Transaction Costs," Working Paper 18709, National Bureau of Economic Research.

Campbell, J. Y., R. J. Shiller, and L. M. Viceira (2009): "Understanding Inflation-Indexed Bond Markets," Working Paper 15014, National Bureau of Economic Research.

Campbell, J. Y., A. Sunderam, and L. M. Viceira (2017): “Inflation Bets or Deflation Hedges? The Changing Risks of Nominal Bonds,” *Critical Finance Review*, 6, 263–301.

Cantú, C., P. Cavallino, F. De Fiore, and J. Yetman (2021): “A Global Database on Central Banks’ Monetary Responses to Covid-19,” Working Paper 934, Bank for International Settlements.

Chinn, M. D. and H. Ito (2019): “A Requiem for “Blame It on Beijing”: Interpreting Rotating Global Current Account Surpluses,” Working Paper 26226, National Bureau of Economic Research.

Choi, J., R. Kirpalani, and D. J. Perez (2022): “The Macroeconomic Implications of US Market Power in Safe Assets,” Working Paper 30720, National Bureau of Economic Research.

Choudhury, S. R. (2016): “Duterte’s Antics Shake Investor Confidence in the Philippines,” *CNBC*, https://www.cnbc.com/2016/09/19/duterte-news-philippine-presidents-intemperate-remarks-shaking-foreign-investor-confidence-in-the-country.html, September 19.

Christensen, J. H. E. and N. Mirkov (2022): “The Safety Premium of Safe Assets,” Working Paper 2019-28, Federal Reserve Bank of San Francisco.

Clemens, J. and S. Veuger (2020): “Implications of the Covid-19 Pandemic for State Government Tax Revenues,” *National Tax Journal*.

Cuevas, C. C. (2023): “Safe Assets in Emerging Market Economies,” Working paper.

Cusatis, P. and I. Hoxha (2022): “Municipal Bond Performance During the COVID-19 Pandemic,” *Municipal Finance Journal*.

Dang, T. D., F. Hollstein, and M. Prokopczuk (2023): “Which Factors for Corporate Bond Returns?” *The Review of Asset Pricing Studies*.

Davis, J. S. and E. van Wincoop (2021): “A Theory of the Global Financial Cycle,” Working Paper 29217, National Bureau of Economic Research.

Davis, J. S. and A. Zlate (2022): “The Global Financial Cycle and Capital Flows During the Covid-19 Pandemic,” Working Paper 416, Federal Reserve Bank of Dallas, Globalizaation Institute.

Dedola, L., G. Georgiadis, J. Gr˘ ab, and A. Mehl (2021): “Does a Big Bazooka Matter? Quantitative Easing Policies and Exchange Rates,” *Journal of Monetary Economics*, 117, 489–506.

Di Tella, S. (2020): “Risk Premia and the Real Effects of Money,” *American Economic Review*, 110, 1995–2040.

Diamond, W. and P. Van Tassel (2023): “Risk-Free Rates and Convenience Yields around the World,” Staff Reports 1032, Federal Reserve Bank of New York.

Dube, A., D. Girardi, O. Jordà, and A. M. Taylor (2023): "A Local Projections Approach to Difference-in-Differences Event Studies," Working Paper 31184, National Bureau of Economic Research.

Edwards, S., F. A. Longstaff, and A. Garcia Marin (2015): "The US Debt Restructuring of 1933: Consequences and Lessons," Working Paper 21694, National Bureau of Economic Research.

Egan, M., S. Lewellen, and A. Sunderam (2021): "The Cross Section of Bank Value," Working Paper 23291, National Bureau of Economic Research.

English, B., K. Forbes, and A. Ubide (2021): "Monetary Policy and Central Banking in the Covid Era: Key Insights and Challenges for the Future," in *Monetary Policy and Central Banking in the Covid Era*, ed. by K. F. Bill English and A. Ubide, CEPR Press, 3–26.

Erel, I., B. Julio, W. Kim, and M. Weisbach (2009): "Market Conditions and the Structure of Securities," Working Paper 14952, National Bureau of Economic Research.

Fama, E. F. and J. D. MacBeth (1973a): "Risk, Return, and Equilibrium: Empirical Tests," *Journal of Political Economy*, 81, 607–636.

——— (1973b): "Risk, Return, and Equilibrium: Empirical Tests," *Journal of Political Economy.*

Farhi, E. and X. Gabaix (2016): "Rare Disasters and Exchange Rates," *The Quarterly Journal of Economics*, 131, 1–52.

Fleckenstein, M. and F. A. Longstaff (2018): "Floating Rate Money? The Stability of Premium in Treasury Floating Rate Notes," Working Paper 25216, National Bureau of Economic Research.

Fraiberger, S. P., D. Lee, and a. R. R. Puy, Damien (2021): "Media Sentiment and International Asset Prices," *Journal of International Economics*, 133.

Fritsch, N., J. Bagley, and S. Nee (2021): "Municipal Markets and the Municipal Liquidity Facility," Working Paper 21-07, Federal Reserve Bank of Cleveland.

Fukuda, S.-i. (2016): "Strong Sterling Pound and Weak European Currencies in the Crises: Evidence from Covered Interest Parity of Secured Rates," Working Paper 21938, National Bureau of Economic Research.

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

Galgano, T. (2020): "Will Your Airport Revenue Bonds be Impaired?" Municipal brief, UBS.

GAO, P., C. LEE, AND D. MURPHY (2019): "Municipal Borrowing Costs and State Policies for Distressed Municipalities," *Journal of Financial Economics.*

GARCÍA, D. (2013): "Sentiment during Recessions," *Journal of Finance*, 68, 1267–1300.

GARRETT, D., A. ORDIN, J. W. ROBERTS, AND J. C. SUÁREZ SERRATO (2023): "Tax Advantages and Imperfect Competition in Auctions for Municipal Bonds," *The Review of Economic Studies.*

GAVA, J., W. LEFEBVRE, AND J. TURC (2020): "Beyond Carry and Momentum in Government Bonds," *The Journal of Fixed Income.*

GERAATS, P. (2002): "Central Bank Transparency," *Economic Journal*, 112, F532–565.

GILLERS, H. AND G. BANERJI (2020): "How the Muni Market Became the Epicenter of the Liquidity Crisis," *Wall Street Journal.*

GOPINATH, G. AND J. C. STEIN (2018): "Banking, Trade, and the Making of a Dominant Currency," Working Paper 24485, National Bureau of Economic Research.

GORTON, B. B. (2016): "The History and Economics of Safe Assets," Working Paper 22210, National Bureau of Economic Research.

GORTON, G., T. LAARITS, AND T. MUIR (2019): "1930: First Modern Crisis," Working Paper 25452, National Bureau of Economic Research.

GORTON, G., S. LEWELLEN, AND A. METRICK (2012): "The Safe-Asset Share," *American Economic Review*, 102, 101–106.

GORTON, G. B. AND G. ORDOÑEZ (2020): "The Supply and Demand for Safe Assets," Working Paper 18732, National Bureau of Economic Research.

GOURINCHAS, P.-O., W. D. RAY, AND D. VAYANOS (2022): "A Preferred-Habitat Model of Term Premia, Exchange Rates, and Monetary Policy Spillovers," Working Paper 29875, National Bureau of Economic Research.

GOURINCHAS, P.-O. AND H. REY (2016): "Real Interest Rates, Imbalances and the Curse of Regional Safe Asset Providers at the Zero Lower Bound," Working Paper 22618, National Bureau of Economic Research.

GOURIO, F. (2009): "Disasters Risk and Business Cycles," Working Paper 15399, National Bureau of Economic Research.

GREEN, R. C., B. HOLLIFIELD, AND N. SCHÜRHOFF (2007): "Dealer Intermediation and Price Behavior in the Aftermarket for New Bond Issues," *Journal of Financial Economics.*

GREENWOOD, R., S. G. HANSON, J. C. STEIN, AND A. SUNDERAM (2020): "A Quantity-Driven Theory of Term Premia and Exchange Rates," Working Paper 27615, National Bureau of Economic Research.

Guerrieri, V. and R. Shimer (2012): "Dynamic Adverse Selection: A Theory of Illiquidity, Fire Sales, and Flight to Quality," Working Paper 17876, National Bureau of Economic Research.

Gutiérrez, G. and T. Philippon (2016): "Investment-Less Growth: An Empirical Investigation," Working Paper 22897, National Bureau of Economic Research.

Habib, M. M., L. Stracca, and F. Venditti (2020): "The Fundamentals of Safe Assets," *Journal of International Money and Finance*, 102.

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

——— (2023): "Whatever it Takes? The Impact of Conditional Policy Promises," Working Paper 31259, National Bureau of Economic Research.

Hale, G. and L. Juvenal (2021): "External Balance Sheets and the Covid-19 Crisis," Working Paper 29277, National Bureau of Economic Research.

Harris, L. E. and M. S. Piwowar (2006): "Secondary Trading Costs in the Municipal Bond Market," *The Journal of Finance*.

Hart, O. D. and L. Zingales (2011): "Inefficient Provision of Liquidity," Working Paper 17299, National Bureau of Economic Research.

Hassan, T., S. Hollander, L. van Lent, and A. Tahoun (2019): "Firm-Level Political Risk: Measurement and Effects," *Quarterly Journal of Economics*, 134, 2135–2202.

Haughwout, A., B. Hyman, and O. Shachar (2022): "The Option Value of Municipal Liquidity," Working Paper.

He, Z., A. Krishnamurthy, and K. Milbradt (2016a): "A Model of Safe Asset Determination," Working Paper 22271, National Bureau of Economic Research.

——— (2016b): "What Makes US Government Bonds Safe Assets?" *American Economic Review*, 106, 519–523.

——— (2016c): "What Makes US Government Bonds Safe Assets?" Working Paper 22017, National Bureau of Economic Research.

——— (2019): "A Model of Safe Asset Determination," *American Economic Review*, 109, 1230–62.

Holston, K., T. Laubach, and J. C. Williams (2023): "Measuring the Natural Rate of Interest after COVID-19," Staff Report 1063, Federal Reserve Bank of New York.

Israel, R., D. Palhares, and S. Richardson (2018): "Common Factors in Corporate Bond Returns," *Journal of Investment Management*.

Kashyap, A. K., D. P. Tsomocos, and A. P. Vardoulakis (2014): "How Does Macroprudential Regulation Change Bank Credit Supply?" Working Paper 20165, National Bureau of Economic Research.

Kekre, R. and M. Lenel (2021): "The Flight to Safety and International Risk Sharing," Working Paper 29238, National Bureau of Economic Research.

Kekrel, R. and M. Lenel (2021): "The Flight to Safety and International Risk Sharing," Working Paper 29238, National Bureau of Economic Research.

Kiff, J., A. Holland, M. Kisser, S. Nowak, S. Saab, L. Schumacher, H. van der Hoorn, and A.-M. Westin (2010): "The Uses and Abuses of Sovereign Credit Ratings," Global Financial Stability Report Ch. 3, International Monetary Fund.

Kose, M. A., S. Kurlat, F. Ohnsorge, and N. Sugawara (2022): "A Cross-Country Database of Fiscal Space," *Journal of International Money and Finance*, 128.

Krishnamurthy, A., S. Nagel, and A. Vissing-Jørgensen (2018): "ECB Policies Involving Government Bond Purchases: Impact and Channels," *Review of Finance*, 22, 1–44.

Krishnamurthy, A. and A. Vissing-Jørgensen (2011): "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," Working Paper 17555, National Bureau of Economic Research.

——— (2012): "The Aggregate Demand for Treasury Debt," *Journal of Political Economy*, 120, 233–267.

Lennon, J., T. Galgano, S. Mukherjee, and T. McLoughlin (2020): "Impact of Coronavirus on Large New York Obligors," Municipal brief, UBS.

Li, T. and J. Lu (2020): "Municipal Finance During the COVID-19 Pandemic: Evidence from Government and Federal Reserve Interventions," Working Paper.

Liu, Y., L. Schmid, and A. Yaron (2019): "The Risks of Safe Assets," 2019 Meeting Paper 1418, Society for Economic Dynamics.

Mankiw, N. G. (2017): *Principles of Economics*, Cencage Learning, 8th ed.

McCormick, L. C. (2023): "Treasury Downplays Fitch Rating, Sees 'Limited' Yield Impact at Most," *Bloomberg*, https://www.bloomberg.com/news/articles/2023-08-02/treasury-downplays-fitch-move-sees-limited-yield-impact-at-most#xj4y7vzkg, August 2.

Meeuwis, M., J. A. Parker, A. Schoar, and D. I. Simester (2021): "Belief Disagreement and Portfolio Choice," Working Paper 25108, National Bureau of Economic Research.

Miranda-Agrippino, S. and H. Rey (2020): "U.S. Monetary Policy and the Global Financial Cycle," *The Review of Economic Studies*, 87, 2754–2776.

——— (2021): "The Global Financial Cycle," *Handbook of International Economics*, 6, 1–43.

Moreira, A. and A. Savov (2014): "The Macroeconomics of Shadow Banking," Working Paper 20335, National Bureau of Economic Research.

Mota, L. (2021): "The Corporate Supply of (Quasi) Safe Assets," Available at https://ssrn.com/abstract=3732444, Social Science Research Network.

Mukherjee, S. (2020): "Impact of Covid-19 on Not-for-Profit Hospitals," Municipal brief, UBS.

Odusami, B. O. and I. Mansur (2022): "Economic Fundamentals, Policy Responses, and State-Level Municipal Bond Sensitivity to COVID-19 Prevalence," *The North American Journal of Economics and Finance*.

Painter, M. (2020): "An Inconvenient Cost: The Effects of Climate Change on Municipal Bonds," *Journal of Financial Economics*.

Panageas, S. (2009): "Bailouts, the Incentive to Manage Risk, and Financial Crises," Working Paper 15058, National Bureau of Economic Research.

Park, D., Y. J. Kang, and Y. H. Eom (2024): "Asset Pricing Tests for Pandemic Risk," *International Review of Economics and Finance*.

Pavlova, A. and R. Rigobon (2005): "Wealth Transfers, Contagion, and Portfolio Constraints," Working Paper 11440, National Bureau of Economic Research.

Pflueger, C., E. Siriwardane, and A. Sunderam (2019): "Financial Market Risk Perceptions and the Macroeconomy," Working Paper 26290, National Bureau of Economic Research.

Rebucci, A., J. Hartley, and D. Jiménez (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*, ed. by C. H. Alexander Chudik and A. Timmermann, Emerald Publishing Limited, 291–322.

Rosen, H. S. and S. Wu (2003): "Portfolio Choice and Health Status," Working Paper 9453, National Bureau of Economic Research.

Schuele, F. and L. Shiner (2020): "What's Going on in the Municipal Bond market? And What is the Fed Doing About it?" *The Brookings Institution Blog*.

Schwert, M. (2017): "Municipal Bond Liquidity and Default Risk," *The Journal of Finance*.

Shanken, J. (1992): "On the Estimation of Beta-Pricing Models," *Review of Financial Studies*, 5, 1–33.

Shapiro, A. H., M. Sudhof, and D. J. Wilson (2020): "Measuring News Sentiment," Working Paper 2017-01, FRB San Francisco.

Sialm, C. (2002): "Stochastic Taxation and Asset Pricing in Dynamic General Equilibrium," Working Paper 9301, National Bureau of Economic Research.

Sibears, J. (2017): "Navigating Municipal Bonds with Factors," Research Notes, Newfound Research.

Song, D. (2017): "Bond Market Exposures to Macroeconomic and Monetary Policy Risks," *Review of Financial Studies*, 30, 2761–2817.

Swanson, E. (2021): "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets," *Journal of Monetary Economics*, 118, 32–53.

Swinkels, L. (2019): "Treasury Bond Return Data Starting in 1962," *Data*, 4, 1–6.

Tran, N. and C. Uzmanoglu (2022): "COVID-19, Lockdowns, and the Municipal Bond Market," *Journal of Banking & Finance*.

Tuckman, B. and A. Serrat (2011): *Fixed Income Securities: Tools for Today's Markets*, Wiley, 3rd ed.

Van Binsbergen, J. H., W. F. Diamond, and M. Grotteria (2019): "Risk-Free Interest Rates," Working Paper 26138, National Bureau of Economic Research.

——— (2022): "Risk-Free Interest Rates," *Journal of Financial Economics*, 143, 1–29.

Viceira, L. M. (2012): "Bond Risk, Bond Return Volatility, and the Term Structure of Interest Rates," *International Journal of Forecasting*, 28, 97–117.

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

Wang, S. Y. (2022): "The Cross-Section of Municipal Bond Returns," LP Working Paper, Dimensional Fund Advisors.

Woodford, M. (2012): "Methods of Policy Accommodation at the Interest-Rate Lower Bound," Presented paper, Changing Policy Landscape Federal Reserve Bank of Kansas City Economic Policy Symposium, Jackson Hole, WY.

Wu, S. Z. and N. J. Ostroy (2021): "Transaction Costs During the COVID-19 Crisis: A Comparison between Municipal Securities and Corporate Bond Markets," Research Paper, Municipal Securities Rulemaking Board.

——— (2022): "Primary Offerings of Municipal Securities: Impact of COVID-19 Crisis on Competitive and Negotiated Offerings," Research Paper, Municipal Securities Rulemaking Board.

Yang, L. (2019): "Not All State Authorizations for Municipal Bankruptcy Are Equal: Impact on State Borrowing Costs," *National Tax Journal*.

Zhengyang, J., A. Krishnamurthy, and H. Lustig (2018): "Foreign Safe Asset Demand for US Treasurys and the Dollar," *AEA Papers and Proceedings*, 108, 537–541.

——— (2020): "Foreign Safe Asset Demand and the Dollar Exchange Rate," Working Paper 24439, National Bureau of Economic Research.

——— (2021): "Foreign Safe Asset Demand and the Dollar Exchange Rate," *Journal of Finance*, 76, 1049–1089.