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Income Distribution and Poverty in a CGE Framework: A Proposed Methodology[†]

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Abstract: The paper discusses methodologies addressing income distribution and poverty in a Computable General Equilibrium (CGE) model framework, by describing how to link CGE results with household survey data to analyze income distribution and poverty implications. The most basic approach is simply to fit the household income/expenditure to the survey data by suitable parametric distribution functions. The post-simulation poverty indices can be estimated by either assuming that the income of each individual household within the group moves proportionally with the group's mean income, or by our proposed elasticity method. In our proposed method, we use the elasticity estimated from existing surveys to calculate the change in expenditure of each subgroup category in response to change in the household category's mean consumption, supplied by the core model's simulation, to derive post-simulation poverty indices. Our approach may better capture intra-group income distribution of households and moderate gains or losses in welfare from economic growths.

***Keywords*:** Computable General Equilibrium, Income Distribution, Poverty.

***JEL classification*:** D58; O15; I32

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1. Introduction

Theory of income distribution are divided into two types: functional and size distribution (Garvy, 1954; Denison, 1954). The “functional distribution” theory concerns with the distribution of income accrued to factors of production (various kinds of labour, capital, and land) which are defined by their function in the economy (Dervis *et al*., 1982). This theory seeks to explain how factor prices are determined and how they in turn determine the shares of each factor of production in the national income, which is predominant in classical economics (Howard, 1979; Sundrum, 1990). The “size distribution of income” theory focuses on the distribution of income between individuals or households (Blinder, 1974; Atkinson, 1975).

Most contemporary studies on income distribution focus on personal (household) or size distribution of income. However, most of these theories tend to take the economic system as given, overlooking the structural characteristics of the aggregate economy (Dervis *et al*., 1982). Therefore, these theories provide rather limited policy implications. A unified theory has yet to be established to capture the most important social, political, and economic forces that determine the distribution of ownership of assets (both physical and human) and its evolution over time.

Nonetheless, a combination model of a moderately detailed functional and size distribution is reasonable in the context of income distribution and poverty analysis. A multi-sector, general equilibrium model which provides important mechanisms affecting the distribution of income to individuals, factors, and socioeconomic groups is a sensible option (Dervis *et al*., 1982). Since the pioneer work by Adelman and Robinson (1978), the computable general equilibrium (CGE) model has become a commonly used tool in analysing income distribution and poverty.

Filho and Horridge (2004) and Savard (2005) provide very helpful literature reviews and good discussions on income distribution and poverty within a CGE model framework. According to them, the application of CGE in income distribution and poverty analyses can be classified into three main categories, depending on how households are integrated into the CGE model. A general equilibrium analysis of the distributional implications of macroeconomic shocks and policies may follow three basic approaches: (1) the standard representative household (RH) approach, (2) the extended representative household approach (ERH), and (3) the micro-simulation (MS) approach.

The first approach is a model with a single representative household (RH) through which poverty analysis can be performed by using the variation of income or expenditure of the RH generated by the model, with household survey data, to conduct *ex ante* poverty comparison. Even though the RH approach is easy to implement, its main drawback is that it provides no information on the intra-group income distribution.

The second approach is the extended representative household approach (ERH), in which large numbers of representative households are included. The main advantage of this approach is that it provides richer information on inter-group income distribution. However, this approach limits the analysis of the distributional impact of shocks and policies to their effects on the mean welfare within that number of representative socioeconomic groups. In this framework, poverty analysis requires the specification of the size distribution within groups. Usually, a well-known density function of distribution such as the lognormal or the beta is used to model intra-group income distribution (Dervis *et al*., 1982; Decaluwé *et al*., 1999).

The third approach is the application of micro-simulation (MS) techniques. This approach provides richer information on household behaviour (consumption and labour supply) for large record units of household survey data. The approach uses unit record data drawn directly from a household survey to represent the size distribution of economic welfare (Dixon *et al*., 1995; Cogneau and Robilliard, 2000; Bourguignon and Spadaro, 2006). However, the main drawback of this approach is the lack of consistency and the feedback between the CGE model and the micro-simulation model.

This paper discusses the second approach, linking results from the CGE model with an imposed statistical income distribution function to each household category, in order to estimate poverty indices. Moreover, we propose a simple method to derive post-simulation poverty indices with an illustration from the Cambodian CGE model and household survey data. We then compare the poverty estimates from our approach with the commonly used approach and draw a conclusion that our proposed approach may better capture intra-group income distribution of households and moderate gains or losses in welfare from economic growths.

2. Poverty Estimate and a Proposed Methodology

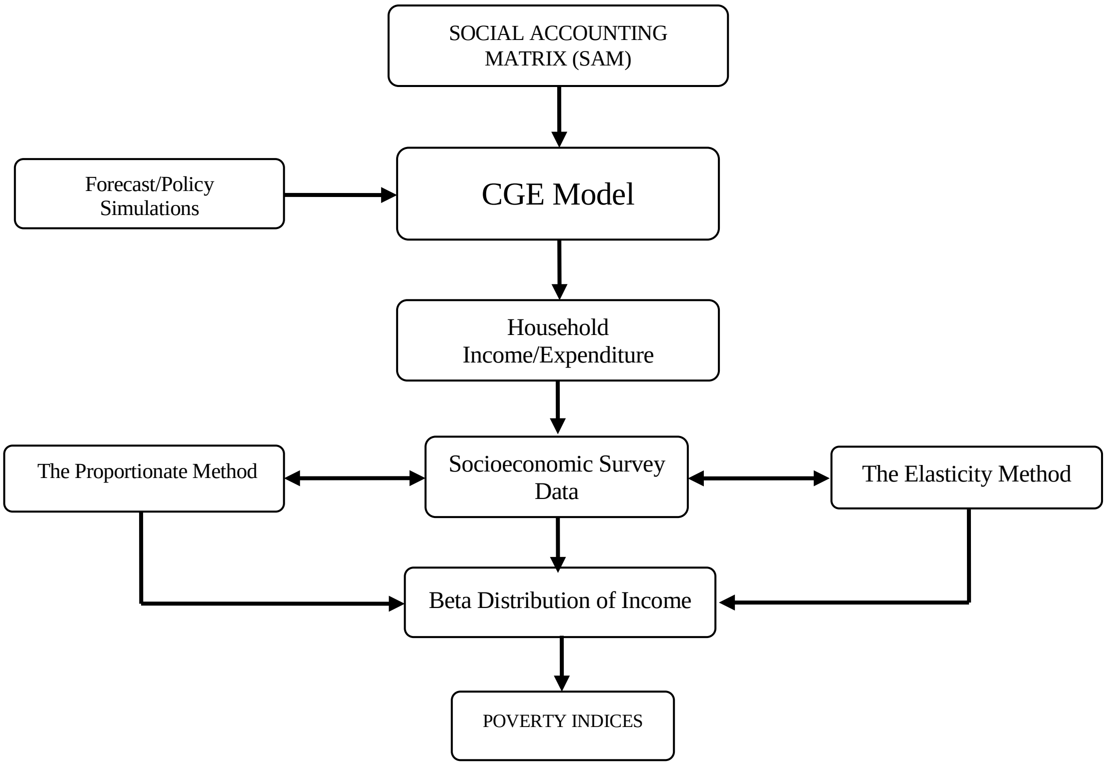
Among the most popular choices in using functional forms of income distribution within a CGE framework is the Lognormal distribution, earlier applied by Adelman and Robinson (1978) in their study of income distribution in Korea, and later by Dervis *et al*. (1982) on three archetypal economies. De Janvry *et al*. (1991) uses both Lognormal and Pareto distributions for their study on Morocco. The Beta distribution is used by Decaluwé *et al*. (1999) on an African archetypal economy. A more comprehensive review of the distinguishing features of these functional forms and others such as Displaced Lognormal, Gamma, Champernowne, Singh-Maddala, and Dagum is discussed by Boccanfuso *et al*. (2003). In this paper we choose the Beta distribution function as an illustration.

Normally, regardless of functional forms chosen, most analysis within this tradition assumes no change in intra-group income distribution (inequality neutral). This assumption implies that the post-simulation expenditure of every household within the group changes proportionally with change in its group's mean consumption. This approach can be called "the Proportionate Method". It is very likely that this method overstates welfare gains or losses from a particular shock or policy reform.

However, the post-simulation change in each individual household's income (expenditure) can be in a (fixed) proportion to changes in its group's mean income (expenditure), not necessarily at the same proportion, reflecting a continued worsening or improvement in income inequality. A measure of the percentage change in each household's income (expenditure) to its group's mean income can be called "the Elasticity Method". The method may moderate the exaggeration of the actual gains or losses in welfare as in the case of the proportionate method, since it provides more information on intra-group income distribution.

A summary of the two approaches is given by Figure 1 below. Given the post-simulation income/expenditure of each individual household from these two methods, the poverty indices can be estimated. The most commonly used poverty measures in the literature are Sen's poverty index Sen (1976) and that of Foster *et al.* (FGT, 1984). In this paper, we use the FGT index, which is not only easy to interpret but also satisfies the basic properties (monotonicity and transfer axiom) proposed by Sen (1976) and transfers sensitivity axiom discussed by Foster *et al*. (1984)[1].

Figure 1. Steps in Poverty Estimates



Given a vector of individual household incomes (expenditures) $y = (y_1, y_2, ... , y_n)$ in increasing order and a predetermined poverty line $z > 0$, the FGT index is given by the following formula:

$$P_\alpha(y; z) = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{g_i}{z}\right)^\alpha$$

where $g_i = z - y$, is the income shortfall of the i^{th} household, $q = q(y; z)$ is the number of poor households (having income no greater than z), and $n = n(y)$ is the total number of households.

[1] There are many other poverty axioms discussed by Hagenaars (1987). He defines the main axioms as follow. Monotonicity Axiom: a decrease in the income of a poor person should increase the poverty index, and vice versa; Transfer Axiom: a transfer from a poor person to a richer person should increase the poverty index, and vice versa; Transfer Sensitivity Axiom: the increase of a poverty index as a result of a transfer of a fixed amount of money from a poor person to a richer person should be decreasing in the income of the donator, and vice versa.

When α=0, P_0 is commonly known as the poverty headcount index, the percentage of the population with per capita consumption below the poverty line. When α=1, P_1 is the poverty gap index, which is the average shortfall of income from the poverty line, and when α=2, P_2 is the poverty severity index, which gives greater weight to those that fall far below the poverty line than those that are closer to it. As proved by Foster *et al.* (1984), the poverty measure *P*, satisfies the Monotonicity Axiom for $\alpha > 0$, the Transfer Axiom for $\alpha > 1$, and the Transfer Sensitivity Axiom for $\alpha > 2$.

When the *y* vector is broken down into subgroup *m* expenditure vectors *y*(1), … , *y*(*m*), the index can also be written as:

$$P_\alpha(y; z) = \sum_{j=1}^{m} \frac{n_j}{n} P_{\alpha,m}(y^{(j)}; z)$$

Therefore, the total index is the weighted sum of the subgroup levels.

2.1. Poverty Indices Using Proportionate Method

Using the proportionate method as commonly practised, the income of each individual household within the group moves proportionally with the group's mean income. The post-simulation poverty indices can be calculated by using the Beta distribution, *B*(*p*,*q*). P_α for each household category can be written as follows:

$$P_\alpha(y; z,p,q) = \int_{min}^{z} \left(\frac{z-y}{z}\right)^{\alpha} \frac{1}{B(p,q)} \left[\frac{(y-y_{min})^{p-1}(y_{max}-y)^{q-1}}{(y_{max}-y_{min})^{p+q-1}}\right] dy$$

where

$$B(p,q) = \int_{y_{min}}^{y_{max}} \frac{(y-y_{min})^{p-1}(y_{max}-y)^{q-1}}{(y_{max}-y_{min})^{p+q-1}} dy, \quad y_{min} < y < y_{max}, \quad \text{and } p,q > 0$$

The poverty line *z*, and parameter *p*, *q* of the Beta distribution function are estimated from the base-year survey data. Since the proportionate method does not alter the post-simulation parameters of the Beta distribution, the same parameters are used to derive the post-simulation poverty indices.

2.2. Poverty Indices Using the Elasticity Method

The post-simulation poverty indices can also be calculated by our proposed simple method. Rather than allowing each household to move with the same rate of change as the group's mean income, we can use the elasticity estimated from the previous surveys. We use this elasticity to calculate the change in expenditure of each subgroup category in response to change in the household category's mean consumption supplied by the core model's simulation. The relationship between the model's mean income of household category and its subgroup is governed by:

$$y_{h,g} = \alpha_{h,g}.y_h \quad \text{and} \quad \sum_g y_{h,g}.S_{h,g} = y_h$$

where $y_{h,g}$ and y_h are the percentage changes in income of the subgroup household (thus individual household within the subgroup) and the model's mean income of household category, respectively;

$S_{h,g}$ is the share of income (expenditure) of the sub-group households in its main household category; and

$\alpha_{h,g}$ is an income (expenditure) elasticity of the sub-group households in response to changes in its main household category estimated from the previous households' expenditure surveys.

We then re-estimate the *p* and *q* of the Beta distribution function before deriving the poverty indices.

Our approach is distinguished from the so-called "poverty elasticity of growth" as discussed by Kakwani (1993), Heltberg (2002), and Bourguignon (2003). Their approach is to look at a direct relationship between the growth in household mean income/expenditure and poverty bypassing the link between the mean income/expenditure of a particular group of households and each individual household within that group.

3. An Illustration

In order to illustrate the proposed methodology, we use a dynamic Cambodian CGE model developed based on ORANI and ORANI-RD, the Australian CGE model to forecast the Cambodian economy and draw upon poverty implications (Dixon *et al*., 1982; Horridge, 2000 and 2002; Oum, 2009). The model's demand and supply of private-sector agents are the solutions to the optimization problems (cost minimization, utility maximization, etc.) which are assumed to underlie the behavior of the agents in conventional neoclassical microeconomics. All markets are cleared and the agents are assumed to be price takers, with producers operating in competitive markets, which prevent the earning of pure profits (i.e., zero profit condition). Following Johansen (1974), the model is solved by representing it as a system of linear equations relating percentage changes in model variables using GEMPACK developed by Harrison and Pearson (1996). The dynamic mechanisms of the model include: (i) a stock-flow relation between investment and capital stock, which assumes a one-year gestation lag; (ii) a positive relation between investment and the rate of profit; (iii) a relation between wage growth and employment.

The model is calibrated with a social accounting matrix (SAM) at the base year 2004. The SAM maps details on flows of factorial and other incomes (including taxes and transfers) from producing industries to households and other agents.

In the next step, we use our model to forecast the economy from 2005 to 2015 from which the sectoral growths and household income and expenditures can be then decomposed[2]. The resulting poverty estimates are compared against the 24% poverty reduction target of the country's Millennium Development Goals (CMDG) by 2015 (World Bank, 2006). Table 1 shows actual GDP growth rates from 2005 to 2008 and the hypothetical forecast growth rates from 2009 onward.

[2] The detailed explanation of simulation and results is given by Oum (2009). However, in this paper we are concerned only with how the projected growths are translated into household gains in income and expenditure and how these gains are felt by each individual household, whereby poverty indices are estimated.

Table 1. Percentage Change in GDP Forecast 2005 – 2015 (%)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gross Domestic Product	13.5	10.8	10.2	7.2	7.0	7.0	7.0	7.0	7.0	7.0	7.0

With these forecast growth rates, the model's simulation implies that by 2015 the accumulated household consumption by each category is given by Table 2.

Table 2. Percentage Change in Accumulated Real Household Consumption in 2015 (%)

1	Banteay Mean Chey	31.7
2	Battambang	37.0
3	Kampong Cham	37.6
4	Kampong Chhnang/Pursat	42.4
5	Kampong Speu	36.9
6	Kampong Thom	36.5
7	Kampot	34.8
8	Kandal	46.2
9	**Phnom Penh**	**75.5**
10	Prey Veng	31.8
11	Siem Reap	33.1
12	Sihanouk/Kep/Koh Kong	36.9
13	Svay Rieng	30.2
14	Takeo	32.1
15	Others	42.5

Source: Oum (2009).

Since the household consumption is measured in real terms, we do not need to update the poverty line from the base period in order to calculate post-simulation poverty rates in 2015. In the base year, poverty is prevalent in Kampong Speu, Kampong Thom, Siem Reap, and other small provinces. As shown in table 3, Capital Phnom Penh, Sihanouk/Kep/Koh Kong, and Kandal province have the lowest rate of poverty across all measures. The average poverty headcount of the country in the base year is 35%.

Using the proportionate method, every individual household within each group moves proportionately with its mean expenditure. As a result, the poverty headcount index decreases from 35% in 2004 to 17% in 2015, i.e., 8 percentage points better than the CMDG target of 24%.

Table 3. The FGT Poverty Indices Using the Proportionate Method (%)

		Base 2004			2015		
		P0	**P1**	**P2**	**P0**	**P1**	**P2**
	Cambodia	**34.7**	**9.3**	**3.4**	**16.6**	**3.2**	**0.9**
1	Banteay Mean Chey	36.9	9.8	3.5	20.3	3.8	1.0
2	Battambang	34.0	9.6	3.7	17.3	3.6	1.1
3	Kampong Cham	36.9	10.7	4.2	19.2	4.2	1.3
4	Kampong Chhnang/Pursat	37.2	8.8	2.9	12.9	1.9	0.4
5	Kampong Speu	53.2	14.8	5.5	27.3	5.3	1.4
6	Kampong Thom	49.4	14.2	5.5	26.2	5.5	1.6
7	Kampot	33.5	8.2	2.7	15.1	2.5	0.6
8	Kandal	27.3	6.5	2.2	8.9	1.3	0.3
9	**Phnom Penh**	**10.3**	**3.1**	**1.3**	**2.8**	**0.6**	**0.2**
10	Prey Veng	37.7	8.4	2.5	16.6	2.4	0.5
11	Siem Reap	44.5	14.5	6.1	28.4	7.1	2.4
12	Sihanouk/Kep/Koh Kong	25.2	6.5	2.3	11.5	2.1	0.5
13	Svay Rieng	39.2	9.2	2.9	19.3	3.1	0.7
14	Takeo	29.9	7.7	2.8	14.8	3.0	0.9
15	Others	42.4	11.6	4.2	18.8	3.4	0.9

Source: Oum (2009).

Applying our proposed method, we first calculate the income (expenditure) elasticities of the decile households in response to the means of their main household categories from the Cambodian socioeconomic survey 1994 and 2004 (Oum, 2009). We then use these elasticities to derive the accumulated changes in consumption of each decile-household in response to its mean regional household consumption as shown in Table 4.

Since each decile-household consumption value does not move in the same proportion as its mean, i.e., consumption of all poorer decile-households moves less than one-to-one to changes in the mean consumption of their regional households, the poverty reduction gains are less significant than those derived by the proportionate method. The gains in household consumption are skewed toward the rich, leading to worsening income inequality. The estimated poverty indices are given in Table 5.

Table 4. Accumulated Changes in Real Household Consumption by Categories and Deciles (%)

		Mean	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
1	Banteay Mean Chey	31.7	3.4	12.7	18.0	19.4	24.5	29.3	30.2	31.9	47.8	44.2
2	Battambang	37.0	10.6	9.7	7.3	9.3	12.8	16.7	19.5	24.1	29.6	69.6
3	Kampong Cham	37.6	4.2	10.2	12.9	16.6	20.7	25.2	30.2	33.5	43.4	54.7
4	Kampong Chhnang/Pursat	42.4	6.9	13.9	20.4	22.7	31.3	40.3	36.3	42.0	80.0	46.2
5	Kampong Speu	36.9	4.1	10.1	12.7	16.3	20.3	24.7	29.6	32.9	42.6	53.6
6	Kampong Thom	36.5	4.1	10.0	12.5	16.2	20.1	24.5	29.3	32.5	42.1	53.1
7	Kampot	34.8	4.3	10.5	13.2	17.0	21.1	25.7	30.9	34.3	44.4	56.1
8	Kandal	46.2	5.0	12.3	15.5	20.1	25.0	30.6	36.9	41.0	53.6	68.1
9	**Phnom Penh**	**75.5**	**8.0**	**16.3**	**28.4**	**29.6**	**42.2**	**53.4**	**63.7**	**69.9**	**100.7**	**72.6**
10	Prey Veng	31.8	3.6	8.8	11.0	14.2	17.6	21.4	25.6	28.4	36.6	45.9
11	Siem Reap	33.1	1.1	7.7	8.7	9.5	13.7	17.0	20.4	24.8	28.4	44.5
12	Sihanouk/Kep/Koh Kong	36.9	3.6	8.6	10.8	13.9	17.3	21.0	25.1	27.8	35.8	44.9
13	Svay Rieng	30.2	3.5	8.4	10.5	13.5	16.8	20.4	24.3	27.0	34.7	43.5
14	Takeo	32.1	12.0	10.7	13.9	17.0	24.3	28.9	35.9	39.4	53.1	31.0
15	Other	42.5	4.7	11.4	14.4	18.6	23.2	28.3	34.0	37.8	49.2	62.3

Source: Oum (2009).

Table 5. The FGT Poverty Indices Using Elasticity Method (%)

		Base 2004			2015		
		P0	P1	P2	P0	P1	P2
	Cambodia	**34.7**	**9.3**	**3.4**	**25.6**	**7.1**	**2.7**
1	Banteay Mean Chey	36.9	9.8	3.5	26.5	7.1	2.5
2	Battambang	34.0	9.6	3.7	27.5	8.3	3.3
3	Kampong Cham	36.9	10.7	4.2	28.0	8.6	3.5
4	Kampong Chhnang/Pursat	37.2	8.8	2.9	24.4	5.9	1.9
5	Kampong Speu	53.2	14.8	5.5	41.7	12.0	4.6
6	Kampong Thom	49.4	14.2	5.5	38.9	11.6	4.6
7	Kampot	33.5	8.2	2.7	24.3	6.1	2.1
8	Kandal	27.3	6.5	2.2	17.8	4.4	1.5
9	**Phnom Penh**	**10.3**	**3.1**	**1.3**	**4.5**	**1.3**	**0.5**
10	Prey Veng	37.7	8.4	2.5	27.9	6.3	1.9
11	Siem Reap	44.5	14.5	6.1	38.2	13.1	5.7
12	Sihanouk/Kep/Koh Kong	25.2	6.5	2.3	19.4	5.2	1.9
13	Svay Rieng	39.2	9.2	2.9	29.4	7.0	2.3
14	Takeo	29.9	7.7	2.8	18.6	4.6	1.6
15	Others	42.4	11.6	4.2	31.9	9.0	3.4

Source: Oum (2009).

The poverty headcount index for the whole country is down to 26% in 2015 compared with 17% that of the proportionate method. Therefore, the country would miss the CMDG poverty reduction target by two percentage points in spite of a large increase in mean consumption.

It is obvious that our proposed elasticity method projects the growing gap of income/expenditure inequality within groups of households. Should the reverse be true (pro-poor policies), the poverty reduction would be larger.

In general, policies that result in narrowing income inequality, such as increasing agricultural productivity and land reforms in the case of Cambodia, will give a significant boost to the fight against poverty.

4. Concluding Remarks

This paper discusses methodologies addressing income distribution and poverty in a CGE model framework by describing how to link CGE results with household survey data to analyze income distribution and poverty implications.

The most basic approach is simply to fit the household income/expenditure with the survey data by suitable parametric distribution functions. The post-simulation poverty indices can be estimated by either assuming that income of each individual household within the group moves proportionally with the group's mean income or by our proposed elasticity method. In our proposed method, we use the elasticity estimated from the existing surveys of household income and expenditure to calculate the change in expenditure of each subgroup category in response to change in the household category's mean consumption, supplied by the core model's simulation, before post-simulation poverty indices can be estimated.

The post-simulation poverty estimates from the elasticity method can be either lower or higher than those of the proportionate method, depending on the elasticity of each subgroup category in response to the change in the household category's mean consumption. In our illustration, the reduction in the post-simulation poverty estimates from the elasticity method is lower than that of the proportionate method, demonstrating the growing gap of income/expenditure inequality within a group of households. This is due to the fact that the expenditure elasticities of poorer households are less than unity, whereas those of the rich are mostly larger.

Our proposed method may be more appropriate for developing countries, since it may better capture the growing income inequality in their early stage of development. Moreover, in the absence of drastic reforms, it is very unlikely that the benefits of growth can be equally distributed.

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