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Abstract

This paper examines episodes of sudden large exchange rate depreciations (currency crashes) in industrial countries and characterizes the behavior of government bond yields during and after these crashes. The most important determinant of changes in bond yields appears to be inflationary expectations. When inflation is high and rising at the time of a currency crash, bond yields tend to rise. Otherwise--and in every currency crash since 1985--bond yields tend to fall. Over the past 20 years, inflation rates have been remarkably stable in industrial countries after currency crashes.

Keywords: exchange rate, depreciation, interest rate, inflation

JEL Classification: E43, F31, F41

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I. Introduction

In recent months, many commentators have voiced concerns that the large U.S. current account deficit could lead to a crash of the dollar and a hard landing for the U.S. economy. The link most often cited between a sharp dollar depreciation and a hard landing is a rise in long-term U.S. interest rates that chokes off consumption and investment.[1] Such an outcome was highly visible in a number of emerging market crises in recent years, including Mexico in 1995 and East Asia in 1997 and 1998.

There are three economic mechanisms that could link currency crashes to bond market crashes. First, exchange rate depreciations may be expected to push up domestic inflation through higher prices for imported goods and services. Investors are likely to demand a higher nominal rate of return to compensate for expected inflation. This is the "Fisher effect" or inflation expectations channel. Second, investors may expect that the monetary authority will raise short-term interest rates even more than the increase in inflation in order to prevent higher inflation from becoming entrenched. This is the "monetary reaction" channel. Finally, the currency crash could cause investors to demand a higher risk premium on bonds because of heightened uncertainty about future inflation, future real interest rates, or even the possibility of a future default.[2] This is the "risk premium" channel.

This paper shows that currency crashes do not generally lead to higher bond yields in industrial countries. Indeed, over the past 20 years, currency crashes in industrial countries have always been followed by *falling* bond yields. Why has the response to currency crashes been so different in industrial countries compared to that in emerging markets? The primary answer

[1] See, for example, *The Economist* (2005), Obstfeld and Rogoff (2005), Roubini and Setser (2005), and Volcker (2005).
[2] Note that any currency risk premium that is not related to these bond-market factors can affect the level of the exchange rate, but not the bond yield, because it affects all dollar-denominated assets equally.

appears to be that industrial countries—especially since the mid-1980s—have more stable monetary frameworks with greater anti-inflationary credibility.[3]

In particular, the change in the bond yield after a currency crash is strongly related to the level and change of the inflation rate after the crash. Since 1985, inflation rates have been low and stable after currency crashes, and these outcomes are related to the tendency of bond yields to decline or at least not to rise.[4] Moreover, bond yields do not appear to be particularly sensitive to changes in net purchases of a country's bonds by foreigners. Current account deficits appear to be associated with the occurrence of currency crashes, but the size of the deficit has only a small effect on the change in bond yields after a crash.

The next section presents a brief review of the literature on currency crises and crashes. Section III describes the data. Section IV defines and identifies currency crashes. Section V introduces and estimates a simple model of bond yields, allowing for changes in behavior around currency crashes. Section VI discusses interpretations, implications, and extensions of the empirical estimates. Section VII offers some brief conclusions.

II. Previous Studies

An extensive literature seeks to explain financial crises or to identify early warning indicators of such crises, particularly in emerging markets. This literature encompasses banking crises, sovereign debt crises, and currency crises, where "currency crisis" may be defined to include periods of sharp depreciation as well as periods in which a central bank successfully defends a currency peg from a speculative attack. A good review of the early warning literature on currency crises is Berg, Borensztein, and Pattillo (2004). Two studies that focus on sharp

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[3] Another factor behind the adverse output effects of emerging-market currency crashes has been substantial stocks of foreign-currency debt on which the repayment burden grew more onerous. Industrial countries generally have low levels of foreign-currency debt.

[4] Gagnon and Ihrig (2004) document the decline in pass-through from exchange rates to consumer prices in the industrial countries over the past 35 years and link this decline to monetary policy credibility against inflation.

depreciations, or "currency crashes," in emerging markets are Frankel and Rose (1996) and Milesi-Ferretti and Razin (1998). Both of these studies find that crashes are robustly associated with a running down of foreign exchange reserves and high industrial-country interest rates, with weaker evidence of an association with rapid domestic credit growth and an overvalued exchange rate. Somewhat surprisingly, neither study finds a robust correlation between crashes and the level of foreign debt or the current account balance. Milesi-Ferretti and Razin also study current account reversals, which are periods of significant narrowing of large current account deficits. They find that about one-third of current account reversals were accompanied or preceded by a currency crash and about one-third of currency crashes were accompanied or followed by a current account reversal.

In an interesting study that bridges the gap between emerging markets and industrial countries, Osband and van Rijckeghem (2000) search for ranges of relevant macro and financial variables which historically have been associated with extremely low probabilities of a currency crisis in the following year. They find that high foreign exchange reserves, low foreign debt, and a higher (more positive) current account balance imply a very low probability of a currency crisis. After estimating these relationships on developing-country data, they apply them to industrial countries and show that they hold up well.

Tudela (2004) applies indicator analysis to industrial countries and finds that import growth, fiscal deficits, non-FDI capital inflows, and an appreciated real exchange rate are all positively related to the probability of currency crisis in the following year.

Croke, Kamin, and Leduc (2005) examine reversals of major current account deficits in industrial countries. Over the five years centered on the trough of the current account balance, they find that the real effective exchange rate tends to depreciate and the real long-term interest rate tends to rise, though the average magnitudes of these movements are modest. The episodes with the largest currency depreciations and interest rate increases are generally those with the most benign outcomes for GDP growth. Although they do not focus on currency crashes, ten of their 23 reversals occurred shortly after a currency crash as identified in this paper.

III. Data

The sample period is from 1970 through 2004. The dataset includes government bond yields, exchange rates, consumer prices, real GDPs, and current account balances, all from the IMF's International Financial Statistics database. All data are reported on an annual average basis. Every country for which local-currency long-term bond yields are available over most of the period is included, for a total of 20 countries.[5] These are all currently classified as industrial countries by the IMF except for South Africa, which used to be classified as such. South Africa has several features in common with the industrial countries, including a well-developed local-currency bond market and a stable banking system.[6]

The exchange rates are the annual average values of each country's currency in terms of SDRs.[7] An increase in the exchange rate is a depreciation of the country's currency. Nine of the sample countries adopted a common currency with the formation of the euro area in 1999.[8] To avoid statistically overweighting the euro, the exchange rate series of the euro-area members end in 1998, except for Germany. The German exchange rate series is extended past 1998 by

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[5] The countries are Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, South Africa, Spain, Sweden, Switzerland, United Kingdom, and United States. The Portuguese and Spanish bond data begin in 1976 and 1978, respectively. The current account data begin in 1972 for New Zealand, 1974 for Ireland, 1975 for Belgium, Denmark, France, Norway, Portugal, and Spain, and 1977 for Japan and Switzerland. Belgian current account data cover Belgium and Luxembourg. German data prior to 1991 refer to West Germany.

[6] The results are not sensitive to dropping South Africa.

[7] The IMF SDR, or special drawing right, is defined as a chain-weighted basket of the dollar, euro, yen, and sterling. The weights are updated every five years based on each currency's role in international trade and finance.

[8] Finland, Greece, and Luxembourg are not in the sample due to lack of bond yield data, although they are in the euro area. (Greece joined in 2001.)

splicing in the euro at the conversion rate of 1.95583 DM/euro. Figure 1 plots logarithmic percentage changes of the SDR exchange rates used in this paper. The shaded regions denote currency crashes as defined in the next section.

The bond yields are an average over all long-term government bonds outstanding, and therefore do not have a constant maturity. Figure 2 plots the bond yields.[9] Figure 3 plots (logarithmic) rates of inflation based on consumer price indexes. Figure 4 plots the (logarithmic) growth rate of real GDP for each country. Figure 5 plots the ratio of each country's current account balance to its nominal GDP.

IV. Identification of Currency Crashes

A "currency crash" begins in year t when a country's exchange rate depreciates at least 8 percent in year t; the cumulative depreciation in years t and $t+1$ exceeds 20 percent; and this two-year depreciation is at least 10 percentage points greater than the depreciation over years $t-2$ and $t-1$. A crash is defined to have ended when the annual rate of depreciation falls below 5 percent. This definition is somewhat *ad hoc*, but it was chosen to yield a reasonable number of episodes that are characterized by rapid, large, and sustained exchange rate depreciations.[10]

There are 26 currency crashes over the sample period. Two of them occurred in Portugal and Spain before there is sufficient bond data for the regression analysis. Two others (in Portugal and Italy) occurred only one year after a previous crash ended; including these two crashes reduces the fit and significance of the crash effects--probably because these events were not a sharp break from previous experience--and so they were excluded. Thus, the analysis

[9] To be consistent with the definition of inflation, bond yields are expressed as 100*log(1+yield/100).

[10] The eight-percent criterion for the first year may seem low, but it reflects the fact that a large depreciation late in the year may have little effect on the annual average exchange rate. In their study of emerging markets, Frankel and Rose (1996) define a currency crash as a depreciation of at least 25 percent that is at least 10 percentage points greater than the rate of depreciation in the previous year. Applying their criteria to these 20 countries would identify only 5 crashes.

focuses on the remaining 22 episodes. The mean total exchange rate depreciation in the two years from the beginning of the crash is 30 percent, with a minimum of 22 percent and a maximum of 59 percent. The United States experienced one currency crash between 1970 and 2004; in 1985 and 1986 the dollar depreciated 22 percent against the SDR followed by a further 15 percent depreciation in 1987.

On average, bond yields rose only 0.3 percentage points at the beginning of a currency crash and were unchanged on average in the following year. But the experience across episodes is rather diverse. Figure 6 plots the change in the bond yield between the year before a crash and the year after the crash begins. In the 1970s and early 1980s, bond yields tended to rise during currency crashes, and in a few cases these rises were large. Since 1985, bond yields have always fallen during currency crashes. In particular, the U.S. bond yield fell more than 4 percentage points between 1984 and 1986.

Appendix 1 uses monthly data which allow for more precise timing of currency crashes at the cost of a reduced set of macroeconomic covariates. Analysis on the somewhat different set of crashes identified in monthly data leads to similar results to those obtained with annual data. In addition, monthly data allow for a closer examination of bond yields immediately before and after the onset of a crash.

V. Modeling Bond Yields

The approach of this paper is empirical and somewhat *ad hoc*. Rather than build a structural model of bond yields with all the assumptions and auxiliary equations that would be necessary, this paper examines historical correlations between macroeconomic variables that can shed light on the implications of currency crashes for bond yields. Consider the following regression equation for the change in the bond yield in a panel with countries denoted by *i* and years denoted by *t*. The equation includes key macroeconomic variables and dynamic adjustment terms, while allowing for a change in behavior associated with the onset of a currency crash.

$$\Delta BOND_{it+1} = \alpha_0 + \alpha_1 \, BOND_{it} + \alpha_2 \, \Delta BOND_{it} + \alpha_3 \, INFL_{it+1} + \alpha_4 \, \Delta INFL_{it+1}$$

$$+ \alpha_5 \, \Delta RGDP_{it} + \alpha_6 \, (CA/GDP)_{it} + \alpha_7 \, \Delta EXCH_{it}$$

$$+ DUMCR_{it} \begin{bmatrix} \alpha_8 + \alpha_9 \, BOND_{it} + \alpha_{10} \, \Delta BOND_{it} + \alpha_{11} \, INFL_{it+1} + \alpha_{12} \, \Delta INFL_{it+1} \\ + \alpha_{13} \, \Delta RGDP_{it} + \alpha_{14} \, (CA/GDP)_{it} + \alpha_{15} \, \Delta EXCH_{it} \end{bmatrix}$$

$$+ \sum_i \beta_i + \sum_t \gamma_t$$

Δ denotes the change in a variable from the previous year. α, β, and γ denote coefficients to be estimated, with β_i denoting a fixed effect for country *i* and γ_t denoting a fixed effect for year *t*. All variables and changes are expressed in percentage points. *BOND* is the long-term (logarithmic) government bond yield. *INFL* is the (logarithmic) rate of change of the CPI. *RGDP* is the log of real GDP; changes in real GDP are demeaned on a country-by-country basis so that they reflect each country's growth rate relative to its 1971-2004 average. *CA/GDP* is the ratio of the current account to nominal GDP. *EXCH* is the log of the SDR exchange rate. *DUMCR* is a dummy variable that equals one in the first year of a currency crash for a specific country and zero otherwise.

The first two lines of the equation reflect observable macroeconomic factors behind changes in bond yields and dynamic adjustment terms during normal, or non-crash, years. After the intercept, α_0, the next two terms relate the future change in the bond yield to the current level and change in the bond yield. If bond yields are stationary, or if they are cointegrated with the explanatory variables, the coefficient on the level of the bond yield (α_1) should be negative.

Inflation should have a positive effect on bond yields, both through the Fisher effect and through any expected increase in future real interest rates that may be associated with anti-inflationary monetary policy. Real GDP growth is expected to push up bond yields.[11] The current account balance may have a negative effect on bond yields to the extent that investors demand a risk premium on investments in borrowing countries. Finally, the change in the exchange rate may be expected to have a positive effect on bond yields to the extent that depreciations help to predict future inflation beyond period t+1. Note that the inflation rate is the only explanatory variable that is contemporaneous with the future change in the bond yield, on the assumption that bond yields respond immediately to inflation but that inflation responds to bond yields with a lag.[12] Only current and lagged values of the other variables are used to avoid biased coefficient estimates from any effect of future bond yields on them.

The terms in brackets test for changes in bond yield behavior during currency crashes. All of the terms in the first two lines are repeated within the brackets and interacted with the dummy variable for the first year of a currency crash. Thus, these terms are not present for most observations, and they enter only in the 22 observations when a currency crash begins for a given country. The view that currency crashes lead to higher bond yields requires that currency crashes should be associated with some combination of 1) higher nominal yields due to higher expected inflation, 2) higher real yields due to tighter monetary policy to combat inflationary pressures, and 3) higher risk premiums caused by inflation uncertainty or confidence effects related to the crash. To the extent that these factors are related to the explanatory variables, there may be an intensification of their effects after the onset of a crash. To the extent that these

[11] Various estimates of output gaps were never statistically significant.
[12] The robustness of the results to this assumption is tested below.

factors are not related to the explanatory variables, there may be an increase in the equation intercept, α_8.

Unit root tests on these variables applied independently for each country found that their first differences are stationary in nearly all cases but that their levels appear to be nonstationary in most cases.[13] As the regression equation includes the levels of the bond yield, inflation rate, and current account ratio, valid statistical inference requires cointegration among these three variables. Tests of cointegration between bond yields and inflation rates could not reject the null of non-cointegration in most countries.[14] However, there are strong economic reasons to believe that current account ratios are stationary and that bond yields are cointegrated with inflation rates. The failure to reject the null hypotheses of non-stationarity and non-cointegration probably reflects the small sample of available data for each country.

A panel cointegration test can provide more power under the assumption that cointegration properties are the same across all countries. As described in Appendix 2, a panel cointegration test found extremely strong evidence in favor of cointegration between bond yields and inflation rates. The current account ratios do not appear to be cointegrated with bond yields and inflation rates, but their estimated coefficient is generally close to zero and including them in the regression has little effect on the other coefficients and standard errors. As the remaining variables are stationary, their coefficients should have standard distributions.[15]

The bond-yield equation was estimated in a panel regression over the 20 countries and up to 33 years per country. Full sets of (demeaned) country and year fixed effects were included in the initial specification. The year effects capture global influences on bond yields not present in

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[13] Tests are based on the modified Dickey-Fuller *t*-test of Elliott, Rothenberg, and Stock (1996).
[14] Tests are based on the error-correction test of Ericsson and MacKinnon (2002).
[15] The crash-interacted terms are all stationary by construction as they revert to zero immediately after the start of a crash.

the explanatory variables and they are always highly significant. The country effects capture static differences in bond yields across countries that are not present in the explanatory variables and they are never significant at any level. A dummy was included for Germany in 1991 (not reported) to control for the effect on the output growth term of the addition of East German GDP. The equation generally fits well with a high R^2. Additional lags of the dependent or explanatory variables are not statistically significant at any level.

Column 1 of Table 1 presents results for the preferred specification. The coefficient on the bond yield is negative, with a t-ratio of -9.0, providing confirmation of the cointegration results shown in Appendix 2.[16] The coefficient on inflation is positive and highly significant, indicating that high inflation tends to raise bond yields. Rising inflation has a positive effect on bond yields in addition to the effect of the level of inflation. Output growth has a small but significant positive effect on bond yields. Neither the current account ratio nor the exchange rate change has a large or significant effect on bond yields.

Most of the crash interaction coefficients in the full regression equation are not significant, and a restriction to just the intercept, bond yield, and current account ratio shown in column 1 cannot be rejected at any significance level. These three crash interaction terms are individually and jointly significant at the 1 percent level. Together, the first two crash interaction coefficients imply that the change in the bond yield after a crash will be lower than normal if bond yields are less than 14 percent during the crash and higher than normal if bond yields are greater than 14 percent during the crash. In addition, there is a significant effect of the current account balance after crashes. The bond yield falls 14 basis points more than normal for

[16] Appendix 2 tests for cointegration between bond yields and inflation rates without auxiliary variables or crash effects. These nuisance parameters may affect the critical values of the test statistic. Given the large margin by which the t-ratio of -9.0 exceeds the 5-percent critical value of -3.15, adjusting for nuisance parameters is not likely to affect our finding of cointegration.

each percentage point of current account surplus (ratio to GDP) at the onset of a crash and it rises an equivalent amount for each percentage point of current account deficit.

Because of the close connection between inflation and bond yields, the significance of the bond yield coefficient after a crash may reflect inflation expectations. Indeed, tests show that either the interaction term on the bond yield or the interaction term on the inflation rate is significant on its own but that both are not needed. The equation fit is slightly better with the bond yield. However, column 2 shows results with the interaction term on inflation. The non-crash coefficients are essentially unchanged. The intercept shift and the interacted inflation coefficient together imply that bond yields will be lower than normal after a crash if inflation remains less than 13 percent. The effect of the current account after a crash is somewhat smaller in this specification.

Column 3 presents results in which the level and change of inflation are included only as current values, like the other explanatory variables. Both coefficients decline and the change term is no longer significant. Note, however, that the GDP growth and exchange rate change coefficients have increased in magnitude and significance. These terms are likely to be proxying for future inflation. Overall, the equation fit is significantly poorer. Nevertheless, the crash effects are not substantively different from those of the preferred specification.

By focusing on the change in bond yields in the year after a crash begins, we may be missing some effects that occur contemporaneously with the onset of a crash. Column 4 presents results for $\Delta BOND_{it}$ as the dependent variable and replacing $BOND_{it}$, $\Delta BOND_{it}$, $INFL_{it+1}$, and $\Delta INFL_{it+1}$ as explanatory variables with their lagged values. The non-crash coefficients are essentially unaffected. The crash coefficients are all jointly and individually small and insignificant. Thus, it appears that most of the effect of crashes on bond yields occurs after the crash begins.

Column 5 shows that adding country fixed effects has little effect on any coefficient. Column 6 shows that eliminating the year fixed effects has little effect on the non-crash coefficients, but it amplifies both the negative effect of crashes on the change in bond yields when the initial bond yield is very low and the positive effect when the initial bond yield is very high. The cutoff point for no effect occurs at an initial bond yield of around 13 percent.

How well does the preferred specification predict changes in bond yields after currency crashes? Figure 7 displays the changes in bond yields after crashes begin (in large font) and the fitted values of these changes based on the preferred specification (small font). The fitted value is generally smaller in magnitude than the actual value, reflecting the standard result that optimal predictors have lower variance than the series they are predicting. The R^2 of the equation in the first year after a currency crash is 0.63. Moreover, the direction of the fitted movement is almost always the same as that of the actual movement. Only for Spain in 1980 does the fitted movement deviate noticeably in direction from the actual movement; in this case the equation predicts a yield increase of 2 percentage points whereas the actual yield edged down a bit.

VI. Interpretations, Implications, and Extensions

Why the Change Since 1985?

Perhaps the most striking finding is exhibited in Figure 6, namely that bond yields have always declined after currency crashes since 1985. The main reason appears to be the dramatic decline in inflation rates since 1985.[17]

[17] I tested for the possibility of an unexplained structural break in the crash intercept from 1985 on, but this coefficient was small and insignificant and had little effect on the remaining coefficients. There is modestly significant evidence of such a break in the monthly data of Appendix 1, though this break may also be associated

Prior to 1985, bond yields rose an average 1 percentage point after a currency crash. Since 1985 bond yields have fallen an average 1.5 percentage points, representing a swing in behavior of 2.5 percentage points after 1985. Applying the coefficients from the preferred specification to the mean values of the explanatory variables both before and after 1985 explains 2.3 percentage points of the 2.5 percentage point decline in the average change in bond yields. 1.0 percentage point of this decline is accounted for by the decline in the average inflation rate in the year after a crash begins from 13 percent before 1985 to just 4 percent since then. Another 1.0 percentage point is explained by falling global interest rates after the onset of crashes that are embedded in the year fixed effects.[18] Using the specification in column 2 of Table 1, which focuses on inflation behavior after currency crashes, 1.6 percentage points of the decline can be accounted for by lower inflation rates.

It is interesting to note that inflation has remained subdued in crashes since 1985 despite the fact that the mean exchange rate depreciation in the first year of the crash rose from 13 percent before 1985 to 17 percent since then. Figure 8 displays the change in the inflation rate in the year after a crash begins. Before 1985, there are some episodes with large changes in inflation, both up and down. Since 1985, changes in inflation have been quite small.[19] The stability of inflation is particularly remarkable given that all of the countries that experienced crashes after 1990 have high levels of imports. For example, imports equaled 28 percent of New Zealand GDP in 1997 and 26 percent of South African GDP in 2000. The comparable share for the United States was 15 percent in 2004. Moreover, many studies indicate that the response of

with the change in inflation credibility and it did not affect the strong significance of the inflation variable in determining the behavior of bond yields after the onset of a currency crash.

[18] The equal-weighted average of the year fixed effects is close to zero both before and after 1985. However, the average of the year effects weighted by crash episodes is 0.2 percent before 1985 and -0.8 since then.

[19] This result also holds for the change two years after the beginning of a crash. Gagnon and Ihrig (2004) show that there has been a secular decline in the effect of exchange rates on consumer prices in industrial countries.

import prices to exchange rates is even lower in the United States than in other countries.[20] Thus, it seems reasonable to expect that U.S. inflation need not rise noticeably in the event of a future depreciation of the dollar.

Importance of Fixed Exchange Rate Regimes

Ten of the 22 currency crashes involve devaluations or departures from a fixed-rate regime. However, there does not appear to be a fundamental difference between fixed and floating regimes in the behavior of bond yields after a crash. The three episodes with the greatest two-year increase in bond yields (Italy 1980, France 1980, and New Zealand 1984, shown in Figure 6) occurred under fixed exchange rates. However, the three episodes with the next greatest yield increases (South Africa 1981, Italy 1973, and Spain 1980) occurred under floating rates. In the other direction, Italy, Sweden, and Spain experienced falling bond yields after their devaluations from fixed rates in 1992. But Australia and New Zealand experienced similar declines in bond yields after their flexible-regime depreciations of 1997. The primary difference appears to be the behavior of inflation, which was high for the crashes with rising bond yields and low for the crashes with falling bond yields.

Interest Rate Parity and Expected Exchange Rates

One possible explanation for falling bond yields after a currency crash is that financial markets anticipated the crash and that bond yields had already risen before the crash. This arbitrage behavior is captured in the open interest rate parity relationship:

$$BOND_t = BOND^*_t + E_t \sum_{i=1}^{n} \Delta EXCH_{t+i}$$

where *BOND** is the foreign bond yield, E_t denotes market expectations as of date *t*, and *n* is the term to maturity of the bonds.[21] Empirically, there is very little evidence that exchange rate

[20] Goldberg and Knetter (1997) provide a survey of the literature.

movements are predictable for these countries.[22] Nevertheless, if markets did anticipate at least some of the 22 crashes identified here, bond yields should have risen prior to the crash.

On average across these 22 episodes, bond yields rose 0.5 percentage points in the year before the crash started, 0.3 percentage points in the year the crash started, and were unchanged in the year after the crash started. If prior expectations were particularly important in explaining the episodes in which bond yields fell after a crash, focusing on those episodes should reveal even greater increases in bond yields prior to a crash. However, the opposite is true. On average across the 13 crash episodes in which bond yields fell after the crash, bond yields rose only 0.2 percentage points in the year before the crash started, were unchanged in the year the crash started, and fell 1.2 percentage points in the year after the crash started.[23]

<u>The Role of the Current Account</u>

Much of the concern over a sharp depreciation of the dollar is motivated by the large U.S. current account deficit. Indeed, there does appear to be a link between currency crashes and current account deficits. The average current account ratio to GDP in the entire dataset is -0.5 percentage points, whereas the average ratio for countries at the beginning of a currency crash is -4.0 percentage points. Moreover, the current account is positive in 44 percent of the total observations, but in only 1 of the 22 currency crashes.

Table 1 shows that a negative current account balance at the start of a crash is associated with a greater increase in bond yields. But the magnitude of this effect is rather small. Figure 9 displays the initial current account ratios and the subsequent changes in bond yields for the 22 currency crashes. The negative relationship is driven by New Zealand's crash of 1984. Notably,

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[21] This equation ignores risk effects and is based on zero-coupon bonds.
[22] See the collection of papers edited by Engel, Rogers, and Rose (2003).
[23] On average across crash episodes in which bond yields fell, bond yields rose less than 0.1 percentage points in the period two years before the crash. (Two-year lagged bond yield data are missing for 1 of the 13 episodes.) The monthly data of Appendix 1 confirm that there is little run-up in bond yields as close as one month prior to a crash.

the other episodes with initial current account deficits in excess of 5 percent of GDP (New Zealand 1974 and 1997, South Africa 1981, and Australia 1985) all were associated with only modest changes in bond yields.

Perhaps a more relevant variable to include in the regression would be a country's net foreign asset ratio to GDP. Unfortunately, these data are available for relatively few countries and years. However, it is unlikely that inclusion of net foreign assets would substantially change these results. New Zealand has long had a very large negative net foreign asset position (-83 percent of GDP in March 1997) yet it still experienced a substantial decline in bond yields after the onset of the 1997 currency crash.[24] Australia and South Africa also had significant negative net foreign assets prior to their most recent crashes, yet bond yields declined in these countries as well.

Composition of International Financial Flows

The *sine qua non* of a currency crash is a sharp decline in demand for assets denominated in domestic currency relative to assets denominated in foreign currencies. This subsection explores whether the composition of this demand shift across asset types has a material impact on bond yields. A plausible conjecture is that bond yields are more likely to rise if the shift in relative demands is concentrated in bonds rather than in other assets such as equity or bank loans. To test this conjecture, the preferred regression of Table 1 was rerun after adding net foreign purchases of debt securities (ratio to GDP, from the IFS database) either as a level or as a rate of change. This additional variable was not significant when interacted with the crash dummy. As a non-interacted term, the change in bond inflows (but not the level) is marginally

[24] Some of the striking difference in the behavior of bond yields between New Zealand's 1984 crash and its 1997 crash may reflect the government's decision to cease borrowing in foreign currencies after 1984 and to pay down the entire stock of foreign-currency debt by 1996. The increased fiscal burden associated with the 1984 crash may have contributed to inflationary expectations, a mechanism that was absent in 1997. See New Zealand Debt Management Office, "About Debt Management," at http://www.nzdmo.govt.nz/debtmgmt/default.asp.

significant with the correct (negative) sign. But the estimated coefficient is small. An increase in bond inflows of 1 percent of GDP lowers the bond yield less than 3 basis points.

These results are consistent with a casual examination of the crash episodes. For example, the Australian currency crash of 1997-98 was associated with a dramatic reversal of bond inflows from more than 5 percent of GDP in 1996 to -1 percent in 1998. Over the same period portfolio equity inflows increased 2 percent of GDP and direct investment inflows were relatively stable. Despite the sharp collapse of bond inflows, bond yields fell more than 200 basis points.

Behavior of Equity Prices

Figure 10 displays the two-year change in real equity prices around currency crashes.[25] Despite a wide range of outcomes, there is no particular tendency for currency crashes to be associated with poor stock market performance, especially since 1985. Regressions similar to those of Table 1 using equity prices found no statistically significant effect of currency crashes.

What Causes Bond Yields to Fall after a Crash Begins?

The results presented here demonstrate that high and rising inflation—and thus presumably high market fears of future inflation—are responsible for episodes of rising bond yields after currency crashes. However, it is less clear why bond yields should sometimes fall significantly after the beginning of a crash rather than just remain stable.[26] In other words, what explains the downward shift in the crash-interacted intercept that is displayed in Table 1? We have already seen that such falls are not explained on average by the unwinding of a prior run-up in bond yields in anticipation of the crash. Rather, the factors behind the declines in bond yields

[25] MSCI equity price index divided by CPI. Equity prices not available for four episodes: Ireland 1975, New Zealand 1974 and 1984, and South Africa 1981.

[26] One conjecture is that the fall in yields may occur with a lag of a few weeks or months as markets wait to assess the policy reaction to the currency crash. However, Appendix 1 show that, in episodes with declining yields, the decline in yields typically begins in the very first month after a crash begins.

appear to differ across episodes. The most common element appears to be declining inflation and inflationary expectations, albeit perhaps operating with a lag that is longer than can be estimated with these data.[27] The remainder of this section sketches out plausible explanations for the behavior of bond yields after each currency crash since 1985.

In the case of the U.S. crash of 1985, inflation and inflationary expectations had been falling for several years as the anti-inflationary monetary policy of the early 1980s bore fruit. Bond yields were falling prior to the crash, and they continued to fall after the crash began, primarily reflecting the lagged effect of falling inflation on the inflation premium in long-term bond yields. GDP growth was close to its historical norm before and after the crash started. A similar pattern is also apparent in Canada in 1985, probably reflecting in part the influence of events in the United States.

In 1992, Italy and Spain had fixed exchange rates within the European Monetary System and Sweden had pegged the krona to the Deutschemark. These arrangements came under attack by financial markets in the aftermath of German unification in 1990, which pushed up German bond yields and the exchange value of the Deutschemark. Financial conditions that were appropriate for Germany were not appropriate for Italy, Spain, and Sweden; GDP growth in these countries was much lower than normal in 1991 and 1992. Markets began to expect that policymakers in these countries would seek to stimulate growth by devaluing their currencies. This expectation proved to be correct, although it had the elements of a self-fulfilling prophecy. It is somewhat puzzling that bond yields rose in anticipation of the devaluation only in Italy, whereas they declined immediately prior to devaluation in Spain and Sweden.[28] In any event,

[27] Gagnon (1996) presents evidence of slow adjustment of long-run inflationary expectations. Gagnon (1997) develops a model to explain this slow adjustment in terms of expectations of future policy regimes.
[28] In Sweden this decline could have been a reaction to the sharp fall in inflation immediately prior to the crash. Inflation was relatively stable in Italy and Spain.

bond yields in all three countries declined further after the devaluation as markets focused on their weak economic conditions.

Australia and New Zealand had experienced declining inflation rates for two years before their currencies crashed in 1997. Increasing anti-inflationary credibility under their relatively new inflation-targeting regimes is likely responsible for the declines in bond yields before and after the onset of the crash. Also, given the collapse in aggregate demand in their major Asian trading partners at this time, markets may have had fears over the growth outlook in Australia and New Zealand.

Finally, the South African experience after the 2000 crash appears to be another case of secularly declining inflation and inflation expectations. South African inflation had declined by an average of 1 percentage point per year over the nine years leading up to the crash. Bond yields declined both before and after the crash began.

Could Yields Rise after a Crash without High Inflation?

As discussed above, a combination of idiosyncratic factors may have been responsible for the tendency of bond yields to fall after the onset of crashes since 1985. Should these factors be absent in a future currency crash, bond yields are less likely to fall. In particular, the process of disinflation and the decline of inflationary expectations in industrial countries has largely run its course. Long-term inflation expectations, as measured in surveys or in premiums between nominal and indexed bonds, generally show that inflation is expected to remain both very low and close to its targeted value in those countries that have adopted inflation targets. In recent years, central banks in the United States and Japan have expressed their determination to prevent inflation from falling further, and long-term inflation expectations have stabilized in both countries. Thus, this channel for falling bond yields is not likely to be as important in the future as it was over the past two decades.

Are there circumstances under which bond yields could increase substantially after a currency crash without an associated loss of credibility on inflation? The regression results indicate that such an outcome is very unlikely, but, as discussed above, the regression results may partly reflect the influence of omitted factors that are not likely to be repeated. A sharp exchange rate depreciation that is not accompanied by a drop in foreign aggregate demand or by a fiscal contraction is likely to boost a country's growth through higher net exports. In the case of an economy that is operating at or above its non-inflationary potential, such a depreciation would likely lead the central bank to tighten monetary policy in order to prevent a buildup of inflationary pressure. If the tighter monetary policy were expected to be sustained over several years, bond yields would likely rise.

It is important to note that any increase in bond yields under the above circumstances would serve merely to damp the attendant increase in economic growth and would not be an independent impetus for a "hard landing" or an indicator of widespread financial distress. Moreover, there are other plausible circumstances in which a currency crash would not likely be associated with higher bond yields. For example, a currency crash may be sparked by a negative demand shock that pushes down a country's growth rate, in which case higher bond yields are not likely. Also, to the extent that fiscal policy moves to offset any stimulative demand effects of a currency crash, monetary policy would need to move less and bond yields could remain stable.

VII. Conclusion

Sudden and large depreciations, sometimes referred to as currency crashes, have on occasion led to sharp rises in bond yields. Examination of the data for 20 industrial countries over the past 35 years reveals that these instances of rising bond yields are closely related to high and rising inflation rates. Rising bond yields presumably reflect market fears of future inflation and/or future tight monetary policy to combat inflation. However, since 1985, currency crashes in these industrial countries have never been followed by rising bond yields. This change in behavior reflects the anti-inflationary credibility earned by central banks in these countries. Indeed, since 1985, currency crashes in these countries have not led to higher inflation.

In many cases, bond yields fell significantly after the onset of a crash. Declining bond yields may have reflected idiosyncratic factors such as ongoing declines in inflationary expectations or negative shocks to aggregate demand. Bond yields do not appear to be strongly affected by the composition of international financial flows. In particular, bond yields fell substantially even after the onset of currency crashes that were associated with sharp reductions in net foreign purchases of domestic bonds.

Currency crashes also have not been associated with declining equity prices. Indeed, since 1985, real equity prices have generally risen in the aftermath of currency crashes.

These results are at odds with the views expressed by some observers that a sharp decline in the exchange value of the dollar would likely lead to a significantly higher bond yield or other widespread financial distress in the United States.

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Table 1. Annual Change in Bond Yields, $\Delta BOND_{it+1}$, 1971-2003

	Preferred (1)	Crash Inflation (2)	Current Inflation[1] (3)	Year of Crash[2] (4)	Country Effects (5)	No Fixed Effects (6)
Intercept	0.70***	0.67***	0.77***	0.78***	0.93***	0.52***
	(.12)	(.12)	(.13)	(.12)	(.20)	(.12)
$BOND_{it}$	-0.17***	-0.16***	-0.15***	-0.17***	-0.21***	-0.17***
	(.02)	(.02)	(.02)	(.02)	(.02)	(.02)
$\Delta BOND_{it}$	0.07**	0.08**	0.10**	0.08**	0.07*	0.02
	(.04)	(.04)	(.04)	(.04)	(.04)	(.04)
$INFL_{it+1}$	0.12***	0.11***	0.07***	0.12***	0.14***	0.15***
	(.02)	(.02)	(.02)	(.02)	(.02)	(.01)
$\Delta INFL_{it+1}$	0.06***	0.06***	0.03	0.06***	0.04*	0.13***
	(.02)	(.02)	(.02)	(.02)	(.02)	(.02)
$\Delta RGDP_{it}$	0.04**	0.04**	0.07***	0.04**	0.04**	0.04*
	(.02)	(.02)	(.02)	(.02)	(.02)	(.02)
$(CA/GDP)_{it}$	-0.01	-0.01	-0.02	-0.02*	-0.01	-0.01
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
$\Delta EXCH_{it}$	0.006	0.007	0.018***	0.007	0.005	-0.001
	(.004)	(.004)	(.004)	(.004)	(.004)	(.005)
$DUMCR_{it}$	-2.51***	-0.90**	-2.35***	-0.31	-2.60***	-3.79***
	(.80)	(.35)	(.86)	(.77)	(.81)	(.96)
$DUMCR_{it}$ $\times BOND_{it}$	0.18*** (.06)		0.15** (.07)	0.04 (.07)	0.19*** (.06)	0.29*** (.08)
$DUMCR_{it}$ $\times INFL_{it+1}$		0.07** (.03)				
$DUMCR_{it}$ $\times (CA/GDP)_{it}$	-0.14*** (.04)	-0.09** (.04)	-0.19*** (.04)	0.05 (.06)	-0.15*** (.04)	-0.10* (.05)
Year Effects	Yes***	Yes***	Yes***	Yes***	Yes***	No
Country Effects	No	No	No	No	Yes	No
R-squared	.636	.633	.591	.626	.651	.408
Deg. Freedom	525	525	517	525	506	557

***, **, and * denote significance at 1, 5, and 10 percent levels, respectively.
[1] $INFL_{it+1}$ and $\Delta INFL_{it+1}$ replaced by $INFL_{it}$ and $\Delta INFL_{it}$.
[2] Dependent variable is $\Delta BOND_{it}$ and BOND and INFL terms on right-hand side are lagged.

Figure 1. Annual Changes in SDR Exchange Rates

Figure 2. Bond Yields

Figure 3. Inflation Rates

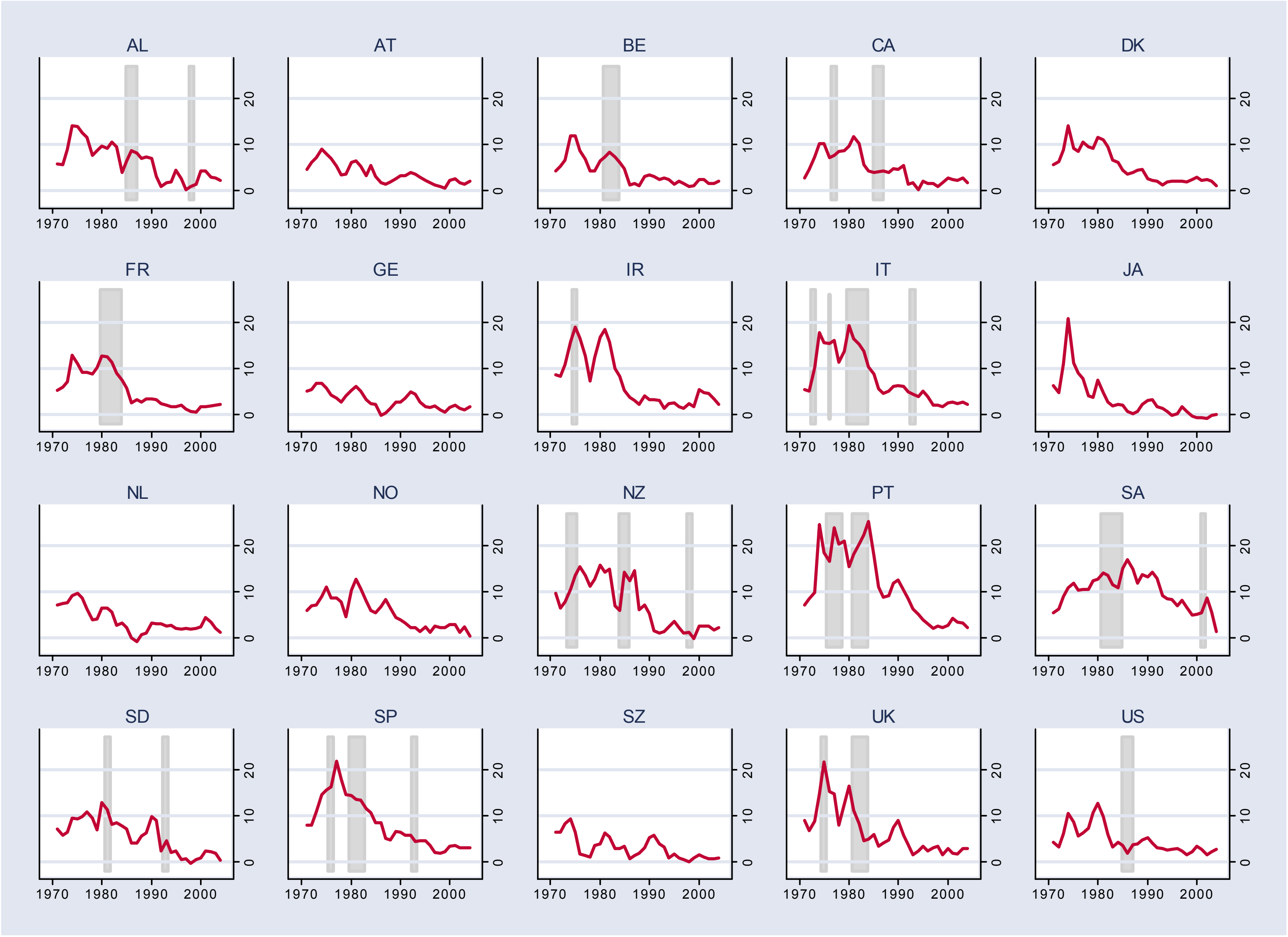


Figure 4. Growth Rates of GDP

Figure 5. Current Accounts (Ratio to GDP)

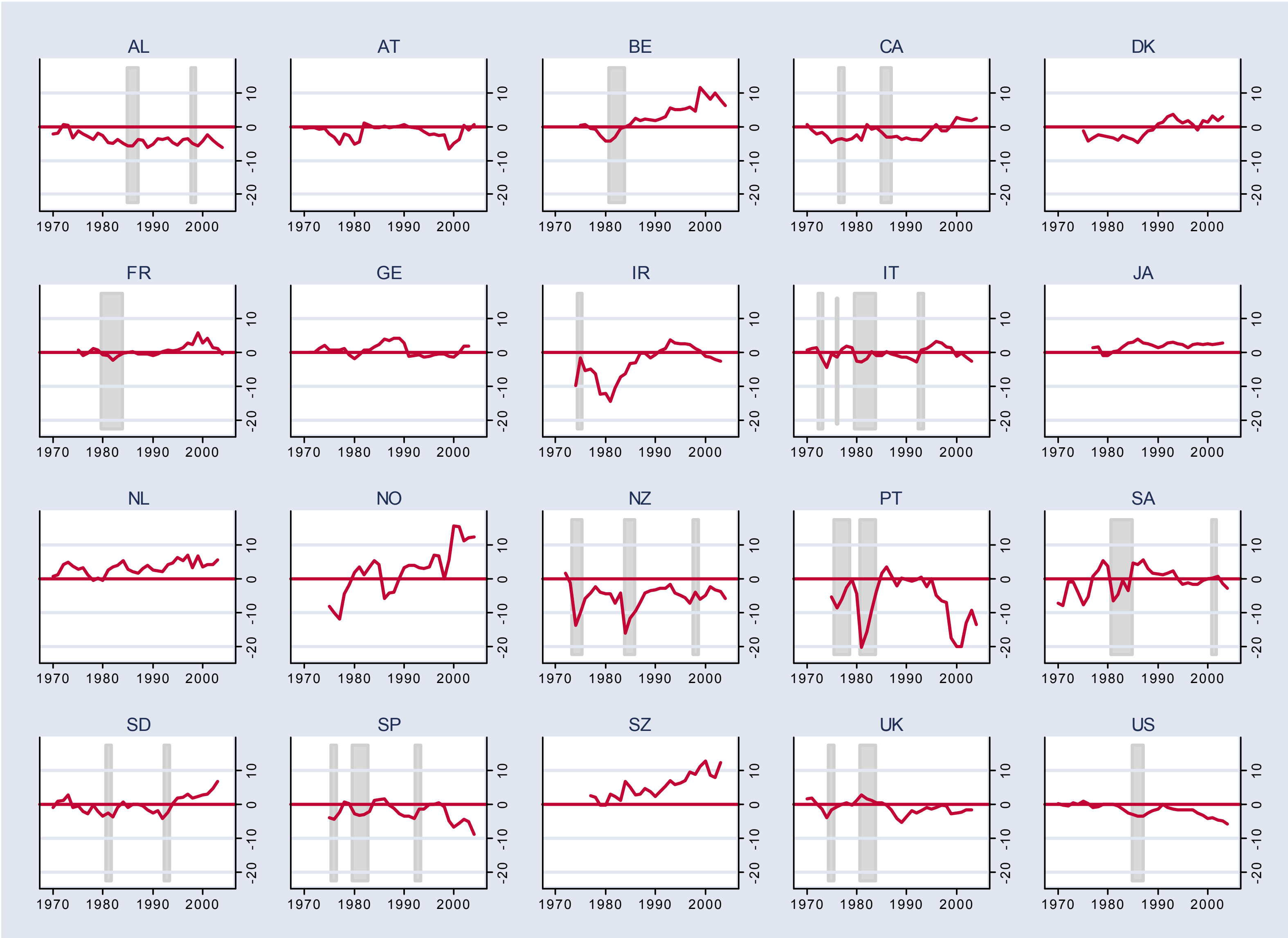


Figure 6. Changes in Bond Yields, Year Before to Year After Beginning of Currency Crash

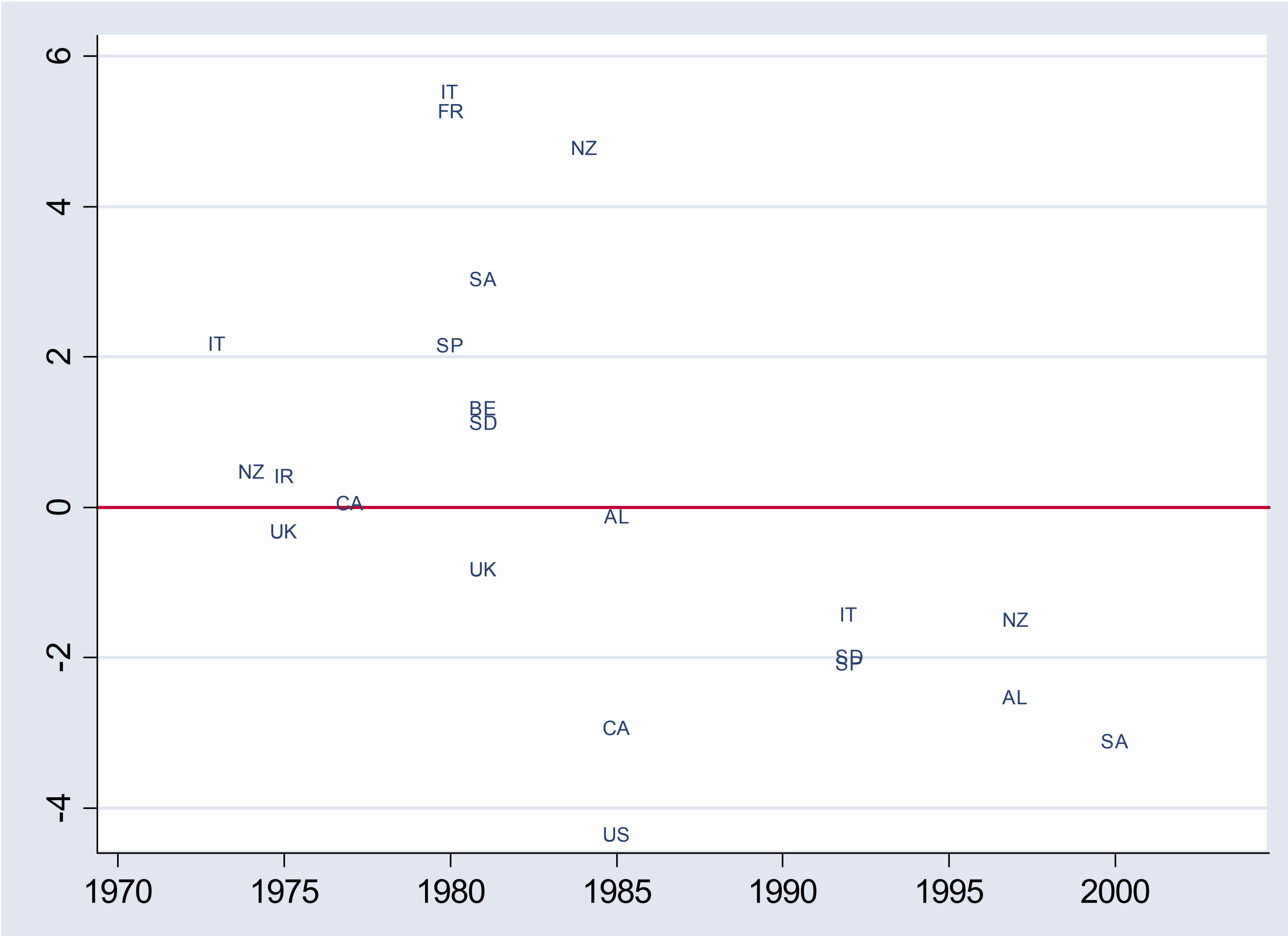


Figure 7. Changes in Bond Yields, Year After Beginning of Currency Crash (Fitted Values in Small Font)

Figure 8. Changes in Inflation Rates, Year After Beginning of Currency Crash

Figure 9. Initial Current Account Ratios (x-axis) and Changes in Bond Yields (y-axis)

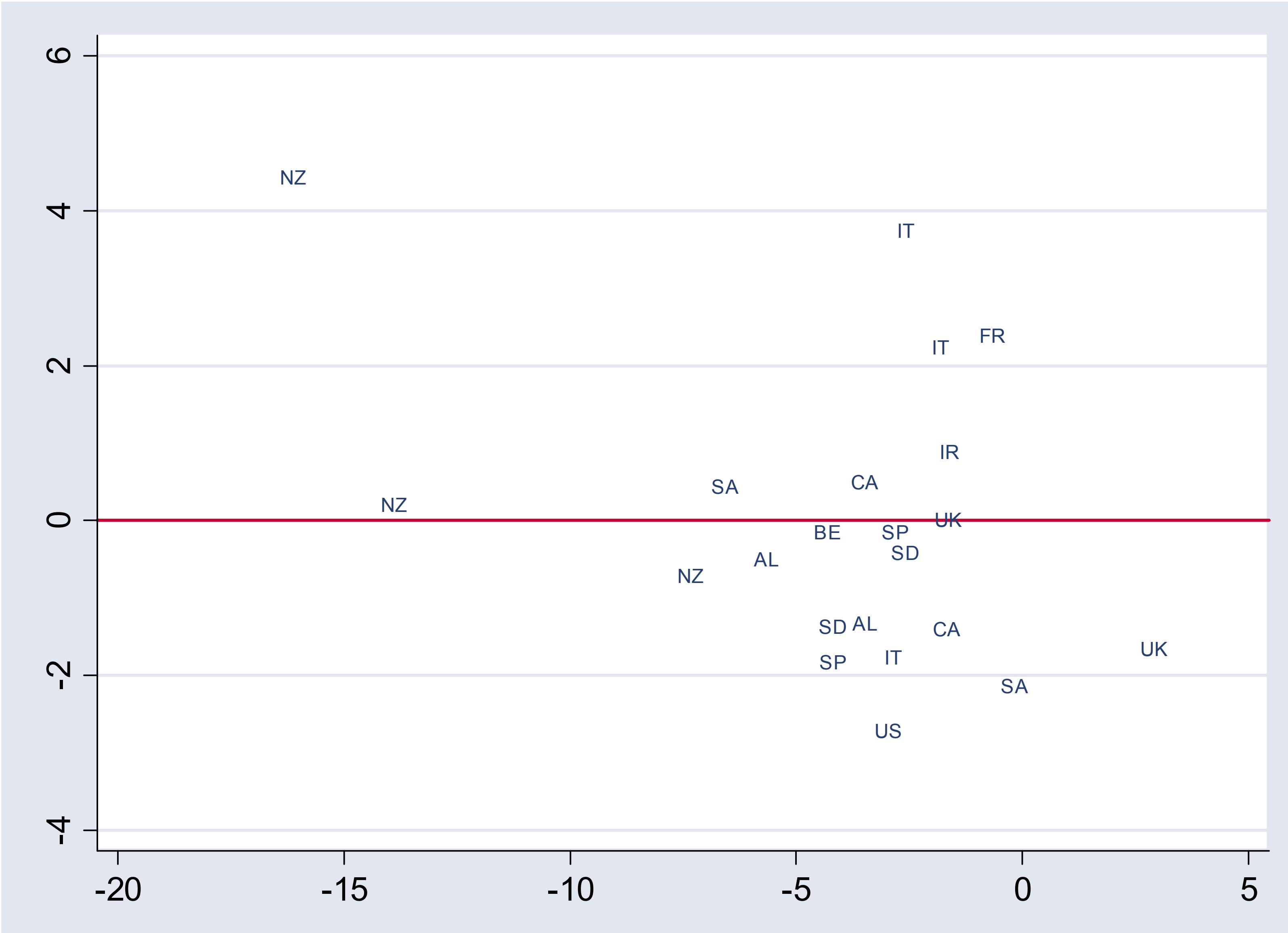
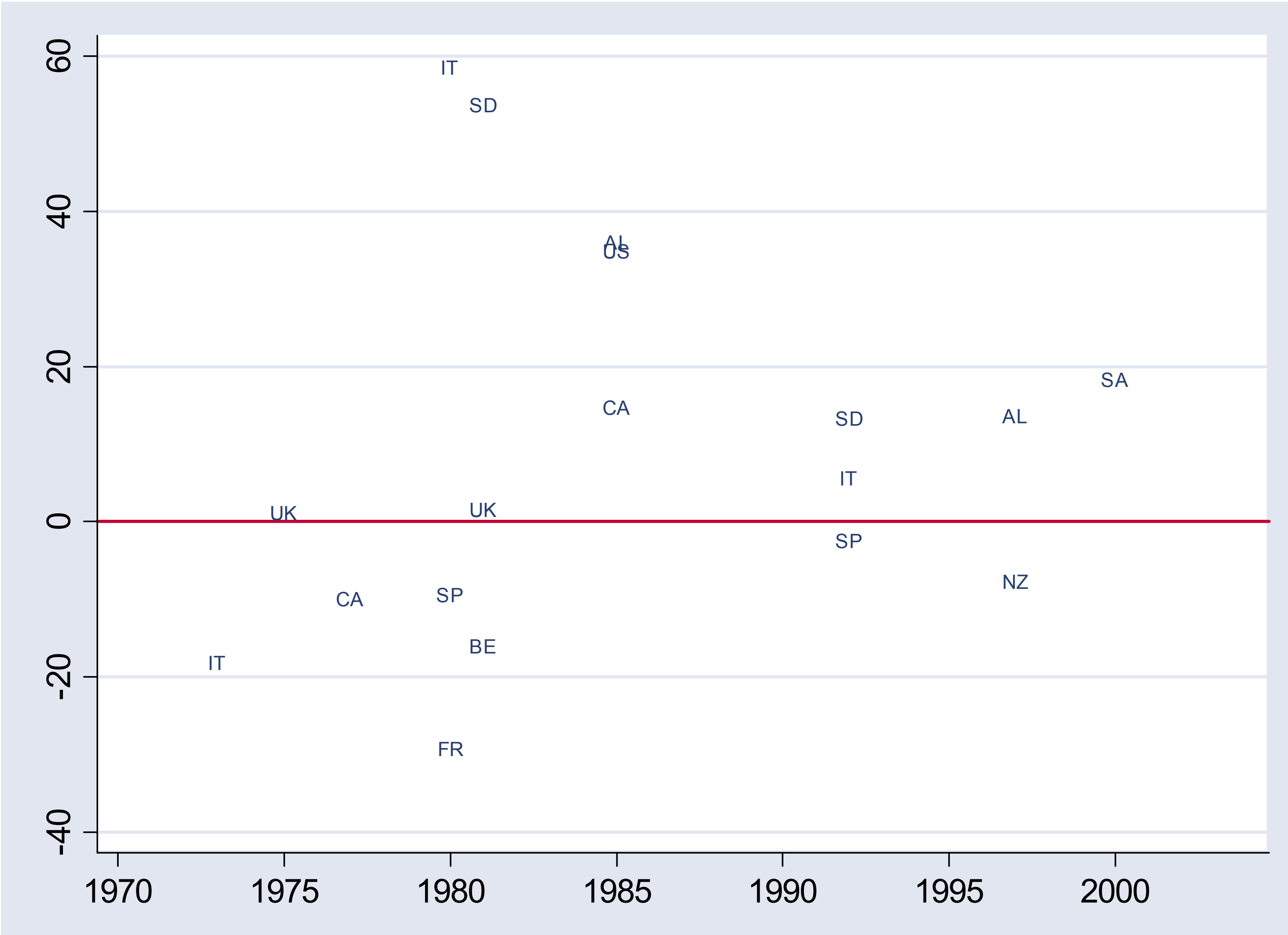


Figure 10. Changes in Real Stock Prices, Year Before to Year After Beginning of Currency Crash



Appendix 1: Analysis of Monthly Data

Monthly data allow for a more precise timing of currency crashes. As described below, I analyze 30 crashes; more than half of these correspond to the crashes identified with annual data.[29] One drawback of the monthly data is that the current account and other macroeconomic variables are not widely available at this frequency for many countries over a long period. Nevertheless, the basic conclusions from the annual data hold true in this dataset. Early in the sample, bond yields often rise after currency crashes. But over the past 20 years, bond yields have almost always fallen after currency crashes. The change in bond yield responses to currency crashes appears closely connected to the decline in inflation and inflation variability over the sample period.

The bond yields, exchange rates, and consumer price indexes are available at a monthly frequency from the International Financial Statistics database, except for German and Irish price indexes, which were obtained from Haver Analytics. Price indexes for Australia, Ireland, and New Zealand are available only at the quarterly frequency and were interpolated.

I work with the following transformations of the data:

$$\Delta BOND(12)_t = BOND_t - BOND_{t-12} \qquad \Delta EXCH(12)_t = \log\left(\frac{EXCH_t}{EXCH_{t-12}}\right)\times 100$$

$$INFL(12)_t = \log\left(\frac{CPI_t}{CPI_{t-12}}\right)\times 100 \qquad \Delta INFL(12)_t = INFL(12)_t - INFL(12)_{t-12}$$

where *BOND* is the bond yield and *EXCH* is the SDR exchange rate.

I define a "currency crash" to begin in period *t* when the 12-month change in a country's exchange rate ($\Delta EXCH(12)_t$) exceeds 20 percent and is at least 10 percentage points higher than the change over the preceding 12-month period (that is, $\Delta EXCH(12)_t - \Delta EXCH(12)_{t-12} > 10$). A

[29] 17 of the 22 crashes identified in annual data are also identified as crashes in the monthly data.

crash is defined to have ended when $\Delta EXCH(12)$ falls below 5 percent. A new crash episode cannot start until the previous episode has ended.

There are 36 currency crashes over the sample period. One of them occurred in Spain before the bond yield data start. Five others occurred within 24 months of a previous crash, making it difficult to measure changes in interest rates from a pre-crash level. Thus, I focus my analysis on the remaining 30 episodes. Using this definition of a currency crash, there was no crash in the U.S. dollar over the sample period.

On average, bond yields fell slightly in currency crashes, but the experience across episodes is rather diverse. Figure A1 plots the change in the bond yield from 12 months before the crash to 12 months after the crash begins. The general pattern is quite similar to that observed with annual data, with bond yields often rising after currency crashes in the 1970s and early 1980s, but generally falling after 1985.

One advantage of the monthly data is that it provides higher-frequency detail on the behavior of bond yields around the onset of crashes. In particular, we can test the hypothesis that bond yields generally rise in the first month or so after a crash but then fall if the market becomes satisfied with the policy response. There is little evidence to support this hypothesis. On average across the 30 episodes: bond yields rise 22 basis points in the month the crash begins; they rise 4 basis points in the first month afterwards; and they fall between 1 and 14 basis points in each of the next five months.[30] There is also little evidence that bond yields tend to rise

[30] Across the 15 episodes in which bond yields had fallen 12 months after the onset of a crash, yields fell an average 23 basis points in the first month after the crash.

in the months immediately prior to a crash. On average, bond yields fall 3 basis points in the six months before a crash begins.[31]

To further explore the behavior of interest rates around currency crashes consider the following regression equation:

$$\Delta BOND(12)_{i\,t+12} = \alpha_0 + \alpha_1\, BOND(12)_{i\,t} + \alpha_2\, \Delta BOND(12)_{i\,t}$$

$$+ \alpha_3\, INFL(12)_{i\,t+12} + \alpha_4\, \Delta INFL(12)_{i\,t+12} + \alpha_5\, \Delta EXCH(12)_{i\,t}$$

$$+ DUMCR_{i\,t}\begin{bmatrix} \alpha_6 + \alpha_7\, BREAK86_t + \alpha_8\, BOND(12)_{i\,t} + \alpha_9\, \Delta BOND(12)_{i\,t} \\ + \alpha_{10}\, INFL(12)_{i\,t+12} + \alpha_{11}\, \Delta INFL(12)_{i\,t+12} + \alpha_{12}\, \Delta EXCH(12)_{i\,t} \end{bmatrix}$$

$$+ \sum_i \beta_i + \sum_t \gamma_t$$

This equation is analogous to that used in the annual regressions except for the omission of GDP growth rates and current account ratios and the addition of a break in the effects of currency crashes from 1986 onward, which is marginally significant.[32] Because the 12-month differences of the variables overlap in successive months and because estimating a time effect for every month in the sample would use an inordinate number of degrees of freedom, the regression includes only December observations except for the onsets of currency crashes. To avoid overlap with currency crash observations, the December observations immediately before and after the beginning of a currency crash for the country experiencing the crash are excluded from the regression.[33]

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[31] Across the 15 episodes in which bond yields had fallen 12 months after the onset of a crash, yields rose an average 30 basis points in the six months before the crash and another 25 basis points in the month the crash began. This rise is much less than the 150 basis point average fall in yields during the six months after the crash began.

[32] BREAK86 equals 1 from January 1986 through the end of the sample and 0 otherwise.

[33] In the case of currency-crash observations, the time effects are modified as follows: For a crash that begins in December of year t, the time effect for year t equals 1 and the time effects for other years equal 0. For a crash that begins in November of year t, the time effect for year t equals 11/12 and the time effect for year t-1 equals 1/12. Analogous adjustments are made to the time effects for crashes beginning in other months. This procedure implies

Column 1 of Table A1 presents the final preferred specification after removing insignificant terms.[34] (The intercept term is not reported because the time effects in this specification do not have a mean value of zero.) Mean reversion in bond yields is significant. Bond yields tend to rise one-for-one with inflation in the long run. The small but significant negative effect of lagged changes in bond yields probably reflects the greater noise in monthly as opposed to annual bond yields.[35] The crash-interaction terms show that bond yields are especially sensitive to changes in inflation immediately after currency crashes begin. This result is robust to allowing for a structural break in the effects of crashes, as well as including country effects or excluding year effects. Moreover, the negative structural break in the effect of crashes may itself reflect the improved inflation credibility of the post-1985 sample.

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that the overall time effect in a crash period equals the weighted average of the time effects in the immediately preceding and subsequent Decembers.

[34] The omitted terms were never significant at the 10 percent level either jointly or individually. (The fixed effects were tested only jointly by type and not individually.)

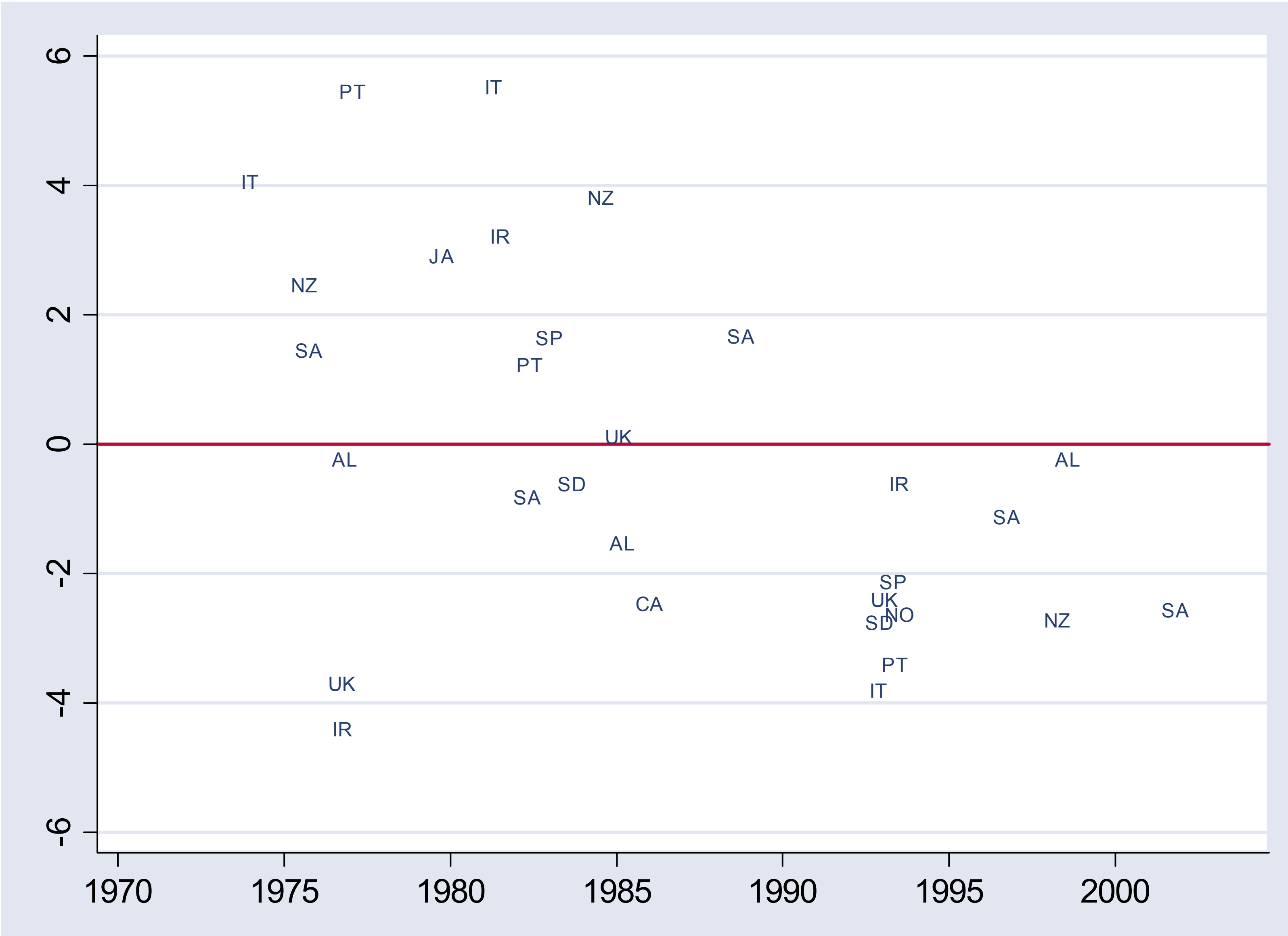
[35] The positive coefficients on lagged yield changes in annual data probably reflect the autocorrelation induced in period-average data when the underlying variable has properties similar to a continuous-time random walk.

Table A1. 12-Month Change in Bond Yields, $\Delta BOND(12)_{it+12}$
(December to December, 1971-2003, except for Crash Episodes)

$BOND(12)_{it}$	-0.21***	-0.22***	-0.25***	-0.17***
	(.02)	(.02)	(.02)	(.01)
$\Delta BOND(12)_{it}$	-0.12***	-0.12***	-0.12***	-0.19***
	(.04)	(.04)	(.04)	(.03)
$INFL(12)_{it+12}$	0.21***	0.21***	0.23***	0.23***
	(.02)	(.02)	(.02)	(.02)
$DUMCR_{it} \times$	0.25***	0.23***	0.24***	0.23***
$\Delta INFL(12)_{it+12}$	(.05)	(.05)	(.05)	(.06)
$DUMCR_{it}$	-0.71**		-0.61*	-0.82**
$\times$ $BREAK86_t$	(.32)		(.33)	(.36)
Year Effects	Yes***	Yes***	Yes***	No
Country Effects	No	No	Yes	No
R-squared	.565	.561	.585	.352
Deg. Freedom	558	559	539	591

***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Figure A1. Changes in Bond Yields, 12 Months Before to 12 Months After Beginning of Currency Crash



Appendix 2: Panel Cointegration of Bond Yields and Inflation Rates

Consider the following panel regression in annual data:[36]

$$\Delta BOND_{it} = \alpha_0 + \alpha_1\, BOND_{it-1} + \alpha_2\, \Delta BOND_{it-1} + \alpha_3\, INFL_{it} + \alpha_4\, \Delta INFL_{it} + \textit{time effects}$$

The "t-ratio" on the estimate of α_1 can be used as a test statistic for cointegration. Because the time effects do not necessarily remove all covariance in the errors across countries, the critical values of the test statistic are non-standard.

To calculate critical values, I conduct a Monte Carlo simulation with 10,000 replications using an estimated covariance matrix of disturbances across countries. The null hypothesis is given by estimating the following regression in which bond yields are not cointegrated with inflation:[37]

$$\Delta BOND_{it} = \alpha_0 + \alpha_1\, \Delta BOND_{it-1} + \alpha_2\, \Delta INFL_{it} + \alpha_3\, \Delta INFL_{it-1} + \alpha_4\, \Delta INFL_{it-2} + \textit{time effects}$$

In order to obtain a positive definite covariance matrix given the large number of countries relative to observations, I drop five countries with the shortest sample periods.[38] I treat the fixed time effects as non-stochastic and generate 10,000 replications of my 35-year sample. I then regress the cointegration equation on these data for each replication. The 5-percent critical value of the test statistic is -3.15 and the 1-percent critical value is -3.91. The test statistic in the cointegration regression on the actual data is -7.00, which is extremely significant.

[36] Neither country effects nor additional lagged difference terms were statistically significant. Addition of lead difference terms on inflation, as in Phillips and Loretan (1991), had no material effect on the test statistic.
[37] An additional lag of Δ*BOND* was not significant, so I added a lagged inflation term to keep the same number of parameters as under the cointegration regression. Again, country effects are not significant.
[38] The dropped countries are Austria, Ireland, Norway, Portugal, and Spain.