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# Growth and technological progress in selected Pacific countries

Benedetto Molinari [a], Jesús Rodríguez [a], José L. Torres [b,*]

[a] Department of Economics, University Pablo de Olavide, Spain
[b] Department of Economics, University of Málaga, Spain

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ABSTRACT

This paper studies the sources of technological progress that determined output and labor productivity growth across a group of leading Pacific economies – Australia, Japan, South Korea, and the U.S. – in the period 1980–2006. We consider three alternative sources of technological progress: disembodied and factor-embodied technical change both to capital and labor. The contribution to growth of each of these sources is evaluated using both traditional and equilibrium growth accounting techniques. We find that capital accumulation is the main determinant of GDP growth in Australia, Japan and the U.S., whereas the main contribution in South Korea is given by Total Factor Productivity (neutral technology). In general, about a half of the contribution to growth of capital-embodied technical change comes from Information and Communication Technology in all the considered economies. We conclude that the higher growth of South Korea, due to Total Factor Productivity change, can be explained by changes in the intensity in the capital/labor use.



## 1. Introduction

This paper studies the sources of technological progress that determined GDP and labor productivity growth across a group of leading Pacific economies – Australia, Japan, South Korea, and the U.S. – during the period 1980–2006. Technological progress is the key factor driving output and productivity growth in the long-run. From the seminal neoclassical growth theory, a large branch of theoretical and empirical literature investigated technical change as determinant of economic growth in modern economies, reaching a wide consensus about its primary role. This paper analyzes in detail the relationship between technology and growth by studying among the sources of technological progress which is the one that mostly affected and determined the growth rate of output and labor productivity.

The sources of technological progress are various and heterogenous. Technical change may occur as neutral progress, as investment-specific progress, or as labor efficiency progress. While the first is typically associated with multifactor productivity,[1] e.g., improvement of business organization or institutional factors, the second represents the improvement of capital efficiency in production due to technical change embodied in capital assets. The last form of progress refers to every possible source of improvement in labor efficiency, i.e., higher fraction of skilled workers, learning-by-doing tasks, or enhanced accumulation of common productive knowledge spread in the society. We group all these types of progress as human capital accumulation and incorporate it as a factor-embodied technical change associated with labor.

Although a large branch of literature emphasized the importance of human capital as a source of output and productivity growth,[2] still growth decomposition exercises rarely account for the effect of human capital [henceforth, HC], thus imputing to Total Factor Productivity [henceforth, TFP] its contribution to growth. In our opinion, such miscalculation is not a minor issue and it may have costly implications for the policy maker insofar as policies targeted on TFP are different from the ones meant to enhance human capital in the society. Similarly, most growth decomposition exercises do not account for capital embodied technical

* Corresponding author. Tel.: +34 952131296; fax: +34 952131299.
*E-mail address:* jtorres@uma.es (J.L. Torres).

[1] In the rest of the paper we refer to this source indistinctly as disembodied or neutral technical change.

[2] There is a countless literature on the importance of human capital as determinant of growth, starting with Schultz (1961) and Denison (1962), among others.

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change as a technological factor different from disembodied technical change.

We identify investment-specific technical change [henceforth, ISTC] using the series of quality-adjusted prices of investment. These prices are constructed combining the information contained in EU KLEMS database[3] with the quality-adjusted investment prices for the U.S. estimated by Gordon (1990) and extended by Cummins and Violante (2002) [henceforth, the GCV]. These GCV prices refer to the U.S. economy. For the analysis presented in this paper, we extend the GCV database to the period 2000–2006 and use the methodology proposed by Schreyer (2002) to obtain quality-adjusted series for Australia, Japan and South Korea.[4] We disaggregate the measures of capital to scrutinize the marginal effect of each investment asset. Particularly, we compute ISTC for each asset category given in the EU KLEMS database, namely: (i) hardware, (ii) software, (iii) communication equipment – these three typically referred to as Information and Communication Technology [henceforth, ICT] equipment – (iv) transport, (v) machinery and (vi) other equipment – or non-ICT equipment – and (vii) structures. The quality and efficiency improvements widely differ among different assets: ICT assets have bolstered productivity more effectively than earlier technologies, and have had a definite impact on the economy. Numerous studies have pointed to the special role played by these technologies in the recovery of productivity growth since the mid-1990s in the United States and some European countries (see among others, Colecchia and Schreyer, 2002; Stiroh, 2002; Timmer et al., 2003; Timmer and van Ark, 2005).

Once we identify the technological progresses embodied in factors (ISTC and human capital improvement), we use two different approaches to estimate neutral progress: (i) the traditional growth accounting decomposition and (ii) a calibrated general equilibrium model. There is a long-standing debate in the literature about which of these two approaches better identifies the determinants of growth, e.g., Greenwood et al. (1997), Hulten (1992), Oulton (2007) and Greenwood and Krusell (2007). We take a neutral stance in this debate, thus performing our analysis using both approaches. In turn, for the traditional growth accounting, we report the results using three versions of it: the traditional one proposed by Solow (1956), the one suggested by Jorgenson (1966) and the one of Hulten (1992). Regarding the general equilibrium approach, we use an extension of the Greenwood et al. (1997) model, developed in Rodríguez-López and Torres (2012) augmented with endogenous human capital accumulation.

Our main finding is that growth has a similar composition in Australia, Japan and the U.S., while it has an opposite pattern in South Korea. We find that factors accumulation explains about 60–70% of output growth in Australia, Japan and the U.S., whereas technological progress explains about 30–40%. In the case of South Korea, factors accumulation only explains approximately 36% of output growth, while technology explains 64%. We show that this difference is explained by the neutral technical change. Whereas in the first three countries, TFP contribution to output growth is close to zero or even negative according to Hulten's decomposition, in South Korea neutral technology alone explains approximately 40% of output growth, being the most important determinant of growth in that country. Similar results are obtained in terms of labor productivity growth. The general equilibrium approach confirms these results, showing that in Australia, Japan and the U.S. the main factor of labor productivity growth in the long-run is ISTC. In the case of South Korea the main contribution comes from TFP, followed by human capital. Additionally, we obtain that TFP contribution to productivity is positive for South Korea and Japan, but negative for the U.S. and Australia. Getting to a more detailed analysis, we show that ISTC contribution to growth is similar in Japan and South Korea, 0.79 and 0.70 percentage points, respectively, 0.96 percentage points in Australia and 1.09 percentage points in the U.S. However, using the Jorgenson (1966) approach, the larger contribution to output growth from ISTC corresponds to South Korea (0.71 percentage points), whereas for the other three countries the contributions is lower (0.58 for Australia, 0.46 for Japan and 0.49 for the U.S.). The differences between the two approaches are explained by the much higher capital investment process in South Korea compared to the other countries. Our results show that the large output and productivity growth observed for South Korea, due to TFP or neutral technological change, can be explained by changes in the intensity in the capital/labor use. Efficiency gains by increasing the capital/labor ratio drives Total Factor Productivity of the Korean economy. In fact, capital factor shares of South Korea are lower than the observed for Australia, Japan and the U.S. Moreover, the capital share has increased over the selected period for the Korean economy, evincing a pattern consistent with an economy in transition to a balanced growth path corresponding to more advanced economies.

The rest of the paper is structured as follows. Section 2 describes the data set and the logic of the calibration. Section 3 introduces the different growth accounting approaches: the statistical growth accounting and the equilibrium growth accounting. Estimates of the contribution to output and labor productivity growth are presented in Section 4. Finally, Section 5 summarizes and concludes.

## 2. Data

Although originally created to keep track of economic growth in European countries, the EU KLEMS Database also reports data on some non-European countries. We use it to collect Australian, Japanese, Korean, and U.S. data on nominal and real output and productive factors compensations, on the amount (measured as total worked hours) and quality of labor services, and finally on nominal and real investment in physical capital break up in seven categories: (i) hardware and office equipment, (ii) communication equipment, (iii) software, (iv) transport equipment, (v) machinery, (vi) other equipment, (vii) structures. Data on investment are then used to construct the series of capital stock by mean of the permanent inventory method.

The upper panel of Table 1 reports the mean value over the period 1980–2006 of annual growth rates for the set of considered variables. The average growth rate of real output has been fairly similar across Australia, Japan, and the U.S. (around 3%), while it has been sensibly higher in the case of South Korea (approximately

**Table 1**
Average annual growth rates, 1980–2006.

| | Australia | Japan | Korea | U.S. |
|---|---|---|---|---|
| Variables | | | | |
| Output | 3.50 | 2.29 | 7.70 | 2.92 |
| Labor productivity | 1.84 | 2.55 | 6.33 | 1.64 |
| Worked hours | 1.66 | −0.26 | 1.37 | 1.28 |
| Capital | 3.58 | 3.79 | 8.19 | 3.51 |
| Technology | | | | |
| HCI | 0.64 | 0.69 | 1.53 | 0.30 |
| ISTC | 3.20 | 1.95 | 2.39 | 3.27 |

[3] All details about EU KLEMS project can be found at http://www.euklems.net.

[4] In fact, the EU KLEMS database uses Schreyer's methodology to quality-adjust the prices of ICT equipment starting from the corresponding NIPA prices. GCV prices are used because non-ICT equipment prices are not quality-adjusted in EU KLEMS. The updated series of quality-adjusted prices for all asset categories is a key contribution of this paper. It is worth noting that if only quality-adjusted ICT prices are used, then growth accounting exercises tend to overweight the importance of ICT as a factor of growth behind the 1995 U.S. productivity growth upsurge (see, for example, Collechia and Schreyer, 2001; Jorgenson and Stiroh, 2000).