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# The heterogeneous relationship between income and inequality: a panel co-integration approach*

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**Abstract**

We study the relationship between per-capita income and income inequality with a heterogeneous panel co-integration approach. We extend previous studies in two respects: first, we compile a more extensive data set for 61 countries over 26-51 years and consider measures for both pre-tax and post-tax income inequality; second, we take into account country heterogeneity rather than relying on average panel estimates alone. We find a negative group-mean based relationship using pre-tax income inequality, but no such relationship for post-tax income inequality. Moreover, we find estimates on the country level to be heterogeneous in both cases.

**Key messages**

- The long-run relationship between income inequality and GDP per capita is analyzed using heterogeneous panel co-integration techniques.
- We find a negative group-mean based relationship using pre-tax income inequality.
- No such relationship is found using post-tax income.
- Estimates on the country level are heterogeneous in both cases.

*Keywords*: Development, Inequality, Growth, Panel co-integration

*JEL Codes*: O11, O4, O15, D30

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Table 1: Unit root tests (IPS)

| | **GDP per capita (log)** | | | | **Gini index, pre-tax (log)** | | | | **Gini index, post-tax (log)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W-t-bar | 8.576 | -1.778 | 1.171 | 4.108 | 0.317 | 1.275 | 4.3933 | 2.416 | -0.937 | -0.522 | 2.597 | -0.511 |
| p-value | 1.00 | 0.038 | 0.879 | 1.000 | 0.625 | 0.899 | 1.000 | 0.992 | 0.174 | 0.301 | 0.995 | 0.305 |
| Panel means | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Time trend | no | yes | no | yes | no | yes | no | yes | no | yes | no | yes |
| Panel-specific means removed | | | yes | yes | | | yes | yes | | | yes | yes |
| # of lags (AIC) | 1.34 | 1.53 | 1.75 | 1.69 | 1.59 | 1.69 | 1.56 | 1.78 | 2.08 | 2.12 | 2.64 | 2.64 |

Number of panels: 59; AR parameter: panel-specific.

# 1 Introduction

Evidence on the long-run relationship between a country's level and distribution of income has been inconclusive (see e.g. Neves et al, 2016). Recent advances in panel co-integration techniques may lead to more clarity, since they are more robust against common problems in panel regressions (Herzer and Vollmer, 2012). Two recent studies followed such an approach: Herzer and Vollmer (2012) used a sample of 46 countries for the period 1970-1995 and Malinen (2012) for 53 countries between 1970-1999. Both identify a negative long-run relationship between inequality and per-capita income.

We extend their work in two respects. First, we compile a more extensive data set covering 61 countries over 26 (minimum) to 51 (maximum) years and use measures for both pre-tax and post-tax income inequality. We find a statistically significant negative relationship with pre-tax, but not post-tax inequality. Our second contribution puts this finding into perspective. We quantify the effect heterogeneity at the country level and find estimates on the country level to be highly heterogeneous in both cases. This indicates that looking exclusively at overall panel estimates based on group-mean comparisons shallows important country heterogeneity.

# 2 Data and econometric approach

We measure within-country inequality with Gini indices for pre- and post-tax income, both from Solt (2016), and per-capita income using expenditure-side real GDP at chained PPPs from Feenstra et al (2015). We use annual rather than averaged data, for the reasons summarized in, *inter alia*, Herzer and Vollmer (2012). The panel is unbalanced.

The analysis follows the typical steps of a panel co-integration approach. First, the $H_0$ that all panels contain unit roots is evaluated using the Im—Pesaran—Shin (IPS) test (Im et al,

Table 2: Tests for a co-integration relationship between inequality and income

**GDP per capita (log) and Gini index, pre-tax income (log)**

| | Pedroni | | Westerlund |
|---|---|---|---|
| Augmented Dickey-Fuller t/ Variance statistics* | 6.3804 | 12.9906 | -6.0977 |
| p-value | 0.000 | 0.000 | 0.000 |
| Panel means included | yes | yes | yes |
| Time trend included | no | yes | no |
| AR-parameter | panel-specific | | same |

**GDP per capita (log) and Gini index, post-tax income (log)**

| | Pedroni | | Westerlund |
|---|---|---|---|
| Augmented Dickey-Fuller t/ Variance statistics* | 5.1360 | 12.3008 | -6.0259 |
| p-value | 0.000 | 0.000 | 0.000 |
| Panel means included | yes | yes | yes |
| Time trend included | no | yes | no |
| AR-parameter | panel-specific | | same |

Number of panels: 59. *We report variance statistics for the Westerlund and augmented Dickey-Fuller statistics for the Pedroni test. Other statistics from the Pedroni test (variance ratio, Phillips-Perron t) yield similar results.

2003). This test is suitable for unbalanced panels and does not rely on a common autoregressive parameter for all countries, which is sensible considering unobserved heterogeneity. The test estimates the equation

$$\Delta y_{i,t} = \phi_i y_{i,t-1} + \boldsymbol{z'}_{i,t}\gamma_i + \epsilon_{i,t}, \tag{1}$$

where $i$ indicates countries and $t$ the time-series. The autoregressive parameter $\phi$ is country-specific and in case $\phi_i = 0 \; \forall \; i$, all panels contain a unit root. The IPS test confirms that all time-series contain unit roots (see table 1): we cannot reject $H_0$ under a variety of specifications.[1]

Second, we employ two different methods to test for a potential co-integration relationship between inequality and income (see table 2). We reject the $H_0$ of no co-integration relationships, with $H_1$ being that all (Pedroni test) or some (Westerlund test) panels are co-integrated.

We can then estimate the bi-variate relationship between inequality and income. We employ a dynamic OLS estimator for heterogeneous co-integrated panels with homogeneous long-run covariance structure across cross-sectional units (Pedroni, 2001) and estimate the equation

[1]The only exception is the test for GDP with panel means and time trends without panel-specific means, which remains inconclusive. However, previous empirical and theoretical work has provided numerous arguments for GDP time series having unit roots.

$$\log(\text{GDP per capita}_{it}) = \alpha_i + \delta_i t + \beta_i \log(\text{Gini})_{it} + \sum_{j=-q}^{q} \phi_{ij} \Delta \log(\text{Gini})_{it+j} + \epsilon_{it}, \tag{2}$$

where $i = 1, 2, ..., N$ indicates countries; $t = 1, 2, ..., N$ indicates years; $\phi$ is the coefficient for leads and lags (included to account for serial correlation and endogeneity); $q$ is the number of leads and lags in the regression; and $\beta$ and $\gamma$ are the slope coefficients.

We follow Pedroni (2001) and compute the $\beta$ coefficients as averages over the entire panel using

$$\hat{\beta}^*_{GM} = \left[ \frac{1}{N} \sum_{i=1}^{N} \left( \sum_{t=1}^{T} z_{i,t} z'_{i,t} \right)^{-1} \left\{ \sum_{t=1}^{T} z_{i,t} (y_{i,t} - \bar{y}_i \right\} \right], \tag{3}$$

where $z_{i,t}$ is the vector of regressors, and the group-mean $t$ statistics as

$$t_{\hat{\beta}^*_i} = (\hat{\beta}^*_i - \beta_0) \left\{ \hat{\sigma}_i^{-2} \sum_{t=1}^{T} (x_{i,t} - \bar{x}_i)^2 \right\}^{\frac{1}{2}}. \tag{4}$$

Our specification differs from both Herzer and Vollmer (2012) – who include a control for investment – and Malinen (2012) – who includes further controls for education. We restrain from adding controls for the following reasons. First, the estimator we use requires only the assumption that all integrated variables are included into the estimation. Detecting co-integration for inequality and income implies that no further integrated variables need to be considered (see e.g. Johansen, 2000; Herzer and Vollmer, 2012). Second, controls for, say, education (as in Malinen, 2012) would absorb all effects of inequality on income operating through the channel of education. Since we are not concerned with the particular mechanisms underlying the long-run relationship between inequality and income, such an absorption runs counter to the objective of our analysis.

## 3 Results and discussion

We have three main results. First, the results in table 3 confirm the significant negative long-term relationship between pre-tax income inequality and GDP per capita found in Malinen (2012) and Herzer and Vollmer (2012). Second, no such relationship can be found once post-tax income inequality is used instead. Third, the nature of the relationship is heterogeneous across countries (figure 1). There are three groups. Some countries (such as China or Norway) show a consistent statistically significant positive relationship between inequality and income. Some other countries experience a consistent significantly negative relationship, e.g. Canada

Table 3: Co-integration relationships, Pedroni's PDOLS group-mean based estimator

| | GDP per capita (log) |
|---|---|
| Gini, post-tax (log) | 0.0819 |
| | [0.625] |
| Gini, pre-tax (log) | -1.644** |
| | [0.691] |
| Standard errors in brackets | |
| *** p<0.01, ** p<0.05, * p<0.1 | |

Table 4: Countries with a consistently positive and negative relationship. We classify a country as having a consistently positive (negative) relationship between inequality and income if the relationship between *both* the post-tax and the pre-tax Gini and income is positive (negative) and statistically significant. Countries not mentioned show ambiguous results.

| | |
|---|---|
| Consistently positive relationship | Argentina, China, Great Britain, Guatemala, Hong Kong, India, Japan, Norway, Pakistan, Philippines, Poland, Singapore, Sri Lanka, Switzerland, Turkey |
| Consistently negative relationship | Canada, Costa Rica, Greece, Iran, Ireland, Italia, Jordan, Malaysia, Netherlands, Nigeria, Panama, South Korea |

or Malaysia. Table 4 lists the countries with consistently positive and negative relationships. Finally, there are also countries, such as Germany or Brazil, for which we cannot find consistent statistically significant patterns.

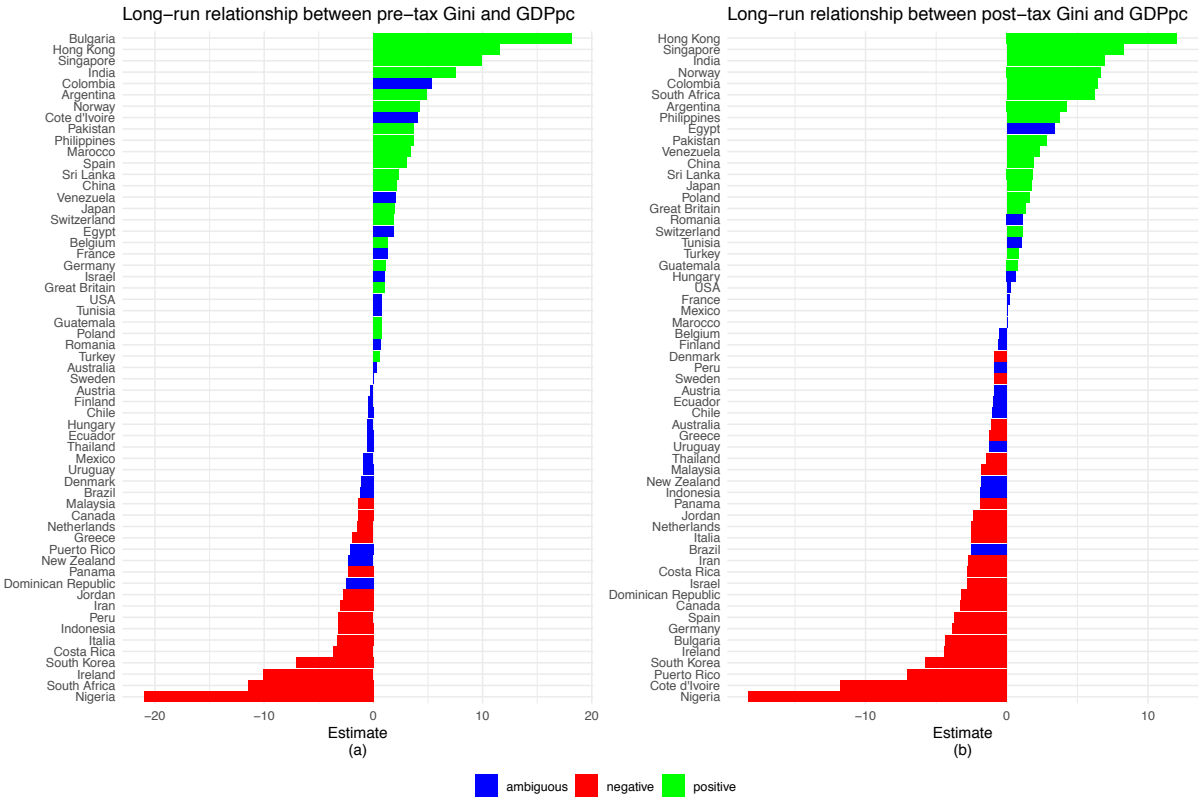
These results suggest that the relationship between inequality and income is context-dependent, a fact that is reflected by the ambiguous results of previous (meta) studies.

## 4 Conclusion

We studied the long-run relationship between inequality and income using co-integration techniques. While we confirm the overall negative relationship between pre-tax inequality on income found in Malinen (2012) and Herzer and Vollmer (2012), we do not find such relationship for the case of post-tax inequality. We also identified a systematic heterogeneity of estimates across countries, a finding consistent with a recent meta-study of Neves et al (2016).

Our results and the recognition of such contextual dependence of the relationship suggest several avenues for further research: on the inductive side one might use clustering techniques as in Gräbner et al (2019) to refine country classifications. More importantly, comparative investigations of the country groups summarized in table 4 might suggest theoretical rationalizations of the heterogeneity and lead to models proposing concrete mechanisms underlying the context-dependency of the income-inequality relationship.

Figure 1: Heterogeneity across estimates. Panel (a) refers to the estimation of equation (2) with the post-tax Gini, (b) to the estimation of the same equation with the pre-tax Gini. We speak of an ambiguous effect when the estimates are not significant at the 5% level.



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