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# Gini Decomposition and Gini Income Elasticity Under Income Variability

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**Abstract**

The Gini income elasticity has been used to assess the impact of marginal proportional changes in income from a given source on inequality in total income. This note extends the methodology to take into account income variability.

**Keywords:** Inequality, Gini Decomposition, Uncertainty.
**JEL Codes:** D31, I30.

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# 1 Introduction

The Gini Income Elasticity (GIE hereafter) is a parameter that measures the impact on the (extended) Gini index of income inequality of a marginal proportional change in an income source (e.g., Lerman and Yitzhaki 1985). Estimates of the GIE have been used, among others, for assessing the impact on inequality of increases in outlays for social programs (e.g., Lerman and Yitzhaki 1994, Wodon and Yitzhaki 2002). However, while an increase in funding for programs such as unemployment benefits may reduce inequality in mean income, it may also reduce income variability or risk, and this is not taken into account in the traditional decomposition of the Gini index. In this note, we show that under income variability (assuming that the observations represent a draw from states of nature), an income source has three GIEs corresponding to the three ways in which the income source affects the certainty equivalent income: a) the mean income from the source over time, b) the variability in income from the source, and c) the correlation over time between income from the source and income from other sources. The total impact on inequality of a marginal change in income from the source is then a function of these three GIEs.

# 2 Method

Consider a situation where total income is the sum of income from $J$ sources. The standard decomposition of the Gini index is

$$G = \sum_{j=1}^{J} \underbrace{\left[COV\left(y_j, F\right)/COV\left(y_j, F_j\right)\right]}_{R_j} \underbrace{\left[2COV\left(y_j, F_j\right)/m_j\right]}_{G_j} \underbrace{\left[m_j/m\right]}_{S_j} \tag{1}$$

where $y_j$ is income from source $j$, $F$ is the rank of the individual (or household) in the distribution of total income, $F_j$ is the rank in the distribution of income from source $j$, $m_j$ is the source's mean income, and $m$ is mean total income. In equation (1), $R_j$ is the Gini correlation between total income and income from source $j$, $G_j$ is the Gini of source $j$, and $S_j$ is the source's share of total income. It can be shown that the impact on inequality of a marginal proportional change in income from source $j$ is such that

$$\frac{\frac{\partial G}{\partial e}}{G} = S_j(\eta_j - 1) \tag{2}$$

where the GIE, denoted by $\eta_j$, is defined as

$$\eta_j = \frac{R_j G_j}{G}. \tag{3}$$

A GIE higher (lower) than one denotes an income sources that is inequality increasing (decreasing) at the margin.

In this note, we extend this decomposition and the concept of the GIE to a context in which individuals are subject to income variability over time. Our strategy consists in considering the income variable $y$ in (1) as the certainty equivalent income of the individual, and to apply the decomposition to that certainty equivalent. If the actual income for individual $i$ is denoted by $x_i$ – this is a random variable with density function $g_i(\cdot)$, the certainty equivalent income $y_i$ is defined through

$$u(y_i) = \int_0^\infty u(x)\, g_i(x)\, dx. \tag{4}$$

where $u(\cdot)$ does not represents the Bernoulli utility function of the individual, but rather a social judgement on the impact of income variability on welfare. Denote by $\mu_i$ the individual's mean income over time. The cost of variability, $c(g_i; u)$, is defined by

$$u(\mu_i - c(g_i; u)) = \int_0^\infty u(x)\, g_i(x)\, dx, \tag{5}$$

Using a Taylor expansion, an approximation of this cost is

$$c\left(g_i;u\right) \simeq 0.5\overline{r}_a^i\sigma_i^2, \tag{6}$$

where $\overline{r}_a^i$ is the Arrow-Pratt absolute risk aversion index measured at $\mu_i$, and $\sigma_i^2$ is the variance of the individual's income. In this note, for simplicity, we assume a constant absolute risk aversion (denoted by $\rho$), so that

$$y_i = \mu_i - 0.5\rho\sigma_i^2. \tag{7}$$

Return now to the fact that there are $J$ sources of income with means over time $\mu_{ij}$ for individual $i$ so that

$$\mu_i = \sum_{j=1}^{J} \mu_{ij} \tag{8}$$

and

$$\sigma_i^2 = \sum_{j=1}^{J} \sigma_{ij}^2 + 2\sum_{j=1}^{J}\sum_{k=j+1}^{J} COV\left(x_{ij}, x_{ik}\right), \tag{9}$$

where $COV\left(a,b\right)$ is the covariance between $a$ and $b$. We have

$$\sum_{j=1}^{J}\sum_{k=j+1}^{J} COV\left(x_{ij}, x_{ik}\right) = 0.5\sum_{j=1}^{J} COV\left(x_{ij}, x_{ij}^{-}\right). \tag{10}$$

where $x_{ij}^{-} = x_i - x_{ij}$. Using (8), (9) and (10), (7) may be rewritten as

$$y_i = \sum_{j=1}^{J} \left\{\mu_{ij} + \phi_{ij} + \xi_{ij}\right\}, \tag{11}$$

where $\phi_{ij} = -0.5\rho\sigma_{ij}^2$ is the cost of the income variability of source $j$, and $\xi_{ij} = -0.5\rho COV\left(x_{ij}, x_{ij}^{-}\right)$ is the cost (or benefit) due to the covariance between source $j$ and other income sources. If we denote by $m_j^{\mu}$, $m_j^{\phi}$ and $m_j^{\xi}$ the mean values over the population as a whole of $\mu_{ij}, \phi_{ij}$,and $\xi_{ij}$, and as before by $m$ the mean value of $y_i$, applying (1) to (11) yields for each income source three components in the decomposition of the Gini

$$\begin{aligned} G &= \sum_{j=1}^{J} \{ \left[ COV\left(\mu_j, F\right) / COV\left(\mu_j, F_j^{\mu}\right) \right] \left[ 2COV\left(\mu_j, F_j^{\mu}\right) / m_j^{\mu} \right] \left[ m_j^{\mu} / m \right] \\ &+ \left[ COV\left(\phi_j, F\right) / COV\left(\phi_j, F_j^{\phi}\right) \right] \left[ 2COV\left(\phi_j, F_j^{\phi}\right) / m_j^{\phi} \right] \left[ m_j^{\phi} / m \right] \\ &+ \left[ COV\left(\xi_j, F\right) / COV\left(\xi_j, F_j^{\xi}\right) \right] \left[ 2COV\left(\xi_j, F_j^{\xi}\right) / m_j^{\xi} \right] \left[ m_j^{\xi} / m \right] \right\}, \end{aligned}$$

Using a notation similar to (1), this yields

$$G = \sum_{j=1}^{J} \left\{ R_j^{\mu} G_j^{\mu} S_j^{\mu} + R_j^{\phi} G_j^{\phi} S_j^{\phi} + R_j^{\xi} G_j^{\xi} S_j^{\xi} \right\}. \tag{12}$$

Consider now a small proportional change in an income source by a factor of $e$, such that $y_{ik}(e) = (1+e)\mu_{ik} + (1+e)^2 \phi_{ik} + (1+e)\xi_{ik}$. It is shown in appendix that

$$\frac{\partial G}{\partial e} = S_j^{\mu}\left(R_j^{\mu} G_j^{\mu} - G\right) + 2S_j^{\phi}\left(R_j^{\phi} G_j^{\phi} - G\right) + S_j^{\xi}\left(R_j^{\xi} G_j^{\xi} - G\right). \tag{13}$$

Dividing by $G$, we get

$$\frac{\frac{\partial G}{\partial e}}{G} = S_j^{\mu}(\eta_j^{\mu} - 1) + 2S_j^{\phi}(\eta_j^{\phi} - 1) + S_j^{\xi}(\eta_j^{\xi} - 1), \tag{14}$$

where $\eta_j^{\mu} = \frac{R_j^{\mu} G_j^{\mu}}{G}$, $\eta_j^{\phi} = \frac{R_j^{\phi} G_j^{\phi}}{G}$, *and* $\eta_j^{\xi} = \frac{R_j^{\xi} G_j^{\xi}}{G}$.

With cross-section data, since we do not observe income variability, only the first term on the righ hand side of (14) appears, so that whether an income source increases or decreases inequality at the margin is solely determined by whether the GIE $\eta_j^{\mu}$ is above or below one. In a panel setting, we have instead three sources of impact at the margin, and thereby three GIEs related to a) the mean income from the source over time, b) the variability of the source, and c) the correlation between the source and other sources over time. For example, a source such as unemployment benefits may reduce inequality in certainty equivalent income at the margin not only through targeting individuals with comparatively low mean income, but also through reducing income variability for these individuals, with this beneficial effect appearing through the third GIE in (14).

One last point: to introduce flexibility in the measurement of inequality, we may use the extended Gini coefficient (Yitzhaki, 1983), in which case the weights placed on various parts of the distribution of the certainty equivalent income will depend on a parameter $\upsilon$. A value of 2 yields the standard Gini. A higher (lower) value places more (less) weights on lower parts of the distribution. All the results will remain valid. We will have

$$G(\upsilon) = \sum_{j=1}^{J} \left\{ R_j^{\mu}(\upsilon)\, G_j^{\mu}(\upsilon)\, S_j^{\mu} + R_j^{\phi}(\upsilon)\, G_j^{\phi}(\upsilon)\, S_j^{\phi} + R_j^{\xi}(\upsilon)\, G_j^{\xi}(\upsilon)\, S_j^{\xi} \right\}, \tag{15}$$

where

$$R_j^{\mu}(\upsilon) = \frac{COV\left[\mu_j, (1-F)^{\upsilon-1}\right]}{COV\left[\mu_j, \left(1-F_j^{\mu}\right)^{\upsilon-1}\right]}, \tag{16}$$

and

$$G_j^{\mu}(\upsilon) = -\upsilon \frac{COV\left[\mu_j, \left(1-F_j^{\mu}\right)^{\upsilon-1}\right]}{m_j^{\mu}}. \tag{17}$$

$R_j^{\phi}(\upsilon)$, $G_j^{\phi}(\upsilon)$, $R_j^{\xi}(\upsilon)$, and $G_j^{\xi}(\upsilon)$ are defined analogously. Following a small proportional change in income from a source, we will have

$$\frac{\frac{\partial G(\upsilon)}{\partial e}}{G(\upsilon)} = S_j^{\mu}(\eta_j^{\mu}(\upsilon) - 1) + 2S_j^{\phi}(\eta_j^{\phi}(\upsilon) - 1) + S_j^{\xi}(\eta_j^{\xi}(\upsilon) - 1)$$

where $\eta_j^{\mu}(\upsilon) = \frac{R_j^{\mu}(\upsilon)G_j^{\mu}(\upsilon)}{G(\upsilon)}$, $\eta_j^{\phi}(\upsilon) = \frac{R_j^{\phi}(\upsilon)G_j^{\phi}(\upsilon)}{G(\upsilon)}$, *and* $\eta_j^{\xi}(\upsilon) = \frac{R_j^{\xi}(\upsilon)G_j^{\xi}(\upsilon)}{G(\upsilon)}$.

# 3 Conclusion

Most of the work for assessing the impact of public transfers on inequality is based on cross-sectional data. Yet many transfers are designed not only to reach the poor, but also to offset the impact of income variability on welfare. In this note, we have extended the source decomposition of the Gini index of inequality to show how to evaluate the impact at the margin on inequality of a proportional increase in program outlays under income variability. When considering inequality in certainty equivalent income, each income source can be said to have three Gini Income Elasticities corresponding to the three terms appearing in the Taylor approximation of the individual's cetainty equivalent income, namely the mean income from the source, the variability of the source over time, and the covariance between the source and other income sources over time.

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# A Proof of (13)

This proof follows closely Stark et al. (1986). We first note that after a marginal proportional change in income from source $k$

$$S_j^{\mu}(e) = \begin{cases} \frac{m_j^{\mu}}{\sum_{l=1}^{J}\left\{m_l^{\mu}+m_l^{\phi}+m_l^{\xi}\right\}+e\left\{m_k^{\mu}+m_k^{\phi}+m_k^{\xi}\right\}+e(1+e)m_k^{\phi}} & \text{for } j \neq k \\ \frac{(1+e)m_k^{\mu}}{\sum_{l=1}^{J}\left\{m_l^{\mu}+m_l^{\phi}+m_l^{\xi}\right\}+e\left\{m_k^{\mu}+m_k^{\phi}+m_k^{\xi}\right\}+e(1+e)m_k^{\phi}} & \text{for } j = k \end{cases}. \quad (19)$$

$S_j^{\xi}(e)$ is defined analogously. However,

$$S_j^{\phi}(e) = \begin{cases} \frac{m_j^{\mu}}{\sum_{l=1}^{J}\left\{m_l^{\mu}+m_l^{\phi}+m_l^{\xi}\right\}+e\left\{m_k^{\mu}+m_k^{\phi}+m_k^{\xi}\right\}+e(1+e)m_k^{\phi}} & \text{for } j \neq k \\ \frac{(1+e)^2 m_k^{\mu}}{\sum_{l=1}^{J}\left\{m_l^{\mu}+m_l^{\phi}+m_l^{\xi}\right\}+e\left\{m_k^{\mu}+m_k^{\phi}+m_k^{\xi}\right\}+e(1+e)m_k^{\phi}} & \text{for } j = k \end{cases}. \quad (20)$$

If the change in income from source $k$ is suffciently small, all ranks are preserved. As in Stark et al. (1986), this implies that

$$\begin{aligned} G(e) - G &= \sum_{j=1}^{J}\left\{R_j^{\mu}G_j^{\mu}S_j^{\mu}(e) + R_j^{\phi}G_j^{\phi}S_j^{\phi}(e) + R_j^{\xi}G_j^{\xi}S_j^{\xi}(e)\right\} \\ &\quad -\sum_{j=1}^{J}\left\{R_j^{\mu}G_j^{\mu}S_j^{\mu} + R_j^{\phi}G_j^{\phi}S_j^{\phi} + R_j^{\xi}G_j^{\xi}S_j^{\xi}\right\}, \end{aligned}$$

$$
\begin{aligned}
G(e) - G &= \sum_{j=1}^{J} R_j^{\mu} G_j^{\mu} \left[ S_j^{\mu}(e) - S_j^{\mu} \right] \\
&+ \sum_{j=1}^{J} R_j^{\phi} G_j^{\phi} \left[ S_j^{\phi}(e) - S_j^{\phi} \right] \\
&+ \sum_{j=1}^{J} R_j^{\xi} G_j^{\xi} \left[ S_j^{\xi}(e) - S_j^{\xi} \right].
\end{aligned} \tag{21}
$$

From (19) and (20), we can compute for $j \neq k$,

$$
\begin{aligned}
S_j^{\mu}(e) - S_j^{\mu} &= \frac{m_j^{\mu}}{\sum_{l=1}^{J} \left\{ m_l^{\mu} + m_l^{\phi} + m_l^{\xi} \right\} + e \left\{ m_k^{\mu} + m_k^{\phi} + m_k^{\xi} \right\} + e(1+e) m_k^{\phi}} \\
&- \frac{m_j^{\mu}}{\sum_{l=1}^{J} \left\{ m_l^{\mu} + m_l^{\phi} + m_l^{\xi} \right\}},
\end{aligned}
$$

$$
S_j^{\mu}(e) - S_j^{\mu} = \frac{-e S_j^{\mu} \left\{ S_k^{\mu} + S_k^{\phi} + S_k^{\xi} + e(1+e) S_k^{\phi} \right\}}{1 + e \left( S_k^{\mu} + S_k^{\phi} + S_k^{\xi} \right) + e(1+e) S_k^{\phi}}. \tag{22}
$$

$S_j^{\phi}(e) - S_j^{\phi}$ and $S_j^{\xi}(e) - S_j^{\xi}$ have analogous forms. For $j = k$,

$$
\begin{aligned}
S_k^{\mu}(e) - S_k^{\mu} &= \frac{(1+e) m_k^{\mu}}{\sum_{l=1}^{J} \left\{ m_l^{\mu} + m_l^{\phi} + m_l^{\xi} \right\} + e \left\{ m_k^{\mu} + m_k^{\phi} + m_k^{\xi} \right\} + e(1+e) m_k^{\phi}} \\
&- \frac{m_k^{\mu}}{\sum_{l=1}^{J} \left\{ m_l^{\mu} + m_l^{\phi} + m_l^{\xi} \right\}},
\end{aligned}
$$

$$
S_k^{\mu}(e) - S_k^{\mu} = \frac{e S_k^{\mu} - e S_k^{\mu} \left\{ S_k^{\mu} + S_k^{\phi} + S_k^{\xi} + e(1+e) S_k^{\phi} \right\}}{1 + e \left( S_k^{\mu} + S_k^{\phi} + S_k^{\xi} \right) + e(1+e) S_k^{\phi}}. \tag{23}
$$

$S_j^{\xi}(e) - S_j^{\xi}$ has an analogous form. However

$$
\begin{aligned}
S_k^{\phi}(e) - S_k^{\phi} &= \frac{(1+e)^2 m_k^{\phi}}{\sum_{l=1}^{J} \left\{ m_l^{\mu} + m_l^{\phi} + m_l^{\xi} \right\} + e \left\{ m_k^{\mu} + m_k^{\phi} + m_k^{\xi} \right\} + e(1+e) m_k^{\phi}} \\
&- \frac{m_k^{\mu}}{\sum_{l=1}^{J} \left\{ m_l^{\mu} + m_l^{\phi} + m_l^{\xi} \right\}},
\end{aligned}
$$

$$S_k^\phi(e) - S_k^\phi = \frac{eS_k^\phi + e(1+e)S_k^\phi - eS_k^\phi\left\{S_k^\mu + S_k^\phi + S_k^\xi + e(1+e)S_k^\phi\right\}}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi}. \tag{24}$$

Using (24), (23), (22) and (21), we get

$$\begin{aligned}
G(e) - G &= \sum_{j=1}^{J} \frac{-eS_j^\mu\left\{S_k^\mu + S_k^\phi + S_k^\xi + (1+e)S_k^\phi\right\}}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi} R_j^\mu G_j^\mu \\
&\quad + \frac{eS_k^\mu}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi} R_k^\mu G_k^\mu \\
&\quad + \sum_{j=1}^{J} \frac{-eS_j^\phi\left\{S_k^\mu + S_k^\phi + S_k^\xi + (1+e)S_k^\phi\right\}}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi} R_j^\phi G_j^\phi \\
&\quad + \frac{e(2+e)S_k^\phi}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi} R_k^\phi G_k^\phi \\
&\quad + \sum_{j=1}^{J} \frac{-eS_j^\xi\left\{S_k^\mu + S_k^\phi + S_k^\xi + (1+e)S_k^\phi\right\}}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi} R_j^\xi G_j^\xi \\
&\quad + \frac{eS_k^\xi}{1 + e\left(S_k^\mu + S_k^\phi + S_k^\xi\right) + e(1+e)S_k^\phi} R_k^\xi G_k^\xi.
\end{aligned}$$

Taking the limit, we get

$$\begin{aligned}
\lim_{e\to 0}\frac{G(e)-G}{e} &= -\lim_{e\to 0}\left\{S_k^{\mu}+S_k^{\phi}+S_k^{\xi}+(1+e)\,S_k^{\phi}\right\}\sum_{j=1}^{J}\frac{S_j^{\mu}}{1+e\left(S_k^{\mu}+S_k^{\phi}+S_k^{\xi}\right)}R_j^{\mu}G_j^{\mu} \\
&\quad+\lim_{e\to 0}\frac{S_k^{\mu}}{1+e\left(S_k^{\mu}+S_k^{\phi}+S_k^{\xi}\right)+e\,(1+e)\,S_k^{\phi}}R_k^{\mu}G_k^{\mu} \\
&\quad-\lim_{e\to 0}\left\{S_k^{\mu}+S_k^{\phi}+S_k^{\xi}+(1+e)\,S_k^{\phi}\right\}\sum_{j=1}^{J}\frac{S_j^{\phi}}{1+e\left(S_k^{\mu}+S_k^{\phi}+S_k^{\xi}\right)}R_j^{\phi}G_j^{\phi} \\
&\quad+\lim_{e\to 0}\frac{(2+e)\,S_k^{\phi}}{1+e\left(S_k^{\mu}+S_k^{\phi}+S_k^{\xi}\right)+e\,(1+e)\,S_k^{\phi}}R_k^{\phi}G_k^{\phi} \\
&\quad-\lim_{e\to 0}\left\{S_k^{\mu}+S_k^{\phi}+S_k^{\xi}+(1+e)\,S_k^{\phi}\right\}\sum_{j=1}^{J}\frac{S_j^{\xi}}{1+e\left(S_k^{\mu}+S_k^{\phi}+S_k^{\xi}\right)}R_j^{\xi}G_j^{\xi} \\
&\quad+\lim_{e\to 0}\frac{S_k^{\xi}}{1+e\left(S_k^{\mu}+S_k^{\phi}+S_k^{\xi}\right)+e\,(1+e)\,S_k^{\phi}}R_k^{\xi}G_k^{\xi}.
\end{aligned}$$

$$\lim_{e\to 0}\frac{G(e)-G}{e}=-\left(S_k^{\mu}+2S_k^{\phi}+S_k^{\xi}\right)G+S_k^{\mu}R_k^{\mu}G_k^{\mu}+2S_k^{\phi}R_k^{\phi}G_k^{\phi}+S_k^{\xi}R_k^{\xi}G_k^{\xi}. \tag{25}$$

It is straitforward to get (13) from (25). The proof for the extended Gini index is similar.

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