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Decomposing changes in the conditional variance of GDP over time

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ABSTRACT

A well established fact in the growth empirics literature is the increasing (unconditional) variation in output per capita across countries. We propose a nonparametric decomposition of the conditional variation of output per capita across countries to capture different channels over which the variation might be increasing. We find that OECD countries have experienced diminishing conditional variation while other regions have experienced increasing conditional variation. Our decomposition suggests that most of these changes in the conditional variance of output are due to unobserved factors not accounted for by the traditional growth determinants. In addition to this we show that these factors played very different roles over time and across regions.

1. Introduction

Cross-country empirical growth studies commonly focus on β-convergence, in part to address such questions as "Do poor countries grow faster than richer ones?" or "How long will it take for a poor country to become rich?" Both of these questions are geared towards economies catching up with one another and highlight how relative income disparities are changing over time. However, it is well known that focusing on a coefficient in a conditional mean regression is limited (Quah, 1993a) and cannot explain concepts such as intra-distributional churning, multimodality, and expansion/contraction of the distribution over time. To more adequately study additional features of the cross-country distribution of output, growth empiricists have deployed a wide array of statistically rich modeling techniques to sharpen focus on how this distribution has changed. Within these studies a common 'distributional moment' that is of interest is the variance (see Pittau et al., 2010), leading to speculation on σ-convergence.

It its most basic form, unconditional σ-convergence is assessed by looking at differences in the variation of the logarithm of cross-country output at two periods in time. As Quah (1996a) notes, while σ-convergence may be more illuminating regarding the behavior of the cross-country distribution of output than its β-convergence counterpart, it is still only a *feature* of the distribution and as such cannot capture entirely what is happening over time to the distribution. For instance, if one were to witness σ-convergence, intra-distribution churning and/or the appearance of multiple modes could occur, either of which would not be captured concomitantly with the observance of σ-convergence.

However, one of the great appeals of studying β-convergence (even with the litany of econometric issues that impact the analysis; Durlauf, 2009), is that conditioning variables, such as quality of institutions, can be used to guide insight into how to promote growth. Consider, for instance, that if a given covariate, again using quality of institutions, has a positive effect in a cross-country growth regression the main intuition is that the speed at which a country approaches its steady state, conditional on institutions, would be higher, so the policy implication is improving institutional quality. A traditional analysis, which places very specific assumptions on the convergence equation provides limited policy insight as little in the way of heterogeneity is accounted for. If one considers parameter heterogeneity[1] then specific impacts of a given covariate, in a given country, can be made.

In this paper we investigate a counterpart of this reasoning, focusing on the conditional variation of output. When attention turns to conditional variation, questions like "If African nations had levels of human capital and population growth as in OECD countries, would we witness a diminution of income dispersion over time?" or, more generally, "Without the observed changes in human or physical capital stocks would we observe less dispersion in cross-country output?" can be addressed. The focus on conditional variation provides straightfor-

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[1] We may think to several forms of parameter heterogeneity in growth context as a semi- or nonparametric treatment of the production structure (Liu and Stengos, 1999), mixture modelling (Pittau et al., 2010) or.

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ward intuition on the role of a specific covariate not for promoting growth, but for influencing variation in output across countries. We see how these questions are the variational equivalents of the conditional β-regressions and are undoubtedly more interesting/insightful than their unconditional counterparts, that only focus on simple variance patterns over time. This can improve the complementary role of information of β- and σ-convergence approaches advocated by Sala-i-Martin (1996).

Using recently developed nonparametric kernel smoothing methods, we suggest a decomposition of the conditional variance of output based on covariates and time. This allows splitting overall variation in cross-country output into changes due to covariates and time. The deployment of nonparametric methods allows us to eschew both distributional and parametric functional form assumptions, which could produce misleading results due to model misspecification. To our knowledge, there currently does not exist an empirical study of cross-country variation of output in a nonparametric framework. This makes our combination of methods and application important for the growth empirics field.[2]

With our nonparametric decomposition in tow, we see two main results emerge. First, over the period 1960–2010, OECD countries observed a decreasing conditional variation, split almost equally across time and covariates. Second, all other regions of countries experienced an increasing conditional variation, with differences emerging across the role played by time and covariates. We also present a series of robustness checks over various dimensions of our empirical exercise. Qualitatively, our two main findings remain intact.

The remainder of the paper is organized as follows. Section 2 reviews the related literature, Section 3 outlines our construction of the conditional density and how we will estimate the conditional variance. Section 4 will investigate the change in the conditional variance based upon time and covariates. Section 5 summarizes our findings and offers avenues for further research.

2. Background discussion

Even with the extant shortfalls of studying different 'moments' of the distribution of output, one can still discern important information by studying the behavior of these moments over time. More directly, by focusing on the behavior of these moments in a conditional setting, empirical growth studies can glean information not available in restricted unconditional settings. Here, we use methods similar to Maasoumi et al. (2007) and Henderson et al. (2012) to estimate the conditional density of cross-country per capita output but use the focus of Pittau et al. (2010) to analyze the variance of these conditional densities over time and for different subsets of countries. The work of Maasoumi et al. (2007) focused primarily on the behavior of the conditional distribution/density of growth rates (actual and predicted) over time between OECD and non-OECD countries whereas the work of Pittau et al. (2010) decomposed the density of cross-country output into three groups and then subsequently analyzed the (unconditional) variance of these three groups over time.

Here we blend these two studies together and offer a decomposition of the variance of the conditional density. We depart from Maasoumi et al. (2007) by explicitly focusing on the variance of the distribution while we extend the work of Pittau et al. (2010) by examining conditional variances as opposed to unconditional ones. In addition to this, we decompose overall changes in the variance over time into a covariate component and a time component, logic that is close to Beaudry et al. (2005). The covariate component can be taken as measure of the impact that covariates have on overall variation in output, which cannot be discerned in an unconditional setting.

To obtain a sense for the importance of conditioning, consider the multimodality finding of Quah (1993a). While subsequently illuminating regarding the relative polarization of the distribution over time, given the unconditional framework of the analysis, only speculative evidence could be provided underlying the root for the emerging bimodal shape and increasing variance. The work of Feyrer (2008) and Henderson et al. (2008) both examined the behavior of the corresponding Solow growth determinants, along with cross-country output to see if similar patterns emerged that may provide further evidence to Quah's initial discovery of a bimodal distribution.

However, whether or not σ-convergence is an interesting phenomenon, it is useful to note that absolute β-convergence is a necessary condition for absolute σ-convergence to occur (Quah, 1993a; Furceri, 2005) and with the abundance of studies showing no tendency for absolute β-convergence across countries, it comes as no surprise that there is no supporting evidence for absolute σ-convergence. A stimulating research agenda would be to determine if a parallel necessary condition for conditional β-convergence exists for conditional σ-convergence to materialize, and moreover, if this mode of convergence is supported by the data? To begin to answer these types of questions appropriate concepts of conditional σ-convergence are needed. However, constructing a conditional counterpart has proved elusive since Barro and Sala-i-Martin (1991) formally defined this concept.[3] As Durlauf et al. (2005, p. 53) note "An economically interesting formulation of conditional σ-convergence would be a useful contribution."

Evidence in favor of absolute σ-divergence is provided in Table 1. Taking a balanced sample of 70 countries for whom we have data in Penn World Table 8.1 (Feenstra et al., 2015) and Barro and Lee (2013) from 1960 to 2010, we can look for evidence of absolute σ-convergence across decades and various measures of output per capita. Table 1 shows the variation in the logarithm of output for RGDPE, RGDPO and RGDPNA as well as for the standard growth accounting variables as investment rates (INV), population growth (POP) and years of schooling (EDUC). We immediately notice that all three of the common measures of per capita output (RGDPE, RGDPO and RGDPNA) display increasing variation over each decade, aside from a modest reduction over the last decade (where we have the financial crisis). There is not even the appearance of the variance stabilizing over time for any measure of output from 1960 to 2000. While this yields conclusions regarding the lack of absolute σ-convergence, identifying the underlying causes for this increase remain elusive in an unconditional setting.[4]

It is interesting to note that the variation in investment rates seems to be declining over time, in line with the research of Caselli and Feyrer (2006) while levels of education do not display a clear pattern of absolute σ-convergence. The apparent σ-divergence is in accord with the development accounting findings of Stamatakis and Petrakis (2005) and Henderson et al. (2008) and the underlying reasons for this divergence represents an interesting research agenda not explored here.

Taking into account the reduction in variance of population, we see how in a traditional augmented Solow model a lá Mankiw et al. (1992) the diverging pattern of output is not mimicked by the diverging pattern of the determinant variables. Notwithstanding that, we could still have that the returns to these variables could be changing over time, and as such, may explain this increasing variation. In order to provide more intuition consider for instance the situation where a country that is in the extreme right of the distribution (a high income country) in the previous decade, grows much more than the average, becoming even richer. Now, *ceteris paribus*, we could have for instance

[2] See Boccanfuso et al. (2013) and Li et al. (2016) for additional applications of nonparametric kernel smoothing methods in alternative growth and income contexts.

[3] See Phillips and Sul (2007), who develop a panel time varying idiosyncratic convergence test.

[4] We caution that the appearance of σ-divergence can be attributed to the measure of dispersion used and not the actual phenomena of output diverging over time (Dalgaard and Vastrup, 2001).