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Abstract

The paper tests whether there were events of contagion, and portfolio shift, in the sovereign bond markets of eleven emerging countries' between January 1995 and November 2001. From existing definitions, we narrow down the concept of contagion by focusing on pricing errors, after general market movements have been taken into account with a three-factor asset pricing model. We measure contagion (and portfolio shift) in terms of a causal positive (negative) dynamic co-movement between sovereign bond pricing errors. Downgrades of sovereign ratings are used as proxies for a shock. We find empirical support for contagion and portfolio shift for a number of countries on the basis of our definition.

JEL Classification: F30, F33, G12, G15

Key words: Financial linkages, financial crisis, Granger causality, international asset pricing

1. Motivation

In the last few years, the economic literature has devoted substantial efforts to explain the phenomenon of contagion between countries. The possibility of separating pure contagion from fundamental-related changes in financial variables is key in the design of the international financial architecture. In fact, one of the most important changes of the international financial architecture in recent years is the clear distinction made between countries suffering contagion –or creating it due to their systemic importance– and those suffering crises because of their own fundamentals. The first group of countries appears to be in a better position to receive larger amounts of funds from the IMF than the second group[3].

The phenomenon of contagion is also of particular interest for investors since they can profit from events where there is no perfect arbitrage or where herd behaviour exists. In particular, if an investor were to know beforehand that a country's financial variables suffer contagion from another country's financial variables when a shock occurs, he or she could profit from this information.

For both interests (the international community's and investors'), the concept of contagion needs to be defined accurately since decisions need to be taken on the basis of its existence or absence. This is particularly problematic if we consider that there is no consensus in the literature on the definition of contagion and the extent of the phenomenon. This lack of consensus is related to the difficulty in measuring such a high frequency event because of potential problems of simultaneity, omitted variables, conditional and unconditional heteroskedasticity, serial correlation, non linearity and non-normality[4]. Therefore, distinguishing contagion events from other market movements is an empirical question, which still needs to be answered.

[3] More specifically, the IMF Supplementary Reserve Facility (SRF) is designed for countries which "may create a risk of contagion that could pose a potential threat to the international monetary system", while the Contingent Credit Line (CCL) was designed for those countries who could suffer from contagion (IMF, 1997).

[4] For a review of these potential problems see Rigobon (2001).

In this paper, we build upon existing definitions of contagion by narrowing down the concept in several ways. Our objective is to improve the measurability and comparability of events of potential contagion. This seems crucial in view of the role that contagion plays in the provision of international financial assistance, and is certainly also useful for investors.

This is a demanding endeavour, which cannot be a accomplished in a single project. We now concentrate on one market, emerging countries' sovereign bonds, and in one type of shock, a downgrade in a country's sovereign rating different than the one that may potentially suffer from contagion.

The reasons for these two choices are the following. First, emerging countries are those more dependent on international financial assistance and their sovereign bonds are particularly relevant financial assets, being closely associated with country risk. In addition, emerging countries' sovereign bonds constitute an asset class in which investors are interested. Second, sovereign ratings are an aggregate measure of a country's fundamentals. Downgrades in sovereign ratings should be a good proxy for a shock since they generally reflect a sharp deterioration in fundamentals. However, there could be problems with this proxy if the timing of the downgrade does not coincide with the shock. In addition, not all shocks are reflected by a downgrade. As far as investors' are concerned, though a rating downgrade is an important piece of information, which is incorporated in their investment decisions. This implies that the proxy we have chosen for a shock is probably more appropriate for an analysis of contagion from an investor's point of view than for the international community, more interested in the propagation of crisis events.

Another important objective of this study is to concentrate, to the extent possible, on pure contagion and not on relations between emerging countries' sovereign bonds which can be explained by other factors, such as general market movements. This idea can be associated with the literature of herd behaviour [Calvo (1999), Calvo and Mendoza (1999), Kodres and Pritsker (1999) and Kumar and Presaud (2001)].

The most appropriate methodology to answer this question is, in our view, the application of a multifactor asset pricing model for sovereign bonds' returns, as can be found in the work of Bekaert *et al.* (2003) and Díez de los Ríos (2003). This framework has three main advantages with respect to other tests of contagion. Firstly, the factor structure implicitly defines common shocks and the links between financial and real activity. Secondly, it takes into account the statistical fact that correlations increase during periods of financial turmoil. Thirdly, any pricing model is ultimately based on utility maximizing agents, which implies that rational decisions should be incorporated in the model and whatever is left (potentially contagion) could be considered irrational as long as the model appropriately describes asset price movements.

As a second step, we measure contagion from a dynamic point of view. We do so by testing whether the pricing errors of a country's bond excess returns from our asset pricing model are dynamically causing another country's pricing errors. This is an innovation to the existing literature. Another innovation is the distinction between contagion and portfolio shifts.

In sum, this paper has two objectives: narrowing down the definition of contagion to make it more comparable among different events, and testing for contagion in the sovereign bond markets of emerging countries. The paper is organized as follows. Section 2 reviews the literature on the definitions of contagion and the empirical results for emerging markets' sovereign bonds. Section 3 presents our working definition of contagion and our estimation methodology. Section 4 describes the data. Section 5 presents the results and Section 6 the conclusions and future extensions of the work.

2. Review of the literature

In the literature, there is a considerable amount of debate concerning the precise definition of contagion, and how to measure it [Pericoli and Sbracia (2001), Forbes and Rigobon (2001), Rigobon (2001) and Bayoumi *et al.* (2003)]. The existence of contagion conveys the idea that economic models based on fundamentals or channels of international transmission (i.e., trade or financial links) exclude important issues, such as changes in risk appetite [Kumar and Peraud (2001)], asymmetric information or, more generally, the way international investors' operate [Goldfjan and Valdes (1997) and Calvo (1999)] or the indeterminacy of equilibrium [Masson (1998)]. For some authors, these are "rationally justifiable" reasons for contagion, for others they are not. In this study, we do not attempt to identify the channels of contagion or its rationality or irrationality. We take this as given and focus on delimiting existing definitions of contagion to make the phenomenon more comparable across events. However, the fact that we limit our definition to a very narrow set of events approaches our definition to that of "pure contagion".

The first, and perhaps most important attempt, to make the concept of contagion more operational is that of Forbes and Rigobon (2001)[5]. The authors define contagion as "a significant increase in cross-market asset linkages after a shock to an individual country or group of countries"[6]. We note that the focus is on developments after a shock, to distinguish it from normal times. However, the authors do not specify clearly what kind of shock may lead to contagion. In addition a general expression –cross-country asset linkages– is used to describe the co-movement between different countries' financial assets when contagion occurs. In the authors' mind such linkages can be measured by "anything from the correlation in assets returns, to the probability of an speculative attack, to the transmission of shocks or volatility". The main thing is that the interlinkages increase after a shock, compared with tranquil periods.

Such interlinkages have generally been identified with bi-variate correlations [King and Wadwani (1990), Baig and Goldfajn (1998) and Bayoumi *et al.* (2003)]. However, it is widely acknowledged that a high correlation could be due to common factors other than contagion.

Another approach is the estimation of the variance-covariance transmission mechanism across countries, using ARCH or GARCH models. Edwards (1998) uses a univariate GARCH model for bond markets after the 1995 Mexican crisis, and finds that the

[5] Another recent attempt can be found on Bayoumi *et al.* (2003), but they focus on correlations.
[6] They call it shift-contagion, to differentiate from other more general definitions of contagion.

increase in volatility in Mexico's bond market had a significant impact on Argentina´s volatility, but not on Chile's. However these studies focus on volatility spillovers between asset returns so their co-movement is not really measured.

Other authors have concentrated on changes in long-run relationships, which however do not fit very well with Forbes and Rigobon's definition of immediate increases in linkages after a shock. Finally, another strand of the literature has opted for identifying simple models of propagation of shocks after exogenous events [Kaminsky and Reinhart (1999)]. While potentially very informative, this approach does not offer a very precise measure of contagion. One of the main objectives of our paper is finding a more precise definition of "interlinkages" which distinguishes contagion from other events.

In order to narrow down the definition of contagion to a more operational one, it seems important to identify which are the main factors determining the returns of emerging countries' sovereign bonds. In fact, only what cannot be explained by such factors should be called contagion. Interest rate, exchange rate and credit (or sovereign) risks are the most widely accepted determinants of sovereign bond excess returns [Kamin and Von Kleist (1999)]. The interest rate risk hinges on the interest rate structure (and maturity) of sovereign bonds as compared to other bond portfolios. Exchange rate risk is particularly relevant for local currency-denominated sovereign bonds. Credit risk depends on the country's economic fundamentals [Min (1998)]. The ability to clean sovereign bonds from these factors' influence before testing for contagion is another important objective of our paper.

The measure of credit risk is particularly problematic, because it is related to a large number of variables reflecting a country's fundamentals. Several authors have used credit ratings, together with macroeconomic variables, as a proxy of credit risk [Cantor and Packer (1996), and Eichengreen and Moody, (1998)]. Others have used credit ratings as single variable determining credit risk [Erb, Harvey and Viskanta (2000), and Kamin and Von Kleist (1999)]. We will follow the latter line for reasons explained in Section 4.

3. Definition of contagion and methodology

Taking Forbes and Rigobon's working definition of contagion as a benchmark, ours will necessarily have to refer to (i) a situation after a shock, and (ii) cross-country interlinkages. From a broad concept, such as that of "interlinkages", we exclude those movements related to the main determinants of sovereign bond returns and obtain the pricing errors. We, then, test for a dynamic causal relation between pricing errors, after a shock occurs. In this more restrictive framework, contagion can be defined as the causal dynamic co-movement between the pricing errors of sovereign bonds, after a shock occurs. In the case of contagion, the co-movement will necessarily be positive while it will be negative in the event of a portfolio shift.

One of the advantages of this narrower definition is that we can limit ourselves to pure contagion (pure portfolio shift), and not market driven interlinkages. Another one is that we can say something on the direction of the transmission of pricing errors and, thereby, which countries are sources of contagion (or a portfolio shift) and which are recipients. We now describe the methodology used in more detail.

3.1 An asset pricing model of sovereign bond excess returns

As previously mentioned, we choose to apply a multifactor asset pricing model to explain the developments in emerging countries' sovereign bond returns. This framework has three main advantages with respect to other tests of contagion. Firstly, the factor structure implicitly defines common shocks and the links between financial and real activity, or as Bekaert *et al.* (2003) put it, the "mechanism that links the fundamentals to asset returns". Secondly, it takes into account the statistical fact that correlations increase during periods of financial turmoil [Corseti *et al.* (2002), Forbes and Rigobon (2002), and King, Sentana and Wadhwani (1994)]. Thirdly, any pricing model is ultimately related to a model with utility maximizing agents. This means that a systematic behaviour of pricing errors, such as a causal dynamic co-movement between two pricing errors, will be close to "pure contagion" (or "irrational", as a strand of the literature would call it).

It should be acknowledged that the explanatory power of the asset pricing model may be reduced by the lack of integration of asset markets, scarce liquidity and/or infrequent trading. Notwithstanding these potential problems, the asset pricing model has been proven to be a useful tool to describe asset price movements in most markets, including emerging countries' sovereign bonds [Bekaert *et al.* (2003) and Díez de los Ríos (2003)].

As for the precise methodology, a three factor asset pricing model is taken to extract general market movements from the information of emerging countries' sovereign bonds. The three factors reflect movements in world assets, those of the same asset class and those of the currencies of investing countries. Credit risk will be tackled later because of the difficulties of incorporating it in the asset pricing model.

We use the dynamic version of the Arbitrage Pricing Theory proposed by King, Sentana and Wadhwani (1994) and Sentana (2002). We make use of the estimation method proposed by Sentana (2002) who applied this methodology to measure the impact of the European Exchange Mechanism (ERM) on the cost of capital for European firms. In the method is based on the generalized moments method (GMM) developed by Hansen (1982).

The analysis is based in a world with a large number of countries $j = 1,..., N$, and assumes that for each country there is one long-term bond portfolio, whose random gross holding return over period t, and denominated in US$, is R_{jt}. Let $R_{c\$t}$ be the gross return on a safe asset during period t, also denominated in US$. The excess return of the bond portfolio for each country in terms of US$ is, thus, given by:

$$r_{jt} = \log R_{jt} - \log R_{c\$t}$$

Provided that excess returns consist of a risk premia (μ) and an unanticipated (η) component (as of $t - 1$), r_{ajt} can be expressed as:

$$r_{jt} = m_{jt} + h_{jt}$$

If the relevant model for investors were an international CAPM and the global market bond portfolio were mean-variance-efficient, the expected return on any security or portfolio would be fully explained by its loading on the global market bond portfolio excess return. But, as pointed earlier, such traditional risk factor models perform poorly when applied to emerging financial markets, given that there are other substantial risks not captured in the CAPM. It seems, therefore, reasonable to include additional factors, other than the global market bond portfolio, to explain the returns of a country's sovereign bonds, summarized in the EMBI index, by means of an APT model. We propose a three factor model to capture the systematic risk in emerging bond returns:

$$h_{jt} = \underbrace{b_{ej} f_{et} + b_{wj} f_{wt} + b_{rj} f_{rt}}_{\text{Systematic Risk}} + \underbrace{u_{jt}}_{\text{Idiosyncratic Risk}} \qquad (1)$$

where the first factor $-f_{et}-$ is a currency risk component stemining from the deviations from Purchasing Power Parity in the home countries of investors. This risk is not related to the host country´s local currency since the emerging countries' sovereign bonds chosen are all denominated in US dollar. However, the exchange rate risk still exists depending on the country of origin of investors, since not all currency movements can be diversified away[7].

Secondly we include a world factor $-f_{wt}-$ in order to capture the international comovements in bond returns, and an asset-class factor $-f_{rt}-$ in order to capture comovements within the asset class of emerging markets bonds.

Furthermore we will assume that:

(i) Common and specific factors are unpredictable on the basis of past information, to guarantee that the η's are innovations.

[7] When PPP does not hold, there is a currency risk premia that is related to the conditional covariance of the asset excess return with the excess return of a diversified currency deposit portfolio. See Adler and Dumas (1983) for further details.

(ii) The common factors are orthogonal to each other and for the idiosyncratic terms, which by definition are orthogonal to $f_t = \left(f_{et,} f_{wt,} f_{rt}\right)'$, we assume that they are orthogonal to one another for a given country *j*.

Under a no arbitrage assumption, it can be proven that there is a stochastic discount factor that prices the available assets by discounting the uncertain payoffs across different states of the world. In particular, assuming a linear model for the discount factor, the risk premia will have a beta representation which implies[8]:

$$m_{jt} = b_{ej} p_{et} + b_{wj} p_{wt} + b_{rj} p_{rt} \qquad (2)$$

where p_{kt} is the risk premium that corresponds to the factor k. Note that this benchmark model implies that country specific risk should not be priced, as long as risk premia depend on the common factors, not on the assets.

Combining (1) and (2) we obtain:

$$r_{jt} = b_{ej} f_{et}^{R} + b_{wj} f_{wt}^{R} + b_{rj} f_{rt}^{R} + u_{jt} \qquad (3)$$

or in matrix notation $r_{jt} = \mathbf{b}_j \mathbf{f}_t^R$, where $\mathbf{b}_j = (b_{ej}, b_{wj}, b_{rj}),\ f_{kt}^R = p_{kt} + f_{kt}\ (k = e, w, r)$. This can be interpreted as the excess returns of three portfolios, $\mathbf{f}_t^R = (f_{et}^R, f_{wt}^R, f_{rt}^R)'$, that mimic the three factors introduced, as long as p_k represents the risk premium and f_{kt} the unanticipated component (as of $t - 1$) associated to the common factor k.

Since $\mathbf{f}_t^R$ are not directly observable we can construct, as proposed by Sentana (2002), three fully diversified portfolios of currency deposits *(c)*, a global bond portfolio *(s)* and an emerging-local bond portfolio *(g)*, with excess returns given by $\mathbf{r}_{pt} = (r_{ct}, r_{st}, r_{gt})'$ that capture the systematic risk structure:

$$r_{ct} = f_{et}^{R}$$

[8] See Sentana (2002) for an extended discussion of the pricing relationship. For the sake of clarity, the same notation is used as in Sentana's paper.

$$r_{st} = b_{es} f_{et}^{R} + f_{wt}^{R} \qquad (4)$$

$$r_{gt} = b_{eg} f_{et}^{R} + b_{wg} f_{wt}^{R} + f_{rt}^{R}$$

or in matrix notation $\mathbf{r}_{jt} = \mathbf{B}_j \mathbf{f}_t^R$, and where the scaling of the common factors are set to $b_{ec} = b_{ws} = b_{gr} = 1$. Therefore we can obtain estimates of $\mathbf{p} = (p_e, p_w, p_r)', \mathbf{B}_p$ and $\mathbf{b}_j$ by employing the Generalised Method of Moments (GMM)[9]. Robust standard errors are calculated using the Newey-West approach with a bandwidth of 7 lags $(\cong T^{1/3})$.

3.2 Contagion Tests

As a second step, we test whether the pricing errors of a country's sovereign bonds explain future pricing errors of another country's sovereign bonds. To this end, we use the residuals from the asset pricing equations (i.e., the pricing errors) and test whether the co-movements in pricing errors are causally related after a shock occurs in a certain country. Causality will be measured in the Granger sense.

We test whether the coefficient of country *i*'s lagged pricing error is different from zero in the equation of country *j*'s pricing error.

$$u_{it} = g_{ij} u_{jt-1} + e_{ijt} \qquad (5)$$

Note that this implementation is equivalent to the traditional Granger causality test where it is imposed that other lagged pricing errors different from that of country *i*'s are zero. Although both tests are equivalent under the null hypothesis of no contagion, this implementation has the advantage that our alternative hypothesis coincides with our working definition of contagion, namely that there is a causal dynamic co-movement between the pricing errors of two countries' sovereign bonds.

At this stage, we need to introduce a shock from which to test for contagion. The choice of was is meant by a shock is crucial in this setting. We use downgrades in sovereign

[9] See Sentana (2002) for details.

ratings with a double aim: First, downgrades in a country's own ratings proxy should mirror a worsening in a country's fundamentals, that is, in credit risk. This is how sovereign ratings are generally used in the empirical literature on sovereign bonds. In our empirical strategy, including changes in a country's own rating allows us to extract any information related to credit risk that may have remained in the pricing errors from the asset pricing model. Second, changes in another country's ratings stand for the worsening of fundamentals in another country, which is our proxy for a shock. Note that the rating downgrade does not necessarily have to be that of the country against which we test for causality but it could also be a third country. This allows us to consider potential contagion from third countries, transmitted through another one.

While not all shocks are accompanied by rating downgrades and not all downgrades occurred under very difficult circumstances, this is, in our view, the best available proxy of a shock with a high enough frequency. Using ratings has several advantages: First, their simplicity, since all the information about a country´s fundamentals is summarized in one single indicator. Second, rating agencies can decide to change a rating at any point in time, which implies that they can be incorporated in the analysis of high frequency data.

There are, however, disadvantages in using rating downgrades as a proxy for a shock. One is the persistence of ratings, shown by the high first order positive auto-correlation, even higher than that of sovereign bond yields[10]. Another disadvantage is the fact that ratings may change due to factors different than those suggested by the literature [Mulder and Perrelli (2001), and Sy (2001)] and that there may be an overshooting of downgrades in crisis periods [Ferri, Liu and Stiglitz (1999)].

More precisely, we introduce a dummy variable, $DownOwn_{it}$, which takes the value of 1 in the 4 weeks before and after a downgrade is announced for country *i*; and another dummy variable, $DownOther_{it}$, which takes the value of 1 in the 4 weeks before and after

[10] Monfort and Mulder (2000) attribute such autocorrelation to the fact that ratings should only respond to new information. This corresponds well to the professed objective of rating agencies to limit changes in grading.

a downgrade is announced in any other country *j* different from i[11]. We, thus, augment the regressors in equation (5) to include interaction terms of the lagged pricing error with these two dummies. In particular, we want to test whether coefficients on the lagged pricing error and the interaction term with $DownOther_{it}$ are equal to zero, which would imply that no causal dynamic comovement exists from excess returns in country j to country i:

$$u_{it} = g_{ij} u_{jt-1} + V_{ij} u_{jt-1} DownOwn_{it} + x_{ij} u_{jt-1} DownOther_{it} + e_{ijt} \qquad (6)$$

Given that the pricing errors depend on the estimates of the asset pricing model, these equations must be estimated jointly with the asset pricing equations to obtain a correct inference.

4. Data

Our sample is composed of weekly data for 11 countries, starting on January 18, 1995 and ending on November 4, 2001. This amounts to 326 observations per country.

We take information from sovereign bond returns for the largest number of emerging countries possible for which there is comparable data for a relatively long time series. J.P. Morgan Securities offers a number of different daily indices of emerging market bond returns. We choose the EMBI+, which includes dollar-denominated Brady bonds and other non-local currency-denominated bonds starting from January 1995. J.P. Morgan also produces an index of local currency-denominated bond paper (the Emerging Local Currency Index) but we prefer to use foreign-currency denominated bonds since credit risk and local exchange rate risk are many times closely intertwined. Furthermore, the EMBI+ offers a relatively longer series than other J.P. Morgan emerging country bond indices. Finally, the choice of EMBI+, with its relatively high

[11] We also consider the period before the downgrade because of the widely accepted view that rating agencies tend to react late to a change in a country's fundamentals.

minimum liquidity criteria[12] as compared with single sovereign bonds, allows us to disregard a potential liquidity risk premium.

We take those countries with an EMBI+ index and without missing observations[13] from January 1995 onwards. These are eleven countries: Argentina, Brazil, Ecuador, Mexico, Morocco, Nigeria, Panama, Peru, Poland, Russia and Venezuela[14]. Data are weekly to avoid week-of-day effects.

We calculate the weekly excess return for country *j* sovereign bond portfolio r_{jt} by subtracting the weekly U.S. Federal Fund rate to the EMBI+ index for country *j*. Although J.P. Morgan offers readably calculated EMBI spreads, which control for potential distortions in US Treasuries, such as floating coupons, principal collateral and rolling interest rate guarantees, we prefer to calculate the excess returns, rather than use the EMBI+ spreads for homogeneity with other asset returns used in the two-factor asset pricing model described in the previous section. Table 1 present summary statistics of the weekly excess returns.

The data for the three factors of our asset pricing model are the following. To measure world market risk, we use weekly data of the MSCI World Index and, as before, subtract the weekly U.S. Federal Fund rate to obtain excess returns. To measure asset class market risk, we take weekly excess returns of the full EMBI+ Index[15] and subtract the weekly U.S. Federal Fund rate. Finally, for the exchange rate risk, we calculate an aggregate equally weighted, portfolio using weekly data on currency deposits excess returns for Australia, Canada, Japan, and ten European countries (Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and UK)[16]. Note that the limited availability of the short interest rates needed to build the currency deposits excess returns also limits the sample.

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[12] Instruments in the EMBI+ must have a minimum $500 million of face value and must be available and liquid.

[13] The GMM procedure requires that there are no missing observations.

[14] There was daily data available for the Philippines from January 1995 onwards but, unfortunately, there was a period close to the Asian crisis where data was missing.

[15] JP Morgan calculates the EMBI+ Index as an aggregation of single indices for 24 countries.

[16] These are the main investors´ in emerging countries´ sovereign bonds and this subject to exchange rate risk against the US dollar. The US is obviously excluded.

Finally, we use the sovereign ratings history for each country from January 1995 onwards from Moody's foreign currency sovereign ratings (2002), as a proxy for shocks in fundamentals in the own country and elsewhere.

5. Results

We, first, estimate the three-factor asset pricing model, which explain sovereign bond returns. The results show which is the degree of comovement implied by the factorial structure and the asset pricing model. Table 2 presents the estimates of the diversified portfolios. It shows that the excess returns of the MSCI portfolio and those of the currency portfolio are significantly and positively correlated $\beta_{es}>0$, in the same way as those of the MSCI portfolio and the EMBI+ $\beta_{wr}>0$. On the other hand, the excess returns of the EMBI+ portfolio and those of the currency portfolio are negatively correlated $\beta_{er}< 0$.

Moreover, the world and emerging market risks have a positive reward, being p_w and p_r positive (although both are estimated imprecisely) while p_c is found to be negative. The latter can be explained by the continuous appreciation of the US with respect to the euro in our estimation period[17].

The results from estimating the factor loadings of the asset pricing model are presented in Table 3. The coefficient of the bond excess returns on the exchange rate factor (β_{ej}) is negative for every country, although it is only significant at a 5% level for Nigeria. This implies that in a few cases, sovereign bond returns suffer when there is a generalized appreciation of other currencies against the dollar. Sensitivities of the bond returns to common world and asset class factors (β_{wj} and β_{rj},, respectively) are both positive. Therefore, an increase in world and emerging excess returns lead to increases in individual countries' returns. Finally, we note that the estimated pricing error a_j, where $\alpha_j = E(\upsilon_{jt})$, is not significantly different from zero. This shows that the three factors of

[17] A robustness exercise excluding the asset class market risk was conducted. In particular, taking out the asset-class market risk probably implies a misspecification of the model and, thus, larger pricing errors. The results of the Granger causality are much weaker than for the three-factor model. The corresponding tables are available upon request to the authors.

our asset pricing model are able to explain excess returns of emerging countries sovereign bonds relatively well.

We, then, extract the pricing errors from the three factor model for each of the eleven countries and conduct bilateral Granger causality tests. We first disregard shocks for the purpose of comparison. The estimated equation on which we run the Granger causality test is:

$$u_{it} = g_{ij} u_{jt-1} + e_{ijt}$$

Table 4 presents the estimates of this equation and shows that several causal comovements are found, which however should not be interpreted as contagion since they refer to the whole sample and not necessarily to the developments after a shock. For example, Argentina's pricing errors granger cause those of Ecuador and Russia for the whole sample period. The negative sign of their dynamic relation indicates that there has been a portfolio shift from Argentina to Ecuador and Russia –and not contagion– in the way we have defined it.

We, now, introduce shocks in the equation, by including sovereign ratings as an additional regressor.

$$u_{it} = g_{ij} u_{jt-1} + V_{ij} u_{jt-1} DownOwn_{it} + x_{ij} u_{jt-1} DownOther_{it} + e_{ijt}$$

Several results change: The previous negative Granger causality (the portfolio shift) found from Argentina to Ecuador disappears but that of Argentina to Russia remains (Table 5). Evidence of portfolio shift after a country's downgrade is also found, at least at a 5% confidence level, from Brazil to Venezuela, from Mexico to Russia and Venezuela, from Morocco to Brazil, from Panama to Russia, from Peru to Venezuela, from Poland to Russia and from Venezuela to Poland. We conduct a Wald test to determine if it is the change in the rating of the source country (or another country's rating) which explains the portfolio shift and find that this is the case only for a few cases (at least at the 5% confidence level), namely that of from Mexico to Venezuela, from Poland to Russia and from Venezuela to Poland (Table 6). These can be considered the only clear cases of portfolio shift stemming from a rating downgrade of the source country or a third one. These results are robust to reverse causality since it is not found in any of the three cases.

As for contagion, we find a positive causal relation from Argentina to Mexico, from Brazil to Mexico, from Ecuador to Nigeria and Russia, from Morocco to Argentina[18] and Venezuela, from Nigeria to Argentina and Venezuela, from Panama to Brazil, from Peru to Brazil, and from Poland to Argentina (Table 5). When conducting Wald tests on the explanatory power of the downgrade, and contagion is only confirmed from Brazil to Mexico, from Ecuador to Nigeria, from Morocco to Argentina and Poland to Argentina, at a 5% confidence level, at least (Table 6). As before, these contagion events are not weakened by reserve causality, except in the case of Ecuador and Nigeria at a 10% confidence level. In addition in the case of Morocco, the potential lack of liquidity is a concern.

6. Conclusions and future extensions

In this paper we narrow down the definition of contagion taking into account general market, movements, those of the same asset class, investors´ currency risk and credit risk. When these factors are discounted, we find empirical evidence of a few events of causal negative (positive) dynamic co-movement after a shock. We consider these contagion (portfolio shift) on the basis of our working definition.

In particular, portfolio shifts seem to have occurred from Mexico to Venezuela, from Poland to Russia and from Venezuela to Poland in the period of analysis. Contagion events seem to have occurred from Brazil to Mexico, and from Poland to Argentina.

It is important to note that the cases of portfolio-shift and contagion cannot be due to general market developments since they have been previously extracted from the pricing errors thanks to the methodology used. In addition, the introduction of the own country's downgrades should have contributed to eliminating credit risk in the pricing errors. This implies that the events of contagion found can be considered very close to pure contagion.

[18] The relative lack of liquidity of the EMBI for Morocco implies that it should be taken with caution.

The question remains, though, whether a downgrade in another country's rating is an appropriate proxy for a substantial shock to a country. In addition, our working definition focuses on short-term causal co-movements (one week after the shock). This means that the cases of contagion (or portfolio shift) we find do not have to coincide with longer term causal relations. This makes our definition more useful for investors in search of arbitrage opportunities than for policy decisions by international organizations related to the international financial architecture. Furthermore, rating downgrades are a variable that investors focus on more than the international community. For the latter, a longer-term definition of contagion and a broader definition of a shock would be warranted since the granting of financial assistance to a country subject to contagion needs to be based on a problem which is not to disappear very quickly. However, the broadening of the definition should not be such as to make it impossible to compare across events in an objective way.

Given the importance that contagion has for the international financial architecture, additional work in this direction is clearly a useful endeavour and will constitute the objective of future extensions of our paper. To do so, we need to extend the period in which the causal dynamic co-movements between two countries' excess returns are tested. We also need to apply broader definitions of a shock. Finally, the analysis could be extended to other emerging countries' financial assets of relevance for contagion, mostly exchange rate movements and, to a lesser extent, the stock exchange.

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Table 1
Summary Statistics Weekly Returns (%)

Portfolio	Mean	Std Dev
Currency	-0,119	0,997
MSCI	-0,020	0,813
EMBI+	0,230	2,477
Argentina	0,195	2,672
Brazil	0,220	3,170
Ecuador	0,197	4,599
Mexico	0,219	2,102
Morocco	0,218	2,512
Nigeria	0,263	2,949
Panama	0,350	2,696
Peru	0,288	3,427
Poland	0,251	1,803
Russia	0,274	6,312
Venezuela	0,302	2,935

Table 2
Risk premia and factor loading for diversified portfolios
Three Factor Model

World Portfolios	Common Exchange Rate Risk		Common World Market Risk		Common asset-class Market Risk	
Currency	βec=	1,000				
MSCI	βes=	0,616*** (0,040)	βws=	1,000		
EMBI	βer=	-0,235 (0,207)	βwr=	0,566** (0,259)	βgr=	1,000
	πe=	-0,119** (0,059)	πw=	0,053* (0,031)	πr=	0,172 (0,140)

GMM estimates of the following system of equations:

$$r_{ct} = p_{et} + f_{et}$$
$$r_{st} = p_{wt} + b_{es} f_{et}^{R} + f_{wt}$$
$$r_{gt} = p_{rt} + b_{eg} f_{et}^{R} + b_{wg} f_{wt}^{R} + f_{rt}$$

where: $p_e = E(p_{et}),\ p_w = E(p_{wet}), p_r = E(p_{rt}),$

(***), (**), (*) indicates coefficient significantly different from zero at the 1%, 5% and 10% level respectively

S.E. in parenthesis

Table 3
Factor Loadings for Bond Returns: Three Factor Model

Countries	Common Exchange Rate Risk (βej)	Common World Market Risk (βwj)	Common A. Class Market Risk (βrj)	Idiosyncratic Risk Pricing (αj)
Argentina	-0,330	0,788**	0,973***	-0,054
	(0,265)	(0,322)	(0,058)	(0,065)
Brazil	-0,303	0,326	1,202***	-0,040
	(0,225)	(0,292)	(0,089)	(0,054)
Ecuador	-0,485*	1,004**	1,340***	-0,144
	(0,267)	(0,466)	(0,107)	(0,179)
Mexico	-0,196	0,599***	0,744***	0,035
	(0,146)	(0,204)	(0,057)	(0,055)
Morocco	-0,229	0,241	0,877***	0,027
	(0,180)	(0,234)	(0,059)	(0,063)
Nigeria	-0,456**	0,543	0,765***	0,048
	(0,220)	(0,383)	(0,101)	(0,086)
Panama	-0,495*	0,951***	0,815***	0,100
	(0,278)	(0,274)	(0,079)	(0,106)
Peru	-0,267	0,950***	1,045***	0,026
	(0,311)	(0,316)	(0,108)	(0,096)
Poland	-0,259	0,789***	0,490***	0,094
	(0,183)	(0,191)	(0,083)	(0,066)
Russia	-0,055	0,366	1,597***	-0,027
	(0,367)	(0,842)	(0,289)	(0,401)
Venezuela	-0,180	0,693***	0,942***	0,082
	(0,192)	(0,267)	(0,093)	(0,102)

GMM estimates of the following system of equations:

$$r_{jt} = b_{ej} f_{et}^{R} + b_{wj} f_{wt}^{R} + b_{rj} f_{rt}^{R} + v_{jt}$$

where:

(***), ($a_j = E(v_{jt}) = E(r_{jt} - b_{ej} f_{et}^{R} - b_{wj} f_{wt}^{R} - b_{rj} f_{rt}^{j})$ ferent from zero at the 1%, 5% and 10% level respectively

S.E. in parenthesis

Table 4
Granger Causality Tests: Three Factor Model

Countries i\j	Argentina	Brazil	Ecuador	Mexico	Morocco	Nigeria	Panama	Peru	Poland	Russia	Venezuela
Argentina	0,096*	0,070	-0,005	-0,015	0,133***	-0,021	-0,053	-0,045	-0,073	-0,019**	-0,023
	(0,058)	(0,065)	(0,016)	(0,085)	(0,039)	(0,035)	(0,045)	(0,031)	(0,072)	(0,008)	(0,037)
Brazil	0,019	-0,215*	0,020	0,032	-0,035	0,079	0,071**	0,037	0,030	0,018	0,018
	(0,107)	(0,124)	(0,031)	(0,079)	(0,057)	(0,055)	(0,031)	(0,028)	(0,044)	(0,020)	(0,048)
Ecuador	-0,290**	0,374*	-0,108	-0,102	-0,278***	0,040	-0,213**	-0,028	-0,155	0,027	0,045
	(0,126)	(0,195)	(0,083)	(0,179)	(0,098)	(0,106)	(0,104)	(0,098)	(0,149)	(0,034)	(0,099)
Mexico	0,127*	-0,087	-0,001	0,029	0,042	-0,021	0,003	0,010	0,086	-0,012	-0,033
	(0,066)	(0,094)	(0,013)	(0,083)	(0,055)	(0,026)	(0,038)	(0,028)	(0,095)	(0,014)	(0,031)
Morocco	0,045	-0,086	-0,026	-0,036	0,002	-0,008	0,018	-0,019	0,084	0,014	0,008
	(0,066)	(0,082)	(0,018)	(0,052)	(0,065)	(0,027)	(0,053)	(0,031)	(0,067)	(0,014)	(0,034)
Nigeria	-0,111	0,274**	-0,029	-0,053	-0,163	-0,144**	-0,064	0,060	-0,033	-0,006	-0,038
	(0,084)	(0,112)	(0,045)	(0,104)	(0,115)	(0,069)	(0,067)	(0,051)	(0,076)	(0,022)	(0,065)
Panama	0,144	0,129*	-0,048	0,014	-0,001	-0,011	0,085	-0,083	-0,174	-0,027	-0,030
	(0,096)	(0,073)	(0,047)	(0,164)	(0,102)	(0,039)	(0,054)	(0,076)	(0,148)	(0,020)	(0,060)
Peru	0,122	0,204**	-0,094**	-0,192	-0,060	0,017	-0,019	-0,153	-0,144	-0,017	-0,014
	(0,109)	(0,103)	(0,042)	(0,166)	(0,115)	(0,059)	(0,064)	(0,063)	(0,132)	(0,024)	(0,072)
Poland	0,074	0,131*	0,003	-0,044	-0,087	-0,021	0,018	0,036	0,084	-0,019	-0,104
	(0,094)	(0,069)	(0,017)	(0,078)	(0,061)	(0,024)	(0,039)	(0,036)	(0,052)	(0,020)	(0,045)
Russia	-0,866***	0,403	0,090	0,016	-0,406	-0,221	-0,200	0,006	-0,041	0,132*	-0,123
	(0,322)	(0,265)	(0,108)	(0,259)	(0,298)	(0,149)	(0,173)	(0,125)	(0,210)	(0,078)	(0,238)
Venezuela	0,010	0,055	-0,030	-0,242***	0,076	0,025	-0,008	-0,054	-0,090	0,006	0,133
	(0,112)	(0,151)	(0,041)	(0,088)	(0,132)	(0,062)	(0,054)	(0,050)	(0,079)	(0,030)	(0,079)

GMM estimates of:

$$v_{kt} = r_{kt} - b_{ej} f_{et}^{R} - b_{wj} f_{wt}^{R} - b_{rj} f_{rt}^{R}$$

where:

$$v_{it} = g_{ij} v_{jt-1} + e_{ijt}$$

(***), (**), (*) indicates coefficient significantly different from zero at the 1%, 5% and 10% level respectively

S.E. in parenthesis

Table 5
Granger Causality Tests: Three factor Model with Ratings Estimates

Countries	Argentina		Brazil		Ecuador		Mexico		Morocco		Nigeria	
i\j	γij	γij + ζij + ξij	γij	γij + ζij + ξij	γij	γij + ζij + ξij	γij	γij + ζij + ξij	γij	γij + ζij + ξij	γij	γij + ζij + ξij
Argentina	0,072	0,204	0,061	0,191	0,004	-0,100	-0,020	0,422	0,101**	0,411***	-0,035	0,242***
	(0,064)	(0,197)	(0,074)	(0,190)	(0,017)	(0,029)	(0,098)	(0,455)	(0,045)	(0,117)	(0,039)	(0,060)
Brazil	-0,010	-0,653*	-0,272*	0,013	0,025	-0,160	0,002	0,244	-0,017	-0,234**	0,084	0,010
	(0,120)	(0,368)	(0,151)	(0,245)	(0,037)	(0,132)	(0,099)	(0,288)	(0,063)	(0,097)	(0,068)	(0,057)
Ecuador	-0,271*	-0,752	0,526**	-0,848	-0,106	-0,226**	-0,066	-0,282	-0,266**	-0,353*	0,012	0,182*
	(0,141)	(0,815)	(0,209)	(0,699)	(0,095)	(0,096)	(0,201)	(0,508)	(0,109)	(0,208)	(0,124)	(0,105)
Mexico	0,116	0,185***	-0,142	0,276***	0,003	-0,033	0,013	0,182	0,058	-0,025	-0,016	-0,052
	(0,078)	(0,067)	(0,103)	(0,094)	(0,015)	(0,023)	(0,086)	(0,189)	(0,066)	(0,052)	(0,029)	(0,058)
Morocco	0,061	-0,039	-0,063	-0,239	-0,031	0,014	-0,045	0,045	-0,013	0,065	-0,012	0,015
	(0,067)	(0,105)	(0,077)	(0,215)	(0,020)	(0,046)	(0,056)	(0,177)	(0,076)	(0,073)	(0,027)	(0,089)
Nigeria	-0,078	-0,281	0,350**	-0,223	-0,051	0,149***	-0,054	-0,043	-0,158	-0,188	-0,126*	-0,248***
	(0,094)	(0,212)	(0,121)	(0,369)	(0,047)	(0,049)	(0,118)	(0,293)	(0,127)	(0,254)	(0,075)	(0,075)
Panama	0,151	0,107	0,144*	0,033	-0,047	-0,064	-0,042	0,533	0,030	-0,135	-0,033	0,109
	(0,108)	(0,171)	(0,073)	(0,230)	(0,051)	(0,122)	(0,174)	(0,389)	(0,118)	(0,110)	(0,039)	(0,093)
Peru	0,075	0,367	0,224**	0,073	-0,114***	0,064	-0,227	0,130	-0,051	-0,097	-0,019	0,223
	(0,130)	(0,243)	(0,096)	(0,463)	(0,044)	(0,101)	(0,167)	(0,419)	(0,112)	(0,373)	(0,052)	(0,210)
Poland	0,078	0,052	0,151**	0,000	0,002	0,004	-0,083	0,315	-0,077	-0,128	-0,018	-0,037
	(0,104)	(0,081)	(0,075)	(0,086)	(0,019)	(0,056)	(0,082)	(0,197)	(0,067)	(0,101)	(0,026)	(0,044)
Russia	-0,498**	-4,155***	0,612**	-1,531	0,011	2,420***	0,197	-3,244**	-0,152	-1,450*	-0,116	-0,838
	(0,229)	(0,652)	(0,311)	(1,565)	(0,125)	(0,650)	(0,245)	(1,486)	(0,255)	(0,752)	(0,159)	(0,531)
Venezuela	0,035	-0,160	0,194	-1,051***	-0,032	-0,146	-0,116	-1,787***	-0,054	0,759***	-0,034	0,541***
	(0,103)	(0,630)	(0,148)	(0,244)	(0,044)	(0,434)	(0,077)	(0,342)	(0,101)	(0,244)	(0,059)	(0,100)

GMM estimates of:

$$v_{it} = g_{ij} v_{jt-1} + z_{ij} v_{jt-1} \cdot DownOwn_{it-1} + x_{ij} v_{jt-1} \cdot DownOther_{it-1} + e_{ijt}$$

where $v_{kt} = r_{kt} - b_{ej} f^{R}_{et} - b_{wj} f^{R}_{wt} - b_{rj} f^{R}_{rt}$

(***), (**), (*) indicates coefficient significantly different from zero at the 1%, 5% and 10% level respectively
S.E. in parenthesis

Table 5
Granger Causality Tests: Three factor Model with Ratings Estimates (cont.)

Countries	Panama		Peru		Poland		Russia		Venezuela	
i\j	γij	$\gamma ij + \zeta ij + \xi ij$	γij	$\gamma ij + \zeta ij + \xi ij$	γij	$\gamma ij + \zeta ij + \xi ij$	γij	$\gamma ij + \zeta ij + \xi ij$	γij	$\gamma ij + \zeta ij + \xi ij$
Argentina	-0,064	0,176	-0,071**	0,096	-0,099	0,405***	-0,011	-0,063	-0,024	-0,051
	(0,050)	(0,293)	(0,033)	(0,133)	(0,077)	(0,147)	(0,011)	(0,050)	(0,039)	(0,260)
Brazil	0,058*	0,280***	0,021	0,177***	0,007	0,364	0,038	0,017	0,062	-0,068
	(0,034)	(0,077)	(0,032)	(0,028)	(0,044)	(0,246)	(0,030)	(0,030)	(0,073)	(0,064)
Ecuador	-0,213*	-0,044	-0,033	-0,101	-0,157	-0,672	-0,017	0,114	0,054	0,067
	(0,111)	(0,362)	(0,112)	(0,169)	(0,152)	(0,811)	(0,045)	(0,081)	(0,137)	(0,146)
Mexico	0,008	-0,050	-0,001	0,075	0,091	-0,021	-0,008	-0,020	0,007	-0,149
	(0,039)	(0,106)	(0,030)	(0,052)	(0,099)	(0,162)	(0,018)	(0,021)	(0,034)	(0,034)
Morocco	-0,016	0,418*	-0,039	0,097	0,057	0,584*	0,022	0,000	-0,016	0,081
	(0,044)	(0,250)	(0,035)	(0,081)	(0,066)	(0,328)	(0,018)	(0,022)	(0,036)	(0,067)
Nigeria	-0,044	-0,292	0,063	0,042	0,000	-0,655*	-0,009	0,000	-0,110	0,175*
	(0,071)	(0,247)	(0,057)	(0,087)	(0,072)	(0,379)	(0,030)	(0,064)	(0,080)	(0,104)
Panama	0,082	0,124	-0,094	-0,021	-0,200	0,314	-0,028	-0,023	0,012	-0,155
	(0,057)	(0,182)	(0,087)	(0,120)	(0,149)	(0,311)	(0,026)	(0,027)	(0,071)	(0,114)
Peru	0,007	-0,335	-0,119	-0,354***	-0,149	-0,039	-0,010	-0,033	-0,030	0,031
	(0,066)	(0,218)	(0,074)	(0,121)	(0,133)	(0,620)	(0,030)	(0,040)	(0,084)	(0,165)
Poland	0,021	-0,018	0,038	0,025	0,085	0,049	-0,027	-0,002	-0,104*	-0,106**
	(0,041)	(0,091)	(0,039)	(0,045)	(0,055)	(0,141)	(0,025)	(0,013)	(0,056)	(0,040)
Russia	-0,044	-2,395***	0,122	-0,160	0,184	-5,434***	-0,005	0,580***	-0,243	0,645
	(0,134)	(0,902)	(0,126)	(0,422)	(0,132)	(1,636)	(0,084)	(0,081)	(0,256)	(1,014)
Venezuela	0,001	-0,105	-0,010	-0,374**	-0,077	-0,513	0,003	0,002	-0,022	0,658***
	(0,060)	(0,327)	(0,044)	(0,164)	(0,085)	(0,752)	(0,034)	(0,081)	(0,076)	(0,097)

Table 6
Granger Causality Tests: Three factor Model with Ratings
Wald Tests

Countries i\j	Argentina	Brazil	Ecuador	Mexico	Morocco	Nigeria	Panama	Peru	Poland	Russia	Venezuela
Argentina	11,570***	3,140	0,380	0,110	16,821***	1,213	2,044	10,909***	9,675***	6,957**	0,402
	(0,003)	(0,208)	(0,827)	(0,946)	(0,000)	(0,545)	(0,360)	(0,004)	(0,008)	(0,031)	(0,818)
Brazil	4,107	6,157**	0,731	1,995	0,459	2,797	4,068	0,468	2,201	9,569***	1,957
	(0,128)	(0,046)	(0,694)	(0,369)	(0,795)	(0,247)	(0,131)	(0,791)	(0,333)	(0,008)	(0,376)
Ecuador	6,632**	11,272***	3,100	2,630	6,063**	1,674	7,471**	0,885	1,948	5,305	0,250
	(0,036)	(0,004)	(0,212)	(0,268)	(0,048)	(0,433)	(0,024)	(0,642)	(0,378)	(0,070)	(0,882)
Mexico	10,031***	9,139**	2,129	0,931	0,998	1,116	0,283	2,094	0,899	1,085	19,923***
	(0,007)	(0,010)	(0,345)	(0,628)	(0,607)	(0,572)	(0,868)	(0,351)	(0,638)	(0,581)	(0,000)
Morocco	1,326	1,513	2,578	0,698	0,843	0,221	2,997	2,858	4,071	1,487	1,546
	(0,515)	(0,469)	(0,276)	(0,705)	(0,656)	(0,895)	(0,223)	(0,240)	(0,131)	(0,475)	(0,462)
Nigeria	2,914	8,304**	10,928***	0,275	2,025	12,701***	1,715	1,422	3,010	0,996	4,232
	(0,233)	(0,016)	(0,004)	(0,872)	(0,363)	(0,002)	(0,424)	(0,491)	(0,222)	(0,951)	(0,121)
Panama	2,231	3,875	1,094	1,937	1,593	2,310	2,595	1,228	2,934	1,839	1,861
	(0,328)	(0,144)	(0,579)	(0,380)	(0,451)	(0,315)	(0,273)	(0,541)	(0,231)	(0,399)	(0,394)
Peru	3,134	5,470*	7,046**	2,073	0,280	1,203	2,395	12,361***	1,259	0,759	0,152
	(0,209)	(0,065)	(0,030)	(0,355)	(0,869)	(0,548)	(0,302)	(0,002)	(0,533)	(0,684)	(0,927)
Poland	0,701	4,033	0,250	3,252	2,702	1,094	0,296	1,045	2,672	1,289	8,957**
	(0,704)	(0,133)	(0,988)	(0,197)	(0,259)	(0,579)	(0,862)	(0,593)	(0,263)	(0,525)	(0,011)
Russia	4,771*	5,128*	2,280	1,682	3,148	3,915	2,820	11,867***	6,754**	0,749	4,267
	(0,092)	(0,077)	(0,320)	(0,431)	(0,207)	(0,141)	(0,244)	(0,003)	(0,034)	(0,688)	(0,118)
Venezuela	0,706	1,744	0,850	9,403***	1,879	2,938	0,687	0,055	0,837	0,669	0,227
	(0,703)	(0,418)	(0,654)	(0,009)	(0,391)	(0,230)	(0,709)	(0,973)	(0,658)	(0,716)	(0,893)

Wald Test of the joint hypothesis that: $g_{ij} = 0,\ x_{ij} = 0$

in estimated equation:

$$v_{it} = g_{ij} v_{jt-1} + z_{ij} v_{jt-1} \cdot DownOwn_{it-1} + x_{ij} v_{jt-1} \cdot DownOther_{it-1} + e_{ijt}$$

where

$$v_{kt} = r_{kt} - b_{ej} f^R_{et} - b_{wj} f^R_{wt} - b_{rj} f^R_{rt}$$

(***), (**), (*) indicates coefficient significantly different from zero at the 1%, 5% and 10% level respectively. p -value in parenthesis