Institutional Investors and Government Bonds
A Demand System Approach*

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August, 2023

Abstract

This paper estimates an equilibrium demand-based sovereign debt model linking institutional holdings with bond characteristics. Using the universe of assets and bondholders in the 2014-2022 period for Chile, we document heterogeneous sensitivities to different relevant factors across investors, particularly for yields and time to maturity. We then document a decreasing impact of idiosyncratic demand shocks over yields during this period, mostly due to the decreasing participation of pension funds in the sovereign bond market, consistent with an unprecedented liquidity measure for households that allowed them to withdraw retirement saving during the pandemic. Finally, we show a heterogenous impact across investors along the yield curve.

*Financial Research Unit, Central Bank of Chile. We thank the comments and suggestions of Victor Aguirregabiria and the Inter-American Development Bank for their support through their Mentorship Program 2022. The views expressed are those of the author and do not necessarily represent the views of the Central Bank of Chile or its board members. This study was developed within the scope of the research agenda conducted by the Central Bank of Chile (CBC) in economic and financial affairs of its competence. The CBC has access to anonymized information from various public and private entities, by virtue of collaboration agreements signed with these institutions

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1 Introduction

The term structure of the interest rate is crucial for both central bankers and private investors. It provides information about the expected path of monetary policy and the degree of financial stability in the economy. Moreover, the yield curve sets benchmark interest rates for the private sector and provides information about the relative cost of credit. Because the supply of bonds is relatively inelastic in the short run, the demand side of the market, characterized chiefly by institutional investors, shapes the yield curve. Therefore, understanding how institutional investors determine their demand for bonds at different maturities and what factors drive their investment decisions is crucial to assess the overall status of financial markets.

In this paper, we study the investment patterns in the sovereign bond market by institutional investors in Chile during 2014-2022. To guide our analysis, we follow Koijen and Yogo (2019) and estimate an equilibrium demand-based sovereign bond pricing model that recognizes that the demand for assets depends on their observed characteristics, including prices. We use security-level holdings data of pension funds, mutual funds, insurance companies, and banks and merge those holdings with asset prices and other characteristics of securities. Our data covers the universe of sovereign bonds issued in Chile and more than 80 percent of the total outstanding.[1] These unique features of the Chilean market provide a unique opportunity to understand the role of institutional investors in shaping demand.

We start our work by summarizing the demand-based model proposed by Koijen and Yogo (2019), in which investors must allocate their wealth across different assets. The model assumes that the available investment opportunities are sovereign bonds and an outside asset (corresponding to the rest of the wealth not invested in sovereign bonds). Crucially, the model assumes that the demand of each investor for a particular asset depends on observable characteristics of the asset, such as yields or time to maturity, and unobserved characteristics synthesized in a latent demand component. This latent demand component corresponds to demand shocks which are investor, asset, and time specific.

Because investors' bond holdings and yields are endogenous, we follow the instrumental variable (IV) approach of Koijen and Yogo (2019) and Bretscher et al. (2022). To motivate our IV, we document three facts: (i) institutional investors hold persistent portfolios; (ii) there are sizeable

[1] We denote the remaining fraction of market participants as the residual sector or "households" and correspond to the difference between the total outstanding and the fraction captured by our data. This computation allows us to cover the market's universe without characterizing this residual investor's complete portfolio.

differences in AUM across investors; and (iii) there are significant and persistent differences in market shares across investors and assets. The first observation suggests that institutional investors allocate their AUM as if they follow mandates or investment rules. Because such mandates do not depend on asset prices, we can construct counterfactual portfolio shares based on holdings' persistence. The other observations imply that the market comprises many atomistic players and a few large investors. We improve on Koijen and Yogo (2019) and Bretscher et al. (2022) IV strategy by constructing an instrument that considers all these facts. Conceptually, our instrument captures the counterfactual residual demand on each market given mandates, the relative size of investors, and the historical relative market share. Therefore, for each investor, asset, and period, we consider the counterfactual residual demand by giving more weight to large market players.[2]

Our estimation results show heterogeneous sensitivities to key asset characteristics. In particular, we show that yields positively affect only the holdings of banks and the residual sector. This result suggests that the demand for pension funds, mutual funds, and insurance companies is upward-sloping. One possible mechanism behind this result is the duration mismatch in the balance sheet of these institutional investors because their liabilities have a longer maturity profile relative to their assets. Consequently, changes in long-term interest rates generate an increase in demand for long-term bonds to match the duration of their liabilities. This result is consistent with previous literature that estimates demand curves for pension funds and insurance companies (Domanski et al., 2017; Koijen et al., 2021; Bretscher et al., 2022; Jansen, 2021) and also with the sensitivity of demand to assets' maturity, in which pension funds, mutual funds, and insurance companies tend to hold long-term bonds in their portfolios.

Equipped with our demand system estimates, we document heterogeneous and time-varying demand elasticities across investors. We show that banks have the most elastic demand among institutional investors, with a value above one for most of the sample period. However, we also show that this elasticity has declined over time. We observe the opposite for pension funds and insurance companies, with elasticities below one but increasing over time. Similar results are documented by Bretscher et al. (2022) for the demand for corporate bonds. Finally, we present evidence regarding the price impact of demand shocks and its mechanisms. We find that demand shocks from banks are the most important determinant of yield changes over time, especially for nominal bonds. We

[2] While is not the same application, our instrument shares the concepts behind the granular instrumental variable proposed by Gabaix and Koijen (2020) and recently applied by Galaasen et al. (2020) and Camanho et al. (2022), among others.

attribute this increased impact to a higher participation in this market, steady in terms of portfolio diversification. Further, the yield impact of pension funds and mutual funds has decreased in time.

Overall, our findings suggest that the type of institutional investors holding sovereign bonds and in which segment of the yield curve they invest affect equilibrium prices. In addition, we document heterogeneous sensitivities to yields and time to maturity. In particular, while banks tend to affect the short part of the curve, pension funds and insurance companies affect the long part, consistent with the preferred habitat hypothesis (Vayanos and Vila, 2021). Moreover, we document an increasing overall price impact of demand shocks in the last part of our sample, composed of a decreasing (increasing) role for pension funds (banks). All our results should have implications in setting the benchmark rates for the private sector (Longstaff and Schwartz, 1995).

Related Literature. Our work is related to the demand-based asset pricing literature pioneered by Koijen and Yogo (2019) in the context of the stock market. Other papers have used this modeling approach to study the equilibrium of asset prices and exchange rates around the European sovereign debt crisis (Koijen and Yogo, 2020), the portfolio rebalancing associated with quantitative easing programs (Koijen et al., 2021), the asset pricing of corporate bonds (Bretscher et al., 2022), and the consequences of changes in regulation (Jansen, 2021). Our paper studies the demand for sovereign bonds of all the institutional investors in Chile, considering the universe of available assets. Our work quantifies the price impact of demand shocks and allows us to study how structural changes in financial markets can transmit to the rest of the economy. Also, and to our knowledge, we are the first to estimate demand curves for an emerging economy.

This paper is also related to the recent debate regarding the role of financial intermediaries in asset pricing. Recent contributions include Gompers and Metrick (2001), He and Krishnamurthy (2012), Basak and Pavlova (2013), He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014), Adrian et al. (2014), He et al. (2017) and Cai et al. (2019), among others. We contribute to this literature by presenting empirical evidence on how institutional investors shape the yield curve of sovereign bonds and what is the market impact of demand shocks.

Finally, our paper is related to the literature analyzing the role of institutional investors in fostering systemic risk (Ben-David et al., 2021). While some contributions have focused on the government bond market (Greenwood and Vayanos, 2010), the equity market (Ben-Rephael et al., 2011; Khan et al., 2012; Da et al., 2018) and the corporate bond market (Ellul et al., 2011; Goldstein et al., 2017), other has focused on the impact of institutional herding (Nofsinger and Sias, 1999;

Wermers, 1999; Walter and Moritz Weber, 2006; Choi and Sias, 2009). We show that a significant fraction of the market exhibits upward-sloping demands, implying that investors move in tandem after exogenous price changes. Moreover, our results relate to previous literature on the duration mismatch in the portfolio of institutional investors and the upward-sloping demand (Domanski et al., 2017), implying that well-intended policies, such as the decrease of short-term interest rate, might backfire to generate a run by a significant fraction of the market.

The rest of the paper is organized as follows. Section 2 presents the characteristic-based asset demand model, as well as the definition of price elasticity. Section 3 presents the data and provides descriptive statistics about portfolio holdings. Section 4 presents our identification strategy and presents results for our IV estimation. Section 5 presents our measure of price impact. Section 6 concludes.

2 A Demand System for Sovereign Bonds

This section presents the characteristic-based asset demand system for sovereign bonds. The model follows the work of Koijen and Yogo (2019) and Bretscher et al. (2022) closely, and focuses on the importance of bond-specific characteristics to explain bond holdings by different institutional investors in the economy.

2.1 Characteristic-Based Demand

We consider $i = 1, \ldots, \mathcal{I}$ investors in the economy. Assets are indexed by $n = 0, \ldots, N$, where $n = 0$ denotes an outside asset, different from a sovereign bond. Each period is denoted by t. We let $y_t(n)$ be the yield associated with bond n in period t. Other characteristics (such as time to maturity, initial offering amount, and turnover) are collected in the vector $\mathbf{x}_t(n)$. This vector of sovereign bonds' characteristics is meant to capture key sources of risk that investors value to determine their holdings. We discuss the details of bonds' characteristics in Section 3.1.

Each investor i allocates her wealth (assets under management) in period t, $A_{i,t}$, across the different available sovereign bonds and the outside asset. As Koijen and Yogo (2019), we assume that investors choose bonds only from their investment universe, $N_{i,t}$. This assumption is motivated by managers holding concentrated portfolios (i.e., they do not invest in all available bonds) with a stable maturity structure over time, suggesting that managers are restricted by investment mandates. Throughout the paper, we assume that both assets under management and bonds' characteristics are exogenously determined.

Let $A_{i,t}(n)$ be the dollar amount of bond n in the portfolio of investor i at period t. Let $w_{i,t}(n)$ be the portfolio weight that investor i puts in bond n in period t, $A_{i,t}(n)/A_{i,t}$, such that $\sum_{n=0}^{N} w_{i,t}(n) = 1$. For the description of the demand system, it is convenient to define also the share ratio $\delta_{i,t}(n) \equiv \frac{w_{i,t}(n)}{w_{i,t}(0)}$, where $w_{i,t}(0)$ denotes the portfolio weight in the outside asset. By definition, the following equation holds

$$w_{i,t}(n) = \frac{\delta_{i,t}(n)}{1 + \sum_{m \in N_{i,t}} \delta_{i,t}(m)}, \tag{1}$$

Koijen and Yogo (2019) derive an empirically tractable model of portfolio weights from traditional portfolio theory, based on three assumptions. First, investors have preferences deriving in a mean-variance portfolio (Markowitz, 1952). Second, returns follow a factor structure. Finally, expected returns and factor loadings depend only on an asset's prices and characteristics. Under these assumptions, we can write Eq. (1) as a logit function of yields and asset characteristics

$$\log \frac{w_{i,t}(n)}{w_{i,t}(0)} = \log \delta_{i,t}(n) = \alpha_{i,t} + \beta_{0,i,t} y_t(n) + \beta'_{1,i,t} \mathbf{x}_t(n) + \varepsilon_{i,t}(n), \tag{2}$$

where $\varepsilon_{i,t}(n)$ is the log of latent demand, which captures the investor's i demand that does not depend on bonds' characteristics.

2.2 Market Clearing

Up to this point, the economy is characterized by partial equilibrium in each bond market. We close the description of the model by imposing market clearing for each bond in every period. Let $M_t(n)$ be the market value of bond n in period t, which corresponds to the supply of the asset in that period. By assumption, this amount is exogenous and does not depend on prices. Then, market clearing requires that the sum of the invested amounts across the distribution of investors equals the market value of each bond

$$M_t(n) = \sum_{i=1}^{\mathcal{I}} A_{i,t} w_{i,t}(n). \tag{3}$$

Note that even though we observe the position of several investors in the market, it could be the case that the total invested amount observed in the data does not coincide with the market value of each bond. Therefore, for each bond, we define the position of an additional investor ("households") as the difference between the bonds' outstanding amount and the sum of holdings across the observed investors. Finally, note that given $M_t(n)$, Eq. (3) implicitly defines the price of a bond and its yield. This observation is useful for the counterfactual exercises to be shown later on.

2.3 Demand Elasticity

As shown in Eq. (2), the coefficients associated to characteristics are indexed by i and t and therefore vary across investors and time. This implies that investors have time-varying heterogeneous elasticities. Let $\mathbf{q}_{i,t} = \log(A_{i,t}\mathbf{w}_{i,t}) - \mathbf{p}_t$ be the vector of log quantities held by investor i in period t, which is defined over the set of bonds with strictly positive portfolio weights. We define the elasticity of individual demand as[3]

$$-\frac{\partial \mathbf{q}_{i,t}}{\partial \mathbf{p}_t'} = \mathbf{I} - \beta_{0,i,t}\,\mathrm{diag}(\mathbf{w}_{i,t})^{-1}\mathbf{G}_{i,t}, \tag{4}$$

with $\mathbf{G}_{i,t} \equiv \mathrm{diag}(\mathbf{w}_{i,t}) - \mathbf{w}_{i,t}\mathbf{w}_{i,t}'$. Note, however, that the previous expression corresponds to the price elasticity of a bond. Therefore, we adjust the $\beta_{0,i,t}$ coefficient by $-1/(T(n) - t)$, which is the time-to-maturity of bond n in period t, to account for the fact that the demand equation depends on yields rather than prices.

In the same fashion, let $\mathbf{q}_t = \log(\sum_{i\in\mathcal{I}} A_{i,t}\mathbf{w}_{i,t}) - \mathbf{p}_t$ be the vector of log quantities held by *all* investors, summed over the set of bonds with strictly positive portfolio weights. The elasticity of aggregate demand is

$$-\frac{\partial \mathbf{q}_t}{\partial \mathbf{p}_t'} = \mathbf{I} - \sum_{i\in\mathcal{I}} \beta_{0,i,t}A_{i,t}\mathbf{H}_t^{-1}\mathbf{G}_{i,t}, \tag{5}$$

where $\mathbf{G}_{i,t}$ is defined as before and $\mathbf{H}_t \equiv \sum_{j\in\mathcal{I}} A_{j,t}\,\mathrm{diag}(\mathbf{w}_{j,t})$.

3 Bonds' Characteristics and Institutional Holdings Data

In this section, we describe the data sources and construction of our rich and comprehensive dataset linking sovereign bond holdings, yields, and characteristics.

3.1 Bonds' Characteristics

Data Sources. Daily prices, yields, turnover, outstanding amounts, and issuance characteristics such as maturity, currency, and issuance amount are obtained from Riskamerica. The database

[3]See Appendix D for derivations.

is constructed by obtaining the time series of bonds. As the yield and characteristics are in daily frequency, we convert it to monthly frequency by computing the last available data of each bond in any given month (our results are similar if we use monthly averages). Our sample is restricted to locally issued sovereign bonds in nominal terms (Chilean pesos) and inflation-indexed bonds. Those instruments are issued by the Central Bank of Chile and the Ministry of Finance through the general treasury of the republic. Further, we restrict our sample to bonds with non-missing yields.

Observed Characteristics. First, to capture duration risk, we include the time-to-maturity of each bond (Koijen et al., 2021). Second, we capture the liquidity of a bond by using the (log) of rotation or turnover of each bond (Datar et al., 1998). This metric is computed as the trade volume relative to the amount outstanding in a particular period. Higher turnover proxies for higher liquidity.[4] Finally, we include the (log of the) initial offering amount of each bond to also proxy for liquidity (Bretscher et al., 2022). Our specification does not include spreads or returns, as these might violate the identifying assumption that characteristics other than yields are exogenous to latent demand. In addition, the explanatory power of certain characteristics outside our specification (e.g. duration, convexity, and the number of coupons are highly correlated to time-to-maturity) is absorbed by those included.[5]

As mentioned before, our analysis focuses on locally issued sovereign bonds in local currency. Thus, these make up the investment universe. The outside asset includes the complement set of bonds, which are corporate bonds, equity, or any other asset in the portfolio of investors.

3.2 Institutional Holdings Data

Data Sources. We obtain monthly holdings for pension funds from the Chilean Pensions Supervisor. For mutual funds, insurance companies, and banks, we obtain monthly holdings from the Chilean Financial Markets Commission. These holdings are reported for varying periods, with pension funds and mutual funds reporting since 2003, insurance companies since 2009, and banks since 2014.

[4] Alternatively, we capture the liquidity of a bond by using the (log) of the liquidity measure proposed by Amihud (2002), which is computed by taking the monthly average of daily returns over daily volumes. A higher value for this statistic implies that current transactions have a higher impact on asset prices, implying lower liquidity. When replaced by this measure, we obtain similar qualitative results for the coefficients associated with other observable characteristics.

[5] However, in practice, we will run our estimations by controlling for investor×date fixed effects, which control for any unobservable characteristic varying on those levels.

Therefore, we restrict our sample from 2014 to the third quarter of 2022.[6] We merge the bonds in Riskamerica with the holdings database by asset-id (ticker) and drop any holdings that do not match. There are 166 different sovereign bonds available throughout the period.

Descriptive Statistics and Holding Patterns. Table 1 provides an overview of the bond holdings in our final sample. At the beginning of the sample, 83 institutions held 90% of the market, with a median of US$ 626 million assets under management in their portfolios. The number of institutions increases through the study period, though the median portfolio decreases regarding assets under management. In contrast, the higher part of the distribution faces enlarged assets. Similarly, we observe a decrease in the number of sovereign bonds that constitute the portfolios across the period. Our sample covers 90% of the sovereign bond markets at the beginning of the period. Nonetheless, the share of bonds in the institutional portfolios decreases to 80% by the end of the period.[7]

Table 2 further outlines holdings, by institutional type. Pension funds are the largest actors in the market, but with fewer participants. Their median holdings of sovereign bonds were US$83,551 million in 2014, declining to US$68,743 million in 2021, coupled with the entrance of a new fund by the end of the period. They hold the least concentrated portfolios, with a median going from 62 different sovereign bonds in their portfolios in 2014, to 36 by 2021. At the same time, insurance companies are the smallest institutions in terms of holdings and contracting value of portfolios, but with the most participants in this market, growing from 43 to 59 throughout the sample.

The investment universe of each institution is defined as the set of bonds that are currently held or ever held in the previous six quarters, at each date. Table 3 reports the percentage of bonds held in the current quarter that were ever held in the previous one to six quarters, by quintiles of assets under management (AUM). For the median institution in AUM, 83% of bonds that are currently held were also held in the previous quarter. This percentage slightly increases to 98% at six quarters, thus no substantive change appears in time. Similarly, the percentage rises from 91 to 94 after six quarters for the institutions with the most AUM. We confirm these patterns hold also at the institutional level, as we report in Table A.1 of Appendix A.2.

In our setup, market clearing requires that the sum of holdings equals the total amount outstanding

[6] Pension Fund Administrators are required to report with three-month delays, therefore the most recent holding information available is of the third quarter of 2022.

[7] 2022 is not directly comparable to the previous years as it only consists of the first three quarters. Thus we will not mention it for describing trends in the institutional portfolios.

Table 1. Summary of Institutional Investors Sovereign Bond holdings

			Assets Under Management (US$ Millions)		Number of Bonds Held	
Period	Institutions	% Held	Median	90th Percentile	Median	90th Percentile
2014	83	90	626	12,966	21	60
2015	85	91	498	12,195	15	62
2016	85	89	546	13,124	18	60
2017	90	86	601	19,937	16	53
2018	94	80	527	14,192	13	46
2019	93	79	410	15,569	11	38
2020	98	79	246	20,665	9	37
2021	96	80	387	23,993	8	38
2022	91	76	277	9,953	7	28

Note: This table reports the time-series median of each summary statistic within the given period. The quarterly sample period is from 2014:1 to 2022:3.

of bonds held across investors. For each bond, we define assets held by the household sector as the difference between the amount outstanding and the sum of outstanding held by the reporting institutions. We are, therefore, uncertain about the actors that constitute the household sector. However, it is likely smaller institutions and foreign investment.

As our holdings data comes from a granular, self-reported source (directly from institutional investors through their official supervisors), we examine whether our sample represents the prevalent holding patterns. Indeed, our sample fairly matches the consolidated registry provided by the custodian of Chilean securities (DCV).[8] When comparing aggregate holdings from our microdata to the reports of DCV, we see that pension funds are the largest holders of nominal and indexed sovereign bonds, followed by banks, mutual funds and insurance companies. The greatest divergence between our data and the DCV stems from nominal mutual fund holdings, where we capture slightly lower participation, most likely associated to differing private investment funds reporting practices.[9]

[8] *Depósito Central de Valores* provides its participants with a securities registration, transaction, settlement, and custody service

[9] See Appendix A.2 for detailed comparison.

Table 2. Summary of Institutional Investors Sovereign Bond holdings

	Number of Institutions				Assets Under Management (US$ Million)				Number of Assets			
Period	PF	MF	IC	BA	PF	MF	IC	BA	PF	MF	IC	BA
2014	6	16	43	17	83,551	1,916	99	3,410	62	44	10	46
2015	6	16	44	18	82,866	1,458	87	1,836	65	41	9	39
2016	6	15	46	17	95,004	2,117	74	3,184	61	38	10	38
2017	6	16	51	16	94,389	1,966	82	5,372	46	34	6	37
2018	6	16	55	16	81,781	1,825	63	7,485	46	30	6	35
2019	7	16	54	15	94,861	1,882	75	5,085	34	26	6	26
2020	7	16	59	15	82,305	1,468	51	5,601	33	29	5	30
2021	7	15	59	14	68,743	1,254	49	9,712	36	29	5	30
2022	7	16	53	14	39,517	482	49	4,585	30	18	5	22

Note: This table reports the time-series median of each summary statistic within the given period for each institutional type, i.e. pension funds (PF), mutual funds (MF), insurance companies (IC), and banks (BA). The quarterly sample period is from 2014:1 to 2022:3.

Table 3. Persistence of the Set of Bonds Held

	Previous Quarters					
AUM quintile	1	2	3	4	5	6
1	83	85	86	87	88	88
2	83	84	85	86	87	87
3	83	84	86	87	87	88
4	83	85	86	87	88	88
5	91	92	93	94	94	94

Note: This table reports the percentage of bonds held in the current quarter that were ever held in the previous one to five quarters. Each cell is a pooled median across time and all institutions in the given asset under management (AUM) quintile. The quarterly sample period is from 2014:1 to 2022:3.

4 Estimated Demand System for Sovereign Bonds

This section outlines the results of our estimated characteristics-based demand system, describing institutional investors' demand for Chilean sovereign bonds. First, we describe our identification strategy, as well as the details of our empirical implementation. We estimate the system using pooled IV regressions for each institution type for each quarter in the 2014-2022 period. Then we present the results for the first stage of our empirical strategy. Finally, we describe the instrumental variables estimates and the elasticities of demand for each institutional investor.

4.1 Identification Strategy

Estimating Eq. (2) with OLS requires the condition $\mathbb{E}_t[\varepsilon_{i,t}(n)|y_t(n), \mathbf{x}_t(n)] = 0$ to hold to get unbiased estimates. As described in Section 2, we assume that bonds' characteristics other than yield are exogenous. Hence, the orthogonality restriction for $\mathbf{x}_t(n)$ holds. For the error term to be orthogonal to yields, it should be the case that investors are atomistically small, so idiosyncratic demand shocks have negligible effects on prices. However, even if this assumption holds, there still could be correlated errors across investors having a price impact on the economy. Therefore, we require an instrumental variable for yields.

Following Koijen and Yogo (2019), we build an instrumental variable based on investment mandates at the institutional level. Such mandates restrict the universe of assets in which managers can invest. Based on the persistent holding patterns across institutions (discussed in Section 3), we define the investor's universe at each date, $N_{i,t}$, as the subset of sovereign bonds held either in the current period or at any point in the previous two years. With this assumption at hand, we instrument the yield of bond n in period t for investor i as

$$\widehat{y}_{i,t}(n) = \log\left(\sum_{j \neq i} A_{j,t} \frac{\mathbb{I}_{j,t}(n)}{1 + \sum_{m=1}^{N} \mathbb{I}_{j,t}(m)}\right), \tag{6}$$

where $\mathbb{I}_{j,t}(n)$ is an indicator variable equal to one if bond n belongs to the investment universe of investor j in period t. Because this variable only depends on the assets under management of different investors and their investment universe, which by our identifying assumptions are exogenous, then it operates as a proper instrumental variable. In constructing the instrument, we exclude the counterfactual holdings of investor i and interpret this variable as the counterfactual residual demand for bond n. Therefore, the instrument captures the notion that when an asset is included in the investment universe of more institutions, it has a larger exogenous component demand. A larger exogenous demand increases prices, hence decreasing yields.

4.2 Implementation

The characteristics-based system approach to asset pricing has been previously applied to the U.S. securities market, which, compared to the Chilean market, is less concentrated regarding the number of investors and availability of investment vehicles. Indeed, the main players of the Chilean securities market are banks, which in 2021 held assets by US$346 (122% GDP), pension funds US$180 Billion (63,7%), investment funds US$64 Billion (3%), and insurance companies US$61 Billion (2%).[10] Of special interest are pension funds, which in the same period accounted for 37.5% of household financial assets,[11] and additionally face a series of executive-imposed investment restrictions, forcing their portfolios within prevalent limits (e.g. by ceiling foreign investment).[12] As a result, the property of different investment vehicles is concentrated among institutional investors. Figure 1 portrays this prevailing trend for the sovereign bond market, which indicates that the cross-section of institution holdings may not be large enough to estimate Eq. (2) accurately. With this issue at hand, as well as the heterogeneity in the size of institutions measured by their assets, and concentrated portfolios, we estimate the demand system using the methods described in the following.

First, we pool institutions by type to estimate instrumental variable (IV) regressions specific to each investor class. This creates the following groups: (i) pension funds, (ii) mutual funds, (iii) insurance companies, and (iv) banks, assigning the remaining holdings to the (v) household sector (further discussed in Section 3.2). An alternative approach to grouping is to estimate at the institution level. However, such a granular approach dilutes the observed holdings, deteriorating estimation quality. Likewise, we estimate the demand functions pooling by quarters despite our access to monthly holdings, further improving estimation.

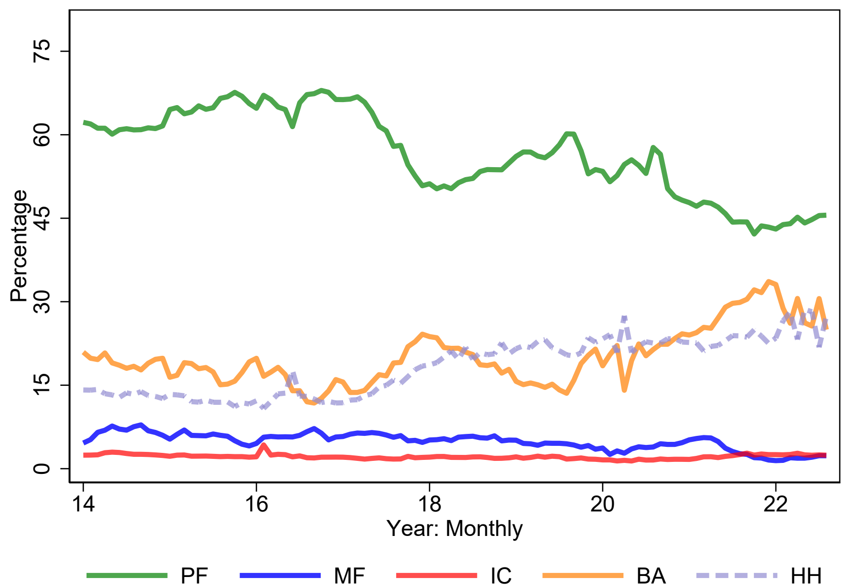
Second, we exploit the fact that there are appreciable differences in the relative size across investors, either in their assets under management (AUM) or relative importance for a particular bond n. Figure B.1 in the Appendix shows the pooled distribution of AUM and relative shares. It is clear from the figure that the distribution is highly skewed, implying that shocks to specific investors

[10] Central Bank of Chile, National Accounts by Institutional Sector

[11] OECD (2022), Household financial assets (indicator). doi: 10.1787/7519b9dc-en

[12] This is further discussed in Appendix E which provides a brief introduction to the Chilean retirement system, and its overall prevailing mandates.

Figure 1. Institutional Share of Sovereign Bonds



Note: The chart shows the share of institutional investors for the Chilean sovereign bond market for the period 2014:1 - 2022:8. The data are monthly taken from the Pension Supervisor and Commission for Financial Markets.

may have larger price demands.[13] Note that our instrument described in Eq. (6) already takes into account the relative size of investors by including $A_{j,t}$. To further overcome the substantial heterogeneity in the size of institutions, we modify the previously introduced instrument in Eq. (6) to include the relative importance of each investor within a particular bond issuance

$$\widehat{y}_{i,t}(n) = \log \left(\sum_{j \neq i} A_{j,t} \times \gamma_{j,t}(n) \frac{\mathbb{I}_{j,t}(n)}{1 + \sum_{m=1}^{N} \mathbb{I}_{j,t}(m)} \right), \tag{7}$$

with $\gamma_{j,t}(n) \equiv A_{j,t}(n) / \sum_k A_{k,t}(n)$, accounting for institutional investment proportional to the bond outstanding amount. We also exclude the residual or household sector in the computation of the instrument. These modifications induce more variation across investors, improving the quality of the IV estimation. Note, however, that $\gamma_{j,t}(n)$ would be endogenous if we include this variable contemporaneously. We alleviate this concern by replacing the time-varying market share with its time-series average for each investor and bond. The holding patterns described in the previous section, as well as the high persistence of the market shares, give us confidence regarding the validity of this variable.

[13] We confirm this intuition by estimating a power law for each distribution and find a coefficient of 1.10 for AUM and 2.04 for shares. These results imply that shocks to granular investors do not cancel out when aggregating.

Third, the universe of sovereign bonds comprises a nontrivial distribution across nominal and inflation-indexed yields, where the latter represents close to 70% of the sample.[14] Moreover, nominal bonds have a systematically larger yield just by including a premium for not protecting against inflation; otherwise, nominal and indexed bonds should be substitutes (Fleckenstein et al., 2014). To provide a fair comparison between these assets, we control for the indexation mechanism by including an indicator variable that takes a value of one if the bond is inflation-indexed and zero otherwise in the first stage of our estimation.

Finally, Chilean sovereign bonds mostly pay non-zero coupons, usually with a twice-per-year frequency. We, therefore, convert yield to maturities to bond-specific pseudo-zero-coupon yields, which, as introduced by Bretscher et al. (2022), allow for straightforward computation of counterfactual equilibrium simulations, in addition, to ease of interpretation. See Appendix C for a description of the procedure. It is worth mentioning that our estimates for the demand system do not change considerably using yield to maturities instead of pseudo-zero-coupon yields.

4.3 First-stage Results

As described in section 4.2, our first-stage estimation relates our instrumental variable with observed yields, controlling for the nature of each bond (i.e., if its payments are in nominal terms or if it is indexed to inflation). We focus on the statistical significance and sign of the t-statistic associated with the instrumental variable. Column (1) of Table B.1 in Appendix B.2 summarizes the distribution of this statistic for each institutional investor. As we can see, on average, our instrumental variable negatively correlates with yields over time, with the exception of insurance companies. This is particularly the case for pension funds and mutual funds, and to a lesser extent, for banks and households. Also, we notice that the right tail of the distribution of the statistic tends to be positive, with the notable exception of pension funds. This is due to the fact that the relationship between the instrument and yields tends to revert by the end of the sample, coinciding with the COVID-19 period and the turmoil in financial markets, both locally and at a global scale.

To complement our analysis, column (2) in Table B.1 analyzes the statistical significance of our instrument over time. Considering both positive and negative values of the t-statistic, we see that the instrument is statistically significant (i.e., above 1.96 in absolute value) at least 70% of the time. In the case of pension funds and banks, which are the largest investors in the market, this statistic is

[14]Such bonds are indexed to the *Unidad de Fomento* or UF, a daily price index tracking inflation. See Appendix A.1 for details about the implementation of monetary policy in Chile and the supply of inflation-indexed bonds.

significant more than 80% of the time. If we focus only in cases in which the correlation between our instrumental variable is negative and significant (i.e., below -1.96), at least 75 and 46% of the time the association is significant for pension funds and banks. We see these simple tests as evidence of a strong association between yields and counterfactual residual demand, which gives us confidence in the validity of our instrumental variable approach.

4.4 Estimated Demand Parameters

Once we have analyzed the results of our first-stage estimates, we present our main results related to the IV estimation. Table B.2 shows the estimated demand parameters on instrumented yield, time to maturity, issuance amount, and turnover across institutions and compares them to an OLS setup. We find varying preferences for characteristics between the main actors of the Chilean sovereign bond market. Furthermore, these divergences are persistent over time, as portrayed in Figure 2, with the time-series coefficients for the bonds' characteristics. Table B.2 also reports the Kleibergen-Paap F-statistic, documenting the first stage strength. For all institution types, the test is well above the Stock and Yogo (2005) critical value of 10 for rejecting the null of weak instruments. In addition, our estimated IV coefficients for the instrumented yield are above the OLS coefficients in absolute value. Thus, OLS negatively biases results.

Instrumented Yields. A higher coefficient on the instrumented yields implies a higher demand elasticity. Figure 2 shows that banks have a more elastic demand than other institutions and less elastic compared to households for most of the period. Indeed, banks and households are the only two types of investors with mostly positive coefficients on yields. On the other hand, pension funds, mutual funds, and insurers face negative coefficients. Similarly, Bretscher et al. (2022) find negative coefficients for insurers in the context of corporate bonds. (Domanski et al., 2017; Koijen et al., 2021; Jansen, 2021) further provide evidence consistent with this result, possibly due to duration matching strategies of those institutions with long-term liabilities. Pension funds, insurance companies, and households have become more elastic from 2014 to 2022, while banks and mutual funds have become less elastic. All institutions are more elastic, compared to households, by the end of the period. The differences between pension funds and banks, the two largest actors in this market, are persistent until 2019, after which they level. In Section 4.5, we transform these estimates into elasticities.

Time to Maturity. The coefficients on the bond's time to maturity capture the preference for duration across institutions. We find noticeable segmentation along maturity for institutions; moreover, while the coefficient is positive for pension funds, mutual funds, and insurance companies, it is negative for banks, depicting how these institutions tilt their portfolios towards shorter maturities and pension funds toward longer ones. In comparison, insurers and mutual funds hold similar maturity portfolios. Heterogeneous preferences for duration risk are consistent with the liability structure of each institution, pension funds face obligations with pensioners along the curve; however more concentrated towards longer horizons. On the other hand, banks maintain a higher proportion of contingent claims. Both insurers and mutual funds have low coefficients on time to maturity, depicting little preference variation along the curve.

Bond Size. Subsequently, we examine how the demand varies by issuance amount, which captures the size of the bond after factoring in liquidity through turnover. All institutions face positive coefficients for most of the sample period, with little variation in time. Still, after 2020 the preferences of insurance companies and pension funds face significant volatility, with an abrupt change favoring smaller bonds.

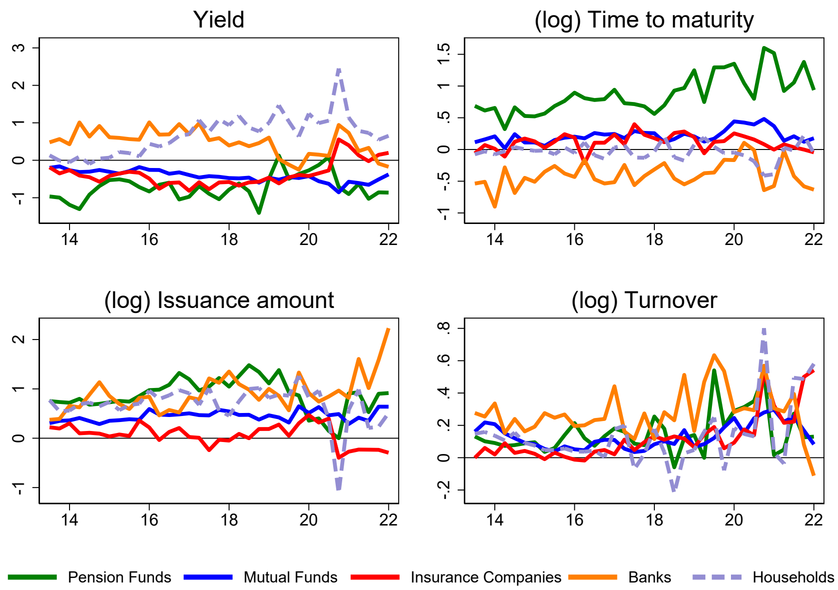
Turnover. Turnover captures the demands for liquidity. Notwithstanding varying coefficients across the sample period for banks, this institution type shows an upward trend throughout the sample, depicting their predilection for more liquid bonds. Insurance companies and mutual funds move in tandem regarding their preferences for size, also portraying an ascending trend, thus tilting their portfolios towards more liquid bonds. In contrast, pension funds face more volatile coefficients, which drop abruptly toward the end of the period.

4.5 Demand Elasticities

In this section, we compute the equilibrium demand elasticities for individual investor types and the sovereign bond market as a whole. Figure 3 reports the time series of estimated demand elasticities by investor type for the period 2014:1 to 2022:3. We describe the main results in the following paragraphs.

Banks have the highest demand elasticities. While banks portray demand elasticities above 1 for the whole sample, insurance companies, pension funds, and mutual funds face inelastic demand

Figure 2. Evolution of the Estimated Demand System by Institutional Investor



Note: The chart shows the estimated coefficients by institutional type, for the IV demand system regression, in quarterly frequency for the 2014:1 - 2022:3 period.

curves (< 1) for most of the period. These differences suggest a higher demand for liquidity by banks relative to other investors, thus more responsiveness to smaller yield movements.

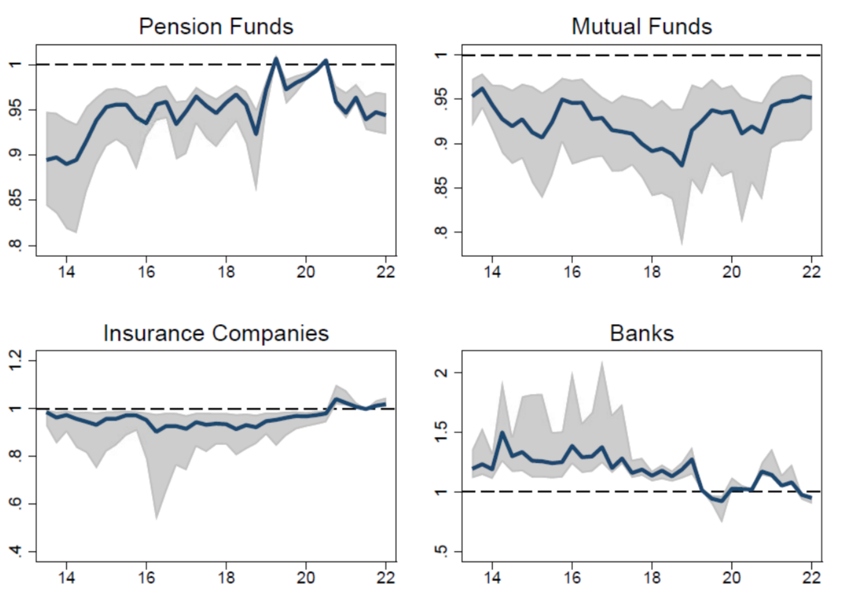
Pension funds have become more elastic, while banks have become less elastic. Elasticities for banks have decreased substantially from 1.2 to 1, suggesting that banks have become more passive over time and pension funds have increased from 0.9 to 1, leveling with banks, however with a relative increase in activeness. We interpret this trend as a result of increasing uncertainty for pension funds, with pension fund reform in sight, as well as withdrawals from individual accounts that took place as a measure to improve household liquidity during the COVID-19 pandemic.[15] Furthermore, increased liquidity for households translated to an increase in bank saving accounts,[16]

[15]In the Chilean pension system, workers are not allowed to access their funds until retirement. However, as part of a series of exceptional relief measures for households during the COVID-19 pandemic, they were allowed to make up to 3 withdrawals approved in July 2020, December 2020, and April 2021, during the time span of a year after each approval. As a result, 35% of workers were left without saving in their retirement accounts, according to the Pension Fund Supervisor. See Appendix E.2 for further information on withdrawals.

[16]The 2021 Household Financial Survey by the Central Bank of Chile accounts for this fact, showing an increase in the number of savings accounts and their amounts compared to 2017. Moreover, more than 80% of the withdrawals were deposited in bank accounts.

effectively influencing the liabilities of both institutionals.

Figure 3. Demand Elasticities of Institutional Investors



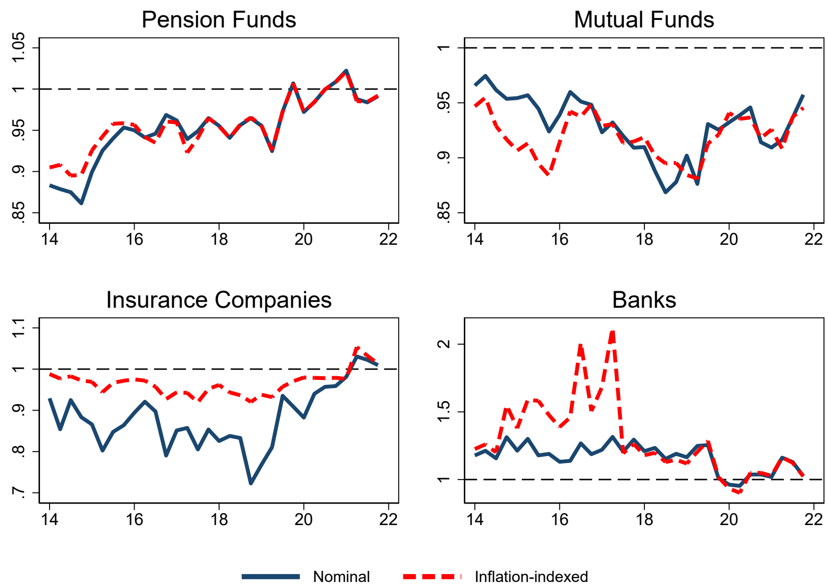
Note: The chart shows the demand elasticities by institutional type, in quarterly frequency for the 2014:1 - 2022:3 period. Solid blue line denotes median estimate. Gray area denotes interquartile range.

The demand for indexed bonds is more elastic for Insurance companies and Banks. Figure 4 reports the time series of estimated demand elasticities by investor type, differentiating between nominal and inflation-indexed bonds. Insurance companies have noticeably more elastic demands towards inflation-indexed bonds relative to the nominal alternative. For banks, this trend ends abruptly by the end of 2017, when the demand elasticities for both instruments aligned. Interestingly, pension funds and mutual funds amount for little divergence in response to changes in the yield of the different asset classes.

5 Price Impact of Demand Shocks

In this section, we use our estimates for the characteristic-based asset demand system to compute the price impact of idiosyncratic demand shocks. Such price impact is estimated for all bonds, investors, and periods at the most granular level, and we present aggregate trends. We start the analysis by characterizing the behavior of demand shocks over time, to then present our measure of price impact and our results.

FIGURE 4. Demand Elasticities of Institutional Investors by bond class

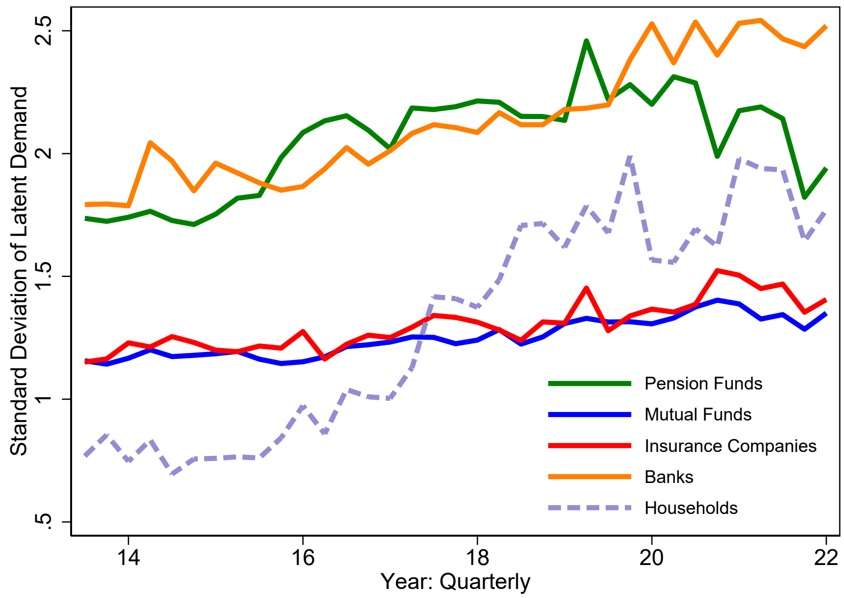


Note: The chart shows the demand elasticities by institutional type for nominal and inflation-indexed bonds, in quarterly frequency for the 2014:1 - 2022:3 period.

5.1 Latent Demand

Given the estimated coefficients presented in the previous section, we recover our latent demand estimates. Such latent demand captures investors' beliefs, not captured by asset characteristics, that help to explain asset holdings. Figure 5 summarizes the cross-sectional standard deviation of latent demand for each institutional investor group. We highlight three observations from this figure. First, there is an upward trend in the volatility of latent demand over time for all investor groups, with some decrease by the end of the sample for pension funds. This implies more extreme portfolio weights over time, not fully explained by characteristics. Second, we observe a clustering in the volatility of latent demand across investors: the volatility for pension funds and banks is similar and larger than that for mutual funds and insurance companies. Such differences tend to be stable over time, reflecting that latent demand tends to be larger for the most important investors in the sovereign bonds market. Finally, note that the volatility of latent demand of households has significantly increased since 2018, which is consistent with the notion that these investors have gained importance in the market (see Figure 1).

FIGURE 5. Standard deviation of latent demand by Instituional Type



Note: The chart shows the cross-sectional standard deviation of log latent demand by institutional type, in quarterly frequency for the 2014:1 - 2022:3 period.

5.2 Price Impact

Following Koijen and Yogo (2019) and Bretscher et al. (2022), we define the coliquidity matrix for investor i as

$$\frac{\partial \mathbf{p}_t}{\partial \varepsilon'_{i,t}} = \left(\mathbf{I} - \sum_{j \in \mathcal{I}} \beta_{0,j,t} A_{j,t} \mathbf{H}_t^{-1} \frac{\partial \mathbf{w}_{j,t}}{\partial \mathbf{p}'_t}\right)^{-1} A_{i,t} \mathbf{H}_t^{-1} \frac{\partial \mathbf{w}_{i,t}}{\partial \varepsilon'_{i,t}}$$
$$= \left(\mathbf{I} - \sum_{j \in \mathcal{I}} \beta_{0,j,t} A_{j,t} \mathbf{H}_t^{-1} \mathbf{G}_{j,t}\right)^{-1} A_{i,t} \mathbf{H}_t^{-1} \mathbf{G}_{i,t}, \quad (8)$$

where $\mathcal{I}$ denotes the set of investors holding asset n in period t. The (n, m) element of this matrix is the elasticity of asset price n with respect to investor i's latent demand for asset m and captures the price impact of idiosyncratic shocks to an investor's latent demand. The expression in Eq. (8) is composed of two elements. The matrix inside the inverse corresponds to the aggregate demand elasticity for asset n. This term implies a larger price impact for assets held by less elastic investors. The second component, which is the matrix outside Eq. (8) captures the relative importance of investors in the market, as well as the diversification in their portfolio. To gain intuition is useful to write the n-th diagonal element of this matrix, which takes the form $\frac{A_{i,t} w_{i,t}(n)}{\sum_j A_{j,t} w_{j,t}(n)}[1 - w_{i,t}(n)]$, where the first element corresponds to the relative size of investor i in market n, while the second corresponds to the relative importance of bond n in the portfolio of investor i. This expression implies a larger price impact for (i) investors that are relatively important in market n, and (ii) have a less concentrated portfolio away from asset n.

Summing Eq. (8) across all investors, we define the aggregate coliquidity matrix as

$$\sum_{i\in\mathcal{I}} \frac{\partial \mathbf{p}_t}{\partial \varepsilon'_{i,t}} = \left(\mathbf{I} - \sum_{j\in\mathcal{I}} \beta_{0,j,t} A_{j,t} \mathbf{H}_t^{-1} \mathbf{G}_{j,t}\right)^{-1} \sum_{i\in\mathcal{I}} A_{i,t} \mathbf{H}_t^{-1} \mathbf{G}_{i,t}. \tag{9}$$

This matrix measures the price impact of a systematic shock to latent demand across all investors. The n-th diagonal element outside the inverse is a holding-weighted average of the diversification term, $1 - w_{i,t}(n)$, implying a larger price impact for bonds with a more diversified portfolio away from a specific bond.

Even though the coliquidity matrix is informative about the importance of idiosyncratic shocks, our object of interest is the impact of those shocks on yields, $\frac{\partial y_t(n)}{\partial \varepsilon_{i,t}(n)}$. Noticing that we work with zero-coupon bonds, to obtain the yield impact of idiosyncratic shocks, we compute

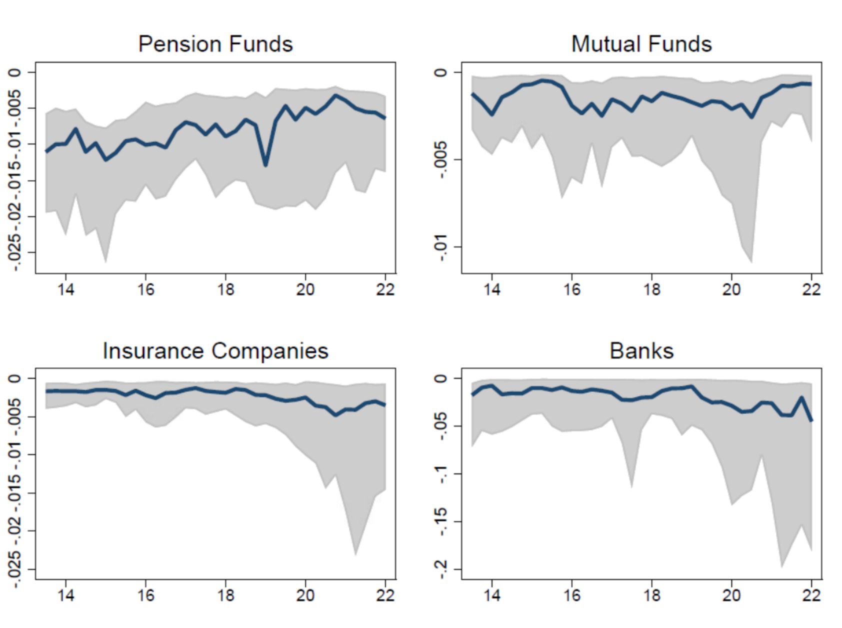
$$\frac{\partial y_t(n)}{\partial \varepsilon_{i,t}(n)} = \frac{\partial y_t(n)}{\partial p_t(n)} \frac{\partial p_t(n)}{\partial \varepsilon_{i,t}(n)} = -\frac{1}{[T(n)-t]} \frac{\partial p_t(n)}{\partial \varepsilon_{i,t}(n)}, \tag{10}$$

where the last equality uses the coliquidty matrix and the relationship between the yield and price for a zero-coupon bond, and is valid for small values of yields.

Investor-specific and Aggregate Yield Impact. We estimate the price impact of idiosyncratic shocks for each bond, period, and investor. Then, we recover the diagonal elements of matrix (8) to compute then the yield impact in (10). In what follows, we present averages by institution type and the cross-sectional distribution of yield impact across bonds held by each type of investor. Figure 6 presents the median price impact for each investor and the interquartile range across all bonds the investor group holds. The figure shows that the yield impact of pension funds and mutual funds has decreased to less than a half over time, which is consistent with decreasing participation in the market over time. The opposite happens for insurance companies, banks, and households (not reported), with increasing participation in the sovereign bond market (especially for the latest two). Importantly, note that yield impact is more dispersed by the end of the sample, especially for insurance companies and banks. We come back to this issue later on.

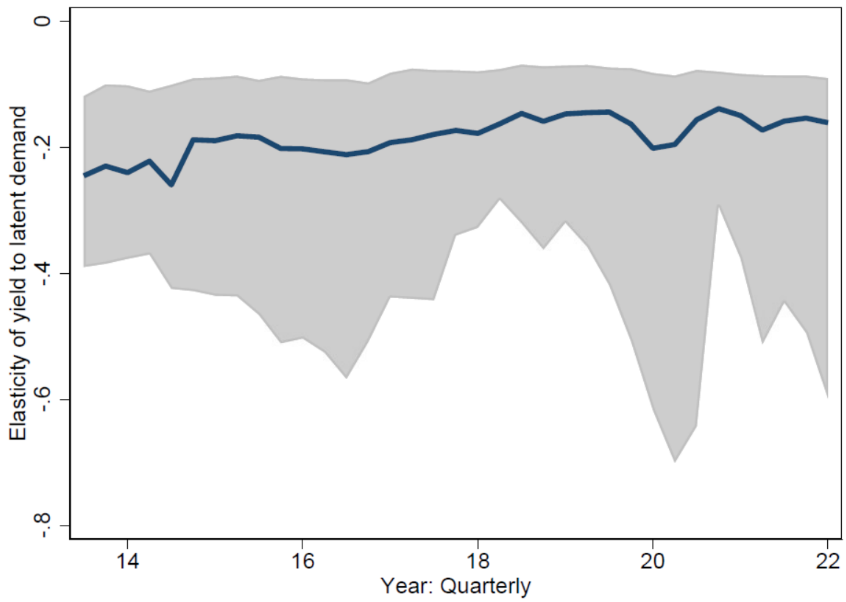
Figure 7 shows the aggregate yield impact when combining the aggregate effect of all bondholders in the market. We can see that the yield impact of idiosyncratic shocks over the median asset in the sample has gone from -0.24 to -0.17. This implies that the yield response of the median asset in the sample after a 10% aggregate shock has decreased from 2.4 to 1.7 basis points.

FIGURE 6. Yield Elasticity to Latent Demand–By Investors



Note: The chart shows the yield elasticities to latent demand by institutional type in quarterly frequency for the 2014:1 - 2022:3 period. The solid blue line denotes the median estimate. The gray area denotes the interquartile range.

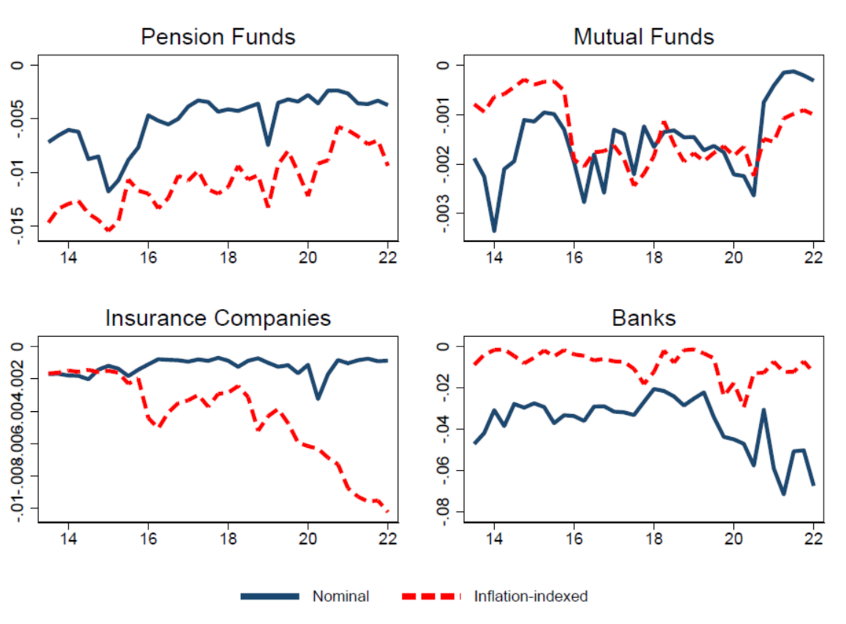
Figure 7. Yield Elasticity to Latent Demand–Aggregate



Note: The chart shows the yield elasticities to latent demand at the aggregate level, in quarterly frequency for the 2014:1 - 2022:3 period. The solid blue line denotes the median estimate. The gray area denotes the interquartile range.

Heterogeneity Across Nominal and Inflation-indexed Bonds. Our previous analysis shows a great variation in the yield impact of idiosyncratic shocks across institutions, especially by the end of the sample. To further explore this heterogeneity, we decompose the yield impact between nominal and inflation-indexed bonds. Figure 7 compares the impact over the median nominal/inflation-indexed bond for each investor type. In the case of pension funds, their yield impact has decreased over time for both types of funds, in line with their decreasing participation in both markets. However, their impact on inflation-linked bonds is larger than for other investors. While for mutual funds, we observe a small and stable impact over time, the contrary happens for insurance companies. Their impact on inflation-indexed bonds has quadruplicated over time, reaching a similar impact as pension funds. Finally, demand shocks from banks are the most important determinant of yield changes over time, especially for nominal bonds, and have increased by the end of the sample. This result is consistent with their increasing participation in the sovereign bond market, particularly from the onset of the COVID-19 crisis.

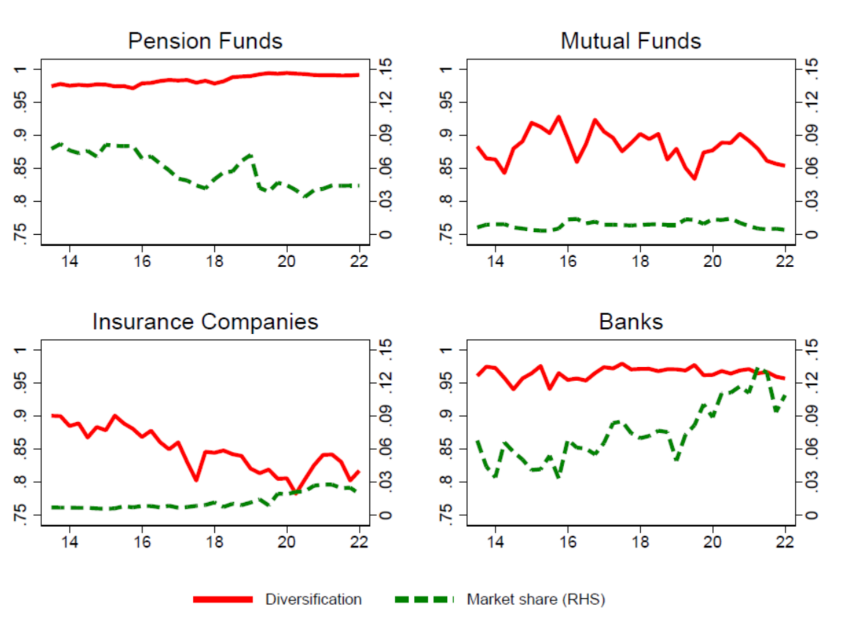
Figure 8. Yield Elasticity to Latent Demand–Nominal and Inflation-indexed Bonds



Note: The chart shows the yield elasticities to latent demand by institutional type and type of bond (nominal and inflation-indexed), in quarterly frequency for the 2014:1 - 2022:3 period.

Mechanisms. As mentioned at the beginning of this section, the evolution of yield impact might be due to three effects: (i) the aggregate demand elasticity of bonds in which investors put their money, (ii) the relative importance of investors on each market or market share, and (iii) the level of diversification in their portfolios. To gain intuition about the drivers behind the evolution of the yield impact across investors, we compute the median of each component. Figure 9 shows the evolution of two of these three terms. We have two observations about the patterns observed in the figure. First, pension funds have increased their diversification over time, while mutual funds and insurance companies have decreased it. In the case of banks, this variable remains largely stable over time. This implies that the diversification channel should imply a higher yield impact for pension funds but not the rest of the investors. Second, the most noticeable difference between the institutional investors comes from their market share: while the average pension funds have decreased their participation in the median asset from 9 to 5%, the rest has become consistently more important over time, especially for banks. Therefore, we conclude that most of the evolution in the yield impact comes from the differential market participation of investors over time.

Figure 9. Yield Elasticity to Latent Demand–Mechanisms



Note: The chart shows the diversification and market share components of yield elasticity of latent demand by institutional type, in quarterly frequency for the 2014:1 - 2022:3 period.

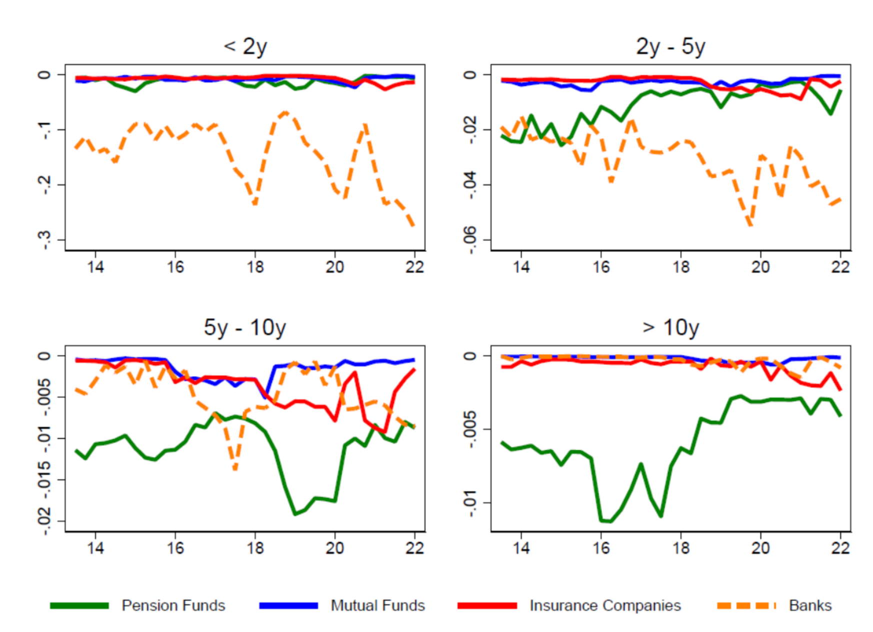
Heterogeneity Across Time to Maturity. We conclude our analysis of the effect of idiosyncratic demand shocks by analyzing the relative contribution of each kind of investor to different segments of the yield curve. As shown in Section 4.4, one key difference between investors–especially pension funds and banks–comes from their sensitivity to the time to maturity of bonds, where banks specialize in short instruments while pension funds specialize in long instruments. Therefore, we expect a differential impact of idiosyncratic demand shocks to different segments of the curve by different investors. We proceed as follows. First, we group assets into four groups regarding their time to maturity: below two years, between two and five years, between five and ten years, and above ten years. Then, we present the median yield impact for each investor for each group of maturities.[17]

Figure 12 presents the results separating for each maturity bin and comparing across investors. There are two clear patterns behind this figure. First, as long as we move along the yield curve towards bonds with higher maturity, the impact effect is lower. For example, for bonds with time to maturity below two years, such impact reaches values close to -0.2, while for bonds with time to maturity above 10 years, such impact is just -0.01. Naturally, this is partially and mechanically due

[17] Note that, as shown in Eq. (10), the time to maturity mechanically affects this yield impact. However, by grouping into these "maturity bins" and comparing across investors, we control for this effect.

to the definition of the yield impact, which is just the price impact adjusted by the inverse of time to maturity. Our second observation corresponds to the differential impact across investors along the curve. Consistent with our descriptive statistics and the differential sensitivity of institutional to time to maturity, we observe a clear trend of who impacts which segment of the curve. For short-maturity bonds, undoubtedly, the impact over yields is dominated by banks, with an impact that has even increased over time from -0.15 to -0.2. Once we move towards bonds with higher maturity, pension funds kick in as essential drivers of the yield curve. In particular, pension funds are the main driver of yield impact for bonds with remaining maturity above ten years, even though their importance has decreased over time.

FIGURE 10. Yield Elasticity to Latent Demand–Heterogeneity Across Time to Maturity

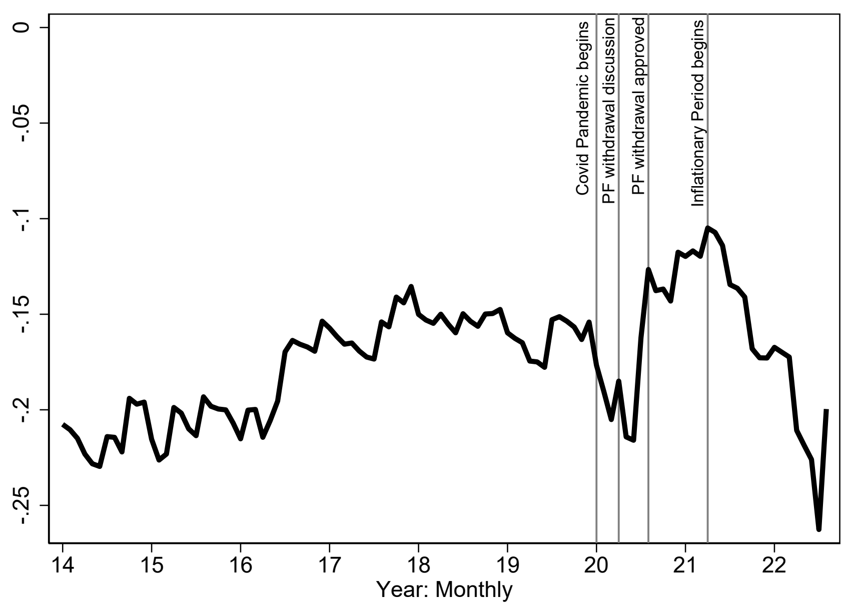


Note: The chart shows the yield elasticities to latent demand by institutional type and maturity bins (in years), in quarterly frequency for the 2014:1 - 2022:3 period.

Aggregate Trends and Recent Developments. An alternative way to present the price impact of demand shocks is to construct the aggregate impact by investor type rather than an average measure. Figure 12 presents such measure over time, with selected developments in the Chilean economy. In particular, we highlight the beginning of the Covid pandemic, as well as the discussion and execution of the pension funds' withdrawals, and the start of the rise in inflation. As we can see, at the beginning of the pandemic, there was a significant increase in the impact of latent demand, moving from -0.16 to -0.20. After a short recovery period, the discussion of the support program that included fund withdrawals from pension fund accounts increased the price impact again. (See Appendix E.2.) Note, however, that when such withdrawals were executed, the price impact had almost no changes because the market previously internalized all the movements. Finally, the period of higher inflation starting by mid-2021 implied a significant increase in yield impact, reaching the highest levels in our sample: about -0.25 by the second quarter of 2022.

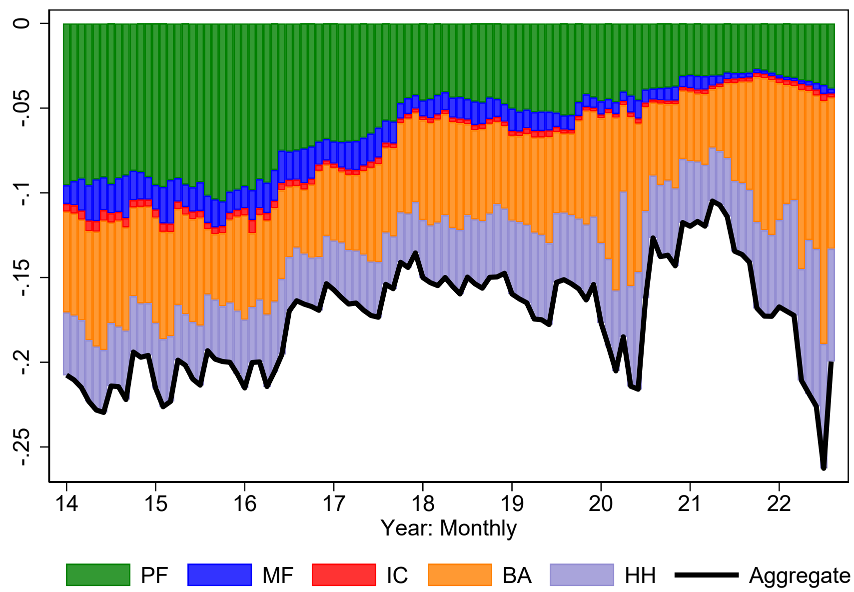
Moreover, we can decompose the relative contribution of each institution type as in Figure 12. We highlight three facts. First, the relative contribution of mutual funds and insurance companies has always been small and has decreased over time. Second, the contribution of pension funds has also decreased over time: by 2014, they represented about half of the movements in the sovereign bond market, while by 2022, their impact had decreased by less than a fifth. Finally, the relative contribution of banks has increased from 2021, consistent with the highest market participation of these institutions, as shown before.

Figure 11. Aggregated Yield Elasticity to Latent Demand–Events



Note: The chart shows the stacked yield elasticities to latent demand by institutional type, in quarterly frequency for the 2014:1 - 2022:3 period.

Figure 12. Aggregated Yield Elasticity to Latent Demand–Contribution



Note: The chart shows the stacked yield elasticities to latent demand by institutional type, in quarterly frequency for the 2014:1 - 2022:3 period.

6 Conclusions and Next Steps

This paper estimates a demand system for sovereign Chilean bonds, covering the universe of instruments and market participants in the 2014-2022 period. Following the approach of Koijen and Yogo (2019), we estimate demand systems in which bond holdings are explained by yields and other (exogenous) asset characteristics. We estimate the demand system using an instrumental variable approach and show that Chilean institutional investors have heterogeneous sensitivities to different factors (particularly, yield and time to maturity). Equipped with our demand system estimates, we compute the investor-specific and aggregate demand elasticities, as well as idiosyncratic demand shocks for the sovereign bond market. We also present statistics about the evolution of demand shocks over yields, showing that it has decreased for pension funds but has increased for other investors. This is consistent with a lower market share of pension funds in the sovereign bond market.

Our work contributes to the literature by being the first to estimate demand systems for the universe of an asset market (both in terms of the available assets and the universe of participants). The focus on the sovereign bond market has particular relevance for policymaking, due to its role as a benchmark for the pricing of other assets in the economy. finally, our work provides precise estimates of the impact of idiosyncratic demand shocks, which is crucial to understand movements across the yield curve.

Our next steps correspond to the analysis of asset prices under counterfactual scenarios. In particular, we are interested in (i) understanding the effect that the pension funds' withdrawals during the COVID-19 crisis had on the yield curve, (ii) evaluating the potential outcomes behind the debate about the transformation of the pension fund system in Chile, and (iii) the impact that tax reforms would have over the whole financial system.

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A Data Appendix

A.1 Inflation-Targeting Framework in Chile and the Supply of Sovereign Bonds

Since 1999, with the implementation of a floating exchange rate regime and gradual improvements to institutions, fostered a fully-inflation targeting scheme in the monetary policy framework in Chile. The inflation target is defined for the annual 12-month change in the Consumer Price Index (CPI), prepared by the National Statistics Bureau. The Central Bank of Chile has set the midpoint of the inflation target range at 3% annually. That is, monetary policy focuses on keeping the average and expected CPI variation at around 3% annually. The width of the target range is set at plus or minus one percentage point.[18] The CPI is the price index used most broadly in the country. It is the reference unit for index prices, wages, and financial contracts, and to compute the inflation-indexed accounting unit (Unidad de Fomento, UF) based on the previous month's CPI.

The operative objective of the monetary policy is to keep annual inflation expectations at around 3% annually over a horizon of about two years. This is the maximum period for which the Central Bank normally attempts to bring inflation back to 3%. It reflects the average lag between changes in the policy instrument and their impact on output and prices. The two-year horizon mitigates concerns about the volatility of output and other variables, as well as the presence of temporary shifts in some CPI components. Given the relevance of expectation at the monetary policy horizon, the Central Bank of Chile constantly monitors the expected inflation from different sources (financial instruments such as government bonds or economic surveys). The Central Bank carries out its monetary policy by influencing the daily interbank interest rate, that is, the rate at which commercial banks grant credit to each other on a daily basis (overnight). The Central Bank of Chile conducts monetary policy by controlling the supply of liquidity or the monetary base so that the resulting interest rate is close to the monetary policy rate (MPR). For longer horizons, the Central Bank controls the supply of government bonds (nominal and inflation-linked).

The Central Bank has auctioned off discount promissory notes due in 30 to 90 days, nominal bonds (BCP) of two-, five- and ten-year maturity, and bonds indexed to inflation (BCU) with similar maturities. There is an annual calendar establishing issuances of debt due in more than one year. In practice, the Central Bank's debt policy is to maintain a stable size and structure over time.

[18]This range sends three main signals: tolerance to temporary deviations of actual inflation away from the 3% target; symmetrical concern about deviations below target and above target; and the level of normal variability of inflation along the business cycle.

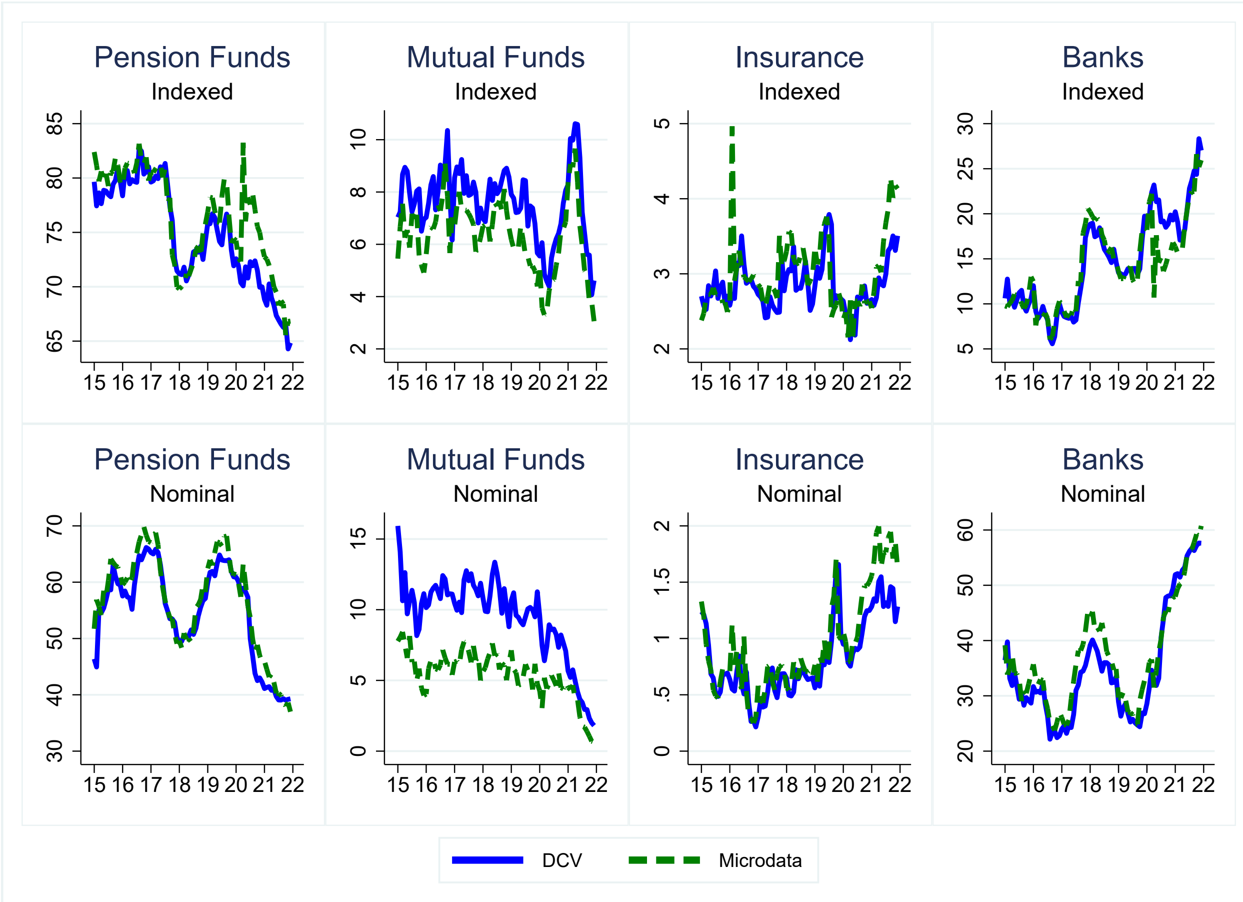
Renewing and issuing new debt (promissory notes and bonds) make possible gradual adjustments of the net supply of funds in the interbank market. Regulating amounts or quotas for new debt issues, whose calendar for short-term documents is announced one working day in advance of the reserve period, allows the Bank to adjust for the overall monthly liquidity in a way that is consistent with its goal of keeping the interbank rate around the monetary policy rate.

The importance of inflation-linked bonds can be categorized into two main objectives. First, as an inflation-targeting economy, the information embedded in the nominal and inflation-linked bonds allows financial authorities (e.g. Central Bank) to monitor implied market inflation expectations by focusing on the difference between these bonds at similar maturities. Thus, the government bond market is one of the main sources to gauge inflation expectations. Second, inflation-linked bonds serve as a market benchmark for funding costs for firms and households at longer horizons. For firms, corporate bond issuance by non-financial firms represents a 27% of GDP, from which one-half is issued in the domestic market (BCCh, 2017). Corporate bonds in the local market are issued mainly in UF (linked to effective CPI), and, thus, are identical to the inflation-linked bonds issued by the government. For households, inflation-linked bonds are the main benchmark to set mortgage rates. The mortgage credit in Chile exhibits three main mortgage types; mortgage bonds, endorsable, and non-endorsable mortgage loans. Similar to corporate bonds, 95% of total mortgage loans originated in UF, by which the inflation-linked bonds serve as the main benchmark in setting the baseline cost of credit.

In sum, inflation-linked bonds are relevant in gauging inflation expectations at the monetary policy horizon (two years) and act as an essential benchmark in setting financing costs for firms (corporate bonds) and households (mortgage loans) at longer horizons (ten years).

A.2 Data Validation

Figure A.1. Institutional holdings comparison by bond class



Note: The chart shows the percentage holdings by institutional type for nominal and inflation-indexed bonds, comparing aggregated microdata sources, to official DCV reports. For the monthly period of 2014:1 - 2021:12.

B Additional Empirical Results

B.1 First-stage Results

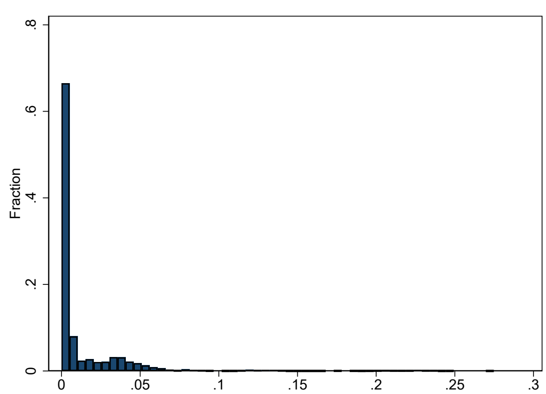
Figure B.1 presents the pooled distribution of assets under management and the market share of every investor across assets. Both figures show a fat-tailed distribution, with power laws of 1.01 and 2.04.

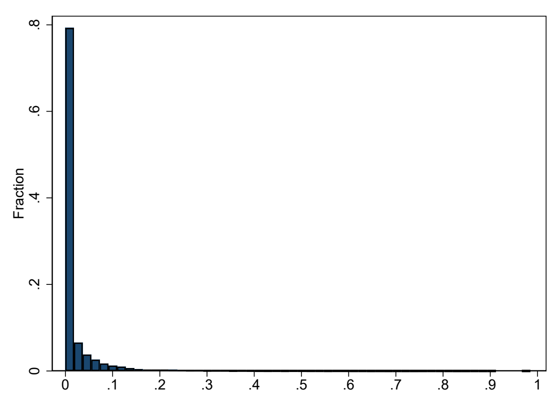
Table A.1. Persistence of the Set of Bonds Held by Institutional Investor

	Previous Quarters							Previous Quarters					
AUM quintile	1	2	3	4	5	6	AUM quintile	1	2	3	4	5	6
Panel A: Pension Funds							Panel B: Mutual Funds						
1	94	95	95	96	97	97	1	86	88	90	90	91	92
2	96	97	97	97	98	98	2	84	87	88	89	90	91
3	96	97	97	98	98	98	3	84	87	88	89	89	90
4	97	97	97	98	98	98	4	85	88	89	90	90	91
5	97	97	98	98	98	98	5	84	87	88	89	90	90
Panel C: Insurance Companies							Panel D: Banks						
1	95	96	96	97	97	97	1	91	92	93	93	94	93
2	94	95	95	95	95	96	2	92	94	94	95	96	96
3	95	95	95	96	96	96	3	94	95	96	97	97	97
4	94	95	96	96	96	96	4	94	96	96	97	97	97
5	95	96	96	97	97	97	5	96	97	97	98	98	98

Note: This table reports the percentage of bonds held in the current quarter that were ever held in the previous one to five quarters. Each cell is a pooled median across time and all institutions in the given asset under management (AUM) quintile. The quarterly sample period is from 2014:1 to 2022:3.

Figure B.1. Distribution of Assets Under Management and Relative Shares across Institutions





Note: The charts show the distribution of assets under management and bond shares across the 2014:1 - 2022:8 period.

B.2 First-stage Results

Table B.1. First Stage t-statistics–Institution Level Estimates

	Distribution					Significance	
	(1)					(2)	
	Mean	Median	P25	P75	Std. Dev.	All	Negative
Pension Funds	-6.600	-7.394	-10.514	-1.957	8.000	90.625	75.000
Mutual Funds	-2.917	-4.065	-7.359	1.080	7.133	81.250	59.375
Insurance Companies	0.619	1.328	-2.409	3.864	4.383	71.875	28.125
Banks	-0.827	-1.351	-4.241	3.005	5.023	81.250	46.875
Households	-1.079	-1.114	-2.696	0.387	2.229	53.125	40.625

Note: This table summarizes the distribution of the first stage t-statistics, in quarterly frequency for the 2014:1 - 2022:3 period.

B.3 Pooled IV Results

Table B.2. Heterogeneity in the Estimated Demand Parameters by Institution Type–Pooled Regressions

	Pension Funds		Mutual Funds		Insurance Companies		Banks		Households	
	(1)		(2)		(3)		(4)		(5)	
	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS
Yield	-0.584***	-0.377***	-0.316***	-0.206***	-0.423***	-0.242***	0.604***	0.540***	0.563***	0.385***
	(0.011)	(0.010)	(0.006)	(0.005)	(0.015)	(0.012)	(0.022)	(0.019)	(0.020)	(0.018)
Time to maturity	0.630***	0.638***	0.177***	0.169***	0.122***	0.111***	-0.367***	-0.355***	-0.155***	-0.165***
	(0.006)	(0.006)	(0.004)	(0.004)	(0.007)	(0.007)	(0.011)	(0.011)	(0.011)	(0.009)
Issuance Size	0.835***	0.830***	0.319***	0.325***	0.122***	0.130***	0.739***	0.740***	0.794***	0.786***
	(0.009)	(0.009)	(0.006)	(0.006)	(0.014)	(0.014)	(0.023)	(0.023)	(0.018)	(0.018)
Turnover	0.060***	0.047***	0.136***	0.135***	0.032***	0.031***	0.268***	0.264***	0.054***	0.061***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.006)	(0.005)	(0.010)	(0.009)	(0.007)	(0.007)
Observations	152170	153397	187190	188637	38054	38837	28533	28977	9828	9828
Adj. R-squared	0.158	0.333	-0.079	0.350	-0.148	0.242	0.078	0.264	0.211	0.351
Kleibergen-Paap F-stat	92675.245		136672.032		18299.260		29622.935		4150.726	

Note: This table compares pooled regression (IV and OLS) for each institutional investor for the 2014:1 - 2022:3 period.

C Pseudo Zero-Coupon Yields

Most of the bonds available in our data include coupon payments. While this is not a problem for the estimation of the demand system in Eq. (2), it complicates the computation of counterfactual scenarios. This section describes the procedure for computing pseudo zero-coupon yields, which simplifies the task.

Price of a zero-coupon bond. Recall the yield of a zero-coupon bond n in period t is related to its price as

$$\log(1 + Y_t(n)) = -\frac{\log P_t(n)}{(T(n) - t)}, \tag{C.1}$$

where $T(n) - t$ denotes the time to maturity of the bond.

Price of bond with coupons. For expositional purposes, suppose bond n pays the coupon rate c every semester and the principal F at the maturity. Then, the price of the bond can be written as

$$P_t(n) = \sum_{k=1}^{2N} \frac{c/2}{(1+\widetilde{Y}_{k,t})^k} + \frac{F}{(1+\widetilde{Y}_{2N,t})^{2N}}, \tag{C.2}$$

where $\widetilde{Y}_{k,t}$ denotes the zero-coupon yield associated to a bond maturing k-periods ahead. Note that the term $\frac{F}{(1+\widetilde{Y}_{2N,t})^{2N}}$ equals the price of a corresponding zero-coupon bond with the same time to maturity and face value as the original coupon bond. Therefore, by recovering this last term, we can obtain the pseudo-zero-coupon yield associated with bond n.

The first term in Eq. (C.2) would be a finite sum with a closed-form expression if the yields are constant across maturities k. We assume that the yield-to-maturity of the bond, $Z_t(n)$, is a good approximation for this whole term. In such case, we can write this sum as

$$\sum_{k=1}^{2N} \frac{c/2}{(1+\widetilde{Y}_{k,t})^k} \approx \sum_{k=1}^{2N} \frac{c/2}{(1+Z_t(n))^k} = \frac{c}{2}\left[\frac{1-(1+Z_t(n)/2)^{-2N}}{Z_t(n)/2}\right].$$

Using the previous expression and the observed price for bond n, we recover the term $\frac{F}{(1+\widetilde{Y}_{2N,t})^{2N}}$ from Eq. (C.2). Finally, we use (C.1) to recover the pseudo-zero-coupon yield.

D Derivations

This section summarizes the derivation of elasticities using the model presented in Section 2.

D.1 Elasticity of Individual Demand

For any particular investor-period (i,t), it must be the case that the value of asset n held by the investor equals the fraction of her total wealth invested in that asset: $P_t(n)Q_{i,t}(n) = A_{i,t}w_{i,t}(n)$. Taking logs to this expression, the elasticity of individual demand with respect to price k reads as

$$-\frac{\partial q_{i,t}(n)}{\partial p_t(k)} = \frac{\partial p_t(n)}{\partial p_t(k)} - \frac{\partial \log(A_{i,t}w_{i,t}(n))}{\partial p_t(k)} = \frac{\partial p_t(n)}{\partial p_t(k)} - \frac{\partial \log(w_{i,t}(n))}{\partial p_t(k)},$$

where lower-case variables are denoted in logs and where the last equality comes from the fact that total wealth is predetermined.

From Eq. (1), the last derivative when $n = k$ reads as

$$\frac{\partial \log(w_{i,t}(n))}{\partial p_t(k)} = \frac{1}{w_{i,t}(n)}\left[\frac{\delta'_{i,t}(n)(1+\sum \delta_{i,t}(m)) - \delta'_{i,t}(n)\delta_{i,t}(n)}{(1+\sum \delta_{i,t}(m))^2}\right]$$

$$= \frac{\delta'_{i,t}(n)}{w_{i,t}(n)} \frac{1}{1+\sum \delta_{i,t}(m)} \left[1 - \frac{\delta_{i,t}(n)}{1+\sum \delta_{i,t}(m)}\right]$$
$$= \beta_{0,i,t}[1 - w_{i,t}(n)],$$

where the last line uses $\delta'_{i,t}(n) = \delta_{i,t}(n)\beta_{0,i,t}$ from Eq. (2) and the definitions for $w_{i,t}(n)$ and $w_{i,t}(0)$.

For the case $n \neq k$ we have

$$\frac{\partial \log(w_{i,t}(n))}{\partial p_t(k)} = -\frac{1}{w_{i,t}(n)} \frac{\delta'_{i,t}(k)}{1+\sum \delta_{i,t}(m)} \frac{\delta_{i,t}(n)}{1+\sum \delta_{i,t}(m)} = -\beta_{0,i,t} w_{i,t}(k).$$

So, we can write the demand elasticity as

$$-\frac{\partial q_{i,t}(n)}{\partial p_t(k)} = \frac{\partial p_t(n)}{\partial p_t(k)} - \frac{\partial \log(w_{i,t}(n))}{\partial p_t(k)} = \begin{cases} 1 - \beta_{0,i,t}[1 - w_{i,t}(n)] & \text{for } n = k \\ \beta_{0,i,t} w_{i,t}(k) & \text{for } n \neq k \end{cases}.$$

Stacking across assets for investor i, we have the following expression for the demand elasticity

$$-\frac{\partial \mathbf{q}_{i,t}}{\partial \mathbf{p}'_t} = \mathbf{I} - \beta_{0,i,t} \operatorname{diag}(\mathbf{w}_{i,t})^{-1} \mathbf{G}_{i,t}, \tag{D.1}$$

with $\mathbf{G}_{i,t} \equiv \operatorname{diag}(\mathbf{w}_{i,t}) - \mathbf{w}_{i,t}\mathbf{w}'_{i,t}$.

The final step is to recall the relationship between the yield and the price of zero-coupon bond, from Eq. (C.1) and to adjust the $\beta_{0,i,t}$ coefficient by $-1/(T(n) - t)$, where the denominator corresponds to the time-to-maturity of the bond.

D.2 Elasticity of Aggregate Demand

Aggregating the individual clearing condition across investors who hold the asset ($\mathcal{I}$) we have

$$\sum_{i \in \mathcal{I}} P_t(n) Q_{i,t}(n) = P_t(n) Q_t(n) = \sum_{i \in \mathcal{I}} A_{i,t} w_{i,t}(n),$$

where the second equality defines the total amount of assets available in the market in period t.

Taking logs, the aggregate elasticity of demand with respect to price k is

$$-\frac{\partial q_t(n)}{\partial p_t(k)} = \frac{\partial p_t(n)}{\partial p_t(k)} - \frac{\partial \log(\sum_{i \in \mathcal{I}} A_{i,t} w_{i,t}(n))}{\partial p_t(k)}.$$

As before, the previous expression depends on the value of k. For $n = k$ we have

$$\frac{\partial \log(\sum_{i\in\mathcal{I}} A_{i,t}w_{i,t}(n))}{\partial p_t(k)} = \frac{1}{\sum_{i\in\mathcal{I}} A_{i,t}w_{i,t}(n)} \sum_{i\in\mathcal{I}} A_{i,t}\frac{\partial w_{i,t}(n)}{\partial p_t(k)}$$
$$= \frac{1}{\sum_{i\in\mathcal{I}} A_{i,t}w_{i,t}(n)} \sum_{i\in\mathcal{I}} A_{i,t}\frac{\partial \exp[\log w_{i,t}(n)]}{\partial p_t(k)}$$
$$= \sum_{i\in\mathcal{I}} \beta_{0,i,t}\frac{A_{i,t}w_{i,t}(n)}{\sum_{j\in\mathcal{I}} A_{j,t}w_{j,t}(n)}[1 - w_{i,t}(n)].$$

For $n \neq k$

$$\frac{\partial \log(\sum_{i\in\mathcal{I}} A_{i,t}w_{i,t}(n))}{\partial p_t(k)} = -\sum_{i\in\mathcal{I}} \beta_{0,i,t}\frac{A_{i,t}w_{i,t}(n)}{\sum_{j\in\mathcal{I}} A_{j,t}w_{j,t}(n)}w_{i,t}(k),$$

so each component is a weighted average of the individual components.

The aggregate demand elasticity reads as

$$-\frac{\partial q_t(n)}{\partial p_t(k)} = \begin{cases} 1 - \sum_{i\in\mathcal{I}} \beta_{0,i,t}\frac{A_{i,t}w_{i,t}(n)}{\sum_{j\in\mathcal{I}} A_{j,t}w_{j,t}(n)}[1 - w_{i,t}(n)] & \text{for } n = k \\ \sum_{i\in\mathcal{I}} \beta_{0,i,t}\frac{A_{i,t}w_{i,t}(n)}{\sum_{j\in\mathcal{I}} A_{j,t}w_{j,t}(n)}w_{i,t}(k) & \text{for } n \neq k. \end{cases}$$

As before, we can stack across assets and investors to get

$$-\frac{\partial \mathbf{q}_t}{\partial \mathbf{p}_t'} = \mathbf{I} - \sum_{i\in\mathcal{I}} \beta_{0,i,t}A_{i,t}\mathbf{H}_t^{-1}\mathbf{G}_{i,t}, \tag{D.2}$$

where $\mathbf{G}_{i,t}$ is defined as before and $\mathbf{H}_t \equiv \sum_{j\in\mathcal{I}} A_{j,t}\,\mathrm{diag}(\mathbf{w}_{j,t})$.

E Mandates

The actors in the Chilean financial system face a series of restrictions and regulations that shape their portfolios. Thus certain institutions face investment mandates that are established exogenously in order to comply with the law. We illustrate this scenario using pension fund investment limits.

E.1 Pension Funds[19]

Chile has a privately managed retirement system based on individual capitalization. All pension fund members are obliged to contribute 10% of their monthly income to their individual accounts, to be managed by Pension Fund Administrators (PFA). By law, PFA's must offer five different types of

[19] The information in this section corresponds to the current investment regime for pension funds valid from February 2022 to date, as retrieved from the Chilean Pensions Supervisor website.

funds, labeled alphabetically according to their risk exposure, depending on the proportion of funds that can be invested in equity, as laid out in Table E.1 . Workers are free to choose their preferred PFA and fund. Investment limits are actively supervised by the Chilean Pensions Supervisor (CPS), ensuring that these requirement are met.

TABLE E.1. Investment Limits for Chilean Pension Funds

		Equity	
Fund	Type	Maximum	Minimum
A	Riskiest	80	40
B	Risky	60	25
C	Balanced	40	15
D	Conservative	20	5
E	More Conservative	5	-

Note: This table reports the maximum percent participation of equities in chilean pension fund portfolios, by fund type.

The law not only establishes the upper limits of exposure to risk, but also limits instruments, issuers, instrument classes and distinguishes between foreign and locally issued instruments. Such restrictions impose structural limits to portfolios, thus creating a strong investment mandate, which PFA's do not deviate from.

E.2 Pension Fund Withdrawals

The Pension Fund withdrawals consist of a series of laws that allowed affiliates to exceptionally withdraw savings from their retirement accounts. The first withdrawal process began on July 2020, which was then followed by two more on December 2020 and April 2021, each one could be requested during a period of 12 months after its approval.

Affiliates where allowed to withdraw up to 10% of their savings, however those with less than CLP 1.000.000 (USD 1,300 approximately), could retire their entire balance. By June 2021 the total withdrawal amounted to USD 50.000 million (25% of the total holdings of pension funds and 18% GDP) and 35% of affiliates where left with no funds Fuentes et al. (2021). Further withdrawals have been proposed since, yet none have been approved.