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Measuring industry productivity and cross-country convergence

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ABSTRACT

This paper introduces a new method for simultaneously comparing industry productivity across countries and over time. The new method is similar to the method for making multilateral comparisons of Caves, Christensen and Diewert (1982b) but their method can only compare gross outputs across production units and not compare real value added of production units across time and space. The present paper uses the translog GDP methodology for measuring productivity levels across time that was pioneered by Diewert and Morrison (1986) and adapts it to the multilateral context. The new method is illustrated using an industry level data set and shows that productivity dispersion across 38 countries between 1995 and 2011 has decreased faster in the traded sector than in the non-traded sector. In both sectors, there is little evidence of decreasing distance to the productivity frontier.

1. Introduction

Determining whether and how fast productivity is converging across countries is a question of enduring interest, and for good reasons.[1] Most importantly, it tells us if lower-income countries are catching up to high-income countries and, if so, how fast. Furthermore, it can help shed light on the circumstances under which countries would benefit from an 'advantage of backwardness', which is helpful information for designing development policies.[2]

A sectoral perspective on convergence is particularly valuable as it can provide clearer policy targets. For instance, if – as found by Rodrik (2013) – convergence in manufacturing is unconditional, i.e. it occurs regardless of country circumstances, it could be helpful to gear policies towards building and strengthening this sector. Alternatively, if the finding for OECD countries by Bernard and Jones (1996) of convergence in services but not in manufacturing would hold more broadly, the argument for support of the manufacturing sector would be much weaker.

Despite the interest in the results, the methods used in compiling the productivity measures used in these studies are not well-suited for analyzing productivity convergence. Obviously, convergence is a topic that requires a simultaneous comparison of productivity levels across countries *and* over time.[3] Instead, the typical analysis uses measures that are comparable across

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1 For a recent study and overview, see Barro (2012).

2 See e.g. Aghion et al. (2014).

3 See Hill (2004) and Diewert and Fox (2015) for more general discussions of consistency of price indexes across countries and over time. See also Lichtenberg (1994) on σ-convergence, a more direct and robust concept than β-convergence.

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countries only in a single year or national growth rates that are comparable only over time.

A major contribution of this paper is to propose a new method for measuring industry productivity levels that are comparable across both countries and over time. The proposed approach resolves the comparability problem through an extension of the work of Caves et al. (1982b, CCD henceforth), who showed how to compare productivity across countries at a point in time. Their approach was based on the use of distance functions to construct output and input aggregates. Unfortunately, their approach cannot be used to compare real value added, since distance functions are, in general, not well-defined when accounting for intermediate inputs. Thus, we will use the GDP function, or value added function, approach pioneered by Diewert and Morrison (1986) as a basic building block in our new approach to replace the distance function approach used by CCD.

Section 2 shows how outputs, inputs and productivity levels for an industry (or sector of an economy) can be compared across countries and time in a consistent manner. In Section 3, we show how the analysis of Section 2 can be extended to construct measures of "world" productivity at time t, Γ_t, that are consistent across time and space. We also define the relative efficiency of the industry (or production unit) in country k at time t, Γ_{kt}, with the most efficient production unit across all countries and time periods up to time t, $\Gamma_{t,max}$.

Section 4 defines two measures of industry convergence. The first measure, E_t, is the ratio of actual world productivity, Γ_t, to the maximum possible value of world productivity $\Gamma_{t,max}$, all at time t. If all countries produce at the maximum possible level of productivity at time t, then E_t will equal unity. Thus if E_t increases over time, this indicates a movement towards productivity convergence. The second measure of convergence at time t, σ_t, is an input-weighted average of the dispersion of the country productivity levels relative to the world average productivity level, both at time t. If all country productivity levels are the same in period t, then σ_t will equal 0, so if σ_t declines over time, productivity levels across countries are converging towards the mean level of productivity.

Section 5 gives a brief description of the data used in this study. The data set covers 38 economies across two sectors of each economy for the period 1995–2011. The two sectors are the *traded sector* and the *non-traded sector*. A third sector is the *market sector* for each economy, which is an aggregate of the traded and non-traded sectors. This setting is of interest as these 38 economies include most advanced economies as well as major emerging economies, like China and India. Moreover, the period since 1995 has seen rapid growth across many of these emerging economies, raising the question whether aggregate productivity levels converged and, if so, which sectors contributed most. There is also interest in determining whether the global financial crisis affected convergence. The data are constructed mainly using the World Input–Output Database[4]; see Section 5 and Inklaar and Diewert (2015) for additional details.[5]

In Section 6, we show that convergence of productivity levels towards the mean has indeed been strong over this period, with the weighted standard deviation of market sector productivity levels (the dispersion measure) decreasing by 23% over the sample period. Based on the literature on the Harrod–Balassa–Samuelson (HBS) model, productivity dispersion should be larger and productivity growth should be faster in the traded sector than in the non-traded sector.[6] We confirm that dispersion in the traded sector is about 50% greater than in the aggregate market economy and a new finding is that aggregate convergence is almost entirely due to convergence in the traded sector of the economy.[7] However, we find that there is no evidence that countries are converging towards the productivity frontier over our sample period. We also find that the global financial crisis did not decrease the rate of growth of the productivity frontier but it did decrease realized "world" productivity growth substantially from an average of 1.1% per year over the years 1995–2007 to 0.6% per year over the years 2007–2011.[8] Section 7 concludes.

2. An economic approach to the measurement of productivity over time and space

To analyze the degree of convergence towards the productivity frontier, it is necessary to measure output and input levels that are comparable across countries and over time. It is also useful to have measures that are invariant to the choice of a reference point—i.e. a single country and year that acts as a basis for comparison for all other countries and years. Finally, it is useful to have a methodology that is based on an economic approach to production theory. Such an approach was developed by CCD but their approach has a significant limitation. Their approach relies on the distance function methodology for aggregating inputs and outputs that can be traced back to Malmquist (1953) and further developed by Caves et al. (1982a). The problem is that this distance function methodology does not allow us to compare real GDP or real value added across countries as that methodology requires a strict separation of outputs and inputs. Net output aggregates based on distance function techniques do not work if the output aggregate includes intermediate inputs or imports. In this section, we show how this problem can be addressed in a production theory framework by using the methodology that was developed by Diewert and Morrison (1986).[9] Our suggested methodology also draws on the techniques used by CCD.

We give a brief explanation of the methodology developed by Diewert and Morrison (1986) for a comparison of real outputs, inputs and productivity levels across two time periods or two production units in the same industry.[10] Consider a set of production units that produce a vector of M net outputs,[11] $y \equiv [y_1, \ldots, y_M]$, using a nonnegative vector of N primary inputs, $x \equiv [x_i, \ldots, x_N]$. Let the feasible set of net outputs and primary inputs for production unit i be denoted by S^i for $i = 1, \ldots, I$. It is assumed

4 See Timmer et al. (2015) for an overview of this database.

5 We draw on the World Bank's PPPs for 1996, 2005 and 2011 as a starting point for developing PPPs for our industry data. A full set of industry PPPs covering the years 1995–2011 is required for our purposes so the World Bank PPPs for the three benchmark years are interpolated using the method that makes use of national growth rates that was suggested by Diewert and Fox (2015). Our full set of PPPs does not make use of country exchange rates.

6 See Asea and Corden (1994) for an overview of the model, Hsieh and Klenow (2007) and Herrendorf and Valentinyi (2012) on productivity dispersion and De Gregorio et al. (1994) and Ricci et al. (2013) on relative productivity growth. We find that realized "world" productivity growth over 1995–2011 was 1.3% per year for the traded sector and 0.6% per year for the nontraded sector.

7 When we decomposed the traded sector into additional sectors, we found that the manufacturing sector is the main contributor to convergence, confirming a result of Rodrik (2013).

8 The data used in this paper are listed in Inklaar and Diewert (2015).

9 A similar methodology was independently developed by Kohli (1990). Shiu (2003) applied the Diewert/Morrison/Kohli methodology in a multilateral context. The difference is that we use the *averaging approach*, pioneered by Gini (1931), to obtaining base-country invariant multilateral comparisons, whereas Shiu (2003) uses *the similarity linking approach*, pioneered by Hill (1999).

10 We interpret the "same industry" to comprise the production units that produce the same outputs using the same set of inputs.

11 If $y_m > 0$, then net output m is an output and y_m denotes the production of this commodity; if $y_m < 0$, then net output m is an intermediate input and y_m denotes the negative of the amount of this input that is used by the production unit.

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