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Spiliopoulos, Leonidas

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Leonidas Spiliopoulos

Abstract Bayesian model averaging is applied to robustly ascertain the determinants of various output volatility measures, including the downside semideviation of growth rates. Financial sophistication variables are found to have qualitatively different effects on volatility. The ratio of government expenditure to GDP exhibited a significant positive relationship with volatility and the trade share of GDP was positively related for a balanced dataset of developed and developing countries between 1960-89, and negatively related for developing countries between 1974-89. Other significant determinants were the black market premium, civil liberties, political rights, rule of law, and ratios of short-term debt and taxation to GDP.

Keywords Macroeconomic volatility, Growth, Government policy, Bayesian model averaging, Model selection

JEL codes C11, C52, E32, E60, F00, O47

Hong Kong University of Science and Technology
E-mail: leonidas.spiliopoulos@uni.sydney.edu.au

1 Introduction

There are numerous reasons why research into the determinants of output volatility is important, especially for developing countries which exhibit significantly greater output volatility than developed countries. Volatility in growth rates creates economic uncertainty impacting future growth rates negatively as first documented in Ramey and Ramey (1995). Also, assuming that agents in the economy are risk-averse, volatility in growth rates and therefore income produces adverse real welfare effects. The effects of volatility on welfare can be significant, even reaching 5-10 percent of consumption (Athanasoulis and Van Wincoop, 2000). A better understanding of the causes of volatility can lead to more effective government policy that directly addresses the long term, underlying causes of volatility instead of relying only on fiscal policy which is an ex post attempt to temporarily reduce short-run volatility. Readers are referred to Loayza et al (2007) for an overview of macroeconomic volatility, possible causes and welfare effects for developing countries.

The macroeconomic literature is rife with econometric studies on the determinants of the growth rates of economies (Barro and Sala-i-Martin, 1995; Temple, 2000; Levine and Renelt, 1992; Levine et al, 2000) to name but a few. The initial phase of research focused on specific types or subsets of variables and their effects on growth rates, for example variables of financial sophistication. These studies usually attempt to address the issue of robustness of their results in the face of model specification uncertainty by conditioning on other variables considered to be significant. Despite this, the majority of studies used relatively small, non-overlapping subsets of variables in the growth regressions estimated, so that it was common to find disagreement amongst different studies as to the effect of certain variables upon growth rates.[1]

The second phase of this research was driven by the application of various econometric techniques designed to specifically address model specification. The first attempt by Levine and Renelt (1992) was based on a variant of a frequentist approach, Extreme Bounds Analysis (EBA) recommended by Leamer (1983). This involved estimating models of all possible combinations of variables and concluding that a variable's relationship with the growth rate is considered robust if at the extreme bounds the coefficient remains significant and of the same sign. Sala-i-Martin (1997) relaxes the strictness of the EBA approach by examining the whole distribution of the estimated coefficients instead of only their values at the extreme bounds. Kalaitzidakis et al (2002) follow a

[1] Of course the conflicting results were not just due to different conditioning sets but also due to the use of different datasets which included different countries and/or time periods.

different approach focusing on the estimated coefficients of models that are well specified according to non-nested hypothesis tests. With the increase in computational power and associated decrease in computational cost, the literature turned to either approximate Bayesian techniques (Sala-i-Martin et al, 2004) or Bayesian Model Averaging (Fernandez et al, 2001) for a more statistically rigorous analysis of model specification. Finally, Ley and Steel (2009) and Eicher et al (2007) examine the robustness of Bayesian Model Averaging techniques with respect to the alternative specifications over priors.

The current state of the literature on the determinants of volatility parallels the first phase of the growth literature, as it is comprised of a number of studies using very different and specific subsets of variables with often diametrically opposite conclusions. The effects of financial variables on growth volatility are addressed in Easterly et al (2001); Denizer et al (2000); Ferreira da Silva (2002), of trade/openness variables in Frankel and Rose (1998); Anderson et al (1999); Bejan (2006); Hakura (2007); Di Giovanni and Levchenko (2009); Cavallo (2007), of fiscal policy and government size in Van den Noord (2000); Fatas and Mihov (2001); Virén (2005) and of the role of institutions in Mobarak (2005); Malik and Temple (2009).

It is our contention that the evolution of this literature now calls for studies that specifically address model specification and uncertainty. Hence, this paper will use the latest Bayesian Model Averaging techniques in order to ascertain the robustness of a large set of possible determinants of volatility. This paper will also contend that a more relevant measure of volatility is the downside semideviation (the standard deviation of growth rates below the mean growth over the time period in question) as risk is more closely associated with the volatility of undesirable outcomes. Finally, the datasets employed include variables rarely or never investigated in the literature such as measures of different types of taxation and short/long term government debt.

The expositional structure of the paper follows. A literature review of both theoretical and empirical work regarding the determinants of volatility follows directly in Section 2. The BMA methodology is presented in Section 3.1, followed by a discussion of the dataset and of the various measures of volatility in Section 3.2. The following sections discuss the results using a dataset of 60 countries from 1960-89. Section 4.1 concerns the determinants of downside semideviation volatility, whilst Section 4.2 compares the results with other measures of volatility. The forecasting performance of the BMA technique is contrasted to that of other modeling techniques in Section 4.3. The determinants of the downside semideviation volatility for non-OECD countries are examined in Section 4.4. Finally, Section 4.5 investigates the determinants of downside semideviation volatility for a dataset including the years 1974-89 for 50 countries but with a broader range of explanatory variables than the previous dataset. Section 5 concludes, whilst Appendix A discusses the robustness of the results with respect to different priors and Appendix B contains information about the countries and variables included in the dataset.

2 Literature review

There exists less theoretical research compared to empirical research regarding the determinants of volatility. Aghion et al (1999) show that if there exists a high degree of physical separation between investors and savers, and there exist capital market imperfections in the sense that borrowers are constrained as to how much they can borrow from savers, then the economy may cycle around its long run steady state growth rate. Hence, according to this theory proxies of financial market sophistication should be included as determinants of volatility and the relationship between financial sophistication and volatility is negative. Acemoglu and Zilibotti (1997) in their model show that in the early states of development of an economy with capital scarcity and investment project indivisibility, economic agents will not be able to diversify away risk effectively as they can only invest in a limited number of imperfectly correlated investment projects. The theoretical predictions of these two papers are supported empirically by Ferreira da Silva (2002) who discovers that financial variables proxying for financial development and real GDP per capita are negatively related to output, investment and consumption volatility.

However, a positive relationship between financial sophistication and volatility can also be defended. For example, more sophisticated and larger financial markets can channel more credit to the economy leading to greater leverage and volatility. Also, if more credit is available then the resulting lower interest rates will lead to an increase in the average risk of investments in the economy as the quality of the marginal investments undertaken will be lower.

Easterly et al (2001) find evidence for a non-linear relationship between financial sophistication and volatility exhibiting both a negative and positive relationship with volatility. The ratio of private credit to GDP was initially found to reduce volatility up to a certain degree of financial sophistication but thereafter was found to exacerbate volatility. Also, they find that countries with greater trade openness suffer from greater volatility as they are more exposed to foreign shocks.

Investigating the link between financial openness and volatility over time Buch et al (2005) conclude that the relationship is unstable and that the dependence is influenced by the type of underlying shock to the economy e.g. the effect of interest rate volatility is enhanced in open financial markets, whilst the effect of volatility of government spending is reduced. Equity market liberalization is found to be negatively related to both GDP and consumption volatility (Bekaert et al, 2006), although the magnitude of the effect is reduced for a dataset including the South East Asian crisis.

The literature relating trade openness to volatility has not been able to conclusively agree on the direction of the effect, with many studies also advocating that the effects of openness on volatility could depend on the wealth of a country. The most prominent argument put forth for a negative relationship for developing countries is that based on the stylized fact that trading partners' business cycles are more synchronized the higher the level of trade between them (Anderson et al, 1999). Since developing countries that are more open will tend to trade with developed countries, they will benefit from synchronizing their economies closely to developed countries which exhibit significantly lower volatility. A further observation is that export sectors will be correlated less with the domestic economy thereby further reducing volatility. Cavallo (2007) argues that more open countries are deemed to be more creditworthy and therefore are less credit-constrained allowing them greater access to foreign capital with which to smooth fluctuations. This argument is especially relevant to developing countries which tend to be more constrained in raising capital than developed countries. Finally, wealthier trading partners may be more willing to provide foreign aid to countries in dire economic circumstances in order to indirectly protect their country's own trading sectors.

On the other hand, Bejan (2006) finds that openness is positively related to volatility for developing countries and contends that this is mainly due to increased exposure to terms of trade risk. Hakura (2007) argues that a positive relationship occurs because government spending is volatile if a government faces significant budget restrictions. Also, developing countries may have to specialize in relatively fewer industries than developed countries leading to non-diversified exports and increased vulnerability to industry-specific demand shocks. Using industry data in a cross-section of countries Di Giovanni and Levchenko (2009) conclude that the relationship between volatility and trade openness is positive, with the magnitude of the effect five times higher for a typical developing nation compared to a developed nation. They find that the negative effect on volatility due to the export sectors' higher correlation with the global rather than local economy is swamped by the positive effect of the other two channels, increased volatility due to specialization and exposure to global shocks.

Using a panel data set of 175 countries from 1950-2002 Kim (2007) distinguishes between openness and external risk finding an insignificant effect of the former on volatility but a significant effect of the latter. Cavallo (2007) finds that contrary to the majority of the literature the link between trade openness is negative after conditioning for the effects of exposure to larger terms of trade risk for more open economies. The explanation put forth for this finding is that openness leads to a reduction in volatility propagated through financial channels.

The size of government is often assumed to be a proxy for the degree of automatic stabilisers (such as transfer payments and progressive taxes systems) in an economy as the two are highly correlated according to Van den Noord (2000), who conclude that automatic fiscal stabilisers contributed to a decrease in cyclical volatility in the 1990s. Fatas and Mihov (2001) find a significant negative relationship between government size and volatility for OECD countries and US states even after correcting for possible endogeneity. Virén (2005) examines a large sample of 208 countries and finds a weak or even non-existent effect of government size on volatility. Bejan (2006) finds that for a pooled sample of developed and developing countries openness increases volatility whereas larger government leads to a decrease. For developing countries government expenditure and trade openness both exacerbate volatility. For developed countries greater trade openness and larger government lead to less volatility. Developing countries may exhibit a positive relationship between government size and volatility if the former is accompanied by greater volatility in government expenditure.

The link between taxation and volatility is one of the least studied topics. In a sample of OECD countries Posch (2008) finds statistically and economically significant effects of various types of taxation on volatility, namely labor and corporate income tax are negatively related to volatility whilst capital tax is positively related.

Cecchetti et al (2006) concentrate on the stylized fact that volatility in the last twenty years has been declining, finding that this is primarily due to improved inventory management processes, financial innovation and increased central bank independence. In a similar paper Kent et al (2005) discover that less product market regulation and stricter monetary policy have also contributed to this decline over time.

A non-parametric study of volatility is undertaken in Fiaschi and Lavezzi (2005), concluding that volatility is negatively related to the size of an economy, to a proxy of structural change as measured by the income share of the agricultural sector, and finally is not found to depend on per capita GDP when other controls are used.

Acemoglu et al (2003) conclude that the fundamental cause of post-war instability arises from the effects of weak institutions, through channels such as distortionary macroeconomic policies. The primary results of Mobarak (2005) is that democracy significantly reduces volatility, whilst also finding that countries with higher income, more outward orientation and lower inflation rates tend to exhibit less volatility. Malik and Temple (2009) focus on the role of institutions and geography finding that weaker institutions contribute to volatility and that countries that are more remote exhibit higher volatility due to a lack of export diversification.

3 Methodology

3.1 BMA methodology

Applications of Bayesian model averaging to the economics field have primarily been made in the empirical growth regression literature, due to the large number of possible determinants of growth with little theoretical guidance regarding model/variable selection. Fernandez et al (2001) employ a Markov chain Monte Carlo Model Composition (MC3) technique to perform BMA for cross-country growth regressions. In a related paper Ley and Steel (2009) recommend the use of a hierarchical prior for the prior probability of inclusion of each variable rather than using a fixed probability which has strong implications for model size, and also argue against the use of the unit information prior (UIP). Eicher et al (2007) also investigate the effects of twelve different prior distribution assumptions on the results of BMA methods concluding that although priors affect the selection of models, the economic impact of the variables as measured by the posterior means of regression coefficients is very stable across priors. Excellent general discussions of the BMA procedure can be found in Raftery et al (1997), Hoeting et al (1999) and Montgomery and Nyhan (2010).

Following the notation of Montgomery and Nyhan (2010), let a dependent variable Y be a vector of size $n \times 1$ observations, and X be a matrix of size $n \times p$, where p is the number of potential explanatory variables that may influence Y (for simplicity assume that these variables have been centred at their means so that the constant can be ignored). Define the number of possible model configurations, $q = 2^k$ and let the model space M be comprised of $[M_1 ... M_q]$. The prior probability distribution of models $M_k \sim \pi(M_k)$ is uniformly distributed, and the distribution of the variance conditioned on a specific model is $\sigma^2 \mid M_k \sim \pi(\sigma^2 \mid M_k)$. Let $\Omega = \omega_1, ..., \omega_p$ represent a vector of zeros and ones for each model M_k denoting which variables are included in said model, then the conditional distribution $\beta_\omega \mid \sigma^2, M_k \sim \pi(\beta_\omega \mid \sigma^2, M_k)$. If a standard linear regression with normally distributed errors is assumed then the conditional distribution of the dependent variable is $Y \mid \beta_\omega, \sigma^2, M_k \sim N(X_\omega \beta_\omega, \sigma^2 I)$. The distribution of the data conditional on the model is given by:

$$p(Y \mid M_k) = \iint p(Y \mid \beta_\omega, \sigma^2, M_k)\pi(\beta_\omega \mid \sigma^2, M_k)\pi(\sigma^2 \mid M_k) d\beta_\omega d\sigma^2 \tag{1}$$

Finally, the posterior probability of any model M_k given the dependent data observations Y is:

$$p(M_k \mid Y) = \frac{p(Y \mid M_k)\pi(M_k)}{\sum_{k=1}^{q} p(Y \mid M_k)\pi(M_k)} \tag{2}$$

The expected values of the coefficients account for model uncertainty by averaging them across the entire model space according to:

$$E(\beta_k \mid Y) = \sum_{k=1}^{q} p(M_k \mid Y) E(\beta_k \mid M_k, Y) \tag{3}$$

Computational limitations dictate the use of priors with closed-form solutions for $p(Y \mid M_k)$ without the need to sample from the posterior distribution of M_k. Liang et al (2008) suggest imposing a prior distribution on g thereby also incorporating uncertainty about the g-prior parameter. The results presented in the main sections of this paper assume the hyper-g prior in equation 4, setting the hyper-parameter a equal to 3 as recommended by Liang et al (2008).

$$\pi(g) = \frac{a-2}{2}(1+g)^{a/2} \;\; where\, g > 0 \tag{4}$$

The robustness of the results with respect to the imposition of alternative priors, defined below, is examined in Appendix A.

1. Zellner's g-prior (Zellner, 1986) for specific values of g:

$$\pi(\beta_\omega \mid M_k, \sigma^2) \sim N_{p_\omega}(0, g\sigma^2(X_\omega' X_\omega)^{-1}) \;\;\&\;\; \pi(\beta_0, \sigma^2 \mid M_k) \propto \sigma^{-2} \tag{5}$$

2. The Zellner and Siow (1980) prior where g is distributed according to the $\Gamma(0.5, n/2)$ distribution. The resulting prior on β_ω is given by:

$$\pi(\beta_\omega \mid M_k, \sigma^2) \propto \int N(\beta_\omega \mid 0, g\sigma^2(X'_\omega X_\omega)^{-1})\pi(g)dg \tag{6}$$

3. Finally, an alternative approach is to set the value of g as the maximum marginal likelihood estimate, constrained to be nonnegative - the local empirical Bayes prior (EB-local) estimates a different value of g for each model, whereas global empirical Bayes (EB-global) assumes a common value of g for all models.

This paper employs the Bayesian Adaptive Sampling methodology advocated in Clyde et al (2009) which samples without replacement from the model space allowing this algorithm to visit a larger number of models for a given number of samples. This is shown to be computationally more efficient than other Markov chain Monte Carlo methods such as the MC^3 algorithm of Madigan et al (1995); Raftery et al (1997) and the hybrid MC^3/Gibbs sampler technique of Clyde et al (1996), whilst also exhibiting more accurate inclusion probabilities in simulation studies. The software utilized for the estimation is the freely distributed R-package BAS (Clyde, 2009) implementing the technique in Clyde et al (2009).

3.2 Datasets and definitions of volatility measures

The datasets were compiled from Sala-i-Martin (1997), King and Levine (1993) and the Penn World Table (Heston et al, 2009) - a list of included countries, explanations and abbreviations of variables can be found in Appendix B. Independent variables were chosen from the variables used in the growth literature as there is reason to believe that the same variables may be affecting volatility, albeit in different ways and for different reasons. A total of 42 possible determinants of volatility were included in this study, of which 31 were included in a dataset of 60 countries between 1960-89, and 28 variables in a dataset of 50 countries between 1974-89.

Various measures of volatility have been used in the literature, the most common for cross-section analyses being the standard deviation of growth rates (Ramey and Ramey, 1995; Kormendi and Meguire, 1985; Grier and Tullock, 1989; Martin and Ann Rogers, 2000), whereas times series data studies often use unexpected or surprise volatility as measured by the variance of residuals of an appropriate forecast regression (Ramey and Ramey, 1995; Lensink et al, 1999).

This paper introduces to the literature the notion of downside risk, measured by the downside semideviation of growth rates, as a more appropriate measure of volatility than the standard deviation of growth rates (sd), especially for asymmetric distributions. Let $g_{i,t}$ be the growth rate for country i for year t, and define the downside standard deviation of real growth rates of country i, abbreviated to downside semideviation or sd^-, by equation 7 and the upside semideviation sd^+ by equation 8:

$$sd_i^- = \sqrt{E_{t\in T_i^-}\left(\sum_{t\in T_i^-}[g_{i,t} - E_t(g_{i,t})]^2\right)} \tag{7}$$

$$sd_i^+ = \sqrt{E_{t\in T_i^+}\left(\sum_{t\in T_i^+}[g_{i,t} - E_t(g_{i,t})]^2\right)} \tag{8}$$

The use of downside semideviation is motivated by the vast behavioral decision making literature on loss-aversion and prospect theory utility functions sparked by Kahneman and Tversky (1979), where losses impact a subjective utility function more than gains relative to a reference point. The relevance of downside volatility in comparison to total volatility for asset pricing was advocated even by Markowitz (1959), although computational limitations at the time precluded its use. In the recent literature, a good introduction to downside risk is Sortino and Van Der Meer (1991).

The downside semideviation measure of volatility implicitly assumes that the relevant reference point is the mean of the growth rate rather than a growth rate of 0 percent. Although at first sight it may be tempting to define negative growth rates as a loss, we argue that habituation will lead agents to expect the mean growth rate, making it a more relevant reference point. Economic agents forecasting future economic conditions for planning purposes, will often base their forecast on a simple linear extrapolation of trending variables. Therefore any surprise deviation from the trend i.e. the average growth rate of a variable, will likely lead to a reassessment and change in behavior.

Empirically, the relevance of sd^- as a measure of risk in the economy can be demonstrated by assessing the impact and explanatory power of various measures of volatility on growth rates. Cross-country growth rates are regressed on each of the three volatility measures defined previously for a cross section of 95 countries from 1960-89 and for the 60 country sample used throughout this paper. The results are given in Table 1. With respect to the 95 country sample, using the standard deviation of growth rates sd as the volatility measure there is a statistically significant negative relationship with estimated coefficient -0.132, similar to the Ramey and Ramey (1995) estimate of -0.154 for 92 countries from 1962 to 1985. If the measure of volatility is sd^- then the estimated coefficient, -0.214, is significantly larger in absolute magnitude and the R^2 fit increases substantially compared to the sd measure. Using the positive semideviation as the regressor provides the smallest fit in terms of R^2, and the null hypothesis that the growth rate is independent of sd^+ cannot be rejected as the 5% level.

Table 1 Linear regressions of growth rates on sd^-, sd^+ and sd volatility measures

Sample size	Ind. var.	Coef. (s.e.)	t-statistic (p)	R^2	F-statistic (p)
95	sd	-0.132 (0.058)	-2.27 (0.026)	0.0524	5.14 (0.025)
	sd^-	-0.214 (0.077)	-2.75 (0.007)	0.0753	7.57 (0.007)
	sd^+	-0.137 (0.084)	-1.62 (0.108)	0.0275	2.63 (0.108)
60	sd	-0.136 (0.654)	-2.08 (0.042)	0.069	4.31 (0.042)
	sd^-	-0.195 (0.082)	-2.39 (0.020)	0.089	5.69 (0.020)
	sd^+	-0.171 (0.099)	-1.72 (0.09)	0.049	2.97 (0.090)

The results for the 60 country 1960-89 sample lead to the same conclusion, and robust regressions (Huber, 1973) on both samples yield very similar results verifying that they are not the result of influential outliers. In conclusion, on the basis of these results sd^- is a more appropriate measure of volatility, and using sd instead of sd^- as an explanatory variable greatly underestimates the impact of volatility upon growth rates.

4 Results

This section investigates the determinants of the three different measures of volatility presented earlier sd^-, sd^+ and sd, both for the 1960-89 dataset in Section 4.1 (and a non-OECD country subset in Section 4.4), and for the 1974-89 dataset in Section 4.5. A comparison of the determinants of the different volatility variables is undertaken in Section 4.2 and the predictive performance on out of sample observations of the BMA technique is contrasted to other models of volatility in Section 4.3.

4.1 The determinants of downside semideviation sd^- in 60 countries (1960-89)

The posterior probabilities of inclusion (or equivalently the posterior probability that the coefficient of a variable is not equal to zero) estimated by the BMA procedure signify the importance of a variable in explaining volatility. The results of the BMA procedure including the posterior inclusion probabilities and posterior statistics for the estimated coefficients are given in Table 2. Focusing first on the downside semideviation measure of volatility the variables whose posterior inclusion probability is greater than 0.5 are (sign of the posterior mean of the coefficient in brackets): government consumption share of GDP (+), the trade share of GDP (+), a civil liberties index (+), a degree of capitalism index (+), the standard deviation of the black market premium (+), the number of assassinations (−), the black market premium (+), the ratio of deposit banks' domestic assets to deposit banks and Central Bank assets (−) and dummy variables for oil producing countries (+), socialist countries (+) and Latin American countries (+).

Table 2 Determinants of sd^{-}, sd^{+}, sd for a cross-section of 60 countries from 1960-89

	Probability of inclusion			Posterior means		
	sd^{-}	sd^{+}	sd	sd^{-}	sd^{+}	sd
Intercept	1.000	1.000	1.000	-3.12E-02	-2.10E-02	-3.09E-02
C	0.160	0.990	0.944	3.38E-06	6.57E-05	7.49E-05
G	0.959	0.998	0.992	1.85E-04	2.07E-04	2.69E-04
I	0.266	0.192	0.191	3.77E-05	1.20E-05	2.35E-05
OPENNESS	0.999	0.989	0.997	4.65E-04	3.05E-04	5.35E-04
PRIGHTSB	0.365	0.361	0.281	4.92E-04	-4.68E-04	-2.58E-04
CIVLIBB	0.616	0.802	0.704	1.18E-03	1.56E-03	1.74E-03
RULELAW	0.167	0.146	0.145	-4.52E-04	1.53E-05	1.45E-05
RERD	0.108	0.166	0.129	4.65E-07	-9.88E-07	-2.28E-07
ECORG	1.000	1.000	1.000	4.18E-03	3.39E-03	5.18E-03
BMS	0.905	0.144	0.246	2.61E-05	3.95E-07	4.15E-06
WAR	0.122	0.170	0.139	-6.76E-05	-1.40E-04	-1.39E-04
DEMO	0.256	0.300	0.297	-1.08E-03	-1.03E-03	-1.59E-03
YEARSOPEN	0.172	0.130	0.114	-5.08E-04	4.73E-05	-1.19E-04
ASSASS	0.886	0.620	0.652	-3.05E-03	-1.38E-03	-2.29E-03
BMP	0.994	1.000	1.000	5.48E-03	5.26E-03	9.05E-03
MIX	0.108	0.154	0.134	-4.01E-05	6.32E-05	3.64E-05
OECD	0.441	0.219	0.344	-2.23E-03	-4.54E-04	-1.73E-03
OIL	0.724	0.252	0.306	5.15E-03	8.01E-04	1.84E-03
PI	0.156	0.655	0.497	-2.70E-06	-2.59E-05	-2.52E-05
REVC	0.251	0.151	0.190	1.29E-03	1.15E-04	8.31E-04
RGDP	0.108	0.177	0.141	1.62E-05	4.79E-05	4.06E-05
SCOUT	0.411	0.532	0.331	-1.09E-03	-1.25E-03	-9.15E-04
SOC	0.997	0.999	1.000	1.56E-02	1.39E-02	2.19E-02
STGDC	0.171	0.983	0.912	4.71E-06	8.95E-05	9.55E-05
PINSTAB	0.126	0.140	0.150	4.08E-04	-1.37E-04	-5.86E-04
AFRICA	0.141	0.177	0.154	-2.36E-04	-2.56E-04	-2.68E-04
LAAM	0.661	0.164	0.188	2.96E-03	8.28E-05	3.35E-04
BANK	0.511	0.983	0.983	-8.08E-03	-2.24E-02	-3.25E-02
PRIVATE	0.415	0.613	0.753	4.78E-03	8.23E-03	1.56E-02
PRIVY	0.113	0.393	0.274	5.44E-07	-3.89E-03	-3.07E-03
MONEY	0.153	0.651	0.426	5.03E-04	6.78E-03	5.18E-03

Downside semideviation is found to be positively correlated with government and trade shares of GDP, implying that economies with a larger government sector and greater degree of openness suffer from greater volatility. Investment share was found to have a low inclusion probability equal to 0.266 and the posterior mean is equal to 3.77×10^{-5}.

Countries that embrace political rights, civil liberties and rule of law are all found to exhibit less volatility. It should be noted that because of the high degree of correlation of these three measures that the BMA procedure often chose only one of these variables. Hence, adding a second variable was largely redundant in terms of explanatory power which explains why *RULELAW* and

PRIGHTSB have low posterior inclusion probabilities. The negative relationship between the number of assassinations per million population and volatility is unexpected.

The economic organization index is higher the more a country favors capitalist forms of production and is found to be positively correlated with downside semideviation. At the same time however the dummy variable for socialist economies is also found to be significant and positive, whereas the dummy variable for mixed economies is not.

As expected the black market premium and its standard deviation both exacerbate downside semideviation, and oil producing economies and Latin American economies were all found to exhibit higher volatility.

Turning to the financial variables the *BANK* variable is significant and negative leading to the conclusion that increasing the role of private banks in comparison to central banks in the financial system leads to lower volatility. This implies that private banks can allocate funds more efficiently than the central bank. King and Levine (1993) argue that this is because private banks are better at risk management, information acquisition and creditor monitoring. The probability of inclusion of the ratio of private domestic assets to total domestic assets (*PRIVATE*) is quite high 0.415, and interestingly the greater the degree of financial sophistication as measured by this variable the higher volatility. This implies that private sector firms use this credit to fund activities that are riskier or more volatile than a public sector firm would. However, these two variables are quite highly correlated ($\rho = 0.77$) and therefore the robustness of these results must be addressed. If multicollinearity is a problem then these estimates should be very sensitive to excluding one of them from the regression, and should also be sensitive to estimating the model using different subsets of the data.

First, we re-estimate the model two times, each time dropping one of these two variables from the analysis. If *BANK* is excluded, then the probability of inclusion and posterior mean of *PRIVATE* are 0.229 and 1.54×10^{-3} respectively. Both of these values are less than the associated values for the full regression, however it is important that the sign of the posterior mean is the same, albeit of less magnitude. Excluding *PRIVATE*, the relevant estimates for *BANK* are 0.375 and -4.459×10^{-3}, again these are smaller than the estimates of the full model however once again the sign of the posterior mean does not change. The second method is to impose restrictions on the coefficients of these two variables thereby eliminating the collinearity. Replacing *BANK* and *PRIVATE* by their difference (i.e. imposing equal in magnitude but opposite in sign coefficients) leads to an inclusion probability of 0.923 and posterior mean of -1.585×10^{-2}. Finally, we replace the individual *BANK* and

Table 3 Robustness of financial variable effects on sd^{-} for subsets of data

	Probability of inclusion		Posterior means	
Subset of data	*BANK*	*PRIVATE*	*BANK*	*PRIVATE*
1	0.948	0.673	-2.53×10^{-2}	1.2×10^{-2}
2	0.810	0.294	-1.28×10^{-2}	2.20×10^{-3}
3	0.258	0.267	-2.96×10^{-3}	2.07×10^{-3}
4	0.975	0.275	-2.30×10^{-2}	2.19×10^{-3}
5	0.999	0.994	-4.02×10^{-2}	3.34×10^{-2}
6	0.270	0.128	-3.23×10^{-3}	5.59×10^{-4}
Mean	0.710	0.438	-1.79×10^{-2}	8.75×10^{-3}

PRIVATE variables with two new interaction variables, *BANK*×*PRIVATE* and *PRIVATE*/*BANK*, by imposing a multiplicative or inverse interaction between these two variables. The former has an inclusion probability 0.106 and posterior mean of -1.029×10^{-4}, whereas the relevant values for the latter variable are 0.623 and 6.106×10^{-3}. These restrictions on the coefficients that eliminate the collinearity provide further evidence that higher values of *PRIVATE* relative to *BANK* lead to higher downside semideviation.

The robustness of the results is also tested by splitting the dataset into 6 subsets of 10 observations and estimate the model each time excluding one of the subsets. This checks the robustness of the results not only with respect to collinearity but also with respect to the possibility that outliers are the main driver of the results. Table 3 provides the probabilities of inclusion and posterior means for *PRIVATE* and *BANK* for each of six subsets of data. The mean probabilities of inclusion are still high, 0.71 for *BANK* and 0.438 for *PRIVATE*, and in all cases the signs of the estimated posterior means remain unchanged. For the third and sixth subset the probabilities of inclusion are quite smaller indicating that countries excluded in these two subsets play an important rule in the effect. Given the high correlation of these two variables it is natural that most of the information will be embedded within a relatively small number of observations that deviate from the strong linear correlation found.

These results lead us to believe that the findings of a negative relationship between *BANK* and a negative relationship for *PRIVATE* are not due to multicollinearity and indeterminacy as the qualitative results survive the exclusion of either variable, various restrictions and transformations, and estimation using different subsets of the data.

4.2 Comparison between the determinants of different measures of volatility

A comparison between the variables driving downside and upside semideviation, presented in Table 2, yields some interesting results. In terms of probability of inclusion the most notable differences are the following. The upside semideviation appears to be driven by the following variables which are not important in explaining downside semideviation (the sign in brackets denotes the sign of the derivative of volatility with respect to a variable): consumption share of GDP (+), inflation (−), the standard deviation of the growth of domestic credit (+) and the ratio of liquid liabilities to GDP (+). Countries with high consumption share of GDP may face greater volatility if consumption is purchased to a large degree using credit, thereby making it more volatile to interest rate shocks to the economy. The negative relationship between inflation and upside semideviation is not economically significant as an increase in one percentage point in inflation leads to a decrease in sd^+ by only -2.59×10^5, a trivial amount compared to the mean of $sd^+ = 0.0148$. Also, although the sign of the relationship between the standard deviation of domestic credit growth is as anticipated it is interesting that this should not affect downside semideviation. The $BANK$ variable's probability of inclusion increases significant from 0.511 for sd^- to 0.983 for sd^+, $PRIVATE$ increases from 0.415 to 0.613 and the ratio of liquid liabilities to GDP ($MONEY$) from 0.153 to 0.651. Also, note that the posterior means of these coefficients are much larger in the case of sd^+. The only variable whose inclusion probability falls significantly when analyzing sd^+ is the standard deviation of the black market premium.

The determinants of the standard measure of volatility sd differ from those of sd^- primarily in terms of a significant effect of consumption share of GDP (+), the standard deviation of the growth of domestic credit (+) and the higher posterior inclusion probabilities of $BANK$ and $PRIVATE$ coupled with larger in magnitude posterior means.

4.3 Cross-validation predictive performance of BMA and other models

One of the advantages of BMA is the increase in out of sample predictive performance in comparison to other methods that do not incorporate model uncertainty. This has been observed for a wide variety of datasets including predicting growth rates (Fernandez et al, 2001), analyzing infra-red data of sugars in aqueous solutions (Brown et al, 1998), in predicting the risk of strokes (Volinsky et al, 1997), in survival analysis (Raftery et al, 1996), in the treatment of primary biliary cirrhosis of the liver and predicting percent body fat (Hoeting et al, 1999).

The predictive performance of the three different models is compared in Table 4 using the cross-validation procedure where the dataset is randomly sorted into 6 subsets of 10 data points each. The models are then estimated on each possible combination of five subsets and used to predict the observations in the excluded subset. Three sets of predictions were made for each of the dependent variables sd^-, sd^+ and sd derived from the model with the highest posterior probability (HPP) as estimated by the BMA procedure, Bayesian predictions from all the models sampled in the BMA procedure as calculated according to equation 9, and finally predictions from a linear regression model (LIN) including all the possible covariates.

$$E(\hat{Y} \mid Y) = \sum_{k=1}^{q} p(M_k \mid Y) E(\hat{Y} \mid M_k, Y) \tag{9}$$

Table 4 presents four different measures of performance, the root mean squared error (RMSE), the root median squared error (RMDSE), the mean absolute percentage error (MAPE) and finally the median absolute percentage error (MDAPE). The results in predicting all the volatility variables are similar, for expositional brevity we discuss those regarding sd^-. The BMA predictions were the most accurate according to all of the performance measures, followed by the model with the highest posterior probability, and the linear model which performs particularly poorly. It should be noted that the model with the highest posterior probability can only be derived by performing the BMA procedure and therefore is not otherwise available to a researcher. The RMSE of the full linear model predictions is 34 percent higher than that of BMA, and in terms of MAPE it is 42 percent higher or 20.5 percentage points higher. These are extremely large differences that have important economic significance in forecasting. The median performance measures are all lower than the equivalent mean performance measures as there is significant positive skew in the errors for each country. Using only the model with the highest posterior probability instead of all the models visited by the BMA procedure increases the RMSE by 5.2 percent and the MAPE by 10.2 percent or 5.03 percentage points. The results are qualitatively similar for the other two measures sd^+ and sd, leading to the conclusion that BMA is desirable not only on the grounds of model uncertainty and specification but also in terms of predictive accuracy.

Table 4 Cross-validation performance of various models in predicting sd^{-}, sd^{+} and sd

	sd^{-}			sd^{+}			sd		
	HPP	BMA	LIN	HPP	BMA	LIN	HPP	BMA	LIN
RMSE ($\times 10^{-3}$)	12.1	11.5	15.4	9.1	8.5	10.2	13.8	13.6	17.2
RMDSE ($\times 10^{-3}$)	5.5	5.1	5.2	4.5	4.1	5.4	7.1	6.5	6.7
MAPE	54.2	49.1	69.6	41.2	38.1	57.8	47.6	42.2	59.0
MDAPE	42.3	35.9	51.8	32.7	32.8	42.5	35.2	28.4	42.9

4.4 The determinants of sd^{-} for non-OECD countries

The validity of the above conclusions with respect to the determinants of sd^{-} is now examined by restricting the dataset to non-OECD countries. Table 5 reiterates the results for the full dataset side by side with the results computed for non-OECD countries for ease of comparison and the following important differences are noted. The probabilities of inclusion in general do not appear to be significantly affected with the exception of the probability of inclusion of real GDP per capita whose probability of inclusion jumps from 0.108 for the full dataset to 0.926 for non-OECD countries, exhibiting a positive posterior mean. Comparing the posterior means of variables with high inclusion probabilities for both datasets the black market premium, government share of GDP and *BANK* have significantly larger effects on sd^{-} for non-OECD countries.

4.5 The determinants of downside semideviation sd^{-} for 50 countries (1974-89)

The previous analysis did not include variables for government deficits or any debt variables as these were not widely available from 1960. This dataset includes such variables of particular interest such as government deficit as a percentage of GDP, long term and short term debt as percentages of GDP, and GDP shares of various tax revenues (individual, corporate, social security, import and export tax revenue), full results are presented in Table 6. The debt data is taken from the Global Development Finance database and the other variables from Levine and Renelt (1992). Since countries were included on the basis of availability of debt statistics, because debt data was mostly available for developing countries with relatively low real GDP per capita, this dataset should be regarded as such. The mean value of *RGDP* for this dataset is 56.3 percent of the mean value for the 1960-89 dataset, further statistics are available in Table 11.

The variables determining downside semideviation with posterior probability of inclusion greater than 0.5 (sign of the posterior mean in brackets) are: government consumption share of GDP (+), the

Table 5 Determinants of sd^- for non-OECD countries

	Probability of inclusion		Posterior means	
	All	non-OECD	All	non-OECD
C	0.160	0.286	3.38E-06	9.57E-06
G	0.959	0.986	1.85E-04	2.45E-04
I	0.266	0.274	3.77E-05	3.73E-05
OPENNESS	0.999	0.995	4.65E-04	4.91E-04
PRIGHTSB	0.365	0.404	4.92E-04	5.61E-04
CIVLIBB	0.616	0.232	1.18E-03	1.47E-04
RULELAW	0.167	0.112	-4.52E-04	3.63E-05
RERD	0.108	0.316	4.65E-07	9.39E-06
ECORG	1.000	0.999	4.18E-03	4.47E-03
BMS	0.905	0.437	2.61E-05	8.36E-06
WAR	0.122	0.144	-6.76E-05	-1.79E-04
DEMO	0.256	0.249	-1.08E-03	-1.13E-03
YEARSOPEN	0.172	0.129	-5.08E-04	-1.45E-04
ASSASS	0.886	0.608	-3.05E-03	-1.81E-03
BMP	0.994	0.999	5.48E-03	7.35E-03
MIX	0.108	0.196	-4.01E-05	-3.68E-04
OIL	0.724	0.274	5.15E-03	1.12E-03
PI	0.156	0.284	-2.70E-06	-7.18E-06
REVC	0.251	0.158	1.29E-03	3.93E-04
RGDP	0.108	0.926	1.62E-05	2.87E-03
SCOUT	0.411	0.146	-1.09E-03	-8.73E-05
SOC	0.997	0.996	1.56E-02	1.85E-02
STGDC	0.171	0.194	4.71E-06	5.14E-06
PINSTAB	0.126	0.225	4.08E-04	1.68E-03
AFRICA	0.141	0.155	-2.36E-04	-1.28E-04
LAAM	0.661	0.185	2.96E-03	-3.34E-04
BANK	0.511	0.556	-8.08E-03	-1.09E-02
PRIVATE	0.415	0.280	4.78E-03	3.00E-03
PRIVY	0.113	0.227	5.44E-07	2.83E-03
MONEY	0.153	0.134	5.03E-04	3.77E-04

trade share of GDP (−), short term debt as percentages of GDP (+), long term debt as percentages of GDP (−), real exchange rate distortion (+), a dummy variable for Outward Orientation (−), the black market premium (+), an index of civil liberties (+), number of revolutions (−), a dummy variable for Mixed Government (−) and the Ratio of Central Government Tax Revenue to GDP (+).

Comparing the variables with posterior inclusion probability greater than 0.5 that are present both in the 1974-89 and 1960-89 datasets they are all found to have the same qualitative effect on sd^- with the exception of *OPENNESS* which is negative for the 1974-89 dataset but positive for the 1960-89 dataset. This may be either due to the different time period or different composition

Table 6 Determinants of sd^-, sd^+, sd for a cross-section of 50 countries from 1974-89

	Probability of inclusion			Posterior means		
	sd^-	sd^+	sd	sd^-	sd^+	sd
Intercept	1.000	1.000	1.000	-2.84E-02	-1.69E-03	-2.28E-02
OPENNESS	0.598	0.164	0.342	-9.04E-05	3.14E-06	-2.71E-05
C	0.256	0.335	0.212	-2.18E-05	4.63E-05	-4.49E-06
G	0.989	0.962	0.994	9.40E-04	5.45E-04	8.26E-04
I	0.233	0.429	0.265	-1.60E-05	-1.90E-04	-7.01E-05
SD	0.988	1.000	0.999	1.72E-03	1.96E-03	2.02E-03
LD	0.769	0.676	0.919	-2.23E-04	-1.45E-04	-2.76E-04
PI	0.231	0.191	0.228	1.56E-06	-2.51E-06	3.24E-07
STGDC	0.277	0.227	0.239	-2.67E-05	-2.07E-05	-1.53E-05
RERD	0.621	0.562	0.857	1.05E-04	8.22E-05	1.79E-04
SCOUT	0.941	0.999	0.996	-1.50E-02	-2.12E-02	-2.06E-02
BMP	0.998	1.000	1.000	3.49E-04	3.08E-04	3.66E-04
AFRICA	0.249	0.987	0.464	7.65E-04	2.31E-02	5.69E-03
CIVL	0.984	0.599	0.982	8.11E-03	2.04E-03	6.38E-03
RGDP	0.462	0.200	0.338	2.42E-03	-3.48E-04	1.19E-03
LAAM	0.236	0.235	0.240	5.91E-04	1.24E-03	-5.72E-05
OIL	0.262	0.152	0.279	2.11E-03	-2.51E-04	2.30E-03
REVC	0.861	0.493	0.908	-3.00E-02	-9.26E-03	-2.92E-02
MIX	0.956	0.551	0.921	-1.53E-02	-4.19E-03	-1.16E-02
SOC	0.361	0.237	0.222	-3.98E-03	1.19E-03	3.87E-04
CGC	0.234	0.233	0.221	-5.70E-03	1.90E-02	3.25E-03
CTX	0.295	0.984	0.561	1.98E-02	1.83E-01	7.26E-02
DEE	0.309	0.189	0.270	-3.84E-02	-9.52E-03	-2.43E-02
DEF	0.273	0.225	0.206	1.64E-02	-1.30E-02	-2.83E-04
ITX	0.308	0.168	0.231	5.37E-02	-1.01E-02	1.84E-02
MTX	0.247	0.340	0.306	-7.90E-03	-1.87E-02	-1.45E-02
SST	0.230	0.147	0.234	-2.61E-02	3.73E-03	-2.03E-02
TAX	0.559	0.176	0.479	6.26E-02	2.99E-03	4.19E-02
XTX	0.243	0.156	0.233	-1.02E-02	-3.26E-03	-8.54E-03

of the datasets as the 1974-89 data has only one OECD country and most countries are relatively poor developing countries. Interestingly, *OPENNESS* has a negligible, positive impact on sd^+ as the probability of inclusion is only 0.164 and the posterior mean 3.14×10^{-6}.

The ratio of short term debt to GDP is an extremely important determinant (posterior probability of inclusion=0.988) adversely affecting sd^- as it increases. The ratio of long term debt to GDP on the other hand is found to have a negative relationship with sd^-, however the short and long term debt variables are highly correlated ($\rho = 0.79$). To ascertain the robustness of these results the BMA model is estimated twice dropping each time one of these debt variables. Including only long term debt leads to an inclusion probability of 0.26 and a posterior mean of 1.13×10^{-5} with a posterior s.d. of 7.29×10^{-5}, clearly calling into question the robustness of this variable. However, including only the short term debt ratio leads to an inclusion probability of 0.98 with a posterior mean of 1.13×10^{-3} and posterior s.d. of 5.546×10^{-4}. The results for short term debt are very similar to those found in the original setup including both short and long term debt. Therefore we recommend accepting the results for short term debt as robust, whereas the effect of long term debt should be viewed as inconclusive.

From the remaining variables included in this dataset but not in the 1960-89 analysis only TAX has a posterior probability of inclusion greater than 0.5 and is found to be positively related to the downside semideviation. The relationship of other tax variables with sd^{-} is also positive for CTX (corporate) and ITX (individual) but negative for XTX (export) and MTX (import), however their inclusion probabilities are small ranging from 0.247 to 0.308.

Other results worthy of mention include the positive relationship between $RGDP$ and sd^{-} with a relatively high probability of inclusion (0.462). Also, a higher ratio of central government deficit to GDP was found to increase sd^{-} however the inclusion probability is 0.273.

Comparing the determinants of sd^{-} to those of sd^{+} and sd there are only a few important qualitative differences. The trade share of GDP exhibits significantly lower probability of inclusion and is positive for sd^{+} but remains negative for sd. Also, CTX now plays an important role as the probability of inclusion is 0.984 and 0.561 for sd^{+} and sd respectively. At the same time the posterior probability of inclusion of TAX falls to 0.176 for sd^{+}.

5 Conclusion

This paper's main contribution to the literature is the application of the Bayesian Model Averaging technique in examining the determinants of volatility. This technique accounted for the inherent model uncertainty and permitted a systematic analysis of the robustness of the effects of variables with respect to the conditioning set of variables. Another innovation is the use of the downside semideviation of growth rates to more accurately represent the true risk economic agents are exposed to, instead of simply using the standard deviation of growth rates which includes favourable deviations in growth rates.

Our conclusions regarding the effects of financial variables on volatility deviate in one respect compared to the literature. Although the ratio of deposit banks domestic assets to deposit banks and Central Bank assets is found to be negatively related to all measures of volatility supporting the argument that financial sophistication and depth lead to lower volatility, the ratio of non-financial, private domestic assets to total domestic assets was found to be positively related.

The ratio of government expenditure to GDP was consistently found to have a significant positive relationship with all measures of volatility. Another variable that entered significantly was a measure of openness, the trade share of GDP, which was positively related to volatility from 1960-89 for a well balanced dataset of developed and developing countries, whilst exhibiting a less strong negative relationship for developing countries between 1974-89. As expected, countries that embraced political rights, civil liberties and rule of law suffered from less volatility. Developing countries exhibited higher volatility the higher the ratio of short term debt to GDP and the ratio of central government tax revenue to GDP.

Future research should be directed towards the development and incorporation of panel data methods into the Bayesian Model Averaging framework, and the requisite collection of sufficiently broad and accurate time-series data to exploit this.

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A Robustness of results with respect to different priors

Perhaps the most common criticism of the BMA technique is the dependence on the selection of the prior specification. Liang et al (2008) investigate the simulated and real performance of the various prior distribution employed also in this study. They conclude that the use of g-priors with fixed parameter is problematic not only because of the theoretical consistency issues that arise with their use, the need to specify the value of the fixed parameter, but also because of their performance in simulated data which was inferior to that of mixture g-priors and global- and local-EB priors.

To allay any fears with regards the robustness of the results of this paper with respect to the prior specification we compare results from five different prior specifications: the Unit Information Prior (UIP) which is the g-prior specification where $g = n^{-1}$ and the Risk Inflation Criterion (RIC) where $g = k^{-2}$, the mixture hyper-g prior using the recommended hyper-parameter value of 3, the EB-global and EB-local prior specification which estimates the value of g and finally the ZS-full mixture prior. We examine the effects of the prior specification on the two most important results of this study, the posterior probability of inclusion of variables and their posterior means. Tables 9 and 10 in Appendix B provide the detailed results of modeling sd^{-} with different priors, whilst the similarity of the results are summarized below in Tables 7 and 8 through the Euclidean distance between the relevant estimates and their correlation.

The posterior probabilities of inclusion are highly correlated ($\rho > 0.9$) for all prior specifications except for the RIC which still exhibits relatively high correlation (in most cases around 0.7). The lowest Euclidean distances were found between the EB-global, EB-local and hyper-g specifications, followed by the UIP and ZS-full priors. The RIC again stands out as being least similar to all the other specifications as the high value of k^2 forces the prior probabilities of inclusion of the variables to be very low leading to much lower posterior probabilities of inclusion.

Table 7 Euclidean distance and correlation between posterior probabilities of inclusion for different priors

$L2$ (ρ)	hyper-g	EB-global	EB-local	UIP	RIC
EB-global	0.12 (0.998)				
EB-local	0.16 (0.997)	0.23 (0.993)			
UIP	0.57 (0.975)	0.60 (0.969)	0.46 (0.985)		
RIC	1.87 (0.721)	1.88 (0.714)	1.78 (0.748)	1.52 (0.776)	
ZS-full	0.70 (0.953)	0.76 (0.942)	0.77 (0.945)	1.08 (0.919)	2.26 (0.628)

Table 8 Euclidean distance and correlation between posterior means for different priors

$L2 \times 10^{-3}$ (ρ)	hyper-g	EB-global	EB-local	UIP	RIC
EB-global	2.0 (0.999)				
EB-local	1.2 (0.999)	2.6 (0.999)			
UIP	3.5 (0.996)	4.6 (0.994)	2.6 (0.998)		
RIC	24.3 (0.966)	25.3 (0.967)	23.6 (0.970)	23.2 (0.977)	
ZS-full	13.6 (0.950)	14.9 (0.937)	14.1 (0.947)	14.5 (0.944)	30.9 (0.884)

The effects of the prior specification on the posterior means as captured by the correlation coefficient is extremely robust to all of the tested specifications as in all cases they are greater than 0.88, and in many cases very close to 1 even for the RIC prior. With respect to the Euclidean distance between estimates the ZS-full and RIC priors are the most dissimilar with respect to the other specifications, whilst EB-global, EB-local and the hyper-g priors again showing a large degree of similarity.

In conclusion, the results appear to be quite robust to prior specifications especially between the mixture priors of hyper-g and ZS-full and EB-local and EB-global which are the priors recommended by Liang et al (2008). As they argue the hyper-g prior in this case may be preferable due to its lower computational cost and the fact that the EB-global prior requires approximation for large k. Hence, for the rest of this paper all models will be estimated using the hyper-g prior with a hyper-parameter value of 3.

Table 9 Robustness of posterior means to prior specification

	Posterior means					
	hyper-g	EB-global	EB-local	g-prior (UIP)	g-prior (RIC)	ZS-full
Intercept	-3.12×10^2	-3.27×10^2	-3.05×10^2	-2.95×10^2	-1.12×10^2	-2.94×10^2
C	3.38×10^6	3.25×10^6	3.13×10^6	6.07×10^6	4.56×10^6	9.85×10^6
G	1.85×10^4	1.91×10^4	1.83×10^4	1.95×10^4	3.43×10^5	2.09×10^4
I	3.77×10^5	4.01×10^5	3.38×10^5	5.10×10^5	2.38×10^6	4.01×10^5
$OPENNESS$	4.65×10^4	4.66×10^4	4.63×10^4	5.04×10^4	4.44×10^4	4.98×10^4
$PRIGHTSB$	4.92×10^4	4.63×10^4	5.64×10^4	6.03×10^4	1.87×10^3	3.12×10^4
$CIVLIBB$	1.18×10^3	1.34×10^3	1.03×10^3	8.64×10^4	5.10×10^4	1.25×10^3
$RULELAW$	-4.52×10^4	-4.32×10^4	-4.90×10^4	-4.54×10^4	-6.66×10^4	-2.73×10^4
$RERD$	4.65×10^7	6.16×10^7	6.89×10^7	8.85×10^7	1.39×10^6	1.30×10^6
$ECORG$	4.18×10^3	4.19×10^3	4.19×10^3	4.40×10^3	1.78×10^3	4.67×10^3
BMS	2.61×10^5	2.65×10^5	2.69×10^5	2.43×10^5	4.22×10^5	2.45×10^5
WAR	-6.76×10^5	-5.67×10^5	-6.33×10^5	-1.17×10^4	-6.36×10^5	-5.68×10^5
$DEMO$	-1.08×10^3	-1.03×10^3	-1.18×10^3	-9.63×10^4	-3.90×10^4	-1.32×10^3
$YEARSOPEN$	-5.08×10^4	-4.66×10^4	-5.60×10^4	-4.39×10^4	-2.96×10^4	-5.72×10^4
$ASSASS$	-3.05×10^3	-3.08×10^3	-2.83×10^3	-2.09×10^3	-4.40×10^4	-3.73×10^3
BMP	5.48×10^3	5.49×10^3	5.57×10^3	6.31×10^3	3.65×10^3	6.47×10^3
MIX	-4.01×10^5	-2.22×10^5	-7.88×10^6	1.63×10^5	-8.09×10^4	-7.31×10^5
$OECD$	-2.23×10^3	-1.98×10^3	-2.73×10^3	-3.63×10^3	-1.60×10^3	-2.64×10^3
OIL	5.15×10^3	5.39×10^3	4.93×10^3	4.93×10^3	1.03×10^3	$4.81 \times$ 10^3
PI	-2.70×10^6	-3.44×10^6	-2.54×10^6	-1.78×10^6	-5.75×10^7	-5.24×10^6
$REVC$	1.29×10^3	1.31×10^3	1.22×10^3	8.22×10^4	1.20×10^4	2.71×10^3
$RGDP$	1.62×10^5	1.40×10^5	1.80×10^5	1.46×10^5	6.95×10^6	2.12×10^5
$SCOUT$	-1.09×10^3	-1.02×10^3	-9.86×10^4	-6.47×10^4	-2.01×10^4	-1.19×10^3
SOC	1.56×10^2	1.56×10^2	1.58×10^2	1.71×10^2	6.39×10^3	1.77×10^2
$STGDC$	4.71×10^6	5.32×10^6	3.91×10^6	3.73×10^6	2.56×10^6	1.29×10^5
$PINSTAB$	4.08×10^4	4.08×10^4	5.09×10^4	4.52×10^4	3.12×10^4	3.29×10^4
$AFRICA$	-2.36×10^4	-2.88×10^4	-2.76×10^4	-1.34×10^4	2.61×10^5	-1.63×10^4
$LAAM$	2.96×10^3	3.39×10^3	2.74×10^3	2.08×10^3	3.84×10^4	2.58×10^3
$BANK$	-8.08×10^3	-7.09×10^3	-7.46×10^3	-7.80×10^3	-1.84×10^3	-1.83×10^2
$PRIVATE$	4.78×10^3	4.28×10^3	4.57×10^3	3.49×10^3	2.28×10^4	1.28×10^2
$PRIVY$	5.44×10^7	4.54×10^5	4.25×10^5	7.87×10^5	-4.61×10^5	-1.14×10^3
$MONEY$	5.03×10^4	6.56×10^4	5.53×10^4	2.43×10^4	-1.77×10^5	2.12×10^3

Table 10 Robustness of inclusion probabilities to prior specification

	Probability of inclusion					
	hyper-g	EB-global	EB-local	g-prior (UIP)	g-prior (RIC)	ZS-full
Intercept	1.000	1.000	1.000	1.000	1.000	1.000
C	0.160	0.169	0.149	0.164	0.084	0.313
G	0.959	0.962	0.953	0.883	0.185	0.984
I	0.266	0.272	0.241	0.261	0.041	0.319
OPENNESS	0.999	0.999	0.999	0.999	0.958	0.999
PRIGHTSB	0.365	0.345	0.403	0.358	0.650	0.354
CIVLIBB	0.616	0.666	0.543	0.425	0.203	0.666
RULELAW	0.167	0.158	0.163	0.112	0.086	0.182
RERD	0.108	0.112	0.110	0.077	0.051	0.163
ECORG	1.000	1.000	1.000	1.000	0.513	1.000
BMS	0.905	0.898	0.917	0.752	0.894	0.891
WAR	0.122	0.115	0.103	0.089	0.038	0.141
DEMO	0.256	0.244	0.265	0.189	0.067	0.315
YEARSOPEN	0.172	0.160	0.179	0.121	0.061	0.198
ASSASS	0.886	0.879	0.825	0.610	0.142	0.970
BMP	0.994	0.993	0.994	0.994	0.619	0.998
MIX	0.108	0.113	0.100	0.069	0.203	0.139
OECD	0.441	0.401	0.508	0.543	0.212	0.538
OIL	0.724	0.735	0.689	0.604	0.149	0.707
PI	0.156	0.181	0.150	0.095	0.037	0.253
REVC	0.251	0.251	0.241	0.153	0.035	0.439
RGDP	0.108	0.107	0.112	0.068	0.032	0.135
SCOUT	0.411	0.388	0.377	0.238	0.071	0.463
SOC	0.997	0.997	0.998	0.997	0.423	0.999
STGDC	0.171	0.189	0.149	0.111	0.058	0.323
PINSTAB	0.126	0.123	0.134	0.090	0.041	0.143
AFRICA	0.141	0.150	0.139	0.085	0.034	0.136
LAAM	0.661	0.717	0.605	0.430	0.097	0.620
BANK	0.511	0.457	0.473	0.425	0.113	0.905
PRIVATE	0.415	0.383	0.399	0.279	0.038	0.825
PRIVY	0.113	0.114	0.101	0.065	0.027	0.216
MONEY	0.153	0.160	0.142	0.077	0.027	0.333

B Further tables

Table 11 Descriptive statistics of gr, sd^-, sd^+, sd and $RGDP$: 1960-89 & 1974-89

Dataset	Variable	Mean	Std. Dev.	Min	Max
1960-89 (60 countries)	gr	0.0091	0.0071	-0.0052	0.0269
	sd	0.0223	0.0137	0.0083	0.0788
	sd^-	0.0168	0.0109	0.0062	0.0579
	sd^+	0.0148	0.0092	0.0054	0.0555
	$RGDP$	2.0400	1.8674	0.2080	7.3800
1974-89 (50 countries)	gr	0.0123	0.0197	-0.0384	0.0667
	sd	0.0572	0.0291	0.0190	0.1790
	sd^-	0.0617	0.0357	0.0190	0.2310
	sd^+	0.0539	0.0275	0.0160	0.1390
	$RGDP$	1.1486	1.0695	0.2440	5.3080

Table 12 List of countries in 1960-89 dataset

Name	Symbol	Name	Symbol	Name	Symbol
Argentina	ARG	Greece	GRC	Netherlands	NLD
Australia	AUS	Guatemala	GTM	Norway	NOR
Austria	AUT	Honduras	HND	New Zealand	NZL
Belgium	BEL	Indonesia	IDN	Pakistan	PAK
Brazil	BRA	India	IND	Panama	PAN
Canada	CAN	Ireland	IRL	Peru	PER
Switzerland	CHE	Iran, I.R. of	IRN	Philippines	PHL
Cote d'Ivoire	CIV	Iceland	ISL	Portugal	PRT
Cameroon	CMR	Jamaica	JAM	Senegal	SEN
Colombia	COL	Jordan	JOR	El Salvador	SLV
Costa Rica	CRI	Japan	JPN	Syria	SYR
Cyprus	CYP	Kenya	KEN	Togo	TGO
Dominican Rep.	DOM	Korea	KOR	Thailand	THA
Algeria	DZA	Sri Lanka	LKA	Turkey	TUR
Egypt	EGY	Morocco	MAR	Tanzania	TZA
Spain	ESP	Malawi	MWI	Uganda	UGA
Ethiopia	ETH	Malaysia	MYS	Uruguay	URY
Finland	FIN	Niger	NER	United States	USA
France	FRA	Nigeria	NGA	Venezuela	VEN
Ghana	GHA	Nicaragua	NIC	South africa	ZAF

Table 13 List of countries in 1974-89 dataset

Name	Symbol	Name	Symbol	Name	Symbol
Argentina	ARG	Honduras	HND	Nepal	NPL
Burundi	BDI	Haiti	HTI	Pakistan	PAK
Benin	BEN	Indonesia	IDN	Panama	PAN
Brazil	BRA	India	IND	Paraguay	PRY
Barbados	BRB	Jamaica	JAM	Rwanda	RWA
Central African Rep.	CAF	Korea	KOR	Senegal	SEN
Chile	CHL	Sri Lanka	LKA	Syria	SYR
Cote d'Ivoire	CIV	Lesotho	LSO	Chad	TCD
Cameroon	CMR	Morocco	MAR	Togo	TGO
Colombia	COL	Madagascar	MDG	Thailand	THA
Costa Rica	CRI	Mexico	MEX	Trinidad & Tobago	TTO
Dominican Rep.	DOM	Mali	MLI	Tunisia	TUN
Egypt	EGY	Mauritania	MRT	Turkey	TUR
Gabon	GAB	Mauritius	MUS	Uruguay	URY
Gambia	GMB	Malaysia	MYS	Venezuela	VEN
Guatemala	GTM	Niger	NER	Zimbabwe	ZWE
Guyana	GUY	Nicaragua	NIC		

Table 14 Description of variables

Variable	Description	Source
gr	Annual growth (log differences) of real, chain-weighted GDP per capita	Penn World Tables (PWT)
sd^-, sd^+, sd	Downside semideviation, upside semideviation and standard deviation of gr	Constructed from PWT
C	Consumption share of GDP (in real terms)	PWT
G	Government expenditure share of GDP (in real terms)	PWT
I	Investment share of GDP (in real terms)	PWT
OPENNESS	Ratio of Imports and exports to GDP (in real terms)	PWT
PRIGHTSB	Political Rights - Larger index values indicate fewer rights	Barro (1999)
CIVLIBB	Index of civil liberties (from 1 to 7; 1=most freedom)	Gastil (1992)
RULELAW	Tradition for law and order (from 0 to 1; 1=greatest tradition)	Barro (1999)
RERD	Real Exchange Rate Distortion	Levine and Renelt (1992)
ECORG	Degree of Capitalism	Hall and Jones (1996)
BMS	Standard Deviation of the Black Market Premium	Levine and Renelt (1992)
WAR	Dummy variable of countries at war anytime between 1960 and 1990	Barro and Lee (1993)
DEMO	Index of Democracy - qualitative index of democratic freedom	Knack and Keefer (1995)
YEARSOPEN	Number of Years economy has been Open between 1950 and 1994	Sachs et al (1995)
ASSASS	Number of assassinations per million population per year	Barro and Lee (1993)
BMP	Black Market Exchange Rate Premium	World Bank data
MIX	Dummy variable for mixed government	Gastil (1992)
OECD	Dummy variable for OECD countries	
OIL	Dummy variable for OPEC countries	
PI	Average inflation of GDP deflator	WBNA
REVC	Number of revolution and coups per year	Barro and Lee (1993)
RGDP	Initial real GDP per capita	PWT
SCOUT	Dummy variable for outward orientation	Levine and Renelt (1992)
SOC	Dummy variable for socialist economy	Gastil (1992)
STGDC	Standard Deviation of GDC (growth domestic credit)	IMF - IFS
PINSTAB	Measure of political instability	Barro and Lee (1993)
AFRICA	Dummy variable for countries in Subsaharan Africa	
LAAM	Dummy variable for countries in Latin America	

Variable	Description	Source
$BANK$	Ratio of deposit banks domestic assets to deposit banks and Central Bank assets	IMF - IFS
$PRIVATE$	Ratio of non-financial, private domestic assets to total domestic assets	IMF - IFS
$PRIVY$	Ratio of gross claims on the private sector by central bank and deposit banks to GDP	IMF - IFS
$MONEY$	Ratio of liquid liabilities to GDP	IMF - IFS
$MINING$	Fraction of GDP in Mining	Hall and Jones (1996)
$LIFE$	Life expectancy	Barro and Lee (1993)
SD	Ratio of short term debt to GDP	Global Dev. Finance
LD	Ratio of long term debt to GDP	Global Dev. Finance
CGC	Central Government Gross Capital Formation	IMF - GFS
CTX	Ratio Central Govt Corporate Income Tax Revenue to GDP	IMF - GFS
DEE	Ratio Central Govt Defence Expenditure to GDP	IMF - GFS
DEF	Ratio Central Govt Deficit to GDP	IMF - GFS
ITX	Share of central govt individual income tax to GDP	IMF - GFS
MTX	Ratio of import taxes to imports	IMF - IFS
SST	Ratio Social Security taxes to GDP	IMF - GFS
TAX	Ratio central government tax revenue to GDP	IMF - GFS
XTX	Ratio central govt export tax revenue to exports	IMF - GFS