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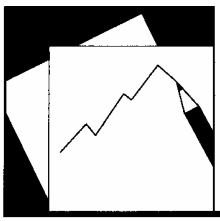

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Cataclysms and Currencies: Does the Exchange Rate Regime Matter for Real Shocks?

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Cataclysms and Currencies: Does the Exchange Rate Regime Matter for Real Shocks?

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Abstract

Does the choice of exchange rate regime affect the way an economy's adjustment to real shocks? Exploiting the randomness of natural shocks, this paper assesses empirically the often contrasting answers found in the theoretical literature. The evidence supports key themes in this literature, and points to an important tradeoff between regimes. First, adverse natural shocks are associated with both higher investment and foreign direct investment (FDI) only in developing countries with fixed rate regimes. Second, over a 24-month horizon, growth rebounds earlier in flexible rate regimes. Third, in the long run, more adverse shocks are associated with higher growth and investment only in predominantly fixed regimes. Thus, while claims of faster adjustment to real shocks under flexible rate arrangements have merit, so does the idea that exchange rate variability can impede investment. And the benefits from faster adjustment may come at the cost of foregoing the long run productivity benefits embodied in the larger investment response in fixed rate regimes.

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I. INTRODUCTION

Does the choice of exchange rate regime affect an economy's adjustment to real shocks? While this question has long been at the center of macroeconomic policy-making, the theoretical literature has often provided contrasting answers. Various of standard arguments (Friedman, 1951; Mundell, 1961; and Poole, 1970) imply that nominal exchange rate movements can restore equilibrium faster in economies with rigid prices. By depreciating the currency, the monetary authorities in a flexible rate regime can increase the domestic currency price of exports, helping to offset the effects of an adverse shock. Higher price levels can also reduce real wages, hastening the adjustment process. In contrast, after a negative shock in fixed rate regimes, output declines until wages and prices fall to their new equilibrium level, with the pace of adjustment determined by nominal rigidities.

However, the many recent instances of macroeconomic instability suggest some important caveats. In part because of concerns about their commitment to price stability, very few central banks in developing countries may have the ability to effectively pursue countercyclical monetary policy Kaminsky et al., 2004; Schmukler and Serven, 2000. Thus, an important component of the adjustment process in flexible rate regimes may be limited in practice. Moreover, fixed rate regimes can reduce exchange rate variability and lower transaction costs, thereby stimulating trade, investment and growth (Frankel and Rose, 2002). Therefore, some have argued that a credible fixed rate regime can be appropriate even for a country facing real shocks (surveys include Calvo and Mishkin, 2003; Dornbush, 2001; and Obstfeld and Rogoff, 2000).

This paper develops stylized facts and empirical tests that help evaluate these theories. To this end, the paper analyzes the relationship between the choice of the exchange rate regime and the economic adjustment to adverse real natural shocks such as wind storms—hurricanes, tornados, typhoons—and earthquakes. Such natural shocks can cause extensive damage to physical and human capital, with economic recovery requiring substantial increases in investment (Benson and Clay, 2004). Moreover, the unpredictability of natural shocks, the fact that their incidence is unrelated to human activity, and the relative ease with which they can be observed can be key to identifying the role of the exchange rate regime in the adjustment process.

Specifically, the exchange rate regime is a policy decision, and sample selection bias can hamper identification. The choice of regime for example may influence the type of shocks that a country experiences. Or countries may choose a particular regime because of the shocks that they expect to receive. In both instances, inferences are likely to be biased.[2] Natural events—windstorms and earthquakes—are in many countries mostly low probability random events, however, and selection bias is less likely to affect inference. It is widely believed, for example, that the choice of exchange rate regime does not physically determine the frequency or intensity—wind speed or Richter scale measure—of natural shocks. Also, it

[2] For example, because of its high terms of trade of volatility—a commonly used shock—a country may choose a particular type of regime, making inferences about the exchange rate regime and the impact of terms of trade movements difficult.

is unlikely that policymakers systematically choose the exchange rate regime in anticipation of these shocks. Of course, it is possible that for a small subset of countries, their general susceptibility to natural shocks may influence exchange rate policy. But susceptibility to natural shocks is usually determined using a broadly agreed upon set of physical observables that can be included in the estimation framework.

The evidence indicates that compared to advanced economies, the choice of exchange rate regime plays an economically large role in the adjustment process in developing countries, reflecting in part the substantial differences in financial and institutional maturity between two groups.[3] Among developing countries with fixed exchange rate regimes, the adjustment process is characterized by an increase in investment of three to five percentage points of GDP over a three year window after the shock. In contrast, there is no detectable impact on investment in developing countries with flexible rate arrangements. In advanced economies, there is no significant investment response regardless of the regime type. These results are robust to various modifications, and underscore the importance of the exchange rate in managing real shocks.

The choice of exchange rate regime also influences the dynamics of the growth response to natural shocks. Among developing countries, the cumulative effect of the shock on growth is about 1.54 percentage points over a three year horizon and is similar across both types of regimes. But as with other studies (Broda, 2002; Edwards and Levy-Yeyati, 2004,) we find that output adjusts much faster in flexible rate regimes, as nearly all of the growth increases occur in the year of the shock. In contrast, economies with fixed exchange rate regimes typically experience a contemporaneous decline in growth, followed by a large rebound one to two years after the shock. In advanced economies there is little evidence that the choice of exchange rate regime has an economically meaningful impact on the growth response.

We interpret these results as supporting key elements of the various theoretical approaches to exchange rate policy. In particular, among developing countries, exchange rate stability appears to confer important advantages when shocks occur, supporting those approaches that emphasize the adverse impact of exchange rate variability on investment and growth. Intuitively, the import content of investment goods in many developing countries can be very large (Burstein et al., 2004), and after a shock, potential movements in the exchange rate can greatly add to the uncertainty surrounding the investment decision. But there is also ample support for theories that emphasize more rapid adjustment under flexible regimes. While the cumulative growth response between regime types over three years is small, the evidence indicates that flexible regimes depreciate the nominal exchange rate to handle adverse real shocks, temporarily spurring exports and growth.

In the long run, however, there appears to be an important tradeoff between the benefits of adjusting to real shocks through the exchange rate, and the impact of nominal exchange rate movements on investment. Over a 30-year period, a higher average incidence of natural

[3] Examples of empirical research on the impact of exchange rate regime include Baxter and Stockman, 1989 and Husain et al., 2004]

shocks is associated with both higher investment and growth only in economies that predominantly maintained fixed regimes. That is, while deprecating the currency can help the economy more quickly adjust to adverse shocks, exchange rate variability itself seems to impede the investment response to these shocks. And over the long run, economies that invest in response to these shocks, also appear to experience faster economic growth from natural shocks. The paper is organized a follows. Section II discuses the data, while Section III presents the main results. Section IV considers various sensitivity analyses, and Section V discussion.

II. DATA

The data on windstorms and earthquakes are taken from the Center for the Research on the Epidemiology of Disasters (CRED). This database records a disaster based on the following conditions: 10 or more reported killed; 100 people reported affected; a call for international assistance; a declaration of a state of emergency. These relatively low thresholds ensure that most disasters are recorded in the database. In the most inclusive specification there are 240 reported earthquakes and 423 reported windstorms in the sample of 120 countries over the period 1961-2000. Table 1 lists the countries in the sample and the mean incidence of each type of shock. They are widely distributed across the planet, but the limited case study evidence[4] does suggest some common features across shocks that make them appealing for studying the relationship between exchange rate regimes and real shocks.

Natural shocks both directly and indirectly affect the capital stock. For example, Hurricane Mitch struck Honduras in 1998, causing severe unemployment in urban areas since the disaster affected business capital (World Bank, 2004a). [5] And many developing countries rely on imported building materials and equipment to rebuild after these events, often with long term consequences. After severe storms and flooding in 1987 and 1988, Bangladesh relaxed restrictions on private agricultural investment and on imports of equipment, initially to encourage recovery. But access to these new technologies was associated with a rapid expansion of dry-season irrigated rice, displacing the flood prone deep water rice and jute. This greatly reduced the volatility and level of the price of rice—a food staple (Benson and Clay, 2004). Thus, the choice of exchange rate regime can potentially shape the economic adjustment to these real shocks.

[4] While these studies are helpful, extrapolation is difficult, as cases are not randomly chosen, but are often performed only when shocks are particularly severe.

[5] To illustrate the mundane yet profound impact of these shocks on the capital stock, high winds blew away one watch repairer's tools, forcing him to layoff his workforce [World Bank 2004].

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Table 1. The Mean Incidence of Windstorms, 1961-2000

Country	Earthquakes	Windstorms
Albania	3.85	0.96
Algeria	12.5	1.92
Antigua and Barbuda	0	7.69
Argentina	4.81	12.5
Armenia	0.96	0
Australia	4.81	25.96
Austria	0	7.69
Azerbaijan	2.88	0
Belarus	0	0.96
Belgium	1.92	11.54
Benin	0	0.96
Bolivia	2.88	0.96
Bosnia & Herzegovina	0	0.96
Botswana	0	0
Brazil	0.96	11.54
Bulgaria	3.85	3.85
Burkina Faso	0	0
Burundi	0	0.96
Cameroon	0	0
Canada	0	23.08
Central African Rep.	0	1.92
Chad	0	1.92
Chile	19.23	9.62
China, P.R.: Mainland	38.46	31.13
Colombia	14.42	4.81
Costa Rica	5.77	2.88
Cote d'Ivoire	0	0
Croatia	0.96	0
Cyprus	1.92	1.92
Czech Republic	0	0.96
Denmark	0	9.62
Dominica	0	9.62
Dominican Republic	0.96	11.54
Ecuador	12.5	0
Egypt	4.81	2.88
El Salvador	5.77	6.73
Finland	0	0.96
France	0.96	19.23

Country	Earthquakes	Windstorms
Gabon	0	0
Gambia, The	0	0
Georgia	2.88	0.96
Germany	0.96	5.77
Ghana	0.96	0
Greece	23.08	4.81
Grenada	0	3.85
Guatemala	10.58	3.85
Guinea	0.96	0.96
Guinea-Bissau	0	1.92
Guyana	0	0
Haiti	0.96	14.42
Honduras	2.88	11.54
Hong Kong, SAR	0	33.65
Hungary	0	1.92
Iceland	1.92	0
India	21.15	52.88
Indonesia	32.69	7.69
Iran, I.R. of	37.5	7.69
Ireland	0	4.81
Israel	0	2.88
Italy	19.23	11.54
Jamaica	0.96	16.35
Japan	27.88	53.85
Jordan	0.96	3.85
Kazakhstan	0	0.96
Kenya	0.96	0.96
Korea	0	26.92
Kuwait	0	0
Kyrgyz Republic	1.92	0
Lao People's Dem. Rep	0	3.85
Latvia	0	0
Lebanon	0.96	2.88
Lesotho	0	2.88
Lithuania	0	0.96

Table 1 (Continued). The Mean Incidence of Windstorms, 1961-2000

Country	Earthquakes	Windstorms
Macedonia, FYR	0	0
Madagascar	0	19.23
Malawi	0.96	0
Malaysia	0	4.81
Mali	0	0
Mauritania	0	1.92
Mauritius	0	15.38
Mexico	18.27	29.81
Moldova	0	1.92
Mongolia	0.96	5.77
Morocco	2.88	0.96
Nepal	3.85	4.81
Netherlands	0.96	8.65
New Zealand	4.81	5.77
Nicaragua	7.69	8.65
Niger	0	0.96
Nigeria	0	1.92
Norway	0	2.88
Pakistan	13.46	16.35
Panama	0.96	3.85
Paraguay	0	1.92
Peru	26.92	1.92
Philippines	17.31	55.77
Poland	0.96	2.88
Portugal	0.96	2.88
Romania	11.54	4.81
Russia	3.85	5.77
Saudi Arabia	0	0.96
Senegal	0	0.96

Country	Earthquakes	Windstorms
Singapore	0	0
Slovak Republic	0	0
Slovenia	0.96	0
South Africa	4.81	9.62
Spain	1.92	11.54
Sri Lanka	0	4.81
St. Kitts and Nevis	0	7.69
St. Lucia	0	9.62
St. Vincent & Grens.	0	5.77
Suriname	0	0
Swaziland	0	0.96
Sweden	0	3.85
Switzerland	0	10.58
Syrian Arab Republic	0	1.92
Tanzania	7.69	0.96
Thailand	0	14.42
Togo	0	0.96
Tunisia	0.96	0
Turkey	36.54	5.77
Turkmenistan	0.96	0
Uganda	3.85	1.92
Ukraine	0	1.92
United Kingdom	0.96	20.19
United States	25.96	73.08
Uruguay	0	4.81
Venezuela, Rep. Bol.	6.73	1.92
Zambia	0	0
Zimbabwe	0	0.64

Note: Countries in bold are classified as advanced.

To measure the choice of exchange rate regime, because of its extensive coverage we rely principally on the Reinhart and Rogoff (2004) 6-way annual exchange rate classification system to construct a binary variable to denote "fixed" or "flexible" regimes—Table 2 provides more detail. That said, we also report results using both the "finer" classification itself with the six exchange rate categories, and the Levy-Yeyati and Sturzenengger (2004) method of classifying exchange rates. We measure the adjustment to shocks using investment, defined as gross capital formation net of inventories, and scaled by GDP; foreign direct investment, also scaled by GDP; and real GDP growth. Most of the macroeconomic data are extracted from World Bank and IMF databases, and are defined in Table 2.

III. Empirical Framework and Main Results

There is a well developed literature on the impact of exchange rate uncertainty on investment Cabellero and Corbo, 1989; Darby et al., 1998.[6] Thus, our approach is purposely minimal, and is intended to motive the role of natural shocks in the empirics. To this end, we consider a simple two period environment where a representative firm maximizes expected profits by choosing the investment level in period one, I, before learning the cost of investment.

In particular, let a denote a random variable that exponentially affects the cost of investment; a is assumed to be normally distributed with mean 0 and variance σ^2 and is realized after the investment decision is made; investment costs are convex. Thus, the total cost of investment in period one is $e^a I^2$. Production occurs using a standard Cobb Douglas technology with capital, k, as the only variable input. Profits in periods one and two respectively are $k_1^{\alpha} - e^a I^2$ and $\left[I + (1-\delta) k_1 \right]^{\alpha}$, where δ is the fraction of capital that depreciates between the two periods. The depreciation parameter, δ, intuitively captures the adverse impact of a shock on the capital stock. By reducing the capital stock, shocks can increase the optimal level of investment in period one: $\frac{\partial I(\delta, \sigma^2)}{\partial \delta} > 0$. But the investment response to an increase in δ negatively depends on the level of uncertainty surrounding the cost of investment: $\frac{\partial^2 I(\delta, \sigma^2)}{\partial \delta \partial \sigma^2} < 0.$

[6] There is of course a much larger literature on the link between more general forms of uncertainty and investment behavior, and classic references include Abel, 1981; and the survey by Dixit and Pindyck, 1994.

Table 2. Variables, Definition and Source

Variable	Definition	Source
Aid	The Ratio of Foreign Aid to Gross National Income	World Bank (2004)
Dem	Democracy Score: general openness of political institutions	Polity IV (2004).
Exchange Rate Dummy	1 if Exchange Rate Regime Classification (RR) ≤ 3 ; 0 otherwise. Note "5" or "freely falling" are excluded from the sample.	Reinhart and Rogoff (2004)
Exchange Rate Regime Classification, RR	1=No separate legal tender, Pre-announced peg or currency board arrangement, Pre-announced horizontal bank narrower than or equal to +/-2 percent, De facto peg; 2=Pre-announced crawling peg, Pre-announced crawling peg narrower than or equal to +/-2 percent, De facto crawling peg, De facto crawling peg narrower than or equal to +/-2 percent; 3=Pre-Announced Crawling Band that is narrower than or equal to +/- 2 percent, De facto crawling band that is narrower than or equal to +/-5 percent, Moving band that is narrower than or equal to +/-2 percent, Managed floating 4=Freely floating 5=Freely falling 6=Dual market in which parallel market data is missing.	Reinhart and Rogoff (2004)
Exchange Rate Regime Classification, LY-S	1=inconclusive;2=float;3=dirty;4=dirty/crawling peg; 5=fixed.	Levy-Yeyati and Sturzenengger (2004)
Exports	The Ratio of Exports to GDP	World Bank (2003).
FDI	The Ratio of Foreign Direct Investment to GDP	World Bank (2003).
Frequency	The Percent of Years With At Least One Recorded Windstorm, 1900-2000.	CRED (2003)
GDP Growth	Growth in Real GDP	World Bank (2003).
Government Consumption Growth	Annual Percent Change in Government Consumption, measured in constant $US	World Bank (2003).
GDP Per Capita	Ratio of Real GDP in constant $US to Population	World Bank (2003).
Growth in the Terms of Trade	The Annual Percent Change in the Terms of Trade	IMF (2003).
Investment	The Ratio of Gross Capital Formation, net of Inventories, to GDP.	World Bank (2003).
Med	An indicator variable that takes on the value of 1 if a country maintained a fixed exchange rate system—see Exchange Rate Dummy—for at least 64 percent of the years from 1960-2000: the median percent among developing countries in the sample.	Author's Calculations
Population Size	Log of Population	World Bank (2003).
Population Density	Population Density: People per Square Kilometer.	World Bank (2003).
Size	Land Area, in square kilometers.	World Bank (2003).
Trade Openness	Imports plus Exports Divided By GDP	World Bank (2003).
Urbanization	Fraction of the Population Living in Urban Areas	World Bank (2003).

While many factors can affect uncertainty, exchange rate volatility, or perceptions about the stability of the exchange rate regime can introduce significant uncertainty over the domestic price of investment goods, and consequently, the investment response after a shock. And exchange rate uncertainty is likely to figure prominently in the investment response in developing countries. The evidence from a subset of these countries indicate that the total import content of investment goods is about 30 percent—significantly higher than consumption goods (Burstein et al., 2004). Moreover, access to hedging instruments are often more limited in these countries. There is also evidence Goldberg, 1993 that even in the case of advanced economies like the U.S. exchange rate uncertainty can negatively affect investment in some sectors.

To examine the hypothesis that the impact of a natural shock on investment depends on the exchange rate regime, let S_{it} denote an indicator variable that takes on the value of one if a shock occurs in country i on year t and zero otherwise. Also, let R_{it} denote an indicator variable that equals one if the exchange rate regime is classified as fixed, and zero otherwise in country i on year t—see Table 2. The vector $\mathbf{X}_{it}$ denotes the set of control variables observed for country i on year t. We then consider the following specification:

$$y_{it} = \varepsilon_i + \sum_{j=0}^{2}\left[\alpha_j S_{it-j} + \lambda_j R_{it-j} + \gamma_j S_{it-j} * R_{it}\right] + \mathbf{X}_{it}\beta + v_t + u_{it} \qquad (1)$$

where the parameters γ_j test whether the impact of a shock on the outcome variable, y_{it}, depends on the prevailing exchange rate regime. Since the exchange rate regime and the shock can affect the equilibrium level of y_{it}, the specification also linearly includes R_{it}, as well as S_{it}. We consider the effects of the shock both in the current year as well as up to two years after the shock.[7] The variables ε_i and v_t are country fixed and year effects, while u_{it} is a residual term that is allowed to be correlated across years for the same country in all regressions.[8] Because the impact of natural shocks are related to the spatial distribution of economic activity, time varying control variables include both population density, urbanization, as well as per capita income, and trade openness.

[7] Much of the case study literature also uses a similar horizon (World Bank, 2003b)—F-tests also suggest little gain in including additional lags.

[8] The data is observed annually and both S_{it} and R_{it} are slowly changing over time for each country, leading to possible serial correlation. See Bertrand et al., 2004 for a discussion of these issues in the closely related difference-in-difference estimation strategies.

A. Investment

We establish our main results using windstorms as the principal source of shocks.[9] But before estimating equation (1), we turn to Figure 1 which foreshadows the parametric results. For advanced countries, the mean difference in the investment level—the ratio of gross capital formation, net of inventories, to GDP—between years with and without windstorms is small, not statistically different from zero, and does not depend on the choice of exchange rate regime. In contrast, this crude but direct measure of impact indicates that among developing countries with fixed exchange rate regimes, the mean investment level when windstorms occur is over 2.5 percentage points of GDP (p-value=0.00) higher than the mean level in non windstorm years. There is no significant investment response in developing countries with flexible rate regimes.

Table 3a now estimates equation (1). Column 2 considers the base specification, controlling for per capita income, trade, population density, urbanization, as well as year and country fixed effects. When advanced and developing countries are combined in the sample, windstorms have no significant impact on investment behavior, and the choice of exchange rate regime does not influence the adjustment process. But these results are substantially different when the data are disaggregated between advanced and developing countries.

In the year of the shock (column 4) the mean level of investment in developing countries operating under fixed rate regimes increases by about 1.87 percentage points of GDP (p-value=0.05) when windstorms occur. One year after the shock the investment level remains about 1.34 percentage points higher (p-value=0.04) in fixed rate economies. There is no significant impact two years after the shock, and the cumulative impact of the shock is a 3.21 percentage point of GDP increase in the investment level (p-value=0.06). In contrast, over the same three year horizon windstorms have no significant impact on investment in either advanced countries (column 3) or in developing countries operating under flexible rate regimes.

While the precise timing of windstorms are random, the exchange rate choice is a policy decision, and a subtle form of selection bias may engender the differences observed in columns 3 and 4. After a very severe windstorm, a country may be unable to maintain a fixed rate regime, opting instead for increased flexibility. If these policy decisions systematically occurred in the sample, they would produce a significant correlation between flexible exchange rate regimes and severe windstorms. And to the extent that severe windstorms impede the investment response, this form of policy endogeneity would generate some of the observed differences in Table 3a.

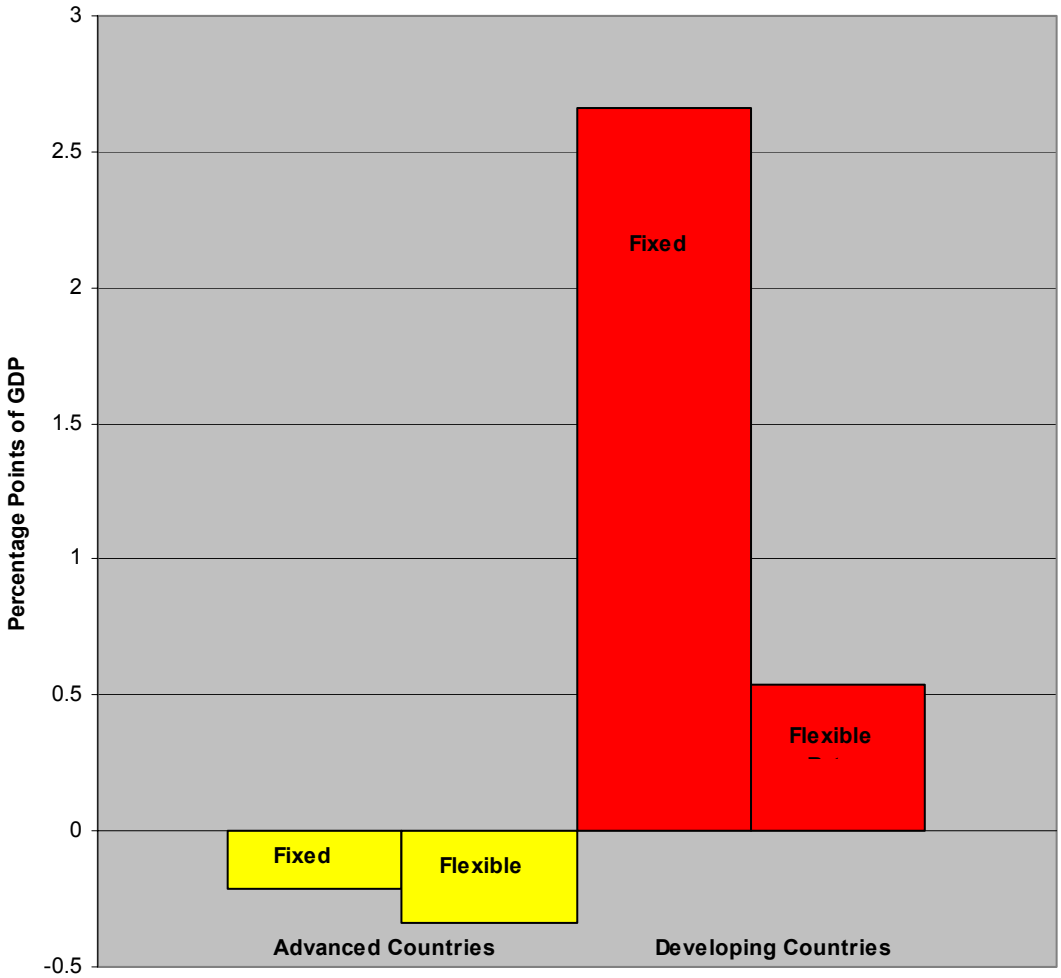
[9] Earthquakes are discussed in the robustness section.

Table 3a. The Exchange Rate Regime, Windstorms, and Investment
Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP

	Pooled Sample (2)	AC (3)	DC (4)	"Constant" Regimes (AC) (5)	"Constant" Regimes (DC) (6)
S_{it}	0.003 (0.004)	0.006 (0.005)	-0.0007 (0.007)	0.006 (0.007)	0.011 (0.010)
$S_{it} * R_{it}$	0.007 (0.007)	-0.008 (0.005)	0.0187** (0.009)	-0.009 (0.006)	0.008 (0.008)
S_{it+1}	0.010 (0.007)	0.004 (0.004)	0.009 (0.009)	0.004 (0.005)	0.003 (0.007)
$S_{it+1} * R_{it+1}$	0.004 (0.005)	-0.005 (0.005)	0.013** (0.006)	-0.006 (0.005)	0.019*** (0.007)
S_{it+2}	0.007 (0.006)	0.006 (0.005)	0.005 (0.009)	0.005 (0.006)	-0.001 (0.008)
$S_{it+2} * R_{it+2}$	0.007 (0.545)	-0.008 (0.006)	0.006 (0.008)	-0.008 (0.006)	0.011 (0.008)
NOBs	2843	748	2095	712	2013
R-squared	0.55	0.67	0.58	0.67	0.58

Note: All regressions linearly include per capita income, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year and country fixed effects—see Table 2. S_{it} is an indicator variable, taking on the value of one if a windstorm occurs in country *i* in year *t* and 0 otherwise. R_{it} takes on the value 1 if the exchange rate regime is fixed, and 0 if flexible—see Table 2. "Constant" Regimes are those where the exchange rate regime remained constant over a four year window, beginning in the year *before* the shock. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only advanced and developing countries respectively—see Table 1.

Figure 1. The Mean Impact of Windstorms on Investment,
by Exchange Rate Regime



To reduce the possibility that the shock might have affected the exchange rate regime, columns 5 and 6 consider only windstorms in which the exchange rate regime both in the year of the windstorm and up to two years after the windstorm remained identical to the regime that prevailed in the year before the windstorm. That is, we limit the sample of windstorms to those where the exchange rate remained constant over a four year window, beginning in the year *before* the shock. We call these "constant" regimes. As columns 5 and 6 indicate, our results are modified only slightly. Windstorms continue to significantly affect investment behavior only in developing countries with fixed exchange rate regimes. The impact estimated impact in this sample of storms is a 1.91 percentage points of GDP increase in investment. Thus, it appears unlikely that our results are driven by shocks that systematically affected the regime choice.

Nevertheless, the frequency with which windstorms strike a country may influence the choice of exchange rate regime. For example, expecting frequent windstorms, countries in a hurricane or typhoon belt may systematically choose flexible rate arrangements; but because shocks are frequent, investment may respond differently compared to countries shocks in countries outside the belt. The link may also be indirect. Frequent storms may shape production patterns and overall economic activity, which in turn can influence the choice of regime and the response to shocks. In both instances, our estimates are likely to be biased. Thus, Column 2 of Table 3b allows the impact of the shock within a country to depend on the percent of years with at least one windstorm over the last 100 years.

Our basic results are quite stable. The impact of the shock is significant only in developing countries with fixed rate regimes, and the cumulative increase in investment over the three years remains around three percentage points of GDP. Likewise, there is little change in the estimated role of the exchange rate when the shock is allowed to vary by physical size (column 3); whether the country is an island (column 4); per capita income (column 5); the size of foreign aid in the economy: the ratio of aid to gross national income (column 6); as well as when all five variables are jointly included as interaction terms along with the exchange rate regime (column 7).[10]

B. Growth

Recovering from natural disasters entails more than just increased investment. In the short run these shocks can disrupt production in some sectors, and damage to the capital stock can lower labor productivity. When nominal rigidities exist, standard models of adjustment suggest that a currency depreciation can help offset some of these adverse effects by stimulating the export sector. At the same time, higher domestic prices can reduce real wages, helping the economy return faster to its equilibrium level of output. Thus, we examine the impact of windstorms on economic growth, and consider whether it depends on the exchange rate regime.

[10] Note that the sample size occasionally changes because of data availability. Results are unchanged holding the sample size constant across specifications, and are available upon request.

Table 3b. The Exchange Rate Regime, Windstorms, and Investment
Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP

	DC (Frequency) (2)	DC (Size) (3)	DC (Island) (4)	DC (Per Capita Income) (5)	DC (Foreign Aid) (6)	DC (Combined) (7)
S_{it}	-0.004 (0.009)	0.001 (0.007)	0.001 (0.007)	-0.001 (0.008)	-0.003 (0.007)	-0.004 (0.011)
$S_{it} * R_{it}$	0.019** (0.010)	0.018* (0.009)	0.017* (0.009)	0.019** (0.01)	0.018* (0.009)	0.016* (0.009)
S_{it+1}	-0.0002 (0.009)	0.012 (.006)	0.012 (0.011)	0.008 (0.009)	0.008 (0.011)	0.001 (0.013)
$S_{it+1} * R_{it+1}$	0.013** (0.007)	0.013* (0.007)	0.014** (0.007)	0.014** (0.007)	0.012* (0.007)	0.012* (0.007)
S_{it+2}	0.001 (0.011)	0.004 (0.010)	0.012 (0.010)	0.004 (0.009)	0.007 (0.010)	0.004 (0.013)
$S_{it+2} * R_{it+2}$	0.007 (0.008)	0.008 (0.008)	0.008 (0.008)	0.006 (0.008)	0.004 (0.004)	0.007 (0.008)
S_{it}*FREQUENCY	0.019 (0.033)	—	--	—	—	0.039 (0.043)
S_{it+1}* FREQUENCY	0.071 (0.069)	—	—	—	—	0.126 (0.087)
S_{it+2}* FREQUENCY	0.021 (0.043)	—	—	—	—	0.062 (0.042)
S_{it}*SIZE * 10^{-5}	—	-0.131 (0.153)	—	—	—	-0.004 (0.003)
S_{it+1}*SIZE * 10^{-5}	—	-0.216 (0.160)	—	—	—	-0.005** (0.002)
S_{it+2}*SIZE * 10^{-5}	—	0.141 (0.112)	—	—	—	-0.001 (0.002)
S_{it}*ISLAND	—	—	-0.003 (0.012)	—	—	-0.008 (0.012)
S_{it+1}*ISLAND	—	—	-0.015 (0.013)	—	—	-0.030** (0.015)
S_{it+2}*ISLAND	—	—	-0.031*** (0.012)	—	—	-0.042*** (0.012)
S_{it}*PER CAPITA INCOME * 10^{-5}	—	—	—	0.015 (0.182)	—	0.004 (0.027)
S_{it+1}* PER CAPITA INCOME * 10^{-5}	—	—	—	0.028 (0.191)	—	0.005 (0.003)
S_{it+2}* PER CAPITA INCOME * 10^{-5}	—	—	—	0.085 (0.237)	—	0.016 (0.021)
S_{it}*FOREIGN AID	—	—	—	—	0.001* (0.0006)	0.001* (0.006)
S_{it+1}* FOREIGN AID	—	—	—	—	0.0009* (0.0005)	0.001** (0.006)
S_{it+2}* FOREIGN AID	—	—	—	—	0.0005 (0.0008)	0.001 (0.007)
NOBs	2095	2095	2095	2095	2020	2020
R-Squared	0.61	0.61	0.61	0.61	0.61	0.61

Note: All regressions linearly include per capita income, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year and country fixed effects; foreign aid linearly enters columns 6 and 7. S_{it} is an indicator variable, taking on the value of one if a windstorm occurs in country *i* in year *t*. R_{it} takes on the value 1 if the exchange rate regime is fixed, and 0 if flexible—see Table 2 Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only advanced and developing countries respectively—see Table 1. Size, the island indicator variable, and the frequency of windstorms are treated linearly as country fixed effects.

To this end, we modify equation (1), supplementing the set of regressors to derive a relatively noncontroversial growth regression—initial income per capita (1961); the ratio of investment to GDP, the growth in government consumption—lagged one year; a measure of democracy; country size; growth in the term of trade; two indicator variables for the countries located in Africa and Latin America as well as variables from our core specification: the ratio of exports and imports to GDP, urban population and population density. To reiterate, the intent is not to revisit the extensive growth literature, but to adapt a standard framework to study the interaction between shocks and the choice of exchange rate.

In the base specification—which pools both developed and developing countries—there is robust evidence that wind storms positively affect growth (Column 2 of Table 4a). Growth is about 0.74 (p-value=0.07) and 0.68 (p-value=0.02) percentage points higher than otherwise in the year of the shock and the year immediately afterwards; there is no significant impact beyond the one year horizon. Moreover, in the pooled sample the impact of windstorms on growth does not depend on the exchange rate regime.

Table 4a. The Exchange Rate Regime, Windstorms, and Economic Growth
Dependant Variable: Economic Growth

	Pooled Sample (2)	AC (3)	DC (4)	"Constant" Regimes (AC) (5)	"Constant" Regimes (DC) (6)
S_t	0.737* (0.400)	-0.175 (0.188)	1.295** (0.602)	-0.127 (0.238)	1.412** (0.620)
$S_t * R_t$	-0.626 (0.382)	0.219 (0.244)	-1.473** (0.611)	0.152 (0.329)	-1.694** (0.761)
S_{t+1}	0.677** (0.291)	0.726*** (0.254)	0.637 (0.425)	0.738** (0.289)	0.594 (0.457)
$S_{t+1} * R_{t+1}$	-0.543 (0.336)	-0.570 (0.346)	-0.365 (0.544)	-0.615 (0.384)	-0.091 (0.522)
S_{t+2}	-0.330 (0.366)	0.652 (0.232)	-0.753 (0.512)	0.528** (0.1901)	-0.689 (0.522)
$S_{t+2} * R_{t+2}$	0.539 (0.379)	-0.530* (0.267)	1.687*** (0.536)	-0.427* (0.224)	1.99*** (0.562)
NOBs	1954	640	1314	611	1268
R-squared	0.25	0.44	0.27	0.44	0.33

Note: All regressions linearly include the exchange rate regime; population density; the percent of urban population; trade openness; initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; investment; Latin America and Africa indicator variables, as well as year effects—see Table 2. "Constant" Regimes are those where the exchange rate regime remained constant over a four year window, beginning in the year *before* the shock. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only advanced and developing countries respectively—see Table 2.

However, disaggregating the data between advanced and developing countries reveal substantial differences in the role of the exchange rate and the impact of windstorms between the two groups of countries. In advanced countries (Column 3) the overall impact of the shock is relatively small, and is associated with a 0.53 percentage points of additional growth over the three years in economies with flexible versus fixed rate regimes. In contrast, in developing countries (Column 4) the cumulative impact of the shock is economically large and slightly higher in fixed rate regimes—1.51 percentage points versus 1.30 percentage in flexible regimes. But the dynamics of the adjustment process is significantly different across the two types of regimes. While fixed rate economies suffer immediate declines in growth followed by large rebounds two years later, those with flexible regimes experience large initial increases in growth, but with no significant impact over the next two years.

Restricting the sample to "constant regimes" yields qualitatively similar results. The overall impact of windstorms on growth in advanced economies over a three year horizon is about 0.43 percentage points less in fixed rate economies. The cumulative impact of windstorms in developing countries with fixed exchange rate regimes is about 1.71 percentage points—about 0.30 percentage points higher than flexible regimes. But most of the increase in growth occurs two years after the shock. Thus, while it is not surprising that windstorms have larger effects in developing countries, these results point to sharp differences adjustment dynamics across exchange rate regimes.

For the set of developing countries, Table 4b gauges the robustness of these results. In particular, we allow the shock to depend on frequency of windstorms (Column 2); the ratio of aid to gross national income (Column 3); physical size (Column 4); whether the country is an island (Column 5); Column 6 jointly includes all the previous interaction terms. Throughout, there is only minor variation in the cumulative impact of shock across regimes, and the sharp differences in the adjustment dynamics across regimes persist.

IV. ROBUSTNESS

This section performs further robustness analyses, and tries to better discern the mechanism through which the choice of regime affects the adjustment process.

A. Regions: Africa, Asia, and the Caribbean

Countries are heterogeneous, and despite conditioning on a wide range of economic and political variables, unobservable country characteristics can still affect inference. For example, many Caribbean islands and Asian nations lie in the Atlantic hurricane and Pacific typhoon belt respectively, and are subject to windstorms. But comparisons across geographic regions with such diverse economic and currency histories, as well as social and cultural institutions might conflate important regional differences in economic adjustment. Hence, this subsection reconsiders the analysis by geographic regions. Currency unions in Africa—the CFA franc zone—and in the Caribbean—the Eastern Caribbean Monetary Union—as well as long standing pegs in Asia, such as Hong Kong SAR, provide variation in the exchange rate regime.

Table 4b. The Exchange Rate Regime, Windstorms, and Economic Growth
Dependant Variable: Economic Growth

	DC (Frequency) (2)	DC (Aid) (3)	DC (Size) (4)	DC (Island) (5)	DC (Combined) (6)
S_{it}	1.654** (0.765)	1.275* (0.721)	0.889 (0.602)	2.305*** (0.679)	1.437* (0.826)
$S_{it*}R_{it}$	-1.791*** (0.666)	-1.311** (0.648)	-1.339** (0.597)	-1.995*** (0.641)	-1.526*** (0.651)
S_{it+1}	1.305* (0.694)	1.346*** (0.564)	0.464 (0.458)	1.389*** (0.424)	1.289* (0.688)
$S_{it+1}*R_{it+1}$	-0.655 (0.570)	-0.733 (0.561)	-0.292 (0.537)	-0.636 (0.588)	-0.725 (0.618)
S_{it+2}	0.431 (0.816)	-0.529 (0.744)	-0.809 (0.575)	0.182 (0.600)	-0.264 (0.885)
$S_{it+2}*R_{it+2}$	1.471*** (0.547)	1.462*** (0.579)	1.674*** (0.543)	1.294** (0.550)	1.356** (0.615)
S_{it*}FREQUENCY	-1.019 (3.937)	—			-1.706 (3.198)
S_{it+1*} FREQUENCY	-3.317 (2.477)	—			-2.271 (2.635)
S_{it+2*} FREQUENCY	-7.992*** (2.911)	—			-4.481* (2.664)
S_{it*}FOREIGN AID	—	-0.025 (0.029)			-0.014 (0.029)
S_{it+1*} FOREIGN AID	—	-0.069 (0.049)			-0.053 (0.049)
S_{it+2*} FOREIGN AID	—	0.016 (0.056)			0.031 (0.056)
S_{it*}SIZE $*10^{-5}$	—	—	0.296** (0.139)	—	-0.288 (0.170)
S_{it+1*}SIZE $*10^{-5}$	—	—	0.094 (0.105)	—	0.105 (0.118)
S_{it+2*}SIZE $*10^{-5}$	—	—	0.012 (0.096)	—	0.226* (0.121)
S_{it*}ISLAND	—	—	—	-2.144** (0.939)	-1.662* (0.977)
S_{it+1*}ISLAND	—	—	—	-1.371** (0.584)	-1.085 (0.829)
S_{it+2*}ISLAND	—	—	—	-1.579** (0.705)	-1.423** (0.661)
NOBs	1314	1264	1314	1314	1264
R-Squared	0.27	0.26	0.27	0.28	0.29

Note: All regressions linearly include the exchange rate regime; population density; the percent of urban population; trade openness; initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; investment; Latin America and Africa indicator variables, as well as year effects—see Table 2. The frequency of windstorms, foreign aid and the "ISLAND" dummy also enter linearly in the regression in columns 2, 3 and 5 respectively; all three variables enter linearly in column 6. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. Sample only includes developing countries—see Table 2.

From Table 5, many of our earlier results are replicated across regions. When the sample is restricted to sub-Saharan Africa (Columns 2 and 3 of Table 5) one year after a windstorm, investment is about 5.30 percentage points higher in fixed rate regimes. In the case of growth, we do not detect a significant impact both contemporaneously, as well as one year later. We do however observe that two years after the shock growth is lower in flexible rate regimes (p-value=0.07).[11] Turning to the developing Asian countries in the sample, while there is no significant investment response, two years after the shock, growth is again significantly higher in fixed rate regimes. There is also some indication that, like the overall sample, growth is lower in the year of the shock for fixed rate regimes, but this is not significant at conventional levels (p-value=0.11). The response among the Caribbean countries is similar, but with much larger point estimates, suggesting that windstorms have a more dramatic impact in these small islands.[12]

B. Foreign Direct Investment

Replacing the affected capital stock after a shock may also attract foreign direct investment (FDI), and focusing on FDI provides a more complete portrait of the investment response. In addition, unlike our previous measure of investment, which because of data constraints, combined both public and private investment, decisions on when and where to undertake FDI are usually made by the private sector. Thus, using FDI helps in isolating how the exchange rate regime might affect private investment behavior.

Column 2 of Table 6 pools both advanced and developing countries. The FDI response is positive and significant only for fixed rate regimes: in the year of the shock (p-value=0.05) and one year after (p-value=0.06). And as with the previous results using overall investment, our results are driven by developing countries. When the sample is disaggregated between the two sets of countries, the FDI response in developing countries is limited to the year of the shock, and is significant only in fixed rate regimes, with FDI increasing by about 0.51 percentage points of GDP (p-value=0.10). Hence, the response of FDI to natural shocks and the role of the exchange rate appear qualitatively similar to gross capital formation.

C. Earthquakes

Earthquakes are also tremendously destructive natural events. But unlike windstorms, which are seasonal and whose path—at least in the last decade—can be predicted up to a day or two in advance, earthquakes occur with almost no warning, and according to current scientific evidence, are not seasonal. In addition, as Table 1 indicates, the relative frequency with

[11] That is, the hypothesis that $S_{it+2} + S_{it+2} R_{it+2}=0$ is rejected at the 7 percent level.

[12] Data are missing for many Caribbean countries; and in the growth specification, we consider a very parsimonious framework.

Table 5. Regions

	Sub-Saharan Africa		Caribbean		Asia	
	Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP (2)	Dependant Variable: GDP Growth (3)	Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP (4)	Dependant Variable: GDP Growth (5)	Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP (6)	Dependant Variable: GDP Growth (7)
S_{it}	-0.001	-0.213	-0.013	4.666**	0.024	2.655*
	[0.015]	[0.368]	[0.036]	[1.286]	[0.016]	[1.180]
$S_{it}*R_{it}$	0.031	0.623	0.023	-5.594***	-0.020	-2.106
	[0.030]	[1.683]	[0.025]	[0.520]	[0.022]	[1.283]
S_{it+1}	-0.004	-0.067	-0.061*	-2.476	0.015	1.251
	[0.011]	[0.866]	[0.032]	[1.527]	[0.031]	[1.489]
$S_{it+1}*R_{it+1}$	0.053*	1.212	0.053	4.171**	-0.009	-1.222
	[0.030]	[1.251]	[0.032]	[1.013]	[0.026]	[1.758]
S_{it+2}	-0.004	-1.380**	0.001	-7.247*	-0.003	-3.594**
	[0.014]	[0.606]	[0.029]	[2.332]	[0.018]	[1.188]
$S_{it+2}*R_{it+2}$	0.028	2.463	-0.020	3.677	-0.009	2.215*
	[0.029]	[2.351]	[0.031]	[2.290]	[0.015]	[1.002]
Observations	680	467	107	153	253	253
R-squared	0.73	0.39	0.94	0.26	0.80	0.52

Note: All columns **except column 5** linearly include the exchange rate regime, population density, the percent of urban population, trade openness, as well as year effects. Columns 2, 4 and 6 also include per capita income and fixed effects. Columns 3 and 7 include initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; and investment—See Table 2. Column 5 linearly includes initial per capita income (1961), the exchange rate regime and year effects. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively.

Table 6. The Exchange Rate Regime, Windstorms, and Foreign Direct Investment
Dependant Variable: Foreign Direct Investment, as a percent of GDP

	Pooled Sample (2)	AC (3)	DC (4)
S_{it}	-0.204 [0.167]	-0.253 [0.284]	-0.136 [0.189]
$S_{it} * R_{it}$	0.469** [0.238]	0.193 [0.304]	0.508* [0.313]
S_{it+1}	-0.239 [0.176]	0.009 [0.209]	-0.191 [0.220]
$S_{it+1} * R_{it+1}$	0.441* [0.234]	0.313 [0.325]	0.304 [0.302]
S_{it+2}	-0.124 [0.193]	-0.053 [0.435]	0.033 [0.221]
$S_{it+2} * R_{it+2}$	-0.079 [0.232]	0.021 [0.444]	-0.234 [0.301]
Observations	2837	615	2222
R-squared	0.47	0.62	0.47

All regressions linearly include per capita income, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year and country fixed effects—see Table 2. S_{it} is an indicator variable, taking on the value of one if a windstorm occurs in country *i* in year *t* and 0 otherwise. R_{it} takes on the value 1 if the exchange rate regime is fixed, and 0 if flexible—see Table 2. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only advanced and developing countries respectively—see Table 1.

which they strike a particular country can be very different from windstorms. Islands for example are about five times more likely to experience windstorms than earthquakes. Thus, these features make earthquakes very useful indicators of how well our results might generalize to different shocks, and across different regions.

Table 7 revisits the base specification using earthquakes as the source of shocks. The investment response to earthquakes is qualitatively similar to windstorm shocks, but with smaller point estimates than in Table 3a. The investment response in developing countries with fixed rate regimes continues to be significantly larger in fixed than in flexible regimes—about 1.20 percentage points of GDP. But there is now evidence that developing countries with flexible rate regimes incur a mean decline in investment of about 0.97 percentage points of GDP the year after an earthquake shock. In advanced economies there remains no discernible impact on investment.

In the case of growth (Column 2), the point estimates indicate a similar adjustment pattern as windstorms in developing countries but they are not significant. Among advanced economies there is some evidence that, as in the case with windstorms, the growth response is lower in fixed rate regimes—about 0.88 percentage points (p-value=0.02) in this case. In sum, our results using earthquakes are qualitatively similar to those obtained using windstorms. The higher standard errors in the growth response among developing countries suggest that the relative infrequency of earthquakes combined with the higher volatility of output growth in these countries make it difficult to detect statistically significant effects.

D. Different Time Periods

While the criteria for entry into the database has remained constant, the incidence of windstorms in the database from 1980 through 2001 is almost double the number from 1960-79. Several factors might explain this difference, including environmental changes; the increased willingness of some countries to report disasters, as well as better information and monitoring systems. Table 8 estimates the base specification from 1960-80, and 1980-2001 separately for both investment and growth to gauge the impact of the database's increased reporting of shocks.

Not surprisingly, the estimates from the first half of the sample are small and in many cases not significant, while the results from 1980 onwards are qualitatively similar to our earlier findings. For example, windstorms have no significant impact on investment levels in either developed or less developed countries in the pre-1980 subsample. But over the period 1980 through 2001 the cumulative impact in developing countries with fixed rate regimes is 5.42 percentage points of GDP, while there remains no significant impact in developed countries, or in DCs with flexible regimes. Likewise, among developing countries, the estimated relationships in the pre 1980 data are not significant.

Table 7. Earthquakes

	Dependant Variable: GDP Growth (2)		Dependant Variable The Ratio of Gross Capital Formation (Net of Inventories) to GDP (3)	
	AC	DC	AC	DC
S_t	0.192 (0.290)	0.122 (0.504)	0.005 (0.004)	-0.007 (0.006)
$S_t * R_t$	-0.881** (0.361)	0.002 (0.646)	-0.008 (0.005)	0.005 (0.007)
S_{t+1}	0.082 (0.242)	0.810 (0.547)	-0.004 (0.003)	-0.010** (0.005)
$S_{t+1} * R_{t+1}$	-0.212 (0.250)	-0.416 (0.674)	0.008 (0.005)	0.012** (0.005)
S_{t+2}	-0.536 (0.360)	0.045 (0.373)	0.003 (0.003)	-0.004 (0.006)
$S_{t+2} * R_{t+2}$	0.285 (0.312)	0.176 (0.536)	-0.006 (0.006)	0.002 (0.008)
NOBs	640	1314	748	2095
R-squared	0.44	0.27	0.70	0.60

Note: All regressions linearly include, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year effects. Column 3 also includes per capita income and fixed effects. Column 2 includes initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; investment; Latin America and Africa indicator variables—See Table 2. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. “AC” and “DC” include only developed and developing countries.

Table 8. Different Time Periods

	Dependant Variable: GDP Growth 1960-80		Dependant Variable: GDP Growth 1981-2001		Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP 1960-1980 Investment		Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP 1981-2001 Investment	
	AC	DC	AC	DC	AC	DC	AC	DC
S_t	0.525 (0.812)	0.665 (1.408)	-0.304 (0.207)	1.248** (0.573)	-0.002 (0.005)	0.004 (0.017)	-0.006 (0.005)	-0.008 (0.007)
$S_t * R_t$	0.178 (0.782)	-1.387 (1.455)	0.168 (0.396)	-1.363** (0.611)	-0.001 (0.005)	0.015 (0.021)	0.005 (0.005)	0.022** (0.009)
S_{t+1}	2.429*** (0.400)	-0.115 (0.915)	0.325 (0.232)	0.685 (0.550)	-0.005 (0.006)	0.026 (0.029)	-0.005 (0.004)	-0.002 (0.009)
$S_{t+1} * R_{t+1}$	-1.616*** (0.455)	-0.904 (1.133)	-0.331 (0.298)	-0.183 (0.641)	0.003 (0.005)	-0.008 (0.023)	0.005 (0.004)	0.018** (0.009)
S_{t+2}	-0.751 (0.633)	-0.790 (1.272)	0.938*** (0.224)	-0.811 (0.636)	0.000 (0.005)	0.010 (0.018)	-0.006 (0.005)	-0.002 (0.009)
$S_{t+2} * R_{t+2}$	0.664 (0.711)	0.961 (1.678)	-0.745*** (0.283)	1.814*** (0.664)	-0.002 (0.006)	-0.018 (0.020)	0.005 (0.006)	0.014 (0.009)
NOBs	243	409	397	905	294	664	454	1431
R-squared	0.49	0.10	0.39	0.31	0.88	0.71	0.71	0.74

Note: All regressions linearly include, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year effects. Columns labeled "Gross Capital Formation" also include per capita income and fixed effects. Columns labeled "GDP Growth" also include initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; investment; Latin America and Africa indicator variables—See Table 2. Huber-White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only developed and developing countries respectively—See Table 1.

E. Exchange Rate Classification

Instead of dichotomizing the exchange rate regime into "fixed" or "flexible," Table 9 reconsiders the base specification using a finer classification scheme. The classification ranges from 1—no independent legal tender through 6—dual market with missing parallel market data; freely floating regimes are ranked 4; we however continue to exclude those classified as "freely falling"—ranked 5. From column 4, the investment response in advanced economies remains uncorrelated with the choice of exchange rate regime. And consistent with our earlier results, the cumulative increase in investment for an economy classified as having no legal tender, pre-announced peg, or currency board arrangement is about 4 percentage of GDP, while the mean response in a freely floating regime is a percentage point of GDP decline in investment.

In the case of growth (column 4), the results remain broadly similar among developing countries, as growth is significantly larger in economies with fixed rate regimes two years after the shock. And as with the simple binary approach to exchange rate classification, using the "finer" measure indicates that growth rebounds faster in developed economies with flexible regimes. As an alternative to the Reinhart and Rogoff classification method, we use the Levy-Yeyati and Sturzenengger [2003] statistical approach to classifying regimes in our base specifications. Ignoring the inconclusive cases, this variable takes on four discrete values, ranging from 2-a floating regime—to 5-a fixed rate regime. As Table 9 indicates, this variable performs relatively poorly in the investment specification, but produces results broadly similar to the Reinhart and Rogoff system in the growth equation: growth is higher in developing economies with fixed rate regimes.

F. Mechanisms

There is robust evidence that the choice of exchange rate regime shapes the adjustment to real shocks. This subsection attempts to better identify these channels. First, to isolate the role of exchange rate uncertainty in the investment response, we use the standard deviation derived from monthly movements in the parallel exchange rate in the year before the shock. In many instances the parallel exchange rate provides a more accurate indication of the price of foreign currency faced by the private sector. As well as the standard deviation of the parallel rate in the year before the shock proxies for the uncertainty surrounding exchange rate movements. Moreover, because this proxy is derived from monthly movements the year prior to the shock, it does not reflect the effect of the current shock on the nominal exchange rate, and is thus, less affected by selection bias. From Table 10, a one standard deviation increase in the parallel rate in the year before the shock is associated with a 2.25 percentage point decline in investment one year after the shock in developing countries. That is, consistent with the uncertainty channel, greater variability in the exchange rate significantly hinders the investment response only in developing countries.

Table 9. Exchange Rate Classification

	"Fine" Classification Dependant Variable: Economic Growth		"Fine" Classification Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP		LY-S Classification Dependant Variable: Economic Growth		LY-S Classification Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP	
	AC	DC	AC	DC	AC	DC	AC	DC
S_{it}	0.347 (0.245)	-0.204 (0.842)	-0.005 (0.006)	0.025*** (0.010)	-0.887* (0.506)	-0.954 (1.316)	0.0010 (0.0051)	0.0135 (0.0136)
$S_{it}*R_{it}$	-0.183* (0.101)	0.267 (0.350)	0.002 (0.002)	-0.007* (0.004)	0.225* (0.126)	0.434 (0.317)	-0.0008 (0.0014)	0.00005 (0.0036)
S_{it+1}	-0.003 (0.415)	0.198 (0.597)	-0.003 (0.007)	0.030*** (0.010)	0.434 (0.800)	-1.212 (1.079)	-0.0002 (0.0052)	0.0036 (0.0147)
$S_{it+1}*R_{it+1}$	0.158 (0.173)	0.096 (0.247)	0.001 (0.002)	-0.006* (0.003)	-0.052 (0.195)	0.501* (0.260)	-0.0004 (0.0014)	0.0033 (0.0036)
S_{it+2}	-0.201 (0.362)	1.974** (0.827)	-0.004 (0.007)	0.015 (0.010)	0.725 (0.716)	0.512 (1.053)	-0.0001 (0.0066)	-0.0049 (0.0126)
$S_{it+2}*R_{it+2}$	0.235 (0.151)	-0.777*** (0.323)	0.002 (0.002)	-0.003 (0.003)	-0.126 (0.172)	-0.171 (0.298)	-0.0001 (0.0020)	0.0037 (0.0031)
NOBs	640	1314	748	2095	419	1154	475	1794
R-squared	0.45	0.27	0.71	0.61	0.41	0.24	0.66	0.68

Note: All regressions linearly include, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year effects. Columns labeled "Investment" also include per capita income and fixed effects. Columns labeled "Growth" also include initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; investment; Latin America and Africa indicator variables—. "Fine" Classification is the Reinhart & Rogoff (2003) 6 way code, including 1 (no legal tender) and 4 (freely floating). LY-S is the Levy-Yeyati and Sturzenegger (2004) classification scheme from 2 (float) through 4 (fixed)—See Table 2. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only developed and developing countries respectively—See Table 1.

Table 10. The Standard Deviation of the Parallel Exchange Rate (PSD), Windstorms, and Investment
Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP

	AC (2)	DC (3)
S_{it}	-0.002 [0.003]	0.015** [0.007]
S_{it+1}	-0.001 [0.004]	0.021* [0.011]
S_{it+2}	-0.001 [0.004]	0.008 [0.008]
$S_{it}*PSD_{it-1}*10^{-04}$	-0.723 [0.680]	-0.172 [0.403]
$S_{it+1}*PSD_{it-1}*10^{-04}$	-0.672 [0.484]	-0.273** [0.142]
$S_{it+2}*PSD_{it-1}*10^{-04}$	-0.101 [0.842]	-0.050 [0.086]
Observations	645	1327
R-squared	0.72	0.59

Note: All regressions linearly include per capita income, the exchange rate regime, population density, the percent of urban population, trade openness, as well as year and country fixed effects—see Table 2. S_{it} is an indicator variable, taking on the value of one if a windstorm occurs in country *i* in year *t*. PSD_{it-1} is the standard deviation of the parallel exchange rate, computed from monthly movements in the parallel rate the year before the shock. Huber -White robust standard errors in parenthesis. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. "AC" and "DC" include only advanced and developing countries respectively—see Table 1.

Second, Table 11 examines whether the differences in the timing of the output response between fixed and floating regimes stem from currency depreciation and its impact on the export sector—a classic channel emphasized in the literature. To this end, we control for trade openness using the ratio of exports to GDP instead of exports plus imports to GDP. Using exports, Column 2 indicates that our earlier across regimes remain robust. Column 3 then allows the impact of the shock to vary by the ratio of exports to GDP. The results are now significantly different from Column 2, suggesting that the behavior of exports can account for a large part of the difference between the two regimes.

Specifically, in the year of the shock, the impact of windstorms on output in flexible regimes depends on the export sector. That is, although the two interaction terms $S_{it} * R_{it}$ and $S_{it} * Exports_{it}$ are both individually insignificant, they are jointly significant at the five percent level (p-value=0.04), implying that the increased output response observed in flexible regimes in the year of the shock may reflect an increase in exports in those economies. As with our earlier results, there is no significant output response in the later years for flexible regimes: S_{it+1}, S_{it+2} and the interaction terms with exports are both individually and jointly insignificant. Meanwhile, the adjustment to shocks in fixed rate regimes remains characterized by an immediate decline in output followed by a rebound two years later.

In search of further evidence, Column 4 of Table 11 estimates the export response to shocks. Compared to flexible rate regimes, windstorms are associated with a cumulative 9.45 percentage points of GDP (p-value=0.02) decline in exports over two years in fixed rate regimes. This is direct evidence of the export channel. We next examine the impact of these shocks on the exchange rate. From Column 5, in developing countries with flexible exchange rate regimes, the year after a windstorm is associated with a 3.52 percentage point (p-value=0.05) depreciation in the real effective exchange rate. In regimes classified as fixed, the depreciation is 44 percent smaller (p-value=0.03). For a larger sample of developing countries, column 6 observes a similar response in the parallel nominal exchange rate. While the parallel rate depreciates about 3.17 percentage points in flexible rate regimes one year after shock, fixed rate regimes experience only a 0.73 percentage point (p-value=0.09) depreciation. From column 7, there is no significant impact on inflation.[13] This is direct evidence of the exchange rate channel. Taken together, this evidence identifies a key channel through which the exchange rate regime can help an economy manage real shocks: movements in the nominal exchange rate and its impact on exports can offset the effects of adverse real shocks. Moreover, this mechanism appears to explain a significant fraction of the difference in the adjustment dynamics between fixed and floating regimes to real shocks.

[13] Holding the sample size constant across all the specifications yields nearly identical results, and are available upon request.

Table 11. Growth, Exports, Depreciation, Inflation and Windstorms

	Dependant Variable: GDP Growth (2)	Dependant Variable: GDP Growth (3)	Dependant Variable: The Ratio of Exports to GDP (4)	Dependant Variable: The Annual Growth in the Real Effective Exchange Rate (5)	Dependant Variable: The Annual Growth in the Parallel Exchange Rate (6)	Dependant Variable: CPI Inflation (7)
S_{it}	1.324**	0.509	0.408	0.211	-2.058	-4.101
	[0.604]	[0.940]	[1.350]	[2.202]	[1.890]	[3.914]
$S_{it*}R_{it}$	-1.509**	-1.472**	-5.588***	-1.315	0.365	-1.279
	[0.612]	[0.647]	[1.924]	[2.42]	[2.263]	[3.615]
S_{it-1}	0.663	0.232	-1.544	-3.515**	3.167**	-0.317
	[0.428]	[0.692]	[1.344]	[1.728]	[1.462]	[3.042]
$S_{it+1*}R_{it+1}$	-0.397	-0.376	-3.873*	1.550	-2.438	-1.951
	[0.545]	[0.520]	[2.068]	[2.146]	[2.087]	[5.181]
S_{it-2}	-0.754	0.662	1.464	-1.830	-0.599	2.395
	[0.516]	[0.874]	[1.695]	[2.208]	[2.300]	[2.407]
$S_{it+2*}R_{it+2}$	1.686***	1.633***	-4.921	2.645	-0.710	-6.372
	[0.542]	[0.566]	[3.610]	[2.720]	[2.909]	[5.008]
$S_{it*}Exports_{it}$	—	0.030	—	—	—	—
		[0.025]				
$S_{it+1*}Exports_{it+1}$	—	0.017	—	—	—	—
		[0.024]				
$S_{it+2*}Exports_{it+2}$	—	-0.055	—	—	—	—
		[0.040]				
Observations	1314	1314	1048	563	1048	1439
R-squared	0.27	0.27	0.53	0.15	0.16	0.04

Note: All columns linearly include the exchange rate regime; population density; the percent of urban population; exports; initial per capita income (1961); one year lagged government consumption growth; terms of trade growth; democracy index; physical size; investment; Latin America and Africa indicator variables, as well as year effects. Columns 2 and 3 also include initial per capita income (1961). Columns 4, 5, 6 and 7 include per capita income—see Table 2. Huber -White robust standard errors in brackets. Regression residual terms are clustered at the country level. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively. Sample includes only developing countries—see Table 2.

G. Long-Run Effects

When examined over a three year horizon, there are robust differences in the investment and output response to real shocks. Table 12 considers whether these shocks influence economic activity over the long run. Specifically, does the mean incidence of windstorms affect the average investment level and growth rate over the period 1960 through 2001? Furthermore, does the fraction of time that the exchange rate regime was classified as fixed over the sample period affect this relationship?

Table 12. Long Run: Windstorms, Investment and Growth

	Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP	Dependant Variable: The Ratio of Gross Capital Formation (Net of Inventories) to GDP		Dependant Variable: Economic Growth	Dependant Variable: Economic Growth	
	(2)	(3)	(4)	(5)	(6)	(7)
	Overall Sample	Mostly Fixed	Mostly Flexible	Overall Sample	Mostly Fixed	Mostly Flexible
S_t	-0.047 (0.044)	0.325*** (0.123)	-0.067 (0.057)	0.715 (1.325)	5.574*** (2.016)	0.149 (1.387)
Med* S_t	0.261*** (0.098)	—	—	3.643* (1.927)	—	—
NOBs	60	30	30	60	30	30
R-squared	0.47	0.74	0.65	0.44	0.51	0.48

Note: The sample includes only developing countries. All regressions include physical size, trade openness, urban population, population density and Latin America and Africa indicator variables. Columns 2, 3 and 4 include per capita income. Columns 5, 6, and 7 include initial per capita income (1961)—see Table 2. Columns 2 and 5 also linearly include "Med". The variable "Med" is an indicator variable taking on the value of one if a country is mostly fixed and 0 if mostly flexible see Table 2. Huber -White robust standard errors in parenthesis. *, **, *** indicates significance at the 10, 5 and 1 percent levels respectively.

To study the long-run impact of natural disasters in developing countries and the role of the exchange rate, Table 12 uses average values over the period 1961-2001 from our base specification. We also include an indicator variable that takes on the value of one for those economies classified as fixed in more than 64 percent of the years—the median level in the sample—and zero for those below the 64 percent threshold. We interact this variable with the mean frequency of windstorms to determine whether the impact of these shocks depend on the choice of regime. While this approach offers insights into the long run role of the exchange rate regime, averaging over the sample period raises the possibility of selection bias. The mean frequency of shocks may affect the frequency with which a country chooses

a particular regime. That said, given that our earlier panel results using "constant" regimes, as well as the mean frequency were not substantially different from the overall sample, we suspect that selection bias may be limited.

From Table 12, there is robust evidence (p-value=0.01) that windstorms positively affect the average investment level in economies with predominantly fixed exchange rate regimes. In those economies a one standard deviation increase in the average number of windstorms is associated with a 2 percentage point increase in the average investment level over the period. In contrast, the mean frequency of windstorms has no significant impact on investment in economies that maintained a flexible regime for more than 36 percent of the years. A similar pattern emerges when examining the impact of windstorms on long-run growth. A one standard deviation increase in the average number of windstorms is associated with a 0.78 percentage point increase in average growth (p-value=0.06) only in those economies that predominantly maintained a fixed rate regime. Note that similar results are obtained when the samples are estimated separately for those economies above and below the median threshold (columns 3 and 4).

V. DISCUSSION

This paper has exploited the inherent randomness of natural disasters to establish some stylized facts about country's choice of exchange rate regime, and its economic adjustment to real shocks. Among developing countries the evidence is quite robust that the choice of regime plays an economically large and significant role in the adjustment process. While it is possible that regime choice may reflect deeper institutional factors, these results cast doubt on those arguments that suggests that the choice of regime may be of second order importance for macroeconomic stability (Calvo and Mishkin, 2003).

Instead, there is ample support for the literature that emphasizes the relative speed of adjustment under flexible regimes. In nearly all cases, economic growth rebounds significantly faster in flexible regimes, due in part to currency depreciation and higher exports. The growth response in fixed rate regimes is negative in the first year of the shock, becoming significantly positive only in the second year after the shock. That said, the cumulative difference in the growth response over the three year horizon across regimes is very small. But there is also ample support for those theories that stress the costs of exchange rate variability on investment. Instead of the exports channel, adjustment in fixed rate regimes is characterized by higher investment in the first two years after shock.

Moreover, these differences in the short-run adjustment mechanism also have long run consequences. Over a 30-year period, a higher average incidence of natural shocks is associated with both higher investment and growth only in economies that predominantly maintained fixed regimes. That is, while currency movements can help the economy more quickly adjust to adverse shocks, it can also impede the investment response to these shocks. And over the long run, economies that invest in response to these shocks, also appear to experience faster economic growth from natural shocks. In sum, there is merit to claims

of faster adjustment to adverse real shocks under flexible rate arrangements. But there is also merit to the idea that exchange rate variability can affect investment. And the benefits from faster adjustment under flexible regimes might come at the cost of forgoing the long-run productivity benefits that arise from the investment response in fixed rate regimes.

We should, however, emphasize several caveats. Natural shocks are, over the short run at least, exogenous to human activity. And, as in the literature on local average treatment effects (Blundell and Dias, 2002, provides a recent survey), randomness greatly helps inference but it raises questions about generalizability. Are "traditional" economic shocks such as terms of trade and productivity shocks sufficiently similar to natural shocks to render our results useful in those cases as well? This remains an open question. However, recent empirical research using the terms of trade as a source of shocks (Broda, 2001; Edwards and Levy-Yeyati, 2004) also document a faster output response in flexible rate regimes, suggesting that our results may generalize.

Moreover, to reduce selection bias, the analysis has used both "constant regimes" and controlled for the frequency with which windstorms occur. Nevertheless, because we lack data on the intensity of the storms—wind speed, etc.—we cannot exclude the possibility that, however, severe storms may affect the choice of regime. Anecdotal evidence suggests that the frequency and intensity of storms are correlated. Economies in hurricane belts, such as some nations in the Caribbean, not only experience more frequent storms, but are also likely to experience more intense storms, making it unlikely that, conditioned on frequency, omitting intensity measures are likely to lead to large biases

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