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Governed by the cycle: interest rate sensitivity of emerging market corporate debt

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Abstract

This study addresses interest rate sensitivity of emerging market corporate debt. Previous research suggests that interest rate sensitivity of corporate bonds depends on residual maturity of issues, creditworthiness of issuers, embedded options and other idiosyncratic factors. However, the dependence of interest rate sensitivity on phases of the business cycle has not received an appropriate academic attention. This paper provides empirical evidence and theoretical interpretation of a dichotomy of interest rate sensitivity across the phases of the cycle, and sheds light on how credit spreads respond to interest rates. The historical span of the research covers the period of 2004–2016. The findings imply that hedging interest rate risk ought to be a dynamic process and take into consideration where the economy is positioned in the current business cycle. This research provides important insights on the nature of interest rate sensitivity, capable of enhancing financial stability and improving efficiency of financial system.

Keywords Fixed income · Downside risk management · Emerging markets · Corporate debt · Interest rate sensitivity · Capital gains

JEL Classification E43 · G11 · G12 · G15 · G20

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1 Introduction

The interest rates (IR) hikes by the Federal Reserve of the United States of America (US) put a great strain on the global financial system, which along with developed economies also includes emerging markets (EM). Because of this, IR sensitivity of assets has attracted much attention of practitioners, financial regulators and academics, especially issues related to the IR impacts on bank performance (Gubareva 2014; Bessis 2015; Neal et al. 2015; Dupoyet et al. 2018; Gubareva and Borges 2016, 2017a, 2018; Beutler et al. 2017; Yasuoka 2017; Hainaut et al. 2018).

There is also large and growing literature on EM corporate debt (Alfaro et al. 2017; Gubareva and Borges 2017b; among many others). These works analyze tendencies and determinants of development of corporate debt markets in the EM economies, with a special focus on interdependence of global financial factors and corporate institutional fundamentals. The present research on the EM corporate debt is motivated by the growing importance of non-US financial markets, illustrated by the fact that corporate debt outstanding in EM has increased six times between 2002 and 2016 (Bank for International Settlements 2016). Such expansion originates an on-going concern of both regulators and academic community regarding the relevance of efficiency, stability and reform issues relative to banking sector in EM economies (Bhaumik et al. 2017).

From the point of view of IR risk hedging and downside risk management of fixed-income portfolios, in general, and of EM corporate portfolios, in particular, it is essential to have adequate measures of IR sensitivity of fixed-income portfolios, capable of providing important insights on how IR changes affect the net present values of financial instruments.

An important aspect of our research resides in the medium-term perspective employed to assess the asset price response to the risk-free rate changes. We directly target interrelations between the changes in the present value of risky and risk-free assets over 1-year long intervals. In other words, we study a comparative dynamics of annual capital gains of risky and risk-free portfolios.

We provide theoretical interpretations of interrelation between risk-free rates and credit spreads of corporate bonds and focus on economic causes of changes in IR sensitivity along the business cycle. Our explanation offers important insights on the dichotomous behavior of IR sensitivity (Gubareva and Borges 2017b). We study IR sensitivity as a function of a point within the business cycle and provide an economic rationale for the observed regime-switching behavior. Our results contrast with findings of previous research (Boulkeroua and Stark 2013; Neal et al. 2015; Dupoyet et al. 2018; among others). Bellalah et al. (2020) also study portfolio performance with regime switching, determined by economic conditions.

Most of the previous research on IR sensitivity of financial assets is focused at the US markets (Piazzesi and Schneider 2010; Bauer and Hamilton 2015, etc.). In respect to the work on non-US markets, one of the most notable is Kamin and Kleist (1999) who study the determinants of credit risk spreads. Recently economic cycle analysis, widely employed for the developed countries studies, has been applied to EM economies (Shen et al. 2018; Ahi et al. 2018). Sensoy et al. (2019) study the European sovereign bond markets. We contribute to this line of investigation, as our current research addresses the IR of EM corporate debt. From a perspective of a financial market practitioner, our research tries to assess the reasonability of hedging USD-denominated EM corporate debt instruments by opening and holding short positions in US Treasuries (UST).

This paper is structured as follows. Section 2 describes the data and the methodology. Section 3 presents empirical results. Section 4 provides the discussion illustrating diverse implications of our results, and Sect. 5 wraps up, and concludes.

2 Data-set and methodology

In this section, we briefly describe the data set and the employed methodology, which is in line with a detailed explanation available at closely related study by Gubareva and Borges (2017b). Our research is based on capital gains analyses. We define capital gain as the difference between the final price of the portfolio and its initial price, not accounting for interim coupon payments.

To describe EM corporate debt performance, we choose two J.P. Morgan Corporate Emerging Market Bond Indices: the Broad High Grade Blended Yield (Bloomberg ticker JBBYIGIG) and the Broad High Yield Blended Yield (Bloomberg ticker JBBYNOIG). These indices are rule-based and measure the performance of USD denominated fixed-rate corporate bonds by issuers in EM. Among each index constituents, there are more than four hundred bonds, issued by more than two hundred issuers, from over forty EM countries. The EM IR sensitivity is studied prior to, around, and after the global financial crisis. We chose July 15, 2016 as the cut-off date for our research. To describe the risk-free bonds, we choose the US Global Generic rate index (Bloomberg ticket USGG5YR) whose maturity is equivalent to the maturity of the two EM bond indices under analysis.

The main element of our framework is the conversion of the available index values into the average price of the modeled portfolios, namely emerging market investment grade (EMIG) portfolio and emerging market high yield (EMHY) portfolio, in accordance with the used index, JBBYIGIG and JBBYNOIG, respectively. We employ the fundamental principle of bond valuation stating that the bond's value is equal to the present value of its future cash flows. The present value of a bond is the present value of a bond's interest payments, plus the present value of a bond's maturity amount.

$$P = \frac{c}{1+y} + \frac{c}{(1+y)^2} + \frac{c}{(1+y)^3} + \frac{c}{(1+y)^4} + \frac{c+p}{(1+y)^5} \tag{1}$$

where y is a market IR for the risk level associated with the bond under analysis.

For simplicity reasons, we consider the term structure of the bond yield to be flat. However, a blended yield index provides us only with the time series of yield value y. Thus, in order to determine bonds coupon values, we employ the following assumptions. Firstly, we utilize a concept of a continuous rebalancing of the portfolio. This assumption is frequently used to study risk minimization strategies for portfolio immunization (Fong and Vasicek 2015). Secondly, we assume that the portfolio rebalancing occurs at a cruising speed, i.e. it is a continuous rebalancing with a constant rate. Each bond entering the portfolio stays in for a certain holding period (n years) and then is sold at the end of that period. The equal weights of the constituent bonds in the portfolios underline the modeling considerations that follow. We assume that the bonds are regularly issued once a quarter, each with an initial maturity of 5.5 years. A newly issued on-the-run bond substitutes any chosen bond, which spends 1 year in the portfolio and whose residual maturity, thus, equals 4.5 years. Therefore, the average residual maturity of the portfolio is always equal to 5 years, the point of the term structure of IR in which we are interested.

This simple example can be generalized for a situation when a bond holding period may equal n years, or $260*n$ banking days. Assuming that bonds are issued at par, we can determine an average coupon c of the modeled portfolio at the date d:

$$c = \frac{1}{n * 260} \sum_{i=1}^{n*260} y_i \tag{2}$$

We consider that the year consists of 260 working days for which index data are available. In this study, we employ three different holding periods n of 1, 2, and 3 years.

Being now capable of generating time series of prices for EMIG, EMHY, and UST modeled portfolios, we quantify asset appreciation/depreciation on a year-on-year basis:

$$ACG_{Portfolio}(t) = P_{Portfolio}(t) - P_{Portfolio}(t - 1Y) \tag{3}$$

where $ACG_{Portfolio}(t)$ stands for annual capital gains of the respective portfolio, experienced during the one-year long period, whose final date is t.

As already mentioned above, following Eq. (1), the formula used to calculate prices of UST and EM corporate portfolios assumes that the respective yield curves are flat. Although this rather strong model assumption is employed in our intermediary price calculations, an eventual roughness is to a certain degree eliminated from the annual capital gains $ACG_{Portfolio}$ (t) as per Eq. (3). The proper focus of our approach on annual capital gains figures leads us to be interested in price changes, rather than in their absolute values, see Eq. (3). By calculating a relative value, a flat-curve caused bias in initial and final prices, in a major part eliminates itself when calculating the annual capital gain measures.

To check that our results are sufficiently robust, we performed robustness checks by relaxing our model flat-curve assumption. Instead of employing this assumption in our calculations, we used the respective risk-free and risky term structures with a linear-slope. As shown in "Appendix A", such positively-sloped and negatively-sloped term structures result in fairly similar outcomes to those obtained under the flat curves assumption, which thus corroborates that the proposed methodology enables one to reach robust conclusions related to the capital gains and IR sensitivity of assets under diverse model choices of term structure profiles.

Equation (3) allows for generating time series of the annual capital gains, ACG_{EMIG}, ACG_{EMHY}, and ACG_{UST}. Now, the pair of the ACG_{UST} and ACG_{EMIG} time series can be used for assessing the sensitivity of the EMIG capital gains to the annual capital gains of the risk-free UST bond portfolio. Similarly, the pair of the ACG_{UST} and ACG_{EMHY} time series can be used for assessing the sensitivity of the EMHY portfolio.

Thus, IR sensitivity can be assessed as the ratio of a capital gain change ΔACG_{EM}, either EMIG or EMHY, over a chosen, time window (from t_1 to t_2) to the capital gain change ΔACG_{UST} of the portfolio composed by the UST over the same time interval:

$$S_{EM/UST}(t_2, t_1) = \frac{ACG(t_2)_{EM} - ACG(t_1)_{EM}}{ACG(t_2)_{UST} - ACG(t_1)_{UST}} = \frac{\Delta ACG(t_2, t_1)_{EM}}{\Delta ACG(t_2, t_1)_{UST}} \tag{4}$$

where $S_{EM/UST}$ (t_2, t_1) stands for a capital gain-wise sensitivity of EM Corporates when the 1-year long capital gain gauging interval is moved forward by $(t_2 - t_1)$ days. We apply Eq. (4) separately to EMIG and EMHY portfolios.

This approach to IR sensitivity arises from the fact that we are interested in capital gains over rather extended, at least 1-year long time intervals. Our method fits well with the basis

IR risk hedging strategy consisting of shorting UST. Thus, while assessing the performance of the EM corporate debt portfolios, we can assess whether short positions in UST could perform the role of an efficient hedge instrument.

As we are interested in price-wise IR sensitivity, we simplify our model and eliminate less important details. For instance, continuous rebalancing involves continuous buying and selling assets. Nonetheless, we exclude transaction expenses and gains as in fact they respectively represent the out-of-pocket and into-the-pocket money, which do not affect present value of future cash flows of assets composing our modeled portfolios.

3 Empirical results

3.1 Modeled capital gains for diverse portfolio rebalancing rates

In this subsection we present our calculations of the historic time series for the current annual capital gains modeling portfolio prices assuming that the modeled portfolio is completely renewed over 1, 2, and 3 years. We consider the face value of the modeled portfolios to be equal to 1000 million USD. Figure 1 shows the time behavior of the current annual capital gains of the EMIG and EMHY corporates portfolios whose complete rebalancing occurs respectively, over 1, 2, and 3 years.

In Fig. 1, any point of a chosen curve, corresponding to a selected rebalancing rate at any given date (for example, December 31, 2003), represents the price change of the respectively rebalanced EM corporates portfolio occurred over the preceding 1-year long period. As the three capital gains plots are similar to each other over the whole span of the analyzed data-set history, this means that the assumption regarding the rebalancing rate of the EMIG/EMHY portfolios does not considerably change annual capital gain dynamics.

Comparing the two portfolios, we observe that the financial crisis influence on the price behavior of the modeled EMHY portfolios is stronger than on the price behavior of the modeled EMIG portfolios. The range of EMHY annual capital gains is more than twice wider while compared to the respective width observed for the EMIG portfolios.

Figure 2 represents the dynamics of the annual capital gains of the UST portfolios whose complete rebalancing occurs respectively, over 1, 2, and 3 years.

Figure 2 evidences no substantial influence of the rebalancing rate of the portfolio to the annual capital gain dynamics of the modeled UST portfolios. It is worth noting that the range of UST annual capital gains is roughly twice narrower than the respective width

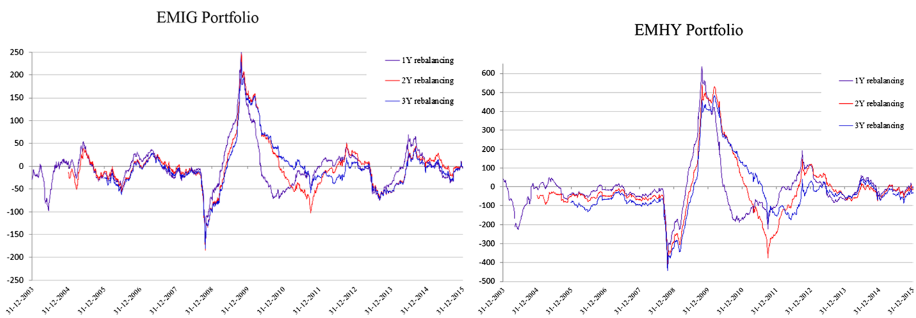

Fig. 1 Current annual capital gains of EMIG and EMHY portfolios with different rebalancing rates

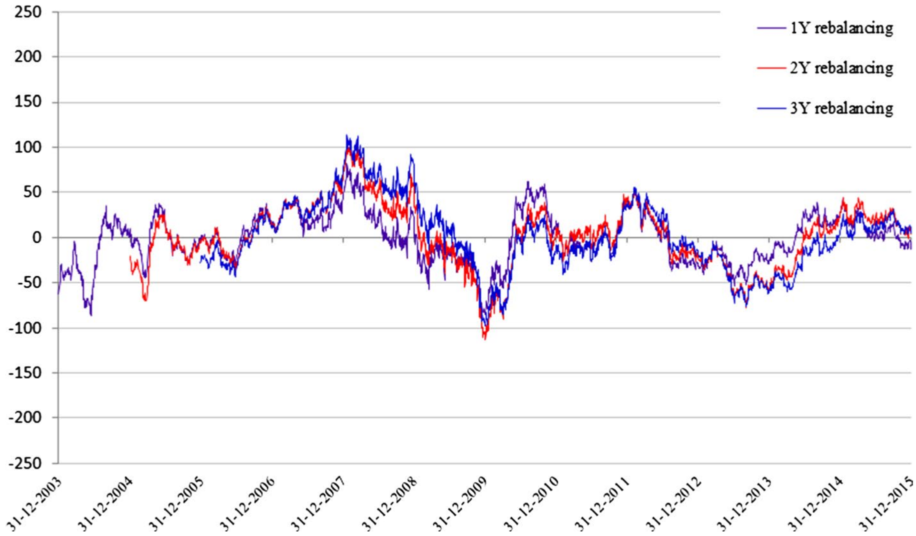

Fig. 2 Current annual capital gains of UST portfolios with different rebalancing rates

observed for the EMIG portfolios and much narrower that the range observed for the EMHY bonds, see Fig. 1. Therefore, Figs. 1 and 2 confirm that the rebalancing rate of the portfolios does not affect, in a noticeable way, the annual capital gain dynamics. As the 1-year long rebalancing results in the most extended available capital gains history, we use the 1-year rebalancing rate in the further sections of this paper.

3.2 Regime-switching behavior of annual capital gains

We study the dynamics of the historic series of the annual changes in value of the EM and UST bond portfolios. The calculations are performed on a daily basis. Figure 3 depicts the time behavior of the 1-year changes in present value of the modeled EMIG and EMHY corporate bond portfolios, compared to the risk-free UST bond portfolio, with the rebalancing rate of the portfolios equal to 1 year.

Analyzing Fig. 3, we can observe that during 2007–2012 the changes in the capital gains of the EM and UST portfolios occur in opposite directions. This implies that holding short positions in UST is not an adequate strategy, as it does not compensate the negative

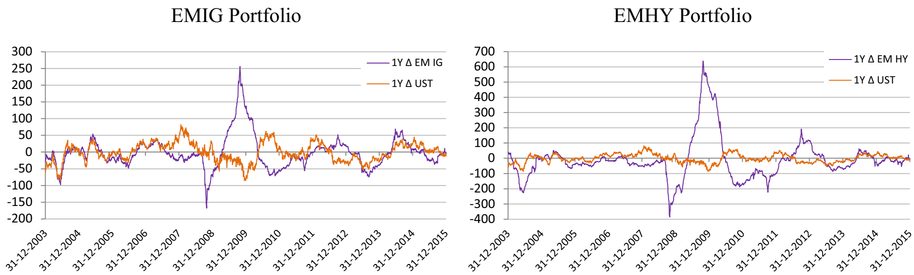

Fig. 3 Current annual capital gains for the EM and UST portfolios on a daily basis

impacts in EM bond valuations. However, prior to 2007 and after 2012, the capital gains of the EM and UST portfolios are positively correlated. Hence, during such conditions, hedging IR risk by shorting UST could be appropriate.

The identified above timescale related difference in the joint behavior of the capital gains indicates the regime-switching behavior of both, the EMIG and EMHY capital gains in respect to the UST capital gains. It also implies dichotomy of IR sensitivity, which we discuss in more detail in the following sections.

Figure 4 depicts the behavior of the annual changes in value of the model EM corporate bond portfolios hedged by short positions in UST bonds.

By comparing Figs. 3 and 4, the volatility of the EMIG and EMHY bond portfolios hedged by short positions in the UST is superior to the volatility of price changes for the non-hedged portfolios. This indicates that in the most crucial moments such hedge in fact increases exposure to downside risk of both EMIG and EMHY portfolios.

3.3 Price-wise interest rate sensitivity of emerging market corporates

In this section, we perform a quantitative assessment of the price-wise IR sensitivity of the two, EMIG and EMHY, corporate bond portfolios to changes in prices of the corresponding portfolio of UST, in the period December 31, 2003 to June 30, 2016.

Instead of trying to determine average sensitivity figures for all the available data history, we apply the methodology developed in Gubareva and Borges (2016), to identify successive periods of price increases, and decreases, of the constructed UST portfolio. Applying this methodology, we identify the local extrema of the modeled historical series of annual changes in present values of the UST bond portfolio.

In this way, we identify 71 considerable rises and falls of the capital gains of the UST portfolio. Following Eq. (4), the price sensitivity figures are calculated separately for each gains/losses move, for both EMIG and EMHY bond portfolios. A statistical analysis, similar, in essence, to structural break tests such as proposed by Chow (1960) and others (see in Muthuramu and Maheswari 2019 and the references therein) is performed to study the homogeneity of the observed sample of the 71 capital-gain wise sensitivities. These sensitivities correspond to the 71 identified time-intervals, grouped in their turn into three periods: pre-crisis, crisis, and post- crisis periods (see Tables 1, 2, 3 presented later in the paper). Instead of an arbitrary choice of the sub periods, we solve the problem of identifying the regime switching, i.e., splitting the whole sample into the three above-mentioned sub periods, by employing a clustering approach based on minimization of standard

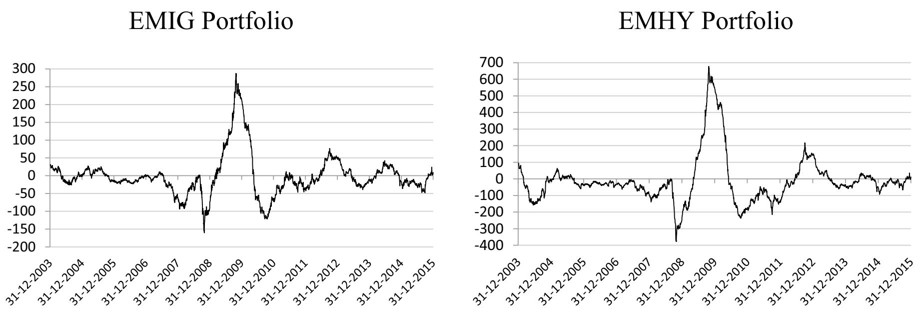

Fig. 4 Current annual capital gains for the EM long + UST short portfolios, daily

Table 1 Price-wise IR sensitivity of EM portfolios during the pre-crisis period

End date of window	Type of window	Endurance window (days) (A)	Δ in UST 1Y price change (B)	Emerging market IG portfolio			Emerging market HY portfolio		
				Δ in EM IG 1Y price change (C)	Sensitivity coefficient (D) = C/B	Endurance and amplitude weighted sensitivity (E) = A × |B| × D	Δ in EM HY 1Y price change (F)	Sensitivity coefficient (G) = F/B	Endurance and amplitude weighted sensitivity (H) = A × |B| × G
2003-12-31									
2004-01-13	Gain	13	32.69	21.39	0.65	278	−6.45	−0.20	−84
2004-03-03	Loss	50	−17.31	−17.74	1.02	887	−99.99	5.78	5000
2004-03-22	Gain	19	43.08	30.05	0.70	571	4.74	0.11	90
2004-06-14	Loss	84	−83.17	−102.16	1.23	8581	−159.91	1.92	13,432
2004-08-31	Gain	78	122.43	107.74	0.88	8404	124.53	1.02	9713
2004-09-30	Loss	30	−38.8	−16.28	0.42	488	31.42	−0.81	−943
2004-10-29	Gain	29	25.07	17.77	0.71	515	7.77	0.31	225
2005-01-11	Loss	74	−33.74	−17.21	0.51	1274	40.98	−1.21	−3033
2005-02-08	Gain	28	11.5	21.18	1.84	593	32.09	2.79	899
2005-03-16	Loss	36	−39.45	−36.3	0.92	1307	−5.54	0.14	199
2005-05-24	Gain	69	71.71	58.67	0.82	4048	28.26	0.39	1950
2005-11-03	Loss	163	−60.44	−71.07	1.18	11,584	−98.82	1.64	16,108
2006-03-24	Gain	141	39.13	27.1	0.69	3821	36.83	0.94	5193
2006-06-26	Loss	94	−42.31	−41.96	0.99	3944	−30.74	0.73	2890
2006-12-04	Gain	161	70.08	79.27	1.13	12,762	40.87	0.58	6580
2007-01-10	Loss	37	−20.35	−15.01	0.74	555	−2.99	0.15	111
2007-04-25	Gain	105	23.27	20.91	0.90	2196	29.22	1.26	3068
2007-06-04	Loss	40	−25.41	−13.53	0.53	541	−9.6	0.38	384
2007-06-27	Gain	23	5.7	2.31	0.41	53	4.01	0.70	92
2007-07-13	Loss	16	−12.89	−14.13	1.10	226	−9.35	0.73	150

Table 1 (continued)

End date of window	Type of window	Endurance window (days) (A)	Δ in UST 1Y price change (B)	Emerging market IG portfolio			Emerging market HY portfolio		
				Δ in EM IG 1Y price change (C)	Sensitivity coefficient (D) = C/B	Endurance and amplitude weighted sensitivity (E) = A × |B| × D	Δ in EM HY 1Y price change (F)	Sensitivity coefficient (G) = F/B	Endurance and amplitude weighted sensitivity (H) = A × |B| × G
Total (Average) UST gain windows		666	444.66	386.39	0.87	0.92	301.87	0.79	0.77
Total (Average) UST loss windows		624	−373.87	−345.39	0.86	1.02	−344.54	0.94	1.19
Sensitivity averaged over the whole period					0.87	0.96		0.87	0.96

Table 2 Price-wise IR sensitivity of EM portfolios along the through-the-crisis period

End date of window	Type of window	Endurance window (days) (A)	Δ in UST 1Y price change (B)	Emerging market IG portfolio			Emerging market HY portfolio		
				Δ in EM IG 1Y price change (C)	Sensitivity coefficient (D) = C/B	Endurance and amplitude weighted sensitivity (E) = A × |B| × D	Δ in EM HY 1Y price change (F)	Sensitivity coefficient (G) = F/B	Endurance and amplitude weighted sensitivity (H) = A × |B| × G
2007-07-13									
2007-11-26	Gain	136	43.60	−35.00	−0.80	−4760	−49.29	−1.13	−6703
2007-12-26	Loss	30	−26.26	−2.19	0.08	66	0.83	−0.03	−25
2008-01-22	Gain	27	56.38	14.17	0.25	383	−5.99	−0.11	−162
2008-02-27	Loss	36	−39.44	−20.30	0.51	731	9.70	−0.25	−349
2008-06-06	Loss	100	−5.67	29.48	−5.20	−2948	33.85	−5.97	−3385
2008-07-01	Loss	25	−20.75	−11.26	0.54	282	−15.14	0.73	379
2008-09-08	Loss	69	−29.85	2.14	−0.07	−148	10.73	−0.36	−740
2008-10-07	Gain	29	35.21	−42.91	−1.22	−1244	−155.80	−4.42	−4518
2008-10-29	Loss	22	−29.36	−113.74	3.87	2502	−211.54	7.21	4654
2008-11-24	Loss	26	−16.25	57.61	−3.55	−1498	83.11	−5.11	−2161
2008-12-16	Gain	22	57.41	36.56	0.64	804	60.64	1.06	1334
2009-03-17	Loss	91	−91.12	33.09	−0.36	−3011	45.16	−0.50	−4110
2009-04-27	Gain	41	57.98	49.81	0.86	2042	133.60	2.30	5478
2009-06-08	Loss	42	−47.43	37.37	−0.79	−1570	147.17	−3.10	−6181
2009-07-22	Gain	44	41.75	35.13	0.84	1546	77.97	1.87	3431
2009-10-29	Loss	99	−25.97	174.54	−6.72	−17,279	473.43	−18.23	−46,870
2009-12-30	Loss	62	−54.23	−126.40	2.33	7837	−169.78	3.13	10,526
2010-08-10	Gain	223	147.54	−173.05	−1.17	−38,590	−559.37	−3.79	−124,740
2010-09-10	Loss	31	−29.52	−23.33	0.79	723	−44.34	1.50	1375
2010-11-04	Gain	55	26.23	15.70	0.60	864	−23.14	−0.88	−1273
2010-11-17	Loss	13	−32.48	−20.40	0.63	265	−15.88	0.49	206

Table 2 (continued)

End date of window	Type of window	Endurance window (days) (A)	Δ in UST 1Y price change (B)	Emerging market IG portfolio			Emerging market HY portfolio		
				Δ in EM IG 1Y price change (C)	Sensitivity coefficient (D) = C/B	Endurance and amplitude weighted sensitivity (E) = A × |B| × D	Δ in EM HY 1Y price change (F)	Sensitivity coefficient (G) = F/B	Endurance and amplitude weighted sensitivity (H) = A × |B| × G
2011-07-01	Loss	226	− 53.29	53.55	− 1.00	− 12,102	96.64	− 1.81	− 21,841
2011-09-09	Gain	70	40.89	3.34	0.08	234	− 38.69	− 0.95	− 2708
2011-10-12	Loss	33	− 37.06	− 28.81	0.78	951	− 48.80	1.32	1610
2012-02-14	Gain	125	71.96	58.55	0.81	7319	144.67	2.01	18,084
2012-03-19	Loss	34	− 42.67	− 4.59	0.11	156	23.89	− 0.56	− 812
2012-04-10	Gain	22	31.96	3.41	0.11	75	− 14.90	− 0.47	− 328
2012-05-31	Loss	51	− 29.62	− 14.42	0.49	735	− 0.39	0.01	20
2012-10-03	Loss	125	− 33.81	51.86	− 1.53	− 6483	206.58	− 6.11	− 25,823
2013-01-29	Loss	118	− 15.88	− 44.72	2.82	5277	− 129.50	8.15	15,281
2013-04-03	Gain	64	37.32	− 12.37	− 0.33	− 792	− 39.89	− 1.07	− 2553
Total (Average) UST gain windows		858	648.23	− 46.66	0.06	− 0.51	− 470.19	− 0.46	− 1.81
Total (Average) UST loss windows		1233	− 660.66	29.48	− 0.33	− 0.55	495.72	− 1.03	− 1.69
Sensitivity averaged over the whole period					− 0.18	− 0.53		− 0.81	− 1.76

Table 3 Price-wise IR sensitivity of EM portfolios along the post-crisis period

End date of window	Type of window	Endurance window (days) (A)	Δ in UST 1Y price change (B)	Emerging market IG Portfolio			Emerging market HY Portfolio		
				Δ in EM IG 1Y price change (C)	Sensitivity coefficient (D) = C/B	Endurance and amplitude weighted sensitivity (E) = A × |B| × D	Δ in EM HY 1Y price change (F)	Sensitivity coefficient (G) = F/B	Endurance and amplitude weighted sensitivity (H) = A × |B| × G
2013-04-03									
2013-07-05	Loss	93	−49.98	−52.51	1.05	4883	−72.22	1.44	6716
2013-08-08	Gain	34	23.37	−2.42	−0.10	−82	−8.95	−0.38	−304
2013-09-05	Loss	28	−21.51	−14.16	0.66	396	−23.13	1.08	648
2013-10-24	Gain	49	39.78	28.88	0.73	1415	12.86	0.32	630
2013-12-27	Loss	64	−17.94	5.20	−0.29	−333	5.20	−0.29	−333
2014-02-03	Gain	38	26.43	16.98	0.64	645	3.71	0.14	141
2014-04-03	Loss	59	−18.88	17.61	−0.93	−1039	20.97	−1.11	−1237
2014-06-25	Gain	83	51.83	72.50	1.40	6018	101.21	1.95	8400
2014-07-30	Loss	35	−12.31	−19.10	1.55	669	−24.69	2.01	864
2014-09-05	Gain	37	21.49	18.21	0.85	674	13.32	0.62	493
2014-11-06	Loss	62	−27.69	−40.52	1.46	2512	−41.81	1.51	2592
2015-01-15	Gain	70	33.83	−16.77	−0.50	−1174	−57.74	−1.71	−4042
2015-03-03	Loss	47	−36.43	−7.29	0.20	343	33.17	−0.91	−1559
2015-04-02	Gain	30	23.96	5.90	0.25	177	8.98	0.37	269
2015-08-18	Loss	138	−33.29	−34.45	1.03	4754	−14.73	0.44	2033
2015-10-02	Gain	45	18.14	15.31	0.84	689	−27.52	−1.52	−1238
2016-01-14	Loss	104	−38.24	5.12	−0.13	−532	54.09	−1.41	−5625
2016-02-10	Gain	27	37.97	8.38	0.22	226	−14.77	−0.39	−399
2016-04-25	Loss	75	−23.51	1.63	−0.07	−122	13.67	−0.58	−1025
2016-06-27	Gain	63	37.94	26.30	0.69	1657	21.29	0.56	1341

Table 3 (continued)

End date of window	Type of window	Endurance window (days) (A)	Δ in UST 1Y price change (B)	Emerging market IG Portfolio			Emerging market HY Portfolio		
				Δ in EM IG 1Y price change (C)	Sensitivity coefficient (D) = C/B	Endurance and amplitude weighted sensitivity (E) = A × |B| × D	Δ in EM HY 1Y price change (F)	Sensitivity coefficient (G) = F/B	Endurance and amplitude weighted sensitivity (H) = A × |B| × G
Total (Average)	UST gain windows	476	314.74	173.27	0.50	0.63	52.39	0.00	0.33
Total (Average)	UST loss windows	705	−279.78	−138.47	0.45	0.53	−49.48	0.22	0.14
Sensitivity averaged over the whole period					0.48	0.57		0.11	0.22

deviation (see Gubareva and Borges 2016), which we describe in more detail in "Appendix B".

Based on the results of our statistical analysis we perform the following grouping. The first 20 capital gain moves of the UST we ascribe to the pre-crisis period of December, 31, 2003–July, 13, 2007; the following 31 moves to the crisis-fueled turmoil of July, 13, 2007–April 03, 2013, and; the most recent 20 moves we assign to the "new normal" post-crisis period of April 04, 2013–June 30, 2016.

3.3.1 Interest rate sensitivity during the pre-crisis period

Table 1 displays 20 major moves in year-on-year price changes observed along the pre-crisis period. For all the subjacent time windows, we compute the corresponding 1-year price change deltas for the UST, EMIG, and EMHY portfolios. In columns D and G, we present the sensitivity coefficients computed as the ratio of the value change delta observed in the respective EM portfolio to the inducing value change delta observed in the UST portfolio. In columns E and H, we present our calculations of the endurance-times-amplitude weighted average of sensitivity coefficients. These values are averaged over three different aggregated arrays of the windows: the aggregate array of the UST positive deltas, the aggregate array of the UST negative deltas, and for the entire span of the pre-crisis interval.

From the portfolio management and risk management perspective, the most comprehensive figures are the three average sensitivity coefficients at the bottom of columns E and H, that is, endurance-times-amplitude weighted average of sensitivity coefficients. In this way, while calculating the averaged figures, we ascribe bigger weights to stronger and more lasting moves of the risk-free rates, as exactly these types of moves provide the most important impacts on EM portfolios from an asset value perspective.

The price-wise sensitivity averaged over the entire pre-crisis period is 0.96 for both EM portfolios, which is very close to 1. This means that price changes relative to EMIG and EMHY portfolios closely mirror price changes of the UST portfolio.

EMIG and EMHY sensitivities averaged over the windows of the positive UST price deltas (risk-free IR downtrend intervals) equal, respectively 0.92 and 0.77, while the sensitivities averaged over the windows of the negative UST price deltas (risk-free rates uptrend intervals) equal, respectively, 1.02 and 1.19. This means that decreases of risk-free IR affect EM bonds in a weaker manner than their increases. I.e., the EM portfolios suffer more from risk-free rate increases than they benefit from risk-free rate decreases. Although the dynamics of sensitivity exhibits certain volatility, the values of sensitivity coefficient always remain positive for EMIG and are predominantly positive for EMHY. Note that when the value of sensitivity coefficient is below 1, the impact of risk-free IR changes is damped. On the contrary, when the value of sensitivity coefficient is above 1, the impact of risk-free IR changes on EM portfolio prices is amplified.

3.3.2 Interest rate sensitivity during the crisis period

Table 2 represents 31 major moves in yearly price changes observed along the "distressed" through-the-crisis period. For all the subjacent time windows, we calculate the corresponding 1-year price change deltas for both, the UST and EM modeled portfolios. As can be seen in columns E and H of Table 2, the respective endurance-times-amplitude weighted sensitivities averaged over the entire through-the-crisis period are negative. They equal to − 0.53, for the EMIG portfolio, and − 1.76 for the EMHY portfolio.

It means that on average price changes of the EM portfolios exhibit inverted behavior while compared to price changes of the UST portfolio. In other words, while the yield on a US government debt is rising, the spread of EM debt over the UST yield is narrowing in such a way that it is absorbing all the increase in risk-free rates and even causes a decrease in the EM yield. On the contrary, while the yield on a US government debt is decreasing, the yield on EM bonds is increasing. This behavior corresponds to the outcomes of structural Merton's (1974) model, positing the influence of IR changes upon creditworthiness of corporate obligors.

The "distressed" through-the-crisis period the dynamics of the EM portfolios sensitivities exhibit volatility considerably superior to the pre-crisis period. The width of the volatility range of the EMIG (EMHY) portfolio equals 10.56 (26.38), being many times wider that the pre-crisis width of 1.44 (6.99). Although the sensitivity coefficients values exhibit several negative and positive spikes, this volatility range is centered at the negative level of −0.53 (−1.76) certifying that the overall price-wise sensitivity of the EM portfolios is negative. In the case of EMIG, this sensitivity is attenuated if compared to the amplitude of inducing price changes of UST portfolio. Differently from the EMIG case, the absolute value of the average sensitivity coefficient for the EMHY portfolio is superior to 1, meaning that the impact on EMHY corporates is not only inverted, but also amplified if compared to the amplitude of the inducing change of UST.

3.3.3 Interest rate sensitivity during the post-crisis period

Table 3 represents 20 major moves in year-on-year price changes observed along the post-crisis period. For all the subjacent time windows we calculate the corresponding 1-year price change deltas for both, the UST and EM modeled portfolios. As can be seen in columns E and H of Table 3, the endurance-times-amplitude weighted sensitivity averaged over the entire post-crisis period, is positive and equal to 0.57, for the EMIG portfolio, and 0.22 for the EMHY portfolio. Differently from the pre-crisis period, the average sensitivity coefficient is not close to 1, certifying a kind of reduced sensitivity of the EM portfolios to price changes of the corresponding UST portfolio. The sign of a price response in the EM portfolios is the same as the sign of the inducing price change occurred in the UST portfolio, but amplitude of the price response observed in the EM portfolios is lower than 100%. In other words, a move in the risk-free IR is only partially passed through to the yield of EM bonds.

EMIG and EMHY sensitivities averaged over the windows of the positive UST price deltas (risk-free rates downtrend intervals) equal, respectively, 0.53 and 0.14, while the sensitivities averaged over the windows of the negative UST price deltas (risk-free rates uptrend intervals) equal, respectively, 0.63 and 0.33. In the post-crisis period, the dynamics of the EM portfolios sensitivities exhibits volatility somewhat superior to the pre-crisis period volatility, but quite inferior to the volatility range of the through-the-crisis period.

The width of the volatility range of the EMIG (EMHY) portfolio equals 2.48 (3.71), being wider (narrower) than the pre-crisis width of 1.44 (6.99) and much narrower than the through-the-crisis width of 10.56 (26.38). Although the sensitivity coefficients values in the case of the post-crisis period exhibit several positive and also a few negative spikes, this volatility range is centered at the positive level of 0.57 (0.22) certifying that the overall price-wise sensitivity of EM portfolios is positive though attenuated if compared to the amplitude of inducing price changes of UST portfolio.

3.4 Holistic perspective: dichotomy of capital gain-wise interest rate sensitivity

Figure 5 below shows on-the-move sensitivities observed during the whole span of our analysis (columns D and G of Tables 1, 2, 3). The dotted line is the sensitivity averaged in each of the three sub-periods (see totals of columns E and H from Tables 1, 2, 3). Although the on-the-move sensitivity exhibits certain volatility, the dynamics of phase-averaged sensitivity clearly exhibits dichotomous behavior. Figure 5 evidences three switches: from the pre-crisis regime positive sensitivity to the through-the-crisis regime negative sensitivity, and then back to the post-crisis regime positive sensitivity. This regime dependent behavior of the IR sensitivity means that during reasonably normal economic conditions, on average, the capital gain-wise IR sensitivity is positive, while during crisis-driven financial turmoil the sensitivity is negative.

From the point of view of economic efficiency of the hedge by short positions in UST, all the gains from the hedge obtained during the pre-crisis period seem to be wiped away while crossing the crisis downturn and recovery. Analyzing the trends, one could conclude that even during the post-crisis period, when shorting UST positions provides a reduced, in comparison to the pre-crisis conditions, efficiency to withstand negative effects of climbing risk-free rates, it is reasonable to gradually diminish the nominal of the hedge anticipating the next financial turmoil. Note, that when next such turmoil comes, the losses in the EM corporates portfolios hedged by short UST will be registered at the both sides: at the asset side, due to the widening of spreads because of augmenting corporate credit risk, and at the hedge side due to the dropping risk-free yields caused by the search of safe haven assets. That is but the flight-to-quality phenomenon (Gubareva and Borges 2016).

4 Discussion and implications

4.1 Dichotomy of interest rate sensitivity of EM bond portfolios

Below we present the detailed analysis of price-wise IR sensitivity per type of credit quality, EMIG and EMHY. In addition to the price-wise sensitivity, we also discuss negative and positive sensitivities in terms of responses of credit spreads to risk-free rates.

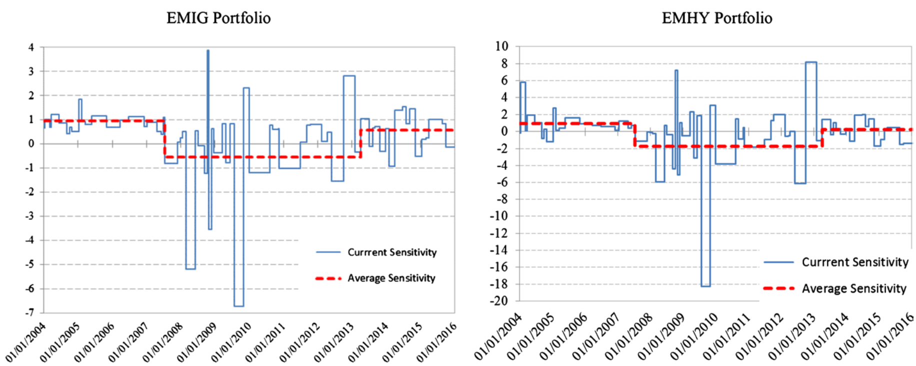

Fig. 5 Dichotomy of phase-averaged sensitivity of EM corporates

4.1.1 Interest rate sensitivity of EM corporate bond portfolios

Investigating the asset sensitivity to IR from the point of view of asset price changes, allows us to reach important insights from the prism of downside risk management. Figure 6 demonstrates the three different regimes of price-wise IR sensitivity of EMIG and EMHY corporate bonds. The pre-crisis period and the post-crisis period exhibit a kind of relation between price changes of EM and UST portfolios, completely different from observed within the "distressed" through-the-crisis regime. Figure 6 evidences that, under the "old normal" pre-crisis and "new normal" post-crisis regimes, the variations in the present value of the EMIG and EMHY modeled portfolios are positively correlated with the variations in the present value of the modeled UST portfolio, as the respective capital gain depicting curves represent rather similar dynamics. On the contrary, along the through-the-crisis period the IR sensitivity sign changes from positive to negative: the changes in the present values of the portfolios composed by risk-free and risky assets behave in an opposite mode.

An interesting feature is that under the pre-crisis regime the EMIG and EMHY portfolios price changes are related to the UST portfolio price changes roughly as 1 to 1. As shown in Fig. 6, in the pre-crisis regime the price responses of the EMIG and EMHY portfolios mirror the inductive price changes of the respective UST portfolio, while the former case represents a stronger adherence between the observed patterns. In line with the analyzed situation, under the post-crisis regime for EMIG corporate bonds, we observe a positive although somewhat reduced price-wise sensitivity, as per Sect. 3.3.3. The sensitivity ratio averaged over this period is found to be 0.58 to 1, which is about 60% of the pre-crisis figure. On the other hand, for EMHY corporate bonds we observe only a slightly positive price-wise IR sensitivity. The sensitivity ratio averaged over this period equals 0.22 to 1, see Sect. 3.3.3. Such a weak sensitivity rather indicates insensitivity to changes in the yields of risk-free assets, as only 22% of a price change in UST portfolio is passed through to the price of EMHY portfolio. Under the post-crisis regime, EMIG bonds price changes exhibit positive average sensitivity to price changes of the respective UST bond portfolio, even though the respective price-change lines move not so closely and jointly as within the pre-crisis period. For the EMHY portfolio, under the "new normal" regime the behavior of the respective lines is not very similar corresponding to the rather reduced, but still positive sensitivity of 0.22. Under the through-the-crisis regime, the situation is very different, and we observe negative price-wise IR sensitivity. The sensitivities of both, the EMIG and

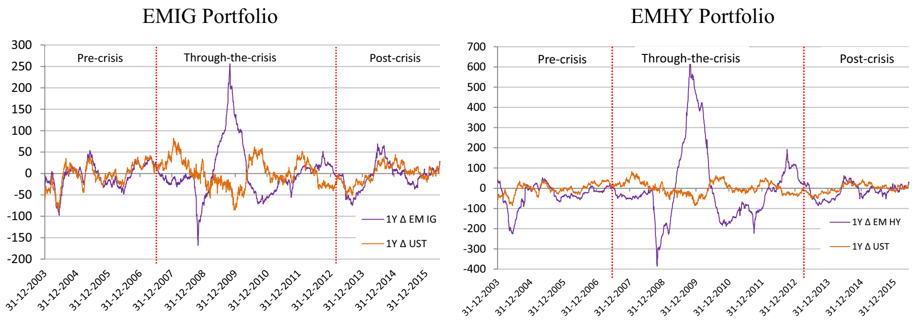

Fig. 6 Regimes of price-wise IR sensitivity of EM corporate bonds

EMHY portfolios price changes to the UST portfolio price changes are rather complex and vary along the period, see Fig. 6. Within the through-the-crisis regime period, the impact of the risk-free IR changes on EMIG and EMHY bonds is inverted, relative to the impact on UST.

Summarizing, for both, the EMIG and EMHY debt we observe alternating regimes of price-wise IR sensitivity, positive sensitivities during the pre-crisis and post-crisis regimes and negative sensitivities during the through-the-crisis regime. In other words, for both EMIG and EMHY debt, we evidence a duality of price-wise IR sensitivity.

4.1.2 Negative/positive sensitivities and responses of credit spreads to risk-free rates

Negative responses of credit spread to risk-free rates are especially well evidenced during the through-the-crisis regime. Under this regime, the amplitude of the credit spread narrowing (widening) is even superior to the amplitude of the increase (decrease) of the risk-free IR. We infer this from the fact that during this period we observe negative price-wise sensitivity for both, EMIG and EMHY bonds. Therefore, it means that the yields of risky and risk-free assets move in opposite directions. As for HY EM bonds the amplitude of the negative price-wise sensitivity is augmented while for IG EM bonds it is dumped. Thus, for the through-the-crisis regime we evidence that HY bonds show a more negative relation of credit spreads to interest rates. Only for this period, our results corroborate with the findings of Dupoyet et al. (2018) who report that HY bonds show more negative relation of credit spreads to interest rates, than IG bonds do. Note, that for the pre-crisis period our results contradict to the findings of Dupoyet et al. (2018) as we do not observe any negative relation of credit spreads to interest rates but evidence the null response of spreads to rates for both EMIG and EMHY portfolios.

On the other hand, our results for through-the-crisis period for EMIG portfolios deeply contradict to the findings of Boulkeroua and Stark (2013), who, not differentiating between distinct regimes, conclude for positive average sensitivity of BBB-rated bonds.

However, conceptually, our findings go far beyond the statement above. We show that it is very important to relate the observed sensitivities to the general risk-on/risk-off regime of the markets, as it could influence the sign, i.e. direction, and the strength of IR sensitivities. For example, during the second half of 2014 (within the “new normal” post-crisis period) we observe an average price-wise IR sensitivity of the EMHY portfolio of 1.52 to 1; see Table 3. Hence, for certain periods even within the normal regimes, the increases (decreases) in risk-free rates could worsen (improve) the creditworthiness of issuers. Additionally, as per Fig. 5, for the EMHY case, we also observe a few intervals of both, IR increases and decreases, with positive sensitivities above 1 within the through-the-crisis period.

Figure 5 also indicates that for the EMIG case, within the through-the-crisis period, positive sensitivities above 1 are observed only for periods of increases in risk-free rates, meaning that the increases in risk-free rates could worsen the creditworthiness of EMIG issuers. At the same time, an improvement in the creditworthiness of EMIG issuers due to eventual decreases in risk-free rates usually is unlikely. Under normal conditions, see Fig. 5, the situation is different. For both, the EMIG and EMHY case, several intervals of IR increases and decreases, with positive sensitivities above 1, are observed. Once again, it is worth noting that, as it is discussed in Sect. 4.1.1, for both EMHY and EMIG we observe average positive price-wise sensitivities under the pre-crisis and post-crisis regimes and average negative price-wise sensitivities under the through-the-crisis regime. Thus, for both types of analyzed EM corporates we evidence a duality of price-wise IR sensitivity, meaning that the responses of spreads to changes in risk-free rates are of a dual nature.

4.2 IR sensitivity of EM bond portfolios in relation to phases of the business cycle

Our empirical observations of EM debt price-wise IR sensitivity allow us to explain the origins of positive and negative sensitivity and link them to different phases of the cycle. The novelty of our approach resides in the fact that we ascribe positive price-wise IR sensitivities to "normal" regime of sustainable economic growth, while we attribute negative price-wise IR sensitivities to the two phases characterized by distressed economic conjunctures, both the recessional downturn and healing bounce-back recovery.

4.2.1 "Normal" regime

Under normal economic conditions (pre-crisis and post-crisis periods), the average price-wise sensitivity of EM corporate bond portfolios to UST portfolios is positive. It implies that changes in the risk-free rates are mirrored by the EM bond yields. For the pre-crisis period, the amplitude of yield changes remains equal to the amplitude of the moves in inducing risk-free rates. For the post-crisis period, the responses are attenuated. Thus, under the "normal" regimes, the ups and downs in risk-free rates do not influence the obligors´ creditworthiness. Eventual moderate gradual increases in the cost of funding are compensated by gradual increases in prices of goods and services. This was observed during the pre-crisis period, when price responses of both EMIG and EMHY corporate bonds were related to inducing price moves of UST approximately as 1 to 1. However, under the post-crisis regime, on average, the price changes of the UST portfolios are not passed through to EM portfolios entirely, as they result in the responses of reduced amplitude.

In other words, average sensitivities of approximately 1 to 1 mean that market participants interpret the creditworthiness of the issuers as not depending on the risk-free IR, and hence the present value of securities of different credit quality in fact is affected in the very same way, through the discount factor. All market participants follow the risk-free IR behavior. During the pre-crisis period, the level of the US government bonds yield curve was in the center of bond investors´ attention. Thus, under this regime investors are focused on IR and not so much on the idiosyncratic credit quality of issuers.

We posit that the post-crisis regime is positioned somewhere in-between the fully recovered phase with positive IR sensitivities, and the through-the-crisis regime, with negative IR sensitivities. Still, in general, this regime is closer to fully recovered than to the distressed conditions, as this post-crisis regime is characterized by positive price-wise IR sensitivities. Moving from significantly negative to significantly positive IR sensitivities, we reach close to insensitivity or attenuated positive IR sensitivity. The sensitivity ratio averaged over this period is found to be 0.58 to 1 for EMIG and 0.22 to 1 for EMHY bond portfolios. Thus, we conclude that the creditworthiness of issuers is only partially improved by the increase in risk-free rates. The stronger are idiosyncratic factors (EMHY), the more insensitive is the portfolio under these post-crisis conditions to changes in risk-free rates.

Concluding this topic, we attribute positive price-wise IR sensitivity to periods of normal economic conditions characterized by moderate sustainable growth rates, which do not result from any asset bubble causing inflated prices. Analyzing EM corporate bond portfolios covering diversified geographies, our considerations implicitly deal with economic growth on a global scale. However, our economic interpretation of positive IR sensitivity being associated with normal growth conditions seems to remain valid for EMIG and EMHY assets in isolated economies selected on a regional and/or country basis.

4.2.2 "Distressed" regime

This subsection presents the analysis of the distressed economic conditions that result in negative price-wise sensitivities of EM portfolios. We consider that the "distressed" through-the-crisis regime spreads over two successive periods: the recessional downturn causing economy deterioration and the subsequent recovery of economic conditions. Transposing this to the recent global financial crisis, those two phases are the development of the crisis and the recuperation of economic conditions from the lowest recession levels. In other words, the "distressed" regime could be interpreted as a slump to the economic bottom caused by a bursting bubble and then the recovery from depression to expansion, i.e. back to the normal economic conditions, allowing for future economic growth.

During crises, market participants usually interpret the increases in risk-free IR as recovery indicators evidencing improvement in economic conditions. Thus, negative average IR sensitivities are observed, as increases in risk-free rates are judged to reduce the risk of default. The lower creditworthiness of an issuer, the stronger is the narrowing of the issuer's credit spread. This is consistent with the fact that, for the through-the-crisis period, the IR sensitivity is -0.53 for the EMIG portfolio, and is -1.76 for the EMHY portfolio.

Such "distressed" regime is not an idiosyncrasy-focused state of markets as usually it is characterized by "risk-off" attitude of bond investors, meaning that there is no risk appetite in the market. No one seems to be interested in the idiosyncratic features of issuers and all attention is centered on the risk-free IR behavior. One of the main drivers during the "distressed" period was a level of UST yield in the mid to long term. Credit spreads depended strongly on the level of risk-free rates. Changes in risk free-rates were negatively correlated with credit spreads. "Anti-sensitivities" were observed.

4.3 Additional considerations

It is quite intuitive that interest rates for different types of bonds are not expected to change by the same degree in response to moves in risk-free interest rates. In this way, our results corroborate with a part of the findings of Boulkeroua and Stark (2013), related to the fact that IR sensitivities vary across rating categories. In our case for the EMHY portfolios, we observe weaker positive sensitivities under the "normal" regime and stronger negative sensitivities under the "distressed" regime than for the EMIG portfolios.

At this point, we approach the issue, whether or not it makes sense from an economic perspective to hedge EM corporate USD-denominated debt by short positions in UST securities. Or, perhaps, by more or less equivalent derivative instruments being they pay-fixed receive-float interest rate swaps. Our findings indicate that such hedge is eventually justified only under normal economic conditions, corresponding to the periods of rather moderate growth rates. On the other hand, as our research suggests, while implementing hedge strategies against downside risk, especially in times of financial distress, it is advisable to eventually analyze the possibility of augmenting exposure to IR risk, for example, by going long on UST or contracting pay-float receive fixed interest rate swaps.

Additionally, a sort of a stability mechanism fund could be implemented. Such fund could potentially accommodate the excess or above the hurdle returns of EM corporate bond portfolio with a purpose of investing in UST securities, allowing to withstand challenges of recessions and other financial distresses. The longer is the stability of economic conditions, the closer is the next slump, and so a bigger reallocation of investment into a stability mechanism fund would be advisable. The details of how such fund could be engineered and operationalized rest outside of the scope of this paper.

Resuming our argument, the results clearly indicate that hedge strategies targeting IR risk and downside risk should not be mechanical, but rather ought to represent dynamic processes aligned with phases of the business cycle.

5 Conclusions

We develop an innovative capital gains-based methodology aimed at investigating IR sensitivity of bond portfolios, based on a previous research by Gubareva and Borges (2017b). The novelty of our approach in the present paper resides in the conversion of the blended yield indices into average prices of the analyzed bond portfolios. The proposed framework is applied to assess IR sensitivity of EMIG and EMHY corporates.

As the investment horizon modeled here equals to one year, our research presents a promising potential for investigating IR sensitivity behavior from the medium to long run perspectives. While the relation between spreads and IR could serve only as an approximate guidance toward an impact on portfolios' value, our approach is focused at a straight-to-the-point quantification of the proper present value of the portfolios, i.e., the bottom line. From this perspective, our IR sensitivity assessment is meaningful from the point of view of portfolio management and risk mitigation, relative to mid- to long-term investments.

The historical span of our research covers the period 2004–2016, which enables us to assess IR sensitivity of assets during the development, apogee, and aftermath of the recent global financial crisis. Our results contrast with the results of previous empirical research and their theoretical interpretations. Previously, all the phases of the business cycle were hold accountable for negative responses of credit spreads to interest rates.

We evidence a dichotomy of IR sensitivity of bond portfolios, switching between positive and negative value ranges depending on an analyzed phase of the business cycle. "Normal" regime, corresponding to the pre-crisis and post-crisis periods, characterized by moderate growth rates, lead to such states of the world where changes in the present value of EM corporate bonds are positively related to variations in the present values of UST. Hence, capital gain-wise sensitivity is positive. Conversely, under the "distressed" regime, spread over recession and sharp early-cycle recovery periods, the changes in the present value of EM bonds are negatively related to the inducing moves in the present values of UST. In this case, IR sensitivity is negative. Therefore, a relevant insight is that the downside risk hedge should be based on a dynamic strategy that takes into consideration how the economy evolves through the different phases of the business cycle.

Thinking about avenues for further research, we propose that the applicability of our capital gain-focused approach for assessing IR sensitivity can be much wider than just to the EM corporate bond portfolios. Given the availability of blended yield or price indices, our approach can be applied to different fixed-income portfolios covering diverse economic sectors, geographies, and different credit qualities of obligors. Further research in this domain is highly desirable, as it potentially allows financial institutions to improve their portfolio management and risk assessment. Additionally, it provides relevant insights regarding the nature of IR sensitivity, which ought to be beneficial for enhancing financial stability and improving the efficiency of the financial system.

Appendix A: Robustness checks

This part of our research is dedicated to the robustness checks performed to certify the fairness and similarity of our results, which were obtained using different assumptions regarding the shape of the modeled yield curves. We assess whether our results are fairly robust by reshaping the UST and EM corporate yield term structures, i.e., we relax our model flat-curve assumption employed for simplicity reasons in our calculations, by using instead the assumption of linearly-sloped term structures for the analyzed risk-free and risky asset portfolios.

We present below a comparative analysis of the annual capital gain-wise sensitivities obtained under the different assumptions for the yield curve. The upward-sloping, i.e., positive slope curves are obtained by adopting the pro rata temporis interpolation of yield values between zero and 5Y point of the respective yield term structure, while the downward-sloping, i.e., negative-slope curves represent their reflections mirrored vertically through the 5Y yield level. They decay downwards with maturity, reaching a flat yield level at the 5Y point.

Table 4 shows the comparison between the UST capital gains, the EMIG capital gains, and sensitivity values obtained for the pre-crisis period for the three above-mentioned cases: (i) flat curve (taken from Table 1); (ii) upward-sloping curve, and; (iii) downward-sloping curve. The results for the two latter cases are specifically calculated for this robustness check exercise. As can be seen in Table 4, in the case of the pre-crisis period, both the upward-sloping and downward-sloping term structures result in similar outcomes to those obtained under the flat curves assumption. The average endurance-times-amplitude weighted sensitivities figures of 0.965 for the flat curve, 0.956 for the positive slope, and 0.969 for the negative slope, are remarkably similar for the reasons explained in Sect. 2 of the main body of this paper.

Table 5, relative to the through-the-crisis period, shows that both the upward-sloping and downward-sloping shapes of term structures result in quite similar outcomes to those obtained under the flat curves assumption. The average endurance-times-amplitude weighted sensitivities figures, −0.526 for flat curves, −0.537 for positive slope, and −0.514 for negative slope, are also approximately the same, similar to the situation observed for the pre-crisis period.

Table 6, relative to the post-crisis period, shows that both the upward-sloping and downward-sloping shapes of term structures once again result in similar outcomes to those obtained under the flat curves assumption. The average endurance-times-amplitude weighted sensitivities figures are, 0.575 for flat curves, 0.561 for positive slope, and 0.586 for negative slope—which are also in very close proximity to each other.

Table 7 provides a comparison between the endurance-times-amplitude weighted sensitivities averaged along the different phases for the three shapes of term structures discussed above.

Table 7 evidences the robustness of both our quantitative outcomes and qualitative conclusions, under different parameter choices. The signs of the sensitivities for all the three studied periods do not depend on the term-structure assumptions. The percentage differences in amplitude, i.e., in absolute value of sensitivity coefficient, always remain below the 2.5% mark. In summary, Table 7 shows that, subject to reasonable diverse assumptions, our conclusions remain robust across the three sub-periods.

Moreover, the advantage of our capital gains and yield-based approach is that it enables us to reach robust conclusions regarding the quantitative magnitude of IR sensitivities, even without having an exact knowledge of the yield term structures. In other words, these robustness checks corroborate that the proposed methodology enables robust conclusions to be drawn concerning the capital gains and IR sensitivity of assets under diverse model choices of term structure profiles.

Appendix B: Clustering approach to split the pre-crisis, crisis, and post-crisis periods

A statistical analysis, similar to structural break tests, is performed to study the homogeneity of the observed sample of the 71 capital-gain wise sensitivities (see Tables 1, 2, 3 of the main body of the paper), which correspond to the 71 identified time-intervals, grouped in their turn into three sub periods: pre-crisis, through-the-crisis, and post-crisis. Instead of an arbitrary choice of the sub-periods, we solve the problem of identifying the regime switching, i.e., splitting the whole sample into the three above-mentioned subsamples, by employing a clustering approach, based on minimization of standard deviation (see Gubareva and Borges 2016).

First, we divide the whole sample into two subsamples, using a clustering approach, based on standard deviation minimization. In other words, we arrange the sensitivities in a chronological order and vary a number of major UST capital gain moves in the subsamples from 1 to 70, i.e., we vary the final date of one trial subsample, which is, in effect, just the initial date of the other subsample. For each of the 70 divisions of the whole spectrum of arrays, the combined standard deviation of sensitivities is calculated in such a way that, instead of calculating the whole sample average, the respective averages of sub-arrays are used to calculate the deviation of each sensitivity value according to its positioning in one of the sub-arrays.

Figure 7 shows the combined standard deviation as a function of the date used to separate time interval into two trial sub-intervals. The behavior of the combined standard deviation shown in Fig. 7 presents the two major local minima, whose dates, namely July 13, 2007 and April 03, 2013, separate the whole sample into the three most homogeneous subsamples.

As a sanity check, we perform the refined calculations of the standard deviation combined from the three sample-as-stand-alone standard deviation values. For instance, as the sub-array border between the first and the second sub-arrays occurs on July 13, 2007, changing the quantity of the constituent time intervals between the first and the second sub-arrays in − 1, 0, and 1, results, respectively, in the following combined standard deviation values: 1.30, 1.29, and 1.30. Similarly, as the sub-array border between the second and the third sub-arrays occurs on April 03, 2013, changing the quantity of the constituent time intervals between the second and the third sub-arrays in − 1, 0, and 1, results, respectively, in the following combined standard deviation values: 1.31, 1.29, and 1.30. Thus, the three statistically selected sub-arrays, with sub-array borders on July 13, 2007 and April 03, 2013 are reconfirmed, which, in fact, represent the most homogeneous sub-samples of sensitivity values, resulting in the minimum possible combined standard deviation of 1.29.

Table 4 Pre-crisis sensitivity figures under different assumptions for the yield curve

Date	Endurance window (days) (A)	Positive slope			Negative slope			Flat curves		
		Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B
31-12-2003										
13-01-2004	13	31.98	20.49	0.64	33.33	22.13	0.66	32.69	21.39	0.65
03-03-2004	50	−16.40	−16.64	1.01	−18.14	−18.66	1.03	−17.31	−17.74	1.03
22-03-2004	19	42.26	28.82	0.68	43.82	31.05	0.71	43.08	30.05	0.70
14-06-2004	84	−79.87	−96.24	1.21	−86.22	−107.12	1.24	−83.17	−102.16	1.23
31-08-2004	78	120.39	104.71	0.87	124.26	110.16	0.89	122.43	107.74	0.88
30-09-2004	30	−37.97	−15.49	0.41	−39.55	−16.94	0.43	−38.80	−16.28	0.42
29-10-2004	29	24.50	17.18	0.70	25.59	18.24	0.71	25.07	17.77	0.71
11-01-2005	74	−32.90	−16.20	0.49	−34.49	−18.05	0.52	−33.74	−17.21	0.51
08-02-2005	28	11.33	20.45	1.81	11.65	21.78	1.87	11.50	21.18	1.84
16-03-2005	36	−38.28	−34.58	0.90	−40.50	−37.75	0.93	−39.45	−36.30	0.92
24-05-2005	69	70.03	56.24	0.80	73.22	60.67	0.83	71.71	58.67	0.82
03-11-2005	163	−58.99	−69.52	1.18	−61.71	−72.27	1.17	−60.44	−71.07	1.18
24-03-2006	141	38.30	26.58	0.69	39.88	27.50	0.69	39.13	27.10	0.69
26-06-2006	94	−40.48	−39.05	0.96	−43.93	−44.42	1.01	−42.31	−41.96	0.99
04-12-2006	161	67.93	77.25	1.14	71.95	80.87	1.12	70.08	79.27	1.13
10-01-2007	37	−19.85	−14.50	0.73	−20.78	−15.43	0.74	−20.35	−15.01	0.74
25-04-2007	105	21.93	19.59	0.89	24.46	22.01	0.90	23.27	20.91	0.90
04-06-2007	40	−25.06	−13.47	0.54	−25.69	−13.55	0.53	−25.41	−13.53	0.53
27-06-2007	23	5.24	1.86	0.35	6.10	2.69	0.44	5.70	2.31	0.41
13-07-2007	16	−13.81	−12.67	0.92	−13.07	−14.38	1.10	−12.89	−14.13	1.10

Table 5 Through-the-crisis sensitivity different assumptions for the yield curve

Date	Endurance window (days) (A)	Positive slope			Negative slope			Flat curves		
		Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B
13-07-2007										
26-11-2007	136	41.02	−34.04	−0.83	45.92	−35.76	−0.78	43.60	−35.00	−0.80
26-12-2007	30	−25.68	−1.89	0.07	−26.77	−2.44	0.09	−26.26	−2.19	0.08
22-01-2008	27	54.24	13.62	0.25	58.31	14.61	0.25	56.38	14.17	0.25
27-02-2008	36	−38.74	−19.33	0.50	−40.05	−21.10	0.53	−39.44	−20.30	0.51
06-06-2008	100	−6.62	29.18	−4.41	−4.83	29.68	−6.14	−5.67	29.48	−5.19
01-07-2008	25	−20.38	−10.55	0.52	−21.07	−11.85	0.56	−20.75	−11.26	0.54
08-09-2008	69	−29.26	2.56	−0.09	−30.33	1.78	−0.06	−29.85	2.14	−0.07
07-10-2008	29	34.08	−40.55	−1.19	36.24	−44.79	−1.24	35.21	−42.91	−1.22
29-10-2008	22	−28.63	−107.51	3.75	−30.00	−118.37	3.95	−29.36	−113.74	3.87
24-11-2008	26	−15.55	56.21	−3.62	−16.86	58.47	−3.47	−16.25	57.61	−3.54
16-12-2008	22	55.97	35.73	0.64	58.75	37.09	0.63	57.41	36.56	0.64
17-03-2009	91	−88.24	34.41	−0.39	−93.78	31.87	−0.34	−91.12	33.09	−0.36
27-04-2009	41	56.67	48.07	0.85	59.18	51.07	0.86	57.98	49.81	0.86
08-06-2009	42	−46.40	35.82	−0.77	−48.39	38.54	−0.80	−47.43	37.37	−0.79
22-07-2009	44	41.12	33.32	0.81	42.33	36.58	0.86	41.75	35.13	0.84
29-10-2009	99	−24.81	162.78	−6.56	−27.03	183.72	−6.80	−25.97	174.54	−6.72
30-12-2009	62	−52.49	−125.99	2.40	−55.86	−126.14	2.26	−54.23	−126.40	2.33
10-08-2010	223	145.95	−174.92	−1.20	149.03	−170.73	−1.15	147.54	−173.05	−1.17
10-09-2010	31	−29.06	−22.41	0.77	−29.95	−24.06	0.80	−29.52	−23.33	0.79
04-11-2010	55	25.71	16.28	0.63	26.74	15.18	0.57	26.23	15.70	0.60
17-11-2010	13	−32.01	−19.11	0.60	−32.93	−21.50	0.65	−32.48	−20.40	0.63
01-07-2011	226	−53.11	57.16	−1.08	−53.44	50.27	−0.94	−53.29	53.55	−1.00
09-09-2011	70	40.55	4.16	0.10	41.23	2.62	0.06	40.89	3.34	0.08

Table 5 (continued)

Date	Endurance window (days) (A)	Positive slope			Negative slope			Flat curves		
		Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B
12-10-2011	33	−36.44	−27.30	0.75	−37.65	−30.11	0.80	−37.06	−28.81	0.78
14-02-2012	125	70.91	57.08	0.80	72.96	59.78	0.82	71.96	58.55	0.81
19-03-2012	34	−42.23	−4.46	0.11	−43.08	−4.70	0.11	−42.67	−4.59	0.11
10-04-2012	22	31.55	3.25	0.10	32.35	3.55	0.11	31.96	3.41	0.11
31-05-2012	51	−29.24	−13.92	0.48	−29.96	−14.85	0.50	−29.62	−14.42	0.49
03-10-2012	125	−33.37	49.57	−1.49	−34.23	53.84	−1.57	−33.81	51.86	−1.53
29-01-2013	118	−15.63	−44.17	2.83	−16.12	−45.12	2.80	−15.88	−44.72	2.82
03-04-2013	64	37.14	−12.01	−0.32	37.49	−12.69	−0.34	37.32	−12.37	−0.33

Table 6 Post-crisis sensitivity figures different assumptions for the yield curve

Date	Endurance window (days) (A)	Positive slope			Negative slope			Flat curves		
		Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B	Δ in UST 1Y price change (B)	Δ in EM IG 1Y price change (C)	Sensitivity D = C/B
03-04-2013										
05-07-2013	93	−49.42	−50.78	1.03	−50.52	−53.99	1.07	−49.98	−52.51	1.05
08-08-2013	34	23.33	−1.94	−0.08	23.41	−2.86	−0.12	23.37	−2.42	−0.10
05-09-2013	28	−21.29	−13.35	0.63	−21.72	−14.86	0.68	−21.51	−14.16	0.66
24-10-2013	49	39.61	28.87	0.73	39.93	28.83	0.72	39.78	28.88	0.73
27-12-2013	64	−17.65	6.07	−0.34	−18.22	4.40	−0.24	−17.94	5.20	−0.29
03-02-2014	38	26.30	17.02	0.65	26.55	16.93	0.64	26.43	16.98	0.64
03-04-2014	59	−18.57	17.72	−0.95	−19.18	17.48	−0.91	−18.88	17.61	−0.93
25-06-2014	83	51.63	70.76	1.37	52.01	73.98	1.42	51.83	72.50	1.40
30-07-2014	35	−12.24	−18.81	1.54	−12.37	−19.34	1.56	−12.31	−19.10	1.55
05-09-2014	37	21.25	17.13	0.81	21.71	19.15	0.88	21.49	18.21	0.85
06-11-2014	62	−27.58	−40.02	1.45	−27.80	−40.92	1.47	−27.69	−40.52	1.46
15-01-2015	70	33.30	−16.90	−0.51	34.34	−16.63	−0.48	33.83	−16.77	−0.50
03-03-2015	47	−36.13	−7.44	0.21	−36.72	−7.15	0.19	−36.43	−7.29	0.20
02-04-2015	30	23.59	5.46	0.23	24.31	6.28	0.26	23.96	5.90	0.25
18-08-2015	138	−33.20	−33.26	1.00	−33.37	−35.49	1.06	−33.29	−34.45	1.03
02-10-2015	45	17.86	15.32	0.86	18.40	15.28	0.83	18.14	15.31	0.84
14-01-2016	104	−37.80	5.32	−0.14	−38.66	4.93	−0.13	−38.24	5.12	−0.13
10-02-2016	27	37.53	8.21	0.22	38.39	8.52	0.22	37.97	8.38	0.22
25-04-2016	75	−23.23	1.71	−0.07	−23.78	1.54	−0.06	−23.51	1.63	−0.07
27-06-2016	63	37.45	25.35	0.68	38.41	27.12	0.71	37.94	26.30	0.69

Table 7 Average sensitivity figures per phases of the cycle under different assumptions

	Pre-crisis period	Through-the-crisis period	Post-crisis period
Average sensitivity, flat curves (A)	0.965	−0.526	0.575
Average sensitivity, positive slope (B)	0.956	−0.537	0.561
Average sensitivity, negative slope (C)	0.969	−0.514	0.586
Δ Amplitude positive (D = ABS (B) − ABS (A))	−0.009	0.011	−0.014
Δ Amplitude negative (E = ABS (C − ABS (A))	0.004	−0.012	0.011
Δ Amplitude positive (%) (F = D/ABS (A))	−0.93%	2.09%	−2.43%
Δ Amplitude negative (%) G = E/ABS (A))	0.41%	−2.28%	1.91%

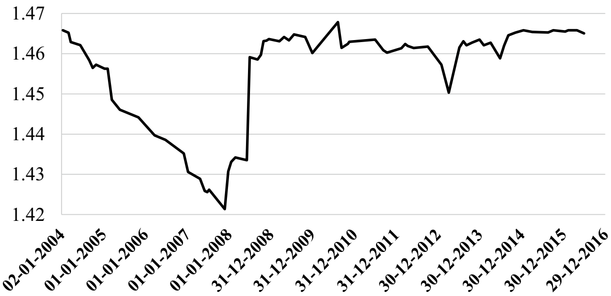

Fig. 7 Standard deviation of sensitivities as a function of a date separating the two-trial sub-arrays

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