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# Cross-country Income Convergence Revisited

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## Abstract

We reassess convergence of income and its determinants across countries using the dataset constructed by Klenow and Rodriguez-Clare (2005) and our updated version of the same data. Consistent with the literature, the ergodic distribution of output per worker features separate convergence clubs. In contrast to previous findings, productivity in the long run is unimodal. The long-run distribution of human capital is multimodal.

KEYWORDS: convergence, development accounting.

JEL CLASSIFICATION: O40, O47.

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# 1 Introduction

Whether the income of poor countries tends to catch up with the income of rich ones is a key question in the empirics of economic growth (Durlauf and Quah, 1999; Durlauf et al., 2005). We reassess the convergence properties of the cross-country distribution of income and the determinants of convergence using the dataset constructed by Klenow and Rodriguez-Clare (2005) and an updated version of the same data. We adopt distribution dynamics techniques in our empirical analysis.

In the analysis of the dynamics of a probability distribution, the more pronounced the multimodality of the long-run distribution and the lower the mobility, the stronger the evidence of polarization. Common findings in the literature are multi-peakedness of the ergodic distribution of output per capita (or per worker) and high persistence/low mobility. Most authors then proceed to uncover the causes of “club convergence” either by conditional distribution dynamics or by analyzing the ergodic distributions of the determinants of output per capita (physical/human capital and productivity).

Feyrer (2008) uses discrete Markov-chain methods to analyze the determinants of convergence across 95 countries over the 1970-89 period.<sup>1</sup> Feyrer finds a twin-peaked ergodic distribution of output. While the distributions of accumulable factors (physical/human capital) display long-run convergence, the stratification of the distribution of total factor productivity (TFP) in two modes is interpreted as responsible for the lack of convergence in output. Johnson (2005) extends Feyrer’s analysis on the same data using a continuous state-space approach. The most important determinant of the bimodal ergodic distribution of output is capital accumulation. TFP, with a “nearly bimodal” long-run distribution, can still play a role.

We investigate cross-country convergence using the data constructed by Klenow and Rodriguez-Clare (2005) and our own updated dataset. Consistent with the literature, we find that the long-run distribution of output is multimodal. Using the dataset by Klenow and Rodriguez-Clare (2005), both physical capital and productivity are bimodal in the long run. The ergodic distribution of human capital is almost single-peaked. With our more recent data, we find that productivity is unimodal in the long run. Human capital instead clusters around multiple modes.

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<sup>1</sup>The data used by Feyrer (2008) are constructed as in Klenow and Rodriguez-Clare (2005) but rely on earlier versions of the Penn World Table and the Barro-Lee educational attainment data.

## 2 Convergence Revisited

### 2.1 Data and Methodology

We consider two datasets: the one constructed by Klenow and Rodriguez-Clare (2005) and an updated dataset that we built relying on Heston et al. (2009) and Barro and Lee (2010).<sup>2</sup> Assuming a standard Cobb-Douglas production function, output per worker,  $Y/L$ , can be expressed as a function of the physical capital-output ratio,  $K/Y$ ,<sup>3</sup> human capital per worker,  $H/L$ , and TFP,  $A$ :

$$\log \left( \frac{Y}{L} \right)_{i,t} = \frac{\alpha}{1-\alpha} \log \left( \frac{K}{Y} \right)_{i,t} + \log \left( \frac{H}{L} \right)_{i,t} + \log (A)_{i,t}. \quad (1)$$

TFP is recovered from equation (1) as a (Solow) residual. The capital-output ratio is constructed, given an initial condition, from a standard capital accumulation equation. The initial capital stock is computed from the steady-state relationship:

$$\left( \frac{K}{Y} \right)_{i,0} = \frac{(I/Y)_i}{g + n_i + \delta}, \quad (2)$$

where we assume a depreciation rate of 8% (i.e.,  $\delta = 0.08$ ). We set the growth rate of GDP per worker to the world average of 1.67% (i.e.,  $g = 0.0167$ ) and the capital share to  $\alpha = 1/3$ . For each country,  $i$ , we set population growth,  $n_i$ , and  $(I/Y)_i$  to the average growth rate of the economically active population and to the average investment share of GDP.

As in Klenow and Rodriguez-Clare (2005), we construct human capital per worker from educational attainment data:  $\log(H/L) \equiv \phi s$ . We adopt the Mincerian return  $\phi = 0.085$ . Educational attainment,  $s$ , is measured by the average years of schooling attained by the population over 25 years of age (see Barro and Lee, 2010).

Our sample covers the period 1960-2007: 98 countries have data available since 1960, 123 since 1970. The dataset constructed by Klenow and

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<sup>2</sup>Klenow and Rodriguez-Clare (2005) rely on an earlier version of the Penn World Table (Heston et al., 2006) and of the educational attainment data (Barro and Lee, 2001).

<sup>3</sup>The Penn World Table mnemonics are `rgdpwok` for  $Y/L$  and `ki` for  $K/Y$ . The economically active population,  $L$ , is computed from output per worker, output per capita (`rgdpch`), and population (POP) as follows:  $L = \frac{\text{rgdpch} * \text{POP}}{\text{rgdpwok}}$ .

Rodriguez-Clare (2005) covers fewer countries: 73 starting in 1960, 78 starting in 1970.

We assume that the distribution of the variable of interest, in logs and relative to its cross-sectional average, evolves according to the following first-order Markov process:

$$f_{t+\tau}(y) = \int_{-\infty}^{+\infty} g_{\tau}(y|x) f_t(x) dx, \quad (3)$$

where  $f_t$  denotes the density at time  $t$  and  $g_{\tau}$  denotes the stochastic kernel relating the distributions for times  $t$  and  $(t + \tau)$ . The ergodic distribution,  $f_{\infty}$ , solves

$$f_{\infty}(y) = \int_{-\infty}^{+\infty} g_{\tau}(y|x) f_{\infty}(x) dx. \quad (4)$$

The joint distribution  $g_{\tau}(y, x)$  is estimated by adaptive Gaussian kernel smoothing with  $\tau = 1$ . We estimate  $f_{\infty}$  as described in Johnson (2005).

## 2.2 Results

Figure 1 shows the contour plots of the stochastic kernels for the period 1960-2007. Most of the probability mass lies along the  $45^{\circ}$  line: Output and its determinant are highly persistent.<sup>4</sup> Consistently, Pittau et al. (2010) document the lack of mobility within the distribution of output per worker. Thus, multiple modes in the corresponding ergodic distribution can be interpreted as convergence clubs.

Figure 2 portrays the long-run distributions of output, productivity, and physical and human capital estimated using our updated dataset and that of Klenow and Rodriguez-Clare (2005). Table 1 reports the modes of the long-run distributions. We find that the long-run distribution is multimodal in all four samples. Our results are consistent with those of Pittau et al. (2010), who document the emergence of three modes over the 1960-2000 period.

The analysis of the long-run distributions of the determinants of output can help explain the lack of convergence. Using the dataset by Klenow and Rodriguez-Clare (2005), both physical capital and productivity are bimodal in the long run. The ergodic distribution of human capital is single-peaked

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<sup>4</sup>This is common to all datasets/samples we consider.

(1960-2000 sample) or nearly so (1970-2000 sample). These results are consistent with the findings in Feyrer (2008) and Johnson (2005). The picture emerging from our more comprehensive dataset is different. We find a unimodal productivity distribution for both groups of countries/sample periods. The long-run distribution of physical capital is unimodal (1960-2007 sample) or nearly-unimodal (1970-2007 sample). Human capital instead clusters around distinct modes. In short, the updated educational attainment data suggest that human capital plays an important role in determining club convergence in the long run at the expense of the role of productivity.

### **3 Conclusions**

We updated the panel data for output, physical and human capital, and productivity in Klenow and Rodriguez-Clare (2005) relying on the most recent versions of the Penn World Table and educational attainment data. The latter point to the preeminence of human capital in driving the long-run club-convergence behavior of the distribution of output per worker across countries. Conversely, productivity plays a minor role.

## References

- Barro, R. J., Lee, J.-W., July 2001. International data on educational attainment updates and implications. *Oxford Economic Papers* 53 (3), 541–63.
- Barro, R. J., Lee, J.-W., April 2010. A new data set of educational attainment in the world, 1950–2010. NBER Working Paper No. 15902.
- Durlauf, S. N., Johnson, P. A., Temple, J. R., 2005. Growth econometrics. In: Aghion, P., Durlauf, S. N. (Eds.), *Handbook of Economic Growth*. Vol. 1A. Elsevier Science, North-Holland, Amsterdam, pp. 555–677.
- Durlauf, S. N., Quah, D. T., 1999. The new empirics of economic growth. In: Taylor, J. B., Woodford, M. (Eds.), *Handbook of Macroeconomics*. Vol. 1A. Elsevier Science, North-Holland, Amsterdam, pp. 235–308.
- Feyrer, J. D., 2008. Convergence by parts. *B.E. Journal of Macroeconomics* 8 (1, Contributions), article 19.
- Heston, A., Summers, R., Aten, B., September 2006. Penn World Table Version 6.2, center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.
- Heston, A., Summers, R., Aten, B., August 2009. Penn World Table Version 6.3, center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.
- Johnson, P. A., March 2005. A continuous state space approach to ‘Convergence by Parts’. *Economics Letters* 86 (3), 317–21.
- Klenow, P. J., Rodriguez-Clare, A., 2005. Externalities and growth. In: Aghion, P., Durlauf, S. (Eds.), *Handbook of Economic Growth*. Vol. 1A. Elsevier Science, North-Holland, Amsterdam, pp. 817–61.
- Pittau, M. G., Zelli, R., Johnson, P. A., March 2010. Mixture models, convergence clubs, and polarization. *Review of Income and Wealth* 56 (1), 102–22.

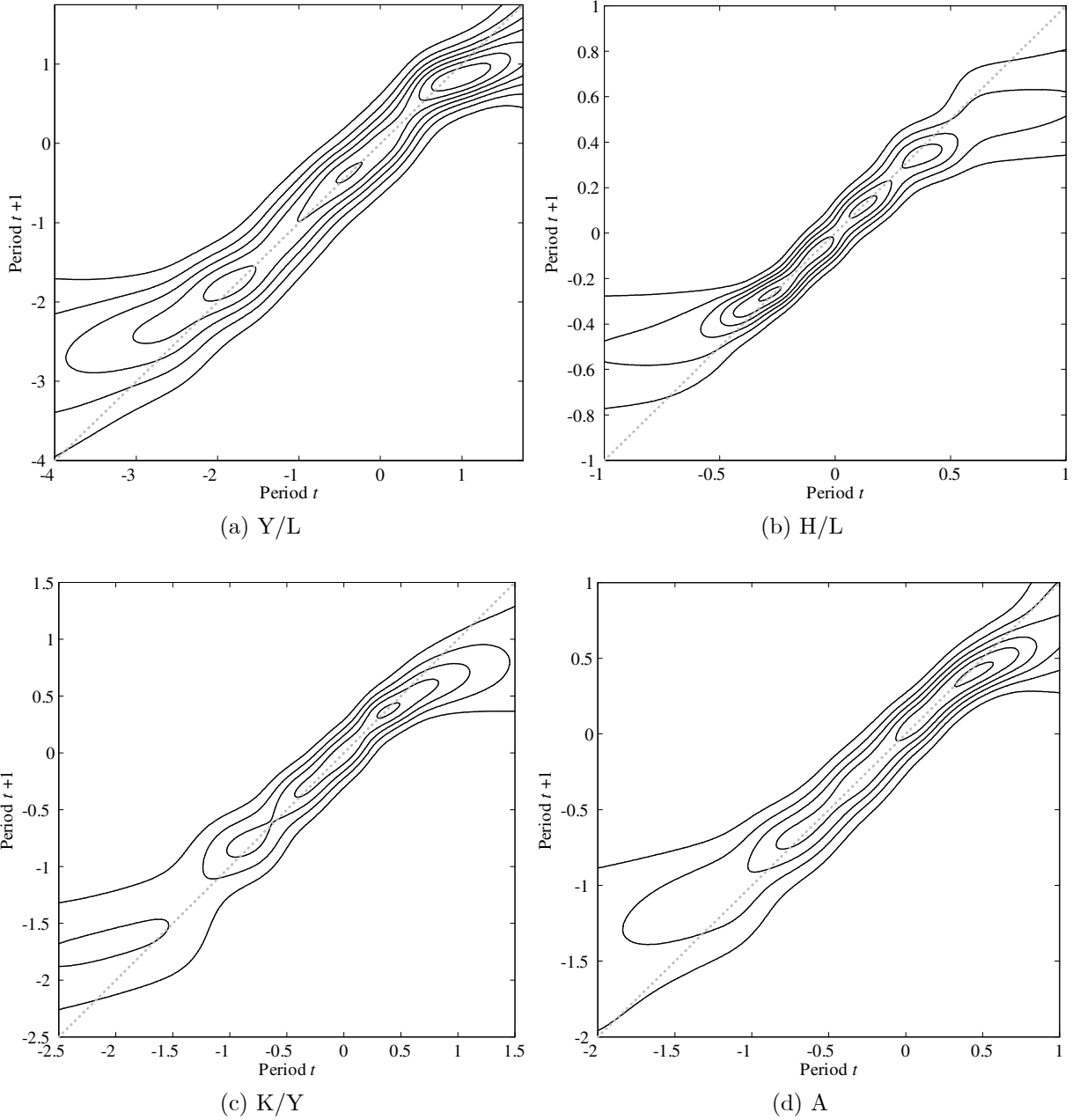


Figure 1: Contour plots of stochastic kernels: updated data (1960-2007 sample).



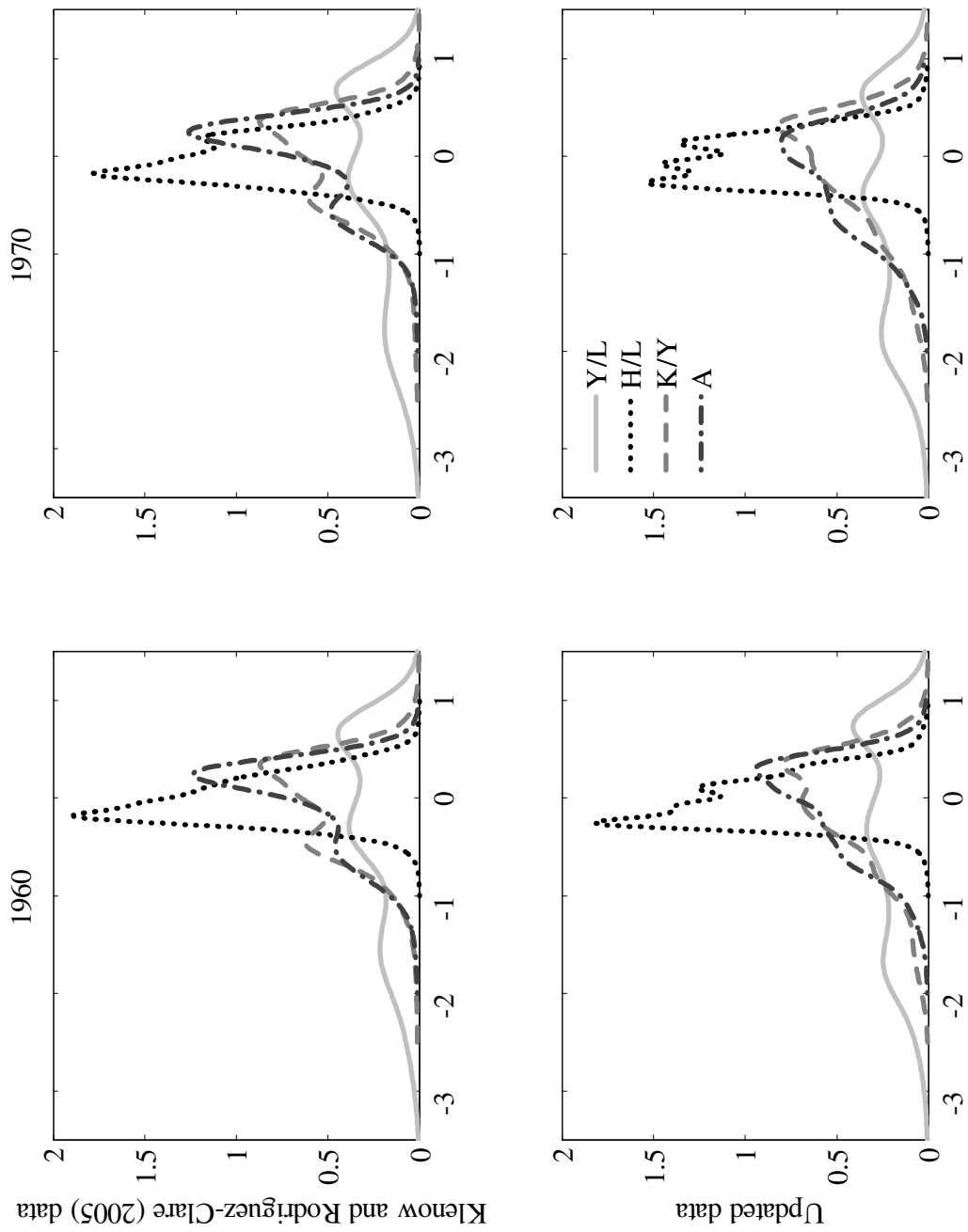


Figure 2: Ergodic distributions: Klenow and Rodriguez-Clare (2005) data (top row) and updated data (bottom row) starting in 1960 (left column) and in 1970 (right column).

| Data                                     | Starting year | No. of countries | Y/L                | H/L                | K/Y         | A           |
|--|---------------|------------------|--------------------|--------------------|-------------|-------------|
| (1) PWT 6.1, Barro-Lee 2001*             | 1960          | 73               | -1.54, -0.28, 0.65 | -0.18              | -0.45, 0.34 | -0.49, 0.25 |
| (2) PWT 6.3, Barro-Lee 2010 <sup>†</sup> | 1960          | 98               | -1.65, -0.32, 0.74 | -0.25, -0.11, 0.11 | -0.04, 0.35 | 0.29        |
| (3) PWT 6.1, Barro-Lee 2001*             | 1970          | 78               | -1.77, -0.21, 0.67 | -0.18, 0.18        | -0.43, 0.35 | -0.56, 0.25 |
| (4) PWT 6.3, Barro-Lee 2010 <sup>†</sup> | 1970          | 123              | -1.81, -0.39, 0.62 | -0.27, -0.08, 0.14 | 0.31        | 0.14        |

\* Klenow and Rodriguez-Clare (2005) data.

<sup>†</sup> Updated data.

PWT: Penn World Table version 6.1 (Heston et al., 2006) and 6.3 (Heston et al., 2009).

Table 1: Modes of the ergodic distributions for various datasets.