WHAT CAN METALS OFFER TO BOND INVESTORS?

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Master en Banca y Finanzas Cuantitativas

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Abstract

The recent sovereign debt crisis has created a need to manage risk and improve portfolio performance for bond investors. In this work, we aim to determine if metals are good instruments for those purposes. Using a sample of 13 bonds and 10 metals, we perform various analysis using econometric tools to find that metals are not good hedges for sovereign bonds. We also show that some metals, especially palladium and copper, can be good safe havens for countries with no serious debt issues. Finally, we find that metals are good diversifying tools for bond portfolios.

1. INTRODUCTION

Gold has traditionally been one of the most used commodities for financial purposes, probably because of its past as a currency. It is widely considered to be a safe haven asset, but also to perform several other roles when used as an investment vehicle. This use of gold has also sparked the utilization of other metals as risk management and diversifying tools.

Several works have studied the use of metals in stock and commodity portfolios. **Connover et al. (2009)** find that adding different weights of precious metals to a US equity portfolio improves its performance. **Chua et al. (1989)** and **Draper et al. (2006)** show that investments in metals and other commodities improve stock portfolios via diversification.

The effects of metals on bond markets have not been widely analyzed, mainly because bonds have always been considered safe investments where hedging is not as important as in stock markets. However, in a period where several countries have suffered profound sovereign debt crises the need to improve bond portfolios has arisen. **Jaffe (1989)** finds that in addition to improving stock portfolios, gold and gold stocks also improve bond portfolios. More recently, **Baur and McDermott (2010)** and **Baur and Lucey (2010)** use regression analysis to study the usefulness of gold as a hedge and safe haven for stocks and bonds; while **Agyei-Ampomah et al. (2013)** extend their work to include several precious and industrial metals, but focusing only on bonds. These studies find that both gold and some other metals are good hedges for some bonds.

In this work, we aim to perform a wide analysis of the capacity of metals to work as hedging vehicles, safe haven assets and diversifying tools for bonds. We focus on sovereign bonds across

Europe (Belgium, Finland, France, Greece, Germany, Ireland, Italy, Netherlands, Portugal and Spain; as well as the EMU Benchmark bond), the US and UK; and compare ten metals (Gold, Silver, Platinum, Palladium, Aluminium, Copper, Lead, Nickel, Tin and Zinc).

The study provides three main findings. First, we find that metals are not good hedging instruments for bonds. Second, we show that metals are good safe havens for countries with good credit ratings, but not for countries with debt issues. Last, we find that allocating even as little as 5% of a bond portfolio to an investment in metals is enough to improve the portfolio results in the mean-variance sense.

The work is structured as follows. Section 2 contains a brief explanation of the DCC-GARCH model, used in the following sections. Information regarding the data and descriptive statistics can be found in section 3. In section 4 we analyze the hedge and safe haven properties of metals using three different methodologies: regression analysis, variance reduction and post-shock performance. Section 5 contains the analysis on metals as diversification tools and section 6 offers our concluding remarks.

2. THE DCC-GARCH MODEL

The Dynamic Conditional Correlation GARCH (**Engle, 2002**) is one of many models in the conditional variance and correlations class. It estimates a model for the covariance matrix of several assets which is conditional to its past. The main advantage of this model is that it is easy to estimate due to the relatively low number of parameters while allowing the covariances to be time-varying.

The model is estimated in two steps. In the first one, a GARCH model is estimated for each series of returns. In this work we estimate a GARCH(1,1) model assuming the returns have zero mean:

$$\sigma_{i,t}^2 = \omega_i + \alpha_i r_{i,t-1}^2 + \beta_i \sigma_{i,t-1}^2$$

From this estimation, the standardized residuals are obtained for each series:

$$\varepsilon_{i,t} = \frac{r_{i,t}}{\sigma_{i,t}}$$

The DCC-GARCH model assumes that the covariance matrix H_t can be decomposed into two matrices: a standard deviation matrix D_t (obtained from the univariate GARCH models previously estimated) and a correlation matrix R_t. Note that both this matrices are time-varying.

$$H_t = D_t R_t D_t$$

$$D_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & & \vdots \\ \vdots & & \ddots & \vdots \\ 0 & \cdots & \cdots & \sigma_{n,t} \end{bmatrix}$$

$$R_t = \begin{bmatrix} 1 & \rho_{1,2,t} & \cdots & \cdots & \rho_{1,n,t} \\ \rho_{1,2,t} & 1 & & & \rho_{2,n,t} \\ \vdots & & \ddots & & \vdots \\ \vdots & & & 1 & \rho_{n-1,n,t} \\ \rho_{1,n,t} & \rho_{2,n,t} & \cdots & \rho_{n-1,n,t} & 1 \end{bmatrix}$$

These correlation coefficients are obtained from auxiliary variables:

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,i,t} q_{j,j,t}}}$$

Which, in the DCC(1,1)-GARCH model are calculated in the following way:

$$q_{i,j,t} = \bar{\rho}_{i,j} + \alpha(\epsilon_{i,t-1}\epsilon_{j,t-1} - \bar{\rho}_{i,j}) + \beta(q_{i,j,t-1} - \bar{\rho}_{i,j})$$

Where $\bar{\rho}_{i,j}$ is the unconditional correlation between assets *i* and *j*. Both the univariate GARCH models and the DCC-GARCH model are estimated by maximum likelihood.

Note that α and β are the same for any pair of assets. Thus, the DCC-GARCH model only estimates three parameters for each series plus two for the dynamic correlations, independently of how many series are included in the problem. This greatly reduces the number of parameters to be estimated which makes this model very useful for dealing with many assets, at the cost of imposing a very strict restriction over the model.

3. DATA AND DESCRIPTIVE STATISTICS

Daily data has been collected for the closing US dollar prices of ten metals and for the return index values for thirteen 10-year benchmark bonds. Additionally, we also collect data for the US dollar to pound exchange rate and the US dollar to euro exchange rate. Finally, we also use data on the 10-year US T-Note Futures and the EUREX Euro-Bund Futures.

Data on metals is denominated in US dollars, while data on sovereign bonds is denominated in the local currency. Using the exchange rates, we calculate the prices of metals in euros and pounds. In section 4, returns on metals are used in the same currency as the bond (pound for the UK bond, no transformation for the US bond and euro for the rest). For chapter 5, we also calculate the prices of the US and UK bonds in euros so every asset is denominated in the same currency.

Our sample starts in July 1993 due to the lack of data available for Nickel before that. We collect data until April 2014. Note that since data for some other series starts later, some analysis is not done for the full period. Data for the Greek and EMU benchmark bonds do not start until 1999, and the EU bond future has no available data before October 1998. All data has been obtained from the DataStream database.

Table 1 reports the descriptive statistics of the returns on bonds and metals in their original currency. Except for aluminium and zinc, metals exhibit higher average returns than bonds. Palladium and lead have the higher average returns, while gold is the metal with the lowest volatility. Bonds present a standard deviation much lower than that of metals. Countries that have had greater debt issues, such as Spain, Portugal or Italy, present higher average returns and volatility. The US bond presents the lowest average return if we exclude Greece, which has a negative average return.

	Mean	Minimum	Maximum	Standard Deviation	Observations
Gold	0.00019199	-0.10059284	0.06847271	0.01008671	5403
Silver	0.00022358	-0.17987155	0.17000966	0.01963334	5403
Platinum	0.00020437	-0.18115800	0.11797745	0.01409583	5403
Palladium	0.00028987	-0.16822371	0.15637781	0.02079646	5403
Aluminium	0.00004435	-0.07484363	0.05626342	0.01324642	5403
Copper	0.00020008	-0.11161697	0.11280667	0.01652625	5403
Lead	0.00027540	-0.13082543	0.12798577	0.01950265	5403
Nickel	0.00019383	-0.18020829	0.12835636	0.02201789	5403
Tin	0.00025526	-0.10843471	0.17664596	0.01618927	5403
Zinc	0.00010877	-0.13366454	0.08703310	0.01756012	5403
Belgium	0.00009009	-0.02669317	0.02345043	0.00356468	5403
EMU	0.00006430	-0.01523868	0.02247527	0.00347796	3980
Finland	0.00009941	-0.04497449	0.02952490	0.00361909	5403
France	0.00008355	-0.02016172	0.02304769	0.00361981	5403
Germany	0.00008109	-0.02525515	0.02247333	0.00345817	5403
Greece	-0.00008979	-0.21668813	0.29227644	0.01317580	3917
Ireland	0.00007112	-0.05087588	0.08353987	0.00498526	5403
Italy	0.00011354	-0.03687780	0.05929938	0.00460951	5403
Netherlands	0.00008617	-0.01809818	0.01866386	0.00329641	5403
Portugal	0.00011929	-0.11627123	0.11364801	0.00659986	5395
Spain	0.00013735	-0.02674769	0.06503896	0.00435534	5404
UK	0.00006788	-0.02364858	0.02418660	0.00405644	5404
US	0.00003360	-0.02875560	0.04052948	0.00473549	5404

Table 1: Descriptive statistics for the return in their respective currency on metals and bonds.

In tables 2, 3 and 4 we show the correlations between metals, between bonds and between bonds and metals, respectively. First, we observe that metals co-move, and that their positive correlation is stronger among their own group (precious metals have higher correlation coefficients with other precious metals than with industrial metals, and vice versa), **Agyei-Ampomah et al. (2013)**. Bonds also co-move, and present higher correlation than bonds. If we divide every bond in two groups (countries that have suffered serious debt crises and countries that have not), they also present an effect similar to metals in that they have stronger correlations with their own group.

	Gold	Silver	Platinum	Palladium	Aluminium	Copper	Lead	Nickel	Tin	Zinc
Gold	1									
Silver	0,41	1								
Platinum	0.4131	0.4488	1							
Palladium	0.2766	0.3627	0.5652	1						
Aluminium	0.2442	0.1344	0.2180	0.1792	1					
Copper	0.2568	0.1332	0.2098	0.1791	0.6541	1				
Lead	0.1907	0.1441	0.1880	0.1695	0.5049	0.5630	1			
Nickel	0.1746	0.1087	0.1574	0.1427	0.5056	0.5613	0.4736	1		
Tin	0.2086	0.1661	0.2039	0.1719	0.4434	0.4777	0.4280	0.4373	1	
Zinc	0.2409	0.1332	0.2009	0.1760	0.6092	0.6582	0.6200	0.5298	0.4480	1

Table 2: Correlations between metals

	Belgium	EMU	Finland	France	Germany	Greece	Ireland	Italy	Netherlands	Portugal	Spain	UK	US
Belgium	1												
EMU	0.6937	1											
Finland	0.7111	0.9266	1										
France	0.7508	0.7744	0.6860	1									
Germany	0.7078	0.9856	0.8051	0.7087	1								
Greece	0.2283	0.0423	0.0880	0.1344	0.0419	1							
Ireland	0.5046	0.3067	0.3879	0.4200	0.3336	0.3392	1						
Italy	0.6146	0.3288	0.4311	0.4780	0.4107	0.2757	0.4353	1					
Netherlands	0.7451	0.8898	0.7987	0.7790	0.8058	0.0862	0.4706	0.3999	1				
Portugal	0.3553	0.1868	0.2504	0.2684	0.2275	0.3581	0.5191	0.3751	0.2709	1			
Spain	0.6003	0.3748	0.4227	0.4658	0.4166	0.3167	0.4544	0.7156	0.4040	0.4003	1		
UK	0.2931	0.4391	0.4021	0.3603	0.3817	-0.0143	0.2245	0.0996	0.4705	0.0896	0.0770	1	
US	0.1266	0.3262	0.2663	0.2207	0.2714	-0.0646	0.0594	-0.0139	0.3055	0.0127	-0.0256	0.5119	1

Table 3: Correlations between bonds

	Gold	Silver	Platinum	Palladium	Aluminium	Copper	Lead	Nickel	Tin	Zinc
Belgium	0.0159	-0.0345	-0.0503	-0.0477	-0.0906	-0.1080	-0.0825	-0.0762	-0.0770	-0.0823
EMU	0.0943	-0.0160	-0.0618	-0.0888	-0.1610	-0.2082	-0.1696	-0.1398	-0.1365	-0.1596
Finland	0.0690	-0.0230	-0.0328	-0.0577	-0.1011	-0.1402	-0.1148	-0.0942	-0.0916	-0.1045
France	0.0549	-0.0277	-0.0332	-0.0460	-0.1076	-0.1255	-0.1053	-0.0907	-0.0792	-0.0963
Germany	0.0779	-0.0275	-0.0550	-0.0774	-0.1348	-0.1655	-0.1404	-0.1178	-0.1114	-0.1345
Greece	-0.0432	-0.0102	-0.0011	0.0088	0.0140	0.0003	0.0059	0.0052	-0.0055	0.0005
Ireland	-0.0343	-0.0574	-0.0435	-0.0225	-0.0457	-0.0743	-0.0537	-0.0385	-0.0646	-0.0462
Italy	-0.0238	-0.0374	-0.0447	-0.0269	-0.0490	-0.0565	-0.0523	-0.0381	-0.0436	-0.0424
Netherlands	0.0665	-0.0203	-0.0438	-0.0594	-0.1203	-0.1541	-0.1344	-0.1090	-0.1018	-0.1160
Portugal	-0.0320	-0.0210	-0.0203	0.0002	-0.0315	-0.0427	-0.0336	-0.0211	-0.0354	-0.0259
Spain	-0.0218	-0.0259	-0.0391	-0.0211	-0.0679	-0.0836	-0.0719	-0.0599	-0.0666	-0.0626
UK	0.1982	0.0517	0.0991	0.0491	0.0851	0.0471	0.0291	0.0254	0.0714	0.0488
US	0.2115	0.0450	0.1377	0.0317	0.0994	0.0176	0.0005	0.0221	0.0791	0.0471

Table 4: Correlations between bonds and metals

Looking at the correlations between metals and bonds, we find that these assets move in opposite directions, which suggests the possibility that metals could serve as hedging instruments and diversification tools for bonds. While gold shows positive correlation with bonds from countries with no serious debt issues, the rest of metals are negatively correlated to every country. The exceptions for this are the UK and the US, which are positively correlated to every metal, and Greece, that is positively correlated to palladium, aluminium, copper, lead, nickel and zinc. For the other countries, the negative correlation is stronger with industrial metals, especially aluminium, copper and lead, which suggests that these commodities may be a better hedging instrument than their precious counterparts.

4. HEDGE AND SAFE HAVEN

In this first part of the work, we study how the chosen metals perform as hedges and safe havens for the bonds. We do so using three different methodologies. First, we perform a regression analysis and look at the coefficients obtained . After that, we use the DCC-GARCH model to design a hedging strategy for a bond using a metal; and observe how useful they are in reducing the variance of the investment. Finally, we take a look at how an investment in metals can help recover loses from bond crashes analyzing the post-shock performance of bond and metal portfolios.

Regression analysis

The theoretical argument for the regression analysis is based on the following definitions, first presented by **Baur and Lucey (2010)**, and later extended by **Baur and McDermott (2010)**:

Hedge: A metal is a hedge when it is negatively correlated (strong hedge) or uncorrelated (weak hedge) with a bond on average.

Save haven: A metal is a safe haven when it is negatively correlated (strong safe haven) or uncorrelated (weak safe haven) with a bond in periods of large bond losses.

Note that while the hedge property requires the negative correlation (or uncorrelation) to hold on average for the whole sample, the safe haven property only requires that to happen during certain periods. Thus, a metal can be a hedge but not a safe haven if it is negatively correlated on average during the whole sample but co-moves with the bond when there is market turmoil. Similarly, a metal can be a safe haven but not a hedge.

To test which metals hold to the definitions for which bonds, we estimate the following model:

$$R_{M,t} = \alpha + \delta_0 R_{B,t} + \delta_1 D_{1,t} + \delta_2 D_{5,t} + \delta_3 D_{10,t} + \epsilon_t$$

where $R_{M,t}$ is the return of the metal, $R_{B,t}$ the return of the bond, ε_t the error term and $D1_t$, $D5_t$ y $D10_t$ are $R_{B,t}$ when this return is in the lowest 1st, 5th and 10th percentiles, respectively, and 0 otherwise.

There are four parameters that measure the capabilities of the metals as hedges and safe havens: δ_0, SH1 = $\delta_0 + \delta_1$, SH2 = $\delta_0 + \delta_1 + \delta_2$ y SH3 = $\delta_0 + \delta_1 + \delta_2 + \delta_3$.

δ_0 is the effect over the return on the metal of a change in the return on the bond, on average. Given what we saw in section 2 when analyzing the correlations between bonds and metals, we expect this coefficient to be negative. SH1 is the same effect but only for periods when the return on the bond is in the lowest 1st percentile. SH2 and SH3 are equivalent but for the 5th and 10th percentiles, respectively.

δ_0 is, thus, the indicator of the hedging property. The metal will be considered a strong hedge for that bond if the parameter is negative and significantly different from zero (negative correlation on average), and a weak hedge if it is statistically not different from zero (uncorrelation on average). If the parameter is positive and significant, the metal is not a hedge for that bond. We look for negative parameters given that the correlations between metals and bonds are negative.

SH1, SH2 and SH3 are the coefficients that account for the safe haven property of a metal. When this coefficients are negative and significant (not statistically different from zero), the metal will be negatively correlated (uncorrelated) with the bond when this suffers a loss in that percentile, which means that the metal is a strong (weak) safe haven for that bond at the level of exposure represented by the coefficient.

The results of this estimation are shown in tables 5 and 6. Coefficients that are statistically significant at the 95% level are colored, red for the negative ones and blue for the ones that are positive.

	GOLD				SILVER			
	δ_0	SH_1	SH_2	SH_3	δ_0	SH_1	SH_2	SH_3
Belgium	0.0126	-0.0407	0.3635	0.1469	-0.2706	0.2872	0.7843	0.3831
EMU	0.3044	0.4261	0.7755	0.4165	-0.0851	-0.0445	0.4383	-0.0397
Spain	-0.0129	0.1010	0.2025	-0.0184	0.1544	0.1970	0.6746	0.1891
Finland	0.1854	0.2168	0.3733	0.2532	-0.0937	0.6297	0.5238	0.2519
France	0.1572	0.0754	0.2910	0.1417	-0.1452	0.4667	0.8752	0.3479
Germany	0.2378	0.4221	0.6752	0.4006	-0.2149	-0.1624	-0.0397	-0.0036
Greece	-0.0506	-0.0074	-0.1678	-0.0162	-0.0468	-0.0436	-0.0747	0.0160
Ireland	-0.0464	-0.3099	0.1706	-0.1612	-0.2502	0.4210	0.3617	-0.2234
Italy	-0.0480	-0.0486	-0.1291	-0.0728	-0.1502	-0.1268	0.0703	-0.1236
Netherlands	0.1717	0.2938	0.7318	0.4454	-0.1348	0.8528	0.6270	0.5398
Portugal	-0.0293	-0.1115	-0.0521	-0.0926	-0.1271	-0.3154	0.2176	-0.0046
UK	0.2294	0.3146	0.6511	0.4306	-0.0594	0.6329	0.4444	0.4358
US	0.0358	-0.0583	0.1765	0.0620	-0.1214	-0.2721	-0.1108	-0.1299
	PLATINUM				**PALLADIUM**			
	δ_0	SH_1	SH_2	SH_3	δ_0	SH_1	SH_2	SH_3
Belgium	-0.2396	-0.0775	0.1244	0.0056	-0.2970	0.0930	0.3878	0.0571
EMU	-0.2219	-0.2899	-0.2115	-0.3720	-0.5589	-0.1691	0.2096	-0.1217
Spain	-0.1008	-0.0220	0.2872	-0.0527	-0.1064	-0.2268	0.5165	-0.0079
Finland	-0.1354	0.1588	0.3072	0.0925	-0.3547	-0.0787	0.4373	-0.0251
France	-0.1192	-0.1090	0.0963	-0.0896	-0.2313	-0.2265	0.2329	-0.2039
Germany	-0.2378	-0.0762	-0.0325	-0.0819	-0.4924	0.0000	0.3406	-0.0024
Greece	-0.0041	-0.0418	-0.1010	-0.0109	0.0335	-0.0218	-0.0650	-0.0226
Ireland	-0.1136	-0.1616	0.2235	-0.1061	-0.0692	-0.1390	0.5031	-0.0718
Italy	-0.1655	-0.2532	0.0391	-0.0922	-0.1033	-0.1493	0.3075	-0.0908
Netherlands	-0.2543	-0.3689	-0.3241	-0.1560	-0.4348	-0.3422	-0.4962	-0.2571
Portugal	-0.0481	-0.0569	0.1775	-0.0195	0.0181	-0.0951	0.6288	0.0105
UK	-0.0349	0.2287	0.1558	0.0562	-0.1653	0.0237	0.0267	-0.1143
US	-0.1392	-0.2456	-0.1241	-0.1962	-0.2453	-0.2170	-0.2708	-0.2515

Table 5. Hedge and safe haven characteristics of precious metals – regression analysis.

	ALUMINUM				COPPER			
	δ_0	SH_1	SH_2	SH_3	δ_0	SH_1	SH_2	SH_3
Belgium	-0.4607	-0.2782	-0.0270	0.0116	-0.6480	-0.4825	0.0130	-0.0759
EMU	-0.7493	-0.9763	-0.5870	-0.5168	-1.1565	-1.7336	-1.1555	-1.0605
Spain	-0.2687	0.1131	0.3364	0.1826	-0.3667	0.1179	0.3639	0.1197
Finland	-0.5383	-0.2832	-0.0194	0.0621	-0.8348	-0.2816	0.0344	0.0186
France	-0.4938	-0.3270	-0.2467	-0.1087	-0.6774	-0.5401	-0.2366	-0.2483
Germany	-0.6877	-0.6832	-0.4188	-0.1969	-0.9789	-1.2605	-0.7203	-0.5784
Greece	-0.0140	-0.0187	0.1669	0.0518	-0.0448	-0.1095	0.1580	0.0427
Ireland	-0.1788	-0.0564	0.3695	0.0646	-0.2903	-0.1567	0.4605	-0.0456
Italy	-0.2582	-0.1796	-0.0326	0.0952	-0.3593	-0.2336	0.0466	0.1394
Netherlands	-0.6128	-0.5315	-0.3918	-0.1955	-0.8783	-0.6655	-0.6161	-0.4509
Portugal	-0.1071	-0.0288	0.1642	0.0295	-0.1863	-0.1363	0.0120	0.0113
UK	-0.2814	-0.2157	0.1628	-0.1068	-0.5051	-0.3754	-0.0661	-0.3385
US	-0.3836	-0.1091	-0.0709	-0.0709	-0.5890	-0.3269	-0.2775	-0.3323
	LEAD				**NICKEL**			
	δ_0	SH_1	SH_2	SH_3	δ_0	SH_1	SH_2	SH_3
Belgium	-0.6450	-0.3249	0.1627	0.1349	-0.6151	-0.1581	0.2220	0.1069
EMU	-1.1836	-1.7437	-1.2752	-1.0177	-1.1388	-1.8176	-1.7441	-1.1317
Spain	-0.4021	0.1335	0.4430	0.2106	-0.3887	0.0287	0.4131	0.1816
Finland	-0.8774	-0.3462	-0.1107	0.0942	-0.8086	-0.0036	0.1032	0.2492
France	-0.7085	-0.4439	-0.0153	-0.0715	-0.6712	-0.3349	-0.3334	-0.1404
Germany	-1.0168	-1.1181	-0.7444	-0.4396	-1.0206	-1.2409	-0.9837	-0.4426
Greece	-0.0151	-0.0504	0.2659	0.0399	-0.0307	0.0309	0.1386	0.0723
Ireland	-0.2895	-0.1676	0.2952	0.0072	-0.2355	0.0518	0.2363	0.0733
Italy	-0.3549	-0.2529	-0.1204	0.0484	-0.3546	-0.2161	-0.3150	0.1211
Netherlands	-0.9749	-0.8381	-0.5069	-0.3451	-0.8351	-0.7074	-0.7055	-0.4753
Portugal	-0.1806	-0.2191	0.3323	0.0290	-0.1695	0.0963	0.2930	0.1466
UK	-0.5145	-0.6939	-0.1319	-0.4532	-0.4087	-0.5966	-0.1249	-0.3958
US	-0.6007	-0.6357	-0.4702	-0.4472	-0.5282	-0.4489	-0.5312	-0.4887
	TIN				**ZINC**			
	δ_0	SH_1	SH_2	SH_3	δ_0	SH_1	SH_2	SH_3
Belgium	-0.5373	-0.3130	0.1243	0.1573	-0.5542	-0.2364	0.2577	0.1166
EMU	-0.8893	-1.1189	-1.1227	-0.5276	-0.9766	-0.8264	-0.7018	-0.5420
Spain	-0.3952	0.0434	0.2404	0.3105	-0.3171	0.2855	0.5671	0.2913
Finland	-0.6615	-0.1983	-0.4051	0.1597	-0.7325	-0.0818	0.1472	0.2337
France	-0.5174	0.0203	-0.3000	0.1833	-0.5836	-0.1233	0.0549	0.0633
Germany	-0.7464	-0.8123	-0.6171	-0.1889	-0.8713	-0.5110	-0.4051	-0.1311
Greece	-0.0414	-0.0591	0.1224	0.0320	-0.0195	-0.0489	0.2143	0.0261
Ireland	-0.2637	-0.4540	-0.0519	-0.1840	-0.2362	-0.0800	0.4663	0.0750
Italy	-0.3374	-0.3123	-0.2778	0.1273	-0.3033	-0.1799	0.0433	0.1469
Netherlands	-0.6254	-0.4430	-0.2206	-0.1266	-0.7422	-0.1578	-0.1154	-0.0083
Portugal	-0.1719	-0.3104	-0.0733	-0.0172	-0.1644	-0.2662	0.2403	0.0491
UK	-0.3126	-0.3287	-0.2278	-0.2683	-0.3885	-0.0933	0.2829	-0.1174
US	-0.4260	-0.2004	-0.0565	-0.2298	-0.4927	-0.1906	-0.1212	-0.1565

Table 6. Hedge and safe haven characteristics of industrial metals – regression analysis.

In terms of hedging, gold is the worst of any metal, being only a weak hedge for Belgium, Spain, Ireland, Italy, Portugal and the US, and a strong one for Greece. The other precious metals are at least a weak hedge for every bond (except for Palladium in the case of the Greek bond), platinum being the one that perform best as it is a strong hedge for every bond except Spain, Finland, France, Portugal and the UK.

Industrial metals, on the other hand, are strong hedges for every bond except for the Greek, for which they are a weak hedge. As we predicted when analyzing the correlations between metals and bonds, industrial metals are a much better choice as a hedging instrument for bonds than precious metals unless the investor wants to hedge a Greek bond, in which case gold may be a better choice.

Precious metals fail to act a s a safe haven for many bonds at different percentiles. Gold does not provide any safety for the German, British and EMU benchmark bonds at any of the levels considered, and for Finland and the Netherlands in the lowest 5th and 10th percentiles. In the case of Belgium, gold is not a safe haven for the lowest 5th percentile. Additionally, it is only a strong safe haven for Ireland (lowest 1st and 10th percentiles) and Portugal (lowest 10th percentile).

Silver works better for the EMU and Germany as it is a weak safe haven for both of these and has capabilities similar to gold for Belgium, the Netherlands, Finland and the UK; but fails in providing safety for large losses in the French bond, while also being a strong safe haven only for Portugal in the lowest 1st percentile. Platinum and palladium perform much better, being a weak safe haven for every bond at the 1st and 10th lowest percentiles. Platinum is the best safe haven of the precious metals, only failing to provide safety for Spain and Finland when loses are in the lowest 5th percentile.

Once again, industrial metals outperform their precious counterparts, every one of them being at least a weak safe haven for every bond at any one of the levels considered, with a few exceptions in the Irish and Spanish bonds. Copper works specially well as it is a strong safe haven for the EMU, Germany and the Netherlands at the three percentiles considered, as well as for the most extreme loses in Belgium and France and loses in the lowest 10th percentile for the UK and the US.

Variance Reduction

To test whether the coefficients estimated previously account as real measures of hedging capability or not, we build portfolios of single bonds covered by a single metal. We choose a precious metal (platinum) and two industrial metals (copper and lead) that according to the results of the previous section are good hedging instruments. Additionally, we design portfolios using bond futures as a hedging instrument for comparison purposes. The US bond is hedged with 10-year T-Note futures and the rest of the bonds with the Euro-Bund Futures.

The goal of the inclusion of a metal in the portfolio is to reduce the variability of the investment, with respect to that given by a single bond. To find the optimal amount of metal to be included (the *hedge ratio h*), we solve the problem of minimizing the variance of the portfolio given by:

$$r_{portfolio} = r_{bond} - h \cdot r_{metal}$$

Solving this problem we obtain the optimal hedge ratio:

$$\dot{h} = \frac{cov(r_{bond}, r_{metal})}{var(r_{metal})}$$

Which is equivalent to β if we estimate the following equation by Ordinary Least Squares:

$$r_{bond,t} = \alpha + \beta r_{metal,t} + \mu_t$$

We also calculate the optimal hedge ratio using the conditional variances and covariances obtained by estimating a DCC-GARCH model. The model gives us a matrix of covariances for each day, which we use to calculate a daily optimal ratio.

Once we have the hedge ratio we build a portfolio consisting of one unit of the bond and *-h* units of the metal. In the case of the DCC-GARCH estimation this quantity is time-varying. Then, we compare the variance of this portfolio to the variance of investing in the bond alone.

Table 7 shows the reduction of variance obtained by the two methods for each bond and using the three selected metals. Table 8 is equivalent for futures hedges.

	Platinum		Copper		Lead	
	OLS	**DCC**	**OLS**	**DCC**	**OLS**	**DCC**
Belgium	0.25%	0,53%	1.19%	2.46%	0.69%	1.07%
EMU	0,40%	0,76%	4.62%	5.69%	2.99%	3.27%
Spain	0.15%	0.28%	0.71%	1.78%	0.52%	0,72%
Finland	0.11%	0,56%	2.03%	3.07%	1.34%	1.60%
France	0.11%	0.43%	1.62%	2.93%	1.13%	1.66%
Germany	0.30%	0.56%	2.85%	4.19%	2.02%	2.41%
Greece	0,00%	0,00%	0.00%	0.02%	0,00%	0,00%
Ireland	0.19%	0.57%	0.56%	1.32%	0.29%	0.55%
Italy	0.20%	0.78%	0.32%	1.50%	0.27%	0.46%
Netherlands	0.19%	0.78%	2.46%	3.74%	1.85%	2.27%
Portugal	0.04%	0.22%	0.18%	0.24%	0,00%	0,00%
UK	0.03%	0.19%	1.60%	2.42%	1.09%	1.45%
US	0.24%	0.26%	2.66%	4.02%	1.75%	2.21%

Table 7– Variance reduction hedging with metals

Industrial metals provide better hedging capabilities for bonds, as we observed in the regression analysis. Copper, in this case, is the best hedging instrument among these three commodities, while the precious metal (platinum) does the worst.

The results, however, indicate that the hedges using metals are largely inefficient since they only reduce the variance of the investment marginally. The maximum variance reduction is achieved by copper for the EMU benchmark bond, and it only manages to reduce it by 5.69%.

Meanwhile, futures reduce the variance of the portfolio to a much greater degree. For bonds with performances similar to the German one the reduction of variance is usually above 50%. More peripheral countries have worse hedges, but still better than those obtained with metals. The US is the best hedged bond as the future used is specific for that bond, resulting in a variance reduction of almost 80% being achieved. Clearly, any investor willing to hedge a bond would do much better by using futures.

	OLS	DCC
Belgium	36,66%	44,18%
EMU	66,75%	70,30%
Spain	8,45%	23,91%
Finland	69,58%	70,68%
France	47,62%	51,98%
Germany	65,60%	69,02%
Greece	0,20%	2,68%
Ireland	10,32%	19,56%
Italy	5,36%	24,65%
Netherlands	74,09%	74,10%
Portugal	3,44%	8,28%
UK	30,07%	30,96%
US	77,73%	78,03%

Table 8 – Variance reduction hedging with futures.

This results suggest that the ones provided by regression analysis may not be completely accurate in practice. In other words, an asset holding to the definition previously provided for a hedging instrument does not imply that we can always obtain a proper hedge in practice. An investor willing to hedge his or her bond investment should be careful when considering results obtained with this methodology.

Another important remark is that despite the results being bad overall, we obtain better hedges estimating by DCC-GARCH than estimating by OLS. This is not surprising: one is time-varying while the other just estimates a single hedge ratio for all the range and thus, less precise.

Post-shock performance

When performing regression analysis, we studied how the metals performed in the same period a bond crash occurred. An asset that works as a safe haven should perform well after a bond crash, so investors can recover their losses and obtain profit turning into it during market turmoil. For this purpose, in this section we will study how the metals perform the days following a big loss in bonds.

We present the average cumulative results of portfolios consisting of a bond and a metal over 20 trading days after a bond has suffered a loss in its lowest 5th percentile. We assume that at day 0 (the day of the crash) the investor holds a long position in the bond only, and after the event it allocates part of his or her budget (50% or 100%) to a metal in order to recover from the losses. The return at the initial day, then, is the loss caused by the bond. For days 1 to 20, the return is that provided by the portfolio.

The results are very similar among the group formed by some of the European countries (Belgium, Finland, France, Germany and the Netherlands) the UK and the US (which presented a relatively low risk premium during the sovereign debt crisis), on one side; and among the European peripheral countries (Spain, Italy, Greece, and Portugal; which were affected more severely by the crisis) on the other side. Ireland, despite being closer to the second group, presents results similar to the countries in the first.

The two groups present very different results. We show the results obtained for the EMU benchmark and for Spain as examples of countries that presented a low and high risk premium, respectively. In figures 1 and 3 the half the budget is invested in metals after the bond crashes. In figures 2 and 4, the whole budget is invested in metals after the initial shock. Results for every bond can be seen in tables 9 to 12 where we show the cumulative returns of both strategies at days 0 (the loss while holding only the bond), 10 and 20. The figures that are not shown here can be seen in the appendix.

Figures 1 and 2 show that for the EMU benchmark bond investing in metals after a crash helps in recovering the loses. By the end of the period, both the equally weighted portfolio and the portfolio consisting only in metals present a lower cumulative loss than keeping the investment in the bond for every metal except tin and zinc. After the losses that stem from a crash in the bond, an investor is better off allocating part or the totality of his or her budget in any metal that is not tin or zinc.

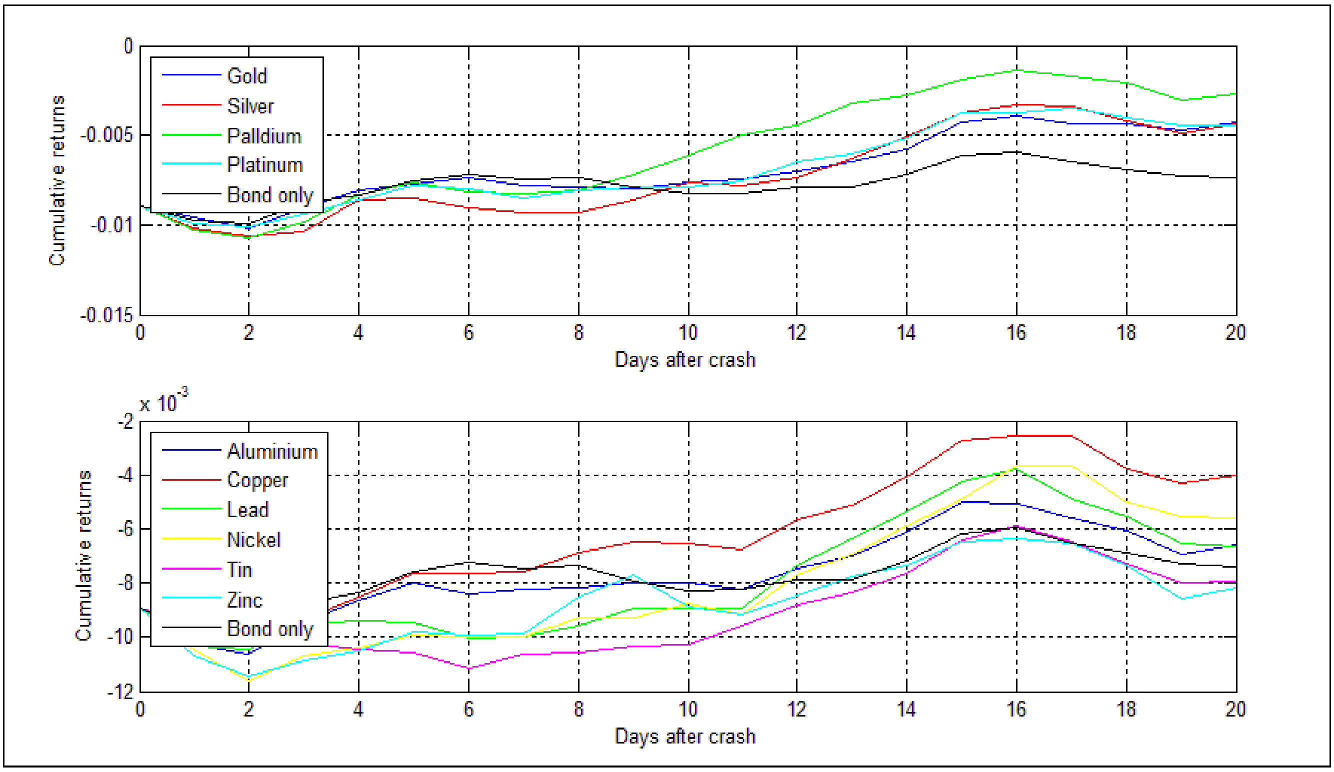

Figure 1: Performance of equally weighted portfolio of EMU bond and metal after an EMU bond crash.

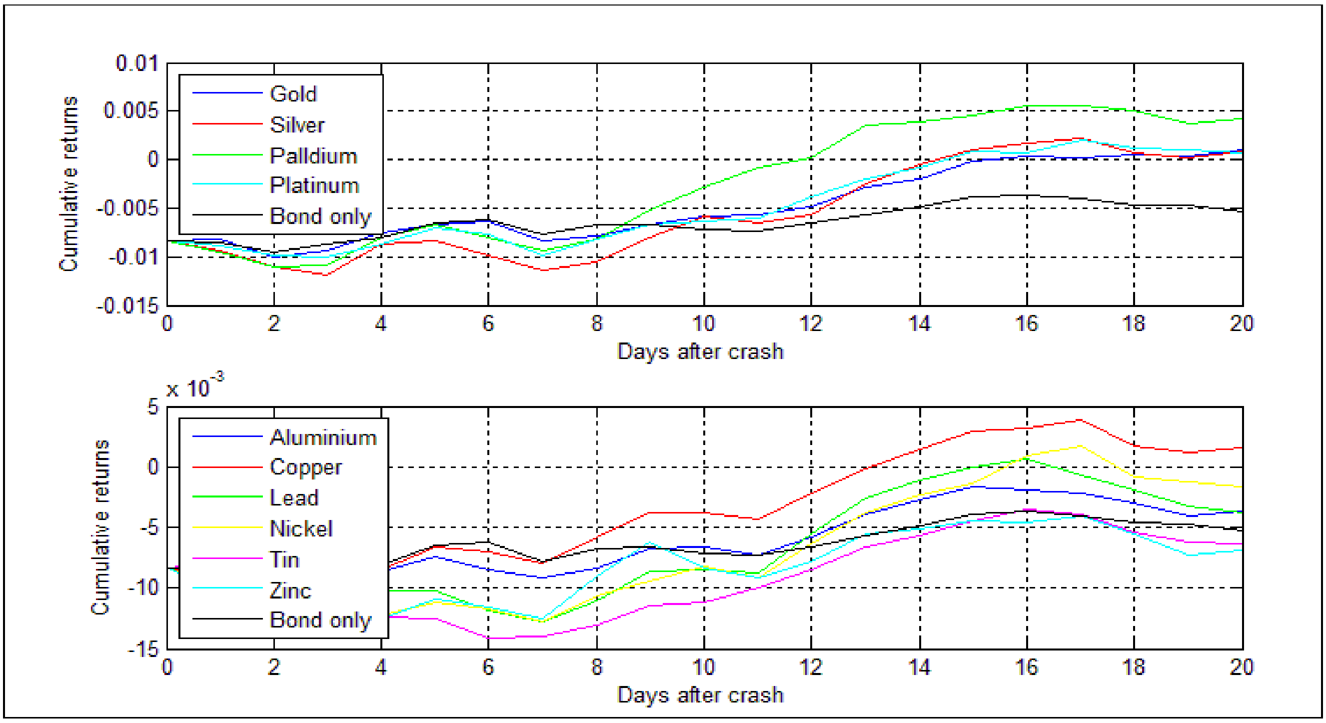

Figure 2: Performance of different metals after EMU bond crash.

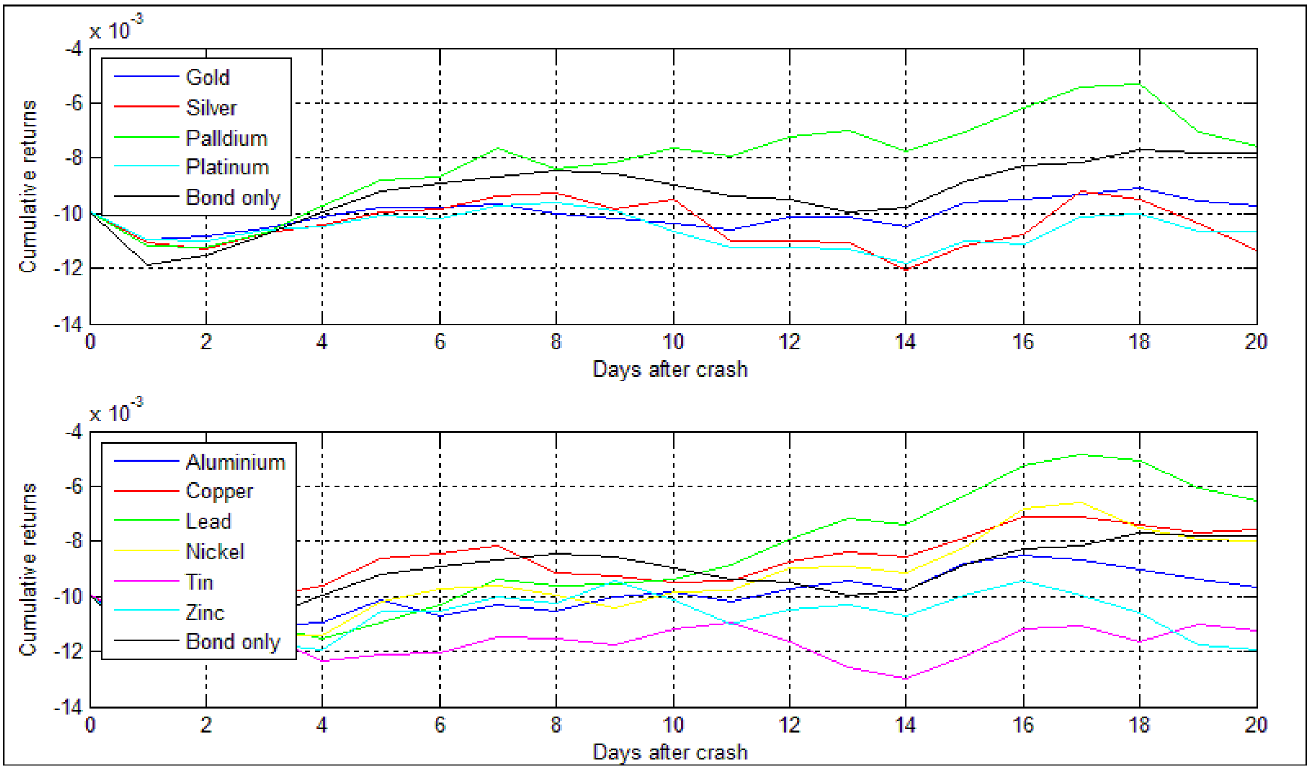

Figure 3: Performance of equally weighted portfolio of Spanish bond and metal after a Spanish bond crash.

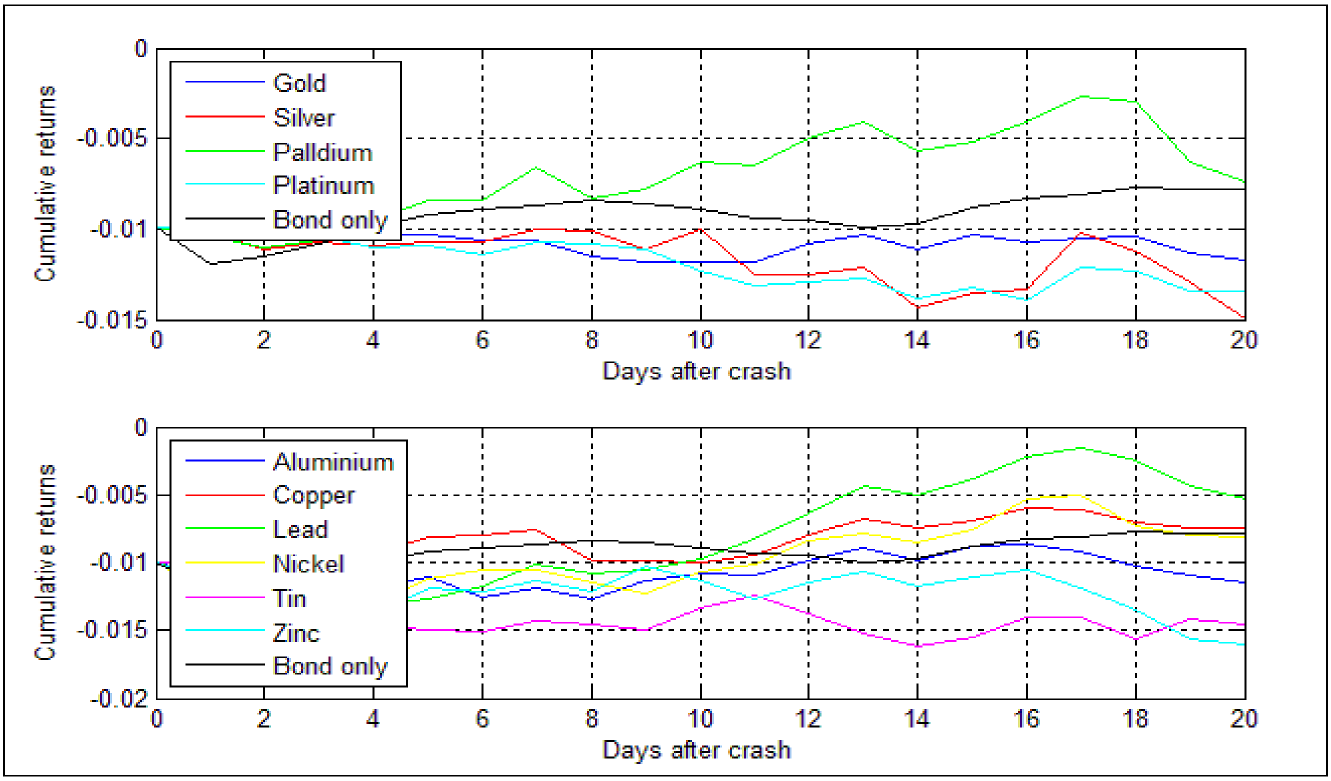

Figure 4: Performance of different metals after Spanish bond crash.

	Bond only			Gold		Silver		Platinum		Palladium	
	Day 0	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**
Belgium	-0.0084	-0.0069	-0.0056	-0.0088	-0.0060	-0.0082	-0.0056	-0.0080	-0.0048	-0.0035	0.0008
EMU	-0.0080	-0.0082	-0.0071	-0.0073	-0.0029	-0.0073	-0.0030	-0.0076	-0.0031	-0.0052	-0.0007
Spain	-0.0100	-0.0090	-0.0078	-0.0104	-0.0098	-0.0095	-0.0114	-0.0107	-0.0106	-0.0076	-0.0076
Finland	-0.0086	-0.0096	-0.0099	-0.0101	-0.0087	-0.0103	-0.0095	-0.0099	-0.0078	-0.0061	-0.0027
France	-0.0084	-0.0079	-0.0085	-0.0089	-0.0073	-0.0094	-0.0076	-0.0081	-0.0063	-0.0060	-0.0039
Germany	-0.0082	-0.0080	-0.0073	-0.0074	-0.0046	-0.0073	-0.0051	-0.0077	-0.0055	-0.0050	-0.0021
Greece	-0.0237	-0.0365	-0.0386	-0.0302	-0.0287	-0.0326	-0.0365	-0.0324	-0.0332	-0.0311	-0.0313
Ireland	-0.0122	-0.0130	-0.0136	-0.0107	-0.0070	-0.0087	-0.0065	-0.0120	-0.0107	-0.0079	-0.0031
Italy	-0.0109	-0.0075	-0.0078	-0.0104	-0.0096	-0.0120	-0.0138	-0.0112	-0.0120	-0.0091	-0.0113
Netherlands	-0.0078	-0.0074	-0.0069	-0.0082	-0.0045	-0.0083	-0.0050	-0.0079	-0.0047	-0.0065	-0.0011
Portugal	-0.0150	-0.0182	-0.0127	-0.0160	-0.0115	-0.0150	-0.0115	-0.0191	-0.0166	-0.0143	-0.0112
UK	-0.0094	-0.0084	-0.0093	-0.0084	-0.0077	-0.0101	-0.0099	-0.0084	-0.0069	-0.0060	-0.0019
US	-0.0110	-0.0113	-0.0120	-0.0117	-0.0105	-0.0106	-0.0079	-0.0104	-0.0088	-0.0093	-0.0073

Table 9: Cumulative returns of equally weighted portfolios of bond and precious metal after bond crashes

		Aluminium		Copper		Lead		Nickel		Tin		Zinc	
	Day 0	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**	**Day 10**	**Day 20**
Belgium	-0.0084	-0.0056	-0.0038	-0.0051	-0.0004	-0.0067	-0.0031	-0.0071	-0.0034	-0.0089	-0.0070	-0.0065	-0.0055
EMU	-0.0080	-0.0078	-0.0060	-0.0058	-0.0025	-0.0090	-0.0061	-0.0088	-0.0047	-0.0109	-0.0078	-0.0089	-0.0082
Spain	-0.0100	-0.0099	-0.0096	-0.0095	-0.0076	-0.0094	-0.0065	-0.0098	-0.0080	-0.0112	-0.0112	-0.0101	-0.0119
Finland	-0.0086	-0.0074	-0.0055	-0.0064	-0.0024	-0.0090	-0.0046	-0.0085	-0.0044	-0.0114	-0.0105	-0.0096	-0.0086
France	-0.0084	-0.0068	-0.0046	-0.0055	-0.0021	-0.0083	-0.0039	-0.0077	-0.0046	-0.0109	-0.0090	-0.0086	-0.0076
Germany	-0.0082	-0.0061	-0.0042	-0.0052	-0.0024	-0.0078	-0.0048	-0.0078	-0.0037	-0.0101	-0.0094	-0.0080	-0.0080
Greece	-0.0237	-0.0328	-0.0365	-0.0346	-0.0361	-0.0368	-0.0411	-0.0338	-0.0383	-0.0337	-0.0340	-0.0345	-0.0382
Ireland	-0.0122	-0.0102	-0.0106	-0.0108	-0.0101	-0.0143	-0.0137	-0.0137	-0.0143	-0.0138	-0.0148	-0.0136	-0.0162
Italy	-0.0109	-0.0100	-0.0108	-0.0111	-0.0095	-0.0094	-0.0075	-0.0133	-0.0114	-0.0146	-0.0158	-0.0099	-0.0109
Netherlands	-0.0078	-0.0076	-0.0053	-0.0075	-0.0045	-0.0094	-0.0058	-0.0077	-0.0046	-0.0098	-0.0079	-0.0093	-0.0088
Portugal	-0.0150	-0.0177	-0.0159	-0.0178	-0.0141	-0.0196	-0.0174	-0.0196	-0.0185	-0.0177	-0.0157	-0.0190	-0.0184
UK	-0.0094	-0.0082	-0.0070	-0.0070	-0.0073	-0.0100	-0.0097	-0.0106	-0.0137	-0.0082	-0.0091	-0.0102	-0.0128
US	-0.0110	-0.0090	-0.0084	-0.0081	-0.0071	-0.0082	-0.0078	-0.0104	-0.0078	-0.0085	-0.0076	-0.0122	-0.0136

Table 10: Cumulative returns of equally weighted portfolios of bond and industrial metal after bond crashes

	Bond only			Gold		Silver		Platinum		Palladium	
	Day 0	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20
Belgium	-0.0084	-0.0070	-0.0056	-0.0106	-0.0065	-0.0095	-0.0057	-0.0091	-0.0040	0.0001	0.0072
EMU	-0.0080	-0.0072	-0.0053	-0.0059	0.0010	-0.0059	0.0009	-0.0064	0.0007	-0.0029	0.0042
Spain	-0.0100	-0.0090	-0.0078	-0.0118	-0.0117	-0.0100	-0.0149	-0.0124	-0.0135	-0.0063	-0.0074
Finland	-0.0086	-0.0096	-0.0099	-0.0106	-0.0076	-0.0111	-0.0091	-0.0102	-0.0058	-0.0026	0.0045
France	-0.0084	-0.0079	-0.0085	-0.0098	-0.0060	-0.0108	-0.0068	-0.0083	-0.0041	-0.0041	0.0008
Germany	-0.0082	-0.0080	-0.0073	-0.0067	-0.0019	-0.0065	-0.0030	-0.0073	-0.0037	-0.0019	0.0031
Greece	-0.0237	-0.0365	-0.0386	-0.0238	-0.0188	-0.0287	-0.0343	-0.0283	-0.0278	-0.0257	-0.0239
Ireland	-0.0122	-0.0130	-0.0136	-0.0084	-0.0003	-0.0044	0.0006	-0.0111	-0.0078	-0.0027	0.0075
Italy	-0.0109	-0.0075	-0.0078	-0.0134	-0.0115	-0.0165	-0.0197	-0.0149	-0.0162	-0.0107	-0.0148
Netherlands	-0.0078	-0.0074	-0.0069	-0.0089	-0.0021	-0.0093	-0.0031	-0.0083	-0.0026	-0.0057	0.0047
Portugal	-0.0150	-0.0182	-0.0127	-0.0139	-0.0103	-0.0118	-0.0103	-0.0200	-0.0206	-0.0105	-0.0096
UK	-0.0094	-0.0084	-0.0093	-0.0085	-0.0061	-0.0119	-0.0104	-0.0085	-0.0045	-0.0037	0.0055
US	-0.0110	-0.0113	-0.0120	-0.0121	-0.0090	-0.0099	-0.0039	-0.0094	-0.0056	-0.0072	-0.0026

Table 11: Cumulative returns of precious metals after bond crashes

		Aluminium		Copper		Lead		Nickel		Tin		Zinc	
	Day 0	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20	Day 10	Day 20
Belgium	-0.0084	-0.0042	-0.0020	-0.0032	0.0047	-0.0064	-0.0006	-0.0072	-0.0012	-0.0109	-0.0085	-0.0060	-0.0054
EMU	-0.0080	-0.0066	-0.0037	-0.0037	0.0016	-0.0084	-0.0038	-0.0082	-0.0017	-0.0112	-0.0063	-0.0083	-0.0068
Spain	-0.0100	-0.0107	-0.0115	-0.0100	-0.0074	-0.0097	-0.0052	-0.0107	-0.0081	-0.0134	-0.0146	-0.0113	-0.0161
Finland	-0.0086	-0.0053	-0.0012	-0.0032	0.0050	-0.0085	0.0006	-0.0075	0.0010	-0.0133	-0.0111	-0.0096	-0.0074
France	-0.0084	-0.0056	-0.0007	-0.0030	0.0042	-0.0086	0.0008	-0.0074	-0.0007	-0.0138	-0.0094	-0.0092	-0.0067
Germany	-0.0082	-0.0041	-0.0012	-0.0023	0.0024	-0.0076	-0.0024	-0.0075	-0.0001	-0.0121	-0.0116	-0.0080	-0.0088
Greece	-0.0237	-0.0292	-0.0343	-0.0327	-0.0335	-0.0372	-0.0435	-0.0311	-0.0380	-0.0309	-0.0293	-0.0325	-0.0377
Ireland	-0.0122	-0.0074	-0.0075	-0.0087	-0.0065	-0.0155	-0.0137	-0.0144	-0.0150	-0.0146	-0.0160	-0.0142	-0.0187
Italy	-0.0109	-0.0124	-0.0139	-0.0147	-0.0112	-0.0113	-0.0073	-0.0191	-0.0150	-0.0217	-0.0237	-0.0123	-0.0141
Netherlands	-0.0078	-0.0079	-0.0037	-0.0076	-0.0022	-0.0115	-0.0047	-0.0080	-0.0022	-0.0122	-0.0089	-0.0111	-0.0107
Portugal	-0.0150	-0.0172	-0.0191	-0.0174	-0.0155	-0.0211	-0.0220	-0.0210	-0.0242	-0.0172	-0.0187	-0.0198	-0.0241
UK	-0.0094	-0.0080	-0.0046	-0.0057	-0.0052	-0.0117	-0.0101	-0.0129	-0.0181	-0.0080	-0.0088	-0.0121	-0.0162
US	-0.0110	-0.0067	-0.0049	-0.0050	-0.0022	-0.0052	-0.0035	-0.0095	-0.0035	-0.0057	-0.0033	-0.0130	-0.0153

Table 12: Cumulative returns of precious metals after bond crashes

The amount of loses that is recovered depends on the metal and on the percentage of the budget allocated to it. For the EMU benchmark the ones that perform better are palladium among the precious metals and copper among the industrial metals. Completely recovering the amount lost and even making a small profit by the end of the period is even possible with a portfolio consisting on any precious metal and almost possible with copper. This is a consistent result among the countries in this group. For most of them allocating the totality of the budget to any of those two metals yields the best results, and in many cases, a remarkable profit by the end of the 20-day period.

The case of the US bond is a bit different since it is not as easy to recover the losses as in other countries, but palladium and copper are still among the best choices. Every metal, except zinc, performs better than the US bond following the crashes. Surprisingly, Ireland has similar results to this group, with palladium allowing the investor to make a small profit and copper and aluminium providing the best results among industrial metals. However, in this case the precious metals clearly outperform their industrial counterparts.

The Spanish case shows a different picture. The only metal that performs significantly better than the bond is lead, which recovers half the losses if we allocate the whole budget to it. With the rest of the metals, an investor would either obtain the same results as keeping the bond (palladium, nickel, copper) or would incur in larger losses (gold, silver, platinum, aluminium, tin, zinc). Overall, metals are not a proper instrument to recover losses from the Spanish bond.

The common trend in this group of countries is that no metal outperforms the bond consistently, with a few exceptions. For Portugal, investing in precious metals (except platinum) is slightly better than keeping the bond, even if the losses are not fully recovered. The other exception is Greece, where almost every metal outperforms a bond that keeps accumulating losses after a crash. The investment in metals also increases the losses in the Greek case, so an investor should not trust metals as a safe haven for this bond.

5. PORTFOLIO DIVERSIFICATION

In the previous section, we have seen that metals are not good hedging instruments for bond investments, but can be useful as a safe haven for several bonds. In this section, we will show that they can perform a role as diversification tools for the bond investor.

We use twelve bonds and a single metal and build the minimum variance portfolio that can be obtained with these assets. EMU benchmark bond is eliminated since it is composed by many of the bonds already in use and thus it does not add anything of value to the investment. Due to the fact that we are using all the bonds, this section studies the period starting in 1999, as there is no data available for the Greek bond before that. We build ten portfolios, one with each of the metals, in order to compare them and see which one of the commodities has better synergies with bonds.

The reason to compare minimum variance portfolios is that we assume the bond investor to be looking for low risk investment opportunities. Further analysis could be made in building riskier portfolios instead of that of minimum variance to see how fixed income investors could turn their investments riskier with metals. This, however, is out of the scope of this work.

The weights of the minimum variance portfolio are obtained with the following formula:

$$w_{MVP} = \frac{\Omega^{-1} l}{l' \Omega^{-1} l^{-1}}$$

Where l is a vector of ones of size equal to the number of assets and Ω is the covariance matrix. We calculate this matrix in two different ways: calculating sample covariance matrices and with DCC-GARCH estimations.

In both cases, we use rolling windows of 3000 observations and calculate the covariance matrix or estimate the DCC-GARCH model for that window. With this estimations, we build the minimum variance portfolio for the day following the last day of the window.

We first obtain a series of portfolios for the last 916 observations of the sample using sample covariance matrices. The mean return and daily volatility of those portfolios are shown in figure 5.

The weight of metals in each portfolio ranges from 2.24% (silver) to 6.48% (aluminium). The first thing that can be noticed is that adding a metal to the bond portfolio we reduce its variance. This is to be expected as a result of diversification: a portfolio consisting of 13 assets will always perform at least as good as one composed of 12, and since the goal is to obtain the minimum possible variance the portfolios including metals are less risky.

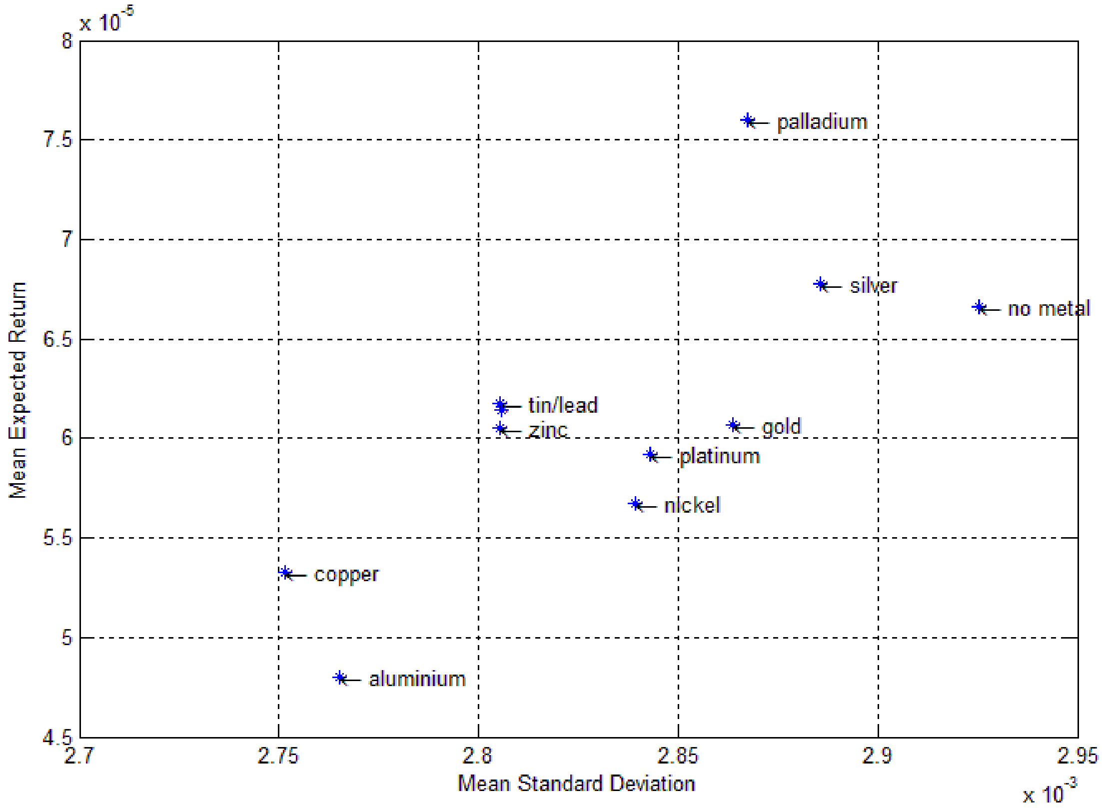

Figure 5: Minimum variance portfolios consisting of 12 bonds and a single metal using rolling windows (means of 916 days).

The metal that achieves the greatest reduction of risk is copper, which also reduces the expected return with respect to investing only in bonds. On the other hand, adding palladium gives the highest expected return while moderately reducing the risk. Tin and lead are found somewhere in between, . Once again, our results indicate that gold is not the best choice as an addition for a bond portfolio.

Copper, tin, zinc and palladium produce portfolios that dominate those created using other metals. An investor should chose among them to complete his or her bond portfolio, choosing palladium for better expected return and copper, tin or zinc if the focus is to reduce risk.

Generally speaking, adding around 5% of metal to a bond portfolio improves it, reducing its risk and possibly increasing its expected return.

We now calculate the covariance matrix using DCC-GARCH estimations. We are still using rolling windows but now, instead of calculating the sample covariance matrix for each window, we estimate a DCC-GARCH model to obtain the matrix for each day.

Due to the computational cost of this procedure, portfolios have been calculated only for the last 10 days of the sample. Note that an investor could estimate the model each day that passes to adjust his or her portfolio conveniently. Figure 6 shows the mean return and daily volatility of the calculated portfolios.

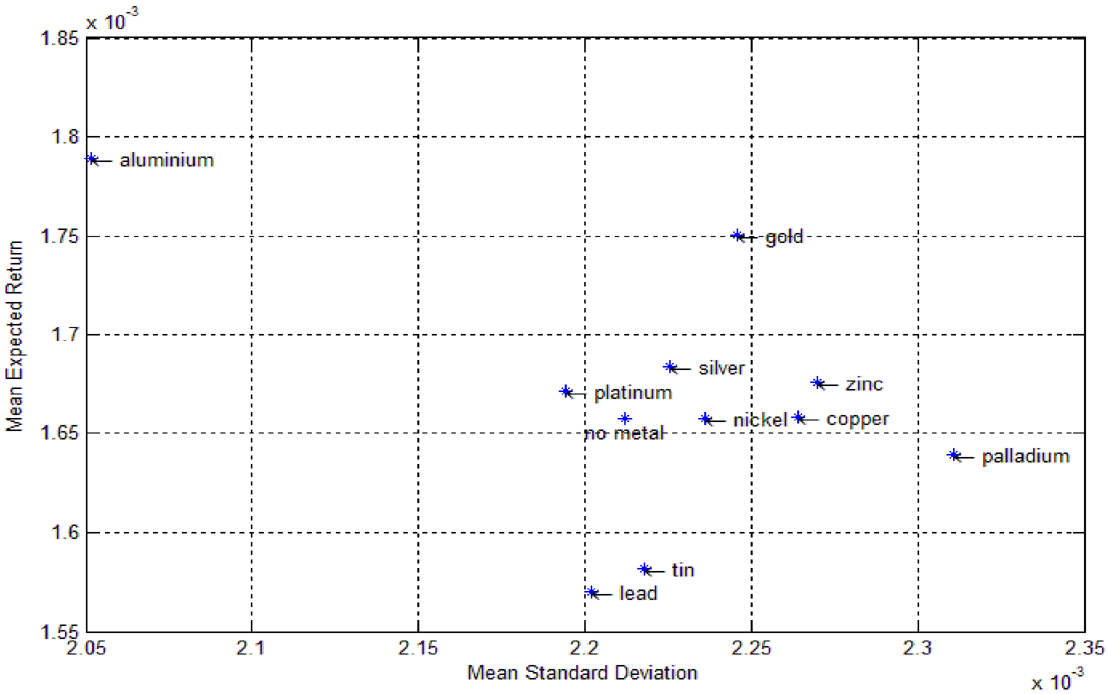

Figure 6: Minimum variance portfolios consisting of 12 bonds and a single metal using DCC-GARCH estimations (means of 10 days).

As we can see in the figure, the portfolios built using the DCC-GARCH estimation of the covariance matrix do not benefit from diversification. Only lead, platinum and aluminium are able to reduce the variance of the bond portfolio.

This results are not directly comparable to those in figure 1 since the portfolios are evaluated only during a 10 day period. This is the reason the expected returns are higher than in the previous section, especially for aluminium, which had remarkably high returns during those two weeks.

In order to have a reference to compare this last results, we have repeated the rolling windows exercise considering the portfolios only for the last 10 days. The results are shown in figure 7.

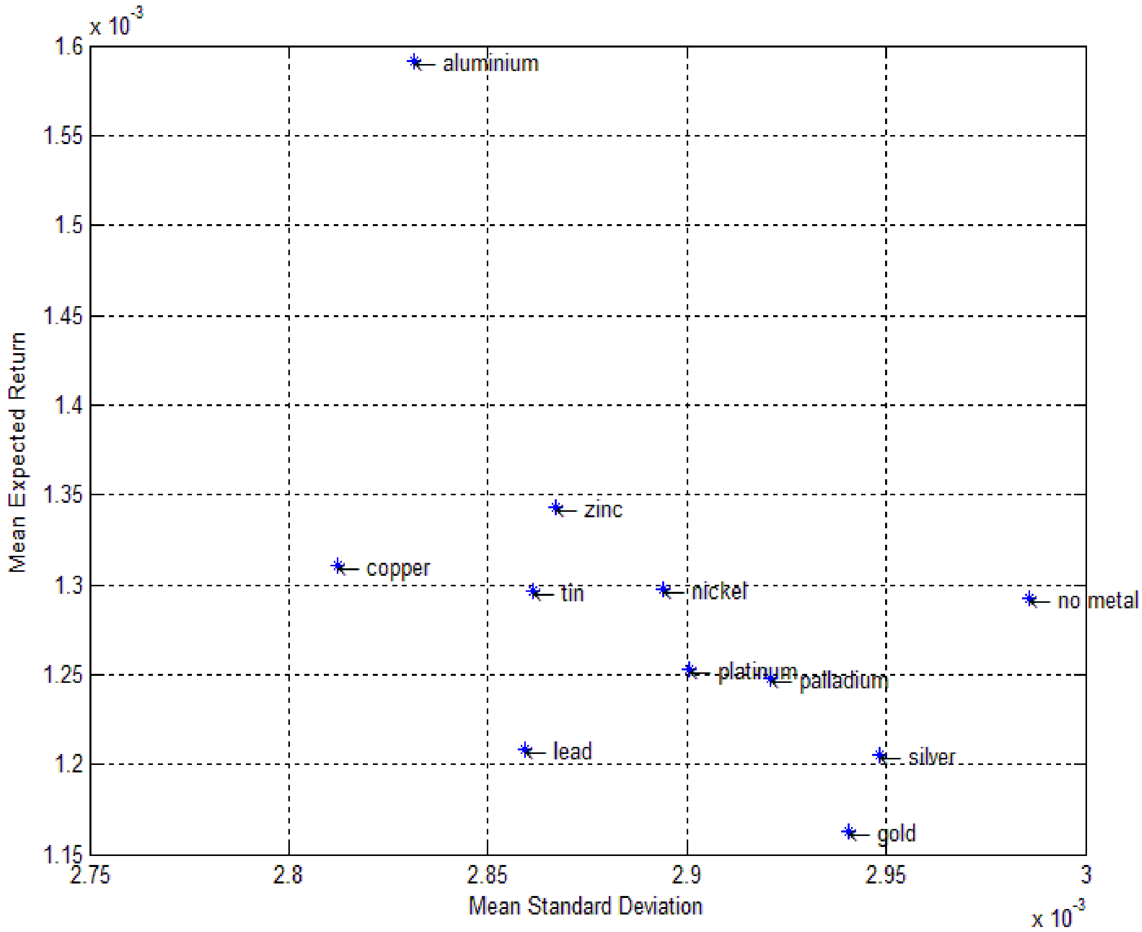

Figure 7: Minimum variance portfolios consisting of 12 bonds and a single metal using rolling windows (means of 10 days).

In this case, diversification plays a significant role as the portfolio without metal has the highest variance. Once again, copper is the metal that reduces the risk the most, while aluminium, given its performance in the two weeks considered, presents the highest return.

In table 13 we compare the portfolios shown in figures 6 and 7 using the Sharpe ratio. We have used the return on the German bond (which is not completely risk-free) as a proxy for the risk-free interest rate, so we do not properly reflect the return per unit of risk. However, the results obtained this way are still useful to compare the portfolios.

	DCC - GARCH	Sample covariance matrix
No metal	0.4233	0.1911
Gold	0.4580	0.1498
Silver	0.4325	0.1641
Platinum	0.4328	0.1831
Palladium	0.3971	0.1802
Aluminium	0.5203	0.3072
Copper	0.4138	0.2093
Lead	0.3853	0.1701
Nickel	0.4185	0.1988
Tin	0.3878	0.2008
Zinc	0.4204	0.2167

Table 13: Sharpe ratios of minimum variance portfolios

As we expected, aluminium has the highest Sharpe ratio both when using DCC-GARCH estimations and sample covariance matrices. In the conditional analysis, only aluminium, gold, silver and platinum perform better than the portfolio without metals, while adding a metal always improve the portfolio when using sample covariances.

Another important conclusion we can draw from these results is that the DCC-GARCH estimations provide better performing portfolios. Even if the conditional method does not properly acknowledge diversification, every portfolio estimated using this methodology dominates (has higher expected return and lower volatility) its counterpart.

6.CONCLUSIONS

This study provides new evidence on the role of precious and industrial metals as hedging instruments, safe havens and diversification tools for bond portfolios. Regarding their value as hedging vehicles, regression analysis suggests that industrial metals provide better hedges then precious metals for most bonds, copper being the one performing best. Contrary to popular belief, gold is not useful for this purpose.

The fact that industrial metals perform better than their precious counterparts is confirmed when calculating variance reduction for hedged portfolios, but the uselessness of metals in hedging bonds was also proven. In the variance reduction method we also found the first evidence that DCC-GARCH estimations are more precise than the ones obtained by the Ordinary Least Squares method.

With respect to the safe haven property, regression analysis showed that, once again, industrial metals are more desirable. Furthermore, when analyzing the post-shock performance of metals, we find that most metals, especially palladium and copper, are very effective for recovering loses produced by bonds of countries with no serious debt issues, but are not significantly better than holding the bond in countries that suffered from the sovereign debt crisis.

When using rolling windows to calculate sample covariance matrices for a long period, we find a low risk portfolio of bonds improves if an investor allocates around 5% of his or her budget to metals. Palladium, tin, lead and copper are the ones that perform best, depending on the level of risk desired.

Due to computational limitations, we have only been able to obtain the DCC-GARCH estimation for minimum variance portfolios for the last ten days of the sample. The results do not allow us to compare between metals with this method, but when compared with the rolling windows estimations we find that the conditional methodology results in more profitable and less risky portfolios.

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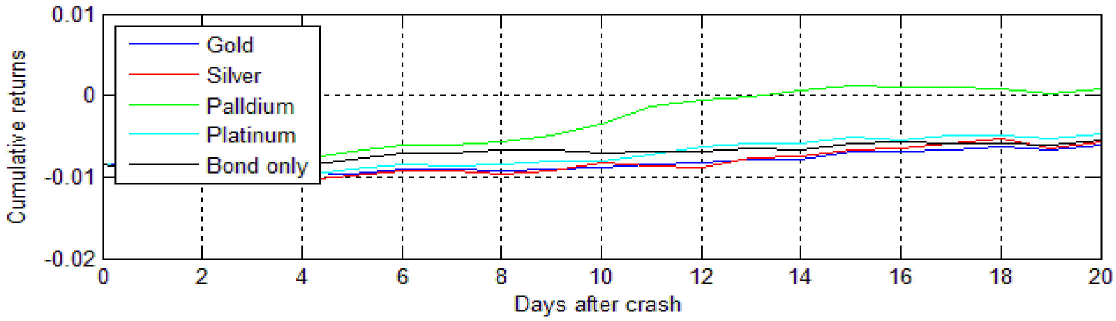
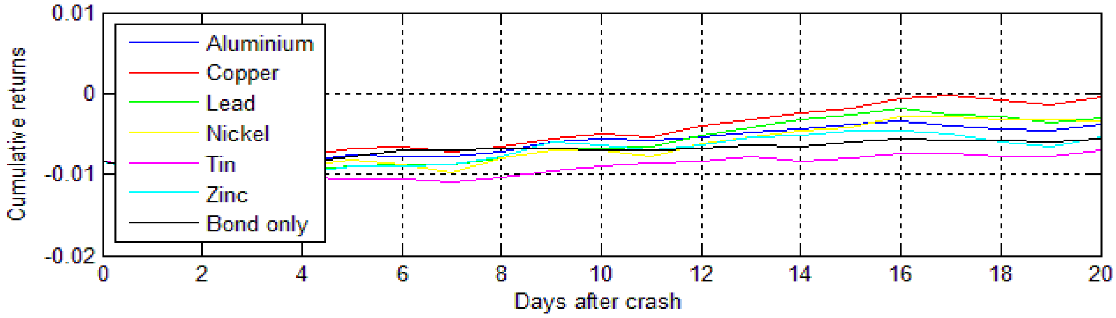
8. APPENDIX

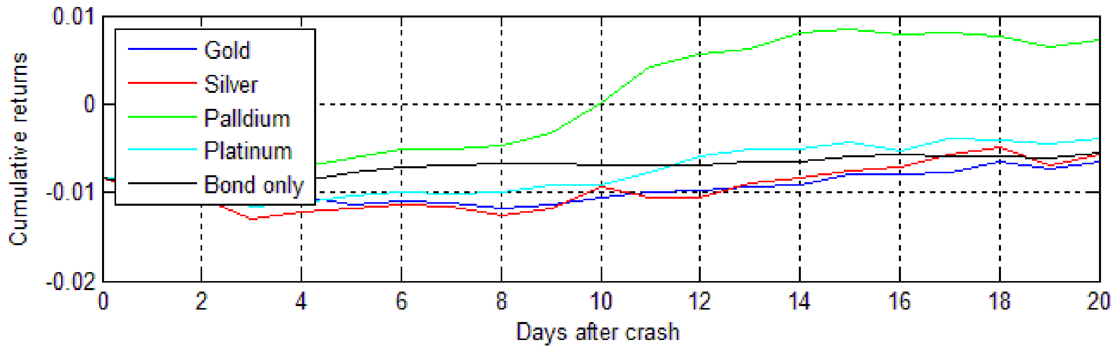
Post-shock performance results

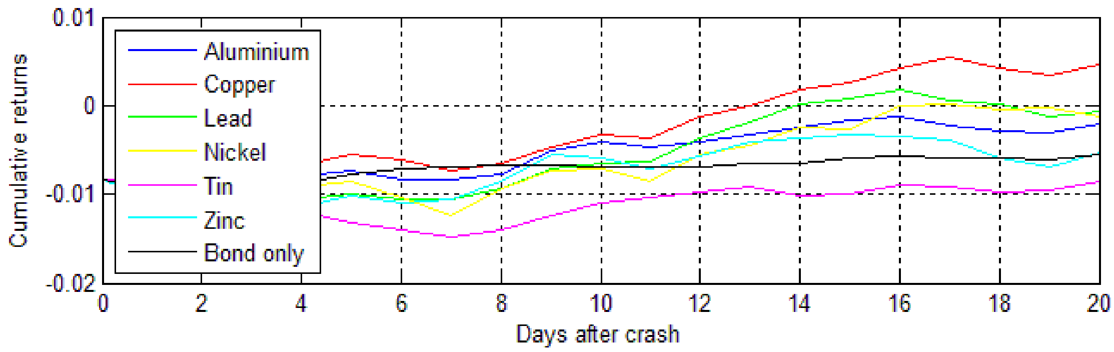
Belgium, equally weighted portfolio of bond and metal:



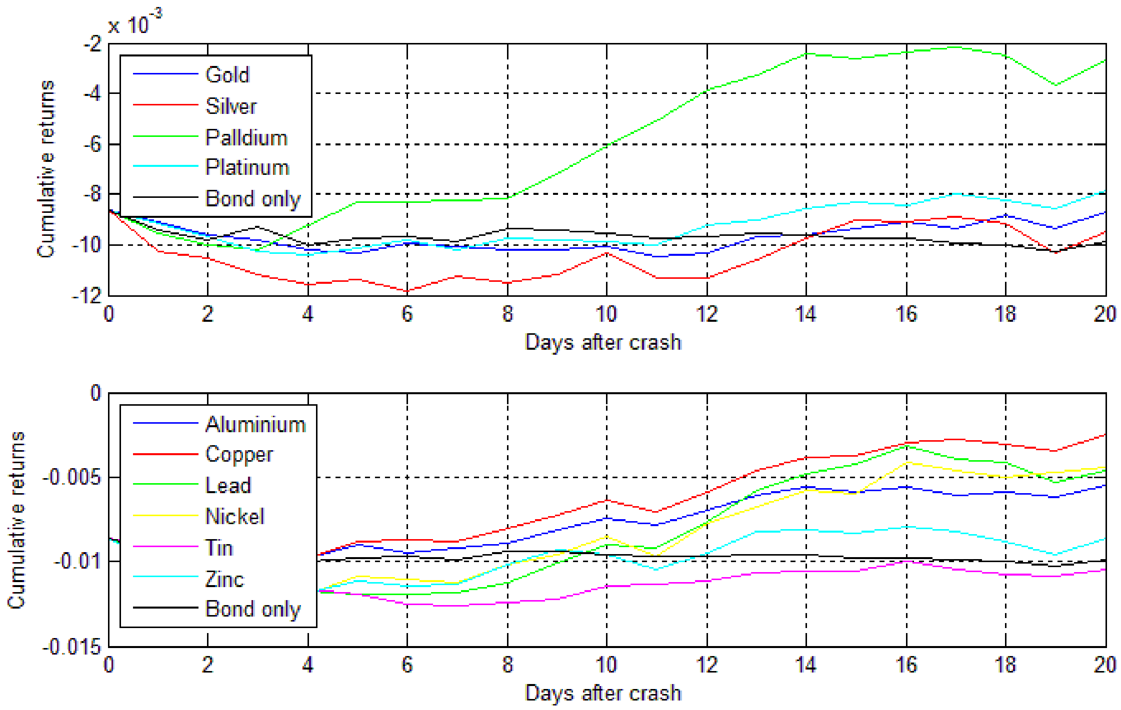


Belgium, all invested into metal after crash:





Finland, equally weighted portfolio of bond and metal:



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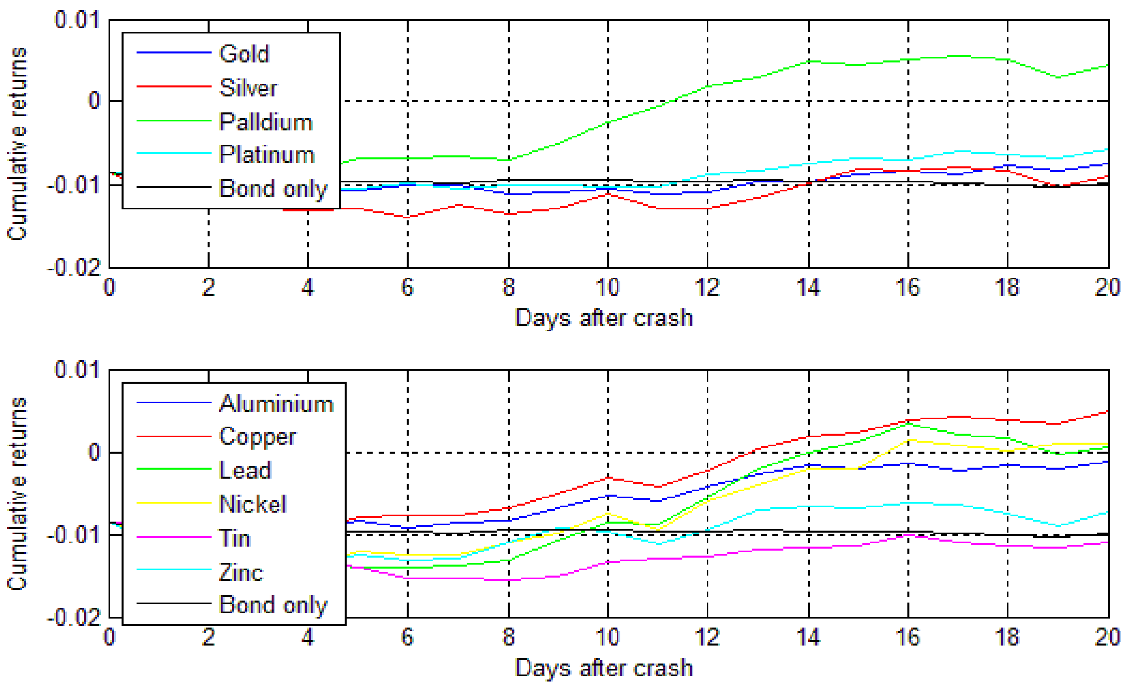
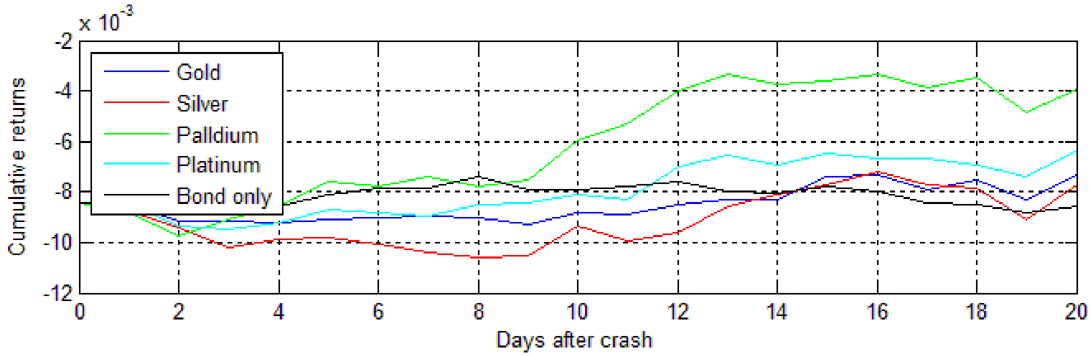
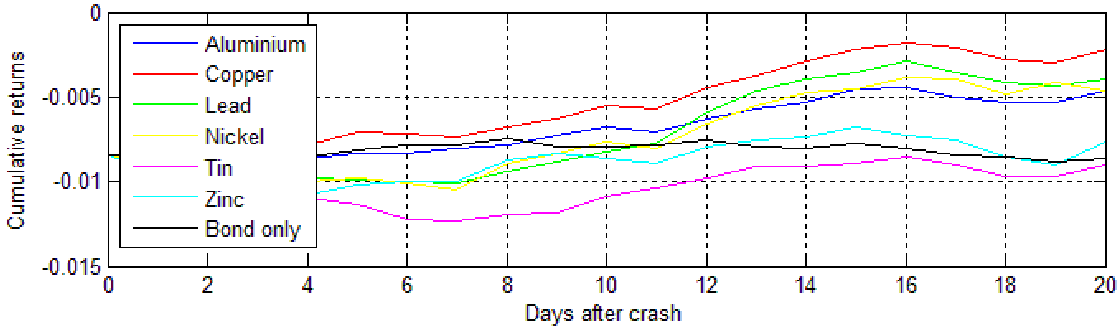


France, equally weighted portfolio of bond and metal:





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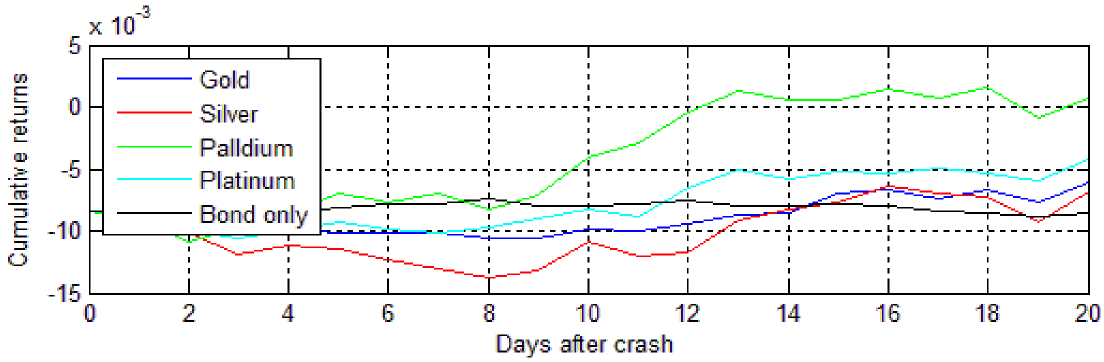
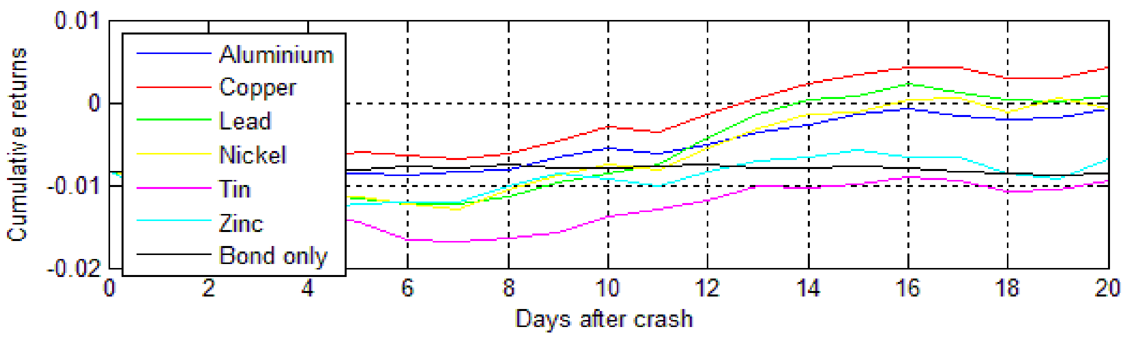
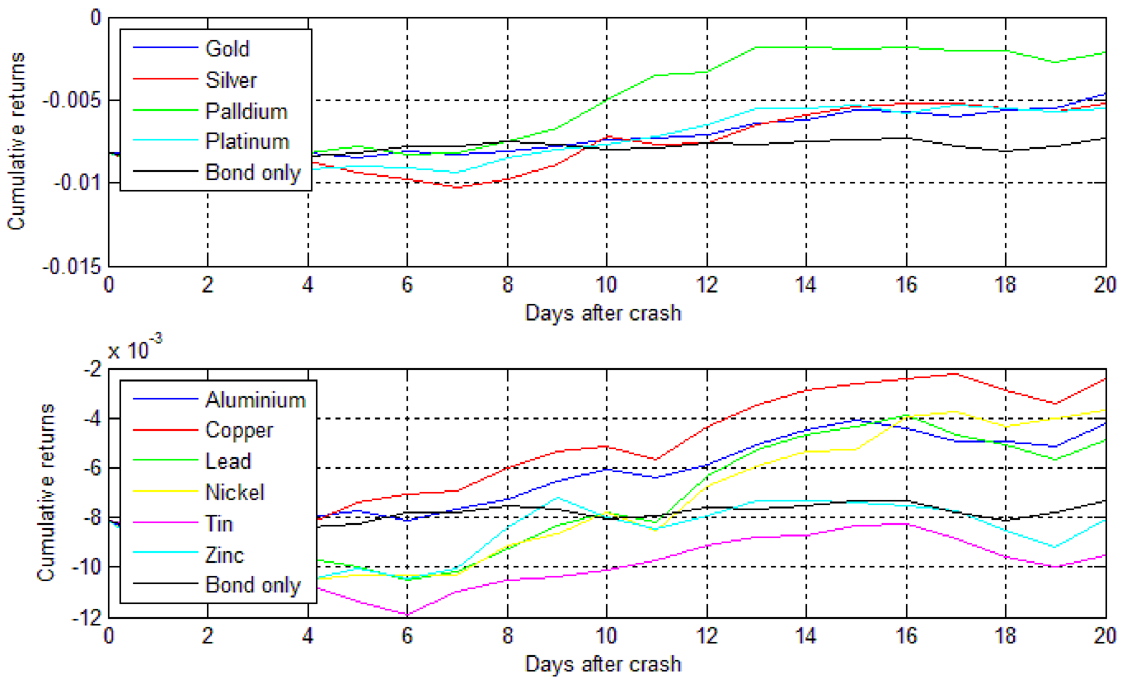
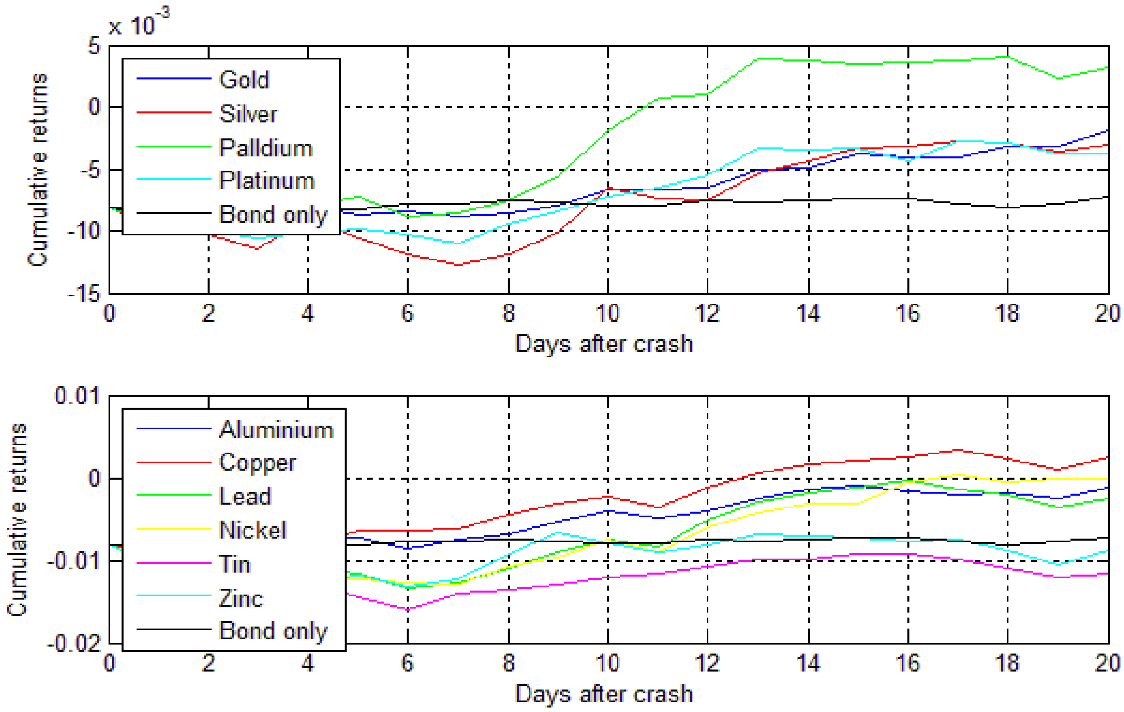




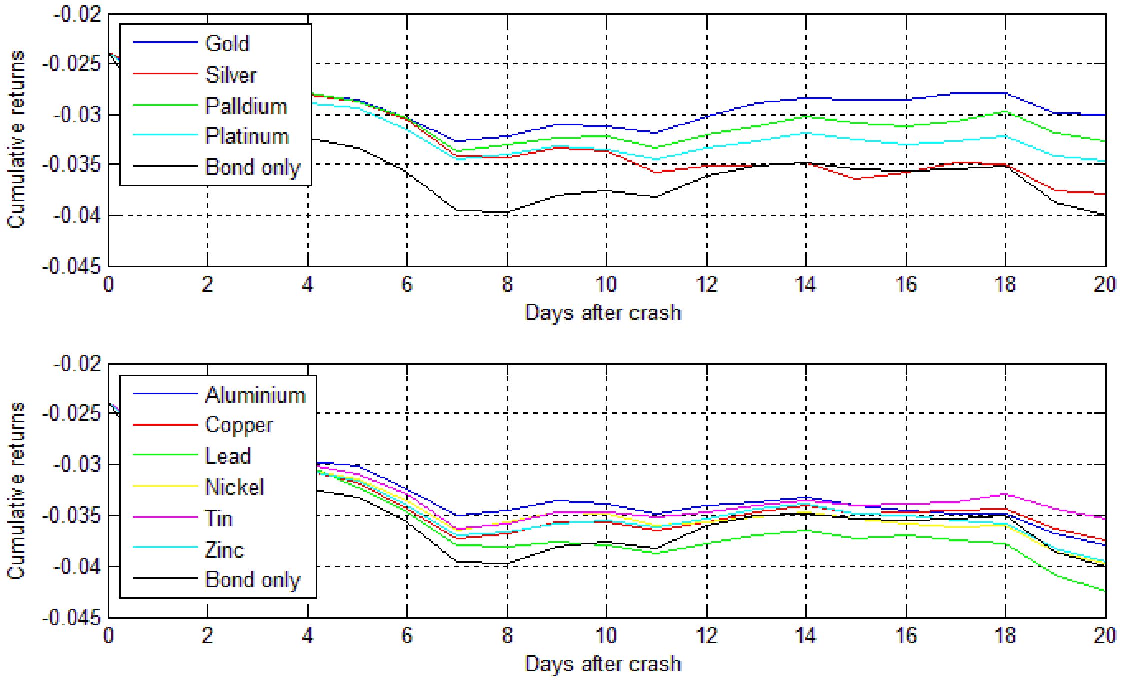
Germany, equally weighted portfolio of bond and metal:



Germany, all invested into metal after crash:



Greece, equally weighted portfolio of bond and metal:



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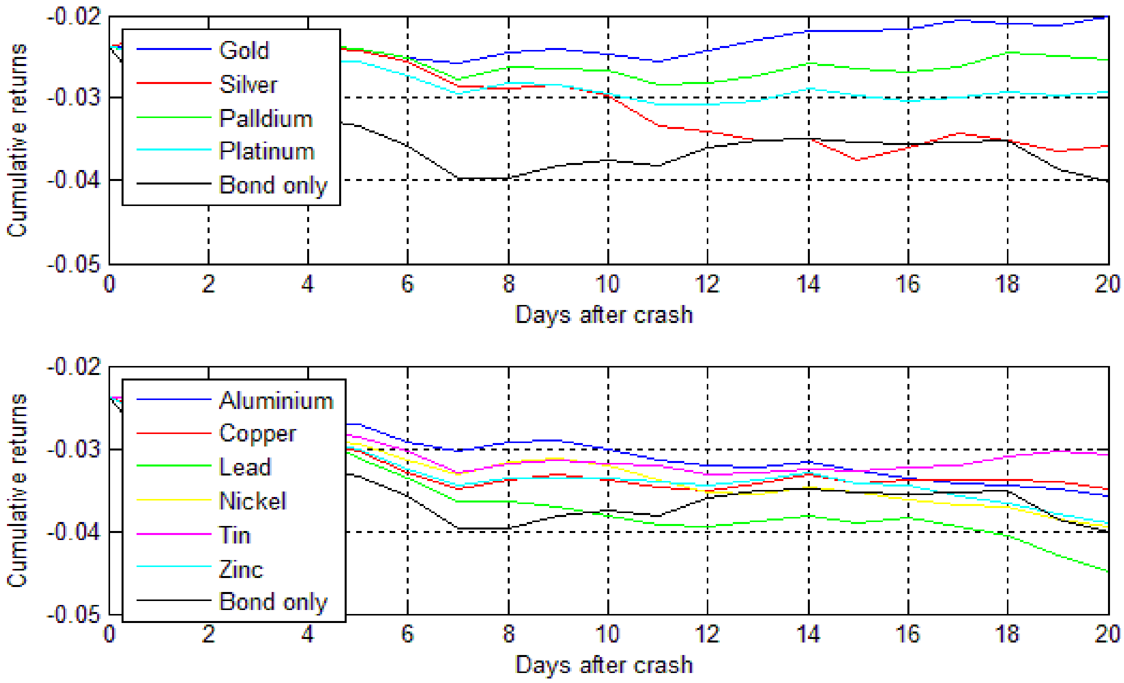
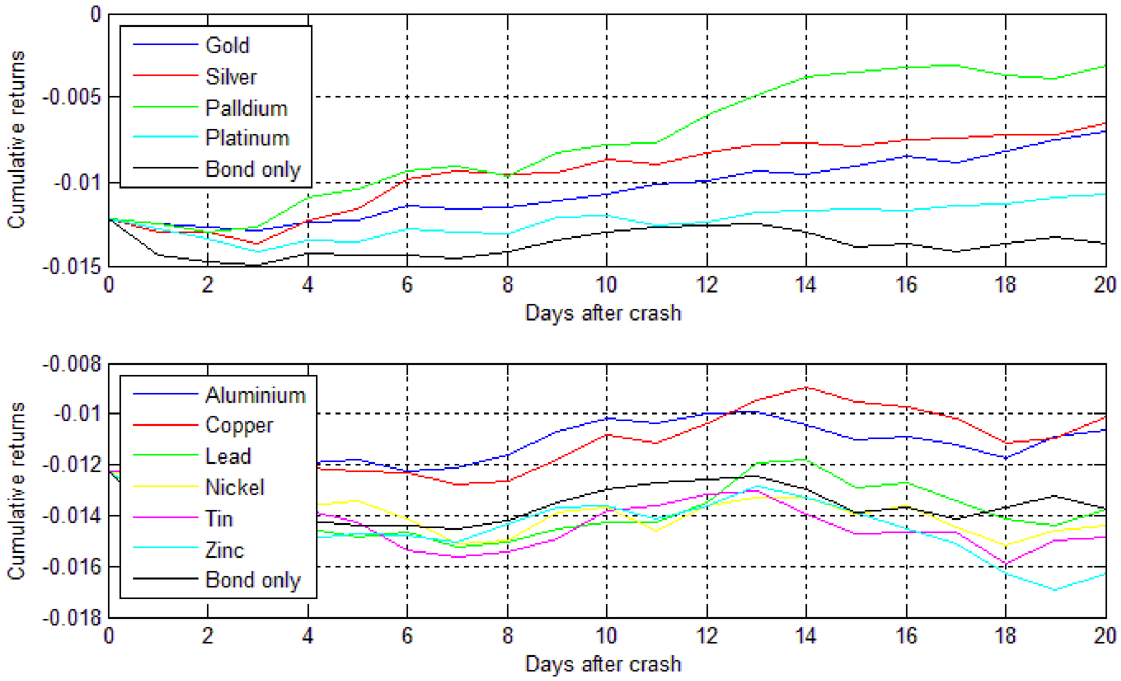


Ireland, equally weighted portfolio of bond and metal:



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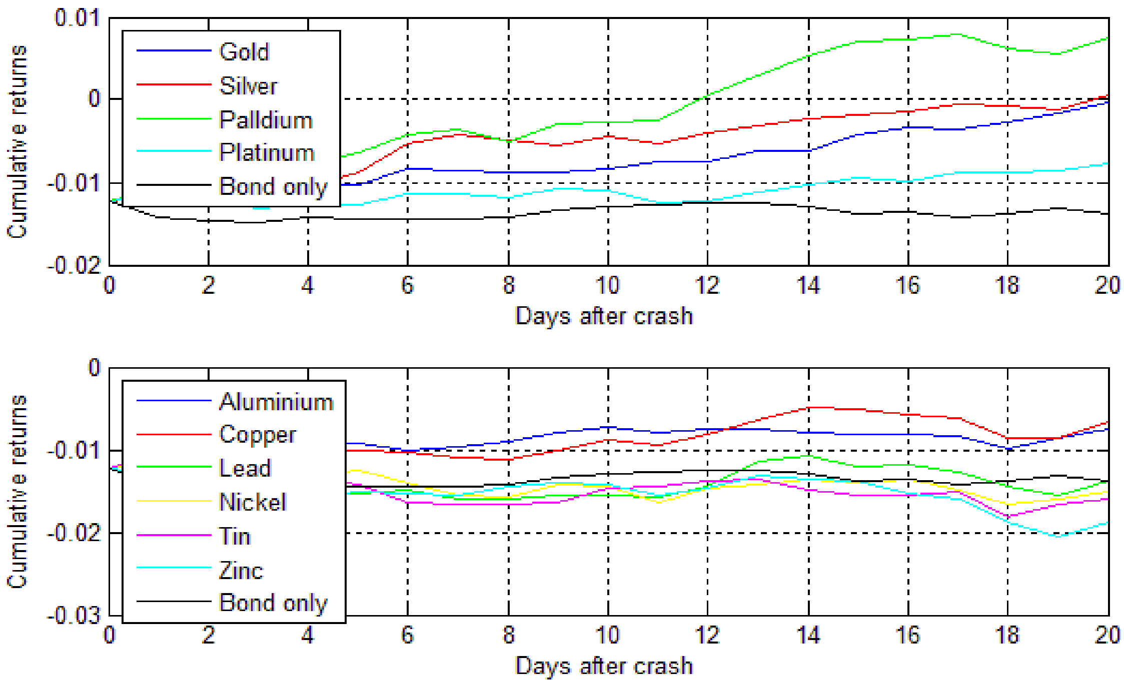

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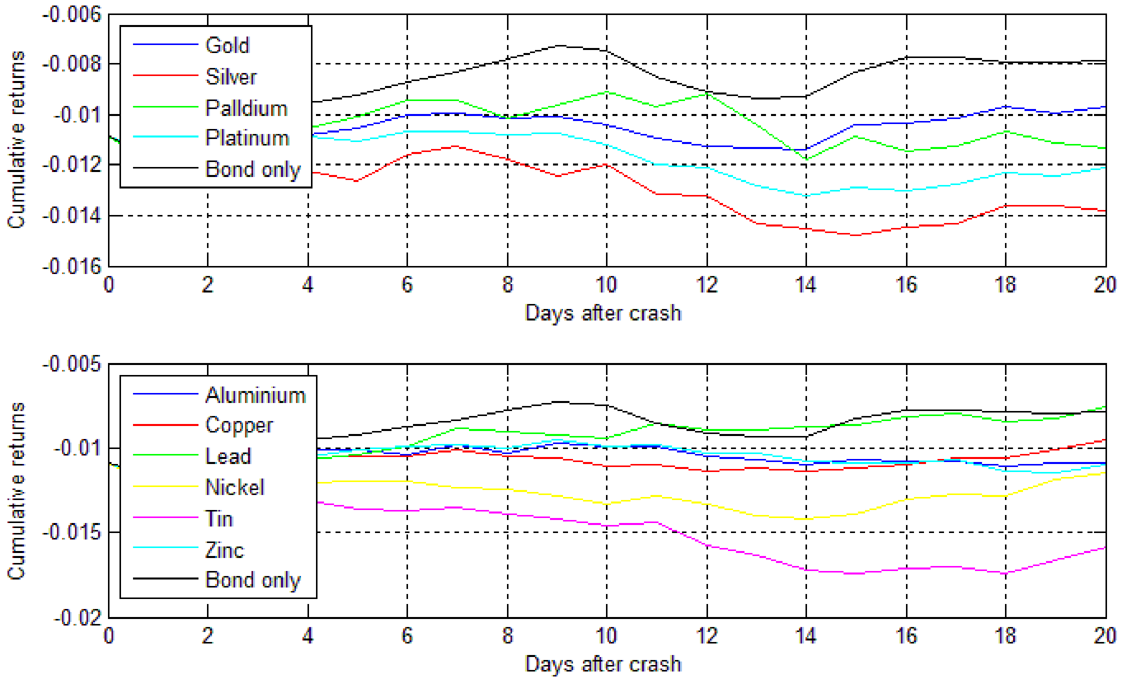

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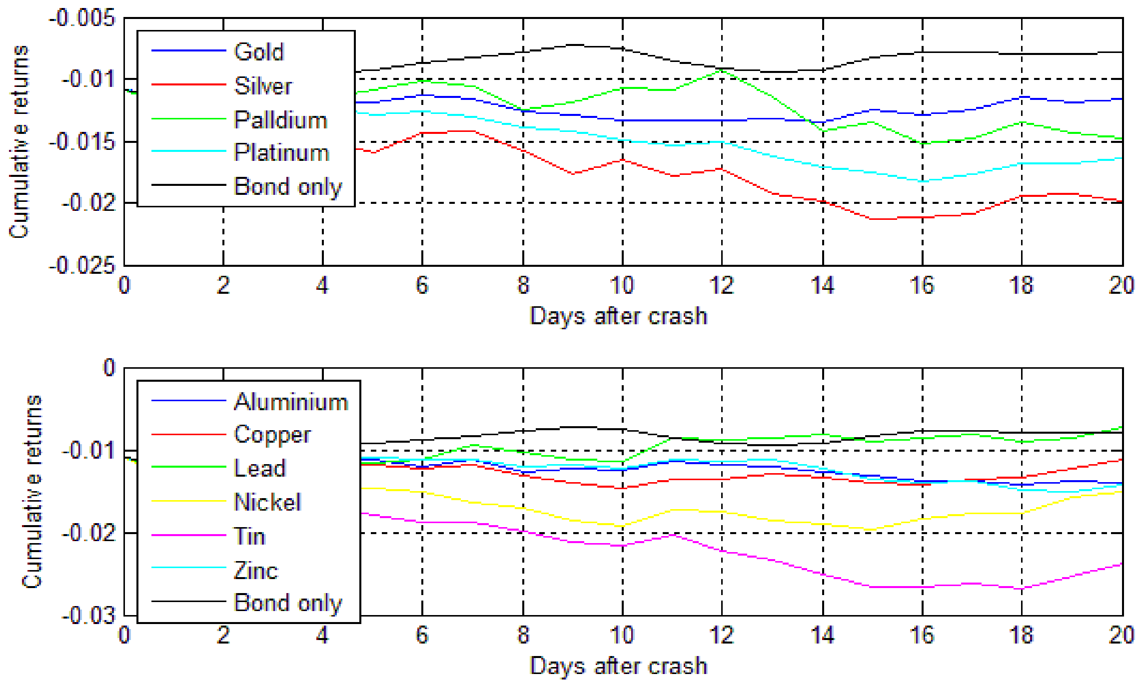
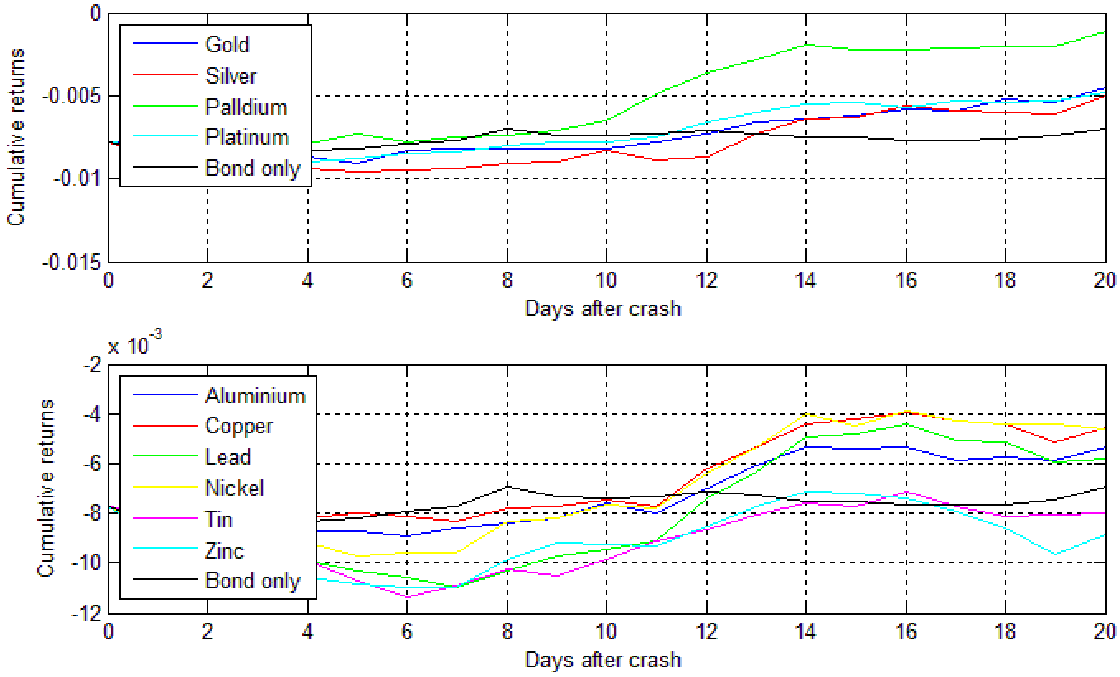


Netherlands, equally weighted portfolio of bond and metal:



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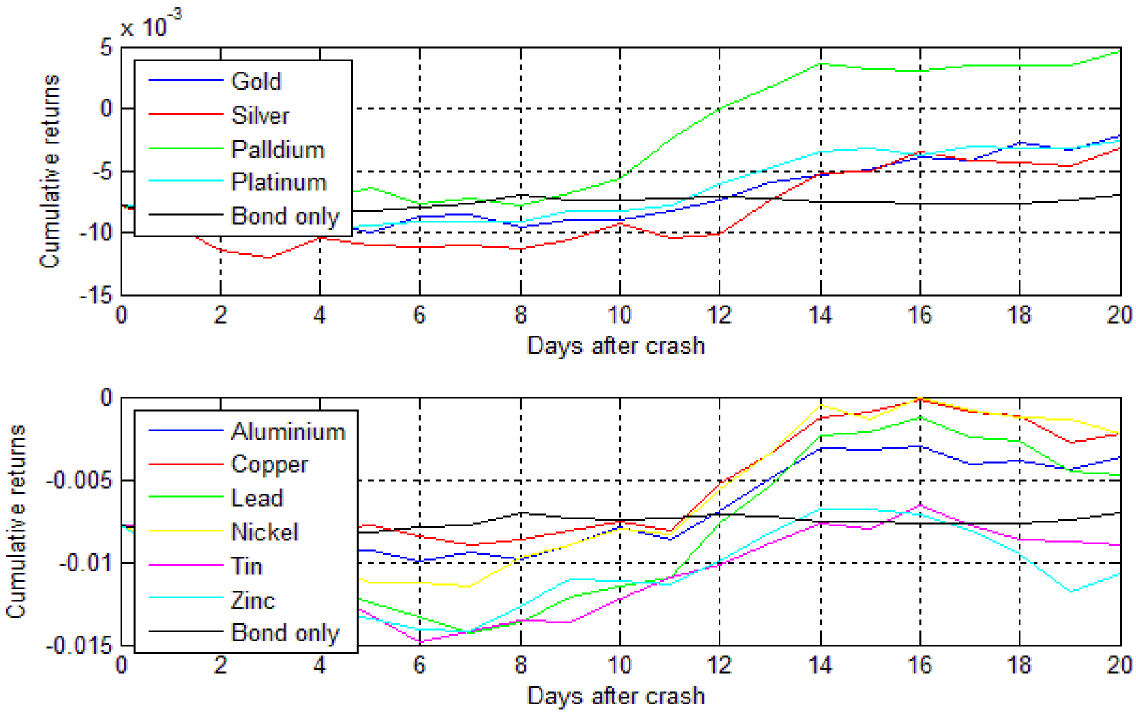
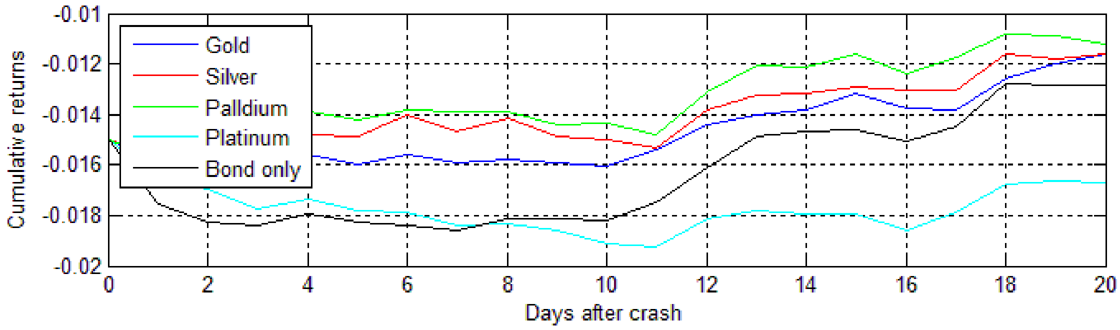
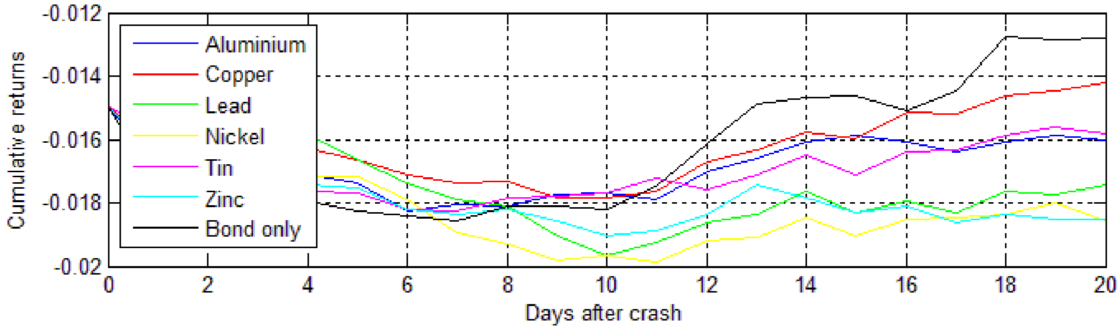


Portugal, equally weighted portfolio of bond and metal:





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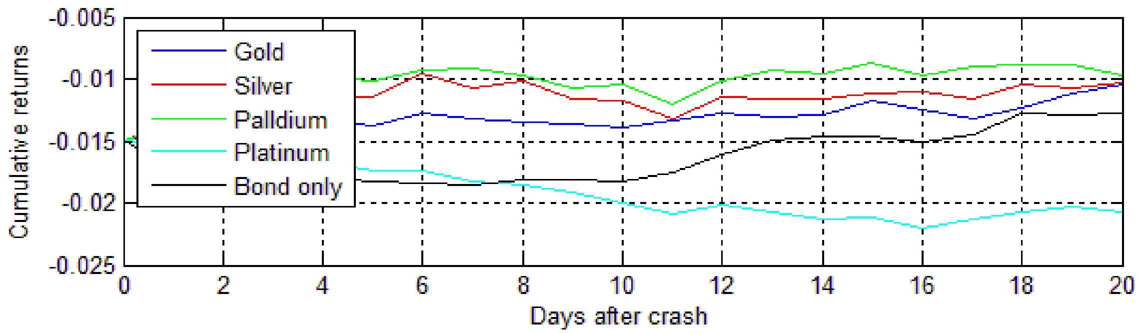
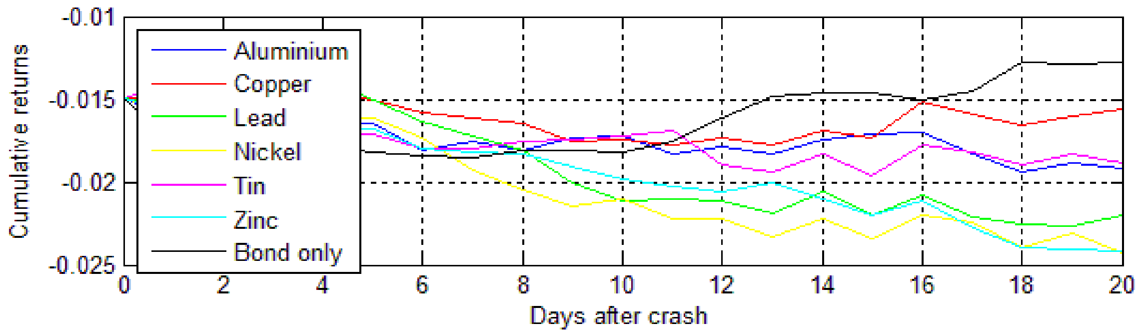
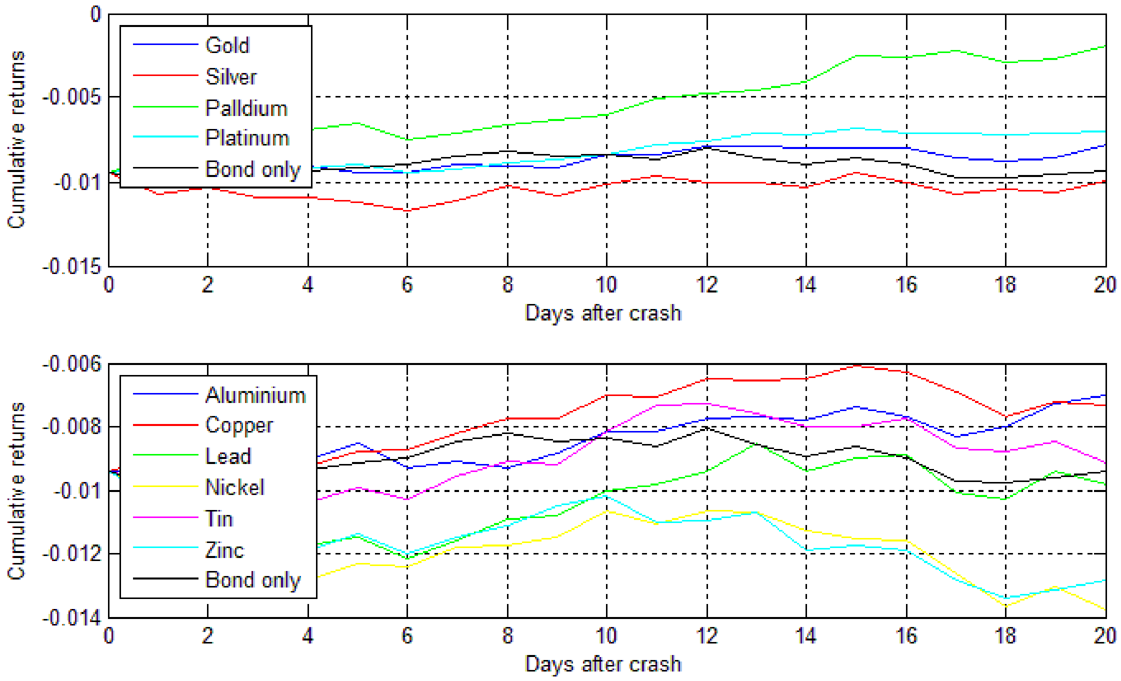




UK, equally weighted portfolio of bond and metal:



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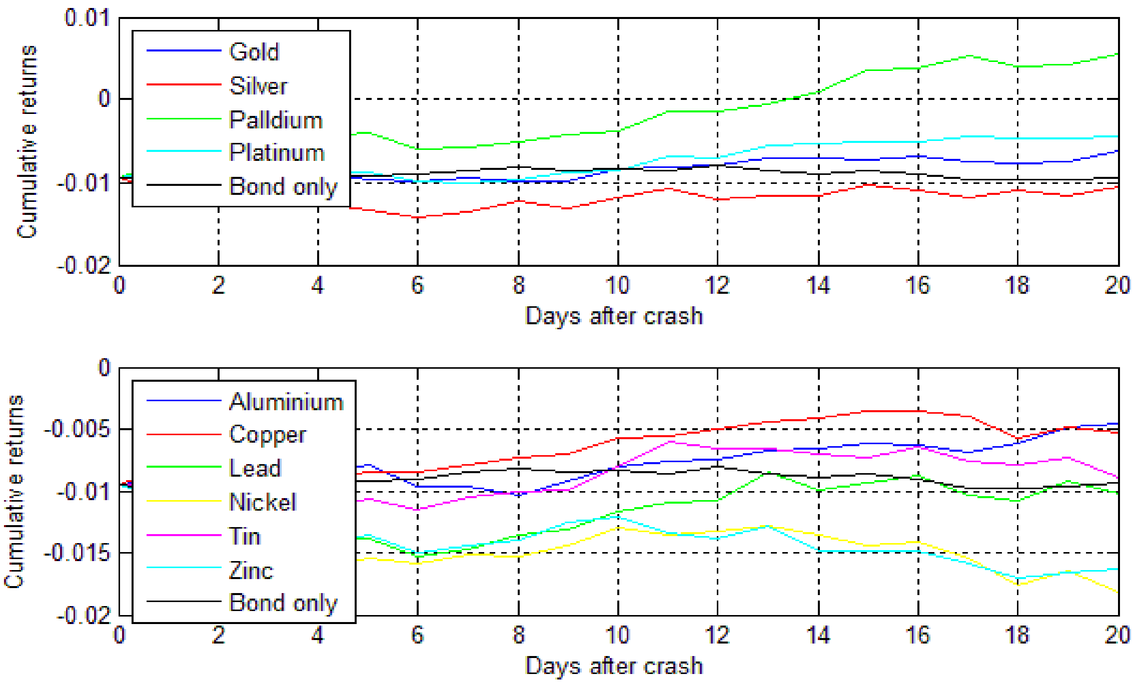

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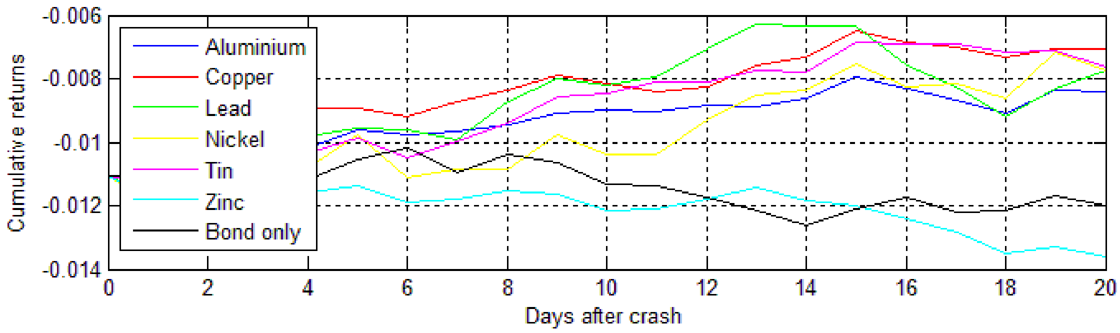

US, all invested into metal after crash: