# DO BUSINESS CYCLES CAST LONG SHADOWS? SHORT-RUN PERSISTENCE AND ECONOMIC GROWTH

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**Abstract.** This paper explores the links between cyclical fluctuations and long-run growth in the context of an endogenous growth model with aggregate demand externalities. In this model, aggregate demand and growth rates are positively correlated. In the presence of exogenous cyclical shocks, the model is able to generate persistent fluctuations through the effects that business cycles have on aggregate demand, profits and technological progress. Persistence becomes a measure of the response to business cycles of growth-related variables. Empirical evidence from a large sample of countries suggests that there is indeed a correlation between how persistent fluctuations are and the long-term growth rates of GDP.

**JEL**: E3, O4.

I would like to thank the Editor, an Associate Editor and a referee for all their comments and suggestions. Robert Barro, Graham Elliott, Michael Kremer, John Leahy, N.Gregory Mankiw, Andrew Metrick, Ilian Mihov and Andrei Shleifer provided helpful comments on previous drafts of the paper.

## 1. Introduction

GDP series for most industrial economies are well described by a log-linear trend dominated by the long-term growth rate of output. Business cycles are implicitly measured as deviations from this trend. In fact, extrapolations of historical data using log-linear trends can produce, in some cases, surprisingly accurate predictions of today's value for GDP levels.[1] This stylized fact has led to the study of growth separately from the analysis of short-term fluctuations. The business cycle literature studies deviations of output from a trend while the growth literature analyzes the slope of the trend.

The evidence of a existence of a unit root in US GDP and the interpretation given by the RBC literature led to a different perspective on the trend-cycle decomposition.[2] Serious consideration was given to the idea that exogenous permanent productivity shocks are a leading source of business cycle disturbances and a large part of the econometric analysis was done under the assumption that GDP was a non-stationary series. Although one stated goal of the RBC models is to integrate growth and fluctuations in the same framework, most of them treat technological progress as exogenous and analyze fluctuations as deviations from the steady-state solution of a neoclassical growth model.[3] In that sense, growth and fluctuations are still treated as two separate entities.

When growth is modeled as an endogenous process interesting connections between growth and fluctuations arise. For example, the variables driving growth can be the ultimate cause of business cycles as in, for example, Shleifer (1986), where the timing of innovations leads to endogenous cycles arising from aggregate demand externalities. In his model, cycles are crucial for growth because implementations of innovations require periods of higher demand.[4] More generally, business cycles can alter the growth process and have permanent effects in the economy. Stadler (1986, 1990) shows how monetary shocks can generate a non-stationary process for output when growth is endogenous as recessions have negative effects on the

[1] For example, fitting a linear trend to US GDP data from 1880 to 1929 can help predict today's GDP level with a forecast error of less than 5%. See Jones (1995).

[2] While there is no agreement on whether or not GDP has a unit root, after the work of Nelson and Plosser (1982) there is a consensus that GDP fluctuations are quite persistent.

[3] See for example Kydland and Prescott (1982) and Prescott (1986).

[4] Using a similar model, Murphy, Shleifer and Vishny (1989) provide a more static picture of the same result by emphasizing the importance of the size of the market in the presence of IRS technology. They show that there could be traps to development in the early phases of growth.

amount of learning by doing.[5] Other authors have stressed the opposite effects by suggesting that recessions are 'cleansing' periods where the opportunity cost of doing research is lower relative to productive activities.[6]

Empirically, there is evidence that growth and business cycles should not be viewed as independent. For example, as Figure 1 shows, variables directly related to technological progress, such as research and development expenditures, are procyclical.[7] There is also evidence that some features of the business cycle are related to long-term growth rates. Persistence of short-term fluctuations is highly correlated with long-term growth rates in a cross section of OECD countries.[8] To understand these facts, one needs to analyze fluctuations in models where growth is endogenous.

**[Insert Figure 1 about here.]**

In this paper we develop a stylized endogenous growth model that illustrates some of the connections between short-term fluctuations and long-term growth. We extend the model of Shleifer (1986) by endogenizing the flow of ideas. This allows us to establish richer conclusions about the effects of cycles in growth. Also, by introducing exogenous shocks we follow a more conventional approach to business cycles.

The model represents an imperfectly competitive economy with aggregate demand externalities. The growth rate is determined by the amount of research done by firms. Optimal research depends on the expected profitability of innovations which is a function of aggregate demand. Exogenous cyclical shocks become persistent through the impact they have on aggregate demand and the incentives to do research. Recessions represent periods of low aggregate demand and low incentives to innovate. As a result, when the economy gets out of a recession, output does not revert to a linear trend but remains at a permanent level forever.

This explanation for the persistence of output fluctuations has interesting

[5] King, Plosser and Rebelo (1988) and Fatás (2000) present similar results in the context of technology-driven business cycles.

[6] See for example, Hall (1991), Galí and Hammour (1991), Caballero and Hammour (1994), DeLong (1990) and Saint-Paul (1993).

[7] Figure 1 shows the procyclicality of *total* R&D expenditures for the US. Other measures of R&D expenditures such as *industry-funded* R&D expenditures behave almost identically. Even if we decompose total expenditures into *basic* research and *applied* research, the behavior of both measures of R&D is clearly procyclical.

[8] See Fatás (2000).

implications for several features of the business cycle. It is consistent with the time series evidence of output without relying on exogenous technology shocks and it does not require periods of technological regress to generate persistent contractions. As a result, the model can explain the high persistence of identifiable demand shocks as compared to productivity shocks found in Blanchard and Quah (1989), Gali (1999), Romer (1989) or Bernanke and Mihov (1998). Also, recent work by Shea (1998) presents evidence that the response of certain macroeconomic variables to identified productivity shocks is quite different from what the standard RBC model driven by productivity shocks predicts. Finally, these results question the framework used by the literature that looked in detail into the issue of persistent fluctuations by decomposing fluctuations into different shocks and where demand shocks where assumed to be transitory.[9]

In the empirical section of the paper we present further evidence on the correlation between long-term growth rates and persistence of output fluctuations. We extend the results of Fatás (2000) by looking at a larger sample of countries and by constructing a measure of output trend to test for the robustness of the correlation.

Section 2 presents the basic model and characterizes the equilibrium. Section 3 introduces cyclical shocks and analyzes the connection between the short run and the long run. Section 4 provides empirical evidence and Section 5 concludes.

## 2. The Model

### 2.1. Setup

The model represents an imperfectly competitive economy with demand linkages across sectors as in Shleifer (1986) where technology is the outcome of an innovative process as in Aghion and Howitt (1992) or Grossman and Helpman (1991).[10] We first present the simplest case with inelastically labor supply to characterize the equilibrium and later we add some cylical shocks and we allow for an elastic labor supply.

The economy is characterized by a continuum of imperfectly competitive sectors uniformly distributed in the unit interval. There is a representative consumer that

[9] See for example Shapiro and Watson (1988), Blanchard and Quah (1989) and Cochrane (1992).

[10] In Shleifer (1986) there is endogeneity in the process of implementing innovations but the long-run growth rate of the economy, measured by the flow of ideas, is exogenous.

owns all claims to profits and maximizes the following utility function

$$U = \sum_{t=0}^{\infty} \beta^t \int_0^1 ln(x_{it}) \; di$$

Where $x_{it}$ represents consumption of good $i$ at period $t$. This is a Cobb-Douglas utility function with equal shares defined for a continuum of goods. Assume that there is no storage so that total consumption must be equal to income every period.

$$\int_0^1 p_{it} x_{it} \, di = \Pi_t + W_t$$

Where $\Pi_t$ and $W_t$ represent profits and wages. From the first order condition of the consumer we get unit-elastic demand for every good so that the consumer spends the same amount on each good (let $d_t$ be this amount). Given the normalization in the unit interval, this amount is equal to total expenditures ($D_t$) and income, $d_t = D_t = \Pi_t + W_t$.

The consumer inelastically supplies 1 unit of labor. There are two types of labor activities: production and research. The wage will be the same for both activities.

There is an innovative monopolist in each sector and a group of imitators. Innovations can be 'patented' only for the period they are discovered so that they can be copied by the fringe of imitators next period. Assume that the research process is memoryless in the sense that the amount of effort to innovate today only affects the probability of finding an innovation today and not in future periods. When the monopolist uses $r_t$ workers in research activity at period $t$, the probability of finding an innovation is given by the function $\Phi(r_t)$. Where $0 < \Phi(\cdot) < 1$, $\Phi'(\cdot) > 0$ and $\Phi''(\cdot) < 0$. This innovation can be implemented in the same period.[11]

The production function of each monopolist is

$$y_t = A_t n_t^P$$

[11] Allowing immediate implementation of innovations differs from the standard assumption where there is a lag between research and successful innovation. Introducing such a lag does not affect any of the main intuitions qualitative findings of the paper and, on the other hand, it unnecessarily complicates the model by introducing dynamics of implementation of the type shown in Shleifer (1986).

Where $A_t$ indicates the technological level at time $t$ and $n_t^P$ is the amount of labor used for production.[12] Innovations raise this technological parameter so that every time a monopolist innovates she improves its production function by $\gamma$, so that $A_t = \gamma A_{t-1}$ whenever there is innovation and $A_t = A_{t-1}$ when research fails.[13] Note that, although there is not capital in this model, $A_t$ could represent the stock of capital or knowledge accumulated in a sector and the level of research could be the investment in this stock with uncertain returns.

*Individual decision*

Let's look first at the optimal policy of a monopolist in a single market, normalizing the wage of labor to one. The monopolist takes demand, summarized by $d$, as given. Now, if she has been successful and has achieved an improvement in her technology, the best thing to do is to price the good to keep all imitators out of the market. Given that the followers can use the 'next' available generation of technology, the monopolist should price at the marginal cost of the followers. If $A_t$ is her technological level she should set a price equal to $p_t = (A_{t-1})^{-1}$. Given the specification of the innovative process, $p_t = (A_t)^{-1}\gamma$. This is optimal because if she charges more than $(A_t)^{-1}\gamma$, she loses all the market to the followers, and if she sets a lower price she receives the same revenue but at higher cost.

Given the optimal pricing policy of the 'successful' monopolist, we can compute her profits by noticing that the amount she sells is equal to $y_t = d_t A_{t-1}$ and the labor it requires to sell this amount is $n_t^p = d_t \gamma^{-1}$. Therefore, profits of a successful monopolist, gross of research costs, are

$$\pi_t = d_t - \frac{d_t}{\gamma} = \frac{\gamma - 1}{\gamma} d_t$$

The independence of profits from the current level of technology comes from the properties of the Cobb-Douglas utility function. For notational simplicity, define $\Gamma$ as

$$\Gamma \equiv \frac{\gamma - 1}{\gamma}$$

[12] The technological parameter, $A_t$ is sector specific. For simplicity, we eliminate the subscript from all expressions when it is not strictly necessary

[13] The parameter $\gamma$ is, obviously, higher than one. The model can be also interpreted in terms of improvements in quality as in Grossman and Helpman (1991) just by modifying the utility function to allow for differences in quality.

Profits of a successful monopolist can be rewritten as $\pi_t = \Gamma\, d_t$.[14]

The unsuccessful monopolist is not able to get any positive profits because the followers are just as productive and have the same marginal cost. Therefore he has losses equal to the costs of research.

Next, we solve for the optimal amount of workers that the monopolist hires for research activities. Given the assumptions about the imitation process, the monopolist only cares about aggregate demand today. Let $r_t$ be the amount of labor employed on research activities at time $t$. Then the following first-order condition holds,[15]

$$\Gamma\, \Phi'(r_t)\, d_t = 1 \tag{2.1}$$

As the function $\Phi(\cdot)$ is concave, the second-order condition is satisfied. The connection between aggregate demand and growth is explicit in equation (2.1). The optimal amount of research at time $t$, for any given individual monopolist, is a function of $d_t$. An increase in demand (as measured by $d_t$) raises the optimal amount of research labor and, thus, increases the possibilities for growth. This is the crucial connection explored in the following sections. Next, we solve for the equilibrium of the whole economy.

## 2.2. General Equilibrium

Equation (2.1) characterizes the optimal behavior of an individual firm that takes aggregate demand as given. Now we look at the equilibrium of the whole economy and solve for $d_t$. From the normalization in the unit interval, $d_t = D_t$ and from the definition of $D_t$, $D_t = \Pi_t + W_t$. Denoting by $R_t$ the total amount of labor devoted to research, aggregate wages are $W_t = 1$. Aggregate profits are equal to the proportion of successful monopolists in the population multiplied by their profits. As there is a continuum of sectors, the actual proportion of successful monopolists coincides with the population mean so that a proportion $\Phi(R_t)$ is successful at period $t$, while the rest have zero profits. From here,

$$D_t = \Gamma\, \Phi(R_t) D_t + (1 - R_t)$$

Thus,

$$D_t = \Big(1 - \Gamma\, \Phi(R_t)\Big)^{-1} (1 - R_t) \tag{2.2}$$

[14] This expression does not include the costs of innovation. To calculate the overall profits of a successful monopolist one needs to subtract the cost of hiring researchers, i.e. $r_t$.

[15] Where it is assumed that firms maximize profits.

This equation together with the first-order condition of each monopolist characterize the equilibrium. Notice that we are looking at symmetric equilibria in which all monopolists employ the same number of skilled researchers. The research effort of each individual monopolist should satisfy

$$\Gamma\,\Phi'(r_t)\Big(1-\Gamma\,\Phi(R_t)\Big)^{-1}(1-R_t)=1$$

At any symmetric equilibria $r_t = R_t$ and the equilibrium is defined by an amount of research labor, $R$, that satisfies

$$\Gamma\,\Phi'(R)\Big(1-\Gamma\,\Phi(R)\Big)^{-1}(1-R)=1$$

To understand the equilibrium of the whole economy, we can define an aggregate output index

$$X_t = \exp\Big(\int_0^1 ln(x_{it}di)\Big)$$

Given that demand is unit elastic, we have that output in sector $i$ can be written as $x_{it} = D(R_t)A_{it-1}$ and, therefore, total output is equal to

$$X_t = D(R_t)A_{t-1}$$

where $A_{t-1}$ is an aggregate productivity index defined as

$$A_{t-1} = \exp\Big(\int_0^1 ln(A_{it-1}di)\Big)$$

Using (2.5) and (2.6), the (gross) growth rate of aggregate output can be written as

$$\frac{X_t}{X_{t-1}} = \frac{D(R_t)}{D(R_{t-1})}\Phi(R_{t-1})\gamma$$

And the balanced growth path, where $R_t = R_{t-1}$ displays a growth rate equal to

$$\frac{X_t}{X_{t-1}} = \Phi(R)\gamma$$

Therefore, the aggregate growth rate is a function of the amount of research and the parameter $\gamma$.

The next sections focus on the determinants of the equilibrium value for $R$. From (2.1) we can see that aggregate demand ($D_t$) determines the expected profitability of research.[16] Higher values of $D$ imply higher equilibrium values of $R$ and therefore a higher growth rate.

A symmetric equilibrium is defined by an amount of research labor hired by each monopolist. This amount determines the number of innovations that occur every period and, therefore, the growth rate. Clearly, there are some interesting interactions between the monopolists in different sectors. From equation (2.1) individual research depends positively on aggregate demand. From equation (2.2), aggregate research affects aggregate demand. The direction of this effect is not monotonic: there is a positive effect which works through the demand externality but there is also a negative effect which comes from the 'unproductiveness' (in terms of output) of the research workers. It turns out that around a symmetric equilibrium, both effects cancel out and additional investment by a monopolist has no first-order effect on aggregate demand. This question is similar to the one encountered by Murphy, Shleifer and Vishny (1989). When pecuniary externalities take place through profits, the fact that profit functions are flat around the equilibrium makes the effect of additional investment on aggregate demand vanish.[17]

## 3. Cyclical Shocks and Growth

The equilibrium of the previous model is such that the growth rate of output is a function of aggregate demand as measured by $D_t$. The causality that runs from $D_t$ to $R_t$ has to do with the relation between aggregate demand and profitability of innovations. In the model this connection is straightforward, lower aggregate demand affects the marginal profitability of an innovation and therefore reduces the optimal amount of research effort. This simple connection implies that any cyclical shock to aggregate demand affects the rate of innovation today and, thus, the productivity level forever. In other words, any shock which affects aggregate demand, regardless of its origin and horizon, has permanent effects.

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[16] In this model, there is a one-to-one connection between demand and profitability of research. In a more general setup, this connection might not be so direct because the degree of competition can be a function of the level of demand.

[17] There are ways to get around this problem. One of them is to introduce a 'disutility' premium of research activities as in Murphy, Shleifer and Vishny (1989). The introduction of this premium leads to the possibility of multiple equilibria. The same effect could be achieved by introducing intermediate inputs in the production function of research. In this case, the increase in individual research increases aggregate demand via the direct effect on the demand for intermediate inputs. We do not follow this approach here because it would unnecessarily complicate the model. See Fatás (1997).

To illustrate these implications we follow three types of exercises. These exercises should be seen as examples of how different shocks have an effect on growth through the aggregate demand effects described above. First, we introduce exogenous short-run dynamics in employment and show that during recessions the rate of innovation is lower. Second, we introduce fiscal policy and we show that transitory shocks to fiscal policy have permanent effects on output.[18] Finally, we perturb the equilibrium with a specific technology shock such that this shock has effects on research activity only because of an aggregate demand effect.

### 3.1. Employment Shocks

We first introduce exogenous cyclical shocks by simply postulating an exogenous random process for the employment rate.[19] We assume that employment is stochastic. We maintain the normalization of the labor supply to 1 so that the unemployment rate is measured as $1 - N$. Suppose now that the employment rate, $N$, follows a simple two-state Markov process where it can take two values: low employment denoted by $N_L$ and high employment denoted by $N_H$. The transition probabilities are defined by $p_L$ and $p_H$ and they represent the probability of remaining in the same state next period. Assume that they are both higher than 0.5 so that there is some persistence in both states. The stochastic process of the employment rate can be summarized as

$$N_t = \begin{cases} N_H \to N_{t+1} = \begin{cases} N_H & \text{with probability} & p_H \\ N_L & \text{with probability} & (1-p_H) \end{cases} \\ N_L \to N_{t+1} = \begin{cases} N_H & \text{with probability} & (1-p_L) \\ N_L & \text{with probability} & p_L \end{cases} \end{cases}$$

Given this process, it is natural to talk about the state $N_L$ as a 'cyclical' recession. To see why this is a valid interpretation, suppose that we did not allow for endogenous growth but assumed it to be exogenous. The trend would be growing at some exogenously given rate and the 'low-state' would be associated to lower temporary levels of output. After the effects of the shock disappeared, output would return to trend.

The presence of endogenous growth alters the response to this type of shocks.

[18] One can think about this example as a way to endogenize the employment dynamics of the first example.

[19] For simplicity, this process is assumed to be exogenous. This dynamic behavior could be endogenized by assuming the presence of redistributive taste shocks that create the need for relocating jobs from low-demand to high-demand sectors.

Output still does return to its trend but the trend is itself affected by the shocks. In other words, these shocks have permanent effects. During recessions, the growth rate of productivity is lower. Shocks to the employment rate have permanent effects.

To understand the effects of these shocks on growth, we can look at aggregate demand. From the individual solution for the optimal amount of research, we see that the first order condition (2.1) is not affected. However, from (2.2), aggregate demand is a function of the employment rate

$$D_t = \Big(1 - \Gamma\,\Phi(R_t)\Big)^{-1} (N_t - R_t)$$

Note also that given the strategic complementarity present around the equilibrium, there is a 'multiplier' effect associated with the change in research labor that operates through the demand externality.

Clearly, the effect that shocks have on research hinges upon the assumption that innovations are immediately implemented. However, this result is more general and also applies when there are lags between research and the implementation of innovations. This is true as long as the expected horizon of success for R&D overlaps with the last period where the effects of the shocks are felt. Also, there are some additional factors that could be introduced in the model to reinforce these effects. For example, cyclical shocks, by reducing firms' cash-flow, could cause a shift from long-run investment projects to high cash-flow short-run projects. Although the channel of transmission in this case is not demand, the optimal amount of research responds to business cycle fluctuations.

It is important to notice that he stochastic properties of the business cycle are translated into the stochastic behavior of the trend. In this model, the trend is stochastic only because of the 'short-run' shocks that affect the economy. The same two-state Markov process that characterizes the cycle is present in the trend. If, for example, 'short-run' shocks were characterized by more general autorregresive process, the trend would also follow a similar autorregresive process.

### 3.2. Fiscal Policy Shocks

Although the previous example illustrates the main intuition of our model, cyclical shocks have been introduced in an ad-hoc manner by assuming an exogenous stochastic process for employment. We now provide a modified version of the model where the same effect is achieved via fiscal policy shocks.[20] . For fiscal policy

[20] The introduction of fiscal policy shocks is done along the lines of Mankiw (1988)

shocks to have meaningful effects we need to allow for an elastic labor supply. For that purpose, we assume a logarithmic utility function separable in labor and consumption

$$\alpha\Big[\int_0^1 ln(x_{it})\ di\Big] + (1-\alpha)L_t$$

where $L$ is leisure. We normalize, as before, the labor supply to 1 so that employment is equal to $N_t = 1 - L_t$.

The government collects taxes ($T_t$) and spends this income by purchasing an equal amount of all goods produced in the economy ($G_t$). The budget is assumed to be always balanced.[21]

The consumer's budget contraint becomes

$$\int_0^1 p_{it}x_{it}\,di = \Pi_t + W_t - T_t$$

where $W_t = 1 - L_t$.

The optimization problem for the consumer implies that she spends a fraction $\alpha$ of her 'full income' in each of the goods

$$p_{it}\,c_{it} = \alpha(1 + \Pi_t - T_t)$$

This means that total demand for each good is now

$$d_t = \alpha(1 + \Pi_t - T_t) + G_t$$

Given that demand is still unit elastic, all the analysis from Section 2 applies and the fist order condition for investment in research, equation (2.1), is unchanged. The main difference is that when we solve for aggregate demand we now have

$$D_t = \alpha\big(1 + \Gamma\,\Phi(R_t)D_t\big) + (1-\alpha)G_t$$

where we have imposed the balanced budget condition $G_t = T_t$. Therefore we have that

$$D_t = \Big[\frac{\alpha + (1-\alpha)G_t}{1 - \Gamma\,\Phi(R_t)}\Big]$$

[21] This is the simplest way of introducing fiscal policy shocks. We could also look at cases of budget imbalances but this would require to deal with additional intertemporal issues unless imbalances are introduced as in Mankiw (1998) where differences between taxes and government purchases of goods and services finance public employment.

As before, this equation together with the first-order condition of each monopolist, equation (2.1), characterize the equilibrium. As it is obvious from this equation, and increase in $G$ increases aggregate demand and increase the equilibrium level of research and therefore the growth rate of output. As a result, transitory shocks to fiscal policy have permanent effects on output. As before, any stochastic process assumed for the cyclical component ($G_t$ in this case) is translated to the trend.

### 3.3. Amplification of Technology Shocks

Now we show that an exogenous technology shock (represented by a period of lower technological progress) is amplified through the aggregate demand channel. This effect can be considered a productivity multiplier in the sense that a true exogenous technology shock can see its effects on *productivity* amplified.

To introduce technology shocks let's assume the 'success function' $\Phi(\cdot)$ has an exogenous autonomous component, $\Phi_0$ so that $\Phi = \Phi_0 + \Phi(r)$.[22] Suppose there is a negative shock that temporarily reduces this autonomous component. This is a technology shock that affects the trend of the economy forever.[23] There is a first direct effect on the growth rate of the economy regardless of the amount of research effort. What happens to the equilibrium amount of research labor? By looking at the first order condition of each individual firm, a decrease in $\Phi_0$ does not *directly* affect their optimal research. But there is an *indirect* effect that is working through the aggregate demand effect. We can rewrite aggregate demand in this case as

$$D_t = \Big(1 - \Gamma\left(\Phi_0 + \Phi(R_t)\right)\Big)^{-1}(1 - R_t)$$

Aggregate demand is affected by the decrease in $\Phi_0$ and, thus, labor research is reduced in equilibrium. We, therefore, observe an effect that is only present because of the connection between aggregate demand and growth rates.

A straightforward implication of this result is that a technology shock that impacts aggregate demand through, for example, nominal rigidities or endogenous policy reaction, will also be amplified. The permanent effects that it leaves on the economy are a combination of the exogenous impact on the production function plus the endogenous reaction of technology. The oil shocks of the 70's and the

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[22] We ignore fiscal policy in this exercise so that we use the simplest version model of Section 2.

[23] The shock is assumed to be temporary so that it has permanent effects on output level but not on its growth rate.

contractionary monetary policy that followed them can be an example of this type of amplification.

## 4. Empirical Analysis

The empirical implications of the models above are twofold. First, productivity and innovative activity are procyclical. Second, certain features of the business cycle, such as persistence, are related to growth-related variables.

There is plenty of evidence that productivity is procyclical but this stylized fact is compatible with many different explanations of the business cycle, including exogenous-growth models with productivity shocks.[24] A prediction which is more specific to this model is the cyclical behavior of the resources that drive long-run growth. Capital accumulation or, as Figure 1 has shown, R&D expenditures are procyclical. But to be able to show that this procyclical behavior is indeed responsible for the persistence of output fluctuations, estimates on the effects of these variables on productivity growth are needed. The evidence on this issue is, however, very weak and inconsistent. For example, the evidence on Jones (1995) questions a large class of endogenous growth models and the results of Shea (1998) show that changes in R&D expenditures are not followed by significant changes in productivity.

Given all the above problems, we follow here a different avenue. The idea is to look at whether long-term growth rates are a determinant of relevant features of the business cycle. More specifically, we are interested in the notion of persistence. A distinctive feature of the model of Section 2, is that persistence is linked to growth itself. In the absence of growth, fluctuations would not be persistent. For example, if one follows strictly the logic of the model, an economy that dedicates no resources to growth (because conditions are such that research activities are not profitable) will not display any persistence in its business cycle, except for the one implied by the shocks themselves. This logic suggests that there should be a correlation between long-term growth rates and the persistence of business cycles.[25] Evidence on this correlation is relevant because alternative explanations of persistence, such as models where growth is treated as exogenous and represented by a technological

[24] For example, Durlauf (1989) shows that productivity is procyclical and cointegrated across sectors and Bernanke and Parkinson (1991) discuss alternative theories of short-run procyclical productivity.

[25] This correlation might not need to be monotonic and might depend on the specific model used. See Fatás (2000) for a quantification of these arguments.

drift, cannot generate a correlation between growth and persistence. Persistence in those models is assumed as part of the exogenous process that drives innovations in the production function.

Fatás (2000) shows evidence that for OECD economies the persistence of output fluctuations is strongly related the average growth rate for the last four decades. Here we extend this analysis to a larger sample of countries using the Summers-Heston data set and we look at a more direct measure of persistence of trend output.

**[Insert Figure 2 about here]**

Figure 2 plots the persistence of annual GNP for 120 countries against the average growth rate in the period 1950-90.[26] Persistence is measured as the 5-year variance ratio as defined by Cochrane (1989) and it provides a measure of the extent to which annual fluctuations are trend reverting.[27] The higher the degree of persistence the larger are the permanent effect of business cycles on trend GNP. There is a clear correlation between the two variables and, as Table 1 shows, a regression produces a positive and significant coefficient. This coefficient becomes stronger and more significant for a sample where we remove the 5 fastest-growing countries and in a sample of OECD economies.[28] Therefore, from Table 1, we conclude that fast-growing economies display annul fluctuations where the permanent effects of business cycles on trend GNP are the largest.

An additional test to check the robustness of this result is to directly see whether the above correlation is related to the reaction of output trend to business cycle fluctuations. For that purpose, we have constructed a measure of trend output and applied the same logic to it. As we are not particularly interested in the measure of trend itself and we want to be as close as possible to the results of the empirical growth literature, we use the information contained in the investment rate to construct our measure of trend. Although there is no agreement in the empirical growth literature on what the driving forces of growth are, the good empirical performance of the investment rate as a explanatory variable of

[26] From the original sample of Summers-Heston we eliminate countries with many missing observations and those that were planned economies. Not all years are available for all countries. See the Summers and Heston data set for more details.

[27] See the appendix for the precise formula used in the figure.

[28] We remove those 5 countries, with growth rates higher than 7%, because visually they seem to be outliers to the regression.

**Table 1. Regression Results. GNP**

$\text{Persistence}_i = \beta_0 + \beta_1 \text{ Avg.Growth}_i + \nu_i$

| Sample | $\beta_0$ | $\beta_1$ | $R^2$ |
|---|---|---|---|
| All (120) | -0.052 | 0.047 | 0.063 |
| | (0.073) | (0.016) | |
| All* (115) | -0.142 | 0.073 | 0.106 |
| | (0.081) | (0.020) | |
| OECD (25) | -0.246 | 0.134 | 0.213 |
| | (0.228) | (0.054) | |

(*) Countries with less than 7% growth.
Standard errors in parentheses.

cross-country differences in long-term growth rates has been shown in the context of both exogenous and endogenous growth models. In both cases, higher investment rates lead to higher capital accumulation and larger growth rates.

**Table 2. Regression Results. Trend**

$\text{Persistence}_i = \beta_0 + \beta_1 \text{ Avg.Growth}_i + \nu_i$

| Sample | $\beta_0$ | $\beta_1$ | $R^2$ |
|---|---|---|---|
| All (120) | 0.336 | 0.070 | 0.026 |
| | (0.165) | (0.037) | |
| All* (115) | 0.166 | 0.118 | 0.056 |
| | (0.185) | (0.045) | |
| OECD (25) | -0.231 | 0.250 | 0.222 |
| | (0.414) | (0.099) | |

(*) Countries with less than 7% growth.
Standard errors in parentheses.

We therefore use the information that the investment rate provides to construct a measure of trend GNP. For each country in our sample, we regress output growth into the lagged values of the investment rate by running time-series regressions of the type

$$\Delta y_t = \alpha_0 + \alpha_1 S_{t-1} + \alpha_2 S_{t-2} + \alpha_3 S_{t-2} + \mu_t$$

Where $S_t$ is the investment ratio from the Summers-Heston data set and $\Delta y_t$ is the growth rate of GNP. We then use the fitted values of these regressions as a measure of the long-run trend of output, and replicate the correlation of Figure 2. Table 2 presents the regression results. In all samples, the size of the coefficient is larger than in the basic regression. As before, in restricted samples where we have removed countries with growth rates larger than 7% and where we look at OECD countries, the fit of the regression improves significantly.

This positive correlation between average growth rates and the persistence of business cycles questions the ability of traditional RBC models, where technological progress is assumed to be exogenous, to account for some relevant features of the business cycle. The model of Sections 2 and 3 provides a framework where growth and business cycles should not be thought of as independent. By having growth-related variables reacting to fluctuations, and being the source of persistence one can incorporate correlations between fluctuations and long-term trends such as the one shown in Figure 2. The explanation provided by our model is one of the many possible explanations of why business cycles might cast long shadows on GDP levels. For example, one could perfectly have endogenous growth models driven by technology shocks as in King, Plosser and Rebelo (1988) or Fatás (2000), generating these results. Also, it can be that the effects that business cycles have on R&D expenditures are not directly related to demand effects but they originate in credit-constrained models of the firm that also result in a procyclical behavior of research expenditures. Discriminating between these alternative explanations is beyond the scope of this paper. Future research should look at how growth affects other features of the business cycle and use this information to discriminate between alternative models.

## 5. Conclusions

In this paper we explore the links between short-run (cyclical) phenomena and the long-run technological trend of output. We present a stylized endogenous growth model where cyclical fluctuations have effects on long-term growth. We focus on the aggregate demand effects of cyclical shocks such as employment, fiscal policy or technology on the growth process. In all cases, business cycles cause long shadows on the economy by slowing down the growth process during recessions.

We provide evidence that R&D expenditures are procyclical. We then explore whether in a cross-section of 120 countries the degree of persistence of the business cycle is, as predicted by the model, related to growth. We find that there exists a positive and significant correlation between these two variables. We check for the robustness of this result by constructing a measure of trend output using the time series information of the investment rate. Our measure of trend output also displays a positive correlation between growth and persistence.

We find that this evidence favors models of the business cycle where business cycles do have effects on growth-related variables such as capital accumulation or R&D expenditures. Further research is needed to understand additional business cycle implications of these models and see whether they can account for the stylized facts of the business cycles better than traditional exogenous growth models.

# Appendix

## Data Sources

**Output**: U.S. GNP, Figure 1, from *OECD Economic Outlook*.

**Research and Development**: U.S. R&D expenditures, Figure 1, from *Science and Engineering Indicators-1998*, published by National Science Board.

**GNP and Investment Rate**: 120 countries from Summers-Heston Data Set.

## Persistence

Persistence in Tables 1 and 2 is measured as the ratio of variances proposed by Cochrane (1988). This ratio can be written as a weighted sum of autocorrelations

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

where $\rho_j$ is the $j-$th autocorrelation of the growth rate of output. In the results of Table 1 we use $J = 5$.

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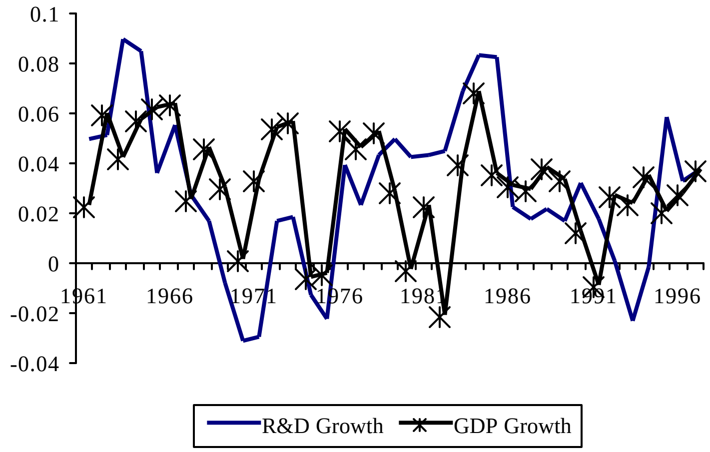


Figure 1. Procyclicality of US R&D expenditures

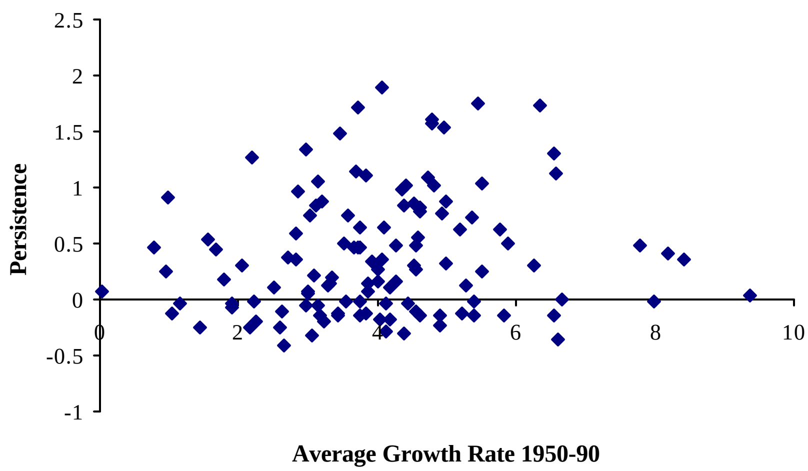


Figure 2. Persistence and Growth