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Long-term growth and persistence with obsolescence☆

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A B S T R A C T

Previous research has shown a strong positive correlation between short-term persistence and long-term output growth as well as between depreciation rates and long-term output growth. This evidence, therefore, contradicts the standard predictions from traditional neoclassical or AK-type growth models with exogenous depreciation. In this paper, we first confirm these findings for a larger sample of 101 countries. We then study the dynamics of growth and persistence in a model that renders a positive link between embodied technological progress, depreciation and output growth. We find that the model's predictions appear consistent with the empirical evidence on persistence, long-term growth and depreciation rates. In addition, we provide evidence of a unit root in output with a large battery of second-generation panel unit root tests. This supports the general validity of the endogenous growth model proposed.

1. Introduction

Empirical evidence on the persistence of output fluctuations shows large differences across countries. Using quarterly GNP data for the Group of Seven (G7) countries, Campbell and Mankiw (1989) find important differences in the estimates of persistence. Consistent with this evidence, Cogley (1990) reports significant differences in the variability of the permanent component of output in a similar sample of countries. In addition, Fatás (2000) finds the existence of a positive and significant correlation between the degree of persistence of short-term fluctuations and long-term average growth rates for a sample of countries that includes the G7 countries and eight additional OECD countries.

Fig. 1 extends the results by Fatás (2000) for the G7 countries by plotting the degree of persistence of the GDP series against long-term average per capita output growth for a broad sample of 101 countries over the period 1970–2008.[1] As in Fatás (2000), the degree of persistence is computed using Cochrane (1988)'s variance ratio with a window of five years. To construct it, we employ heteroskedasticity robust standard errors and correct for small-sample bias in the variance following the procedure outlined in Campbell et al. (1997). The variance ratio is a measure of the extent to which annual fluctuations are trend reverting and, in turn, a measure of the permanent impact of business cycles on trend output. As shown in Fig. 1, there is a clear positive correlation between the persistence of output fluctuations and long-term output growth. The cross-section regression provides evidence of a statistically significant positive coefficient on long-term average growth. This indicates that the greater the growth rate of an economy, the larger the permanent effect of cyclical fluctuations on trend output.

In standard RBC models cyclical fluctuations are simply deviations around an *exogenous* trend driven by the state of technological progress. In these models, there is no correlation between persistence and long-term output growth.[2] As noted by Fatás (2000), however, the

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[1] The annual real GDP series employed throughout the paper are expressed in constant 2000 US$ and were retrieved from the *World Development Indicators* of the World Bank (2010).

[2] This is because all GDP series would be characterized by a random walk with a drift, which would render a variance ratio equal to one for all countries in the sample.

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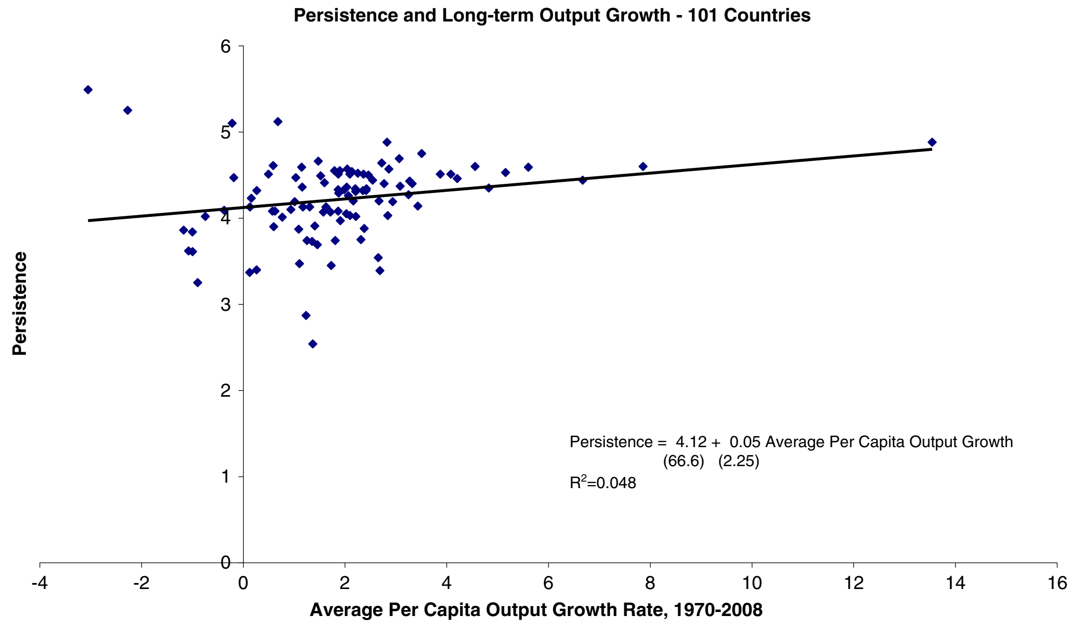

Fig. 1. Short-term persistence and long-term output growth, 1970–2008. Note: Figures in parentheses represent t-statistics.

significantly positive correlation between short-term persistence and long-run growth is consistent with RBC models with *endogenous* productivity shocks. In these models the degree of short-term persistence captures the extent to which cyclical fluctuations affect technological progress, which endogenously determines long-term growth.[3] Using a standard AK model, Fatás shows that a positive correlation between persistence and growth can be obtained when the stochastic nature of the trend is endogenous.

The standard AK growth model considers a constant rate of depreciation, as is usual in the growth literature. The empirical evidence on depreciation rates, however, is not consistent with this assumption.[4] In fact, the empirical evidence on depreciation across countries documents a positive correlation between the depreciation and long-term average per capita income growth rates.[5] Fig. 2 extends the existing evidence on the positive relationship between output growth and the depreciation rate for our sample of 101 countries for which data on depreciation rates were available over the period 1970–2008. As in Fig. 1, we use the growth rate of real per capita GDP averaged over the period 1970–2008 as a measure of long-term output growth. As described in more detail in Section 2, the depreciation rate represents the rate of fixed capital consumption and is obtained from World Bank's estimates based on the National Accounts Statistics of the United Nations Statistics Division.

In line with Gylfason and Zoega (2001a)'s results, there is a highly statistically significant positive coefficient on the depreciation rates, which supports the existence of a positive link between both series.[6] This evidence, however, is in sharp contrast with the theoretical predictions of standard *exogenous* growth models, in which the depreciation rate negatively affects long-run output levels and short-run growth rates, but not long-run growth rates. The endogeneity of growth, however, is not sufficient to generate the observed positive correlation between the depreciation rate and long-term average output growth. In fact, in a traditional AK-type model with exogenous depreciation rate – as the one outlined in Fatás (2000) – the growth rate of output is *negatively* related to the *exogenous* depreciation rate. Hence, the evidence exhibited in Fig. 2 (which will be shown to be further reinforced by the significantly positive link between output growth and depreciation rates in the dynamic panel data estimations shown in Section 2) appears to be inconsistent with the AK model with exogenous depreciation.

Furthermore, both the neoclassical growth model and the traditional AK model are inconsistent with two stylized facts: (i) the observed downward trend in the relative price of investment goods and (ii) the secular rise in the investment to GDP ratio, especially from the 90s. These two facts can be rationalized by considering a two-sector framework with distinct technological trends. Such an approach is taken in Greenwood et al. (1997), Whelan (2003), Boucekkine et al. (2009), among others. In particular, Boucekkine et al. (2009) develop a general theory of capital depreciation based on the existence of maintenance costs within a two-sector vintage capital model with neutral and investment-specific technical progress. They find that an acceleration in embodied technological progress decreases the lifetime of capital goods and increases the use-related depreciation and the scrapping rate (thus increasing depreciation), while depreciation decreases when neutral technological progress accelerates (the lifetime of capital goods increases, the scrapping rate decreases and the use-related depreciation remains constant). However, their model cannot account for the observed positive correlation between persistence and long-term growth as technological progress and growth are exogenous.

The aim of this paper is to provide a theoretical explanation for the aforementioned cross-country positive correlation between short-term persistence and long-term growth by developing a model that is also consistent with the cross-country empirical evidence on depreciation. We are not aware of any previous attempt in the literature to reconcile the empirical evidence with the theoretical predictions on persistence, long-term growth and depreciation rates.

As mentioned above, purely neutral technological progress tends to decrease depreciation, while investment-specific technological

3 Provided that the amount of resources allocated to growth varies procyclically, temporary shocks produce permanent effects on output.

4 Using aggregate US manufacturing data, Epstein and Denny (1980) and Kollintzas and Choi (1985) provide evidence against the standard assumption of a constant depreciation rate. Abadir and Talmain (2001) estimate time-varying depreciation rates for Canada, Germany, Japan and the UK. As shown by Tevlin and Whelan (2003), econometric models based on a constant depreciation assumption cannot capture the early 90s investment boom in the US.

5 Using cross-sectional data of 85 countries from the World Bank averaged over the period 1965–1998, Gylfason and Zoega (2001a) find a positive correlation between the depreciation rate and per capita income growth.

6 Gylfason and Zoega (2001a) employed the same data source for the depreciation rates as in our study.