

Cash Flow Pressure and Portfolio Adjustment in Defined Benefit Pension Plans: Evidence from Brazil.

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Abstract

This study investigates how cash pressure relates to the adjustment of defined benefit (DB) plan portfolios, using monthly data from 78 Brazilian plans between 2015 and 2025. Cash pressure is measured by the relationship between pension deductions and additions, and its temporal stability is assessed by structural change tests that allow changes in level and trend. We examine characteristics associated with the main changes in investment allocations and, above all, we compare the observed flows with a pro-rata benchmark based on the pre-existing portfolio composition. The results show broad instability in the box dynamics, and changes occur both in the direction of increasing and reducing pressure, not characterizing a uniform deterioration process. In the analysis of investments, there is no robust evidence that Fixed Income functions as a disproportionate source of liquidity, although Fixed Income presents marginal evidence of adjustment above pro-rata in the symmetric specification. The decomposition between inflows and outflows, however, reveals that Participant Operations adjust significantly less than pro-rata during months of net outflow, consistent with their limited ability to function as a discretionary source of liquidity. The results show that adjustment volume and settlement preference are distinct concepts and suggest that liquidity management of DB plans must

consider not only the asset composition, but also the effective mobilization capacity of each component of the portfolio.

Keywords: defined benefit plans; cash pressure; liquidity; asset allocation; pension funds; structural changes.

JEL: G11, G23, J32.

Introduction

Defined benefit (DB) plans are undergoing a progressive process of demographic maturation, characterized by an increase in the proportion of beneficiaries, a relative reduction in the contribution base, and greater longevity among their participants. These transformations alter the relationship between contributions received and benefits paid, making cash flow management an increasingly relevant dimension for the sustainability of the plans (Peres, Diekmann & Gonçalves, 2015; Zhou, 2025). As the plan matures, recurring benefit payments may exceed current contributions, making the fulfillment of pension obligations dependent not only on actuarial solvency but also on the ability of the investment portfolio to generate liquidity.

The literature on pension funds has traditionally cited actuarial solvency, liability measurement, and integrated asset and liability management (ALM) as important contributions to understanding longevity risks, interest rate risks, and the intertemporal balance of plans (Cairns & Parker, 1997; Blake et al., 2014). However, solvency and liquidity represent distinct dimensions of financial sustainability. A plan may have sufficient assets to cover its mathematical provisions and, simultaneously, may face recurring net cash outflows when benefit payments exceed contributions received. In this context, the composition and liquidity of the portfolio become relevant elements in determining how these current obligations will be financed.

This need to finance net outflows does not necessarily imply that all portfolio segments are adjusted proportionally. Differences in liquidity, transition costs, institutional constraints, and even contractual characteristics can make certain assets more easily used to accommodate cash needs than others (Amihud, 2002; Duffie & Ziegler, 2001; Ang, Papanikolaou & Westerfield, 2014). The most relevant question, therefore, is not only whether cash flows are associated with portfolio movements, but whether the different investment allocation segments absorb net inflows and outflows in proportion to their share of the equity and whether this response is symmetrical between situations of inflow and outflow of resources.

Academic literature has shown that characteristics such as financing conditions, demographic maturity, liability structure, and governance influence asset allocation and risk-taking in pension funds (Andonov, Bauer & Cremers, 2012a, 2012b; Becker & Ivashina, 2015). This literature focuses predominantly on long-term allocation and solvency decisions. Less understood is the short-term mechanism by which recurring cash pressure is effectively transmitted to movements between different portfolio segments, particularly as seen in mature defined benefit (DB) plans.

Despite these advances, a gap remains between the actuarial sustainability literature and investment decision-making. We know more about the factors that determine the solvency and strategic allocation of pension funds than about how plans mature and structure their portfolios amid recurring imbalances between contributions and benefit payments. In particular, three related issues remain poorly documented: (a) whether cash pressure exhibits persistent regime changes throughout the plan maturation process; (b) whether the demographic, actuarial, and financial characteristics of the plans are associated with the magnitude of these changes; and (c) whether net inflows are

absorbed proportionally by the different portfolio segments or produce asymmetric reallocation responses.

The Brazilian closed-end supplementary pension system offers a particularly suitable environment for investigating these issues. Closed-end supplementary pension entities (EFPCs) manage plans with varying degrees of demographic maturity, financing conditions, liability durations, and investment compositions. Furthermore, the period from 2015 to 2025 encompasses significant regulatory changes, the COVID-19 pandemic, and substantial alterations in domestic financial conditions. The historically high share of fixed income and the observed shift in the average portfolio composition over this period make Brazil an important case study for analyzing the interactions between cash pressure and liquidity management. In this context, the Brazilian experience allows us to examine the problem recently discussed in the international literature as pension liquidity risk (Jansen, Klingler, Ranaldo & Duijm, 2024) within a portfolio structure substantially different from that observed in other markets.

The objective of this study is to investigate how defined benefit plans adjust their portfolios when pension dynamics generate recurring pressure on cash flow. The analysis is developed in three complementary stages. First, we examine whether cash pressure presents persistent structural changes over time. Second, we assess whether the demographic, actuarial, and financial characteristics of the plans are associated with the magnitude and direction of these changes. Finally, we investigate how the aggregate net cash flow is transmitted to the different portfolio segments, comparing the observed adjustment with a pro-rata benchmark and allowing for distinct responses between months of net inflow and outflow of resources.

Our study documents the dynamics of cash pressure in a monthly panel of Brazilian defined benefit (DB) plans throughout 2015-2025, distinguishing current

liquidity from actuarial solvency and allowing persistent changes to be identified endogenously. Additionally, it introduces an economic benchmark to assess portfolio response, where, for each segment, we analyze the effectively observed cash flow against the expected cash flow if the plan's total net cash flow were distributed proportionally to that segment's share of equity in the previous period. This approach allows us to directly test whether a segment absorbs more or less than its pro-rata loss from the adjustment. Finally, we allow this response to be asymmetrical between net inflows and outflows, distinguishing ordinary portfolio movements from those associated with situations of greater liquidity pressure.

The results show that cash pressure is high and exhibits significant instability throughout the analyzed period, although the observable characteristics of the plans have limited capacity to explain the magnitude of the major structural changes. Regarding investments, the symmetrical model does not provide robust evidence that the main segments systematically deviate from the pro-rata benchmark. However, allowing for distinct responses between inflows and outflows reveals that the way the portfolio adjusts depends on the sign of the aggregate flow. We observed that operations with participants show less absorption of net outflows than that implicit in their participation in the portfolio, a result consistent with the contractual nature and lower short-term discretion of this segment. Taken together, the results suggest that the liquidity management of defined benefit plans should be understood not only by the static composition of assets, but also by how different segments respond to the direction of cash flow.

The remainder of the article is organized as follows. Section 2 presents the Brazilian institutional context and develops the conceptual framework and research hypotheses. Section 3 describes the data, the construction of variables, and the empirical strategy, including the identification of structural changes and portfolio adjustment

models relative to the pro-rata benchmark. Section 4 presents the empirical results, from the dynamics of cash pressure to the symmetric and asymmetric response of investment segments. Section 5 discusses the results in light of the literature and the institutional particularities of the Brazilian system. Section 6 presents the limitations of the study, and Section 7 concludes.

Brazilian institutional context and conceptual framework

Brazilian institutional context. Closed-End Pension Funds (EFPCs) manage pension plans under the supervision of the National Superintendence of Supplementary Pensions (PREVIC). This study focuses on Defined Benefit (DB) plans, in which benefits are pre-established and generate obligations that must be financed over time by contributions and the resources accumulated in the plan. As these plans mature, the relative increase in benefit payments compared to contributions can produce recurring net outflows and increase the importance of portfolio liquidity for meeting pension obligations.

Regulation and segmentation of investments. Investments by EFPCs (Closed Private Pension Entities) are governed by regulations from the National Monetary Council, which establishes limits and conditions for the application of plan resources. For empirical purposes, investments are classified into the following segments: Fixed Income, Variable Income, Structured, Real Estate, Foreign, and Transactions with Participants. A residual category of "Other Investments" is maintained in the measurement of the asset composition to ensure full reconciliation of portfolio weights. It represents the values recorded in the "Other Investment Receivables" and "Judicial/Appeal Deposits" accounts and was not included in the regressions by segment because there is no corresponding observed flow in the database.

The period from 2015 to 2025 also encompasses institutional changes relevant to data interpretation. In particular, changes to PREVIC's chart of accounts between 2020

and 2021 affected the accounting classification of certain investments, especially the structured segment. Furthermore, regulatory changes related to real estate investments also occurred during this period. These particularities are considered in the interpretation of the results and motivate specific robustness analyses when temporal comparability may be affected.

Conceptual framework and hypotheses. The economic mechanism analyzed can be represented by the following sequence: (i) demographic maturity; (ii) cash pressure; (iii) liquidity needs; and (iv) portfolio adjustment. The life cycle and ALM literature relates the maturity of plans to the structure of their liabilities and liquidity needs (Cairns & Parker, 1997; Gomes & Michaelides, 2005; Ang, Papanikolaou & Westerfield, 2014). The liquidity literature, in turn, shows that assets differ in costs and trading possibilities, so that cash needs do not need to be distributed uniformly among the portfolio components (Amihud, 2002; Duffie & Ziegler, 2001; Chen, Goldstein & Jiang, 2010). Finally, actuarial and institutional characteristics can influence both the exposure of plans to cash flow pressure and their investment decisions (Andonov, Bauer & Cremers, 2012, 2017; Becker & Ivashina, 2015).

Therefore, the first stage of our analysis considers whether the structural characteristics of the plans are related to the persistent changes observed in cash pressure. Thus, we formulated the following hypothesis:

H1 – Structural characteristics of the plans are associated with the magnitude of changes in cash pressure.

In particular, demographic maturity, financing condition, actuarial duration, and contributory capacity can alter the plan's exposure to persistent changes in the relationship between benefits and contributions.

The main stage of the analysis shifts the focus from the occurrence of these changes to their transmission to the investment portfolio. As a reference, we consider the adjustment that would occur if the aggregate net cash flow were distributed among the segments proportionally to the existing asset composition in the previous period. This benchmark allows us to identify whether certain segments absorb relatively more or less of the observed adjustment; therefore, we develop another hypothesis:

H2 – The adjustment of portfolio segments may differ from the pro-rata benchmark..

Where deviations from the flow proportional to equity participation indicate relative utilization or preservation of different segments during portfolio adjustment. But, in addition, net inflows and outflows represent economically distinct situations. While inflows increase the resources available for investment, net outflows require the plan to obtain resources to meet its obligations, potentially making liquidity and negotiating power more relevant to the allocation decision.

H3 – The response of the portfolio segments is asymmetrical between net inflows and outflows of funds.

Thus, during periods of net outflow, liquidity constraints, transaction costs, and contractual characteristics can alter the distribution of the adjustment among segments, causing the portfolio response to differ from that observed during periods of net inflow. This distinction is particularly relevant for Transactions with Participants, whose flows also depend on demand and participant behavior.

Methodology

Data and sample. We use accounting and actuarial data provided by the National Superintendence of Complementary Pension Plans (PREVIC), covering the period from January 2015 to December 2025. The unit of analysis is the benefit plan, identified by the

National Registry of Benefit Plans (CNPB), which allows for monthly monitoring of the financial, actuarial, demographic, and investment situation.

To ensure sufficient time span for identifying structural changes, we restricted the analysis to defined benefit (DB) plans with at least 84 consecutive months of valid observations for the cash pressure measure. For each CNPB (National Cash Flow Plan), we used its longest continuous observation window¹. The final sample comprises 78 plans and 9,230 plan-month observations.

Cash-flow pressure. The main pension measure is the cash flow dependency ratio. (TD_{flow}), defined as:

$$TD_{it} = \frac{|Deductions_{it}|}{Additions_{it}} \quad (1)$$

where $Deductions_{it}$ represent benefit payments from plan i in month t , while $Additions_{it}$ represent normal and extraordinary contributions received in the same period. Larger values indicate greater pressure from benefit payments on contribution inflows.

Since the variable is strictly non-negative and exhibits direct skewness, we use the transformation in the time series analyses:

$$y_{it} = \ln(1 + TD_{it}) \quad (2)$$

This transformation reduces the influence of extreme values without altering the economic order of the measure.

¹ When the same CNPB (National Pension Fund Card) appears associated with more than one EFPC (Closed Private Pension Entity) in the same month due to a management transfer, the observation is treated as belonging to the same plan, avoiding double counting.

The plan characteristics used in the analysis include funding ratio, actuarial duration, proportion of participants receiving benefits, effective contribution measure, and equity participations of investment segments. For the effective contribution, we used a logarithmic transformation with sign preservation, given the strong asymmetry of the original variable. Equity participation is expressed in relation to the total assets of the plans.

For the analysis of investment response, the aggregate net cash flow is normalized by the plan's total assets in the previous month:

$$F_{it} = \frac{NetFlow_{it}}{A_{i,t-1}} \quad (3)$$

where $A_{i,t-1}$ represents the plan's total assets in the previous period. Positive values represent net inflows of resources and negative values represent net outflows, a situation in which the plan needs to finance the difference between its inflows and current liabilities.

Identifying structural changes. Before identifying the breaks, we removed fixed monthly seasonal effects from y_{it} separately for each plan. To do this, we estimated indicators for the calendar months and contributed an adjusted series that preserves the average of each plan.

For each CNPB, we initially tested the null hypothesis of parameter stability over time using the supF test, considering a deterministic temporal trend:

$$y_{it}^{SA} = \alpha + \beta t + u_{it} \quad (4)$$

where y_{it}^{SA} represents the seasonally adjusted cash pressure measure. The null hypothesis corresponds to the stability of the parameters over the period.

Only when the stability hypothesis is rejected at the 5% level do we proceed to the allocation of multiple structural changes. The dates and number of breaks are then

estimated using the Bai and Perron procedure, allowing for changes in the intercept and slope of the trend between regimes and selecting the number of breaks using the Bayesian Information Criterion (BIC). We adopt a minimum segment fraction of 15% of the available series for each plan.

Since the specification allows for changes in both the level and slope of the trend, the magnitude of each break is measured by the difference between the estimated linear trends in the adjacent regimes, evaluated in the first month of the new regime. For each plan, we select the change with the greatest absolute magnitude. The sign remains preserved, where positive values represent increased cash pressure and negative values represent reduced cash pressure.

Unit root tests are treated separately as diagnostics of the temporal properties of series and are not a prerequisite for applying structural stability tests. This distinction avoids interpreting unit root tests with endogenous breakage as formal tests for the existence of structural changes.

Characteristics associated with structural changes. As a complementary analysis, we examined whether observable characteristics of the plans are associated with the magnitude and direction of the main structural change identified. To avoid post-breakdown values retrospectively explaining its occurrence, the covariates are calculated as averages of the twelve months immediately preceding the date of the largest breakup of each plan.

The first model uses the absolute magnitude of the largest change as the dependent variable:

$$|\Delta_i| = \alpha + X_i' \beta + \varepsilon_i \quad (5)$$

where X_i includes coverage index, actuarial duration, proportion of assisted participants, effective contribution, and participations in Variable Income, Real Estate, and Foreign Investments.

The second model preserves the direction of change and estimates, using logistic regression, the probability that the largest drop represents a reduction in cash flow pressure:

$$P(D_i = 1|X_i) = \Lambda(\alpha + X_i'\gamma) \quad (6)$$

where $D_i = 1$ if $\Delta_i < 0$, indicating the probability of cash deterioration, and $D_i = 0$ when it corresponds to an increase. This model is used to distinguish factors associated with the magnitude of change from those related to the direction of change.

Net Inflow and Portfolio Response. The main step of the empirical strategy investigates how the inflows of the different portfolio segments relate contemporaneously to the aggregate net inflow of the plan, relative to the pro-rata benchmark. Instead of directly comparing inflows normalized by different asset bases, we constructed a pro-rata benchmark, in which each segment would absorb a portion of the aggregate inflow proportionally to its participation in the portfolio in the previous period.

Let $w_{is,t-1}$ be the segment's share of plan i total assets in the previous month. The expected cash flow under pro-rata adjustment is:

$$F_{ist}^{PR} = w_{is,t-1}F_{it} \quad (7)$$

The observed flow of segment F_{ist}^{OBS} is also normalized by the plan's total lagged assets. The excess flow relative to the benchmark is defined by:

$$E_{ist} = F_{ist}^{OBS} - F_{ist}^{PR} \quad (8)$$

Thus, $E_{ist} = 0$ represents an adjustment exactly proportional to the segment's share in the portfolio; $E_{ist} > 0$ indicates a flow higher than the benchmark, and $E_{ist} < 0$ a flow lower than the benchmark.

Additionally, for each of the six segments with observed flows, we also separately estimated the following fixed effects model:

$$E_{ist} = \theta_s F_{it} + \mu_i + \lambda_t + \varepsilon_{ist} \quad (9)$$

where μ_i represents fixed effects of the plan and λ_t represents ordinary monthly fixed effects. The relevant null hypothesis is:

$$H_0: \theta_s = 0$$

Therefore, the absence of significance indicates that the segment response does not differ systematically from the pro-rata benchmark. Non-zero θ_s values indicate a response that is relatively higher or lower than the segment's contribution, conditioned on the sign of the aggregate flow. The standard errors are robust and grouped by plane.

Asymmetry between net inflows and outflows. Since net inflows and outflows can produce distinct responses, we decompose the aggregate flow as follows:

$$F_{it}^+ = \max(F_{it}, 0)$$

and

$$F_{it}^- = \min(F_{it}, 0)$$

We estimate then:

$$E_{ist} = \theta_s^+ F_{it}^+ + \theta_s^- F_{it}^- + \mu_i + \lambda_t + \varepsilon_{ist} \quad (10)$$

The coefficient θ_s^+ measures the deviation from the pro-rata benchmark in months of net inflow, while θ_s^- measures the deviations in months of net outflow. The existence of asymmetry is evaluated by the following hypothesis.:

$$H_0: \theta_s^+ = \theta_s^-$$

allowing for a direct assessment of whether the segment's behavior is asymmetrical between resource inflows and outflows.

Since $F_{it}^- < 0$, a coefficient $\theta_s^- > 0$ implies segment egress greater than that predicted by the pro-rata benchmark, while $\theta_s^- < 0$ implies egress less than proportional, that is, relative preservation of the segment during net egress episodes.

Specifications are estimated separately for Fixed Income, Equities, Structured, Real Estate, Transactions with Participants, and International, with fixed plan and time effects and robust standard errors grouped by plan.

The seven equity participations, including the residual category "Other," fully comprise the plan's assets. However, regressions are estimated only for the six segments with directly observed flows. The "Other" category is not residually inferred as an investment flow.

Finally, considering that changes to PREVIC's chart of accounts may affect the comparability of the Structured segment in 2020–2021, we re-estimated the specifications of this segment excluding this period. This analysis is used exclusively to verify whether the conclusion regarding structured investments depends on the classification change.

Results

Descriptive statistics and evolution of cash-flow pressure. Table 1 presents the descriptive statistics of the final sample, composed of 78 defined benefit plans and 9,230 monthly observations between 2015 and 2025. The cash flow pressure ratio (TD_{flow}) has a mean of 2.10 and a median of 1.72, indicating that, for a significant portion of the observations, benefit payments substantially exceed contribution inflows.

[Insert Table 1 here]

The predominance of liquidity pressure situations is also directly reflected in the net cash flow, where 89.75% of observations correspond to months of net outflow. The median net cash flow is equivalent to -0.52% of assets, reinforcing that current cash deficits are a recurring, not exceptional, condition among the plans in the sample.

The plans also exhibit a high degree of demographic maturity. We observed that the average proportion of assisted participants is 83.6%, with a median of 93.5%. The coverage index has an average of 1.05 and a median of 1.03, revealing that the recurrence of net outflows does not necessarily imply actuarial insufficiency.

The portfolio composition is heavily concentrated in Fixed Income, which represents, on average, 76.2% of assets. Structured Investments account for 12.6%, Variable Income for 5.8%, Real Estate for 3.0%, Transactions with Participants for 1.0%, Foreign Investments for 0.3%, and Other Investments for 1.2%.

[Insert Figure 1 here]

Figure 1 complements the statistics by showing the temporal evolution of cash pressure. The average shows an upward trend over the period, accompanied by wide dispersion among the plans. This behavior suggests that cash pressure is not only high on

average, but also heterogeneous and variable over time, motivating the formal investigation of structural instability..

[Insert Figure 2 here]

Figure 2 shows that the average portfolio composition also changed during the period, especially between Fixed Income and Structured Investments. This evolution should be distinguished from the subsequent analysis of monthly flows. Note that Figure 2 presents changes in asset composition over time, while the flow models investigate the monthly adjustment margin of the portfolio in relation to net inflows and outflows.

Structural instability of the cash-flow pressure. Tests confirm that cash flow pressure exhibits significant temporal instability. The supF test rejects the hypothesis of parameter stability at the 5% level in 72 of the 78 plans (92.3%). However, the rejection of stability does not automatically imply the selection of a break based on the information criterion, where in three of these plans the BIC selects zero breaks. As a result, 69 plans exhibit at least one effectively localized structural change.

Of the 78 plans, 36 exhibit one break, 23 exhibit two, nine exhibit three, one exhibits four, and nine exhibit no break selected by the final procedure. Thus, 33 plans (42.3% of the total sample) exhibit two or more structural changes during the analyzed window.

[Insert Table 2 here]

Among the 69 plans with localized breakdowns, the largest change is a reduction in cash pressure in 38 cases (55.1%) and an increase in 31 (44.9%). The median of the largest change corresponds to -0.087 on a logarithmic scale, equivalent to approximately -8.3% in the original measure. However, the distribution is wide and the largest changes range approximately from -39.7% to +110.4%.

Structural instability is widespread, but does not necessarily represent deterioration. Relevant changes occur in both directions, so disruptions should be interpreted as persistent alterations in cash pressure dynamics, and not as necessarily adverse events.

The dates of the largest discrepancies are also distributed throughout the period. January accounts for 17 of the 69 largest changes (24.6%), followed by April and August, with nine occurrences each. Although there is some concentration at the beginning of the year, the dispersion of the other dates does not support the interpretation of the discrepancies as a simple artifact of a single annual accounting cycle.

Characteristics associated with structural changes. Table 3 presents the models that relate characteristics observed in the 12 months prior to the largest drop to its magnitude and direction. The joint availability of covariates reduces this analysis to 69 plans.

[Insert Table 3 here]

The magnitude model has very limited explanatory power. The R^2 is 0.0485 and the adjusted R^2 is -0.0821 , and neither of the individual coefficients is statistically significant. These results should not be interpreted as evidence that actuarial, demographic, and allocation characteristics are irrelevant to cash dynamics. More precisely, they indicate that the restricted set of observable characteristics considered in this study has low power to describe the cross-sectional variation in the magnitude of the largest structural change. The result is also consistent with the possibility that short-term changes in cash pressure depend on factors not observed in this specification. For this reason, we treat this cross-sectional analysis as complementary and descriptive, and not as a comprehensive explanatory model of structural changes.

In the steering model (Logit - Pressure Reduction), actuarial duration is the only statistically significant variable at the 5% level ($\gamma=0.0328$, $p=0.0496$). The corresponding odds ratio is 1.033, with a 95% confidence interval between 1.000 and 1.068. Since the dependent variable takes on a value of one when the largest change represents a reduction in cash pressure, the positive coefficient associates a longer duration with a higher probability of the main change occurring in that direction.

Portfolio response relative to the pro-rata benchmark.. Table 4 presents the main symmetric specification. After using lagged equity interests and assets, the econometric sample contains 9,152 observations from 78 plans, corresponding to the loss of the first observation from each plan necessary to construct the lags.

[Insert Table 4 here]

At the conventional 5% level, none of the six segments shows a statistically significant deviation from the pro-rata benchmark. Fixed Income, however, constitutes a relevant exception in terms of magnitude and marginal significance, where the estimated coefficient is positive and economically significant ($\theta = 0.206$; $p = 0.086$), although its 95% confidence interval includes zero. The result provides suggestive, but not conclusive, evidence of an adjustment above the pro-rata in this segment. For the other segments, there is no statistical evidence of systematic deviations from the benchmark. Thus, the symmetrical specification does not support a generalized hierarchy of liquidity absorption, although the estimated magnitude for Fixed Income recommends caution when interpreting the proportionality as strict.

Therefore, the symmetrical specification does not support a generalized hierarchy of liquidity absorption among segments. On average, the monthly portfolio movements

are consistent with a distribution of aggregate flow proportional to the existing asset composition.

Asymmetry between net inflows and outflows. The predominance of months with net cash outflows suggests that a symmetrical specification may mask relevant differences between the application of new resources and the acquisition of liquidity. Of the 9,152 hand span months used in the regression, 885 correspond to net cash inflows and 8,267 to net cash outflows.

[Insert Table 5 here]

The results reveal two differences compared to the symmetrical model. First, in months of net inflow, Variable Income shows a positive and significant coefficient ($\theta^+ = 0.0221, p = 0.0306$), indicating inflows higher than the pro-rata benchmark. However, the direct test of equality between the inflow and outflow coefficients does not reject symmetry for this segment ($p = 0.281$). Thus, there is no evidence that the response of Variable Income is statistically different between the two flow regimes, despite the positive coefficient observed in the inflow months.

Second, Operations with Participants show a significantly lower response than the pro-rata benchmark during months of net outflow ($\theta^- = -0.0107, p < 0.001$). Furthermore, the difference between the inflow and outflow coefficients is statistically significant ($p = 0.0016$), providing direct evidence of asymmetry.

Since the outflow assumes negative values in the specification, the negative coefficient for Transactions with Participants means that the segment shows a smaller reduction than predicted by the pro-rata benchmark during periods of net outflow. The result indicates relative preservation of the segment in these episodes, without necessarily implying a

discretionary decision by the manager, since its flows also depend on participant demand and the amortization schedule of the transactions.

For Fixed Income, Structured, Real Estate and International investments, there is no statistically significant evidence of deviation from the benchmark in inflows or outflows, nor of asymmetry between the two regimes.

[Insert Figure 3 here]

Figure 3 visually shows that most confidence intervals cross zero and highlights the negative response of Operations with Participants in months of net outflow.

Conclusion

The results show that the cash pressure of Brazilian defined benefit (DB) plans is persistent and structurally unstable, but this instability should not be automatically interpreted as financial deterioration. The identified structural changes occur both in the direction of increasing and decreasing cash pressure, indicating regime changes in the relationship between contributions and benefit payments, and not a uniform trajectory of worsening. At the same time, the predominance of months with net outflows and the high proportion of beneficiaries characterize a sample of mature plans, for which liquidity availability constitutes a recurring dimension of financial management.

This evidence reinforces the distinction between solvency and liquidity, where a plan may have sufficient assets relative to its actuarial obligations and, simultaneously, face recurring net outflows to finance benefits. The low explanatory power of the cross-sectional model suggests that the observable characteristics considered in this study are insufficient to characterize the heterogeneity in the magnitude of the main regime changes. This result should be interpreted with caution, given the small size of the cross-sectional

sample and the possibility of unobserved factors associated with the short-term dynamics of the flows.

The main contribution of the results, however, lies in the relationship between this cash pressure and the adjustment of investments. When the cash flow of each segment is compared to a benchmark that considers its pre-existing participation in the portfolio, there is no robust evidence that any of the six segments responds disproportionately to the aggregate cash flow in the symmetric specification.

This result has an important economic implication, allowing us to interpret that the adjustment volume does not equate to adjustment preference. A class may concentrate on the largest share of sales or applications because it concentrates on the largest share of assets. Thus, inferring which segments are preferentially used to generate liquidity requires comparing the flow actually observed with that which would occur if the aggregate flow were distributed proportionally to the existing composition. The pro-rata benchmark allows us to separate these two effects.

The results also distinguish strategic changes in long-term allocation from marginal adjustments associated with current flow. The average portfolio composition changed substantially between 2015 and 2025, with an increase in the share of Fixed Income and a reduction in Structured Investments. This evolution does not contradict the absence of a disproportionate monthly response from Fixed Income, where persistent changes in strategic allocation and the contemporary distribution of inflows and outflows represent distinct decision margins. Consequently, the strong presence of Fixed Income in Brazilian portfolios is not, in itself, evidence that it is preferentially used to finance monthly cash deficits.

The decomposition between net inflows and outflows reveals, however, that the proportional benchmark does not fully describe all segments. The main exception occurs

in Operations with Participants, which show a significantly smaller adjustment than the pro-rata in the months of net outflow and a statistically significant difference between the inflow and outflow regimes. This result is consistent with the limited capacity of this segment to function as a discretionary source of liquidity. Its flows depend not only on the manager's allocation decisions, but also on credit granting, amortizations, and participant behavior.

This result broadens the traditional interpretation of investment liquidity. For a pension plan, a segment's ability to meet cash needs depends not only on the existence of a secondary market or transaction costs, but also on the degree of discretion over its cash flows. Assets subject to contractual commitments may remain relatively preserved during exit events even when they represent a portion of the plan's resources. For ALM purposes, therefore, the net asset value and its effective ability to finance benefits in the short term are related but distinct concepts.

From a management and supervisory perspective, the results suggest that the evaluation of mature defined benefit (DB) plans should complement traditional solvency measures with information on cash flow trajectories and the effective mobilization capacity of assets. The recurrence of net outflows does not, in itself, imply financial fragility, but it makes it relevant to identify which portfolio components can effectively be converted into cash without compromising the investment strategy or depending on contractual flows outside the manager's immediate control. In this sense, cash pressure should be treated as a complementary, not a substitute, dimension for traditional solvency and actuarial risk measures.

The results are subject to some limitations. The analysis uses aggregated regulatory segments and therefore does not identify liquidity heterogeneity among individual assets within each segment. Furthermore, the regressions capture

contemporaneous associations between pension flows and investment flows, not allowing for a complete distinction between anticipatory adjustments and responses to unexpected shocks, nor establishing causality. Finally, regulatory and accounting changes throughout 2015–2025 recommend caution in interpreting historical changes in portfolio composition, although the robustness analysis for Structured Investments indicates that this issue does not determine the main results.

Taken together, the evidence suggests a more nuanced sequence between maturity, cash pressure, and investments. Mature DB plans face recurring net outflows and persistent changes in their cash dynamics, but these pressures do not translate into a generalized liquidation hierarchy across asset classes. In most segments, the monthly adjustment remains consistent with the pre-existing portfolio composition. The exception in Participant Operations shows that contractual and operational constraints may limit the ability of certain assets to contribute to liquidity precisely when the plan faces net outflows. This distinction between asset composition and effective mobilization capacity constitutes the main implication of the results for the liquidity management of DB plans.

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AI Usage Statement. During the preparation of this manuscript, the author used Claude Sonnet 4 (Anthropic) between January and July 2026 to assist in the linguistic revision and translation of the manuscript from Portuguese to English, as well as in debugging and troubleshooting the computational code written in Python and R. Access to Claude was via the Anthropic web interface (<https://claude.ai>). The AI tool was not used in the conception of the study, formulation of research questions, research design, data collection, data processing, statistical analyses, interpretation of results, or scientific conclusions. The author assumes full responsibility for the content of this manuscript.

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Table 1 – Descriptive statistics of the sample

Variable	N	Mean	SD	P25	Median	P75	Min	Max
Cash-flow pressure ratio	9230	2.104	1.422	1.073	1.718	2.863	0.001	14.455
Log cash-flow pressure	9230	1.042	0.419	0.729	1.000	1.351	0.001	2.738
Net cash flow / lagged total assets	9230	0.002	0.068	-0.007	-0.005	-0.004	-3.133	2.664
Net cash-outflow month	9230	0.898	0.303	1.000	1.000	1.000	0.000	1.000
Funding ratio	9230	1.054	0.200	0.940	1.028	1.143	0.487	2.191
Actuarial duration	9230	125.651	34.265	107.000	121.000	141.000	0.000	272.000
Retired participants share	9099	0.836	0.216	0.764	0.935	0.991	0.000	1.000
Effective contribution measure (signed log)	7777	1.073	1.528	0.156	0.430	1.279	-5.728	8.477
Fixed income	9230	0.762	0.283	0.718	0.841	0.958	0.000	1.000
Equities	9230	0.058	0.079	0.000	0.029	0.089	0.000	0.560
Structured investments	9230	0.126	0.255	0.000	0.019	0.095	-0.002	1.000
Real estate	9230	0.030	0.043	0.000	0.014	0.046	0.000	0.337
Participant loans	9230	0.010	0.011	0.001	0.007	0.016	0.000	0.080
Foreign investments	9230	0.003	0.012	0.000	0.000	0.000	0.000	0.126
Other investments	9230	0.012	0.046	0.000	0.000	0.002	0.000	1.000

Table 2 – Evidence of instability and number of structural changes

Result	Plan	% sample
Total sample	78	100.0
supF rejects stability at 5%	72	92.3
No evidence from supF	6	7.7
At least one localized breakdown	69	88.5
1 break	36	46.2
2 breaks	23	29.5
3 breaks	9	11.5
4 breaks	1	1.3
2 or more breakages	33	42.3

Table 3 – Characteristics associated with the magnitude and direction of the greatest structural change

Variable	Absolute magnitude OLS (1)	Pressure reduction Logit (2)
Funding ratio	-0.0088	1.2244
Duration	0.0004	0.0328**
Retired participants share	-0.1045	2.2400
Effective contribution measure (signed log)	0.0063	0.2367
Equities	-0.0797	-5.2241
Real estate	0.3007	2.5628
Foreign investments	-0.3497	-32.8478
Observations	69	69
R ²	0.0485	--
Adjusted R ²	-0.0821	--

Notes: *, ** and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 4 – Response of the segments to the aggregate net flow in relation to the pro-rata benchmark

Segment	θ	EP	p-value	IC 95%
Fixed income	0.2057	0.1200	0.0865	[-0.0295;0.4410]
Equities	-0.0361	0.0521	0.4885	[-0.1382;0.0660]
Structured investments	-0.0081	0.0203	0.6880	[-0.0479;0.0316]
Real estate	-0.0124	0.0153	0.4189	[-0.0423;0.0176]
Participant loans	-0.0022	0.0040	0.5726	[-0.0101;0.0056]
Foreign investments	-0.0021	0.0019	0.2656	[-0.0059;0.0016]

Notes: Number of observations: 9,152. 78 plans. Fixed effects of cloth and month.
Standard errors grouped by plan.

$H_0: \theta = 0$, corresponding to the pro-rata response

Table 5 – Asymmetrical response of the segments to net inflows and outflows

Segment	θ^+	p	θ^-	p	$\theta^+ - \theta^-$	p asymmetrical
Fixed income	0,2364	0,2138	0,1687	0,1388	0,0677	0,7581
Equities	0,0221**	0,0306	-0,1064	0,3521	0,1285	0,2814
Structured investments	0,0060	0,8501	-0,0252	0,2296	0,0312	0,3849
Real estate	0,0024	0,5259	-0,0302	0,2857	0,0326	0,2477
Participant loans	0,0047	0,2805	-0,0107***	<0,001	0,0154***	0,0016
Foreign investments	-0,0003	0,4011	-0,0044	0,2818	0,0041	0,3181

Notes: *, ** e *** They indicate significance at the 10%, 5%, and 1% levels, respectively.

Figure 1 – Cash flow pressure of the BD planes over time

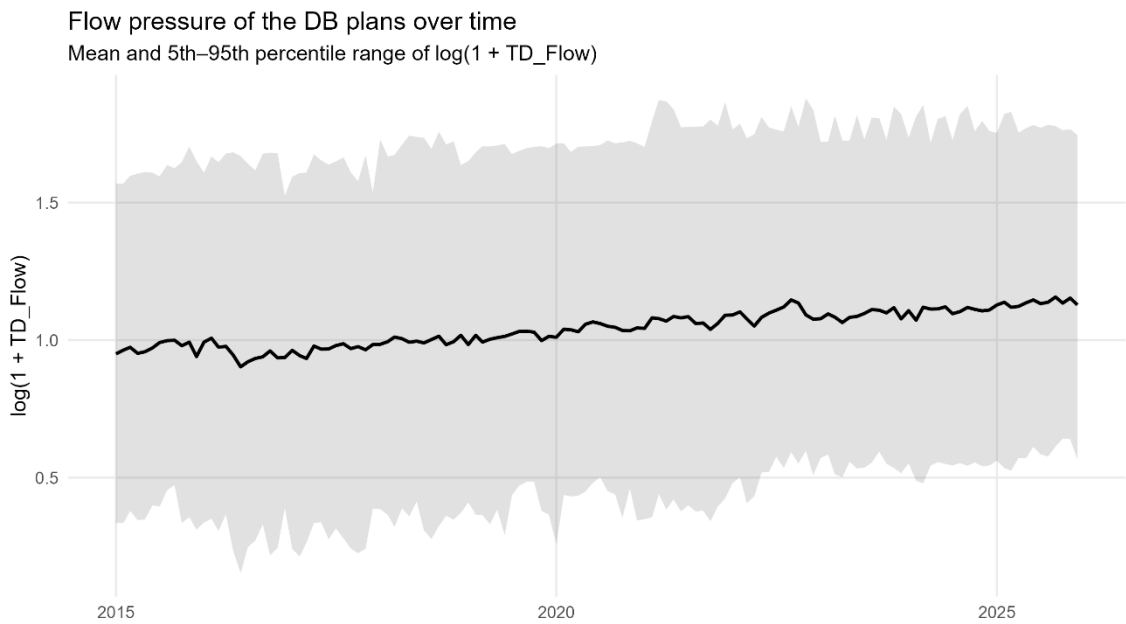


Figure 2 – Average composition of defined benefit (DB) plan portfolios, 2015–2025

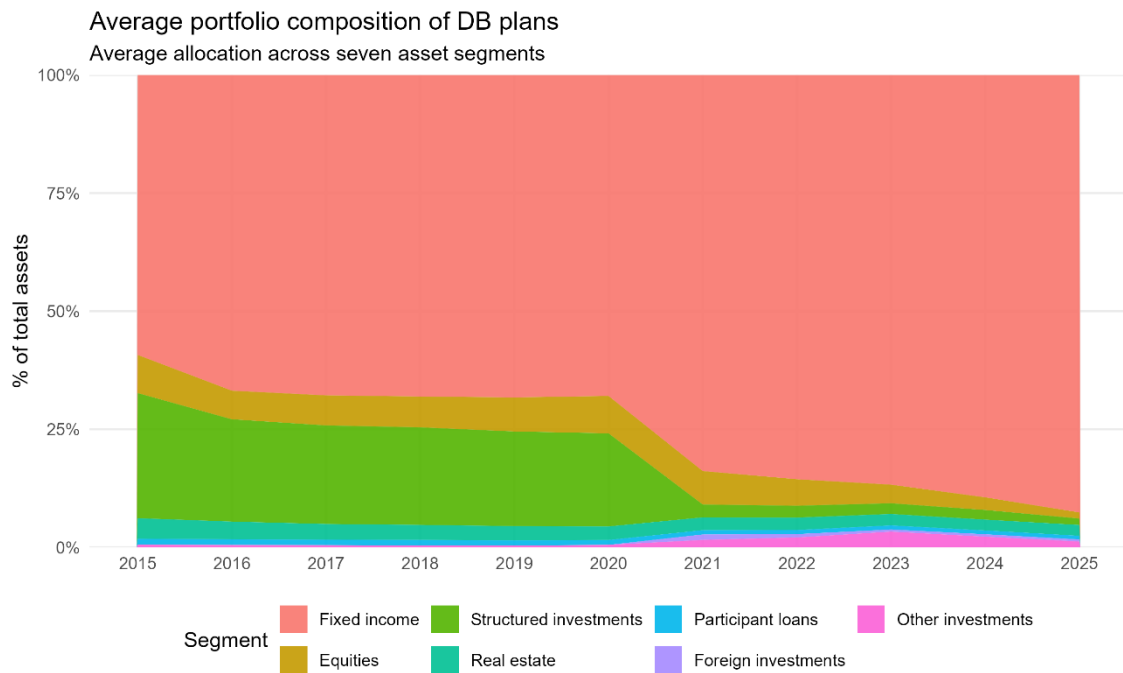


Figure 3 – Response of the segments to net inflows and outflows relative to the pro-rata benchmark.

