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Nonlinearities in productivity growth: A semi-parametric panel analysis

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ABSTRACT

We use country panel data spanning over 1998–2008 for both developed and developing countries to study the productivity growth when countries are close to the technology frontier. Relying on a semi-parametric generalized additive model, we estimate both reduced and structural forms for total factor productivity growth. We consider three measurements of frontier: the economy with the highest level of productivity growth, the world productivity growth and the productivity growth of the USA. We obtain a U-shape relation between productivity growth and the proximity to the world productivity growth. The relation between productivity growth and human capital displays an inverted U-shape form (res. U-shape) when the proximity to the highest productivity growth is used (res. the proximity to productivity growth of the USA). Total staff in R&D has an inverted W-shape effect on productivity growth. The share of R&D expenditure funded by government and from abroad impact positively the growth of productivity. However, the increase in government spending on R&D has a greater impact on productivity growth when the former is weak, and a smaller impact when R&D spending is already high. International trade has a positive effect on productivity growth. Specification tests show that our semi-parametric models provide a better approximation of the data compared to the parametric analogue, revealing a high degree of nonlinearity governing productivity growth.

1. Introduction

In endogenous growth theory (see e.g., Romer, 1990), human capital accumulation is one of the most important factors of growth. Assuming constant returns to technology, Mankiw et al. (1992) show that years of schooling increase the productivity. Nelson and Phelps (1966) have already asserted that the stock of human capital determines the ability to innovate or to catch up with developed countries. As pointed out by Hanushek and Kim (1995) and Hanushek and Kimko (2000), a high human capital accumulation and more fundamental research (university research) generates a higher economic growth. Therefore, expenditure devoted to higher education becomes a key factor for growth and development. This calls for the implementation of a government policy that would readily mop up the flow of financial means into the economic system so that quality higher education can be ascertained.

Most of the empirical studies have shown that human capital (usually measured empirically by years of education) and R&D have a significant positive effect on economic growth. Bassanini and Scarpetta (2001) have used a panel of 21 OECD countries for the period 1971–1998 to study the effect of human capital, R&D, demographic growth and investment on the real GDP per capita. Using "pooled

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mean group estimator", they find that, whereas years of schooling, total R&D expenditure and industry R&D have a significant positive effect on GDP per capita growth rate, public R&D has a negative effect. The latter might be explained by the fact that the part of public R&D expenditure devoted to defence area is higher than those devoted to civilian area. Relying on 16 OECD countries over the period 1980–1998, Guellec and Pottelsberghe (2001) investigate the long term relationship between various types of R&D and multifactor productivity growth (hereafter MFP), within an error correction model and instrumental variables. They find that business R&D and foreign R&D have significant positive effect and only the defence-related part of public funding has a negative and significant effect on MFP. One main result is that the elasticity of public R&D is positively affected by the public research share done by universities.

Moreover, the endogenous growth theory suggested that, the difference in productivity growth rate between countries can be explained by differences in R&D and educational policy systems. In a recent theoretical and empirical study Aghion and Cohen (2004) focus on the increasing importance of higher education when the technology in a country is near to the technology frontier.[1] The authors emphasized two mechanisms through which education influences growth and development: the first one is that educated persons are more productive since they have a high human capital, and the second one concerns technological progress; a higher education level enables to adapt or to develop new technologies in a easier way. Aghion and Cohen (2004) state that countries which are near the technology frontier, have a kind of productivity gain achieved differently from those who are far away from the technology frontier. The authors assert that for countries located far away from the technology frontier, the productivity gain is obtained by the channel of adaptation and imitation of existing technologies. However for those who are near the frontier, innovation becomes the driving force of growth. Also, they develop a theoretical model where they find a critical threshold, below which to invest in primary and secondary education is more efficient and above which the country should invest in higher education.

Using data on 20 OECD countries, Aghion and Cohen (2004) studied the effect of years of schooling and countries labor productivity backwardness relative to USA on total productivity growth. They find that taking separately primary, secondary and higher education, the more a country is near the technology frontier, the more an additional year of schooling in primary or secondary level makes the marginal return to decrease. Their estimated threshold is 24% under the frontier and an additional year in higher education entails 8% effect on total factors productivity.

While this literature has emphasized the crucial role of productivity backwardness, different measurements of the same have been used in different contributions. Aghion and Cohen (2004) used labor productivity backwardness relative to the USA. Griffith et al. (2004) used a panel of industries from 12 OECD countries. The authors considered the economy with the highest level of TFP to study the role of technology transfer, absorptive capacity, human capital and R&D on productivity growth. Vandenbussche et al. (2006) firstly developed a theoretical model to answer the puzzle raised by Krueger and Lindahl (2001).[2] Then, the authors used 19 OECD countries to show empirical evidence of TFP growth by using the world productivity as frontier and also several measures of human capital among which the fraction of population with higher education. These studies and the others are based on parametric specifications of reduced-form productivity equations.

By emphasizing the crucial role of nonlinearity in the productivity process, our study contributes to this literature in several aspects. From a methodological point of view, an innovative aspect concerns our specification. Indeed, previous studies used parametric specifications. Alternative stories of nonlinearities have been investigated. For example, Griffith et al. (2004) include higher-order terms of R&D intensity in their regression. The authors find a negative effect which suggesting diminishing returns to R&D. However, this effect was insignificant. While parametric regressions enable to detect such nonlinearities (high-order terms such as squared, cubic, etc.), they still bear an inferential limitation: the parametric specification is always assumed as the true model. Here, we assumed a *semi-parametric generalized additive model*. To the best of our knowledge, our study is the first one which adopts such specification to study TFP growth. This framework places weak restrictions on the functional form to be estimated and then allows for nonlinearities of unknown form in the relationship between the TFP growth and the control variables.

The contribution of human capital, R&D and some other key factors like trade and FDI to TFP growth is now well established. In this context, there is a growing empirical (Griffith et al., 2003, 2004; Hu et al., 2005; Kneller, 2005; Kneller and Stevens, 2006; Madsen et al., 2010) and theoretical (Vandenbussche et al., 2006; Aghion et al., 2005, 2009) literature which depicts a clear and meaningful relation both at country and firm level. The empirical scrutiny has so far been restricted to the parametric domain. In parametric framework the functional relation between TFP growth and it determinants is assumed to be linear, relegating a complex feedback mechanism underlying the process, which can make the relation highly nonlinear and hence more complicated than it appears to be. While nonlinearity (due to the intricate way human capital and R&D act upon TFP growth and vice versa) can have substantial implications for long-term economic growth and policy, the empirical literature thus far have paid little attention to the importance of nonlinear relationship lacking to explain some puzzling results (Krueger and Lindahl, 2001).

In an attempt to delineate a clear relational structure between the two, we revisit the problem in a nonparametric setting, where the flexibility of the framework allows examining the true functional form of the human

[1] The frontier is measured by the technology of the USA.

[2] The puzzling finding of Krueger and Lindahl (2001) is that education is statistically significantly and positively correlated with growth only for economies with the lowest level of education.