APPENDIX I

Estimation of the Model Using Panel Data

Models with time- and country-specific effects can be estimated using the least-squares dummy variable (LSDV) or "within-group" estimator described in Hsiao [1986, chapter 3.2]. The presence of a lagged dependent variable in equation (4) of the text, however, leaves the LSDV estimator inconsistent when the number of time periods is small; see Hsiao [chapter 4.2]. Thus, an alternative method is desirable. Begin by subtracting the means for time t (across countries) from all variables to eliminate the time effect, η_t, in (4). The time mean for period t is obtained by summing over all i and multiplying by $1/J$ in (4):

$$(1/J)\sum_{i=1}^{J} z_{it} = (1/J)\sum_{i=1}^{J}\mu_i + (1/J)\sum_{i=1}^{J}\eta_t + \pi_1(1/J)\sum_{i=1}^{J}\ln y_{it}^0 + (1/J)\sum_{i=1}^{J}x'_{it}\pi + (1/J)\sum_{i=1}^{J}\varepsilon_{it} \qquad \text{(B1)}$$

where J is the number of countries. In more convenient notation, (B1) can be written as

$$\bar{z}_{\bullet t} = \bar{\mu} + \eta_t + \pi_1 \ln \bar{y}_{\bullet t}^0 + \bar{x}'_{\bullet t}\pi + \bar{\varepsilon}_{\bullet t}. \qquad \text{(B2)}$$

Subtracting (B2) from (4) in the text provides a specification where observations are expressed as deviations from time means, and the time effect disappears since η_t does not vary over countries:

$$(z_{it} - \bar{z}_{\bullet t}) = (\mu_i - \bar{\mu}) + \pi_1(\ln y_{it}^0 - \ln \bar{y}_{\bullet t}^0) + (x'_{it} - \bar{x}'_{\bullet t})\pi + (\varepsilon_{it} - \bar{\varepsilon}_{\bullet t}). \qquad \text{(B3)}$$

Equation (B3) can be written more conveniently as

$$\tilde{z}_{it} = \tilde{\mu}_i + \pi_1 \ln \tilde{y}_{it}^0 + \tilde{x}'_{it}\pi + \tilde{\varepsilon}_{it}. \qquad \text{(B4)}$$

Hsiao [p. 89] provides an instrumental-variable procedure that yields consistent estimates in a model similar to (B4) under the assumption that the ε_{it} are serially uncorrelated. To allow for arbitrary correlations in the residuals, a more general three-stage least squares (3SLS) procedure is appropriate; see Hsiao [chapter 4.5]. Taking the first difference of (B4) to eliminate the country effect, μ_i, and stacking all equations for a single country produces the following system of equations:

$$\begin{aligned} \tilde{z}_{i2} - \tilde{z}_{i1} &= \pi_1(\ln \tilde{y}_{i2}^0 - \ln \tilde{y}_{i1}^0) + (\tilde{x}'_{i2} - \tilde{x}'_{i1})\pi + (\tilde{\varepsilon}_{i2} - \tilde{\varepsilon}_{i1}) \\ \tilde{z}_{i3} - \tilde{z}_{i2} &= \pi_1(\ln \tilde{y}_{i3}^0 - \ln \tilde{y}_{i2}^0) + (\tilde{x}'_{i3} - \tilde{x}'_{i2})\pi + (\tilde{\varepsilon}_{i3} - \tilde{\varepsilon}_{i2}), \end{aligned} \qquad \text{(B5)}$$

$i = 1, \ldots, J$. Writing out the z_{it} and using the fact that $y_{i2}^0 = y_{i1}^T$ and $y_{i3}^0 = y_{i2}^T$, (B5) can be rewritten as follows to emphasize the endogeneity of first-differenced initial income on the right-hand side:

$$
\begin{aligned}
(\ln\tilde{y}^{T}_{i2} - \ln\tilde{y}^{0}_{i2}) - (\ln\tilde{y}^{0}_{i2} - \ln\tilde{y}^{0}_{i1}) &= \pi_1(\ln\tilde{y}^{0}_{i2} - \ln\tilde{y}^{0}_{i1}) + (\tilde{x}'_{i2} - \tilde{x}'_{i1})\pi + (\tilde{\varepsilon}_{i2} - \tilde{\varepsilon}_{i1}) \\
(\ln\tilde{y}^{T}_{i3} - \ln\tilde{y}^{0}_{i3}) - (\ln\tilde{y}^{0}_{i3} - \ln\tilde{y}^{0}_{i2}) &= \pi_1(\ln\tilde{y}^{0}_{i3} - \ln\tilde{y}^{0}_{i2}) + (\tilde{x}'_{i3} - \tilde{x}'_{i2})\pi + (\tilde{\varepsilon}_{i3} - \tilde{\varepsilon}_{i2}).
\end{aligned}
\tag{B6}
$$

3SLS with cross-equation restrictions to impose the equality of π and $\boldsymbol{\pi}$ across equations is applied to (B6) in the panel analysis of section **III**. Since the country effects have been eliminated and the estimation does not depend on the correlation structure of ε_{it}, 3SLS is appropriate whether the μ_i are treated as fixed or random, and regardless of the correlation between μ_i and $\mathbf{x}_{it}$.