Temperature and Income: Online Appendices

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Appendix A: Data

Climate and Geography Data

For the within-country analysis, the climate and geography variables were constructed as follows. Municipal-level temperature and precipitation variables were calculated using 30 arc second resolution (1 kilometer) mean temperature and precipitation over the 1950-2000 period, as compiled by climatologists at U.C. Berkeley (Hijmans, R. et al., 2005). We also use 30 arc second resolution terrain data (NASA and NGIA, 2000), collected by the Shuttle Radar Topography Mission, to construct municipal-level mean elevation and slope. We calculate distance to the coast - accounting for changes in elevation - for every 1 kilometer cell in a grid covering the Americas. Distance is then averaged over all cells that fall within each municipality's boundaries. The GIS municipality boundaries were produced by the International Center for Tropical Agriculture (CIAT, 2008).

For the cross-country analysis, country-level geographic variables were calculated in the Americas sample by aggregating the municipal-level means, weighting by 2000 municipal population (Center for International Earth Science Information Network, 2004). The data for the worldwide sample are described in Dell, Jones, and Olken (2008).

Labor Income Data

Acemoglu and Dell (forthcoming) constructed a database of labor income in the Americas using individual level data from various household surveys and censuses, collected between 2000 and 2006 (Table 1). The sources and methodology are described at length in that paper. In brief, we deflate labor incomes from the household surveys and censuses to national prices, using the state median of a household specific Paasche index calculated by Acemoglu and Dell from recent expenditure survey data (see Table A1 for sources).[1] The data are adjusted by country so that each country's incomes average to GDP per worker in constant international dollars, taken from the 2003 Penn World Tables.

Given that we are interested in variation in climate at the municipality level, we aggregate the individual level data compiled by Acemoglu and Dell by taking municipality level means.

[1] Specifically, Acemoglu and Dell first use the expenditure surveys listed in Table A1 to calculate the household specific Paasche index $P_p^h = \frac{1}{\sum w_k^h \frac{p_k^0}{p_k^h}}$, where w_k^h is the share of household h's budget devoted to good k, and the reference vector p_k^0 is the median of prices observed from individual households in the survey. To reduce the influence of outliers, they replace the individual p_k^h by their medians over households in the same municipality. We use the state median of these indices to deflate the labor income data.

We have also estimated the regressions in Table 2 using the individual level data, with dummy variables for each age x gender combination included on the right-hand side (results available upon request). In no case are the conclusions substantively altered.

Table A1: Price Data

Country	Source	Year	Geo-Referencing
Bolivia	Encuesta de Hogares	2002	Municipality
Brazil	Pesquisa de Orcamentos Familiares	2002 - 2003	State
El Salvador	No Data Available		
Guatemala	Encuesta Nacional de Condiciones de Vida	2000	municipality
Honduras	Encuesta de Condiciones de Vida	2004	municipality
Mexico	Encuesta Nacional de Ingresos y Gastos de los Hogares	2005	municipality
Nicaragua	Encuesta Nacional de Hogares sobre Medicion de Nivel de Vida	2005	municipality
Panama	Encuesta de Niveles de Vida	2003	municipality
Paraguay	Encuesta Integrada de Hogares	2001	municipality
Peru	Encuesta Nacional de Hogares	2001	municipality
U.S.	Municipality cost of living index produced (The Council for Community and Economic Research)	2000	municipality
Venezuela	No Data Available		

Appendix B: Theory

Consider the growth specification

$$\frac{d\log y_i(t)}{dt} = g + \rho\bar{T}_i + \gamma T_i(t) + \varphi\left(\log y_*(t) - \log y(t)\right) \tag{A.1}$$

which is a rewritten version of equation (2) in the text. This appendix provides a derivation of equation (3) in the text, which is the integrated form of (A.1).

1. Rewrite the Growth Equation

First, observe from (A.1) that

$$\frac{d\log y_*(t)}{dt} = g + \rho\bar{T}_* + \gamma T_*(t)$$

Next define a variable $\hat{y}(t) = \log y_i(t) - \log y_*(t)$, and rewrite (A.1) as

$$\frac{d\hat{y}(t)}{dt} = \rho\left(\bar{T}_i - \bar{T}_*\right) + \gamma\left(T_i(\tau) - T_*(\tau)\right) + \varphi\hat{y}(t)$$

Integrate this once to find

$$\hat{y}(t) = bt + \gamma\int_0^t h(\tau)d\tau - \varphi\int_0^t \hat{y}(\tau)d\tau$$

where $b = \rho\left(\bar{T}_i - \bar{T}_*\right)$ and $h(\tau) = T_i(\tau) - T_*(\tau)$ (which is stochastic). Since this is linear, we can take expectations and change the order of integration, producing

$$E\left[\hat{y}(t)\right] = bt + \gamma\int_0^t E\left[h(\tau)\right]d\tau - \varphi\int_0^t E\left[\hat{y}(\tau)\right]d\tau$$

Noting that $E\left[h(\tau)\right] = \bar{T}_i - \bar{T}_*$, this integrated differential equation can be written more simply as

$$E\left[\hat{y}(t)\right] = mt - \varphi\int_0^t E\left[\hat{y}(\tau)\right]d\tau \tag{A.2}$$

where $m = (\gamma + \rho)\left(\bar{T}_i - \bar{T}_*\right)$.

2. Solve by substitution

The equation (A.2) can be solved by repeated substitution of $E\left[\hat{y}(t)\right]$. In particular, substi-

tuting once provides

$$E\left[\hat{y}(t)\right] = mt - \varphi \int_0^t m\tau d\tau + \varphi^2 \int_0^t \int_0^\tau E\left[\hat{y}(\tau')\right] d\tau' d\tau$$

With an infinite set of substitutions and integrating all the terms in m we have

$$\begin{aligned} E\left[\hat{y}(t)\right] &= m\sum_{j=0}^{\infty}(-1)^j\varphi^j\frac{t^{j+1}}{(j+1)!} \\ &\quad + \lim_{n\to\infty}\varphi^n\int_0^t\int_0^\tau\int_0^{\tau'}...\int_0^{t'\{n\}} E\left[\hat{y}(\tau'^{\{n\}})\right] d\tau'^{\{n\}}...d\tau''d\tau'd\tau \end{aligned}$$

The second term on the right hand side limits to zero. This result follows because (i) $\varphi < 1$, and (ii) $E\left[\hat{y}(\tau'')\right] \leq c$ where c is a finite positive constant. The limit is thus less than $\lim_{n\to\infty}\varphi^n\frac{c^n}{n!} = 0$.

The integrated form (1) can therefore be written

$$E\left[\hat{y}(t)\right] = \frac{m}{\varphi}\sum_{j=1}^{\infty}(-1)^{j+1}\varphi^j\frac{t^j}{j!}$$

which is equivalently recognized as

$$E\left[\hat{y}(t)\right] = \frac{m}{\varphi}\left(1 - e^{-\varphi t}\right)$$

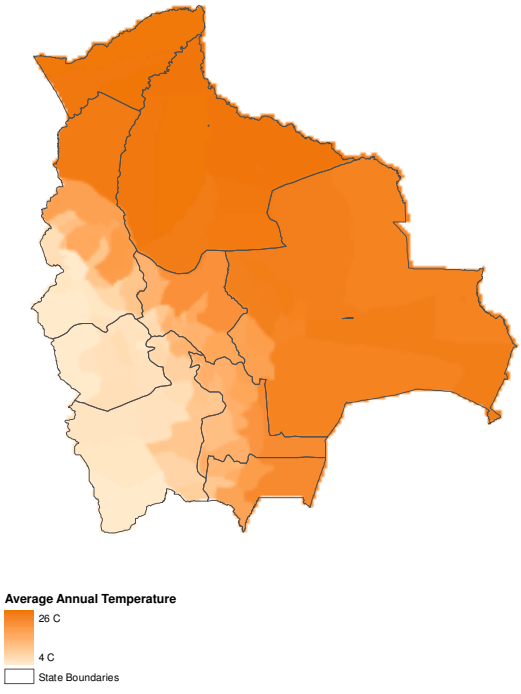
Recalling the definitions of $\hat{y}(t)$ and m, we have

$$E\left[\log y_i(t) - \log y_*(t)\right] = \frac{\gamma+\rho}{\varphi}\left(\bar{T}_i - \bar{T}_*\right)\left(1 - e^{-\varphi t}\right)$$

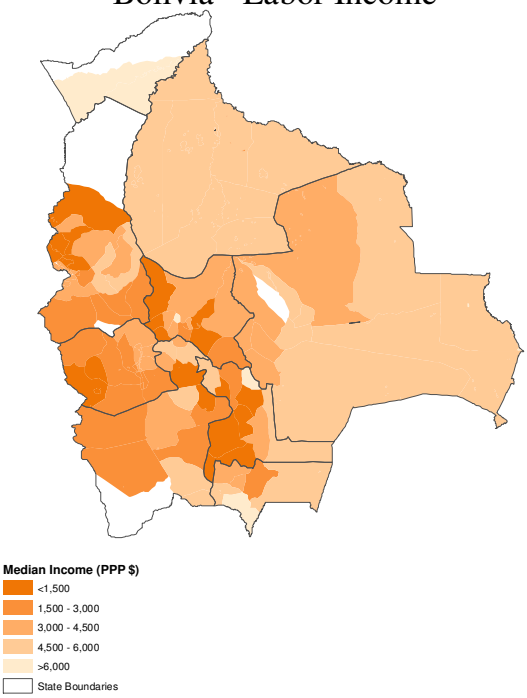
which is equation (3) in the text.

Appendix C: Maps

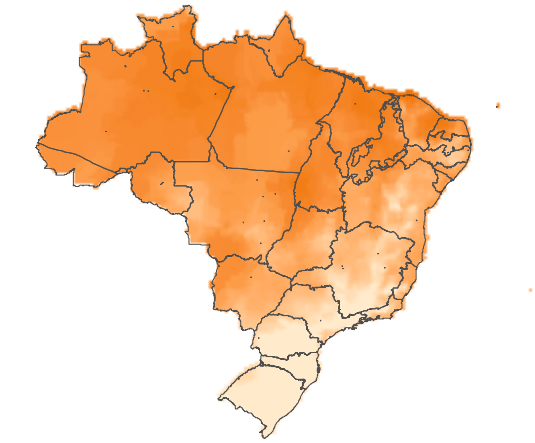
Bolivia - Temperature



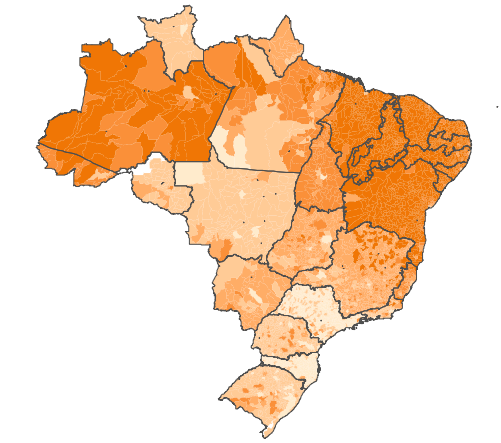
Bolivia - Labor Income



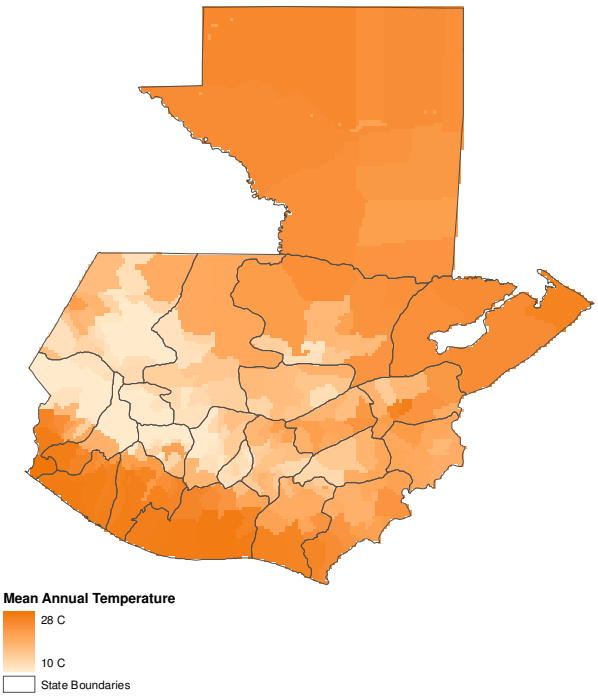
Brazil - Temperature



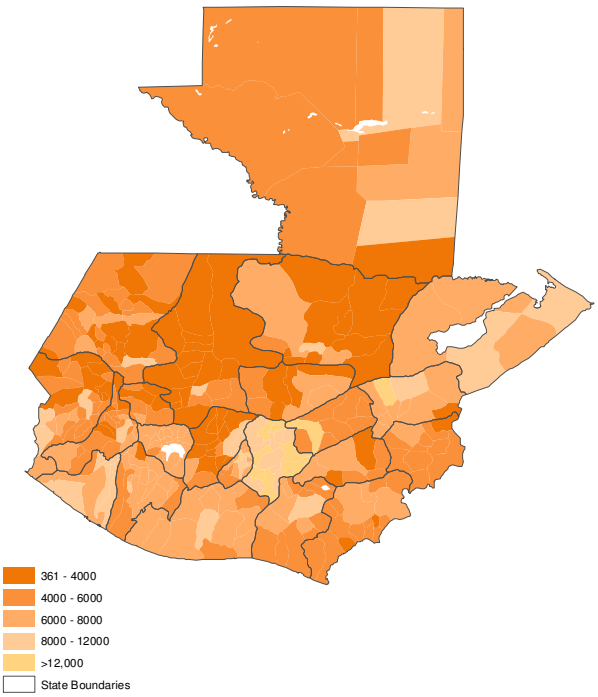
Brazil - Labor Income



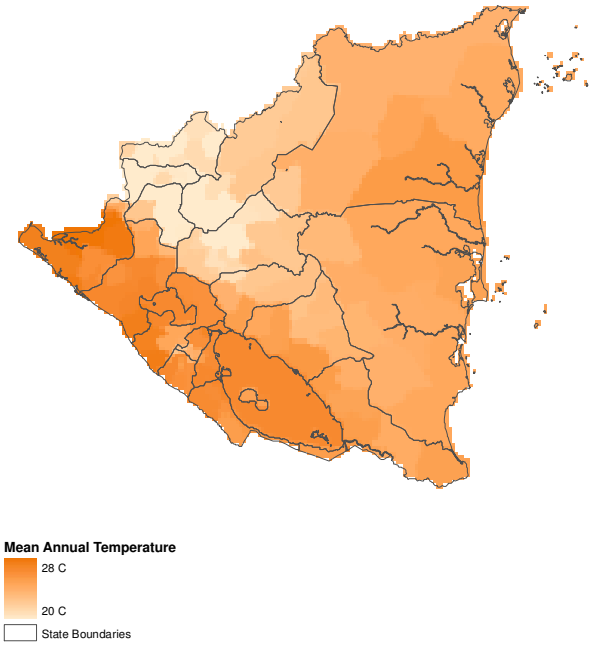
Guatemala - Temperature



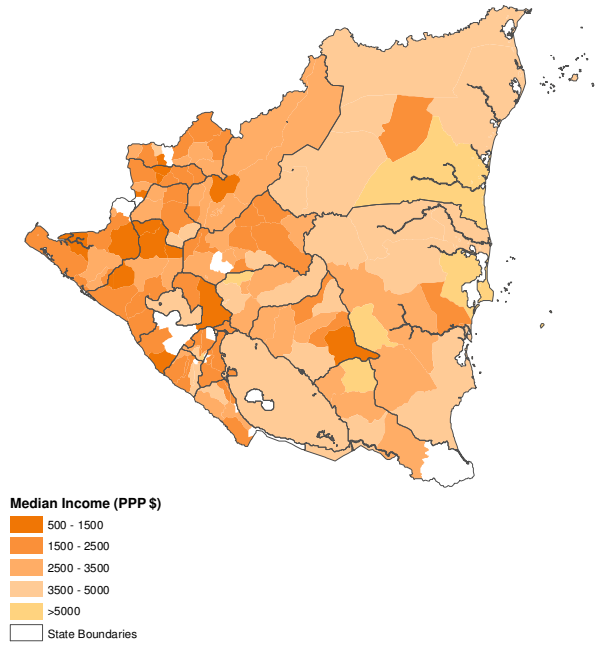
Guatemala - Labor Income



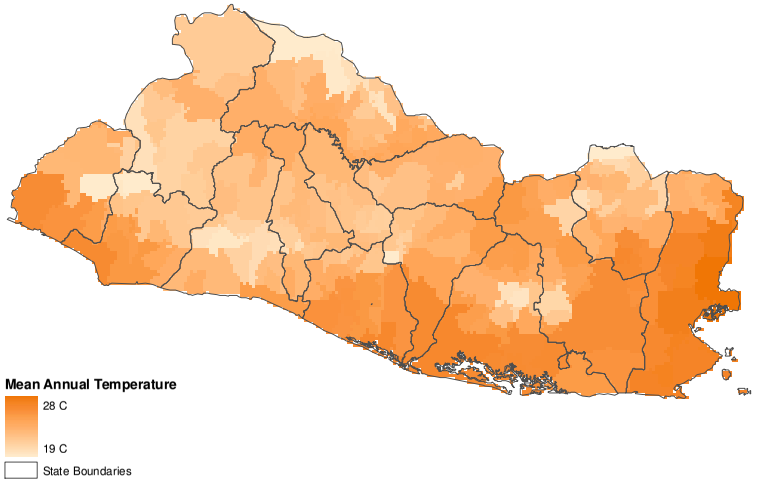
Nicaragua - Temperature



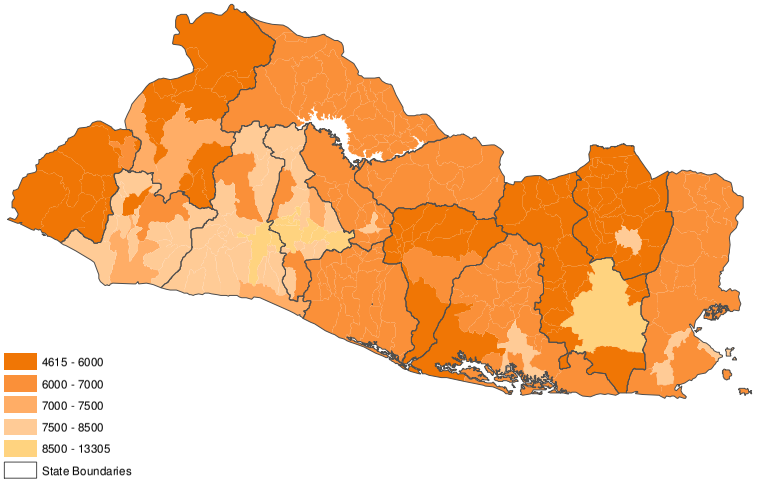
Nicaragua - Labor Income



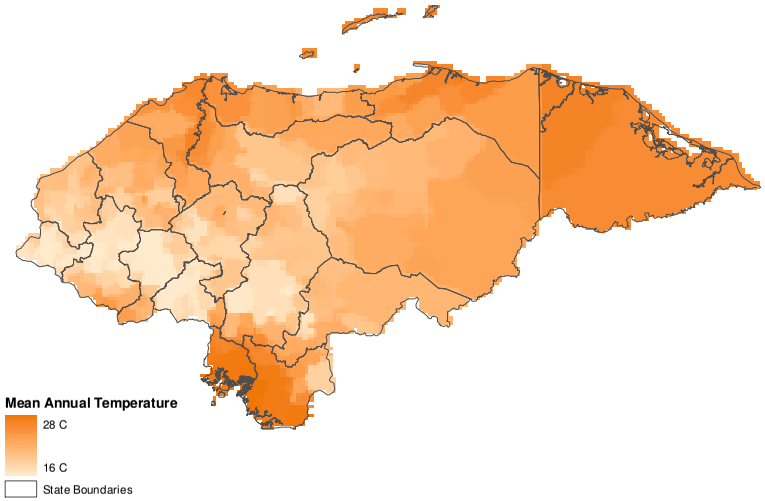
Temperature - El Salvador



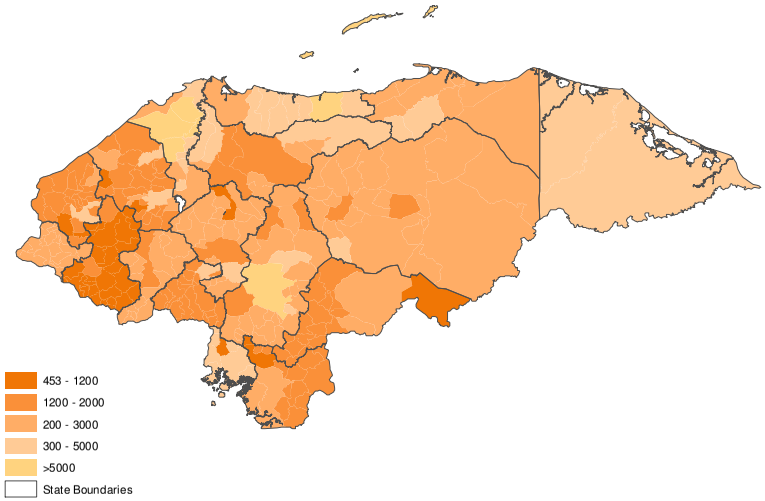
Labor Income - El Salvador



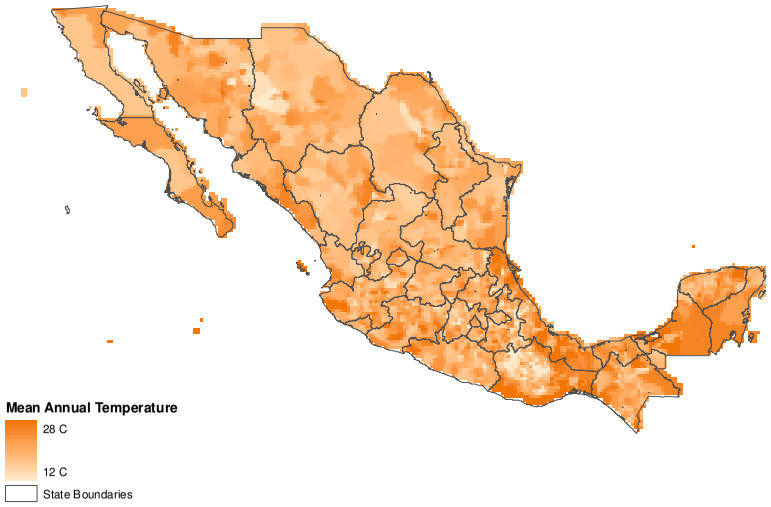
Temperature - Honduras



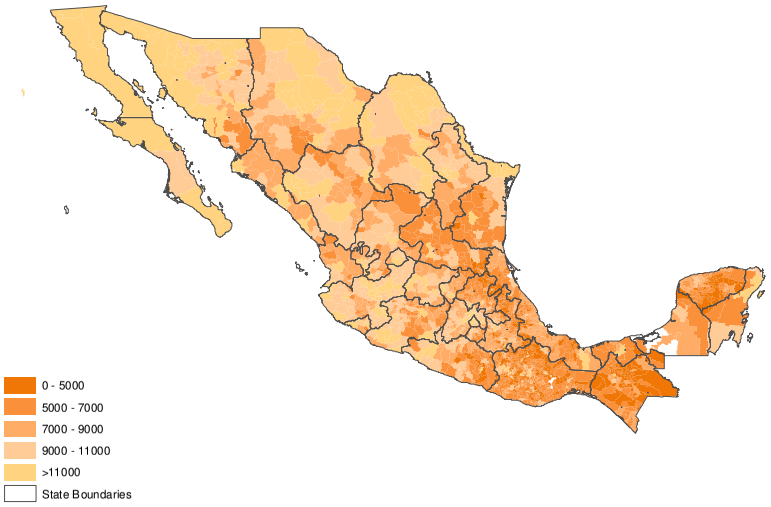
Labor Income - Honduras



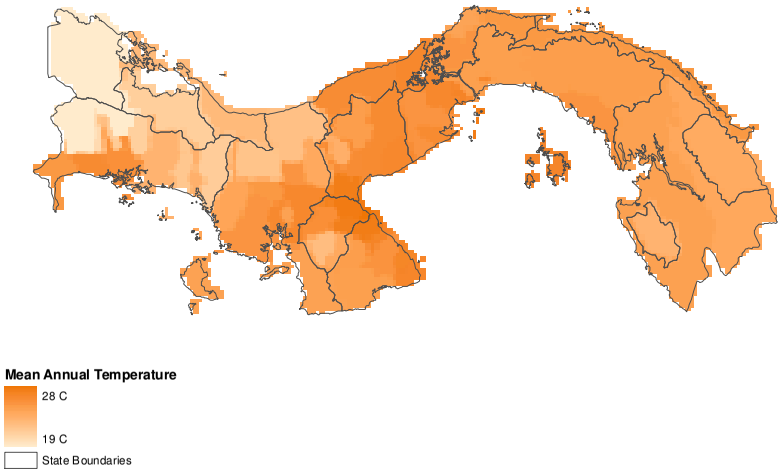
Temperature - Mexico



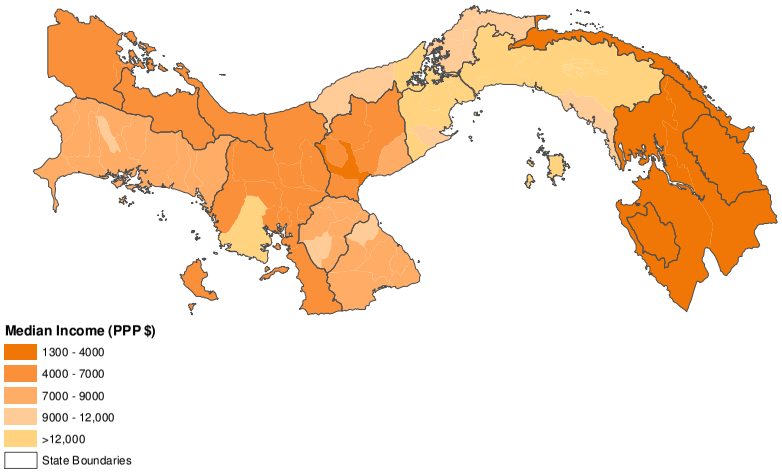
Labor Income - Mexico



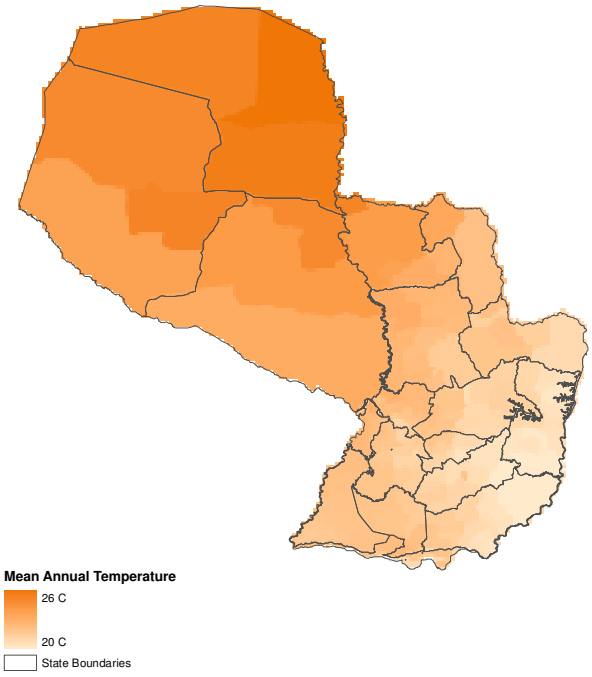
Panama - Temperature



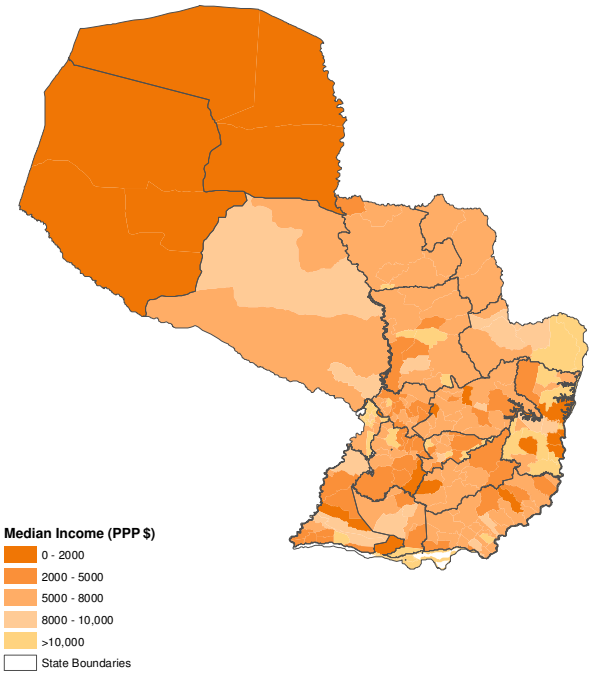
Panama - Labor Income



Paraguay - Temperature

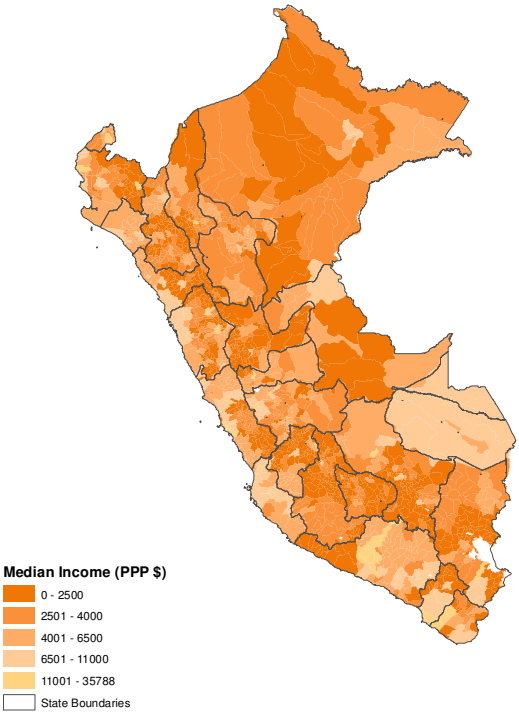


Paraguay - Wage Income

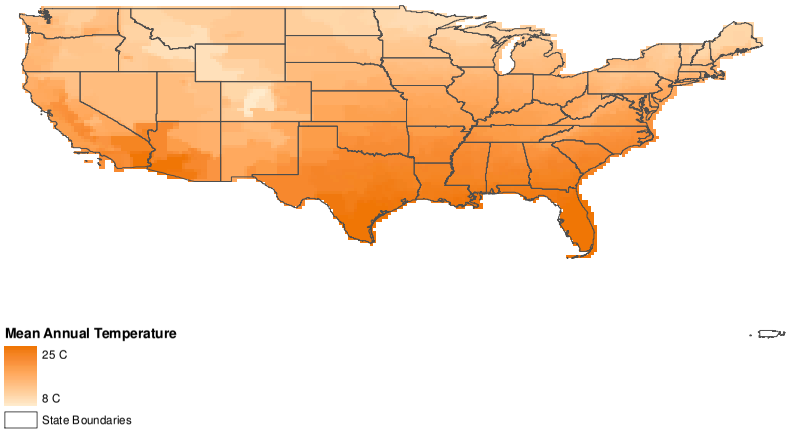


Peru - Temperature

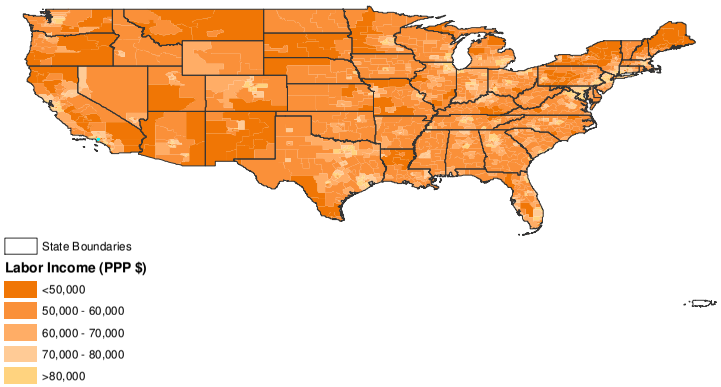
Peru - Labor Income



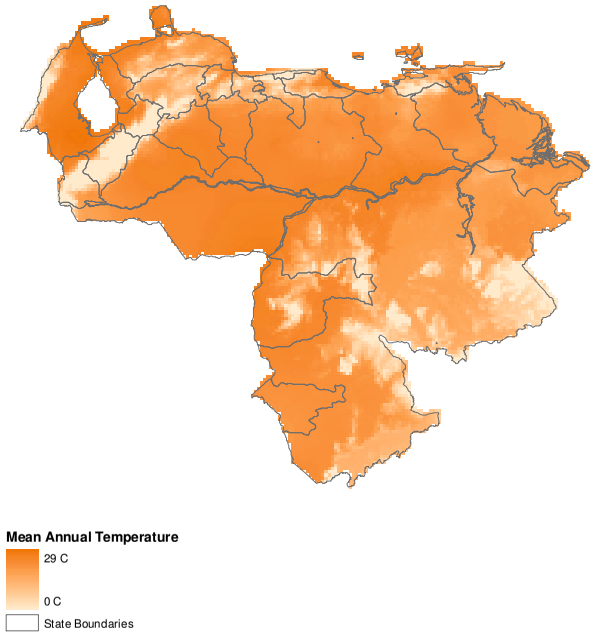
United States - Temperature



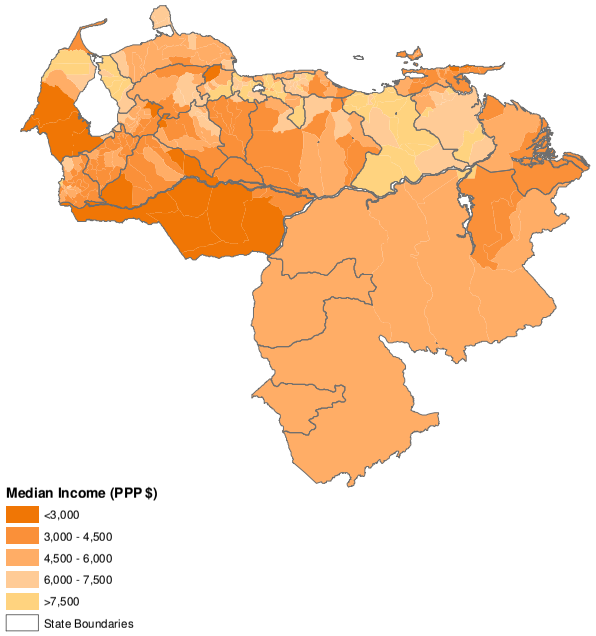
United States - Labor Income



Venezuela - Temperature



Venezuela - Labor Income



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