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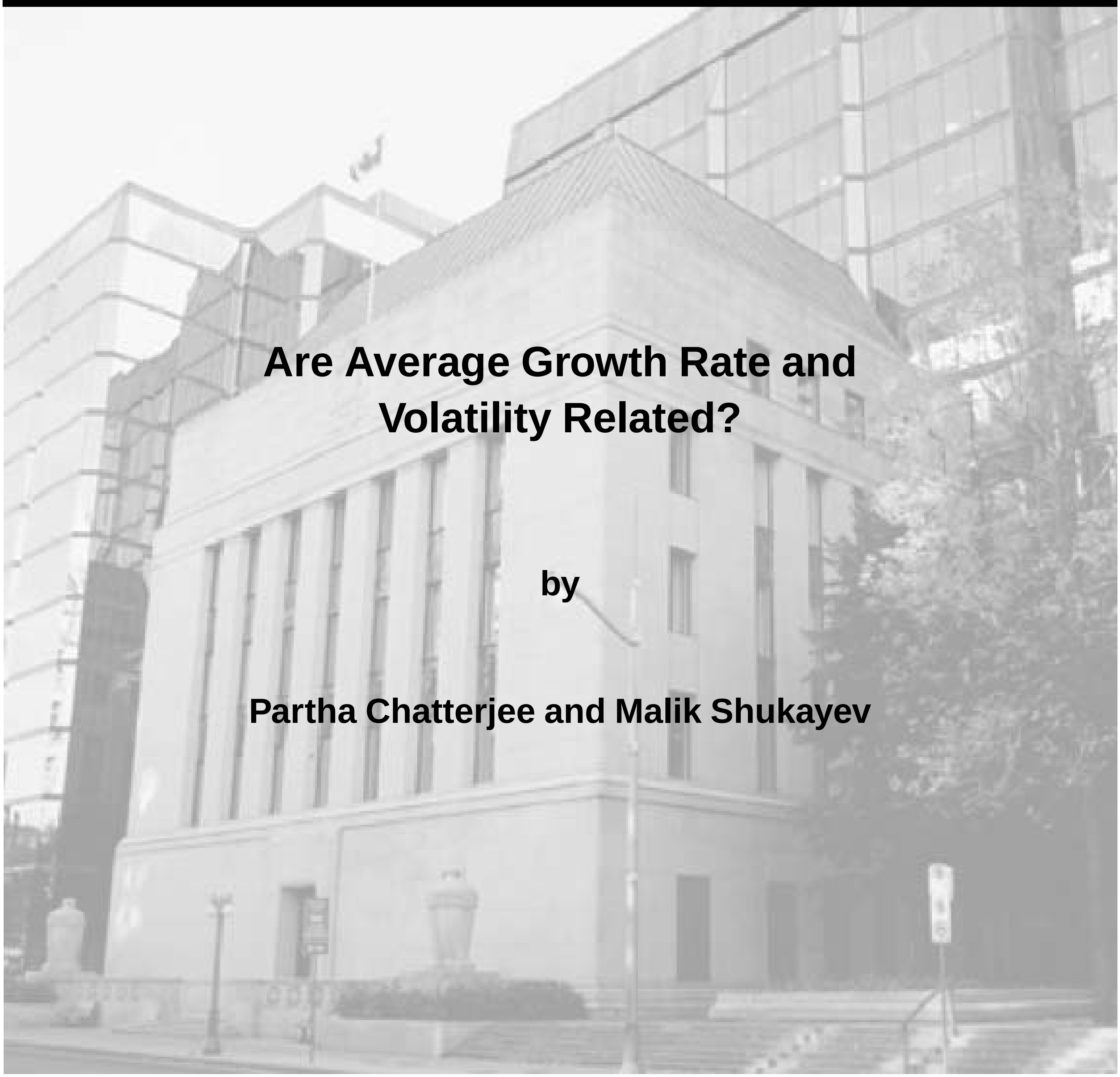

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Partha Chatterjee and Malik Shukayev

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Partha Chatterjee[1] and Malik Shukayev[2]

[1]National University of Singapore
partha@nus.edu.sg

[2]Research Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
mshukayev@bankofcanada.ca

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Abstract

The empirical relationship between the average growth rate and the volatility of growth rates, both over time and across countries, has important policy implications, which depend critically on the sign of the relationship. Following Ramey and Ramey (1995), a wide consensus has been building that, in the post-World War II data, the correlation is negative. The authors replicate Ramey and Ramey's result and find that it is not robust to either the definition of growth rate or the composition of the sample. They show that the use of log difference as growth rates, as in Ramey and Ramey, creates a strong bias towards finding a negative relationship. Further, they exhaustively investigate this relationship, for various growth rates, across time, countries, within groups of countries, and within states of the United States. The authors use different methods and control variables for this inquiry. Their analysis suggests that there is no significant relationship between the two variables in question.

JEL classification: E32
Bank classification: Business fluctuations and cycles

Résumé

La relation empirique qui lie le taux de croissance moyen et la volatilité des taux de croissance, aussi bien dans le temps que dans nombre de pays, a, sur le plan des politiques, des implications importantes, essentiellement déterminées par le signe de cette relation. Or, depuis la parution de l'étude de Ramey et Ramey (1995), il est de plus en plus admis que cette corrélation est négative pour les données postérieures à la Seconde Guerre mondiale. Les auteurs reproduisent ici les résultats de cette étude phare et constatent que ses conclusions ne tiennent pas lorsqu'on modifie la définition du taux de croissance ou la composition de l'échantillon. Ils montrent que le fait d'exprimer le taux de croissance en différence logarithmique, comme dans Ramey et Ramey, conduit à établir une relation négative. Ils analysent en outre de façon approfondie cette relation à l'aide de méthodes et de variables de contrôle différentes et en employant plusieurs taux de croissance et périodes, ainsi que des données de divers pays ou groupes de pays et d'États américains. Leurs résultats indiquent qu'aucun lien significatif n'existe entre les deux variables considérées.

Classification JEL : E32
Classification de la Banque : Cycles et fluctuations économiques

1. Introduction

The policy implications of the relationship between the average growth rate and the volatility of growth rates are significant, and, moreover, depend on the sign of the relationship. In the empirical literature, researchers have found both positive and negative relationships between the two variables, but following Ramey and Ramey (1995) a wide consensus has been building that the correlation is negative.

A negative relationship between the average growth rate and the volatility of growth rates would imply that policies that reduce short-run movements in the average income will also increase the long-term growth rate. In fact, the belief that the two are negatively related is one of the main justifications for short-run "stabilization" policies, which often refer to policies aimed at reducing volatility.[1] The World Bank and the IMF routinely advise governments to reduce fluctuations to achieve higher growth rates.[2] The calculation of the welfare cost of volatility will also be higher if this negative relationship is taken into consideration.

Empirical studies on this issue have yielded contrasting results. As already mentioned, Ramey and Ramey (1995), in the most commonly cited paper on this topic, find that the average growth rate decreases as the volatility of growth rates increases. They draw their conclusion using data from 92 countries for the period 1962–1985 and also separately from a data set of OECD countries for the period 1952–1988. Their finding has been recently confirmed by Aghion et al. (2004) using data from 70 countries for the period 1960-1995. In contrast, in an earlier study using a set of 47 countries for the period between 1950–1977, Kormendi and Meguire (1985) find that the average annual growth rates are positively related to

[1] Note that here we are not trying to ask whether reducing volatility is worthwhile. Volatility may have other effects, particularly welfare effects, which might justify policies aimed at managing volatility. What we are pointing out here is that one of the main justifications of such policies is that reducing volatility increases average growth, and our intention is to question that justification.

[2] A large number of working papers and economic reports published by the World Bank and IMF recommend reducing volatility to achieve a higher growth rate. For example, the World Bank (2003) says that "even short run volatility ... can have persistent effects on growth."

the volatility of growth rates. Grier and Tullock (1989) corroborate the Kormendi and Meguire (1985) result using a sample of 113 countries for the period 1950–1981.

In this paper, we address the robustness of the relationship between the average growth rate and the volatility of growth rates. Methodologically, we follow Ramey and Ramey (1995) for most of the paper. There are two dimensions along which we test their results. First, we examine whether the definition of growth rate matters. Ramey and Ramey (1995) (and Aghion et al. 2004), use the log difference of GDP per capita in consecutive years as the definition of growth rates. We redo their exercise with other definitions of growth rates. Second, we test the robustness of the result in different data sets — we use a larger data set, multiple sources of data, a longer time period, different subsets of the data, and different time periods. We also use time-series data to study the relationship. Our analysis brings out fresh doubts about the relationship — we fail to find a robust significant relationship between the average growth rate and the volatility of growth rates.

2. A Simple Exercise

To begin with, we do a simple and intuitive exercise. Assume that the average growth rate and the volatility of growth rates are related. Now, if we have two groups of countries such that, on average, the mean growth rates are different across groups, then the average volatilities of those two groups must also be different.

We use data from the Penn World Tables (PWT) 6.1 (Heston, Summers, and Aten 2002) and divide the sample of 109 countries into two groups based on the average growth rate for the period between 1960 and 1996. We order the countries according to their average growth rates[3] in that period and put the top 40 per cent

[3]In this exercise, for each country, we calculate the annual growth rate of GDP per capita for each year, $g_t = \frac{y_t - y_{t-1}}{y_{t-1}}$, and then take the arithmetic mean as the average growth rate. Volatility

of the countries in the first group. We call these “high-growth countries.” The second group consists of the bottom 40 per cent of the countries, referred to as “low-growth countries.” The middle 20 per cent of the countries are discarded so that there is a clear difference between the two groups. The average growth rate for the low-growth countries is 0.0027, while the average growth rate for the high-growth countries is 0.0378, which is higher by a factor of 14. Now, if average growth rate and volatility are related, then we would expect the volatilities to be significantly different for these two groups of countries, given that the growth rates are different.

Table 1: Volatility Across Groups with Different Growth Rates

	Mean of Average Growth Rates		*Mean Volatility*	
	Low-Growth Countries	High-Growth Countries	Low-Growth Countries	High-Growth Countries
All	0.0027	0.0378	0.0595	0.0527
Poor	-0.0013	0.0397	0.0663	0.0635
Rich	0.0091	0.0372	0.0441	0.0466

However, from the first row of Table 1, we find that there is no significant difference between the mean volatilities of these two groups of countries — the mean standard deviation for low-growth countries is just 1.1 times that of mean standard deviation for the high-growth countries.

We repeat the exercise to control for wide income differences across countries. Now, we first divide all countries according to their initial income (real GDP per capita in 1961). The poorest 40 per cent of the countries are included in the “poor group” (initial income less than $1694.00), while the richest 40 per cent of the countries make up the “rich group” (initial income greater than $2776.7). Each group consists of 44 countries. We then divide within each group the countries according to their growth rates, as described earlier.

is the standard deviation of those annual growth rates.

From the last two rows of Table 1 we can see that the results for both the groups, poor and rich, are similar to what we have found earlier. In both groups the average growth rates across low-growth countries and high-growth countries differ substantially, but the mean volatilities across them are quite similar.

This simple exercise plants a seed of doubt about whether there is a systematic relationship between the average growth rate and the volatility of growth rates.

3. Definition Matters

In this section we examine whether the results obtained from the regressions of average growth rates on the volatility of growth rates depend on the definition of growth rate used. Ramey and Ramey (1995) and Aghion et al. (2004) calculate the growth rate as the log difference of GDP per capita. So, in particular, we are interested in knowing whether we get different results if we use an alternative definition. We use the standard definition of growth rate as an alternative definition.

Log definition: $g_t^L = log(y_t/y_{t-1})$,

Standard definition: $g_t = (y_t - y_{t-1})/y_{t-1}$.

Volatility is measured as the standard deviation of growth rates for each of the above definitions of growth rates.

We regress the average growth rate against the volatility of growth rates twice, once for each of the above definitions of growth rates. We use the same data set used by Ramey and Ramey (1995) for this exercise. All data are downloaded from Valerie Ramey's website and are exactly what had been used in Ramey and Ramey (1995). The analysis uses data on 92 countries for 1962-1985 from PWT 5.0. The results are reported in Table 2. When we use the log definition of growth rates, we are actually replicating the results reported in Ramey and Ramey (1995), and, like them, we find that the coefficient is negative and significant. However, when we use the standard definition of growth rate in the regression, we find that the relationship is no longer significant. It is, therefore, clear that the result that we get from the regression depends on the choice of definition of growth rate.

Table 2: Growth versus Volatility: Ramey and Ramey (1995) data

	Log definition	Standard definition
Coefficient	-0.1535	-0.0604
t-statistic	(-2.3366)	(-0.8846)

Source: PWT 5.0 from Valerie Ramey's website
<http://econ.ucsd.edu/∼vramey/research/volat/volat.html>

We also redo the regressions with the control variables used in Ramey and Ramey (1995) with their data for both definitions (details of the control variable and the estimation method are provided in section 4). We find from Table 3 that the regression coefficient for volatility is negative when the log definition is used, but it is not significant when the standard definition is used.

Table 3: Growth versus Volatility (Regression with Controls): Ramey and Ramey (1995) data

Constant	**Volatility**	Av. inv. share	Av. pop. gr. rate	Initial human cap.	ln(Initial GDP/cap.)
Log Definition of Growth Rates					
0.0722	-0.2110	0.1267	-0.0581	0.0007	-0.0087
(4.2093)	(-3.0644)	(8.7000)	(-0.4272)	(1.2788)	(-4.0685)
Standard Definition of Growth Rates					
0.0572	-0.0800	0.1275	-0.1162	0.0006	-0.0072
(3.2320)	(-1.1614)	(8.5990)	(-0.8350)	(0.9295)	(-3.2169)

Source: Valerie Ramey's website
<http://econ.ucsd.edu/∼vramey/research/volat/volat.html>
Note: *t*-statistic in brackets.

Thus, often the use of the log difference of GDP per capita as a growth rate produces a result in favour of finding a negative relationship even when no significant relationship is found using the standard definition.

Notice that the two definitions are related. We can expand the log to get,

$$g_t^L = \log(1+g_t) = g_t - \frac{1}{2}g_t^2 + \frac{1}{3}g_t^3 - \cdots = g_t - e_t, \tag{1}$$

where $e_t = \frac{1}{2}g_t^2 - \frac{1}{3}g_t^3 + \cdots$. The error term, e_t, is small when growth rates are near zero and the two definitions are close. However, as g_t increases, e_t is not insignificant. The log function, being a strictly concave function, "squeezes" higher growth rates more than low growth rates. Thus, the volatility of growth rates of countries that tend to have high growth rates across time will be lower when the log approximation is used to measure the growth rate than when the standard definition is used.

A more rigorous demonstration that the log definition creates a bias towards finding a negative relationship between the average growth rate and the volatility of growth rate follows.

Suppose there are two countries, 1 and 2, which have different expected growth rates (defined as $g_t = (y_t - y_{t-1})/y_{t-1}$), but the same standard deviation of the growth rates. More specifically, suppose the growth rates in country 1 are distributed as a random variable X with a well-defined expected value on $[-1, \infty)$ and a positive variance on $(-1, \infty)$. Suppose that country 2's growth rates are distributed as the random variable Z such that $Z = X + a$, where $a > 0$ is a constant. By construction, $var(X) = var(Z)$ and $E(Z) > E(X)$. That is, country 2 has a higher average growth rate than country 1, but the same volatility of growth rates when measured using the standard definition. We want to show that $var\left(\ln\left(1+Z\right)\right) < var(\ln(1+X))$.

Proof.

$$\begin{aligned}&var[\ln(1+Z)] - var[\ln(1+X)]\\&= E[\ln(1+X+a) - E[\ln(1+X+a)]]^2 - E[\ln(1+X) - E[\ln(1+X)]]^2\end{aligned}$$

Define $\widehat{x}$ as the value in $[-1, \infty)$ such that $\ln(1+\widehat{x}) = E[\ln(1+X)]$. We can transform the above difference of variances in the following way:

$$\begin{aligned}&E[\ln(1+X+a) - E[\ln(1+X+a)]]^2 - E[\ln(1+X) - E[\ln(1+X)]]^2\\=\;& E[\ln(1+X+a) - \ln(1+\widehat{x}+a) + \ln(1+\widehat{x}+a) - E[\ln(1+X+a)]]^2\\&-E[\ln(1+X) - \ln(1+\widehat{x}) + \ln(1+\widehat{x}) - E[\ln(1+X)]]^2,\\=\;& E[\ln(1+X+a) - \ln(1+\widehat{x}+a)]^2 + E[\ln(1+\widehat{x}+a) - E[\ln(1+X+a)]]^2\\&+2E[(\ln(1+X+a) - \ln(1+\widehat{x}+a))(\ln(1+\widehat{x}+a) - E[\ln(1+X+a)])]\\&-E[\ln(1+X) - \ln(1+\widehat{x})]^2,\\=\;& E[\ln(1+X+a) - \ln(1+\widehat{x}+a)]^2 - (\ln(1+\widehat{x}+a) - E[\ln(1+X+a)])^2\\&-E[\ln(1+X) - \ln(1+\widehat{x})]^2,\\=\;& E[\ln(1+X+a) - \ln(1+\widehat{x}+a)]^2 - E[\ln(1+X) - \ln(1+\widehat{x})]^2\\&-(\ln(1+\widehat{x}+a) - E[\ln(1+X+a)])^2,\end{aligned}$$

by concavity and monotonicity of the log function, $\forall x \geq -1$ we have $|\ln(1+x+a) - \ln(1+\widehat{x}+a)| \leq |\ln(1+x) - \ln(1+\widehat{x})|$, with strict inequality for any $x \neq \widehat{x}$. Hence we have:

$$E[(\ln(1+X+a) - \ln(1+\widehat{x}+a))^2 - (\ln(1+X) - \ln(1+\widehat{x}))^2] < 0.$$

Thus,

$$var\left(\ln\left(1+Z\right)\right) - var(\ln(1+X)) < 0. \qquad \blacksquare$$

Thus, for two countries for which the distribution of growth rates is identical up to the addition of a positive constant, the country with a higher average growth rate will have lower variance when the log definition is used. This can be easily generalized to N countries.

This shows that the use of log approximation as a measure of growth rates will create a bias towards finding a negative relationship between the average growth rate and the volatility of growth rates.

3.1 Other ways of calculating average growth rate

So far we have used the simple arithmetic average for both definitions of growth rates. Two other methods are sometimes used to calculate the average growth rate over a period of time. One is the geometric average and the other is the average growth rate obtained as the coefficient of an OLS regression of GDP per capita on time. We now use average growth rates calculated by these methods in the regressions. Note that both of these methods give us the average growth rate, but we still have to calculate the volatility of growth rates. We calculate the volatility as the standard deviation of annual growth rates (computed using the standard definition). For these regressions we again use the sample used in Ramey and Ramey (1995).

From Table 4, we find that for the geometric average the coefficient is insignificant at the 5 per cent level of confidence but significant at 10 per cent. For the OLS method, the coefficient is insignificant.

Table 4: Growth versus Volatility: Ramey and Ramey (1995) data

	Geometric	OLS
Coefficient	-0.1318	-0.1385
t-statistic	(-1.9355)	(-0.9382)

Source: PWT 5.0 from Valerie Ramey's website
<http://econ.ucsd.edu/∼ vramey/research/volat/volat.html>

4. Robustness of the Relationship Across Data Sets

Next we explore whether the relationship between the average growth rate and volatility is robust to the choice of data set. To that end, we run two sets of regressions on all the data sets, one without any control and one with controls, for both definitions of the growth rate: log and standard.

The regression equation without any controls is given by:

$$\overline{g}_i = \alpha + \beta\sigma_i + \varepsilon_i, \tag{2}$$

where $\overline{g}_i$ represents the average growth rate (for either definition of growth rate used) in country i for the given period. The measure for volatility in a country i is the standard deviation of growth rates in that period, σ_i.

For the second set of regressions, we use various controls as independent variables in the regressions. Ramey and Ramey (1995) use the following set of modified Levine-Renelt (1992) control variables:

- Average investment fraction of GDP.
- Average population growth rate.
- Initial human capital.

- Initial per capita GDP (in log terms).

Kormendi and Meguire (1985) have also used a similar set of instruments. Following these papers we use the same set of controls in all data sets considered here, except for the data on U.S. states. In that case, the only control we use is the initial per capita GDP (in log terms). Data on all variables, except human capital, are from PWT 6.1. We use the average schooling years in the total population over age 25 in the year 1960 for most of the samples for initial human capital. However, for the sample that consists of only the OECD countries, we use the total gross enrollment ratio for secondary education in 1960 (also following Ramey and Ramey 1995). Data for both of these variables are from the Barro-Lee data set.[4]

We use a panel estimation strategy that is similar to the one in Ramey and Ramey (1995), which is described by the following equations.

$$g_{y_{it}} = \alpha\sigma_{y_i} + \beta\mathbf{X_i} + \epsilon_{it}, \tag{3}$$

$$\epsilon_{it} \sim N(0, \sigma_i^2), \quad i = 1, \cdots, I; \quad t = 1, \cdots, T, \tag{4}$$

where $g_{y_{it}}$ is the growth rate of country *i* at time *t* and σ_{y_i} is the standard deviation of the growth rate for the time period 1 to *T*. X_i is the vector of control variables (including a constant). We use MLE to estimate the coefficients.

The results from the regressions using PWT 5.0 data (the Ramey and Ramey 1995 sample) are already discussed in section 3. The description of the rest of the data sets that we use and the results from the regressions are provided in the following subsections.

[4]Downloaded from <http://www.nuff.ox.ac.uk/Economics/Growth/barlee.htm>.

4.1 Worldwide - PWT 6.1 data

The first sample that we use consists of all countries that we could get data on from the latest version of Penn World Tables, PWT 6.1 (Heston, Summers, and Aten 2002). The PWT 6.1 provides data on a larger set of countries and for a longer time period than PWT 5. We not only regress the average growth rate on volatility for the longest period for which data is available (1962-2000),[5] but also on two subsets, 1962-1985 and 1986-2000. (We run regressions on various other subsets, including data for each decade; conclusions from these regressions are the same as those derived from the regressions reported here.) We do this to check whether the relationship is also robust to the choice of time period.

We have already seen that log definition biases towards finding a negative relationship between the average growth rate and volatility, but then the question remains whether, even with the log definition, the relationship is consistently negative, irrespective of the sample chosen. To address this aspect, we report the results of two sets of regressions: one for the case when the standard definition is used to calculate annual growth rates, and the second for the case when the log difference is used to compute the growth rates.

Table 5 provides the results from the regressions without any control variable, and Table 6 the results with control variables.

In all regressions, we exclude countries for which the volatility of growth rates is greater than four standard deviations of volatilities of all countries in the sample as outliers.[6]

[5] 1962-2000 is the range for the growth rates, so the data actually range from 1961-2000. In all other cases, too, the sample period in the text refers to the years for which growth rate data have been used.

[6] If we include the outliers in the regressions, the coefficient on volatility is insignificant more often.

Table 5: Growth versus Volatility Regression: All Countries

		Average of Annual Growth Rates					
		Standard definition			Log definition		
Period	Countries	Slope	*t*-stat	Significance	Slope	*t*-stat	Significance
1962-1985	112	0.0423	0.6862	N	-0.0585	-0.9447	N
1986-2000	107	-0.1392	-1.9952	Y	-0.2200	-3.4089	Y
1962-2000	98	-0.0725	-1.3227	N	-0.1561	-2.9098	Y

Source: PWT 6.1 (Heston, Summers, and Aten 2002)

Table 6: Full Sample with Control Variables

Period	Coun-tries	Constant	**Volatility**	Av. inv. share	Av. pop. gr. rate	Initial human cap.	ln(Initial GDP/cap.)
Standard Definition of Growth Rates							
1962-1985	83	0.0869	-0.1224	0.1182	-0.2215	0.0005	-0.0094
(*t*-stat)		(5.5909)	(-2.1222)	(8.4601)	(-1.6328)	(0.8941)	(-5.0805)
1986-2000	78	0.0968	-0.0508	0.1007	-0.7175	0.0004	-0.0098
(*t*-stat)		(6.6931)	(-0.7389)	(5.3656)	(-5.1857)	(0.7342)	(-5.6466)
1962-2000	75	0.1049	-0.0873	0.1046	-0.5064	0.0008	-0.0113
(*t*-stat)		(8.3941)	(-1.6379)	(7.9332)	(-4.4864)	(1.7644)	(-7.5521)
1962-1996	83	0.1173	-0.1588	0.1305	-0.3921	0.0008	-0.0133
(*t*-stat)		(9.4962)	(-3.2867)	(10.7307)	(-3.4585)	(1.7449)	(-8.9415)
Log Definition of Growth Rates							
1962-1985	83	0.0860	-0.1850	0.1143	-0.1947	0.0005	-0.0091
(*t*-stat)		(5.6453)	(-3.2236)	(8.3829)	(-1.4604)	(0.8618)	(-5.0224)
1986-2000	78	0.0976	-0.0984	0.1005	-0.6935	0.0004	-0.0098
(*t*-stat)		(6.8537)	(-1.4486)	(5.4471)	(-5.0929)	(0.8342)	(-5.7540)
1962-2000	75	0.1051	-0.1464	0.1028	-0.4759	0.0008	-0.0112
(*t*-stat)		(8.5281)	(-2.7580)	(7.9397)	(-4.2868)	(1.8118)	(-7.5939)
1962-1996	83	0.1167	-0.2176	0.1270	-0.3655	0.0008	-0.0130
(*t*-stat)		(9.6313)	(-4.5387)	(10.7439)	(-3.2794)	(1.7619)	(-8.9636)

Sources: PWT 6.1 (Heston, Summers, and Aten 2002) and Barro-Lee data set (http://www.nuff.ox.ac.uk/Economics/Growth/barlee.htm)

We also run all of the above regressions on a set of countries that exclude oil exporters.[7] The results are the same.

4.2 Worldwide - IFS data

The PWT 6.1 provides data for a large set of countries for a long period of time and hence is extremely useful for our analysis. The PWT provides data in a common currency, which is a necessary requirement for many research agendas. Since we are interested only in growth rates, data on GDP per capita in local currency would be sufficient. In fact, it would avoid any problems in the data that may creep in while converting from local currency to U.S. dollars. International Financial Statistics (IFS) published by the IMF provide data on GDP per capita in local currency. In this section we use those data for our regressions. The problem is, however, that the data are not as comprehensive as the PWT 6.1. The largest set of countries we could get data on is 75, for the period 1986-2000. We report results from regressions for three different periods: 1962-1985, 1986-2000, and 1971-2000 (the latter is the longest period for which continuous data are available for a reasonable number of countries).

Table 7: Growth versus Volatility Regression: All Countries from IFS

		Average of Annual Growth Rates					
		Standard definition			Log definition		
Period	Countries	Slope	*t*-stat	Significance	Slope	*t*-stat	Significance
1971-2000	51	0.0538	0.7145	N	-0.0692	-0.7427	N
1962-1985	34	-0.1159	-0.6239	N	-0.2099	-1.1326	N
1986-2000	75	0.0800	0.9400	N	-0.0639	-0.7677	N

Source: International Financial Statistics

We run regressions for other periods too, but the coefficient is never significant for either of the definitions of growth rates.

[7] Dummy for oil-exporting countries taken from Easterly and Kraay (2000).

We repeat the regressions, now with control variables. The results are reported in Table 8.

Table 8: Full Sample with Control Variables, IFS data

Period	Countries	Constant	**Volatility**	Av. inv. share	Av. pop. gr. rate	Initial human cap.	ln(Initial GDP/cap.)
Standard Definition of Growth Rates							
1971-2000	34	-0.0098	-0.1734	0.2581	-0.4378	-0.0021	-0.0008
(t-stat)		(-1.1425)	(-1.8941)	(10.3117)	(-1.9930)	(-2.6232)	(-2.1138)
1962-1985	27	-0.0370	0.1613	0.3158	-0.0590	-0.0008	-0.0012
(t-stat)		(-2.7574)	(1.1008)	(8.1007)	(-0.2046)	(-0.6021)	(-2.1125)
1986-2000	50	-0.0050	-0.3412	0.2284	-0.4161	-0.0016	-0.0001
(t-stat)		(-0.7252)	(-3.7867)	(8.9235)	(-2.6285)	(-2.9723)	(-0.2304)
Log Definition of Growth Rates							
1971-2000	33	-0.0070	-0.3190	0.2640	-0.4321	-0.0022	-0.0007
(t-stat)		(-0.8213)	(-3.2448)	(10.5294)	(-1.9824)	(-2.8358)	(-1.7900)
1962-1985	27	-0.0317	0.0351	0.3155	-0.0794	-0.0012	-0.0010
(t-stat)		(-2.3715)	(0.2454)	(8.3723)	(-0.2790)	(-0.8841)	(-1.8787)
1986-2000	50	-0.0047	-0.3703	0.2249	-0.4002	-0.0015	-0.0001
(t-stat)		(-0.6938)	(-4.1536)	(8.9919)	(-2.5600)	(-2.9181)	(-0.2117)

Sources: International Financial Statistics and Barro-Lee data set (http://www.nuff.ox.ac.uk/Economics/Growth/barlee.htm)

4.3 OECD

Now we restrict our attention to a subset of countries that share similarities in some dimension. The first sample that we consider is the group of countries in the OECD. The sample includes the 24 countries (23 countries in some subsamples due to the reunification of Germany) that were part of the OECD before 1990. Table 9 provides the results of the regressions without any control variable. The results are similar even if we include all the present OECD members.

The results with control variables for the same sample are reported in Table 10.

Table 9: OECD Countries

	Average of Annual Growth Rates					
	Standard definition			Log definition		
Period	Slope	t-stat	Significance	Slope	t-stat	Significance
1962-1985	0.3226	1.5575	N	0.2465	1.1810	N
1986-2000	0.4637	1.7168	$N^{\star}$	0.3728	1.3886	N
1962-2000	0.3572	1.8310	$N^{\star}$	0.2902	1.4593	N
1962-1996	0.2775	1.8310	N	0.2087	1.0421	N

Source: PWT 6.1 (Heston, Summers, and Aten 2002)

Notes: N $\rightarrow$ Insignificant at 5 per cent confidence level.

$N^{\star}$ $\rightarrow$ Insignificant at 5 per cent, but significant at 10 per cent confidence level.

Table 10: OECD Countries

Period	Coun-tries	Constant	Volatility	Av. inv. share	Av. pop. gr. rt	Initial human cap.	Initial GDP/cap.
	Standard definition						
1962-1985	23	0.1486	0.1298	0.0733	-0.1430	0.0113	-0.0161
(t-stat)		(4.3176)	(0.7455)	(3.0451)	(-0.5017)	(1.4325)	(-4.2132)
1986-2000	23	0.1102	0.2252	0.0067	-0.0980	0.0091	-0.0101
(t-stat)		(1.8405)	(1.1713)	(0.1674)	(-0.2922)	(1.1568)	(-1.5710)
1962-2000	23	0.1310	0.1407	0.0418	-0.2128	0.0067	-0.0133
(t-stat)		(4.5000)	(0.9267)	(1.7720)	(-0.9269)	(1.1521)	(-4.3215)
	Log definition						
1962-1985	23	0.1465	0.0885	0.0708	-0.1315	0.0111	-0.0158
(t-stat)		(4.3521)	(0.5103)	(3.0161)	(-0.4687)	(1.4378)	(-4.1996)
1986-2000	23	0.1180	0.1523	0.0070	-0.0526	0.0082	-0.0108
(t-stat)		(1.9909)	(0.8110)	(0.1769)	(-0.1585)	(1.0469)	(-1.6889)
1962-2000	23	0.1313	0.0892	0.0391	-0.1959	0.0063	-0.0131
(t-stat)		(4.6082)	(0.5873)	(1.6946)	(-0.8635)	(1.0915)	(-4.3643)

Sources: PWT 6.1 (Heston, Summers, and Aten 2002) and Barro-Lee data set (http://www.nuff.ox.ac.uk/Economics/Growth/barlee.htm)

From the table, we find that the coefficient on volatility is always positive, though it is significant only for 1986-2000 when the standard definition is used.

4.4 Geographically separated groups

Next we divide all countries by their geographic region and look for patterns within each region.

We run regressions between the average growth rate and the volatility of growth rates for each of the groups. Table 11 reports results from the regressions without control variables only for cases in which the regression coefficient is significant. For all other cases (regions or time periods) the coefficient is insignificant.[8]

Table 11: Regions where the Coefficient is Significant

Sign	Region	Period	Definition of gr. rate
Positive	Africa	1962-1985	Standard only
	West Europe	1962-2000	Standard,log at 10%
	West Europe, Canada, & US	1962-2000	Standard,log at 10%
Negative	None	All Periods	Standard,log

Source: PWT 6.1 (Heston, Summers, and Aten 2002)

With the control variables included in the regressions, the coefficient on volatility is insignificant for all regions.

4.5 Groups according to political structure

We also divide countries according to the political structure of the country and then test for the relationship within each group of similar countries. We run two sets of regressions, once each for the two widely used measures of political system: the Polity III data by Jaggers and Gurr (1996), and the Gastil scale published by Freedom House (2003).

[8] In PWT 6.1 data, North Africa is grouped along with the Middle East, so while analyzing just African countries (and the complementary set) we did the analysis twice: first we took all African countries except the North African countries, and second we took all African countries plus the Middle Eastern countries. The results are quite similar.

4.5.1 *Polity III data*

We divide the countries into two groups, "Democracies" and "Non-Democracies," using Polity III data (Jaggers and Gurr 1996). The Polity III data provide a score for *democracy* for each country for each period. We add up democracy scores for each country over all years (1960-1994) and classify a country as a non-democracy if the sum is below a certain cut-off.[9] We have 61 countries classified as non-democracies (42 if data till 2000 are used) and 45 democratic countries (42 if data till 2000 are used).

Then we run regressions between the two variables of interest for each group, for each sample period. None of the regression coefficients in these regressions is significant for the standard definition and only one is significant for the log definition. In some cases, the coefficients are positive but insignificant.

Table 12: Growth versus Volatility Regression: Democracies

		Average of Annual Growth Rates					
		Standard definition			Log definition		
Period	Countries	Slope	*t*-stat	Significance	Slope	*t*-stat	Significance
		Democracies					
1962-1985	45	0.1669	1.4303	N	0.0949	0.7976	N
1986-2000	42	-0.1399	-0.8816	N	-0.2069	-1.3403	N
1962-2000	42	-0.1117	-0.8756	N	-0.1767	-1.3778	N
1962-1996	45	0.0469	0.3832	N	-0.0205	-0.1664	N
		Non-Democracies					
1962-1985	61	0.1260	1.4995	N	0.0202	0.2366	N
1986-2000	54	-0.1022	-1.1828	N	-0.1844	-2.3401	Y
1962-2000	52	0.0204	0.2882	N	-0.0715	-1.0219	N
1962-1996	61	0.0120	0.1397	N	-0.0990	-1.1749	N

Sources: PWT 6.1 (Heston, Summers, and Aten 2002) and Polity III (Jaggers and Gurr 1996)

[9] The maximum possible score for any year is 10, so for 35 years a sum of 350 is the maximum possible. We set the cut-off at 150.

Adding the various control variables in the regressions, we find non-democracies have significant negative coefficients for a few sample periods, while the rest are insignificant.

4.5.2 Gastil scale

The Gastil scale gives two seven-point indices, one for "Political Freedom" and another for "Civil Rights," for each country for each year (from 1972-73 to 2001-2002). On this scale, 1 denotes the best performance and 7 is the worst. We take the mean of these indices for each year and take the average of that over the years to divide the countries into two groups. We classify countries with a score greater than or equal to 3.5 as non-democratic.

Table 13: Growth versus Volatility Regression: Democracies (Gastil)

		Average of Annual Growth Rates					
		Standard definition			Log definition		
Period	Countries	Slope	*t*-stat	Significance	Slope	*t*-stat	Significance
		Democracies					
1962-1985	45	0.1196	1.0026	N	0.0374	0.3115	N
1986-2000	40	-0.0829	-0.4153	N	-0.1693	-0.8541	N
1962-2000	41	-0.0990	-0.7834	N	-0.1698	-1.3300	N
1962-1996	45	0.0626	0.5716	N	-0.0063	-0.0575	N
	Non-Democracies						
1962-1985	57	0.1239	1.3774	N	0.0325	0.3509	N
1986-2000	52	-0.1853	-1.8914	$N^\star$	-0.2464	-2.8200	Y
1962-2000	51	-0.0091	-0.1432	N	-0.1055	-1.5915	N
1962-1996	57	-0.0467	-0.4911	N	-0.1469	-1.5567	N

Sources: PWT 6.1 (Heston, Summers, and Aten 2002) and Freedom House (2003)
Note: $N^\star \rightarrow$ Insignificant at 5 per cent, but significant at 10 per cent confidence level.

Using this classification, we find that only one of the regressions without control variables yield a coefficient significant at the 5 per cent level of confidence (for the period 1962-2000, the coefficient is significant at 10 per cent). When control variables are added, the regression on countries classified as "non-democratic" has significant negative coefficients only for 1986-2000.

4.6 U.S. states

One of the most homogeneous groups on which we test the existence and sign of the relationship of interest consists of U.S. states.

We have two different sets of data on real gross state product (GSP) for all U.S. states. The first is from Bernard and Jones (1996), available at Jones' website,[10] ranging from 1963-1989; we denote this data set as BJ. The second is from the Bureau of Economic Analysis (BEA) website[11] for the period 1977-2001 (denoted as BEA). We calculate GSP per capita as well as GSP per employee for each data set for our analysis. Thus, we analyze four sets of data.[12]

Table 14: Average Growth versus Volatility Regression: U.S. States

		Average of Annual Growth Rates					
		Standard definition			Log definition		
Data Set	Period	Slope	t-stat	Significance	Slope	t-stat	Significance
BJ - per employee	1963-1989	-0.2245	-1.2756	N	-0.2779	-1.6102	N
BJ - per capita	1963-1989	-0.1806	-1.3280	N	-0.2394	-1.8431	$N^\star$
BEA - per employee	1977-2001	-0.1252	-1.1677	N	-0.1817	-1.7166	$N^\star$
BEA - per capita	1977-2001	-0.1635	-1.6384	N	-0.2211	-2.3012	Y

Sources: <http://emlab.berkeley.edu/users/chad/datasets.html> and <http://www.bea.gov/bea/regional/data.htm>

Notes: BJ - Bernard and Jones (1996) BEA - Bureau of Economic Analysis.

$N^\star \rightarrow$ Insignificant at 5 per cent, but significant at 10 per cent confidence level.

The results, summarized in Table 14, clearly show a lack of significant relationship between the average growth and volatility of growth - the coefficient is

[10] <http://emlab.berkeley.edu/users/chad/datasets.html>.

[11] <http://www.bea.gov/bea/regional/data.htm>.

[12] Unfortunately, data for the common years did not match across the two data sets, and hence we were unable to combine the two data sets. Also, Alaska was an outlier in all the data sets and was not included in the subsequent data sets for which the results are reported. Including Alaska makes many of the coefficients positive, often significant.

never significant except once (two are significant at the 10 per cent confidence level, but not at 5 per cent).

We run the same set of regressions with the log of initial income (the income in the first year of the sample time period) added as a control variable. After adding this variable to the regression, the sign reverses in two cases, which now have a positive significant coefficient (there is still one case of negative significance).

Thus, even in this homogeneous group we find there is no significant and robust relationship between the average growth rate and the volatility of growth rates.

5. Relationship in Time-Series Data

So far, we have been using cross-section data. We now probe the relationship using time-series data provided by Angus Maddison at his website.[13]

We divide the available data into non-intersecting five-year periods (like 1920-1924, 1925-1929).[14] For each country, we run a regression of average growth rate against volatility calculated for each five-year period.

The results are summarized in Table 15. The coefficient on the volatility is insignificant for a vast majority of the countries, negatively significant for a few, and positively significant[15] for even fewer countries. Thus, there is no conclusive evidence of any relationship between the two variables of interest, even within countries over time.

[13] <http://www.ggdc.net>

[14] We also divide into five-year periods by moving the lowest year for the period by one year from the last period (like 1920-1924, 1921-1925, 1922-1926, etc.). Results are similar.

[15] An interesting observation for data sets that start before 1950 is that countries which were a part of the losing coalition in the Second World War tend to have a negative relationship between average growth and volatility. For example, for the sample 1870-2001, countries with a significant negative relationship include Austria, Germany, Italy, Japan, and Spain, apart from Australia.

Table 15: Time-Series Results

	Number of Countries						
Period	Total	Negative Significance		Positive Significance		Insignificance	
		Standard	Log	Standard	Log	Standard	Log
1870-2001	22	6	8	0	0	16	14
1900-2001	29	9	13	1	0	19	16
1950-2001	137	20	22	7	5	110	110

Source: <http://www.ggdc.net>

6. Conclusion

The central question of this study is whether there is a relationship between the average growth rate and the volatility of the growth rates. We tested the relationship in two dimensions: one, whether the choice of definition of growth rate matters, and two, whether the relationship is consistent across data sets and time periods for either of the definitions.

To test the importance of the definition of growth rates, we regressed average growth rates on volatility using exactly the same sample as Ramey and Ramey (1995), but with two definitions of growth rates. When we used the log difference to define growth rates, we obtained a negative significant relationship between the two, as in Ramey and Ramey (1995). However, when we used the standard definition instead, there was no longer a significant relationship, both for regressions with and without control variables. We also showed mathematically how the use of log difference can create a bias towards finding a negative relationship even when a relationship is absent if the standard definition is used.

We tested the relationship across data sets and time periods using data from Penn World Tables and International Financial Statistics. We also tested the relationship within various subgroups of countries. We found that often the relationship was not significant, with or without controls, both for the log and the standard definition of growth rates. The number of cases where we found a negative significant relationship was higher for the log definition. There were a few cases with positive significance. The same picture emerged in data across U.S. states; the relationship was never significant for the standard definition, but was sometimes negatively significant for the log definition. Using time-series data, the relationship was negatively significant under both definitions, but an overwhelmingly large number of regressions produced insignificant coefficients.

Thus, we establish two things: the use of the log definition for growth rates may create a bias towards finding a negative relationship between average growth rates and the volatility of growth rates. Even with the log definition, the relationship depends on the choice of data. The relationship is non-existent in a large number of data sets under both definitions of growth rates. Thus, overall, we fail to find a consistent relationship between the average growth rate and the volatility of growth rates.

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