Measuring Industry Productivity Across Time and Space and Cross Country Convergence

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Goals and Challenges

- Analysis of productivity convergence is of interest (Barro, 2012; Rodrik, 2013; Aghion et al., 2014), …

- … yet suffers from inadequate methods & data.

  – Simultaneous cross-country/over-time setting

  Devising and implementing a method for simultaneous cross-country & over-time comparability (Inklaar and Timmer 2009, 2014)

  – Accounting for outputs & all inputs

  Using ICP expenditure prices for industry productivity measurement (Feenstra, Inklaar and Timmer 2015, Diewert and Fox 2015 and Rao, Rambaldi and Doran 2010)

- Industry focus, since important heterogeneity is likely.

Structure of the Paper

- New method for cross-country/over-time industry productivity measurement.

  – Combination of Caves, Christensen & Diewert (1982) and Diewert & Morrison (1986).

- Empirical analysis on convergence across 38 economies, 17 years, and 2 sectors.

  – Harmonized data on industry output and inputs from World Input-Output Database (WIOD) from 1995-2011.

  – Rely on ICP 2011, adjusted ICP 2005 and ICP data from mid-1990s.

Theoretical Framework

Define *the value added function* as follows:

$$g^i(p,x) \equiv \max_y \left\{ \sum_{m=1}^{M} p_m y_m : (y,x) \in S^i \right\}; \ i = 1, \dots, I$$

- Define a set of M net outputs y, primary inputs x, output prices p, and the feasible production set for industry i S^i.

- Assume competitive price takers, CRS, and homogeneity within each industry and assume a translog functional form.

- The framework follows Diewert & Morrison (1986).

Relative Value Added Deflator

- Price data are assumed to be comparable across countries and years.

- Given the translog value added function and given the required data, the relative value added deflator of two countries, *k* and *j*, is equal to

$$P_{kt/js} \equiv P_T(p_{js}, p_{kt}, y_{js}, y_{kt})$$

$$\equiv \exp\left[\sum_{m=1}^{M} \frac{1}{2}(s_{jsm} + s_{ktm})\ln(p_{ktm}/p_{jsm})\right]$$

- The output quantity index is calculated as the ratio of the value index v_{kt}/v_{js} and the price index.

Numeraire Independence

- With multiple countries and years, the price index $P_{kt/js}$ is not independent of the base country & year.

- Solution (following Caves, Christensen & Diewert 1982): average over all possible choices of j and s:

$$P_{kt*} \equiv \left[\prod_{j=1}^{K} \prod_{s=1}^{T} P_{kt/js} \right]^{\frac{1}{KT}} = \sum_{m=1}^{M} \frac{1}{2} (s_{..m} + s_{ktm}) \ln \left(\frac{p_{ktm}}{p_{..m}} \right)$$

where $s_{..m}$ is the average net output share and $p_{..m}$ the average price across all countries and years.

Factor Inputs

- Analogous logic, but aggregation of quantities, not prices:

$$X_{kt/js} \equiv Q_T\left(w_{js}, w_{kt}, x_{js}, x_{kt}\right)$$

$$\equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}\left(S_{jsn} + S_{ktn}\right)\ln\left(x_{ktn}/x_{jsn}\right)\right]$$

$$X_{kt*} \equiv \left[\prod_{j=1}^{K}\prod_{t=1}^{T} X_{kt/js}\right]^{\frac{1}{KT}} = \sum_{n=1}^{N} \frac{1}{2}\left(S_{..n} + S_{ktn}\right)\ln\left(x_{ktn}/x_{..n}\right)$$

Productivity

- Relative output divided by relative inputs:
$$\Gamma_{kt/js} \equiv Y_{kt/js}/X_{kt/js}$$

- Multilateral productivity index:
$$\Gamma_{kt} \equiv [Y_{kt*}/X_{kt*}]/[Y_{11*}/X_{11*}] = Y_{kt}/X_{kt}$$

Convergence

1. 'World' efficiency

$$E_t = \Gamma_t / \Gamma_{t,max} \,,$$

where $\Gamma_t \equiv \frac{\sum_{k=1}^{K} Y_{kt}}{\sum_{k=1}^{K} X_{kt}} = \sum_{k=1}^{K} \omega_{kt} \Gamma_{kt}$ (ω_{kt}: country k share of world real input during period t).

- Efficiency measure in the tradition of Debreu (1951) and Farell (1957).

- Fits with the 'distance to the frontier'/Schumpeterian literature (Aghion et al., 2014).

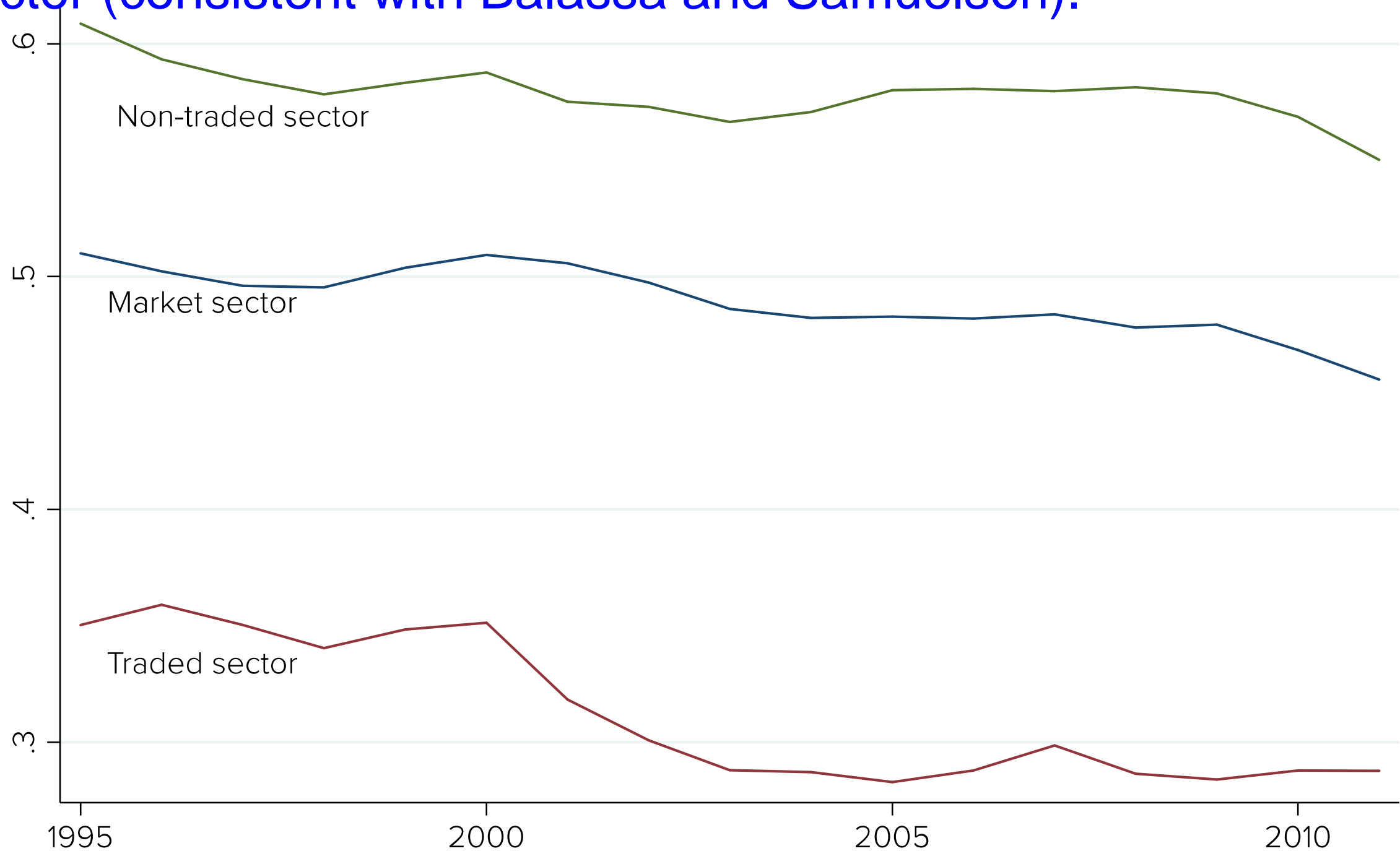# Convergence

2. Cross-country dispersion

$$\sigma_t \equiv \left[\sum_{k=1}^{K} \omega_{kt} \ln(\Gamma_{kt}/\Gamma_t)^2 \right]^{1/2}$$

$$\text{where } \omega_{kt} = \frac{X_{kt}}{\sum_{k=1}^{K} X_{kt}}$$

- Measure of σ-convergence, see Lichtenberg (1994) and Barro (2012)

- Productivity counterpart of cross-country income inequality (e.g. Milanovic, 2012).

Empirical Results: World Efficiency

- World efficiency has declined through the increase of weights of China and India.
- Cross-country productivity gap is greater in the manufacturing sector (consistent with Balassa and Samuelson).

Empirical Results: σ-Convergence

- There is a pronounced σ-convergence in the traded sector.
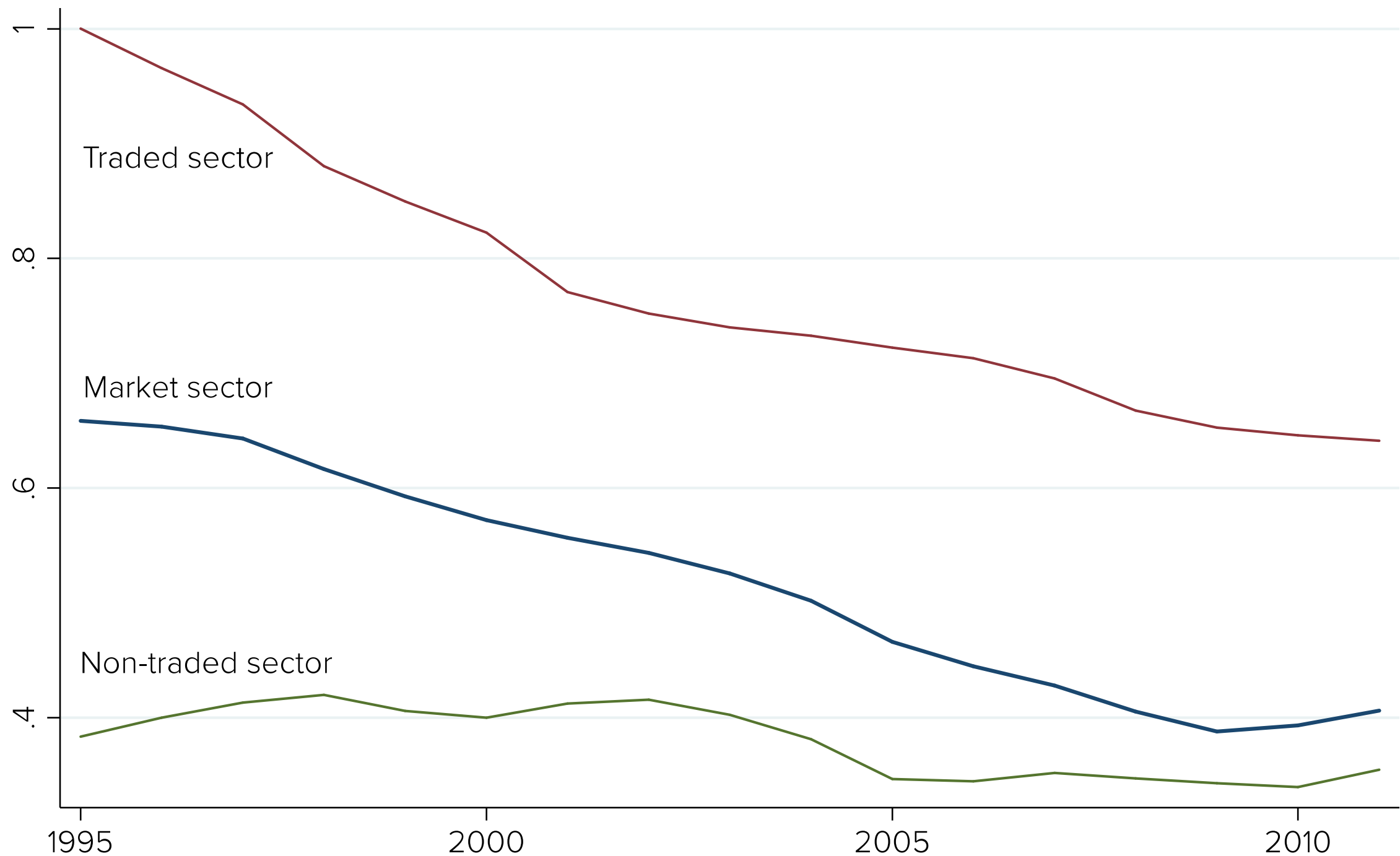
Concluding Remarks

- Has productivity converged?

  – This paper provides a method to answer this question.

  – Aggregate productivity convergence is driven by China & India through increasing weight (world efficiency) and productivity growth (dispersion).

  – Faster convergence in traded than in non-traded sector.

Comments and Questions

1. The new method seems to be very useful. I will try to apply this method to Japan's prefecture-level data (we have regional IO tables, factor inputs, and PPP for 47 prefectures for 1973-2012).

2. Is world efficiency at the macro level a weighted average of sectoral efficiencies? If so, can't we use more disaggregated data and analyze the impact of the world-wide division of labor on world efficiency at the macro level?

3. Is land input taken into account in the agricultural sector? If not, is it OK to assume constant returns to scale?

4. How is labor input compared across countries? Is one hour of work by a high school graduate at a certain age assumed to be identical across countries (like in the EU KLEMS)? Is this assumption plausible?