World technology frontier: an analysis of the relevance of the national system of entrepreneurship

In this study we build a world technology frontier based on the non-parametric Malmquist index to evaluate total factor productivity (TFP) trends among 73 countries during the period 2002-2013. The proposed model extends existing work on country-level productivity by integrating the national system of entrepreneurship (NSE) in the technology (e.g., Färe et al., 1994; Kumar and Russell, 2002). Additionally, our model identifies the components of productivity changes (efficiency change and technical change) and scrutinizes the effects on productivity of the direction of technical change resulting from the countries' technology choices (biased technical change).

Productivity is of great interest to economists and policy makers as it has been invoked as a key factor contributing to economic growth (Barro, 1991). From a policy perspective, the analysis of the factors shaping total factor productivity (TFP) contributes to improve resosurce allocation policies and investment decision making (Acemoglu, Zilibotti, 2001).

Total factor productivity is often estimated by the Solow residual which captures technology shifts resulting from output growth that remains unexplained by growth in inputs (Van Beveren, 2010). Echoing the seminal work by Solow (1957), economists have devoted a great deal of efforts on evaluating the sources of productivity growth between and within countries over time (e.g., Färe et al., 1994; Hall and Jones, 1999; Kumar and Russell, 2002; Caselli and Coleman, 2006; Antonelli and Quatraro, 2010). These studies support the view that productivity differences across economies originate from differences in technology.

In this study we argue that, besides the differences in technology and production factors' availability, the institutional setting backing entrepreneurship—i.e., the national system of entrepreneurship, NSE—and the technology choices linked to the exploitation of production factors play a decisive role in shaping countries' productivity level.

Entrepreneurship is a vital economic component present in any economy to a larger of lesser extent. At the country level entrepreneurship is increasingly operationalized as the capacity of entrepreneurial firms to allocate productive resources to the economy (Autio et al., 2015). In this sense, it seems clear that the analysis of countries' productivity should include the combined effect of individual entrepreneurial initiatives and the context in which these initiatives operate. According to Acs et al. (2014, p. 479) the 'National System of Entrepreneurship is the dynamic, institutionally embedded interaction between entrepreneurial attitudes, abilities, and aspirations by individuals, which drives the allocation of resources through the creation and operation of new ventures'. The analysis of the NSE permits to depict the territory's capacity to mobilize available resources to the market through new business formation processes, and portrays the interactions between entrepreneurial human capital and the multifaceted economic, social, and institutional contexts in which individuals develop their entrepreneurial activity. Thus, the NSE contributes to understand how entrepreneurship fuels territorial economic productivity through the efficient allocation of resources in the economy.

Prior studies on country-level productivity often compute TFP values under the assumption of Hicks neutrality of technical change, as in the classic study of technical change by Solow (1957) (see, e.g., Färe et al., 1994; Boussemart et al. 2003; Caselli and Coleman, 2006; Antonelli and Quatraro, 2010). Following Solow (1957, p. 312), neutral technical change is associated with a constant marginal rate of substitution between inputs that simply increase or decrease the output level of the focal unit of analysis. However, the technology choices of countries (as well as individuals and organizations) is likely heterogeneous over time. In fact, Samuelson and Swamy (1974, p. 592) pointed that 'the Santa Claus hypothesis of homotheticity in tastes and in technical change is quite unrealistic'.

In practical terms, many considerations make us believe that shifts in the production function of countries are non-homothetic. Countries with different factors' endowments will take advantage of technological innovations that allow for a more intensive use of locally abundant production factors. It follows that countries better able to introduce technologies that are able to matching the local conditions of factor markets should show better productivity performances than countries that have put less effort in shaping technologies according to the relative scarcity of production factors. Additionally, countries have clearly differentiated social and economic priorities and the successful implementation of technologies in one country might prove itself ineffective in other contexts with different local conditions of factor markets.

The proposed analysis of countries' TFP and its components offers valuable information on the sources of productivity change during growth and recession periods in developed and developing economies. Additionally, by examining the directionality of technical change we are in a better position to assess whether the direction of technical change matches the technology choices of the analyzed countries, in terms of input usage.

Most important results:

Table 1 presents the summary statistics of the productivity measure and its components for the full sample. Table 2 displays the results distinguishing the period 2003-2008 from the period 2009-2013. Additionally, Figures 1, 2a-2b and 3a-3b break the sample into OECD versus non-OECD countries, and plot the Malmquist TFP index, its components (*EC* and *TC*), and the technical change components between 2003 and 2013, respectively.

Table 1. Malmquist TFP index and its components

	Malmquist index	Efficiency change	Technical change
2003	1.0174	1.0018	1.0156
2004	1.0167	1.0165	1.0016
2005	1.0146	1.0036	1.0109
2006	1.0138	1.0080	1.0056
2007	1.0137	1.0134	1.0003
2008	1.0108	1.0011	1.0097
2009	0.9823	0.9742	1.0082
2010	0.9722	0.9946	0.9776
2011	0.9790	0.9644	1.0157
2012	1.0108	1.0161	0.9951
2013	1.0182	0.9995	1.0191
Total	1.0029	0.9981	1.0052

By examining the differences between OECD and non-OECD countries, we note that these two groups have dissimilar patterns of TFP change, in which OECD countries grew faster than non-OECD countries with progressing technology and more efficient production. During the entire period TFP values are higher among OECD countries (1.0105) viz.-a-viz. non-OECD countries (0.9944). However, differences in the distributions are only significant in the period 2008-2013. Figure 2 shows a slightly higher productivity growth in OECD countries (average: 1.67%) compared to non-OECD countries (average: 1.06%) during the pre-crisis period (2003-2008). Among OECD economies, the contribution of technical change to productivity growth (average: 0.91%) was greater than that of efficiency changes (average: 0.75%).

After 2008, results indicate that OECD recovered more rapidly from the worldwide economic meltdown, and that the average yearly productivity fall among non-OECD countries (1.50%) was mainly caused by a decline in operating efficiency (average decline: 1.74%) (Figures 3a and 3b).

Figure 1. Malmquist index in OECD and non-OECD countries

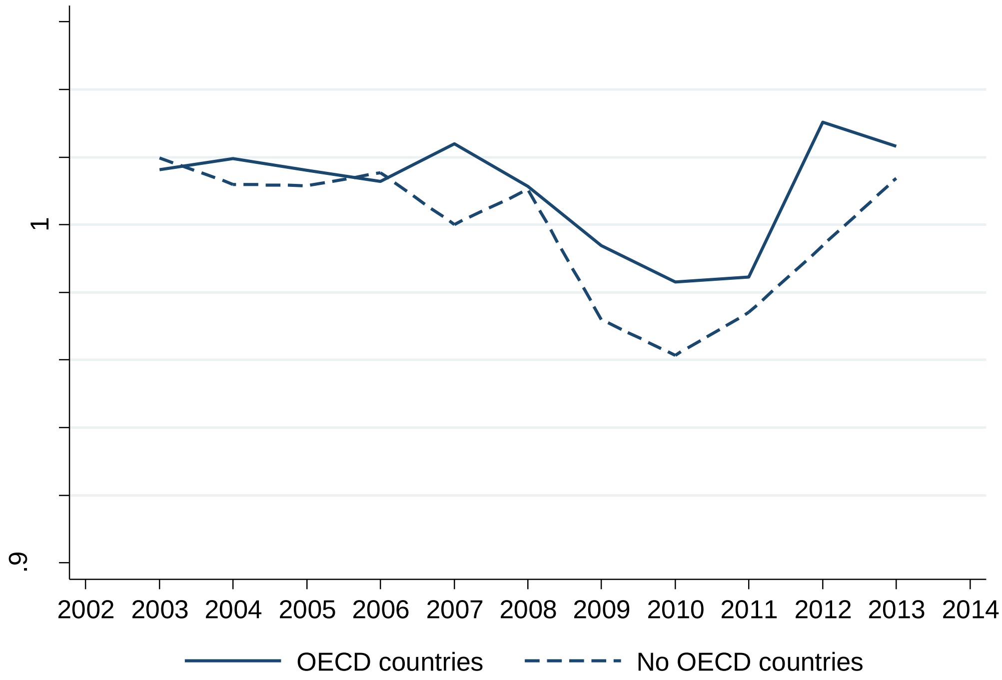


Figure 2a. Efficiency change in OECD and non-OECD countries

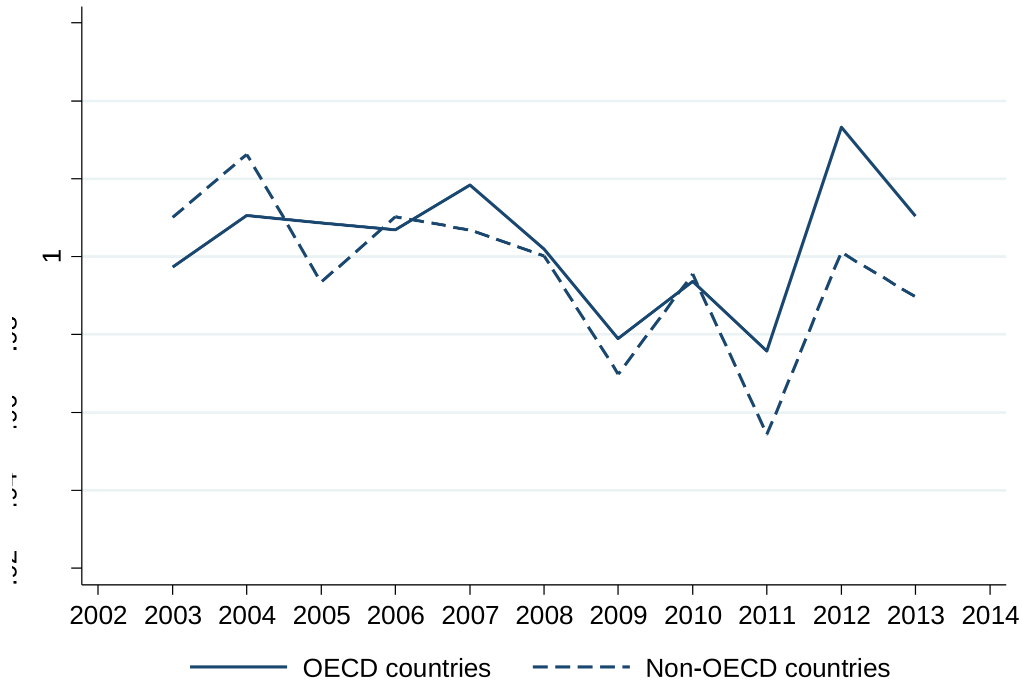
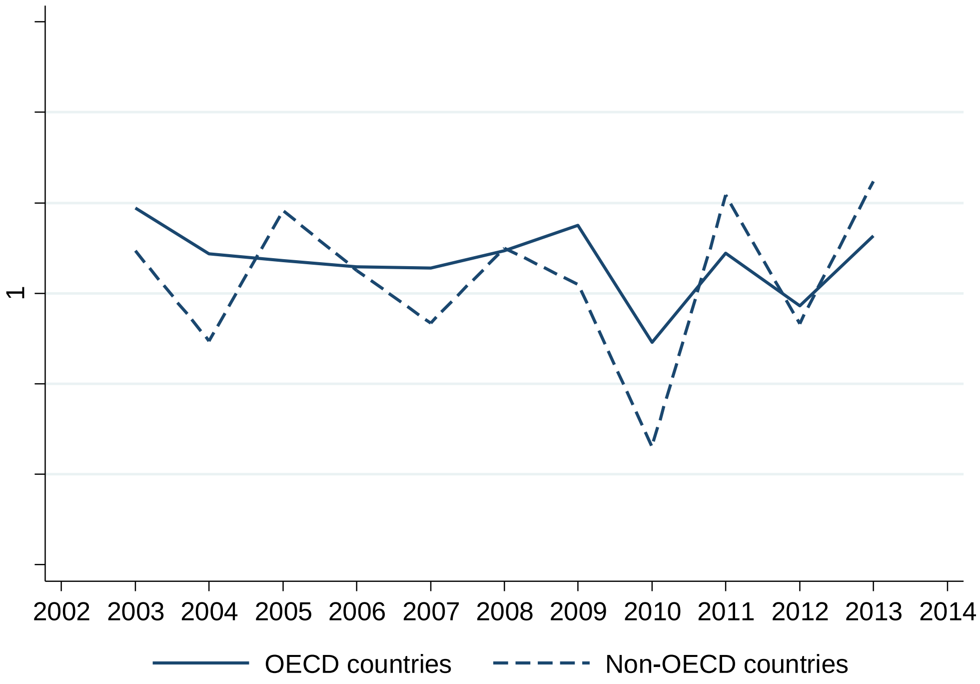


Figure 2b. Technical change in OECD and non-OECD countries



Results in Figure 2a might signal that non-OECD economies—mostly poor or developing countries—are losing the race for convergence. It has been argued that low technological catch-up is behind the slow convergence rates showed by. In the context of our study, the world technology is represented by the production surface in the input-output space, and the potential catch-up effect is captured by movements towards the efficiency frontier, that is, improvements in the efficiency level (the term *EC* in equation (5)).

We ran two additional tests to verify whether poor and developing economies are catching-up developed countries. First, we evaluated the distribution of the efficiency level across countries in the period 2003-2008 and in the period 2009-2013. Results in Figure A2 of the Appendix point to a prominent shift in the probability mass away from the efficient reference value of one between the two sub-periods, thus indicating that economies are predominantly moving away from the efficiency frontier over time. This result is validated by the Kolmogorov-Smirnov test of equality of distributions which confirms that the differences in densities between the two periods is significant (Combined K-S: 0.1128, *p-value* = 0.004).

Second, we tested the convergence hypothesis by running a fixed-effects regression model in which efficiency variations—i.e., *EC* in equation (5)—was regressed against the lagged efficiency level (equation (1)) and a set of time dummies which rule out the effect of time trends. Building on the beta-convergence approach by Barro and Sala-i-Martin (1992), a positive relationship between the efficiency change term (*EC*) and past efficiency (in terms of distance to the efficiency frontier) would evidence that (poor) countries with higher inefficiency levels catch-up (rich) efficient ones.

The results of the fixed-effects model in Table 2 confirm that during the analyzed period countries with greater inefficiency levels have, on average, benefited more from efficiency improvements than have more efficient countries. To further corroborate the robustness of this result, we estimated additional models for two sub-periods (2003-2008 and 2009-2013). The comparison of the efficiency level (equation (1)) between the two analyzed sub-periods reveals that the distance to the frontier of non-OECD countries worsened from 24% (2003-2008) to 51% (2009-2013), while OECD economies show a lower average inefficiency increase from 16% (2003-2008) to 21% (2009-2013). This finding is in line with the result of the density test which suggests that, as a result of the global economic slowdown, non-OECD countries are not only lacking the resources necessary to consolidate their GDP, but also making an inefficient use of their available inputs.

Table 2. Fixed-effects regression results: Convergence test

	Efficiency level (*t*-1)	Intercept	Time dummies	F-test	R2 (within)	Obs.
Panel A: 2003-2013	0.0947** (0.0422)	0.8722*** (0.0529)	Yes	5.49***	0.1558	470
Panel B: 2003-2008	0.1210*** (0.0427)	0.8670*** (0.0487)	Yes	4.43***	0.1507	202
Panel C: 2009-2013	0.1065*** (0.0387)	0.9062*** (0.0714)	Yes	7.19***	0.2048	268

Robust standard errors are reported in brackets. *, **, *** indicate significance at the 10%, 5%, and 1%, respectively.

Overall, this analysis yields mixed results on international convergence. However, these results do not necessarily imply that there is a tendency for technical change to modify (increase or reduce) the gap between rich and poor economies. Instead, results only indicate that OECD countries, which on average have also fallen short of the frontier, might have capitalized on their resources more efficiently than non-OECD countries after 2008. This is the point to which we turn in the next section where we examine how decisions linked to the utilization of inputs impact countries' technical change and, consequently, their productivity level.

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