Draft Chapter for:
***Managing Volatility and Crises:***
***A Practitioner's Guide***
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# Volatility: Definitions And Consequences*

by

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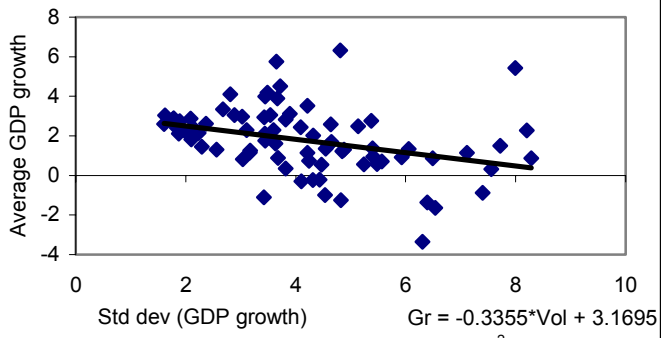
## SETTING THE STAGE

Some decades ago, output volatility was perceived mainly as a fleeting business cycle phenomenon of secondary concern for longer-term development objectives. Theoretical advances have since melded short-term and long-term fluctuations into a single framework, while a growing body of research suggests that higher volatility is causally associated with lower growth. Volatility has hence assumed a more central role in the development debate. This chapter introduces some of the themes taken up in more depth in later chapters.

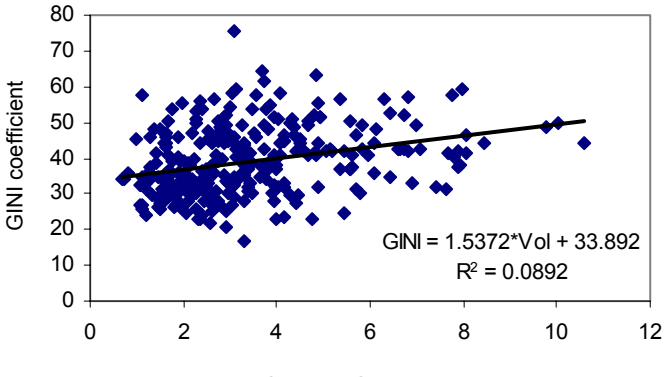
As a background to the discussion, figures 1.1 through 1.7 illustrate some core linkages for a broad sample of countries.[1] Figure 1.1 plots the volatility of GDP per capita growth (measured as the standard deviation of the growth rate) against the mean growth rate of GDP per capita, revealing the broad negative association that has motivated the increased attention to volatility.[2] Figures 1.2 and 1.3 illustrate the link between output volatility and income inequality: higher growth volatility goes hand in hand with a higher Gini coefficient and a lower income share of the lowest quintile of the population.

Fig. 1.1. *GDP Growth vs Volatility, 1960-2000*




*Source*: Author's calculations.

Fig. 1.2. *GINI and Volatility, 1957-99*




*Source* : Author's calculations.

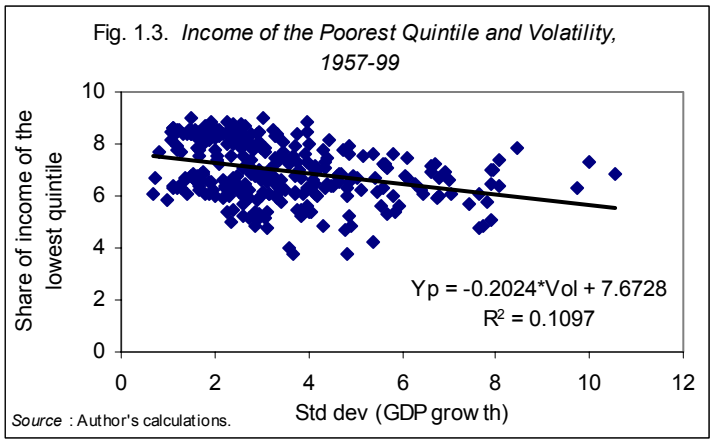



Figure 1.4 differentiates the link between growth volatility and growth by income group. While, as figure 1.1 revealed, the correlation is negative for the full sample, splitting the sample by income groups reveals three distinct relationships. For the group of low-income countries, growth volatility and average growth are negatively associated. For the middle-income group, volatility and average growth are almost uncorrelated, while for the high-income group, there is a positive association.

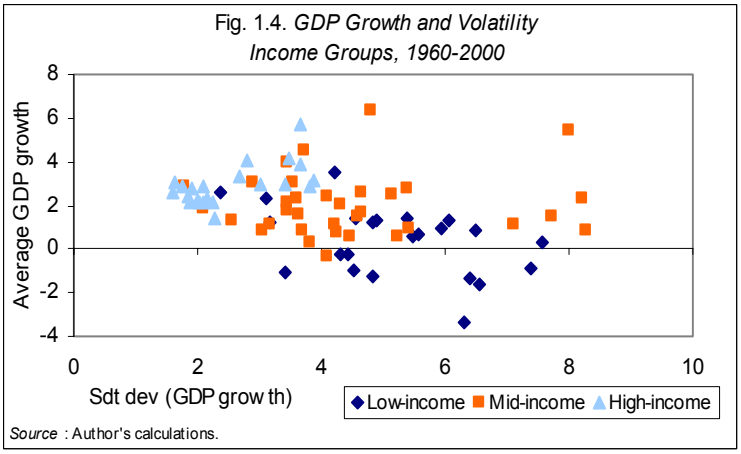
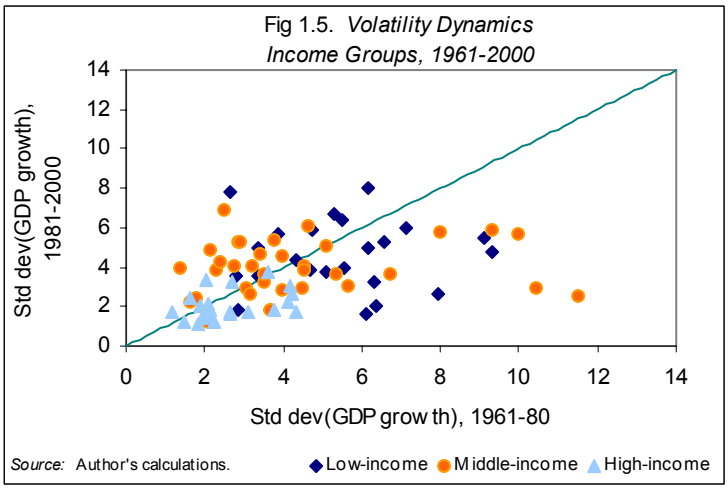
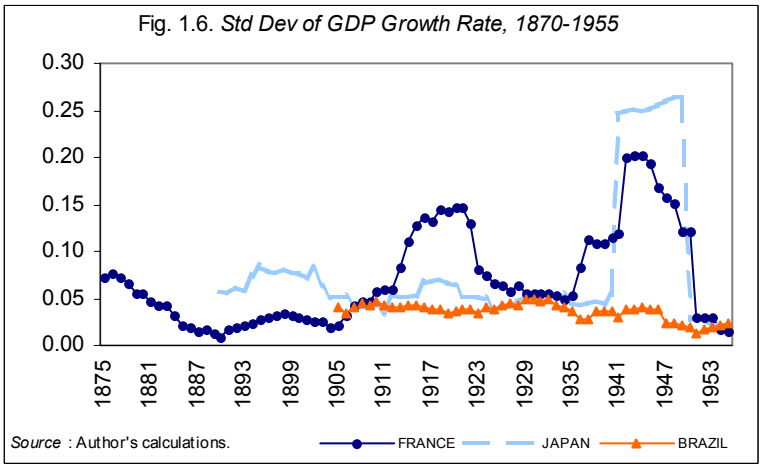
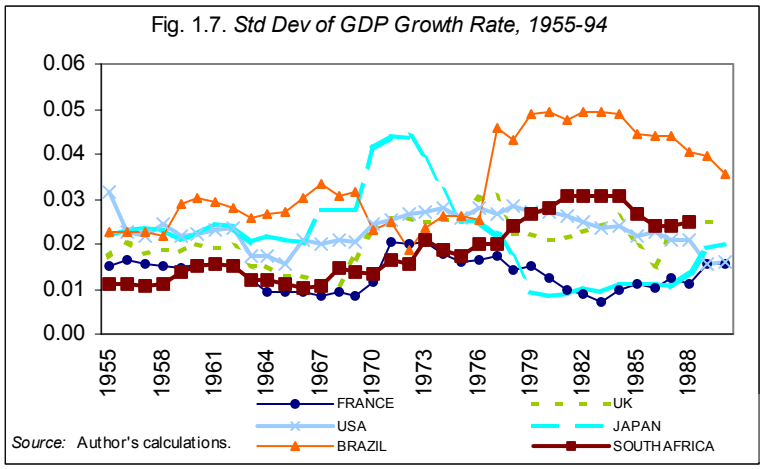



Figure 1.5 illustrates the change of growth volatility over time, plotting the volatility measure for 1961--1980 against the volatility measure for 1981--2000. While no overall pattern emerges, splitting the sample by income group reveals that---with a few exceptions---volatility has declined for high-income countries from the first to the second period. The experience of middle-income and low-income countries is more varied, though a higher fraction of middle-income countries experienced rising volatility.




Figures 1.6 and 1.7 turn to the longer-term evolution of volatility, plotting GDP growth volatility (measured as the nine-year standard deviation) for Brazil, France, and Japan[3] from 1870 to 1994, and for South Africa, the United Kingdom, and the United States for 1955 through 1994. The figures illustrate the prevalence of volatility throughout history and the importance of particular events---notably the two world wars. The postwar evolution shows a trend increase in the volatility of the two middle-income countries and a (muted) decline for the mature economies, consistent with the broader pattern of figure 1.5.[4] The time path suggests a volatility "life-cycle," driven both by changes in the nature and magnitude of the shocks impinging on the economy and by the availability and usage of coping mechanisms.






In conjunction, figures 1.1 through 1.7 establish that cross-sectional differences in volatility are related to cross-sectional differences in growth and income distribution. They also suggest that these links are not necessarily constant across country subgroups or time. It is hence instructive to complement cross-country research with studies of individual economies or a group of related economies. Two recent World Bank studies are particularly insightful in this regard. Phillipe Auffret (2003) explores the role of natural disasters for a group of Caribbean countries; while Douglas Addison and his colleagues (2003) provide an in depth exploration of the causes and consequences of volatility for Nigeria.

If, as the evidence suggests, the linkages are causal and volatility affects consumption, differences in volatility affect well-being. To the extent that differences in volatility can in turn be related to factors under the influence of policy, dealing with volatility becomes part of the broader development challenge. Chapter 2 and 3 take up the growth and poverty linkages in detail. This introductory chapter aims to set the stage by discussing conceptual and measurement issues, reviewing the literature on the sources and effects of volatility, and outlining some of the options available to individuals and governments to reduce and manage excess volatility.

## CONCEPTUAL ISSUES

What is meant by "volatile"? A look at dictionary definitions yields a range of connotations: "tending to vary often or widely," "unstable," "changing suddenly," "characterized by or prone to sudden change," "unpredictable," and "fickle." Beyond the varying definitions of volatility itself, further ambiguities arise from the terms often used in conjunction with volatility, sometimes employed as synonyms, sometimes viewed as implications, such as "crisis," "risk," "fragility," and "vulnerability."

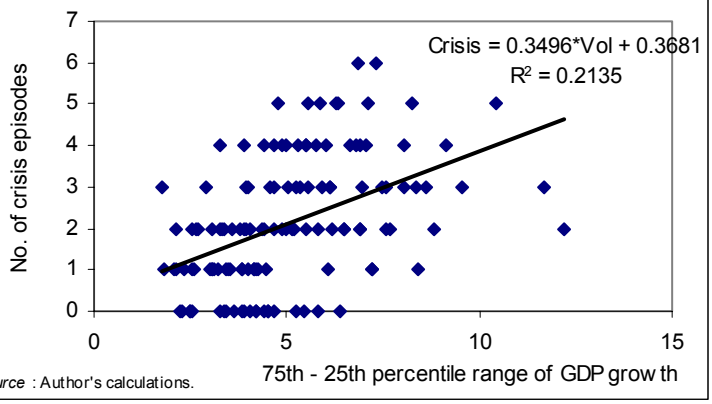
Two key connotations of volatility are *variability* and *uncertainty*. Variability refers to all movement, while uncertainty refers to unknown movement. Conceptually, volatility at a given time can be decomposed into a predictable component and an unpredictable component. The appropriate relative weight of these two features depends on the issue examined. Households and policymakers are however typically better able to cope with predictable variation. The primary concern thus tends to rest with unpredictable movement.

A second distinction is sometimes made between "normal" volatility and "extreme" volatility, or "crisis." From a conceptual point of view, this separation is problematic. Are extreme events simply observations drawn from the tails of the distribution, or do they come from a different source? An answer to this question requires a definition of what constitutes "normal" volatility and is thus intrinsically subjective. Among the options for defining "extreme" volatility is the imposition of an absolute threshold (for example, commodity price changes of more than 10 percent), the imposition of a distributional threshold (the 5 percent

largest declines), or the use of a deviation criterion (observations that are at least 2 standard deviations above the mean).

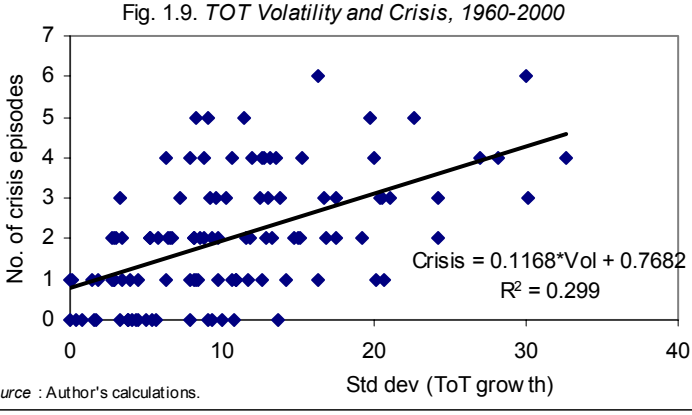
Figures 1.8 and 1.9 explore the association between "normal" volatility and "crisis" for the growth rates of GDP. "Normal" volatility is defined here as the difference between the 25th and the 75th percentile of the growth rate distribution. Crises are defined as two sequential years of negative output growth. The figures plot growth crises against the normal volatility of the growth rate of GDP (figure 1.8) and of the terms of trade (figure 1.9). While the figures indeed reveal a positive association in both cases, the results are conditional on the specific definitions of "normal" volatility and "crisis."

Fig. 1.8. *GDP Volatility and Crisis, 1960-2000*




*Source* : Author's calculations.

Fig. 1.9. *TOT Volatility and Crisis, 1960-2000*

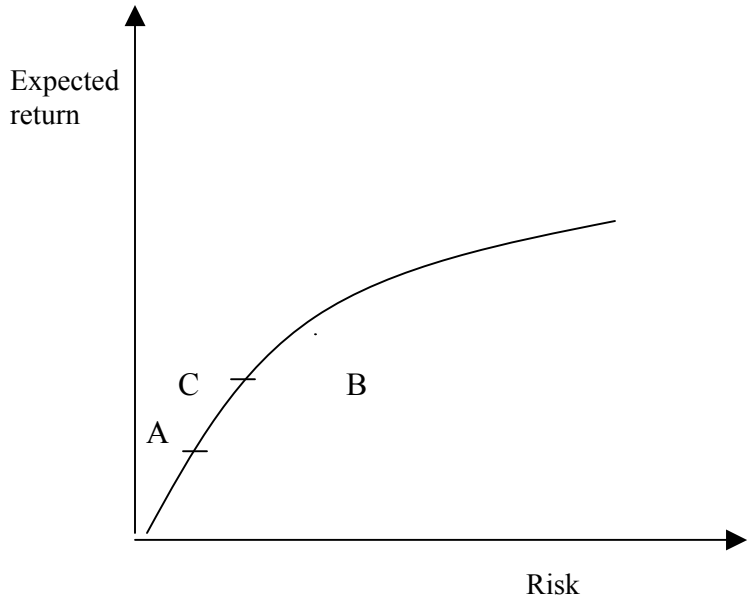



*Source* : Author's calculations.

As a practical matter, looking separately at extreme events is sensible since coping mechanisms may fail once shocks exceed some critical threshold size. The likelihood of shocks exceeding these thresholds, and their economic effects, are thus of interest regardless of the researcher's conceptualization of "normal volatility" versus "crisis."

A third distinction arises between "equilibrium volatility" and "excess volatility." Reducing consumption volatility increases welfare only if the volatility reflects some type of market imperfection. A simple example is given by the tradeoff between expected return and risk in standard portfolio choice, as illustrated in figure 1.10. Investors choose the combination of expected return and risk maximizing their expected utility, depending on their risk aversion. While reducing risk for a given expected return is welfare-enhancing (for example, moving from B to C), that option is not available once optimal choices have been made, a further reduction in volatility to A also implies a lower expected return and would reduce welfare. [5]

**Figure 1.10 Excess versus Optimal Volatility**




By extension, the policy challenge is not the reduction of volatility to zero, but rather the elimination of excess volatility. Empirical research suggests that this caveat may be important. While across sectors *within* countries, there is evidence for a *positive* volatility-growth association (Imbs 2002), *across* countries, the evidence suggests a negative link, particularly for low- and middle-income countries. This suggests the potential presence of a national volatility factor coming atop sectoral factors. The explanation for such national factors, ranging from structural characteristics (notably financial market development and international integration) to active policy measures and the role of the political system in aggravating or offsetting shocks, is at the core of the literature reviewed below, following a discussion of measurement issues.

## MEASUREMENT: CONCEPTUAL AND EMPIRICAL ISSUES

How should a practitioner assess "the volatility" of a particular variable? There is no single best measure. In most cases, a multi-pronged approach---built around the standard deviation as a core measure, but augmented by robustness checks---is likely to yield the best results. This section discusses some of the pertinent considerations, only some of which will likely be operational choices for any particular research question.

### Operational Choices

***Choice 1: Sample length***. The appropriate sample length reflects a cost-benefit tradeoff: a longer sample length increases measurement accuracy, but only if the underlying volatility has been stable over the sample period.[6,7] The problem is particularly acute for aggregate variables, as their volatility can change over time both because of a changing volatility of exogenous and endogenous shocks (such as terms of trade shocks) and because of changing transmission channels (such as the mechanisms determining the impact of terms of trade shocks on output). Alas, there are few objective gauges, as the sample length typically available for macro applications prevents the use of statistical tests for differences in volatility.

***Choice 2: Measurement frequency.*** At what frequency should volatility be calculated? The answer again depends on the question examined. To assess the impact of the arrival of news on asset price volatility,

the appropriate time frame is seconds; for the effect of monetary policy on consumption volatility, a monthly time frame is appropriate; while for an assessment of macroeconomic policy instability on long-term growth, multi-year averages would be reasonable. The choice is not innocuous, as the statistical measure of volatility may differ dramatically depending on the time frame observed.[8]

***Choice 3: Symmetry or weighting?*** The most popular measure of volatility, the standard deviation, treats negative and positive deviations from the mean symmetrically. From a theoretical viewpoint, however, there are good reasons to suspect asymmetric effects for many variables. In particular, a large negative and a large positive shock may have different effects, as evidenced in the asymmetric concern about "crisis" and "booms."[9] If such asymmetries are expected, it might be prudent to attach a lower weight to positive shocks in the computation of the volatility measure.

***Choice 4: Realized versus expected volatility.*** Volatility is commonly measured by computing the standard deviation over some time period. It is important to keep in mind that such an ex post measure does not capture the expected volatility at the beginning of the sample period. If the latter measure is more pertinent to the question examined (such as assessing the effect of expected volatility on investment), construction of a predicted volatility series may be possible for some higher frequency series.

***Choice 5: Allowing for thresholds.*** The potential presence of thresholds at which relationships between input shocks and output changes, or at which coping mechanisms (such as buffer stocks) are overwhelmed, creates another challenge. In such an environment, a complete assessment of volatility must include the likelihood that shocks will exceed the threshold levels at which the economy's coping mechanisms are overwhelmed. Extreme value and at-risk measures explore this dimension of volatility.

***Choice 6: Allowing for persistence and bunching.*** If the coping ability of the economy is limited (for example, reflecting a given buffer stock), then the persistence of shocks---that is, the likelihood that a negative shock today is followed by another negative shock tomorrow, building up into a large cumulative shock---is of separate interest.

***Choice 7: The level of aggregation.*** The income of an individual household is influenced by both idiosyncratic and shared developments. Aggregation eliminates some of the idiosyncratic, regional, and sectoral shocks. In consequence, household income volatility will generally be greater---and possibly much greater---than aggregate GDP volatility, a prediction supported by the strong evidence on the negative link between country size and aggregate volatility (Head 1995). If households lack access to effective risk diversification and management tools, the typical measure of national income volatility---aggregate GDP volatility---may provide a rather benign picture of the volatility faced by the typical household in developing countries.[10]

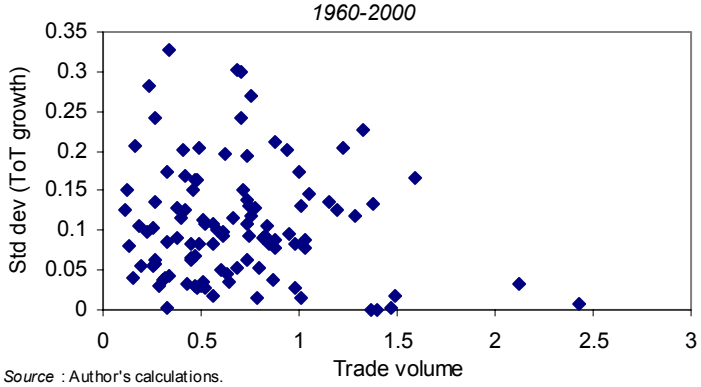
Where does that leave the practitioner? None of the existing measures of volatility captures all relevant aspects of volatility. Prudence suggests a multi-measure approach build around the standard deviation as core measure, but adding robustness checks appropriate to the issue examined.

**Impact Measures: Assessing the Macro Impact of Micro Volatility**

Suppose that the problems raised above have been resolved and that, for a particular micro shock---say, the terms of trade or world interest rates---an appropriate volatility measure has been constructed. To assess whether this particular micro shock "matters" on the aggregate level, the volatility of the shock must be related to a measure of its importance. For the terms of trade, an obvious metric is given by the openness of the economy. The greater the openness of the economy, the greater is the likely impact of a *given* volatility of terms of trade shocks on the economy. For global interest rate shocks, an appealing metric would be net external floating rate indebtedness.

As an illustration, figure 1.11 presents evidence on the first of these links, plotting the volatility of the terms of trade against openness (measured as the ratio of the sum of exports and imports to GDP). In this case, no clear pattern arises. In consequence, the ranking of countries in terms of terms of trade (ToT) volatility would not map closely into the mapping of the importance of ToT volatility in determining aggregate output volatility. This exercise illustrates the importance of separately assessing the size of the shock and the size of the transmission channel.

Fig. 1. 11. *Trade Openness and ToT Volatility, 1960-2000*

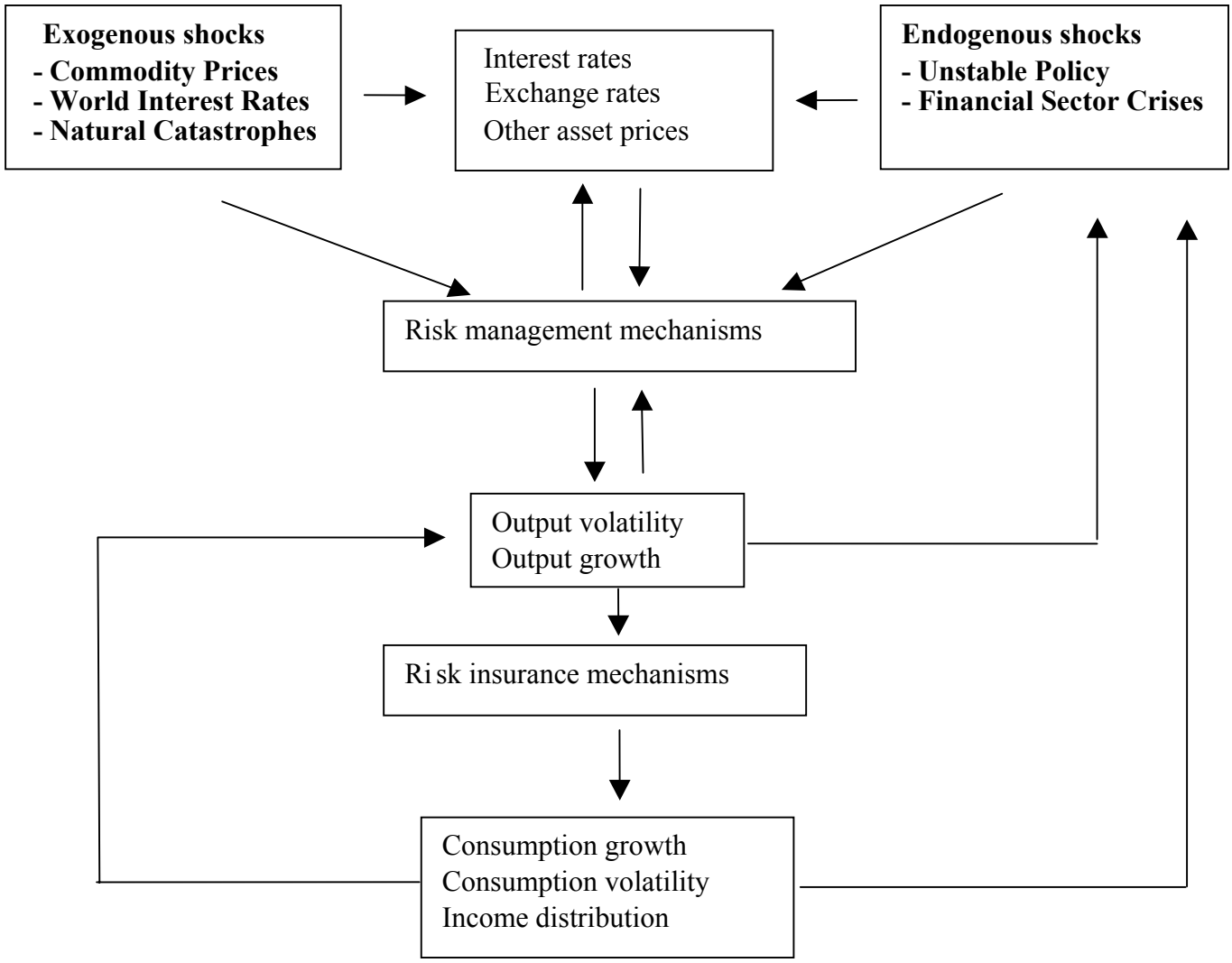



*Source* : Author's calculations.

## CONCEPTUAL FRAMEWORK

Against the background of the above discussion, turn now to a more systematic treatment of some of the main sources of volatility and their transmission to output and consumption.[11] To provide a structure, figure 1.12 summarizes the links discussed below.

Figure 1.12. *Conceptual Framework*




**Input Shocks**

A conceptual distinction may be made between two sources of shocks. *Exogenous volatility* derives from sources that---at least in the short term---are outside the control of both households and policymakers. For small open economies, these include commodity price shocks influencing the terms of trade, changes in world interest rates, climate changes, and natural disasters. *Endogenous volatility* sources include unstable macro policies, political instability, and, to some extent, financial crisis brought about by domestic market imperfections.

As is often the case, the clear theoretical distinction does not always map easily into the empirics. Many shocks are hybrids. Thus capital flow reversals often have both an external exogenous component, such as changes in world interest rates, and a domestic endogenous component, such as perceived fragility due to maturity or currency mismatch. In like vein, productivity shocks, an important source of volatility, typically reflect both exogenous and endogenous factors. The empirical evidence suggests that input shocks play a significant role.[12]

Table 1.1 provides background information on three input shocks. The volatility of the terms of trade is (in the short run) largely exogenous, while the volatilities of inflation and fiscal spending are to a significant extent a reflection of policy choices. The table reports three alternative volatility measures: the regular standard deviation; the standard deviation of the residuals from a bandwidth filter (allowing for a time varying trend); and the maximum absolute annual change, as an extreme value measure. For all three measures, the same pattern emerges: input volatility declines with income. The decline is small between lower- and middle-income countries, and very pronounced between middle- and high-income countries. The table also reports the autocorrelation, revealing greater persistence for upper-income economies.

Table 1.1. *Input Volatilities, 1960--2002*

| *Input Shocks* | *Low-income economies* | *Middle-income economies* | *High-income economies* |
|---|---|---|---|
| Terms of Trade (% change) | | | |
| Standard deviation | 0.162 | 0.096 | 0.040 |
| - Standard deviation of deviation from bandwidth filter (level) | 0.131 | 0.084 | 0.035 |
| - Maximum absolute annual change | -0.146 | -0.092 | -0.030 |
| - Autocorrelation | -0.118 | -0.004 | 0.079 |
| | | | |
| Inflation rate (%) | | | |
| Standard deviation | 0.183 | 0.155 | 0.051 |
| Standard deviation of deviation from bandwidth filter (level) | 0.190 | 0.159 | 0.044 |
| Maximum absolute annual change | 0.738 | 0.668 | 0.209 |
| Autocorrelation | 0.441 | 0.645 | 0.762 |
| | | | |
| Government expenditure (share of GDP) (% change) | | | |
| Standard deviation | 0.138 | 0.089 | 0.034 |
| Standard deviation of deviation from bandwidth filter (level) | 0.112 | 0.081 | 0.029 |
| Maximum absolute annual change | 0.021 | 0.130 | 0.129 |
| Autocorrelation | -0.020 | 0.085 | 0.302 |

*Source*: Author's calculations.

**Transmission Channels from Input Shocks to Output Volatility and Output Growth**

Input shocks are transmitted to output volatility through a variety of channels. These are briefly reviewed here. Chapter 2 provides an in-depth analysis.

***Factor accumulation.*** The link between input volatility and investment depends on a variety of features, including the reversibility of investment decisions and the alternatives available to firms. The net effect is ambiguous. Beyond effects on volume, volatility may also affect the type of investment by tilting incentives toward the accumulation of less specialized capital goods with lower expected returns, which can be re-allocated more easily in response to shocks. Human capital accumulation may be affected in a similar way (Duryea 1998; Flug, Spilimbergo, and Wachtenheim 1999). Such efficiency effects are consistent with the empirical finding that growth in more volatile economies tends to be lower even after controlling for input volumes.[13]

***Domestic finance.*** Finance plays multiple roles. The financial system can both be a source of shocks and, in the presence of market imperfections, can amplify shocks originating both at home and abroad. Yet financial markets also provide the tools to cope with volatility. The empirical literature suggests that for high-income countries, financial development and output volatility are negatively associated. For low- and middle-income economies, the net link is less evident, and may depend on the degree of international financial integration.[14]

***Trade.*** The role of trade and openness is similarly complex. Greater openness allows better insulation against domestic demand shocks. Yet if accompanied by greater specialization, it may also lead to greater exposure to sectoral shocks, and enhance exposure to external demand and supply shocks. Openness also enhances the role of the real exchange rate, which in turn can act both as a stabilizing element and as a source of additional input volatility.

Empirically, a higher volatility of the terms of trade appears to be linked to a higher volatility of output (Agénor, McDermott, and Prasad 2000). The link between generic measures of openness and output volatility in contrast is less settled. While Assaf Razin and Andrew Rose (1994), looking at a nearly comprehensive sample, detect no robust effect, other studies have found a positive link between openness and output volatility.

***Capital mobility.*** Following the recent spate of emerging market crises, renewed attention has focused on the role of international financial linkages and macroeconomic volatility. Theory suffers from an embarrassment of riches. Greater financial integration allows economies, notably emerging markets, to tap external funding sources to achieve more diversified production structures and thus to reduce their exposure to sector-specific shocks. Yet integration also creates new transmission channels for external shocks and may magnify the effect of domestic distortions.[15] The literatures on collateral problems, on currency mismatch/original sin, and on the resource curse trace many of these potential vulnerabilities. The net effect is ambiguous, and likely to be conditional on both country characteristics and on the nature of shocks.

The evidence is similarly mixed. In a regression framework, the search for a robust cross-country link between financial integration and volatility has proved elusive. Studies by Assaf Razin and Andrew Rose (1994) and by Claudia Buch and Christian Pierdzioch (2003) found no robust link; while other authors have found financial integration to be an important determinant of volatility for subgroups. More weakly the evidence suggests a possible reversal of the link between middle- and high-income economies, with middle-income countries experiencing a positive link between financial integration and volatility, and high-income countries, a negative link.[16]

***Politics.*** The political system, including the ability to respond in a speedy way to shocks, may affect the sensitivity of aggregate outcomes to input shocks (Rodrik 1999). Evidence on this linkage is as yet sparse but growing. Daron Acemoglu, Simon Johnson, James A. Robinson, and Yunyong Thaicharoen (2002) find that good institutions are associated with reduced output growth volatility. Over time, institutions may themselves become endogenous to volatility, as unsatisfactory performance may enhance the pressure for reform.[17]

**Avoidance and Mitigation Strategies**

The preceding paragraphs focused on channels by which input shocks are transmitted to output. As emphasized before, not all of the resulting output volatility is undesirable. To the extent that excess volatility is present, or that the ability of households to shield consumption from output volatility is constrained, policy actions taken to reduce output volatility are however potentially welfare enhancing. On the most direct level, countercyclical policy can be used to offset demand shocks. Yet accumulating evidence suggests that fiscal policy in emerging markets often exhibits pro-cyclical tendencies and thus, if anything, acts as an additional source of volatility.[18]

**Output Volatility**

Table 1.2 provides background information on the volatility of GDP per capita.[19] The volatility of output again decreases with income, most notably between the middle-income and the upper-income economies, while persistence, measured by the autocorrelation, increases in the income level.[20]

Table 1.2. *Output and Consumption Volatility, 1960--2002*

| *Volatility* | *Low- income economies* | *Middle-income economies* | *High-income economies* |
|---|---|---|---|
| GDP per capita growth | | | |
| - Standard deviation, full sample | .0608858 | .0590874 | .0375206 |
| - Standard deviation, 1980--latest | .0580189 | .052712 | .0313299 |
| - Standard deviation of deviation from bandwidth filter | .0574366 | .0570887 | .035183 |
| - Maximum absolute annual change | -.0911258 | -.0021264 | .0611574 |
| - Autocorrelation | .1137416 | .2855715 | .2916662 |
| | | | |
| Consumption per capita growth | | | |
| - Standard deviation | .0880907 | .0733261 | .0312265 |
| - Standard deviation, 1980—latest | .087995 | .0703962 | .0275752 |
| - Standard deviation of deviation from bandwidth filter | .0722855 | .0652268 | .0296149 |
| - Maximum absolute annual change | -.0574868 | .041073 | .0898115 |
| - Autocorrelation | -.1011594 | .0721121 | .3092209 |

*Source*: Author's calculations.

**Consumption Volatility: Size and Importance**

From a welfare perspective, what matters is the volatility of consumption, not output. Indeed, in a perfect market environment, households will hold diversified portfolios that will shield their consumption entirely from local shocks.

Before turning to the link between output growth volatility and consumption growth volatility, it is instructive to consider the importance of the welfare effects of consumption volatility. Put differently, how much is it "worth" to households to cut the volatility of consumption (abstracting from any growth effect)? Answers to this question have generally been framed in the context of the growth equivalent: how large a reduction in the permanent growth rate of consumption would a household be willing to accept in return for eliminating consumption volatility? The answer for mature economies appears to be, not much (Lucas 1987). For developing countries, aggregate consumption volatility is higher, as are the gains from smoothing. Stéphane Pallage and Michael Robe (2003) find welfare effects for many countries that are least ten times as large as in the United States; elimination of consumption volatility would be welfare-equivalent to a 1 percent increase in the consumption growth rate. Even these estimates are likely to be lower bounds. As discussed above, volatility as perceived at the level of households is likely to exceed aggregate volatility, as aggregation partly eliminates regional, sectoral, and idiosyncratic factors.

***Options.*** The link between local income volatility and local consumption volatility is determined by the ability of firms, households, and governments to avoid or hedge risks. At the individual level, responses include the accumulation of precautionary savings, diversification of income sources across household members (including choices about participation of multiple household members in the monetized economy), the utilization of domestic and international financial markets, and insurance mechanisms (Hunter and Smith 2002).[21] Various forms of economy-wide insurance, such as reserve holdings, buffer stock arrangements, stockpiles of critical products, and an appropriately constructed welfare net, can complement individual access to insurance. National measures in turn can be complemented by multinational mechanisms aimed at alleviating the effect of volatility on consumption and on poverty (Fischer 2002).

***Evidence.*** In the extreme case of perfect markets with no home preferences, idiosyncratic shocks to local production would have negligible effects on local consumption, as households would hold well-diversified portfolios giving them a claim on world output, rather than local output. By extension, local

consumption growth would depend more closely on world output growth than on local output growth, and consumption growth rates would exhibit a higher cross-country correlation than income growth rates.

These predictions have not been confirmed by empirical evidence (see also bottom of table 1.2).[22] First, consumption growth volatility does not appear to be much smaller than output volatility, and indeed in some low- and middle-income countries, appears to be higher (table 1.2, bottom; see also Kose, Prasad, and Terrones 2003). Second, across countries, output growth correlations do not fall short of consumption growth correlations. Third, there remains a closer dependency between local output and local consumption than between global output and local consumption. Fourth, portfolio holdings exhibit marked home bias. Rendering these stylized facts consistent with theoretical predictions without large deviations from the complete markets framework has proven challenging (Heathcote and Perri 2002), though data problems may account for at least some of the puzzle (Kose, Prasad, and Terrones 2003).[23]

**Volatility and the Poverty of Individuals and Nations**

Income distribution consequences of volatility may arise from three distinct channels. First, individuals may be differently affected by input shocks. Second, the transmission channels may affect some income groups more than others. Third, access to risk management tools may depend on income and wealth. Within countries, individuals living close to or below the poverty level are unlikely to hold internationally diversified investment portfolios, or to have the ability to insure themselves against other risks, or the ability to self-insure by means of precautionary savings.[24]

## OPTIONS TO MANAGE VOLATILITY

The preceding sections illustrated a variety of linkages between input shocks, growth, and consumption volatility and income distribution. Individuals, firms, and governments can resort to a number of steps to reduce volatility or mitigate its impact. Some of these have been alluded to above; this section draws the options together. Three fundamental responses to volatility can be distinguished:

- *Risk-reduction measures* attempt to directly affect the probability of an event occurring. Examples at the personal level include the acquisition of multiple skills to reduce the likelihood of prolonged unemployment and the adoption of a healthier lifestyle to avoid disease. Firms can reduce fragility by following prudent balance sheet policies regarding maturity and currency mismatch and diversifying their customer base. On the industry or regional/national level, examples include emergency food stocks to counteract famine and the construction of dams to avoid flooding.

- *Market insurance* transfers resources across states of nature, in most cases from good to bad states, reducing the exposure of individuals to stochastic events with a well described population distribution (such as fire, earthquakes, and illness) by spreading cost over a large pool of insured individuals.[25] *Public insurance* has a similar function, and is particular prevalent in the areas of health, retirement, and unemployment. Mandatory participation reduces adverse selection, though not moral hazard problems. Within countries, the scope for insurance is limited by the importance of national shocks. Recent proposals by on international risk sharing and GDP indexed bonds extend the principle to the international realm.

- *Self-insurance* re-allocates resources over time for an individual or household. A classic example of self-insurance is precautionary savings, building up net savings in good times to be able to sustain consumption in bad times. Other examples include the maintenance of a backup vegetable garden and the international diversification of portfolios to insulate non-wage income from national shocks. On the household level, having several members active in different parts of the monetary economy provides some protection against misfortunes befalling any one individual member. An interim approach between

market-insurance and self-insurance is provided by intra-family (broadly defined) insurance, prevalent in many societies in which market insurance schemes are limited. Social restrictions associated with being (and wishing to remain) a group member ease the moral hazard and adverse selection problems facing market based insurance schemes.

In practice, a range of options is often available. For example, a healthy individual concerned about income losses or additional costs due to illness might buy health insurance or long-term care insurance (market insurance, pooling across individuals); might increase precautionary savings (self-insurance); or alter his or her diet and lifestyle (self-protection). Preparing for any specific risk may thus involve a mix of steps (World Bank 2000). In addition, these individual steps may be complemented by public mechanisms. Thus in an economy subject to volatile terms of trade, for example, individuals may insure themselves by appropriate diversification of their portfolios, while governments or producer organizations may develop stabilization funds or tax/subsidy scheme correlated to the price in question, possibly with external assistance.

The measures can reduce both output and consumption volatility. As discussed above, steps to reduce output volatility are warranted only if such volatility is excessive, or if tools to deal with consumption volatility are not available. It is also worth noting that a given policy step can have quite asymmetric effects on consumption and output volatility. For example, steps taken to enhance financial and trade integration may increase output volatility (by encouraging greater specialization, and thus exposure to sectoral shocks) but reduce consumption volatility (by enhancing risk management tools).

## CONCLUDING REMARKS

While the web spun by volatility sources, transmission channels, and coping mechanisms is complex, differences in consumption volatility across countries reflect three main factors. First is the relative incidence of input shocks. Second is the ability of the economy to accommodate shocks (or its tendency to aggravate them) through policy responses, structural policy features, and long-term features of the economy, notably its trade and production diversification. Third is the ability of households and economies to insulate consumption from temporary shocks. The following chapters take up these themes in greater depth.

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[1] Figures 1.1 and 1.4 to 1.6 use the same dataset as chapter 2, while Figures 1.2 and 1.3 use the same dataset as chapter 3. The appendixes to these chapters describe the datasets.

[2] The classic reference is Ramey and Ramey (1995). See also IDB (1995); Duryea (1998); Aizenman and Marion (1999); Flug, Spilimbergo, and Wachtenheim (1999); Kaminsky and Reinhart (2002); Kose, Prasad, and Terrones (2003). The effect tends to be both statistically and economically significant.

[3] The spike for Japan reflects a recorded GDP decline of 69 percent in 1945.

[4] See also Buch (2002); Obstfeld and Taylor (2003).

[5] Alternative explanations for a positive link between volatility and growth are given by Schumpeterian notions of cleansing recessions. Caballero and Hammour (1994) and Aghion and Saint Paul (1998) explore these themes.

[6] To illustrate, it is widely accepted that the 1970s were a period of relatively higher "volatility" and the early 1990s were a period of relatively low "volatility." To the extent one views these episodes as realizations of a stable underlying process (with a particular pronounced sequence of large realized shocks in the 1970s and a particularly pronounced series of small realized shocks in the early 1990s), the best single measure of volatility over the entire period is obtained by averaging over both periods. Such averaging would be less appropriate if the underlying volatility process itself had changed over the period: for example reflecting greater financial and real integration.

[7] Time-changing volatility has attracted particular attention in some financial applications. Commencing with Robert Engle's (1982) seminal paper on ARCH models, the finance literature has developed a rich array of parametric and non-parametric techniques allowing, among other features, for asymmetric volatility responses to positive and negative shocks and threshold effects. A complete survey of this literature is beyond the scope of this chapter. For a recent discussion, see Andersen, Bollerslev, and Diebold (2002).

[8] As an admittedly trivial example, consider the measurement of "the" volatility of output growth. Intra-day, output is extremely volatile: production at 3 AM is dramatically lower than at 3 PM; smaller dips occur around lunchtime and each weekend. The very high volatility of hourly GDP generated by these nightly and weekly "recessions" is however of little concern and indeed is not statistically measured.

[9] For instance, given financial and regulatory structures, a particularly large negative shock may lead to the demise of a firm/bank, whereas a commensurate positive shock would not have a similar discrete effect. In like vein, an external shock reducing central bank foreign currency reserves to zero under a pegged regime is likely to have more pronounced effects than a commensurate shock doubling reserves.

[10] The differentiation could be extended further: for example, by distinguishing between shocks to labor and to capital income, or to shocks to particular regions within a country.

[11] See Buch (2002) for a comprehensive survey.

[12] To cite two examples, Michael Gavin and Ricardo Hausmann (1996) conclude that long-run growth volatility in a sample of developing countries has been importantly influenced by input volatilities, notably in the terms of trade and the real exchange rate, while Philippe Auffret (2003) highlights the importance of environmental shocks for the Caribbean.

[13] The discussion focuses on the effect of input volatility. In terms of outcome volatility, the reverse causal linkage may arise. For example, one of the major expected benefits of integration comes from specialization in sectors of comparative advantage. Yet such specialization by definition increases exposure to sectoral shocks, and may thus lead to greater output volatility. This volatility is best thought of as the side effect of the benefits of greater specialization. To

the degree it can be hedged, it may not be reflected in greater consumption volatility and may be of secondary welfare concern compared with its primary growth effect.

[14] Beck, Levine, and Loayza (2001) explore these links in detail. See also Denizer, Iyigun, and Owen (2002); Buch and Pierdzioch (2003); Kose, Prasad, and Terrones (2003); and Kose, Prasad, Rogoff, and Wei (2003).

[15] See Sutherland (1996); Faia (2001); and Buch and Pierzioch (2003).

[16] Thus Bekaert, Harvey, and Lundblad (2002) find that stock market liberalization is associated with reduced volatility of both consumption and output. Looking at measures of more general capital account openness, they find a positive link between financial integration and both output and consumption growth volatility for emerging markets, but a negative link for mature economies. Kose, Prasad, and Terrones (2003), using both capital account restrictions and capital flows, likewise find a positive link between financial integration and consumption growth volatility for non-industrialized countries, but a negative link for industrialized countries.

[17] Arguments along this line have been made for post-1991 India and post-1998 Russia.

[18] One contributing factor may be pro-cyclical access to domestic and external debt markets, coupled with over-spending incentives reflecting political economy incentives. Alesina, Perotti, and Tavares (1998) provide a partial survey of this growing field. See Martin and Rogers (1997) and Talvi and Vegh (2000). Kose, Prasad, and Terrones (2003) find that total consumption (private plus government) is less volatile than private consumption. Agénor, McDermott, and Prasad (2000) find government consumption to be countercyclical for a fairly small set of non-crisis middle-income countries. The pattern however does not seem to be uniform, with evidence of pro-cyclicality for other country groups. Again, a context dependence may arise, as pro-cyclicality has been attributed to a procyclical borrowing capacity, notably of primary producers. Taking a slightly different approach, Buch and Pierdzioch (2003) find a positive link between higher volatility of government consumption spending and output volatility.

[19] See also Kose, Prasad, and Terrones (2003).

[20] There is also strong evidence that output volatility decreases in the size of economy. See Head (1995) and Crucini (1997). On the challenges facing small countries, see also Harden (1985) and Srinivasan (1986).

[21] As discussed above, however, financial markets may again display a Janus face, with volatility-management opportunities being matched by volatility emanating from the financial sector, creating policy challenges on both the national and the multilateral level. Financial markets may thus act both as a source of volatility and a means of dealing with volatility.

[22] See for example Gavin and Hausmann (1996); IDB (1995); Kose, Prasad, and Terrones (2003); Kose, Prasad, Rogoff, and Wei (2003); Buch (2002); Hnatkovska and Loyaza (2004) (chapter 2, this volume).

[23] Theory emphasizes utility smoothing, empirical work measures the volatility of consumption expenditures. Data problems arise to the extent that expenditures are not a good proxy for utilities. Among the caveats in this respect is the lumpiness of durables expenditures relative to their utility flow, the treatment of leisure and other non-market consumption elements, and the treatment of government consumption.

[24] For example, some evidence points to a negative effect of volatility on educational attainment (Duryea 1998; Flug, Spilimbergo, and Wachtenheim 1999). To the degree that human capital provides an avenue for risk diversification, current volatility may thus influence future vulnerability to volatility.

[25] For some risks, such as earthquakes and flooding, the exogeneity of the original event is near complete. Even in these cases however, individual responses to obtaining insurance might influence the probability distribution of damages, for example through increased building in areas susceptible to earthquakes and flooding. In other cases, insurance providers have to incorporate both endogenous responses to the provision of insurance (such as insured drivers driving more aggressively) and, for voluntary insurance schemes, the likelihood that individuals with a higher expected probability of facing the adverse event are more likely to seek insurance. Both moral hazard and adverse selection problems can partly be addressed through the structure of the insurance contract.