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Openness and inflation volatility: Cross-country evidence*

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Abstract

Recent decades have seen a considerable expansion of global trade and a simultaneous decline in inflation volatility. This paper investigates whether greater openness to trade helps achieve inflation stability. Using panel data for a sample of developing and industrial countries over the period 1961-2000, we document a negative and statistically significant effect of openness on inflation volatility. This relationship is estimated after controlling for the potential endogeneity of openness, and the average rate of inflation. We conduct a battery of robustness tests, showing in particular the robustness of our conclusions to controlling for the choice of exchange rate regime. A sub-sample analysis suggests that the relationship between openness and inflation volatility is more pronounced in developing and emerging market economies than in OECD countries. We also identify potential channels underpinning this relationship. In particular, we provide evidence that openness may promote inflation stability through dampening monetary and terms of trade shocks.

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1 Introduction

One of the most striking features of global macroeconomic performance over the past two decades has been a substantial decline in inflation volatility. In the United States there has been a two-thirds reduction in inflation volatility since the mid-1980s and similar trends have been observed in other OECD countries (Blanchard and Simon 2001). Even in developing countries, where inflation is both higher and more volatile, the variability of inflation has fallen since the early 1990s. The recent decline in inflation volatility, part of the 'great moderation' referred to by Bernanke (2004), comes at a time of increasing globalization of trade: the ratio of world exports and imports to GDP rose from 75% in the mid 1980s to over 150% by the end of the 1990s (Kose et al. 2004). This paper considers whether or not the recent fall in inflation volatility is linked to greater trade integration. Can the relative inflation stability observed during the 1990s be described, in the parlance of Rogoff (2003), as a further 'unsung benefit of globalization'?

Preliminary evidence suggests that trade integration is associated with inflation stability: during the period 1984-93 inflation volatility in countries that were slow to integrate into the global economy was twice as high as in countries that achieved rapid integration (Brahmbhatt and Dadush 1996).[1] Recently, Lo et al (2004) provide cross-country evidence showing a negative correlation between openness and inflation volatility.[2] However, beyond these preliminary studies, there is scant evidence on the effects of trade openness on inflation volatility. This paper provides a first systematic account of the openness-inflation volatility relationship. Using panel data spanning 96 countries and four decades, we demonstrate a robust negative effect of trade openness on inflation volatility.

Our work departs from previous research in that we move beyond cross-sectional correlations and utilise temporal variation in the data to examine the dynamic relationship between openness and inflation volatility. More importantly, we seek to address the potential endogeneity of trade openness. This could arise if, for instance, inflation uncertainty acts as a friction to trade, or if macroeconomic shocks simultaneously affect both openness and inflation volatility. We leverage the exogenous variation in openness by using lagged movements in openness and population size as instruments in estimating a dynamic panel model using a recently developed generalised method of moments estimator.

The evidence that we present parallels the negative relationship between openness and average inflation documented in Romer (1993).[3] However, we show that openness has a negative and statistically significant effect on inflation volatility even after controlling for mean inflation, suggesting that the Romer finding does not fully account for the relationship emphasized in this paper. We demonstrate the robustness of our findings to an unusually wide range of controls,

[1] The standard deviation of inflation for slow and fast integrators is 13.27% and 7.24% respectively. The "speed of integration index" used by the authors is based on four indicators: the ratio of trade to GDP, the ratio of foreign direct investment to GDP, institutional investors' credit ratings, and the share of manufactures in exports.

[2] Two other studies, Bleaney and Fielding (2002) and Gruben and McLeod (2004), provide indirect evidence on this issue.

[3] The Romer evidence has been challenged by Terra (1998) and Bleaney (1999), but in a recent contribution Sachsida et al (2004) report strong evidence that greater openness is associated with lower mean inflation, while Chen et al (2004) show that increased trade between European countries reduces firms' markups in key manufacturing industries, and as a result forces down general price inflation.

including per capita income, country size, the growth and volatility of output and the exchange rate regime. Furthermore, our results are not affected by differences that exist across countries in financial development, indebtedness, the extent of political constraints, the adoption of inflation targeting and participation in IMF structural adjustment programmes. However, the relationship is shown to be stronger amongst developing and emerging market economies than amongst OECD countries. Overall, we argue that our results cast doubt on many scenarios in which the relationship between openness and inflation volatility is spurious or incidental, and instead point to a causal link between these variables.[4]

In addition to documenting the effect of openness on inflation volatility we identify potential channels underpinning the relationship. Firstly, the costs of inflation volatility may be greater in open economies, for if domestic firms are unable to maintain a stable price path they run the risk of losing sales and profits to foreign competitors. In relatively open economies such costs figure prominently in the minds of central bankers and policy makers, and this may cause them to pursue more disciplined macroeconomic policies, intended to deliver inflation stability. A second possibility is that openness provides greater opportunities for export diversification, reducing vulnerability to terms of trade shocks and in turn restricting inflation volatility. We test these channels by augmenting our basic regressions with measures of monetary and terms of trade volatility, and find that in doing so the effect of openness falls considerably. Auxiliary regressions are then used to show that trade openness is a negative predictor of monetary and terms of trade volatility, suggesting that openness may restrict inflation volatility through these channels.

Our paper is related to several strands of the literature. The potential consequences of inflation volatility have been shown to be quite serious, for instance high inflation volatility can translate into low investment and growth (Judson and Orphanides 1999; Elder 2004, 2005; Byrne and Davis 2004). Inflation volatility can also increase the forward risk premium in asset markets (Buraschi and Jiltsov 2004). Given these consequences of inflation volatility, it is useful to ask why some countries face greater inflation volatility than others. Additionally, a focus on the links between openness and inflation volatility provides evidence on possible channels linking trade openness with the level and growth rate of per capita income (Frankel and Romer 1999, Sachs and Warner 1995), i.e. one way in which openness promotes growth may be through first delivering inflation stability.

Our work also complements research into the determinants of other forms of macroeconomic volatility. Recent evidence suggests that openness restricts nominal exchange rate volatility (Devereux and Lane 2003). In contrast, the relationship between openness and the volatility of GDP growth appears more complex. On the one hand, trade openness can increase exposure to external shocks, whereas on the other hand it can create opportunities for export diversification that may smooth shocks to export demand. The empirical evidence reflects this ambiguity,

[4]An important issue that we address in an appendix is the role of financial openness in setting inflation volatility. Aghion et al (2004) note that financial openness can exert conflicting effects on volatility: Improved acces to credit may restrict volatility, while on the other hand the pro-cyclicality of foreign capital may exacerbate volatility during periods of macroeconomic stress. Our proxies for financial openness turn out insignificant, reflecting these oppositely signed effects. On the other hand, trade openness remains negatively signed and significant at the 1% level in models that control for financial openness.

as the link between openness and output volatility is found to be either positive or negative depending on the sample coverage and the set of control variables (Easterly et al. 2001; Levy-Yeyati and Sturzenegger 2003; Mobarak 2005; Winters et el. 2004). Our results suggest that the impact of openness on inflation volatility is more systematic, and that the volatility decreasing effects of openness consistently dominate those operating in the positive direction.

This paper is organized as follows. Section 2 discusses potential channels linking openness and inflation volatility and reviews some previous studies. Section 3 sets out the econometric approach that we follow and describes the panel data used in our analysis. Section 4 presents the basic empirical results and some important robustness checks, and in Section 5 we interpret our finding in terms of the adjustment mechanisms identified in Section 2. Finally, Section 6 concludes.

2 Openness and inflation volatility

In this section we survey the relevant literature and consider some of the channels through which openness may affect inflation volatility. It is hard to find a single theoretical model that explicitly analyses all of the mechanisms through which openness and inflation volatility may be related, however a number of recent studies offer insights that bear relevance to the link between openness and inflation volatility.

A good starting point in thinking about inflation volatility is the conduct of monetary policy, which plays a central role in determining inflation performance. Although other aspects of macroeconomic policy may affect inflation, such as tax and spending decisions, such interventions typically require monetary accommodation. A critical question, then, is whether policy-makers are prepared to tolerate inflation volatility, or instead choose to pursue inflation stability. This depends on the perceived costs and benefits of inflation variability. Inflation instability is generally considered welfare decreasing because it impedes the allocative role of markets and deters agents from entering long-term contracts for the exchange of goods and services. Temple (2002) argues that, "the costs of high and variable inflation are potentially greater in open economies", and several arguments can be used to support this view. In relatively open economies inflation instability can undermine the sales and profits of domestic producers who find themselves in competition with firms from countries in which inflation is less volatile.[5] Alternatively, if trade openness is accompanied by liberalization of the capital account, inflation volatility increases the risk of capital flight, which is detrimental to domestic investment.[6]

If inflation volatility is especially costly in open economies, greater openness may increase the incentive for policy authorities to adopt disciplined policies, e.g. the monetary authority

[5] In principle the effects of domestic inflation volatility could be neutralised by exchange rate adjustment. However, the long and large departures from purchasing power parity observed in practice suggest that this is unlikely to be the case. Similarly, perfect indexation of all nominal contracts would eliminate the costs of inflation volatility, but this scenario is of little practical relevance.

[6] The idea that macroeconomic volatility is more costly in open economies has been formally demonstrated by Kollman (2004), who simulates a dynamic stochastic general equilibrium (DSGE) model in which there are shocks to the uncovered interest parity (UIP) condition. This form of volatility is shown to induce larger welfare losses in more open economies.

may resist the temptation to extract seigniorage revenues each time a shock to production leads to a period of fiscal deficits. This logic is exemplified in a recent quarterly report issued by the State Bank of Pakistan (SBP 2005), which recognizes the challenge of restricting inflation volatility in order to maintain export competitiveness. As the State Bank's quarterly report argues, stabilizing inflation expectations - in particular, reducing inflation from around 10% to an annual target of 5% - is important if exporters are to be protected against rising input costs.[7]

Besides imposing greater policy discipline, trade openness can enable countries to stabilise faster in the aftermath of shocks. The roots of inflationary pressures in developing countries can sometimes be located in sharp movements in food prices, caused in large part by underlying agricultural conditions and climatic fluctuations. More open economies may be better able to mitigate the effects of food price inflation by resorting to cheaper imports following a natural disaster or an adverse climatic shock. This would be the case if a strong export base provides the foreign currency/credit necessary to import substitute goods, or if a history of trading links provides the transport infrastructure necessary for rapid delivery of foreign goods. Aron and Muellbauer (2000) emphasise the role of increased openness in containing inflation pressures in South Africa via this channel during the 1990s.[8]

Trade openness also offers greater opportunities for export diversification. For instance, if increased openness leads to diversification in the export and import baskets - either across goods, trading partners or both - the variance of external shocks may fall due to a law of large numbers effect. Any dampening of external volatility may be particularly strong if greater openness is achieved through expansion in manufacturing and services rather than primary commodities, since Baxter and Kouparitsas (2000) show that terms of trade volatility is smaller in high value added sectors.[9]

It is important to note that the effect of openness could operate in the opposite direction, i.e. increased trade integration may destabilise inflation. A common view is that openness increases exposure to global price shocks, in which case inflation volatility would increase with openness. Alternatively, increased trade may be achieved through specialisation in a particular industry, or integration within a region in which the business cycles of member countries are highly correlated, in which case the law of large numbers effect may operate in reverse.

In a recent theoretical contribution, Razin et al (2003) develop a model in which openness induces volatility because terms of trade shocks generate investment cycles that impact on aggregate demand. Another possibility is that trade openness induces financial openness. This can increase volatility if the country in question starts from a low level of financial development. Aghion et al (2004) present a model in which financial openness provides access to credit and

[7]Resisting calls for holding down interest rates, the 2005 quarterly report says: "It is important to note that any attempt to maintain low interest rates for an extended period in the face of high inflation is counter productive for the economy, e.g. any gain to exporters from uneconomically low interest rates would be quickly lost to the rising cost of inputs as inflationary expectations take hold" (SBP 2005, pg. 2).

[8]Another example is India, where policymakers relied on food imports to restrict inflationary pressures (Joshi 1999).

[9]There is some evidence that increased openness is associated with expansion in high value added sectors. Collier (2003) notes that in 1980, 75% of developing country exports were primary commodities, whilst more recently about 80% of such exports were manufactures.

raises investment, but this investment is vulnerable because foreign credit is withdrawn more quickly than domestic credit following a negative demand shock. This can cause a domestic recession, which in turn leads to inflation volatility.

Ultimately, the sign of the relationship between openness and inflation volatility is an empirical matter. As noted in the introduction, empirical research has recently begun to explore the connection between openness and various measures of macroeconomic volatility. Devereux and Lane (2003) show that bilateral nominal exchange rate volatility is negatively related to bilateral trade flows. Similarly, volatility of the real effective exchange rate amongst a group of OECD and developing countries is shown to decrease with openness (Hau 2002; Hausman et al 2004). In related work, Frankel and Cavallo (2004) show that openness decreases the likelihood of a 'sudden stop' in capital flows.

More broadly, evidence linking openness and the volatility of GDP growth is mixed, as noted in a recent review by Winters et al. (2004). Easterly et al. (2001) estimate a positive effect of openness on growth volatility using a sample of both developed and developing countries, but this effect becomes insignificant on controlling for the initial level of development. In contrast, Mobarak (2005) estimates a negative effect of openness on volatility. Similar, though less strong, evidence is presented in Fatas, Mihov and Rose (2004), while Levy-Yeyati and Sturzenegger (2003) find that the relationship is negative amongst non-industrial countries but positive amongst industrial countries.

3 Data and methodology

In this section we describe the data and our econometric methodology. The inflation data measure the annual rate of consumer price inflation at the quarterly frequency and are taken from *International Financial Statistics*.[10] We compile data for an unbalanced panel of 96 countries; the longest period for which data are available for any single country is 1961 : 1 to 2000 : 4.[11] Inflation is defined as growth in the price index over the last year rather than the last quarter in order to avoid seasonal effects that may induce spurious volatility.

In order to measure inflation volatility we divide the data for each country into a maximum of 8 windows, each of 20 quarters (1961 : 1 to 1965 : 4, 1966 : 1 to 1970 : 4 and so on). For each sub-period we then compute inflation volatility ($VINF$) as

$$VINF = \ln[1 + sd(INF)] \tag{1}$$

where sd denotes a standard deviation and INF is the decimal inflation rate.[12] A standard practice in the literature is to take log transforms to downweight very large readings that may occur during hyperinflation episodes. One disadvantage of the log transform is that it

[10] Appendix A provides comprehensive notes on the data sources used.

[11] The 96 countries correspond to the sample used by Romer (1993) in analysing the relationship between openness and mean inflation, except that we have excluded the four Gulf oil states considered by Romer, and included Chad, a country for which Romer was unable to obtain sufficient data. Appendix B lists the 96 countries included in the sample.

[12] For example, an inflation rate of 3% is denoted as 0.03.

overweights observations very close to zero (the log of such a reading is a large negative number). To avoid this, we consider the log of one plus the decimal standard deviation of inflation. However, later sections in this paper show that our results are robust to alternative measures of $VINF$.[13]

It is worth noting that in order for any measure of the standard deviation to be valid, the mean of the process must be constant over the period for which the standard deviation is calculated. By measuring volatility at the five-year frequency, rather than over several decades, we reduce the chances of identifying spurious volatility associated with shifts in mean inflation.[14] On the other hand, short window lengths risk confusing breaks in mean inflation with persistent shocks around a stable mean. In the section on robustness, we analyse the consequences of varying the window length over which inflation volatility is measured.

The data for inflation volatility include some outliers, even after the transformation in (1). In order to ensure that our results are not driven by outliers we exclude observations more than three standard deviations from the mean of the unconditional distribution. This leads to 12 observations, approximately 1.5% of the sample, being dropped. These observations are mainly for Latin American countries that experienced extreme inflation during the 1980s.

Openness is defined as the natural log of imports plus exports relative to GDP, and is denoted as $OPEN$.[15] The trade to GDP ratio is a frequently used proxy for openness and can arguably account for some of the core mechanisms linking openness and inflation volatility emphasised in our earlier discussion. However, being a *de facto* measure of openness, it is potentially endogenous, warranting the use of instrumental variables in the estimation procedure.

Figure 1 describes the evolution of inflation volatility and the trade ratio during the period 1971-2000 for different groups of countries.[16] For the sample of 51 countries inflation volatility has nearly halved since the early 1970s. This reduction appears to be more pronounced in East Asia and Western Europe and North America. In contrast, Sub-Saharan Africa and Latin America have experienced only a marginal fall in inflation volatility since 1971. What is more, a large part of the developing world did not experience the kind of secular fall in inflation volatility experienced in developed countries.

Coinciding with the general fall in inflation volatility, the trade to GDP ratio has exhibited a

[13] A GARCH measure of volatility is not adopted for several reasons. Firstly, the time series available for some countries are too short to justify GARCH estimation. Secondly, fitting a GARCH model for 1961 : 1 to 2000 : 4 and using the parameters of that model to infer inflation volatility in each 5 year window implies that volatility in, say, the 1960s depends on the data from the 1980s, because the latter are used to obtain the full sample parameter estimates. Clearly, policy-makers in the 1960s cannot have been making decisions aimed at influencing this measure of volatility and therefore it would not make sense to ask if policy-makers in open economies made special efforts to restrict it. Thirdly, if 5 years is taken as the window length, high frequency information on the conditional variance taken from a GARCH model would be lost as quarterly readings are averaged to form 5 year readings.

[14] At least for the OECD countries, multiple breaks in mean inflation rates have been observed during the last 4 decades (Corvoisier and Mojon 2005).

[15] We checked $OPEN$ for outliers using the criterion applied to $VINF$, but none were found.

[16] The largest group of countries listed in Figure 1 comprises 51 countries because data for the other 45 countries in the sample of 96 countries that we consider starts after 1971, and we choose to maintain a constant number of countries across the rows of Figure 1 in order that patterns in the evolution of inflation volatility may be discerned.

steady increase since the early 1990s. In Figure 2 plots of $VINF$ against $OPEN$ for each of the five year windows between 1961 and 2000 suggest that inflation volatility is negatively associated with trade openness (the slopes of the lines of best fit in Figure 2 are each significant at the 5% level, except that for the 1966-70 period). In Figure 3 (left-handside) we provide a cross-plot of all the observations for $VINF$ and $OPEN$, pooling the cross-sectional and time series information. Even before controlling for country fixed effects, time dummies, other regressors and potential reverse causation a negative relationship between openness and inflation volatility can be seen in the data. Each of the plots in Figure 3 indicate that some extreme observations for inflation volatility remain even after the steps taken to deal with outliers. In the robustness section we show that our main results do not depend on these observations.

3.1 The econometric model

In order to estimate the effect of openness on inflation volatility we consider the following model:

$$VINF_{it} = \alpha + \beta VINF_{it-1} + \gamma OPEN_{it} + \eta_i + \varepsilon_{it} \tag{2}$$

where i denotes a country, t a 5 year period, η_i a country fixed effect and ε_{it} the error term. The lagged dependent variable in (2) controls for persistence in inflation volatility, which may be either an intrinsic feature of the process or a proxy for other determinants of volatility that are omitted at this stage. Our empirical analysis will employ different variations of the basic specification in (2) and will emphasise the role of further controls such as mean inflation.

The approach to estimating (2) follows Arellano and Bond (1991) and Arellano and Bover (1995). In order to eliminate the time invariant fixed effects we take first differences of (2) to obtain

$$\Delta VINF_{it} = \beta \Delta VINF_{it-1} + \gamma \Delta OPEN_{it} + \Delta\varepsilon_{it} \tag{3}$$

Estimating (3) by least squares is problematic. Firstly, the transformed error term is correlated with the lagged dependent variable (both include ε_{it-1}) and this will lead to biased parameter estimates. Secondly, $OPEN$ may be endogenously determined, e.g. if volatile inflation is an impediment to trade then causation will run from left to right in (3) and the impact of openness on inflation volatility will be overstated. Alternatively, there may exist a common cause for openness and inflation volatility. One possibility is that each is the result of deeper preferences that shape macroeconomic policy, whilst another is that shocks to the terms of trade affect both variables, e.g. a collapse in export prices may reduce the nominal value of exports such that $OPEN_{it}$ falls, and at the same time cause aggregate demand to change so that inflation volatility increases.

In order to address these problems Arellano and Bond (1991) suggest a generalised method of moments (GMM) technique. Assuming that the errors in equation (2) are serially uncorrelated and that the explanatory variables are uncorrelated with future realisations of the errors (their endogeneity implies that they are correlated with only current values of the errors) lags of $VINF$ and $OPEN$ dated $t-2$ and earlier are valid instruments with which to leverage the exogenous variation in openness.[17] A potential drawback of this *Differenced-GMM* estimator is that in the presence of high time-series persistence and short panels, lagged *levels* of the variables may be poor instruments for subsequent first differences. This can lead to finite sample biases, see Blundell and Bond (1998).[18] An alternative approach, suggested by Arellano and Bover (1995) and Blundell and Bond (1998), is the *System-GMM* estimator, which uses lagged differences of each variable as instruments in estimating the levels relationship in (2), and combines this information with the *Differenced-GMM* estimates of equation (3). The validity of these instruments requires a constant correlation between $VINF_{it}$ and the fixed effect, and between $OPEN_{it}$ and the fixed effect. If this is the case, $\Delta VINF_{it-1}$ and $\Delta OPEN_{it-1}$ are orthogonal to future realisations of the error terms and represent valid instruments for estimating the parameters of (2).[19]

In implementing the *System-GMM* estimator we utilise external instruments based on lagged values of log population size, POP. This term is the time-varying element of a standard gravity model of trade flows, see for example Frankel and Romer (1999). Although gravity equations typically use population size to explain cross-sectional differences in openness, we find that past population size helps to predict the evolution of openness and can therefore be used to increase the efficiency of the GMM estimator. The role of the external instrument is further examined in the discussion of the empirical results in Section 4.

The validity of the instruments can be evaluated using the Sargan test of over-identifying restrictions and Lagrange Multiplier tests for lack of second order serial correlation (see Arellano and Bond 1991). It is important to note that the first differenced transformation yielding (3) induces an MA(1) error structure, and therefore we expect that the first-differenced residuals will be negatively autocorrelated at the first lag but uncorrelated at the second lag. The estimated standard errors take account of the first-order negative autocorrelation and any heteroscedasticity in the residuals, see Arellano and Bond (1991). The estimates that we report are based on 1-step GMM estimation in which equal weight is placed on each moment condition. This is the approach recommended by Blundell and Bond (1998).[20]

4 Empirical results

In Table 1 we present our basic empirical results. Columns $1-4$ list the ordinary least squares (OLS), within groups (WG), *Differenced-GMM* and *System-GMM* estimates of a model in which inflation volatility depends on its own lag and openness, plus a full set of time dummies. The *Differenced-GMM* estimates use as instruments $VINF_{t-2}$, $OPEN_{t-2}$, POP_{t-2} and POP_{t-3} and the *System-GMM* estimates use as additional instruments $\Delta OPEN_{t-1}$ and ΔPOP_{t-2}.[21]

[17] To be precise, the GMM estimator for equation (3) uses the following moment conditions: $E(VINF_{i,t-s}\Delta\varepsilon_{it}) = 0$; $E(OPEN_{i,t-s}\Delta\varepsilon_{it}) = 0$ for $t = 3, 4, ...T$, and $s \geqslant 2$.

[18] Levine et al (2000) note that the *Differenced-GMM* estimator may also emphasise measurement errors relative to the systematic information in the data.

[19] Specifically, the following additional moment conditions are available: $E(\Delta VINF_{it-s}(\eta_i + \varepsilon_{it})) = 0$ for $s = 1$ and $E(\Delta OPEN_{it-s}(\eta_i + \varepsilon_{it})) = 0$ for $s = 1$.

[20] All estimations are conducted using the DPD package in *Pc-Give*, see Doornik and Hendry (2001).

[21] The differenced lagged dependent variable is not used as an instrument in the levels part of the system estimator because the marginal restrictions required in order for it to be a valid instrument were rejected by

In each case the effect of openness on inflation volatility is negative and this relationship is propagated through time by the positively signed autoregressive term.

The model that we emphasise is the *System-GMM* estimate in column 4 which shows that $OPEN$ impacts $VINF$ with a coefficient of $-.086$. The standard deviation of the within groups variation in openness is 0.198 while the corresponding statistic for inflation volatility is 0.067.[22] Hence, a one standard deviation increase in openness yields a 0.25 standard deviation reduction in inflation volatility in the first 5 years. This effect then increases through time due to the dynamic propagation implied by the lagged dependent variable - if there is a permanent change in openness the final change in inflation volatility will be a little more than twice the initial effect. It should be noted, however, that additional controls have not yet been introduced to the analysis. In the second part of this section we show that including further controls reduces the openness coefficient by one half. Hence, while statistically significant, the effect of openness that we estimate is modest.

How appropriate are the instruments? Before investigating the robustness of our results we consider the properties of the instrument set. The Sargan test for the validity of the over-identifying moment conditions used in column 4 yields a p-value of 35%. In order to check that this outcome is not a Type II error arising from the pooling of valid and invalid instruments we perform separate Difference-Sargan (D-Sargan) tests for the moment conditions associated with each variable. The p-values are 20% ($VINF$), 76% ($OPEN$) and 34% (POP), suggesting that each type of instrument is individually valid.[23] Furthermore, the AR(1) and AR(2) tests provide strong support for the hypothesis that the errors in (2) are serially uncorrelated, a necessary condition for instrument validity. Hence, the residual diagnostics support the assumptions underpinning the GMM estimator.

A related question concerns the explanatory power of the instruments for the endogenous variables. If the instruments are weak the exogenous variation in openness that we are able to identify will be limited and this may be associated with instability in the estimated effect of openness, see Stock, Wright and Yogo (2002). To address this issue we regressed $\Delta VINF_{t-1}$ and $\Delta OPEN_{it}$ on the instruments used for the differenced equation, and $VINF_{t-1}$ and $OPEN_t$ on the instruments used for the levels equation and then performed *F-tests* for the joint significance of the regressors. The test statistics obtained were 27.96 ($\Delta VINF_{t-1}$ equation), 23.16 ($\Delta OPEN_{it}$ equation), 20.04 ($VINF_{t-1}$ equation) and 83.29 ($OPEN_t$ equation), each of which is significant at the 0.1% level.[24] Hence, the instruments appear to have excellent explanatory

a Sargan test. It appears that there has been some 'inflation volatility convergence' during the sample period - countries with initially high volatility experience relatively large reductions in volatility during later periods. This implies that $\Delta VINF_{it-1}$ is not orthogonal to η_i in equation (2).

[22] These statistics are calculated from the residuals obtained by regressing openness and inflation volatility on a full set of country dummies.

[23] We also performed D-Sargan tests separately for each individual instrument. The smallest p-value obtained using this very stringent procedure was 8.2%, this being for ΔPOP_{t-2}. This outcome is weak evidence that the instrument is invalid. In order to investigate further we lagged the instrument an extra period and obtained a p-value of 20% and virtually no change in the estimated parameters of the model. Based on this evidence we maintain the assumption that ΔPOP_{t-2} is a valid instrument.

[24] Each regression contained a full set of period dummies, but these dummies are *not* included in the *F-tests*

power for the endogenous variables. On a related theme, Blundell and Bond (1998) show that a GMM estimate of the autoregressive parameter that is close to the WG estimate typically reflects a problem of weak instruments. The centrality of the *Differenced-GMM* and *System-GMM* estimates with respect to the OLS-WG range in columns 1 and 2 is further evidence that our results are not affected by a weak instruments problem.

In the final two columns of Table 1 we take a further look at the role of the external instrument, population size. In column 5 all terms in POP are dropped from the instrument set. A comparison of these results with those in column 4 indicates that the main role of the population instruments is to increase the efficiency of the estimation. This is seen most clearly in the case of the openness effect, which is actually of greater magnitude in column 5 than in column 4 but yields a smaller t-ratio because its standard error increases three-fold on the deletion of the external instruments. Hence, the external instrument does not induce the sign or magnitude of the openness coefficient but instead increases the precision with which it is estimated. In column 6 we address the possibility that the significance of $OPEN$ is due to POP having been excluded from the regressors. The results indicate that this is not the case. Instead, it appears that changes in population size matter for inflation volatility only through first inducing a change in openness. As such, POP satisfies the standard requirements of an instrumental variable.

4.1 Robustness: Adding further controls

In this sub-section we investigate the robustness of our basic results to adding further controls. The largest sample for which all of the additional regressors are available consists of 451 observations drawn from 84 countries and this is the sample that we use in each column of Table 2. In order to conserve space we focus on the *System-GMM* estimates.

The first column of Table 2 reproduces the simple specification for the new sample size and yields similar results to those obtained previously, though the size of each coefficient falls slightly due to the loss of observations. In column 2 we control for the natural log of one plus mean inflation (INF) and use as instruments INF_{t-3} and ΔINF_{t-2} (instruments at shorter lags are invalid according to a D-Sargan test). The mean inflation term is highly significant, reflecting the strong correlation between the first two moments of inflation (Ball (1992) presents a theoretical model that explains this relationship). The openness coefficient falls to $-.044$, a little more than half its value in column 4 of Table 1, but owing to the greater precision in the estimation this effect remains significant at the 5% level. Thus, openness reduces inflation volatility even amongst those countries that have the same average inflation rate. The autoregressive parameter is very close to zero after controlling for mean inflation and on deleting the autoregressive term the results are practically unchanged - the openness coefficient remains $-.044$ and the t-ratio is 2.16 (static estimates of all the regressions in columns 2-10 of Table 2 are available on request).[25]

In column 3 we control for the natural log of GDP per capita ($RGDP$) and add the second

for regressor significance.

[25] Although originally proposed for dynamic panel models, the *System-GMM* technique is an efficient estimator for static panels and has often been used in this context, see for example Beck (2002).

lag of that variable to the instruments.[26] This is measured in 1996 US$ and corresponds to the first year from each of the 5 year windows for which inflation volatility is measured. Income per capita may affect volatility if rich countries are able to diversify risk through undertaking indivisible investments (Acemoglu and Zilibotti (1997)), or through setting up more complete capital markets. The effect of per capita income is negative but close to zero. Further (unreported) experimentation showed that this is due to the inclusion of mean inflation in the regression, i.e. the effect of per capita income is entirely mediated through mean inflation. The openness coefficient is further diminished relative to column 1, but is significant at the 6% level.

Column 4 controls for the log product of population and per capita income, $RGDP * POP$, a measure of overall economic size. This is a potentially important control when analysing the effects of openness, see Lane (1997) and Campillo and Miron (1997), but does not alter the overall picture in this instance.

In column 5 we address the possibility that openness exerts a different effect on inflation volatility in the case of primary commodity exporters. Recall that in section 2 we noted that greater openness may increase inflation volatility, or at least reduce it by a smaller amount, if openness implies exposure to large external shocks. Such a scenario is most relevant in the case of primary commodity exporters because the markets in which they participate are relatively volatile, see Baxter and Kouparitsas (2000). The dummy $PRIMEXP$ is equal to unity for primary commodity exporters and zero otherwise (see Appendix B for a precise definition). The results show that the negative impact of openness on inflation volatility is smaller amongst primary commodity exporters. This may be due to increased exposure to global shocks partly offsetting the stabilising effects of greater policy discipline and trade diversification. However, the interaction term is insignificant and the main conclusion is that the overall effect of openness is negative amongst both groups of countries.[27]

The next hypothesis that we explore is that movements in inflation volatility result from changes to the average size of economic shocks. This view is often referred to as the 'good luck' hypothesis in the literature on volatility in the United States, see Ahmed, Levin and Wilson (2002), Stock and Watson (2003). We add the natural log of one plus the decimal standard deviation of annual output growth (VOL) to the model. If smaller supply and demand shocks drive both output and inflation volatility and the link between openness and inflation volatility is coincidental, regression 6 should reveal this fact.

Openness remains significant at the 5% level while output volatility is insignificant. The weak effect of output volatility could be due to supply shocks that reduce output growth and raise inflation. In the aftermath of such shocks a policy authority can trade-off lower inflation volatility for higher output volatility, or vice versa, through shifting the aggregate demand curve. This weakens the positive association between output and inflation variance induced by supply

[26] Unless otherwise stated, regressions $3-9$ use the second lag of the marginal variable as an additional instrument. Additional instruments based on lagged first differences of the marginal terms are not used because we found that in some of the more general specifications the p-value for the Sargan test was very close to unity, which is a sign that the instrument set is too large relative to the model and that estimation may be imprecise.

[27] A caveat that should be added here is that our $PRIMEXP$ variable is time invariant. To the extent that export structures have changed through time it will contain measurement error and the coefficient for $OPEN * PRIMEXP$ will be subject to some attenuation bias.

shocks. In column 7 we address this point using an alternative measure of output volatility, namely the natural log of one plus the decimal standard deviation of the trade weighted mean of output growth in the 5 main trading partners of each country ($TPVOL$). As this measure of output volatility is beyond the control of the domestic policy authority it is more obviously a positive predictor of inflation volatility. This is reflected in the positive and significant effect of $TPVOL$ in column 7 (the large point estimate is due to the standard deviation of $TPVOL$ being very small compared to that of the other variables). We also estimated a model that interacted $TPVOL$ with $OPEN$ in order to allow inflation volatility to be more responsive to foreign GDP volatility in more open economies. This term generated a coefficient of 0.555 (t = 2.03) and the coefficient for $OPEN$ increased in magnitude to $-.050$ (t = 2.43). Hence, our results do not appear to reflect the coincidence of increased trade openness and a decline in the size of shocks to the world economy.

In column 8 we control for the natural log of one plus the black market exchange rate premium (BMP) defined as the percentage markup of the black market exchange rate over the official rate. The rationale is as follows. Suppose that moves towards greater openness and reduced inflation volatility are the result of policy reforms required in return for loans from a body such as the International Monetary Fund (IMF). Such a relationship would not be causal, but merely a by-product of external interventions. The black market premium is a potential indicator of the intensity of reforms because removing obstacles to market clearing is a typical component of IMF sponsored programmes. The fact that the openness coefficient is robust to conditioning on this term provides some evidence that the negative relationship between openness and inflation volatility is not a natural consequence of pro-market reforms (or lack of them) but rather a deeper association that may be linked to the mechanisms previously discussed (later in this section we present further evidence along these lines obtained by omitting the most frequent recipients of IMF and World Bank loans).[28]

In column 9 we control for the natural log of one plus the average rate of economic growth ($GROWTH$), the rationale being that during 'good times' inflation may be more easy to control. The results indicate some evidence of this and the openness effect is diminished such that it is significant at only the 10% level. However, in the next column we pool all of the controls used in Table 2 and find that the $OPEN$ coefficient is significant at the 5% level and of similar magnitude to that estimated in column 2.

We performed a large number of additional robustness checks that we report in appendices. In Appendix C we consider alternative definitions of inflation volatility and openness, while in Appendix D we consider additional controls that are often used in cross-country empirical work - financial depth, the size of FDI and private capital flows, an index of political constraints, government size, climatic volatility, the size of the agricultural sector and the size of the manufacturing sector. The results confirm that the relationship between openness and inflation volatility is robust.

[28] The insignificance of BMP is at first surprising, but turns out to be a consequence of controlling for mean inflation. If mean inflation is removed from column 8 the t-ratio for BMP rises to 1.97.

4.2 The role of the exchange rate regime

In this sub-section we consider the consequences of the exchange rate regime for the relationship between openness and inflation volatility. Textbook arguments suggest that a fixed exchange rate combined with capital mobility forces a country to follow the monetary policy of the country against which its currency is pegged. If discretionary policy is restricted in this way one might expect to observe lower inflation volatility under fixed exchange rates and this could eliminate the relationship between openness and inflation volatility. In related work Alfaro (2005) finds that in a panel setting it is the exchange rate regime rather than openness that explains the level of inflation.

On the other hand fixed rates need not always promote inflation stability. Tornell and Velasco (2000) show that fixed exchange rates may encourage fiscal laxity (potentially leading to volatile inflation) because the costs of such policies occur only after reserves have been exhausted whereas flexible rates imply immediate costs in the form of adverse exchange rate movements. Bleaney and Fielding (2002) present a model in which the effects of the exchange rate regime are non-linear. Fixed rates generally lead to lower inflation volatility but in the case of the most rigid regimes, e.g. the multi-lateral pegs maintained by the Francophone countries in Africa, volatility can increase because the commitment to a peg prevents monetary authorities offsetting the effects of external shocks (Edwards and Levy-Yeyati (2003) present evidence consistent with the latter effect).

In order to investigate these possibilities we consider the de facto exchange rate regime classification proposed by Reinhart and Rogoff (2004). This provides an index in the range $1-4$ where 4 denotes greatest exchange rate flexibility.[29] In contrast to the official IMF classification the Reinhart-Rogoff scheme is based on actual exchange rate movements rather than the policy that the central bank claims to be following, and incorporates information on black market currency exchange in addition to official purchases.[30]

In column 1 of Table 3 we add the exchange rate regime indicator ($XRATE$) to the simple model that controls for openness and lagged inflation volatility and in column 2 we add the square of the exchange rate regime in order to test for non-linearities. The additional control does not alter the role of openness and is insignificant. Adding mean inflation to the column 1 specification induces a negative sign for $XRATE$ that is significant at the 10% level. This may occur because the effect of a fixed exchange rate in restricting discretionary policy is accounted for by mean inflation, leaving a partial effect of $XRATE$ that captures the increases in volatility that can occur if fixed rates restrict stabilisation policies.

A potential problem with these results is that the instruments for $XRATE$ may be ineffective given that it is a discrete variable restricted to the range $1-4$. In column 4 we therefore use

[29] A fifth category is also available but this refers to countries with 'freely falling' rates. One criterion for identifying such cases is an inflation rate above 40%, i.e. a large positive inflation shock automatically places a country in the top tier and therefore this category will be highly endogenous. Consequently we focus on categories $1-4$.

[30] In an important study, Levy-Yeyati and Sturzenegger (2003) propose an alternative de facto classification of the exchange rate regime that utilises information on currency reserves in addition to the nominal exchange rate. However, this index is available for fewer countries than the Reinhart-Rogoff classification. In order to maximise the available sample we use the Reinhart-Rogoff index.

the information on exchange rate regimes in a different way. We restrict the sample to those observations for which the exchange rate regime is classified as a peg or a peg with bands that stretch just 2% either side of the target. Openness retains its significance in this sample of fixed and semi-fixed exchange rates. Such a finding provides some evidence against the hypothesis that our results arise because increased openness is associated with reduced pass-through from exchange rates to consumer prices. Changes in pass-through are unlikely to be an important driver of inflation volatility when exchange rate fluctuations are minimal and therefore the fact that we do not control for shifts in pass-through is unlikely to explain the estimated relationship between openness and inflation volatility.

In columns $5-8$ we side-step the issue of how to instrument the exchange rate regime by reporting simple within groups estimates. The results in column 5 indicate a much stronger positive effect of the exchange rate regime on inflation volatility when the procedure for instrumenting is not applied (the comparison to be made is that with column 1). However, this effect disappears on controlling for mean inflation. In columns 7 and 8 the evidence for a U-shaped relationship between the exchange rate regime and inflation volatility remains weak even though the instrumenting procedure is not applied. In contrast the effect of openness on inflation volatility is quite robust.

4.3 Robustness across sub-samples

Table 5 presents results for a variety of sub-samples. In column 1 we exclude the 5% most extreme values for inflation volatility and openness (2.5% from each tail of each unconditional distribution). This means that Hong Kong and Singapore are omitted from the sample, an important robustness check given that trade ratios may overstate the openness of these countries because many of their imports are for almost immediate re-export. The results show that the effect of openness is robust.

In column 2 we exclude the 38 countries that are not awarded at least a grade C for data quality by Summers and Heston (1988). The 58 countries that remain all belong to the 'good data' sample considered in Romer (1993). Openness is significant at the 5% level, suggesting that our basic findings are not due to low data quality in closed economies inducing spurious inflation volatility.

The next sub-sample that we analyse comprises the 68 low debt countries listed in Terra (1998). Terra argues that the negative relationship between the levels of openness and inflation estimated by Romer (1993) is largely confined to the group of heavily indebted countries and we investigate whether the same is true of the link between openness and inflation volatility. Openness is significant at the 5% level and its coefficient is of similar magnitude to those obtained in Table 2. Hence, it does not appear that the effect of openness on inflation volatility is confined to heavily indebted countries.

In column 4 we omit the 20 countries that maintained an inflation targeting regime during some part of the sample (the dates are taken from Fatas, Mihov and Rose (2004).[31] The

[31] Two countries, South Africa and Thailand, adopted inflation targeting during 2000, the final year of the sample. As a reform occurring in this year is unlikely to affect our results we do not exclude these countries.

openness effect is robust, suggesting that our main results are not due to inflation targeting schemes having caused a reduction in inflation volatility and this reduction in volatility being correlated with openness by chance.

The next hypothesis that we address is that our results arise because structural adjustment programmes associated with IMF and World Bank loans secure both macroeconomic stability and trade openness. In column 5 we exclude 18 countries identified by Easterly (2005) as being amongst the top 20 recipients of IMF and World Bank loans (the other two countries cited, Bangladesh and Mali, are not part of our sample). The negative effect of openness is observed amongst the 78 countries least dependent on structural adjustment loans, suggesting that our basic results do not depend on the effects of IMF and World Bank interventions.

Column 6 focuses on the 71 developing and emerging market economies included in our sample.[32] The results show that the effect of openness on inflation volatility in the developing country sample is significant and of greater magnitude than that obtained using the full sample (and using mean inflation as a control). The opposite is true in column 7, which uses data for the 23 OECD countries excluded from the column 6 sample (the first lag of the first difference of income per capita is added to the instruments used in column 6 because initial estimations produced very imprecise results). The OECD results may arise because there exist reasons to pursue inflation stability in these countries even in the absence of openness, e.g. Posen (1993) emphasises the role of financial sector opposition to inflation in industrial countries. Similarly, production may be more diversified in industrial countries than developing countries, so that the stabilising effects of diversification through trade are smaller (Prasad et al (2004)).

4.4 Robustness to varying the data frequency

In Table 5 we consider the sensitivity of our results to changing the frequency of the data. Column 1 uses a measure of inflation volatility based on 5 year windows but calculated from data at the annual rather than the quarterly frequency. Although quarterly data provide 20 observations with which to calculate volatility in each 5 year window they may be subject to larger measurement errors than annual data. The effect of openness in column 1 is similar to that obtained for equivalent specifications based on quarterly data, however, suggesting that this does not drive our results.

The second column of Table 5 measures inflation volatility using quarterly data and 8 year windows (1961 − 68, 1969 − 76, 1977 − 84, 1985 − 92 and 1993 − 2000) whilst the third column uses 3 year windows (1961 − 63, 1964 − 66, 1967 − 70 .... 1994 − 96, 1997 − 99). If the 5 year window is too short in that shocks to inflation are not given time to dissipate fully then volatility may be understated because a persistent shock to inflation would be recorded as a shift in mean inflation and limited variation around that mean, rather than high variation around a stable mean. On the other hand, if shocks dissipate quickly but there are regular shifts in mean inflation, 5 year

[32] These are the 96 countries in the core sample minus 23 countries that have been OECD members since 1961. Turkey has been an OECD member since 1961, but we include Turkey in the 71 country sub-sample on the grounds that it is best regarded as an emerging market economy. Hong Kong and Singapore are excluded from the column 5 sample even though they are not OECD members; returning these two countries to the sample does not change the results.

windows may be too long in that they span breaks in the mean and therefore identify spurious volatility. The results for alternative window lengths show that the negative effect of openness on inflation volatility is preserved and in each case the relationship is more significant than that obtained using 5 year windows. The AR(1) outcome for the panel based on 8 year windows is puzzling because we expect an MA(1) component in the differenced errors, but this may be due to the test having low power when the sample size is decreased in order to accommodate 8 year windows.

5 Channels linking openness and inflation volatility

In this section we explore potential channels through which openness may decrease inflation volatility. The first mechanism that we discussed in section 2 was that greater openness may lead to more disciplined monetary policy. In order to investigate this hypothesis we augment the inflation volatility regressions with a measure of monetary volatility calculated as the log of one plus the standard deviation of the annual growth rate of money and quasi-money (underlying data are annual). This variable is denoted $VMON$. If greater monetary policy discipline is one of the channels through which openness lowers inflation volatility then on holding constant $VMON$ the effect of openness should diminish. It should be noted that the endogeneity of money with respect to prices is well known and therefore we instrument this term and take care to ensure that the additional instruments pass a D-Sargan test.

The results are reported in Table 6. A constant sample of 344 observations (the largest available for these variables) is used throughout so that the openness coefficients can be compared across columns. The first regression controls for lagged inflation volatility, openness and mean inflation and demonstrates that the effect of openness is similar to that estimated previously. Column 2 adds monetary volatility. The new term is significant at the 5% level while the coefficient multiplying openness is reduced by one third and is insignificant at the 10% level. Hence, there is some evidence that greater monetary policy discipline is one of the channels through which trade openness restricts inflation volatility.

In column 3 we focus on the idea that openness may restrict inflation volatility through promoting greater diversification and dampening terms of trade shocks. The additional covariate ($VTOT$) measures terms of trade volatility and is constructed as the log of one plus the standard deviation of the annual growth rate of the export price deflator relative to the import price deflator. This term is positively signed and significant and its inclusion more than halves the openness coefficient so that it is insignificant at the 25% level. One caveat to note is that whilst openness appears to reduce the average size of terms of trade shocks, it may cause domestic inflation to be more sensitive to those shocks, in which case the overall effect of openness occurring via the terms of trade channel would be ambiguous. The evidence presented here suggests that in combination with the monetary policy channel (and other channels that we may have overlooked) the role of openness in restricting terms of trade volatility dominates any positive effect of openness on inflation volatility arising from greater exposure to shocks.

In column 4 $VMON$ and $VTOT$ are included in the model. Monetary volatility is significant at the 10% level and terms of trade volatility at the 5% level, while the openness coefficient is only a little more than one third its size in column 1. These results suggest that both channels are relevant in explaining the negative impact of openness on inflation volatility. In columns $5-8$ we replicate regressions $1-4$, but include domestic output volatility as a further control. If anything, the role of monetary and terms of trade volatility in accounting for the relationship between openness and inflation volatility is even more powerful in this case.

How does openness affect the intermediate determinants of inflation volatility? In order to further investigate the idea that openness restricts inflation volatility through reducing monetary and terms of trade volatility we present models for these two intermediate measures of volatility in Table 7. In column 1 we report a GMM-SYS estimate of the regression in which monetary volatility depends on its own lagged value and openness. Monetary volatility is a decreasing function of openness and this finding survives the inclusion of a wide range of additional controls in column 2, including the average growth rate of the money supply. Similar results are obtained for terms of trade volatility in columns 3 and 4, in which the openness effect is negative though somewhat more powerful in the specific model than the general model. Overall, these results are consistent with the hypothesis that increased openness reduces inflation volatility through first decreasing monetary and terms of trade volatility.

6 Summary and concluding remarks

In this paper we have examined the panel data evidence linking trade openness and inflation volatility. The econometric approach used pre-determined variables as instruments in order to identify the exogenous variation in openness. The principal finding was that countries that have opened up to trade more rapidly than the global average have experienced relatively large reductions in inflation volatility.

The result is robust to the inclusion of a range of controls, including mean inflation, per capita income, country size, measures of domestic and foreign output volatility, the black market exchange rate premium and the rate of economic growth. We also found that openness reduces inflation volatility even after controlling for the exchange rate regime, indicating that our results are unlikely the by-product of open economies choosing fixed exchange rate regimes and fixed rates delivering inflation stability. Sub-sample regressions were used to cast doubt on scenarios in which our results are induced by outliers, poor data quality, the experiences of heavily indebted countries, the adoption of inflation targeting and IMF or World Bank interventions. Finally, we demonstrated that the negative effect of openness on inflation volatility is robust to measuring volatility over different time intervals.

An important theme of the paper has been the need to pin down the channels linking openness and inflation volatility. Two possibilities were emphasised. Firstly, increased openness may lead to more disciplined monetary policy if governments and central banks believe that inflation volatility is especially costly in open economies, e.g. because it undermines the competitiveness of firms in the tradables sector and leads to uncertainty in real rates of return. Our results showed a weaker link between openness and inflation volatility on holding constant monetary volatility, suggesting that this channel has some relevance. Secondly, openness may lead to greater diversification across production sectors and trading partners, such that the volatility of terms of trade shocks decreases and inflation volatility falls. In combination, these two channels dominate any positive effect of openness on inflation volatility arising from greater exposure to global shocks. Furthermore, the fact that these channels are likely to be stronger in developing countries than industrial countries provides one explanation for the absence of a clear relationship between openness and inflation amongst OECD countries.

The findings presented contribute to the literature in several ways. Firstly, existing research suggests that the effect of openness on the volatility of GDP growth can be either positive or negative depending on the sample and econometric specification. Our paper indicates that the relationship between openness and inflation volatility is more systematic, suggesting that the stabilising effects of increased openness may be stronger for nominal variables than for real variables. Secondly, the results that we present cast light on the mechanisms underpinning some other macroeconomic relationships. Previous work suggests that openness increases growth and per capita incomes (Frankel and Romer (1999)). One channel underpinning this relationship could be that openness restricts inflation volatility, which then boosts investment and growth (Byrne and Davis (2004) and Judson and Orphanides (1999) provide evidence that inflation volatility affects investment and growth respectively).

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Appendix A: List of countries

The 96 countries included in the sample used to estimate the regressions in Table 1 are as follows:

List of countries included in the Table 1 sample		
Algeria	Guatemala	Norway
Argentina	Haiti	Pakistan
Australia	Honduras	Panama
Austria	Hong Kong	Papa New Guinea
Barbados	Iceland	Paraguay
Belgium	India	Peru
Bolivia	Indonesia	Philipines
Burkina Faso	Ireland	Portugal
Burundi	Israel	Rwanda
Cameroon	Italy	Senegal
Canada	Ivory Coast	Sierra Leone
Central African Republic	Jamaica	Singapore
Chad	Japan	South Africa
Chile	Jordan	Spain
Colombia	Kenya	Sri Lanka
Costa Rica	Korea	Sudan
Cyprus	Lesotho	Surinam
Democratic Rep of Congo	Liberia	Swaziland
Dominican Republic	Luxembourg	Sweden
Denmark	Madagascar	Switzerland
Ecuador	Malawi	Tanzania
Egypt	Malaysia	Thailand
El Salvador	Malta	Togo
Ethiopia	Mauritania	Trinidad and Tobago
Fiji	Mauritius	Turkey
Finland	Mexico	Uganda
France	Morocco	Uruguay
Gabon	Niger	United Kingdom
Gambia	Nigeria	United States
Germany	Nepal	Venezuela
Ghana	Netherlands	Zambia
Greece	New Zealand	Zimbabwe

Appendix B: Data sources

Inflation rates are taken from line 64 of the IMF database *International Financial Statistics.*

OPEN: **Openness** measures are taken from the Penn World Tables, version 6.1 (October 2002). The name of the variable used is 'openc'.

POP: **Population** data are taken from the Penn World Tables, version 6.1 (October 2002). The name of the variable used is 'pop'.

RGDP: **GDP** data are taken from the Penn World Tables, version 6.1 (October 2002). The name of the variable used is 'rgdpch'.

PRIMEXP: This variable equals unity for primary commodity exporters and zero otherwise. A primary commodity exporter is a country for which more than 50% of exports are fuels or non-fuel primary commodities, for the period 1988-92. The underlying data are from the World Bank.

VOL: **Output volatility** is calculated from the annual growth rate of real GDP per capita, where real GDP per capita is the GDP variable obtained from version 6.1 of the Penn World Tables (see the definition above).

TPVOL: **Foreign output volatility** is calculated from the trade weighted annual GDP growth rates of a country's trading partners. The source is the IMF's *Direction of Trade Statistics* database.

BMP: **Black market exchange rate premia** are from the World Bank.

GROWTH: **Rates of economic growth** are calculated at the annual frequency using the *RGDP* series described above.

XRATE: **The exchange rate regime** index is taken from Reinhart and Rogoff (2004).

VMON: **Monetary volatility** is calculated from the annual growth rate of money and quasi-money. The source is *World Development Indicators.*

VTOT: **Terms of trade volatility** is calculated from the annual growth rate of the terms of trade, defined as the ratio of export prices to import prices. The source is *World Development Indicators.*

PRIVY: **Private credit to GDP ratio** is taken from Beck, Demirguc-Kunt and Levine (1999).

GOV: **Government consumption** data are taken from *World Development Indicators.* The data measure general government consumption expenditure as a percentage of GDP. This is the measure of government size recommended by Fatas and Mihov (2003).

FDI: **Foreign direct investment** data are taken from *World Development Indicators.*

CAPFLOWS: **Private capital flows relative to GDP** are taken from *World Development Indicators.*

PCI: **Political constraints index** is taken from Henisz (2000).

CLIMVOL: **Climatic volatility** is calculated from data on precipitation anomalies supplied by the Earth Institute at Columbia University.

AGRI: **The share of agriculture in GDP** is taken from *World Development Indicators.*

MANUF: **The share of manufacturing in GDP** is taken from *World Development Indicators.*

Appendix C: Results using alternative measures of inflation volatility

In this appendix we consider alternative measures of inflation volatility and openness. In column 1 of Table A1 we estimate the full sample regression using $\ln(sd(\text{inf}))$ as the dependent variable, where inf is a number such as 3 (in the main text the dependent variable is $\ln(1+sd(\frac{\text{inf}}{100})))$. The sample falls to 530 because the INF term in this regression is $\ln(mean(\text{inf}))$, which is undefined in the 8 instances in which mean inflation is negative. The coefficient multiplying openness is much larger than in comparable specifications from the main text due to the change in the units for the dependent variable, but the statistical significance of the estimate is very robust.

In column (2) we measure inflation volatility as $sd(\ln(1+\frac{\text{inf}}{100}))$. This measure is the volatility of a log rather than the log of a volatility and is intended to address the possibility that the standard deviation may be a poor measure of volatility when then there are sudden blips in the inflation rate. Applying the log transform before taking the standard deviation downweights these outliers before they are squared in order to calculate the standard deviation, and therefore reduces their effect on the dependent variable. The absolute value of the openness coefficient is smaller than those obtained in comparable specifications in Table 2 of the main text, reflecting the downweighting of extreme observations. However, the estimate is also more precise and therefore achieves significance at the 5% level.

In column (3) the dependent variable is that used in the main text but $OPEN$ is measured as the log import share in GDP, rather than the log of the total trade share. This is the measure of openness used by Romer (1993). The results are slightly weaker using this narrower measure of openness, suggesting that the size of the export sector is relevant in determining inflation volatility (this is to be expected on the basis of the discussion that we provide in section 2). Nevertheless, the effect is significant at the 5% level.

Appendix D: Results using additional controls

In this appendix we report models incorporating additional controls. As some of the variables are observed only from the mid-1970s or for just a subset of countries, maintaining a constant sample across the columns of Table A2 would mean discarding a large amount of information in some cases and therefore we allow the sample to fluctuate. Column 1 adds the log ratio of private to credit to GDP ($PRIVY$). This is interpreted as a proxy for financial development which may reduce volatility through allowing agents to smooth expenditures following income shocks. Easterly et al (2001) provide evidence that financial development decreases output volatility, though the results of Beck et al (2005) are less clear cut. In models for inflation volatility financial depth is insignificant while openness is significant at the 10% level but has a smaller coefficient than in Table 2.

Columns 2 and 3 address the role of financial openness in setting inflation volatility by controlling for the log of one plus gross foreign direct investment as a decimal fraction of GDP (FDI) and the log ratio of private capital flows to GDP ($CAPFLOWS$) respectively. In both cases the proxies for financial openness are insignificant. This is consistent with the potentially ambiguous effect of financial openness on volatility - recall that Aghion et al (2004) show that foreign investments can be pro-cyclical and therefore amplify volatility, rather than restrict it through compensating for the absence of well functioning domestic credit markets. In contrast, the role of trade openness remains intact.

In column 4 we control for the political constraints index (PCI) derived by Henisz (2000), which is inversely related to the ability of individual actors to bring about a change in government policy, and in column 5 we control for the log ratio of government spending to GDP (GOV). Political constraints may reduce inflation volatility through restricting discretionary policy interventions, while large governments may stabilise economic activity if state spending is counter-cyclical, while taxation is pro-cyclical (Fatas and Mihov 2003). In both cases the role of openness in restricting inflation volatility is unaltered, while the additional controls are insignificant. Column 6 controls for the log of one plus an index of climatic volatility ($CLIMVOL$) defined as the root mean square of monthly precipitation anomalies, and calculated by the Earth Institute at Columbia University. The role of openness is robust to controlling for this measure of climatic shocks.

Finally, columns 7 and 8 control for the log share of agriculture in GDP ($AGRI$) and the log share of manufacturing in GDP ($MANUF$). The key hypothesis of interest here is that state lead industrialisation programmes may be the main driver of diversification and reduced inflation volatility in many developing nations, and controlling for this channel could affect the relationship between openness and inflation volatility. The column 8 results show a weak negative effect of the size of the manufacturing sector on inflation volatility, but this does not eliminate the relationship between openness and inflation volatility.

FIGURE 1: INFLATION VOLATILITY AND OPENNESS, 1971-2000

	N	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00
Inflation Volatility							
All	51	6.383	4.428	5.103	5.932	6.0258	3.737
Developing	26	7.866	5.928	7.284	10.113	10.292	6.360
Low-income[b]	9	8.410	6.813	6.907	12.527	13.321	6.721
Primary Commodity Exporters[a]	5	6.185	5.688	5.253	7.968	8.139	2.744
Sub-Saharan Africa	6	7.609	6.625	8.867	15.145	16.106	6.982
Latin America & Caribbean	13	8.170	6.338	7.456	11.365	11.621	8.072
South Asia	3	8.514	6.292	4.237	3.270	2.663	3.991
Middle East & North Africa	5	6.210	4.372	3.820	2.985	2.931	1.929
East Asia & Pacific	6	7.132	2.894	5.302	2.626	1.617	1.439
W. Europe & N. America	18	4.127	2.532	2.583	1.302	1.514	0.750
Trade Openness							
All	51	60.008	69.389	69.319	69.230	74.558	73.497
Developing	26	48.304	57.041	52.300	54.560	64.727	68.390
Low-income[b]	9	42.554	49.477	42.810	42.705	51.650	54.657
Primary Commodity Exporters[a]	5	51.643	59.707	53.051	55.026	66.184	72.654
Sub-Saharan Africa	6	50.079	56.049	47.777	47.755	57.753	58.737
Latin America & Caribbean	13	50.138	59.228	52.272	56.778	65.157	67.067
South Asia	3	30.0407	39.376	38.954	37.294	44.443	47.382
Middle East & North Africa	5	66.069	76.911	77.684	76.970	83.871	79.457
East Asia & Pacific	6	82.875	105.662	109.219	110.306	118.645	85.140
W. Europe & N. America	18	65.850	72.149	78.774	75.194	74.685	82.523

Notes:

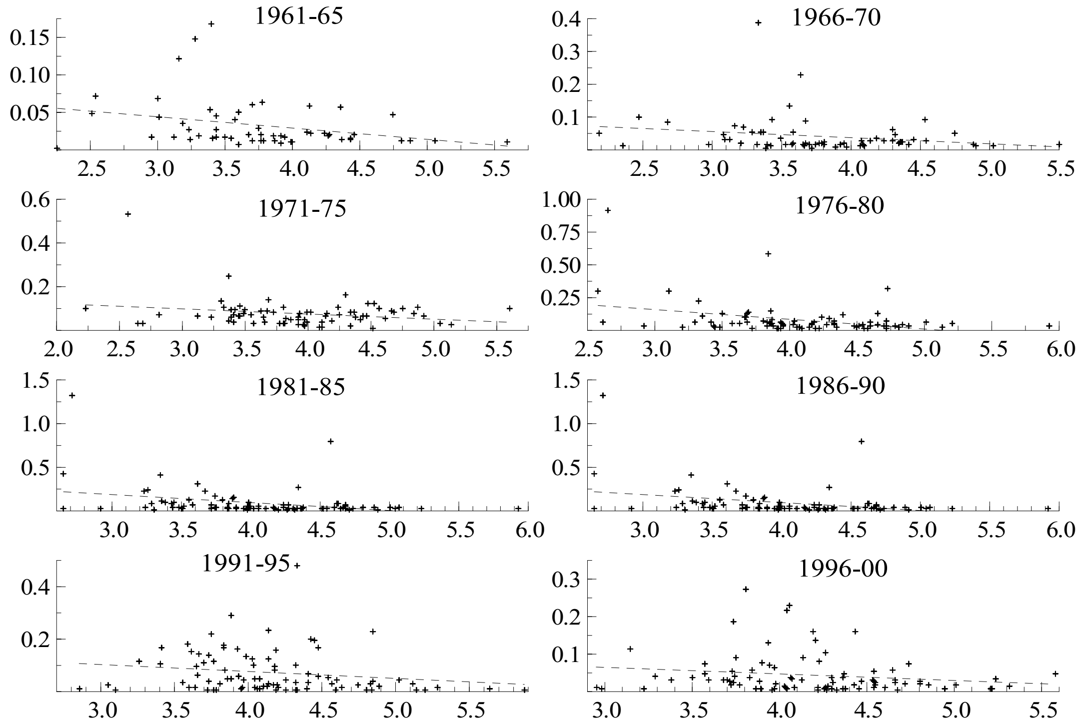
Inflation volatility is the standard deviation of annual percentage inflation at the quarterly frequency

Regions defined on the basis of World Bank classifications.

a. Based on the World Bank classification of fuel and non-fuel primary exporters. Major exports are those that account for 50 percent or more of total exports of goods and services from one category in the period 1988-92 (non-fuel primary exports: SITC 0, 1, 2, 4 and 68; fuel exports: SITC3)
b. The low income group is a sub-set of the developing country group and is based on World Bank classifications

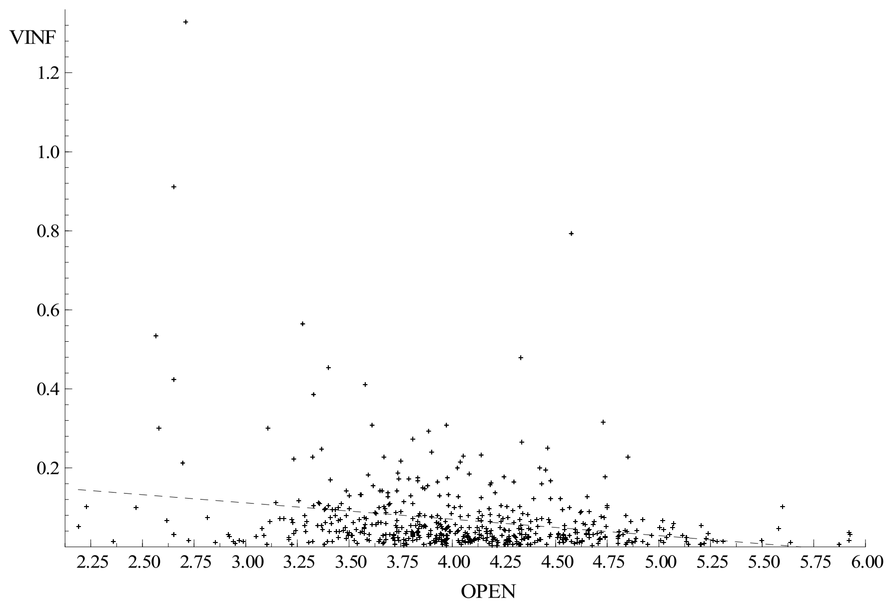
Trade openness is exports plus imports as a percentage of GDP

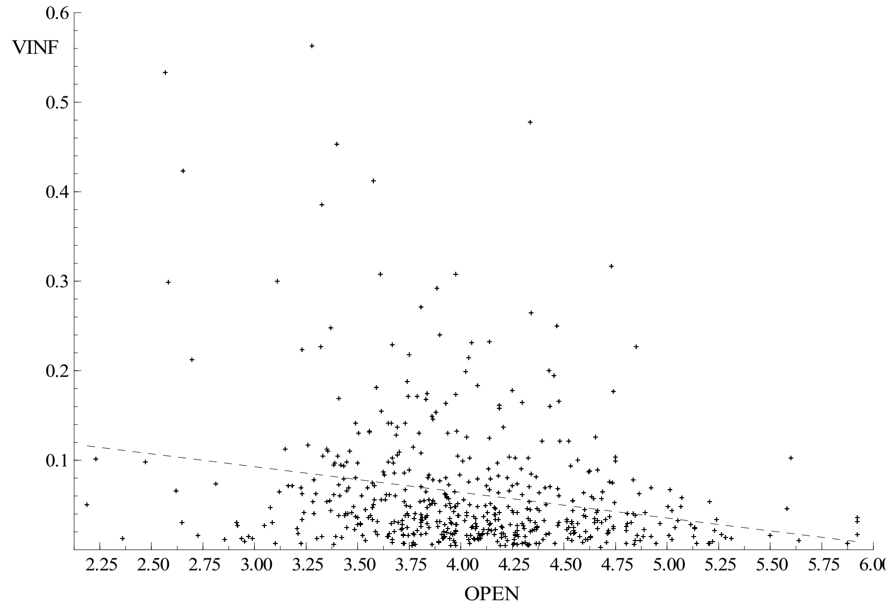
FIGURE 2: CROSS-COUNTRY PLOTS FOR OPENNESS (X-AXIS) AND INFLATION VOLATILITY (Y-AXIS) FOR EIGHT 5 YEAR WINDOWS, 1961-200



Notes: Openness (X-axis) is the log of exports plus imports as a percentage of GDP. Inflation volatility (Y-axis) is the log of one plus the decimal standard deviation of quarterly observations on the annual inflation rate.

Figure 3: Scatter Plots for Openness (x-axis) and Inflation Volatility (y-axis)





Notes: Inflation volatility (VINF) is the log of one plus the decimal standard deviation of quarterly observations on the annual inflation rate. Openness (OPEN) is the log of exports plus imports as a percentage of GDP. The left-hand side graphs plots the 538 observations used to fit column 4 of Table 1. The right-hand side graph is the same except that the three largest readings for inflation volatility are omitted.

TABLE 1: BASIC RESULTS

	DEPENDENT VARIABLE∝ *Inflation volatility (VINF)*					
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
	OLS	*WG*	*GMM*	*System*	*System*	*System*
$VINF_{t-1}$	.737	.384	.530	.581	.729	.587
	(4.13)	(1.91)	(2.36)	(3.28)	(2.82)	(3.06)
OPEN	-.021	-.056	-.124	-.086	-.111	-.104
	(2.58)	(2.51)	(1.94)	(2.34)	(1.03)	(2.48)
POP						-.001
						(0.09)
	DIAGNOSTIC TESTS (P-VALUE)					
SERIAL CORR. TESTS						
First-Order	0.632	0.113	0.017	0.000	0.001	0.005
Second-Order	0.196	0.017	0.762	0.658	0.579	0.826
Sargan	-	-	*0.547*	*0.348*	*0.403*	*0.336*
	Difference-Sargan statistics for column (4): VINF(0.20) OPEN(0.76) POP(0.34)					
NT	538	538	442	538	538	512
	INSTRUMENTS					
	VINF(t-2) OPEN (t-2) POP(t-2, t-3)					
	Instruments for level equations : æOPEN (t-1) æPOP(t-2)					

Notes:
Estimates are based on a sample of 96 countries, with at least 3 time observations available for each country. Period dummies are included in all specifications (but are not reported) and are also part of the instrument set. Numbers in parentheses are absolute t-statistics based on robust standard errors.

OLS denotes ordinary least squares, WG denotes within groups, GMM denotes 1-step generalised method of moments estimation of the first differenced equation and System denotes 1-step joint generalised method of moments estimation of the first differenced and levels equations.

The Sargan and Difference-Sargan tests of over-identifying restrictions are based on 2-step GMM estimates in order to correct for heteroscedasticity and are asymptotically distributed as Û2(*n* ĭ *p*), where *n* is the number of moment conditions and *p* is the number of parameters. The serial correlation tests are asymptotically distributed as *N(0,1)* under the null of no serial correlation.

Table 2: Additional Controls

	Dependent variable∝ *Inflation volatility* (*VINF*)									
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
$VINF_{t-1}$	.367	.020	.007	.002	-.002	.013	.016	.026	-.023	-.030
	(2.01)	(0.33)	(0.10)	(0.03)	(0.03)	(0.22)	(0.27)	(0.44)	(0.43)	(0.54)
OPEN	-.064	-.044	-.037	-.040	-.045	-.046	-.040	-.045	-.028	-.040
	(2.02)	(2.19)	(1.92)	(2.15)	(2.35)	(2.27)	(2.17)	(2.41)	(1.84)	(2.16)
INF		.609	.609	.610	.589	.629	.604	.608	.579	.603
		(9.51)	(9.46)	(9.50)	(8.43)	(10.60)	(9.20)	(9.34)	(6.89)	(9.32)
RGDP			-.003							.003
			(0.47)							(0.28)
*RGDP*POP*				-.004						.003
				(0.67)						(0.29)
*PRIMARY*OPEN*					.007					.010
					(0.97)					(0.89)
VOL						.304				.052
						(1.13)				(0.23)
TPVOL							2.498			1.435
							(2.03)			(1.38)
BLACK MARKET								.001		-.025
								(0.04)		(1.14)
GROWTH									-.465	-.416
									(1.86)	(1.64)
	Diagnostic tests (p-value)									
Serial Corr. Tests										
First-Order	0.002	0.001	0.001	0.001	0.001	0.001	0.004	0.001	.003	.004
Second-Order	0.765	0.364	0.350	0.355	0.351	0.228	0.299	0.393	.129	.107
Sargan	*0.174*	*0.248*	*0.245*	*0.387*	*0.246*	*0.537*	*0.161*	*0.187*	*.306*	*.827*
Diff-Sargan		*0.91*	*0.52*	*0.75*	*0.66*	*0.82*	*0.20*	*0.20*	*.319*	
NT	451	451	451	451	451	451	451	451	451	451

See notes to Table 1. The instruments in column 1 are as in Table 1 except that in the first half of the system *OPEN(t-2, t-3)* is used. In columns 2-10 the additional instrument is the marginal regressor at *t-2*, except for the variables *INF* and *GROWTH* for which *t-3* is used. Also, æ*INF(t-2)* is used to instrument the levels equations in columns that control for *INF*. Column 6 uses æ*VOL(t-2)* as an instrument in the second half of the system. *Diff-Sargan* tests the validity of moment conditions based on the marginal instruments.

TABLE 3: THE ROLE OF THE EXCHANGE RATE REGIME

	DEPENDENT VARIABLE∝ *Inflation volatility* (*VINF)*							
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
	System	*System*	*System*	*System*	*WG*	*WG*	*WG*	*WG*
$VINF_{t-1}$	.435	.426	.089	-.113	.261	.080	.269	.083
	(2.26)	(2.29)	(1.58)	(0.80)	(2.22)	(2.07)	(2.26)	(2.10)
OPEN	-.060	-.058	-.032	-.042	-.022	-.035	-.019	-.034
	(2.31)	(2.30)	(1.87)	(2.03)	(2.01)	(3.37)	(1.66)	(3.22)
INF			.624	.350		.615		.613
			(10.30)	(2.02)		(11.40)		(11.50)
XRATE	.004	-.030	-.009		.019	.002	-.013	-.007
	(0.38)	(0.59)	(1.89)		(3.30)	(0.85)	(0.54)	(0.59)
XRATE squared		.008					.007	.002
		(0.70)					(1.18)	(0.69)
	DIAGNOSTIC TESTS ***(p-value)***							
SERIAL CORR. TESTS								
First-Order	0.004	0.005	0.002	0.004	0.065	0.016	0.065	0.018
Second-Order	0.597	0.629	0.277	0.301	0.051	0.000	0.053	0.000
Sargan	*0.232*	*0.196*	*0.468*	*0.664*	-	-	-	-
Diff-Sargan	0.580	0.570	-	-	-	-	-	-
NT	456	456	456	286	456	456	456	456
	INSTRUMENTS							
	VINF(t-2) OPEN (t-2) POP(t-2, t-3) INF(t-3) XRATE(t-2)							
	Instruments for level equations : æOPEN (t-1) æPOP(t-2) æINF(t-2) XRATE(t-1)							

See notes to Table 1.

Diff-Sargan tests the validity of the moment conditions based on *XRATE*. Columns (1) and (2) exclude the instruments for *INF*, since *INF* is not included in the explanatory variables in those regressions. Column (4) excludes the XRATE instruments because XRATE is not included in the explanatory variables in that regression.

TABLE 4: SUB-SAMPLE ANALYSIS

	DEPENDENT VARIABLE∝ *Inflation volatility* (*VINF)*						
	System GMM Estimates						
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
	Extreme obs omitted	*Good data*	*Low debt*	*No inflation targeters*	*Min IMF intervention*	*Non-OECD*	*OECD*
$VINF_{t-1}$	.022	.075	-.038	.072	.069	-.63	.162
	(0.31)	(1.05)	(0.62)	(0.75)	(1.10)	(0.87)	(1.17)
OPEN	-.042	-.029	-.041	-.040	-.047	-.059	-.010
	(2.17)	(2.07)	(2.10)	(2.02)	(2.08)	(2.47)	(1.33)
INF	.425	.629	.432	.619	.478	.634	.179
	(7.28)	(9.98)	(3.99)	(7.48)	(6.64)	(10.10)	(1.67)
	DIAGNOSTIC TESTS *(p-value)*						
SERIAL CORR. TESTS							
First-Order	0.000	0.086	0.007	0.001	0.002	0.000	0.074
Second-Order	0.568	0.227	0.907	0.265	0.792	0.271	0.612
Sargan	*0.483*	*0.324*	*0.161*	*0.678*	*0.572*	*0.794*	*1.000*
NT	478	353	402	413	452	376	154
	INSTRUMENTS						
	VINF(t-2) OPEN (t-2, t-3) POP(t-2, t-3) INF(t-3)						
	Instruments for level equations : æOPEN (t-1) æPOP(t-2) æINF (t-2)						

See notes to Table 1.

The instrument set varies slightly across columns. Col (2) omits *OPEN(t-2)* and æ*POP (t-2)*. Col (6) omits *OPEN(t-3)* and æ*POP (t-2)*. Col (7) omits *OPEN (t-3), POP(t-3)* and æ*OPEN (t-1)* but includes æ*RGDP (t-1)*.

TABLE 5: VARYING THE DATA FREQUENCY

DEPENDENT VARIABLE∝ *Inflation volatility (VINF)*			
	System GMM Estimates		
	(1)	(2)	(3)
	Measure volatility using annual data	*Quarterly data and eight year windows*	*Quarterly data and three year windows*
$VINF_{t-1}$	-.116	.053	.052
	(1.21)	(0.21)	(0.95)
OPEN	-.053	-.103	-.069
	(2.07)	(2.74)	(2.63)
INF	.593	.494	.551
	(7.72)	(3.07)	(4.16)
	DIAGNOSTIC TESTS *(p-value)*		
SERIAL CORR. TESTS			
First-Order	0.002	0.724	0.069
Second-Order	0.213	0.800	0.690
Sargan	*0.546*	*0.549*	*0.576*
NT	*538*	272	967
	INSTRUMENTS		
	VINF(t-2) OPEN (t-2, t-3) POP(t-2, t-3) INF(t-3)		
	Instruments for level equations : æOPEN (t-1) æPOP(t-2) æINF(t-2)		

See notes to Table 1.
Column (1) excludes æ*POP (t-2)* from the instrument set.

TABLE 6: PROBING DEEPER FOR POSSIBLE CHANNELS

	DEPENDENT VARIABLE∝ *Inflation volatility* (*VINF*)							
	System GMM Estimates							
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
$VINF_{t-1}$	.032	-.016	.020	-.002	.014	-.026	.007	-.011
	(0.61)	(0.36)	(0.41)	(0.96)	(0.26)	(0.60)	(0.15)	(0.25)
OPEN	-.040	-.027	-.018	-.015	-.048	-.032	-.025	-.019
	(2.05)	(1.60)	(1.14)	(1.05)	(2.38)	(1.83)	(1.58)	(1.33)
INF	.500	.424	.491	.423	.516	.436	.500	.430
	(8.15)	(5.09)	(9.51)	(5.70)	(8.79)	(5.20)	(9.65)	(5.81)
VMON		.304		.224		.290		.218
		(1.96)		(1.71)		(1.92)		(1.72)
VTOT			.239	.193			.351	.188
			(2.55)	(2.45)			(1.78)	(2.42)
VOL					.500	.196	.222	.135
					(2.31)	(1.14)	(2.43)	(0.84)
	DIAGNOSTIC TESTS ***(p-value)***							
SERIAL CORR. TESTS								
First-Order	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001
Second-Order	0.708	0.562	0.835	0.677	0.369	0.493	0.641	0.626
Sargan	*0.546*	*0.964*	*0.694*	*0.990*	*0.739*	*0.985*	*0.856*	*0.999*
Diff-Sargan	-	1.00	0.76	-	-	-	-	-
NT	344	344	344	344	344	344	344	344
	INSTRUMENTS							
	VINF(t-2 t-4) OPEN(t-2) POP(t-2, t-4) INF(t-3 t-4) VMON(t-2, t-4) VTOT(t-2) VOL(t-2)							
	For level equations : æOPEN (t-1) æPOP(t-2) æINF(t-2) æVMON (t-1) æVTOT(t-1)							

See notes to Table 1.
Instruments for mean inflation, monetary volatility, terms of trade volatility and output volatility are used only in equations in which those terms are included in the regressors.

TABLE 7: A CLOSER LOOK AT THE INTERMEDIATE CHANNELS

DEPENDENT VARIABLE∝ *Inflation volatility* (*VINF*)				
	System GMM Estimates			
	(1)	(2)	(3)	(4)
Dependent variable	*VMON*	*VMON*	*VTOT*	*VTOT*
OPEN	-.067	-.053	-.134	-.070
	(2.02)	(2.18)	(2.82)	(1.96)
$VMON_{t-1}$	.138	-.058		
	(1.66)	(0.89)		
$VTOT_{t-1}$			.004	-.032
			(0.04)	(0.40)
MON		.422		
		(3.95)		
TOT				.454
				(2.93)
VOL		.487		.432
		(1.18)		(1.32)
RGDP		.006		.009
		(0.48)		(0.45)
*POP*RGDP*		-.015		-.029
		(1.45)		(1.48)
GROWTH		-1.119		.143
		(1.92)		(0.34)
BMP		-.053		.069
		(1.53)		(1.71)
	DIAGNOSTIC TESTS *(p-value)*			
SERIAL CORR. TESTS				
First-Order	0.008	0.002	0.000	0.000
Second-Order	0.450	0.324	0.524	0.409
Sargan	*0.735*	*0.890*	*0.203*	*0.749*
NT	*376*	326	466	421
	INSTRUMENTS			
	VMON(t-2,t-3) VTOT(t-2,t-3) OPEN (t-2,t-3) POP(t-2, t-3)			
	For level equations : æOPEN (t-1) æPOP(t-2) æVMON(t-1) æVTOT(t-1)			

See notes to Table 1.
Columns (2) and (4) use the second lags of each of the extra variables included in those equations as additional instruments for the first differenced equations. Columns (3) and (4) use æ*POP(t-1)* rather than æ*POP(t-2)*.

APPENDIX TABLES

TABLE A1: ALTERNATIVE MEASURES OF OPEN AND VINF

DEPENDENT VARIABLE∝ *Inflation volatility (VINF)*			
	System GMM Estimates		
	(1)	(2)	(3)
	Dependent variable is ln sd(100inf)	*Dependent variable is sd(ln (1+inf))*	*Openness is the import share in GDP*
$VINF_{t-1}$	.255	.064	-.015
	(2.67)	(0.75)	(0.25)
OPEN	-.559	-.038	-.037
	(2.44)	(2.42)	(2.03)
INF	.708	.312	.640
	(6.94)	(7.71)	(12.20)
	DIAGNOSTIC TESTS *(p-value)*		
SERIAL CORR. TESTS			
First-Order	0.000	0.000	0.000
Second-Order	0.290	0.387	0.219
Sargan	*0.177*	*0.360*	*0.386*
NT	*530*	538	538
	INSTRUMENTS		
	VINF(t-2) OPEN (t-2, t-3) POP(t-2, t-3) INF(t-3)		
	For level equations : æOPEN (t-1) æPOP(t-2) æINF(t-2)		

See notes to Table 1.

Table A2: Controls not Considered in the Main Text

	Dependent variable∝ *Inflation volatility* (*VINF*)							
	System GMM Estimates							
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
$VINF_{t-1}$	-.025	.007	.005	-.033	.044	-.004	.004	-.055
	(0.26)	(0.10)	(0.07)	(0.50)	(0.79)	(0.07)	(0.06)	(0.63)
OPEN	-.029	-.061	-.063	-.038	-.039	-.044	-.033	-.061
	(1.86)	(2.64)	(2.86)	(1.94)	(2.25)	(2.10)	(1.97)	(2.33)
INF	.614	.604	.608	.618	.545	.628	.614	.640
	(8.60)	(9.98)	(10.60)	(10.40)	(9.63)	(10.90)	(9.58)	(7.56)
PRIVY	-.004							
	(0.22)							
FDI		-.003						
		(0.01)						
CAP FLOWS			.001					
			(0.14)					
PCI				.012				
				(0.28)				
GOV					.018			
					(0.82)			
CLIM VOL						-.0829		
						(0.66)		
AGRI							-.002	
							(0.30)	
MANUF								-.045
								(1.16)
	Diagnostic Tests *(p-value)*							
Serial Corr. Tests								
First-Order	0.001	0.004	0.005	0.001	0.001	0.000	0.002	0.001
Second-Order	0.359	0.148	0.110	0.215	0.497	0.249	0.481	0.252
Sargan	*0.344*	*0.514*	*0.671*	*0.348*	*0.552*	*0.462*	*0.121*	*0.377*
Diff-Sargan	-	*0.790*	*0.300*	*0.620*	*0.910*	*0.280*	*0.052*	0.330
NT	497	408	372	536	513	487	474	383
	Instruments							
	VINF(t-2) OPEN (t-2,t-3) POP(t-2,t-3) INF(t-3)							
	For level equations : æOPEN(t-1) æPOP(t-2) æINF(t-2)							

See notes to Table 1.

Each column uses the second lag of the additional regressor included in that equation as an instrument for the first differenced equation. Column (1) adds an extra lag of each variable to the instruments used for the first differenced equations and drops æ*POP(t-2)* from the instruments for the levels equations. Column (7) uses the fourth lag of agriculture in the instruments because the second lag led to a rejection on the Difference-Sargan test. Column (8) omits æ*POP(t-2)* from the instruments.