THE EFFECTS OF BUSINESS CYCLES ON GROWTH

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October, 2001

Abstract. This paper studies the link between business cycles and long-term growth rates. We present empirical evidence that uncovers interesting and significant interactions between cycles and growth. We show that business cycles cannot be considered as temporary deviations from a trend and that there is a strong positive correlation between the persistence of short-term fluctuations and long-term growth rates. A simple endogenous growth model where business cycles affect growth can easily replicate this correlation. We then study the link between volatility and growth. We show that countries with more volatile fluctuations display lower long-term growth rates. We also find evidence that there is a nonlinearity in this relationship. The effect of business cycles on growth is much larger for poor countries or countries with a lower degree of financial development.

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* This paper is prepared for the 5th annual conference of the Central Bank of Chile, November 29-30, 2001. I would like to thank Ilian Mihov for usefule comments and suggestions. The most recent version of the paper can be found at http://www.insead.edu/~fatas.

1 Introduction

This paper explores the links between business cycles and long-run growth. Although it is clear that from a theoretical point of view both of these phenomena are driven by the same macroeconomic variables, the interaction between economic fluctuations and growth has been largely ignored in the academic literature. The main reason for this lack of attention is the surprising stability of long-term growth rates and its apparent independence of business cycle conditions, at least among industrial economies. The fact that business cycles in these countries can be characterized by recoveries that follow recessions and bring GDP levels to trend, suggests that one can study growth and business cycles independently. To illustrate this point, Figure 1 displays real GDP per capita for the US economy during the period 1870-1999. Clearly, a simple log-linear trend represents a very accurate description of the long-term patterns of U.S. output per capita.[1] This pattern is very similar for other industrial countries such as France, Germany and Britain, although there are stronger indications of breaks in the slope of the trend, especially after second world war.

[**Insert Figure 1 about here**]

A possible second reason why growth and business cycles have been studied with two different set of models is the lack of an accepted and empirically-valid endogenous growth model. From an empirical point of view, the (augmented) Solow model seems to fit the cross-country data quite well, as shown in Mankiw, Romer and Weil (1992)or Barro and Sala-i-Martin (1992, 1995). Early attempts to validate empirically endogenous growth models have not been very succesful, as argued in Easterly, Kremer, Pritchett and Summers (1993) or Jones (1995b). As a result, there is no established framework to analyze the impact of business cycles on growth.

Despite all these arguments, there is a growing literature that has established interesting theoretical links as well as empirical regularities that relate growth and business cycles. First of all, recent analysis of cross-country growth performances reveals less support for Solow-type growth models.[2] At the same time, despite the powerful message of Figure 1, since the work of Nelson and Plosser (1982), it

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[1] As Jones (1995a and 1995b) has pointed out, an extrapolation of a log-linear trend for the pre-1914 period can produce extremely accurate point estimates of today's GDP levels.

[2] Bernanke and Gürkaynak (2001) or Easterly and Levine (2001).

is commonly accepted that business cycles are much more persistent than what is suggested by Figure 1. Moreover, the GDP profile of countries other than the U.S. is at odds with steady-state models of economic growth, as suggested by Easterly and Levine (2001). There is also direct evidence of the effects of business cycles on variables related to long-term growth. Productivity is affected by the business cycle and seems to react to events that are supposed to be only cyclical.[3] Growth related variables, such as investment or R&D expenditures, are procyclical. Finally, features of the business cycle, such as the volatility or the persistence of economic fluctuations are correlated with long-term growth rates.[4] These empirical regularities are very difficult, or impossible, to reconcile with models where technological progress and long-term growth are exogenous.

This paper presents an overview of the theoretical arguments as well as a summary of the evidence of the effects of business cycles on growth in a large cross section of countries.[5] The analysis is done at two levels. The first part of the paper looks at the connections between certain characteristics of the business cycle and long-term growth rates and establishes a set of empirical regularities. These regularities, although they uncover interesting connections between long-term growth and business cycles, do not lead to a negative growth effect of economic fluctuations. In other words, more volatile economies grow at the same rate than less volatile ones. The second part of the paper addresses directly the case where business cycles have a significant effect on long-term growth rates by analyzing the possibility of asymmetric business cycles as well as considering the effects of uncertainty.

Overall, the evidence presented suggest that business cycles and long-term growth rates are determined jointly by the same economic model. There is evidence that characteristics of the business cycle are not independent of the growth process and we find that the volatility associated to the business cycle is negatively related to long-term growth rates.

The paper is organized as follows, Section 2 looks at the relationship between the persistence of business cycles and long-term growth. Section 3 explores the links between volatility and growth and Section 4 concludes.

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[3] See, for example, Shea(1998).

[4] See Fatás (2000a and 2000b) for evidence of the effects of business cycles on R&D expenditures and the link between persistence and growth.

[5] Our sample of 98 countries is identical to the one used by Bernanke and Gürkaynak (2001), and excludes formerly planned economies. For a detailed description of the data, see Appendix 1.

2 Trends, persistence and growth

The stability of growth rates for the U.S. economy, illustrated in Figure 1, has been used as an argument to keep the analysis of trends separate from the analysis of economic fluctuations. However, this apparent stability of U.S growth rates is at odds with the econometric analysis of its time series propertites. In that analysis, one finds that the log-linear trend is far from being an accurate representation of its long-term properties. This stylized fact was brought up by the work of Nelson and Plosser (1982), who after questioning the traditional method of measuring business cycles as temporary deviations of output from a deterministic log-linear trend, started a debate on the persistence of output fluctuations and the existence of a unit root in GDP. Although some of this debate is still open, one fact that is not questioned is that output does not show a strong tendency to return to trend after being hit by a shock. The importance of this fact is that the separation between growth and business cycles is not possible anymore and one needs to come out with models where the stochastic properties of the trend are somehow related to the business cycle itself.

Initially, this evidence was used by proponents of the real business cycle theory. The interpretation was that the persistence of business cycles was indeed a sign of the nature of the disturbances that caused business cycles (technological events). Despite the fact that growth and fluctuations were now part of the same model, there was still a sense in which growth was left out of the analysis given that long-term growth rates where determined by the exogenous growth rate of technological progress in a Solow-type model.[6]

An alternative explanation to the high persistence of business cycle fluctuations comes from models where growth dynamics becomes a central part of the properties of the business cycle. Within the framework of endogenous growth models, King, Plosser and Rebelo (1988) and Stadler (1989) noticed that many types of disturbances, different from permanent shifts in the production function, can produce persistent fluctuations. The intuition is simple, any temporary disturbance that has an effect on the amount of resources allocated to growth can produce permanent effects on the level of output. In other words, if during recessions investment in growth-enhancing projects is diminished and the recovery is not strong enough to catch up with the time lost, output will not return to its

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[6] See, for example, Kydland and Prescott (1982) or King, Plosser, Stock and Watson (1991).

trend and recessions can have costs that go well beyond the added volatility to the economy.

Can these two explanations be distinguished empirically? The task is difficult and two approaches have been followed. One is to compare the relative ability of both type of models to match features of the business cycle. This is the approach taken by Jones, Manuelli and Siu (2000). Their conclusions are in some cases supportive of endogenous growth models but there are still many difficulties discriminating between the two types of models. An alternative methodology is to look for empirical connections between the degree of persistence of business cycles and long-term growth rates. This is only interesting if there are significant difference in persistence across countries. Cogley (1990) studies the variability of the low-frequency component of output in a sample of 9 countries and shows that there are significant differences among them, the US having the most stable low-frequency component of the sample. Is this degree of persistence related to the long-term growth rates of these countries? If it is, then there would be a direct connection between long-term growth rates and a feature of economic fluctuations that is intrinsically linked to the question of whether business cycles have consequences beyond uncertainty and volatility.

To illustrate the link between persistence and growth, we can think of a reduced-form version of a model that displays endogenous growth.[7] Assume that the economy is characterized by a production function of the type

$$Y_t = A_t L_t^{\alpha} K_t \tag{1}$$

where Y is output, L is labor, A is a technological parameter and K is the stock of knowledge of the economy that for simplicity we assume that affects all firms equally and where no firm is large enough to internalize the effects of its actions on this stock. We assume that knowledge is accumulated by the process of learning by doing and takes the following functional form

$$\frac{K_t}{K_{t-1}} = \left(\frac{Y_{t-1}}{K_{t-1}}\right)^{\alpha} \tag{2}$$

where λ represents the degree of learning in the economy.[8]

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[7] Appendix 2 presents a complete optimizing model that leads to dynamics identical to the ones of this reduced form model.

[8] This production function together with the learning process implies very strong scale effects.

The growth rate of output at any point in time is equal to

$$\Delta y_t = a_t - (1-\gamma)a_{t-1} + \alpha(l_t - (1-\gamma)l_{t-1})) \tag{3}$$

where small letters denote natural logarithms. We will assume that a_t is a stationary process and that the labor supply function is such that labor is also stationary. Let $\hat{a}$ and $\hat{l}$ be the steady state values of labor and productivity. In the absence of any cyclical disturbance, the economy will grow at a rate equal to

$$\Delta y_t = \gamma\hat{a} + \alpha\gamma\hat{l} \tag{4}$$

We introduce now cyclical shocks by postulating an stochastic process for the technology parameter a_t. Assume that it follows an AR(1) process such that

$$a_t = \hat{a}(1-\rho) + \rho a_{t-1} + \epsilon_t \tag{5}$$

Under the assumption that labor supply is inelastic, we can express output growth as a function of ϵ.

$$\Delta y_t = (1-(1-\gamma))L)C(L)\epsilon_t \tag{6}$$

where L is the lag operator and $C(L)$ is the Wold representation of the AR(1) process for a_t so that

$$C(L) = (1 + \rho L + \rho^2 + L^2 + \rho^3 L^3 + ...) \tag{7}$$

From equation (6), it is clear that cyclical fluctuations, despite being transitory in nature have long-lasting effects on output because of the effects on the accumulation of knowledge. One way to look at these long-lasting effects is to measure the change in the long-term forecasts of output when there is a shock to a_t. The answer to this question is simply the sum of the coefficients from the expression (6) for Δy_t above.

$$\Delta y_t = D(L)\,\epsilon_t \tag{8}$$

These scale effects are not necessary for any of the intuitions developed with this simple model and a model without scale effects can display similar dynamics. The reason for having such a simplistic production function and learning process is to make the resolution of the model as simple as possible and provide the reader with the clearest possible presentation of the intuition. See Fatás (2000a) for a detailed discussion of these arguments.

Where $D(L) = d_0 + d_1L + d_2L^2 + d_3L^3 + ...$ is a lag polynomial. Then, the coefficients d_j measure the impact of a shock ϵ_t on the growth rate of y in period $t + j$. If we add up these coefficients we can find the long-run impact of a given shock on the level of output. In general,

$$P^J = \sum_{j=0}^{j=J} d_j \tag{9}$$

represents the impact of a shock ϵ_t on the level of output at $t + J$. The infinite sum of all d_j coefficients, measures the permanent impact of a given shock on the level of output, let P be this sum,

$$P = \lim_{J \to \infty} P^J = D(1) \tag{10}$$

In our model, the sum of these coefficients is equal to

$$P = 1 + (\rho - (1 - \gamma)) + (\rho^2 - \rho(1 - \gamma)) + (\rho^3 - \rho^2(1 - \gamma)) + ... \tag{11}$$

which can be simplified to

$$P = \frac{\gamma}{1 - \rho} \tag{12}$$

This expression is very intuitive, the long-term effects of business cycles are an increasing function of the persistence of the shocks themselves and the parameter γ which represents the speed at which knowledge accumulates through learning by doing. What it is important for our argument, is that long-term persistence becomes a measure of the long-term costs of recessions and the origin of these costs are the effects that recessions have on the accumulation of knowledge (the driving force behind long-term growth). In fact, in this stylized model, in the absence of long-term growth ($\gamma = 0$), output always returns to its log-linear trend.

The model above produces a simple and intuitive explanation that suggests that business cycles leave permanent scars on output through their effects on the growth process. During recessions, the growth process stops (or slows down). Recoveries bring the growth rate back to normal but not above its average value. As a result, output never returns to the trend it was following before the recession started. Countries where growth rates are larger have ‘more to lose’ during recessions and, therefore, end up displaying larger permanent effects of business cycle. Another way of describing what is happening is that fast growing countries end up with more volatile trends.

Before moving to our empirical test, it is worth mentioning that there is a set of papers that postulate that recessions can have the opposite effect (i.e. be beneficial for growth). Caballero and Hammour (1994), Gali and Hammour (1991) or Hall (1991) present models where recessions lead to permanent improvements in productivity because these are times where research activities offer a higher return than production activities or because recessions lead to the destruction of the least productive firms. The importance of the above relationship is that it can be used to discriminate among different theories of growth and business cycle. For example, in a model where growth is coming from exogenous technological progress (assume that A grows exogenously at some rate) this measure of persistence (P) would be simply a function of the parameter ρ. The typical formulation of a Real Business Cycle, would have $\gamma = 0$ and $\rho = 1$ together with exogenous technological progress for the technological parameter A. Under these circumstances, persistence would be independent of growth and $P = 1$

Is there any empirical evidence that persistence and growth rates are correlated? The answer is yes. We have looked at a sample of about 100 countries from the Summers-Heston dataset and calculated the degree of persistence of annual fluctuations and then see if this degree of persistence is correlated to the countries' long-term growth rates. Persistence is calculated using two different methods. First, we estimate an AR1 process for GDP growth and we approximate P above by inverting the lag polynomial associated to the AR1 process. Second, we use Cochrane's variance ration, a measure that has been used many times before to look at the persistence of time series.[9] This measure is equal to

$$V^J = \frac{(1/J)\,\mathrm{var}(y_t - y_{t-J})}{\mathrm{var}(y_t - y_{t-1})} = 1 + 2\sum_{j=1}^{J-1}(1 - j/J)\,\rho_j \tag{13}$$

where ρ_j is the $j-$th autocorrelation of the growth rate of output. Taking the limit of this expression as J tends to infinity, we obtain a measure of long-run persistence,

$$V = \lim_{J\to\infty} V^J \tag{14}$$

Both V and P take value 0 for a trend-stationary series and value 1 for a

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[9] See Cochrane (1988) for a description of this series.

random walk. For any other series,

$$V = |P|^2 \frac{\text{var}(\epsilon)}{\text{var}(\Delta y)} \tag{15}$$

For the model above, this expression is equal to

$$V = \frac{\gamma^2 \,(1-\rho^2)}{(1-\rho)^2(\gamma^2 + 2(1-\rho)(1-\gamma))}$$

This expression is always increasing in γ as long as $\gamma < 2$, a condition that is required for output growth to be a stationary series. In other words, fast-growing countries display a larger degree of persistence measured by any of our two indicators (P or V).

Table 1 presents the results of regressing the degree of persistence of annual fluctuations on the long-term growth rate of output for the full sample (98 countries) as well as the restricted sample of OECD countries. We do this for the two proposed measures of persistence and using GDP per capita as our measures of economic activity. In the case of the variance ration we choose a window of 5 years (i.e. including correlations of GDP growth with its first 4 lags).

In all cases, the coefficient is positive and significant. It is interesting to notice that for the case of the OECD economies the fit of the regression and the size of the coefficient are larger than in the overall sample.[10]

Table 1. Persistence and Growth.

$\text{Persistence}_i = \alpha + \beta\,\text{Avg.Growth}_i + \nu_i$

	P		$V5$	
Sample	All	OECD	All	OECD
β	0.066	0.383	0.090	0.611
	(0.029)	(0.137)	(0.043)	(0.102)
R^2	0.09	0.53	0.07	0.62

Sample: 1950-1998
Robust standard errors in parentheses.

The results of Table 1 show strong support for the idea that growth and business cycles are not independent phenomena. To be able to explain the esti-

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[10] These results are also confirmed when using quarterly data, see Fatás (2000a).

mates of Table 1 one needs a theory where growth and fluctuations are jointly determined.

One has to be careful interpreting this result because of the symmetric nature of the argument. What we just said about recessions (negative shocks) could be said about booms (positive shocks). As a result, fast growing countries would be hurt more by recessions but would also benefit more from positive shocks. In that sense, the correlation between persistence and growth, although encouraging, does not provide a direct link between the volatility of fluctuations and average growth. More fluctuations lead to more volatile trends but the average growth rate should be the same. Next section explores theories and empirical evidence that go beyond this first relationship between growth and business cycles. By introducing asymmetries and by taking into consideration the direct role that volatility and uncertainty can play in determining growth rates one can establish links between volatility and average growth rates.

3 Business cycles, uncertainty and growth

Do business cycles affect long-term performance? Is volatility bad for growth? So far, the evidence presented cannot provide an answer to this question. In models of the type sketched in Section 2, an increase in uncertainty, an increase in the volatility of the disturbance ϵ, has no effect on long-term growth rates. Output growth is not affected by business cycles.

There are two ways of modifying our analysis such that volatility and uncertainty become relevant for long-term growth. The first one is very mechanical and consists on thinking about fluctuations as being asymmetric. What if more fluctuations meant deeper recessions relative to unchanged expansions? An example of this type of model is Rodrik (1991) who considers the case of policy reform and the uncertainty introduced by the possibility that reform is reversed. In his model, additional uncertainty not only increases risk but also lowers the average return to investment because it is assumed that no reform leads to larger distortions. A second example is the analysis of political uncertainty. Political uncertainty is usually measured by variables such as the number of revolutions and military coups or political assassinations. One can argue that an increase in both of these variables does not simply represent more volatility around a constant mean but more volatility *and* a lower mean. Introducing this type of asymmetric fluctuations in an endogenous growth model can lead to a straightforward connection between fluctuations and growth. For example, if in the model discussed in Section 2 we introduced asymmetric fluctuations in the disturbance ϵ, there would be a direct relationship between average technology and its volatility and, therefore, the average growth rate of output. More volatile economies would display a lower mean for the technology parameter A and, as a result, would grow at a lower rate. Another type of asymmetry can come from the accumulation process. What if the negative effects of recessions on learning by doing are stronger than the positive effects of booms. This is the spirit of the model of Martin and Rogers (1997). In this case, there is also a negative relationship between volatility and growth.

If we stick to a world where disturbances and business cycles are symmetric, uncertainty can also affect growth directly. Through risk aversion or irreversibilities in investment one can generate a relationship between uncertainty, investment and growth.[11] Finally, in an endogenous growth model there can also be general equilibrium effects of uncertainty on growth through consumer's behavior and the labor supply as in Jones, Manuelli, Stachetti (1999).

From an empirical point of view there are several papers that have looked at the relationship between volatility and growth. There is a first group of papers that looks directly at the relationship between volatility and growth without focusing on a specific channel through which the effects are taking place. These are the cases of Ramey and Ramey (1995), Kormendi and Meguire (1985) or Martin and Rogers (2000). A second strand of the literature looks into some specific source of uncertainty and how this uncertainty has affected long-term growth. For example, Barro (1991) or Alesina, Ozler, Roubini and Swagel (1996) study the effects of political instability on growth and Judson and Orphanides (1996) analyzes the effects of the volatility of inflation on growth. Most of these papers present evidence in favor of the hypothesis that volatility, uncertainty or political instability hurts growth. We now review some of this evidence and present some additional tests of the robustness of the relationship between volatility and growth as well as investigating some of the specific channels through which the relationship takes place.

We initially measure the volatility of the business cycle by the standard deviation of per capita GDP growth rates. Table 2 displays the results of a regression of average growth rates (1950-1998) on business cycle volatility for all the coun-

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[11] Bernanke (1983) or Bertola and Caballero (1994).

tries in our sample. The coefficient is positive and significant. Conditioning the correlation to the logarithm of 1960 GDP per capita (GDPpc60) does not alter the size of the coefficient although its significance falls.[12] In terms of the size of the coefficient a one standard deviation increase in volatility (about 2.3%) leads to a decrease in the growth rate of per capita GDP of about 0.4%, a relatively large effect.

Table 2. Volatility and Growth.

$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$

	(1)	(2)
Volatility	-0.241	-0.179
	(0.075)	(0.090)
GDPpc60	-	0.365
	-	(0.182)
R^2	0.13	0.15

Sample: 1950-1998
Robust standard errors in parentheses.

This result is consistent with the regressions of Ramey and Ramey (1995) and Martin and Rogers (2000) and it supports the view that volatility hurts growth. The rest of this section explores the robustness of this simple correlation as well as the possible mechanisms behind this effect.

Is it volatility or uncertainty?

In Table 2, we measure business cycle volatility as the standard deviation of per capita GDP growth rates. This measure includes variations in GDP that can be forecasted by economic agents. If what really matters for growth is uncertainty, what we need to do is to look at the residuals of a forecasting equation for output growth. For each of the countries in our sample we regress output growth on its own lagged value as well as a linear and a quadratic trends. Introducing these trends also serves the purpose of removing low frequency movements in output

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[12] Although the data starts for some countries in 1950, we always choose 1960 as the 'initial' year in order to keep consistency across countries. Using 1950 for those countries for which data is available does not change any of the results presented in the paper.

that log-linear detrending cannot take care of.[13] The results, presented in Table 3, are practically identical, both in terms of the size of the coefficient and the fit of the regression. Because of the similarity of the results, for the rest of the paper we will use the standard deviation of per capita output growth rates as our measure of volatility.

Table 3. Uncertainty and Growth.

$\text{Growth}_i = \alpha + \beta\,\text{Uncertainty}_i + \delta X_i + \nu_i$

	(1)	(2)
Uncertainty	-0.247	-0.187
	(0.077)	(0.093)
GDPpc60	-	0.360
	-	(0.181)
R^2	0.13	0.15

Sample: 1950-1998
Robust standard errors in parentheses.

Is it volatility or bad policies?

The biggest concern with the negative correlation between growth and business cycles found in Tables 2 and 3 is the possibility that there is a third variable (or group of variables) that is correlated with both of them and is ultimately responsible for this correlation. The first candidate is 'bad' economic policy. Governments with policies that are unfriendly to growth can also be responsible for introducing additional sources of volatility in the economy. Or it could also be that 'bad' economic policies are generally more volatile policies, leading to more pronounced business cycles. In this case, we could observe that more volatile policies are correlated with lower growth, but the true reason why growth is lower is because of the 'bad' average quality of the policies.[14]

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[13] These low frequency movements could bias some of our results because they could be measured as volatility of output growth when they are simply changes in average growth rates over time.

[14] As discussed before, in the analysis of policy reform in developing countries in Rodrik (1991), a higher probability of failure of reform is associated both to worse economic policy (higher distortions) and more uncertainty.

Empirically, assessing whether volatility is acting as a proxy for bad policies in the regressions of Table 1 and 2, requires identifying variables that can serve as direct measures of policies that hurt growth and be correlated with the volatility of the business cycle. For example, the degree of openness is known to be correlated with long-term growth and is also related to the general degree of uncertainty faced by an economy.[15] Government size appears as a relevant variable in many growth models and it is related to the volatility of business cycles. Finally, inflation or inflation variability are key variables in the business cycle and have been shown to have an effect on growth.

Table 4 presents the results of introducing these four variables in our analysis. Once again, the size of the coefficient is practically unchanged from our previous table. Although this is only a partial list of variables that capture policy effects, we can conclude that, in our regressions, business cycle volatility is not capturing differences in economic policies, at least those related to inflation, openness or government size.

Table 4. Volatility and Growth. Bad policies?

$$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$$

Volatility	-0.187 (0.083)
GDPpc60	0.394 (0.190)
Trade	0.019 (0.007)
Inflation	0.004 (0.003)
Inflation Volatility	-0.002 (0.001)
G/Y	-0.014 (0.017)
R^2	0.29

Robust standard errors in parentheses.

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[15] See Rodrik (1998).

Is growth related to other business cycle variables?

In our previous tables we have measured volatility by the standard deviation of output growth. What are the main variables that determine this volatility? Do all of them have the same effect? The answer to this question can be useful for two reasons. First, it can help discriminating among different theories by providing a more precise measure of the cause of the volatility that affects long-term growth rates. Second, it can be used in our main regression to avoid biases associated to endogeneity or omitted variables. The idea is to introduce variables that are clearly related to economic policy and the business cycle but that, in principle, should not be directly related to long-term growth rates. We look at variables that are normally considered to be neutral in the long run. We first include a set of variables that are associated to monetary policy. We include average inflation, the volatility of detrended money balances and a measure of the exchange rate arrangement of each country.[16] We also include a measure of the volatility of fiscal policy: the residual of a forecasting regression of the budget deficit that includes output growth as well as a linear and a quadratic trend. Our empirical strategy is first to see whether these variables are correlated with our measure of the volatility of the business cycle. Then, we plan to use this correlation to refine the estimates of the effects of volatility on growth.

A regression of the volatility of output on these four variables produces coefficients of the sign that would be expected. Countries with fixed exchange rates, a higher inflation rate, more uncertain monetary policy and more volatile fiscal policy have a more pronounced business cycle.

We now use the information contained in Table 5 to reproduce our estimates of Tables 2 to 4 but where these four variables are used as instruments of the volatility of the business cycle. Results are presented in Table 6. The effect of volatility on growth is still significant and the coefficient is larger in magnitude, when compared to the one found with the OLS regressions.

Clearly, there is no claim that these variables are, under all theories, exogenous to economic growth or unrelated to all possible omitted variables that influence directly economic growth.[17] We see the results of Table 6 as confirming

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[16] Including the volatility of inflation rates does not add much to the analysis as it is highly correlated with the average inflation rate.

[17] For example, and as argued before, inflation rates or the volatility of monetary and fiscal policy can be related to overall ‘bad economic policy’ that leads to lower economic growth.

Table 5. Volatility and Economic Policy.

$$\text{Volatility}_i = \alpha + \delta X_i + \nu_i$$

Flexible	-0.901 (0.401)
Volatility M3/Y	0.132 (0.053)
Volatility BD/Y	0.172 (0.223)
Inflation	0.002 (0.001)
R^2	0.21

Sample: 1950-1998
Robust standard errors
in parentheses.

Table 6. Volatility and Growth. IV

$$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$$

	(1)	(2)
Volatility	-0.483 (0.163)	-0.453 (0.189)
GDPpc60	- -	-0.073 (0.243)

Sample: 1950-1998
Robust standard errors
in parentheses.

the negative relationship between growth and business cycles when the volatility of economic fluctuations is measured using a set of variables that originate in monetary and fiscal policies believed to be neutral to economic growth.

Are all countries equally affected?

There are reasons to believe that the effects of volatility on growth should not affect all countries equally. The development of financial markets, the degree of openness or the level of development can condition the negative effects of uncertainty on investment and growth. We explore this issue by including interaction terms between the volatility of output and GDP per capita as well as a measure of financial development (the average ratio of M3 to GDP). Table 7 shows the results of introducing these two interaction terms in our main regression.

Table 7. Volatility and Growth.

$$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$$

	(1)	(2)	(3)	(4)	(5)	(6)
Volatility	-1.583	-0.418	-1.329	-3.311	-0.411	-3.100
	(0.278)	(0.072)	(0.298)	(0.436)	(0.099)	(0.514)
Volat*GDPpc	0.190	-	0.146	0.399	-	0.363
	(0.040)		(0.047)	(0.055)		(0.066)
Volat*M3/Y	-	0.005	0.002	-	0.005	0.002
		(0.002)	(0.001)		(0.002)	(0.001)
GDPpc60	-	-	-	-1.511	0.009	-1.488
				(0.280)	(0.179)	(0.321)
R^2	0.37	0.21	0.32	0.53	0.20	0.50

Sample: 1950-1998
Robust standard errors in parentheses.

In both cases the interactive terms are significant, suggesting that the effects are larger for poor countries and countries where financial markets are less developed. This is true whether or not we condition for initial GDP per capita. Moreover, there is a large improvement in the fit of the regression as well as in the significance of the coefficient on volatility. Out of the two interaction terms we introduce, the one with GDP per capita comes with a higher significance when both variables are introduced in the regression, in Columns (3) and (6). From an economic point of view, both interaction variables are large in size. For example, if we look at each of the individual regressions (e.g Column (1) and (2)) and we measure the effect of volatility on output for the country with the highest level of development or the highest level of financial deepening, in both cases the answer is similar. The (net) coefficient on volatility for the country with the highest GDP per capita is as high as 0.3, while for the country with the highest level of financial development is about 0.1. In other words, the coefficient turns positive with high levels of development (measured by GDP per capita or financial deepening).

For these countries, there is no negative correlation between growth and business cycles.

We can only speculate about the reason for this effect. One possibility is that there are significant differences in the nature of business cycles depending on the level of development. The other possibility is that fluctuations and uncertainty only results in lower growth in cases where financial markets re not fully developed and cannot provide risk sharing mechanisms to protect agents against uncertainty.

Is investment affected by business cycles?

What is the mechanism that explains the correlation that we observe between growth rates and business cycles volatility? The obvious candidate is investment. Uncertainty can adversely affect investment and investment is one of the most robust variables when it comes to explain long-term growth rates. Ramey and Ramey (1995) found that the link between investment and business cycle volatility was less robust than the one between growth and business cycles. Aizenman and Marion (1998) found, however, that if one includes only private investment, the result is more robust. In table 8 we replicate these regressions for our data set and we find that business cycle volatility is negatively correlated with average investment rates (Column 1 where we run a regression with only volatility on the right hand side). A 1% increase in volatility reduces the average investment rate by about 0.5 percentage points. A quick ('back of the envelope') calculation would suggest that this drop in investment can justify lower growth rates of about 0.07%. This is about one third of the effect that we estimated when we regress average growth rates on volatility. Therefore, according to these numbers, at most one third of the effect of volatility on output growth could be attributed to the effect that it has on lower investment.

Not only is the estimate of the effects of volatility on investment small, but it is not robust to the introduction of the initial level of GDP, as shown in column (2) shows. This result can be overturned if we allow for the effect of volatility on growth rates to depend on the level of GDP per capita. In this case, the coefficient remains significant (see column (3)). This last result suggests that taking into account the possibility that the relationship between volatility and growth is a function of the level of development greatly improves the fit of these regressions. Once again, simple calculations using the range of values of the interaction term suggest that the coefficient of growth on volatility is about -3 for the poorest countries in our sample and about 1 for the richest countries.

Table 8. Volatility and Investment.

$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$

	(1)	(2)	(3)
Volatility	-1.106	-0.244	-8.42
	(0.363)	(0.361)	(3.226)
GDPpc60	-	5.227	0.330
	-	(0.861)	(1.778)
Volat*GDPpc	-	-	1.043
	-	-	(0.418)
R^2	0.11	0.33	0.43

Sample: 1950-1998
Robust standard errors in parentheses.

Regardless of the specification we look at in Table 8 we conclude that investment cannot be the only channel through which uncertainty and volatility affect growth. Even if the best scenario, this channel can only account for about one third of the total effect. This interpretation seems to corroborate the results of Easterly and Levine (2001) who argue that factor accumulation cannot explain most of the cross country variation on growth rates.

Is the correlation robust to other growth-related variables?

All the previous tables, show that volatility seem to matter for growth. More volatile economies tend to display lower long-term growth rates. In this section we run a series of regression to see if this relationship between volatility and growth is robust to the introduction of a series of variables that have been shown to be relevant for growth. Most of the variables we introduce are supposed to be independent of the volatility of business cycles and there is no prior on the direction in which they might affect the results. Therefore, this exercise follows the methodology of Levine and Renelt (1992) of testing the robustness of different sets of variables explaining cross-country differences in growth rates.

The set of variables that we add to our main regression is the one identified by Levine and Renelt (1992). We include a measure of initial human capital (secondary education, Second60), the average investment rate (Investment) and the growth rate of population (Popul. Growth). Table 9 presents the results of including one variable at a time as well as all variables together. In all regressions we also include the 1960 level of GDP per capita. The four columns reveal that the relationship between volatility and growth becomes weaker as we add these controls. It is still the case that the coefficient is always negative but its size goes down to almost a half and its significance fall below standard levels.[18]

Table 9. Volatility and Growth.

$$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$$

	(1)	(2)	(3)	(4)
Volatility	-0.145	-0.142	-0.110	-0.081
	(0.103)	(0.059)	(0.096)	(0.071)
GDPpc	0.016	-0.437	-0.102	-0.753
	(0.227)	(0.207)	(0.213)	(0.271)
Second60	0.069	-	-	0.028
	(0.036)	-	-	(0.019)
Investment	-	0.153	-	0.143
		(0.024)		(0.025)
Popul. Growth	-	-	-0.679	-0.413
			(0.229)	(0.204)
R^2	0.15	0.53	0.21	0.54

Sample: 1950-1998
Robust standard errors in parentheses.

These results cast doubt on the robustness of the relationship between volatility and growth but offer no hints regarding the economic mechanism that lies behind the estimates. It is unclear why a variable such as average population growth will be related to the volatility of the business cycle in a way that breaks down the relationship between volatility and growth.

We look more carefully at these robustness tests by allowing, as we have done before, an interaction term between volatility and the level of development. Table 10 summarizes the results of a regression identical to the one presented in Table 9 but where we have added a new variable to capture the interaction between business cycles and the level of development. We use three variables as possible

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[18] Similar results are obtained if one uses uncertainty, measured by the residual of a forecasting regression for output growth, instead of volatility.

sources of interaction with volatility: average (log) GDP per capita (Column 1), initial (log) GDP per capita (Column 2) and the average ratio of M3 to GDP (Column 3).

Table 10. Volatility and Growth.

$\text{Growth}_i = \alpha + \beta\,\text{Volatility}_i + \delta X_i + \nu_i$

	(1)	(2)	(3)
Volatility	-2.772	-1.700	-0.270
	(0.282)	(0.645)	(0.091)
GDPpc60	-2.229	-1.856	-0.953
	(0.235)	(0.422)	(0.220)
Second60	0.037	0.040	0.026
	(0.015)	(0.018)	(0.017)
Investment	0.083	0.143	0.120
	(0.013)	(0.021)	(0.024)
Popul. Growth	-0.624	-0.562	-0.465
	(0.153)	(0.205)	(0.465)
Volat*GDPpc	0.340	-	-
	(0.036)		
Volat*GDPpc60	-	0.212	-
		(0.082)	
Volat*M3/Y	-	-	0.004
			(0.001)
R^2	0.77	0.58	0.57

Sample: 1950-1998
Robust standard errors in parentheses.

All three columns produce consistent and interesting results. First of all, all variables are significant and with the correct sign. Second, and most importantly, the introduction of an interaction term drastically increases the significance of the estimate of growth on volatility. Now this estimate appears much more robust than in Table 9. In all cases, and confirming our previous estimates, the interaction term is positive suggesting that the negative effects of business cycles on growth are much larger for poor countries. A second reading of the significance of these interaction terms is in terms of the ability of poor economies to converge to the levels of development of rich countries. Table 10 suggests that the speed of convergence is a function of the volatility of business cycles. For countries where business cycles are very volatile, lower GDP per capita does not ensure convergence towards richer economies. If we add to this result theories that postulate that poor economies are more likely to be subject to political and economic uncertainty, we end up with the possibility of countries falling into growth traps. An uncertain environments that does not allow for growth to take off and where the lack of growth does not create conditions for uncertainty to be reduced or eliminated.

4 CONCLUSIONS

This paper studies the link between business cycles and long-term growth rates. Business cycles and growth are generally analyzed separately under the assumption that business cycles can be characterized by transitory dynamics that have no effect on long-term trends. The stability of growth rates over the last hundred years in the U.S. and other industrial economies, combined with the good fit that Solow-type growth models produce in cross-country studies, have been used as strong empirical arguments to keep economic fluctuations out of the growth models and to restrict the study of business cycles to deviations around the steady state.

We present empirical evidence that uncovers interesting and significant, both from an economic and statistical point of view, interactions between cycles and growth. Our argument is based on two related pieces of evidence. First, we show that business cycles cannot be considered as temporary deviations from a trend. This observation, largely studied in the literature that has looked at the trend-cycle decomposition, can be instrumental in understanding the effects of volatility on growth. Under the interpretation presented in this paper, the documented persistence of business cycles is a measure of the effects of volatility on growth. The fact that there is a strong positive correlation between persistence of short-term fluctuations and long-term growth rates contradicts models of business cycles based on small deviations from a steady-state solution of a Solow-type growth model. On the other hand, a simple endogenous growth model where business cycles affect growth, can easily replicate this correlation.

After establishing a connection between business cycles and growth we study the effects on growth rates of an increase in the volatility of business cycles.

We argue that in models where business cycles are asymmetric an increase in volatility can lead to a decrease in long-term growth rates. Alternatively, even without asymmetries, uncertainty related to volatility can lead to lower growth. We take this proposition to the data and we find support for it. Countries with more volatile fluctuations display lower long-term growth rates. We run a series of robustness tests to correct for possible omitted variables bias or problems of endogeneity and we find that the relationship is robust. We also find evidence that there is a nonlinearity in the relationship between growth and business cycles that is well captured by an interaction term between volatility and the level of development. The effect of business cycles on growth is much larger for poor countries. This is also true if the level of development is measured by the degree of financial deepening. A plausible interpretation of this effect is that the development of financial markets reduces the cost associated to volatility and uncertainty because of the possibilities that it opens for risk sharing among individuals.

Although the results are clear and supportive of models that integrate business cycles and long-term growth, we recognize the inherent difficulty interpreting some of the results and extracting policy recommendations out of them. The lack of an accepted theoretical framework limits the ability of producing structural tests of well specified theories. So far, endogenous growth models have had only limited success explaining cross-country growth patterns. Our results encourage further theoretical development of endogenous growth models with business cycles. They also suggest that making explicit the effects of business cycles on growth could improve their ability to explain the data.

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Appendix 1. Data appendix

List of Countries

Angola
Argentina
Australia
Austria
Burundi
Belgium
Benin
Burkina Faso
Bangladesh
Bolivia
Brazil
Burma
Botswana
Cent. Af. Rep.
Canada
Switzerland
Chile
Cote d'Ivoire
Cameroon
Congo
Colombia
Costa Rica
Germany
Denmark
Dom. Rep.
Algeria
Ecuador
Egypt
Spain
Ethiopia
Finland
France
UK
Ghana
Greece
Guatemala
Hong Kong
Honduras
Haiti
Indonesia
India
Ireland
Israel
Italy
Jamaica
Jordan
Japan
Kenya
Rep.of Korea
Liberia
Sri Lanka
Morocco
Madagascar
Mexico
Mali
Mozambique
Mauritania
Mauritius
Malawi
Malaysia
Niger
Nigeria
Nicaragua
Netherlands
Norway
Nepal
New Zealand
Pakistan
Panama
Peru
Philippines
P. N. Guinea
Portugal
Paraguay
Rwanda
Sudan
Senegal
Singapore
Sierra Leone
El Salvador
Somalia
Sweden
Syria
Chad
Togo
Thailand
Trinidad-Tobago
Tunisia
Turkey
Tanzania
Uganda
Uruguay
USA
Venezuela
S. Africa
Zaire
Zambia
Zimbabwe

Source of variables

- GDP, population and investment rate from Summers-Heston dataset. (version 6.0, available at http://www.princeton.edu/~gurkaynk/growthdata.html).
- Inflation, money supply (M3), openness, government size and the budget deficit from the World Development Indicators 2001 (World Bank).
- Exchange rate arrangements from the IMF (several years). Original coefficients (from 1 to 10) have been transformed to a scale of 1 to 3, where 1 is fixed, 2 is intermediate and 3 is flexible exchange rates. Fixed exchange rates correspond to the original values of 1 to 5. Intermediate to the values of 6 to 8 and flexible to the values 9 and 10.

Appendix 2

An endogenous growth model linking persistence and growth.

Assume a production function

$$Y_t = AK_t \tag{$A.1$}$$

where Y represents output, K is the aggregate capital stock and A is a country-specific parameter that will generate differences in long-term growth rates. Labor is supplied inelastically and we normalize the labor supply to 1. The single representative consumer maximizes the utility function

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \, \frac{C_t^{1-\theta}}{1-\theta} \tag{$A.2$}$$

subject to the budget constraint

$$K_{t+1} = K_t(1-\delta) + (Y_t - C_t) \tag{$A.3$}$$

where δ is the depreciation rate.

The solution to this model is characterized by a constant saving rate and a balanced-growth path. We rewrite the maximization problem in terms of the saving rate, S, defined as the proportion of income that is not being consumed. Consumption can be written as $C_t = AK_t(1 - S_t)$ and the budget constraint is just

$$\frac{K_{t+1}}{K_t} = (1-\delta) + AS_t \tag{$A.4$}$$

In steady state

$$S^* = \frac{\beta(A + (1-\delta))^{\frac{1}{\gamma}} - (1-\delta)}{A} \tag{$A.5$}$$

$$G^* = \frac{1}{\gamma} \ln\bigl[\beta(A + (1-\delta))\bigr] \tag{$A.6$}$$

We assume that countries differ in the parameter A and that this is the source of differences in steady-state growth rates.

We now introduce uncertainty to the model by assuming transitory exogenous shocks and analyze the dynamic behavior of output around the steady state. The production function is now

$$Y_t = Z_t A K_t \tag{$A.1$}'$$

Uncertainty originates in Z_t which is assumed to follow an stochastic process with the Wold representation

$$\hat{z}_t = C(L)\epsilon_t \tag{A.7}$$

where small letters represent logarithms and a circumflex on top of the variable denotes deviations from its steady-state value. For simplicity we will assume that the steady-state value of Z_t is 1. Maximization of the expected utility function (2) leads to the following first-order condition

$$\left[\frac{(1-\delta) + AS_tZ_t}{AZ_t(1-S_t)}\right]^{\theta} = \beta E_t\left[\frac{AZ_{t+1} + (1-\delta)}{[AZ_{t+1}(1-S_{t+1})]^{\theta}}\right] \tag{A.8}$$

Equations (4) and (8) define the equilibrium dynamics of the model. As a general closed-form solution to the equilibrium does not exist we approximate the equilibrium solution by linearizing both equations around the steady-state values (S^* and G^*). From the linearization of the first order condition we obtain an expression like

$$\kappa_1\,\hat{S}_t + \kappa_2\,\hat{z}_t = \kappa_3\,E_t(\hat{S}_{t+1}) + \kappa_4\,E_t(\hat{z}_{t+1}) \tag{A.9}$$

Where all κ_i's are functions of the parameters of the model. This is a linear first-order stochastic difference equation. We assume, for simplicity, that $\hat{z}_t$ follows an AR(1) process

$$\hat{z}_t = \rho\,\hat{z}_{t-1} + \epsilon_t \tag{A.10}$$

Using this assumption, (9) can be rewritten as

$$\kappa_1\,\hat{S}_t = \kappa_3\,E_t(\hat{S}_{t+1}) + (\rho\kappa_4 - \kappa_2)\,\hat{z}_t \tag*{(A.9)$'$}$$

and the solution takes the form

$$\hat{S}_t = \kappa\,\hat{z}_t$$

where

$$\kappa = \frac{\rho\,\kappa_4 - \kappa_2}{\kappa_1 - \rho\kappa_3} \tag{A.11}$$

We can now plug this expression into the budget constraint to obtain the equilibrium value for the growth rate. We linearize the resulting expression around the steady state to obtain a solution for the growth rate of capital which is linear in the productivity parameter. Let γ be the coefficient on that linearization so that[19]

$$\widehat{\Delta k_t} = \gamma\, \hat{z}_t \qquad (A.12)$$

where

$$\gamma = \frac{\kappa A + AS^*}{(1-\delta) + AS^*}$$

Using the production function (A.1) together with (A.10) and (A.12), we obtain an expression for the deviations of output growth from its steady state value (G^*)

$$\widehat{\Delta y_t} = (1-L)\, \hat{z}_t + \theta\, L\hat{z}_t = (1-(1-\gamma)L)\ C(L)\, \epsilon_t \qquad (A.13)$$

This expression is identical to the reduced form obtained in the text of the paper so all other results follow.

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[19] Where capital growth is measured as deviations from its steady state value G^*.