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Economic Development and Diet Composition: Cross-Continental Insights into Bennett's Law

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Abstract

The study assesses Bennett's Law, which posits that higher incomes lead to reduced consumption of starchy staples in favor of more diverse, nutrient-dense diets, and its relevance across various global regions. Using regression models, the research examines the relation between GDP per capita and the share of starchy staple foods in caloric intake across continents. The findings indicate significant regional variations in adherence to Bennett's Law. For instance, while South America aligns with Bennett's predictions, Europe deviates, showing increased starchy staple consumption with rising incomes, potentially due to cultural and eco-conscious dietary trends. Africa and parts of Asia display limited dietary diversification, often due to structural barriers and economic constraints. Contrarily, Oceania and North America exhibit a mixed relationship, influenced by income inequality and health trends. These results suggest that Bennett's Law's applicability is region-specific and influenced by socioeconomic, cultural, and policy factors, underscoring the complexity of dietary transitions and cautioning against one-size-fits-all assumptions about the impacts of economic development on food consumption.

Keywords

Food consumption patterns, diet composition, Bennett's Law.

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Introduction

As conceptualized by Merrill Bennett in 1941, Bennett's Law highlights a fundamental shift in dietary patterns as household incomes rise. Specifically, it states that the share of calories derived from starchy staples - such as grains, roots, and tubers - decreases with increasing income. At the same time, the consumption of more nutrient-dense and diverse foods, including meats, dairy, fruits, and vegetables, rises (Bennett, 1941). Bennett's is an extension of Engel's Law, which asserts that the share of total income spent on food declines as income grows, with Bennett's Law focusing specifically on the composition of food expenditure (Grigg, 1996; Manannalage et al., 2023). A dietary transition imposed by Bennett's Law is part of the broader "nutrition transition" seen as economies develop, where populations move away from cheap, energy-dense foods towards higher-quality, diverse diets (Drewnowski and Popkin, 1997).

Over the past few decades, major macroeconomic trends such as globalization, urbanization, and rising incomes have significantly changed what people eat, especially in developing countries. These changes are central to verifying whether Bennett's Law still holds in a globalized and increasingly interconnected world. A striking trend, mainly since the 1960s, is the growing convergence of global food consumption patterns, a phenomenon primarily driven by globalization (Bajan and Sowa, 2019). As economies develop and become more integrated into the global market, diets in wealthier regions tend to influence those in developing areas, resulting in what many researchers refer to as the "Westernization" of diets (Pingan, 2007). This shift toward processed foods, high sugar intake, and animal products is most noticeable in urban areas, where access to various food products has become the norm (Rae, 1998). Such urbanization processes and income growth support Bennett's Law as diets transition from traditional to more diverse compositions (Huang and Bouis, 2001).

Nonetheless, the verification of Bennett's Law is complicated by regional disparities. For instance, while food consumption patterns in many Asian and Latin American countries have indeed moved toward a more Westernized model, African countries present an outlier (Bajan et al., 2021). In Africa, the dietary shift has not been as pronounced, and in some cases, it has even diverged from global trends. The food consumption structure in Africa remains heavily dependent on staple cereals, even as incomes rise (Bajan and Sowa, 2019). This divergence calls into question the extent to which Bennett's Law applies universally, especially in regions where economic growth does not translate into the widespread availability of higher-quality food products. Moreover, rising environmental and health concerns have led to a countertrend in some high-income countries, with a growing preference for plant-based and environmentally sustainable diets (Janssen et al., 2016). This shift, driven by consumer preferences and policy interventions, could lead to a reversal of the trend predicted by Bennett's Law, as wealthier populations reduce their intake of animal products and processed foods in favor of diets more aligned with environmental sustainability goals.

The main goal of this article is to empirically test whether Bennett's Law still holds, given the changes in the population's food consumption patterns over the past half-century. To achieve this, we analyze Bennett's Law on a global scale by examining the relationship between GDP per capita, as a proxy for income (wealth), and the share of starchy staples in total caloric intake across different continents. We employ a panel regression model and perform a time-series regression analysis for each continent, offering a comprehensive, region-specific perspective on how economic development influences dietary composition. The novelty of this study lies in its global scope, using the newest data on food consumption patterns, revealing how the wealth-diet dynamic may differ across regions, and providing insights into the socioeconomic drivers of dietary shifts worldwide.

Literature review

Empirical evidence from various regions affirms Bennett's Law. However, some findings through the years are mixed. Studies show that Bennett's Law holds true in many contexts; however, several factors can moderate its effects, leading to variations in the rate of dietary transition. For instance, Manannalage et al. (2023) discussed that calorie deprivation may slow the dietary shift from starchy staples to nutrient-dense foods. Households with unsatiated calorie needs prioritize inexpensive, calorie-rich staples, delaying the transition to a more diverse diet. Geographic and infrastructural barriers also play a role in moderating Bennett's Law. For instance, households in rural areas with limited access to markets may be slower to adopt more diverse diets, even as their incomes rise (Ansah et al., 2020).

In some regions, cultural preferences for certain foods, particularly starchy staples, persist even as incomes grow. For example, Filippini and Srinivasan (2019) noted that in India, where vegetarianism is prevalent, rising incomes do not necessarily lead to a shift toward animal-based proteins. Instead, dietary diversification occurs within the bounds of cultural norms, especially for members of religious groups. Such findings are further supported by Gouel and Guimbard (2019), who found that food consumption patterns in culturally conservative societies are less elastic and less influenced by income, leading to a slower transition away from starchy staples.

Another factor contributing to the slow transition of food consumption patterns is government intervention. For instance, Pingali (2007) and Timmer et al. (1984) highlight how government policies in countries like India and China have maintained low prices for rice and wheat, distorting the natural food demand pattern expected under Bennett's Law. As a result, even wealthier households may continue to consume a high proportion of starchy staples because they are economically attractive relative to other food options (Reardon and Timmer, 2014).

While Bennett's Law traditionally emphasizes a shift toward animal-based proteins and other nutrient-dense foods as incomes rise, modern food technology is introducing new, affordable alternatives to these products, potentially altering the expected dietary transition. For instance, Drewnowski (2024) examined the rising availability of plant-based proteins and processed foods, which are becoming more affordable and accessible, even in low- and middle-income countries (LMICs). Another factor influencing food consumption patterns in LMICs is the lack of nutrition education. Choudhury et al. (2019) demonstrated that many households do not diversify their diets despite rising incomes due to limited food literacy and knowledge about the benefits of more expensive food groups like meat, fruits, and vegetables.

Historical dietary shifts in 19th-century Europe and North America mirror Bennett's Law.

As incomes rose, populations moved away from cheap staples like potatoes toward more diverse, high-quality foods such as meat and dairy (Fuglie, 2004). Grigg (1996) also proves that caloric intake from starchy staples remains high in poorer countries but declines as incomes grow. This trend has been observed consistently in developing regions like Africa and Asia, where staples dominate diets but are gradually replaced by more nutrient-dense foods. Drewnowski and Popkin (1997) documented how rising incomes in Africa have led to a gradual reduction in the consumption of traditional starchy staples, like maize and cassava, with increased spending on processed foods, oils, and animal products.

Further evidence is provided by Ansah et al. (2020), who found that in Ghana, dietary patterns shift away from starchy staples towards more diverse food groups, including fish, meat, and dairy. This pattern is consistent across urban and rural settings, though urban households tend to spend a higher share of their budget on non-starchy foods. The study also confirms that female-headed households in Ghana allocate more of their food budget to diverse, nutrient-rich foods than their male counterparts.

Choudhury et al. (2019) extended the analysis of Bennett's Law to infant diets, showing that wealthier households tend to introduce more diverse and nutrient-dense foods to their children earlier than poorer households. In the aforementioned studies in Sri Lanka, Manannalage et al. (2023) found that once calorie demands are satisfied, households reduce their consumption of staples and increase spending on non-starchy foods, thus affirming Bennett's Law. Also, Drewnowski (2024) argues that despite the growing presence of alternative plant-based proteins, the aspirational demand for animal proteins remains strong, particularly in developing regions where rising incomes continue to drive demand for high-quality animal-sourced proteins.

Material and methods

Data and its limitations

All the data used in this article come from the open-source data of the Food and Agriculture Organization of the United Nations (FAO). We used data from the FAO food balance sheets to determine the proportion of starchy staples in the average diet (FAO, 2024). It's important to note that while FAO data reflect the food supply available on the market, we refer to it as 'consumption' throughout this paper for simplicity. However, this term doesn't account for food losses at the household level. Despite this limitation, FAO data remain a dependable source for understanding consumption trends, as confirmed by studies that have successfully used food balance sheets to analyze dietary patterns (Unar-Mungala et al., 2019; Bajan et al., 2021).

We used GDP per capita in constant prices as a proxy for the income (wealth) of households in the region. It offers an average income figure but has limitations in the consumption patterns analysis. The main concern is that GDP per capita may not accurately represent food access differences and income disparities within a population. However, a comparison of starchy staple consumption and GDP per capita gives reliable macro trend approximation, which is confirmed by previous studies. The most famous example of such study was probably done by Grigg (1996), who plotted Gross National Product per capita against starchy staple ratios in a long-run analysis of several regions in the world.

Estimation strategy

Our calculation strategy was to first regress GDP per capita with a share of starchy staples based on panel data for six continents and then to regress it for each continent separately. The first step was to ensure the robustness of the models through a series of statistical tests, and after that, the regressions were run.

We employed the Fisher-type panel unit root test to assess the stationarity of GDP per capita in the panel data, which aggregates individual augmented Dickey-Fuller (ADF) test results across panels (Maddala and Wu, 1999). The ADF equation is specified as follows:

$$\Delta y_{it} = \alpha_i + \rho y_{i,t-1} + \sum_{j=1}^{p} \gamma_j \Delta y_{i,t-j} + \epsilon_{it} \tag{1}$$

where: y_{it} represents GDP per capita for panel i at time t, Δy_{it} is the first difference to address potential non-stationarity, α_i is a panel-specific intercept, ρ tests for a unit root (with $\rho = 0$ indicating non-stationarity), $\sum_{j=1}^{p} \gamma_j \Delta y_{i,t-j}$ includes lagged terms to control for autocorrelation, and ϵ_{it} is the error term.

The null hypothesis H_0: $\rho = 0$ (all panels contain a unit root) was tested against

H_1: $\rho < 0$ (stationarity in at least some panels). This step confirmed whether differencing was required to ensure reliable estimation results (Levin et al., 2002).

We next examined serial correlation in the residuals using the Wooldridge test for autocorrelation (Wooldridge, 2002). The test assumes a first-order autoregressive process in the error terms:

$$\epsilon_{it} = \rho\epsilon_{i,t-1} + u_{it} \quad (2)$$

where: ϵ_{it} is the residual for panel i at time t, ρ is the coefficient that indicates first-order autocorrelation, and u_{it} is a white-noise error term.

The null hypothesis H_0: $\rho = 0$ (no autocorrelation) was tested against H_1: $\rho \neq 0$ (presence of autocorrelation). Clustering or alternative adjustments are warranted if serial correlation is present to obtain accurate standard errors.

To determine the appropriate panel model, we performed a Hausman test (Hausman, 1978), comparing the fixed-effects (FE) and random-effects (RE) specifications. The Hausman test statistic is calculated as follows:

$$H = (b_{RE} - b_{FE})'[Var(b_{RE}) - Var(b_{FE})]^{-1}(b_{RE} - b_{FE}) \quad (3)$$

where: b_{RE} and b_{FE} are the coefficient vectors for the RE and FE models, respectively. A significant H value indicates a correlation between the random effects and regressors, validating the use of an FE model.

To verify the presence of homoskedasticity across groups in our panel model, we employed the Modified Wald test for groupwise heteroskedasticity. The test statistic for the Modified Wald test for fixed effects is calculated as (Wooldridge, 2010):

$$W = \sum_{i=1}^{N} (\frac{e_i' e_i}{\sigma^2} - T_i)^2 \quad (4)$$

where: e_i is the vector of residuals for group i, σ is the hypothesized common variance across groups under the null hypothesis of homoskedasticity, T_i is the number of periods for group i, and N is the total number of groups.

To verify the presence of homoskedasticity (constant error variance across groups) with the alternative hypothesis that heteroskedasticity is present (error variances differ across groups).

We tried to keep the same approach as the panel model in the time series models (model for each continent). Similarly, we first employed a stationarity check using the Dickey-Fuller test, as in equation 1, and adjusted it for time series data. To verify the absence of autocorrelation in the time series, we conducted the Durbin-Watson (DW) test for first-order autocorrelation in the residuals from a regression model, as follows (Durbin and Watson, 1971):

$$DW = \frac{\sum_{t=2}^{T}(\epsilon_t - \epsilon_{t-1})^2}{\sum_{t=1}^{T}\epsilon_t^2} \quad (5)$$

where: ϵ_t represents the residuals.

A DW statistic close to 2 suggests no first-order autocorrelation, while values significantly different from 2 indicate potential positive or negative autocorrelation (Durbin and Watson, 1951).

To detect potential heteroskedasticity in our time series models, we used the Breusch-Pagan / Cook-Weisberg test. The Breusch-Pagan test statistic is derived from the regression residuals and calculated as follows:

$$\chi^2 = \frac{1}{2}(\sum_{i=1}^{n}\frac{\hat{\epsilon}_i^2}{\sigma^2} - n)^2 \quad (6)$$

where: n is the sample size, $\hat{\epsilon}_i^2$ represents the squared residuals from the initial regression model, and σ^2 is the assumed constant variance under the null hypothesis.

The Breusch-Pagan test evaluates the null hypothesis that the error variance is homoskedastic against the alternative hypothesis that the variance changes with the independent variables.

Detecting autocorrelation or heteroskedasticity would suggest a need for additional adjustments in the error structure to ensure reliable inference. Therefore, we use robust standard errors with the Newey-West procedure in such cases. The estimator corrects for both heteroskedasticity and autocorrelation, providing consistent standard errors when serial correlation exists in time series data. The Newey-West estimator modifies the Ordinary least squares (OLS) variance-covariance matrix by incorporating weighted autocovariances up to a specified lag q (lag(1) in our case). The formula for the Newey-West covariance matrix is (Newey and West, 1987):

$$\hat{\Sigma}_{NW} = \hat{\Sigma}_{OLS} + \sum_{k=1}^{q}(1 - \frac{k}{q+1})(\Gamma_k + \Gamma'_k) \quad (7)$$

where:

$\widehat{\Sigma}_{OLS} = \frac{1}{T}\sum_{t=1}^{T} \epsilon_t^2 X_t X_{t-k}'$ is the traditional OLS covariance matrix,

$\Gamma_k = \frac{1}{T}\sum_{t=k+1}^{T} \epsilon_t \epsilon_{t-k} X_t X_{t-k}'$ is the lag-k autocovariance of the residuals, T is the total number of observations, ϵ_t is the residual at time t, X_t is the vector of regressors at time t.

Model specification

Based on statistical tests conducted for the panel data, we established strong evidence of unit root for GDP per capita and share of starchy staples (Table 1). Therefore, we applied the first difference to our variables and reran the Fisher-type unit-root test. The results for differentiated data showed stationarity, assuming a significance level of 0.05 (Table 1).

Then, we employed the rest of the statistical tests as described in the estimation strategy, interpreting it at the 5% significance level. We found that in our data, there is no autocorrelation based on the high p-value of the Wooldridge test (Table 2.). The heteroskedasticity is present, based on the low p-value of the Wald test (Table 2.), and the fixed effects model is more appropriate, based on the low p-value for the Hausman test (Table 2.).

To address potential heteroskedasticity, we applied robust clustered standard errors. The FE model is specified as:

$$\Delta Share\ of\ starchy\ staples_{it} = \alpha_1 + \beta \cdot \Delta GDP\ per\ capita_{it} + \epsilon_{it} \quad (8)$$

where: Δ represents the differentiation of variable, α_i represents time-invariant fixed effects, β is the estimated coefficient for GDP per capita, and ϵ_{it} is the error term.

In the case of time series data, we established a high probability of unit root for GDP per capita and share of starchy staples, except for Oceania in the latter case (Table 3). Therefore, we applied the first difference to our variables and reran the ADF test. After the differentiation, there is no evidence of unit root in the data.

Durbin-Watson's test for autocorrelation showed no autocorrelation issues in Africa, Europe, Asia, and North America. We based our interpretation on a well-established view that d-statistic between 1.5 and 2.5 is proof of the absence of strong autocorrelation (Green, 2018). Thus, autocorrelation is detected in the case of Oceania and South America. Moreover, in the case of South America, we detected heteroskedasticity based on the low p-value of the Breusch-Pagan test (Table 3). Therefore, to adjust for autocorrelation or/and heteroskedasticity, we used robust standard errors with the Newey-West procedure in the case of Oceania and South America.

Variable	Statistical Measure	Statistic			
		Inverse chi-squared (P)	Inverse normal (Z)	Inverse logit t(L*)	Modified inv. chi-squared (Pm)
GDP_per_capita	value	1.5300	2.6610	2.5911	-2.1372
	p-value	0.9999	0.9961	0.9926	0.9837
d_GDP_per_capita	value	115.0726	-8.4480	-13.1062	21.0396
	p-value	0.0000	0.0000	0.0000	0.0000
Share_of_Starchy_Staples	value	12.3925	0.8365	0.7484	0.0801
	p-value	0.4147	0.7986	0.7703	0.4681
d_Share_of_Starchy_Staples	value	144.6216	-10.4335	-16.5276	27.0713
	p-value	0.0000	0.0000	0.0000	0.0000

Source: own computation in the STATA 15, based on FAO data

Table 1: Results of the Fisher-type unit-root test for panel data.

Test	Statistic	value	p-value
Wooldridge test for autocorrelation	F	0.1080	0.7555
Hausman FE/RE model	Chi-squared	9.4100	0.0022
Modified Wald test	Chi-squared	28.7300	0.0001

Source: own computation in the STATA 15, based on FAO data

Table 2: Statistical tests for panel data.

Region	Africa	Europe	Asia	Oceania	South America	North America
ADF test GDP_per_Capita	0.9486	0.7416	1.0000	0.9670	0.6091	0.9116
ADF test d_GDP_per_Capita	0.0000	0.0000	0.0017	0.0000	0.0000	0.0000
ADF test Share_of_Starchy_Staples	0.5905	0.6128	0.9804	0.0123	0.7385	0.7398
ADF test d_Share_of_Starchy_Staples	0.0000	0.0000	0.0000	-	0.0000	0.0000
Durbin-Watson d-statistic	1.8163	1.7149	2.3056	0.7136	2.5098	1.8148
Breusch-Pagan / Cook-Weisberg	0.6630	0.6197	0.7387	0.7022	0.0289	0.9233

Source: own computation in the STATA 15, based on FAO data

Table 3: P-values of statistical tests for time series data.

Results and discussion

The African continent has the lowest GDP per capita, with a maximum of around 2 thousand USD. Over the years, a distinct upward trend in GDP per capita is observed across Asia, Europe, Oceania, and North America. North America reached the highest GDP per capita in 2021, exceeding 46 thousand USD, which is more than twenty times that of Africa (Figure 1). A clear opposite trend between GDP per capita and the share of starchy foods in the diet could be observed in Asia and South America during the study period. To some extent, Europe is also characterized by such relations. However, it was primarily significant in the 1970s and 1980s. After the collapse of the Soviet Union, the relation between GDP per capita and starchy staples consumption in newly shaped Europe is unclear. The highest proportion of starch in total caloric intake is found in less economically developed regions, such as Africa, where starch accounts for more than 60% of the diet, and Asia, where the share of starchy staples in the diet was even higher for an extended period.

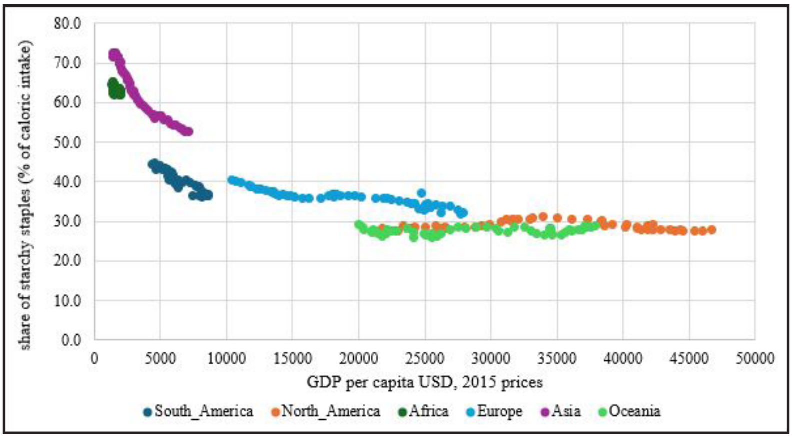
Oceania serves as a contrasting example, with the lowest proportion of starch-rich foods in the diet; here, the share of starchy foods consistently remained below 30% during the study period, reaching a minimum value of 26%. North America is the second continent with the lowest proportion of starch-rich foods in the overall diet, with values ranging between 27% and 31%, alongside the highest GDP per capita among all continents. In both cases, there is no evident trend in the percentage of starchy staple consumption, as it fluctuates.

The panel regression analysis indicates that the change in GDP per capita is not significantly associated with changes in the share of starchy staples, as shown by a non-significant coefficient (0.0000675, $p = 0.354$) (Table 4). The model's within-group R2 is 0.0099, suggesting that changes in GDP per capita within continents explain a minimal variation in the dependent variable. The constant is significant (-0.1461, $p < 0.001$), reflecting a baseline decline in d_Share_of_Starchy_Staples across groups, though this result does not imply a causal effect given the independent variable's non-significance.

An OLS regression was conducted to analyze the relationship between the GDP per capita change and the share of starchy staples in Africa. Table 4 shows that the coefficient for d_GDP_per_Capita is -0.0009683 ($p = 0.509$), indicating no statistically significant relationship (Table 4). The model's R2 is 0.0089, suggesting that less than 1% of the variation in d_Share_of_Starchy_Staples is explained by changes in GDP per capita. The constant term is also not significant.

In Asia, the coefficient for d_GDP_per_Capita is -0.0005761 ($p = 0.399$), indicating no statistically significant association (Table 4). The model's R2 is 0.0145, suggesting that only 1.45% of the variation in d_Share_of_Starchy_Staples is explained by changes in GDP per capita. However, the constant term is significant ($p = 0.002$), indicating a baseline trend in the dependent variable.

For North America, the coefficient for d_GDP_per_Capita is -0.0001105 ($p = 0.133$), suggesting no statistically significant relationship (Table 4). The model's R2 is 0.0455, indicating that approximately 4.55% of the variation in d_Share_of_Starchy_Staples is explained by changes in GDP per capita. The constant term is also not significant.



Source: Own elaboration based on FAOstat data.

Figure 1: Relationship between GDP per Capita and Share of Starchy Staples in Caloric Intake Across Continents.

Variable	Panel	Africa	Asia	North America	Europe	Oceania	South America
d_GDP_per_Capita	0.000067 (0.000066)	-0.00097 (0.001456)	-0.000576 (0.0006777)	-0.0001105 (0.0000723)	0.0001333*** (0.0000313)	0.0000945 (0.0003424)	-0.0008728*** (0.0002805)
Constant	-0.1461*** (0.0152)	-0.03964 (0.061262)	-0.326816*** (0.0987807)	0.0476612 (0.0604273)	-0.2141*** (0.0477)	27.5257*** (0.1830)	-0.0965* (0.0540)
Nr. of Observations	306	51	51	51	51	51	51
F-Statistic	1.04	0.44	0.72	2.34	18.09	0.08	9.68
Prob > F	0.3543	0.5092	0.3994	0.1327	0.0001	0.7837	0.0031
R-squared	0.0148	0.0089	0.0145	0.0455	0.2696		

Note:*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ (standard errors in parentheses)
Source: own computation in the STATA 15, based on FAO data

Table 4: Results of regression models for Starchy Staples Share and GDP per Capita.

For Europe, the coefficient for d_GDP_per_Capita is 0.0001333 ($p = 0.000$), indicating a statistically significant positive relationship (Table 4). This suggests that increases in GDP per capita are associated with increases in the share of starchy staples in Europe, contrary to Bennett's Law. The model's R2 is 0.2696, meaning that about 27% of the variation in d_Share_of_Starchy_Staples is explained by changes in GDP per capita. The constant is also significant and negative, indicating a baseline downward trend in the share of starchy staples, independent of GDP growth. Together, these results imply that while GDP growth may positively impact the share of starchy staples, a broader downward trend remains in place.

A regression with Newey-West standard errors was conducted to assess the relationship between GDP per capita growth (d_GDP_per_Capita) and the share of starchy staples (Share_of_Starchy_Staples) in Oceania, accounting for potential autocorrelation with a lag of 1. The coefficient for d_GDP_per_Capita is 0.0000945 ($p = 0.784$), indicating no statistically significant relationship (Table 4). The constant term is significant ($p < 0.001$), with a coefficient of 27.5257, suggesting an average level of starchy staples share that remains consistent over time.

The same type of regression was conducted for South America. However, Share_of_Starchy_Staples was differentiated. The coefficient for d_GDP_per_Capita is -0.0008728 ($p = 0.003$), indicating a statistically significant negative relationship (Table 4).

This suggests that increases in GDP per capita are associated with a decrease in the share of starchy staples, confirming that Bennett's Law holds in South America. The constant term is not significant at the 5% significance level. However, it is significant at a 10% significance level ($p = 0.080$), indicating a slight downward trend in starchy staples shares.

Confirming Bennett's Law in South America aligns with established theories on dietary transitions in developing regions. Economic growth in South

America has spurred increased access to various foods, leading to diversified diets less reliant on starchy staples (Pingali, 2007). Urbanization has further contributed to this shift; as people move to urban areas, they gain exposure to diverse food markets, with greater availability of non-staple foods like fruits, vegetables, and animal products, encouraging dietary shifts as incomes rise (Rae, 1998). Additionally, in several South American countries, dietary policies and food subsidies have made it economically feasible for households to opt for more nutrient-dense foods, accelerating the departure from starchy staples (Huang and Bouis, 2001).

Another significant factor is the aspiration for Western dietary patterns, which are common in many developing regions experiencing income growth and globalization. Studies indicate that as urban middle-class populations grow, so does the influence of Western diets high in protein-rich animal products, processed foods, and fresh produce (Azzam, 2021). This Western influence reinforces Bennett's Law in South America by shifting consumer preferences away from starchy staples as symbols of lower socioeconomic status toward diversified diets that signal upward mobility (Gouel and Guimbard, 2019).

Contrary to expectations, Europe presents increased starchy staple consumption with rising incomes, a phenomenon that runs counter to Bennett's Law. This deviation may stem from several unique socio-cultural and economic factors. Notably, contemporary dietary trends in Europe - such as vegetarianism, veganism, and plant-based diets - are partly influenced by environmental and ethical concerns, driving an increasing demand for plant-based foods, including whole grains and other starchy staples, often as substitutes for animal-based products (Jansen et al., 2016). This eco-conscious dietary shift aligns with broader trends in high-income societies where a reduction in meat consumption has coincided with a renewed focus on grain-based and other starchy staple foods (Meixner et al., 2024).

Additionally, the European market has seen significant growth in low-cost, processed starchy foods that appeal to health-conscious and budget-conscious consumers (Monteiro et al., 2013; Vandevijvere et al., 2019). Unlike in developing regions, where increased income typically shifts preferences away from staples, European consumers may prioritize sustainable, affordable, and versatile options, often opting for plant-based diets emphasizing starchy staples as primary energy sources.

Lastly, cultural preferences and established dietary patterns play a role. Europe's historical reliance on staples such as bread, pasta, and potatoes remains culturally ingrained, even among wealthier populations. Unlike in South America, where income growth shifts dietary preferences toward more Westernized patterns, Europe's entrenched culinary traditions persist, contributing to continued high consumption of starchy staples, albeit in varied forms adapted to modern dietary sensibilities (Dokova et al., 2022).

In examining Asia, Africa, North America, and Oceania, we observe that Bennett's Law does not exhibit significant applicability in these regions, as the expected relationship between rising income levels and reduced starchy staple consumption does not manifest consistently. We explore potential explanations, grounded in socioeconomic, cultural, and policy-related contexts, for why Bennett's Law may not hold firmly in these continents.

In the case of Asia, despite rapid economic growth and urbanization, it displays unique dietary dynamics that may inhibit the effects of Bennett's Law. In particular, cultural factors, including the high prevalence of vegetarianism, especially in South Asia, contribute to sustained high levels of starchy staple consumption (Lipoeto et al., 2015). Studies indicate that in Asian countries, dietary shifts towards animal proteins and other nutrient-dense foods are moderated by cultural preferences, which strongly rely on cereals, legumes, and rice as primary dietary components even as incomes rise (Chang et al., 2018). Economic policies and market conditions also play a role. Many Asian governments have historically supported the production and subsidization of staple grains like rice and wheat, making these foods more affordable relative to other options reinforcing their position as dietary mainstays (Mughal and Fontan Sers, 2020). Such policies create a price-sensitive market where, despite income growth, consumers continue to prioritize these low-cost staples over higher-priced animal products or imported foods. Starchy staples' affordability and cultural integration make them resilient against the dietary shifts predicted by Bennett's Law (Pingali, 2007).

In Africa, structural economic and market barriers moderate the application of Bennett's Law. Although certain regions experience rising incomes, persistent poverty in rural areas restricts many households from achieving the income levels required to diversify diets substantially. Consequently, most of the population remains heavily dependent on starchy staples such as maize, cassava, and sorghum, which are both locally available and affordable (Zhou and Staatz, 2016). Studies suggest that households in resource-limited settings prioritize meeting caloric needs with cost -effective staples, delaying or even negating the transition to nutrient-dense foods (Ansah et al., 2020). Additionally, limited access to diverse food markets, especially in rural areas, hampers dietary diversification (Douyon et al., 2022). Infrastructure deficiencies, such as poor transportation networks, limit access to various food products, keeping starchy staples the primary option. Unlike in more urbanized continents, Africa's infrastructural constraints restrict the influence of Bennett's Law, as even rising income fails to facilitate access to non-staple foods in many regions (Sibhatu et al., 2015; Fraval et al., 2019).

North America demonstrates a complex relationship between income and food consumption patterns, resulting in weak evidence for Bennett's Law. This complexity stems mainly from a bifurcated food market influenced by socioeconomic inequality (Otero et al., 2015). On one hand, wealthier segments of the population have shifted towards nutrient-dense, diverse diets in line with Bennett's predictions. On the other hand, lower-income households remain dependent on affordable, calorie-rich foods, which often include starchy staples but also highly processed options (Ricciuto and Tarasuk, 2007). As a result, dietary polarization undermines a consistent trend across income groups, complicating the broad applicability of Bennett's Law in this region.

Furthermore, there has been a rise in health-conscious diets favoring whole grains, increasing the demand for staple grains even among affluent consumers (Mancino and Kuchler, 2012). This dietary shift, driven by concerns about health, sustainability, and dietary fiber intake, aligns with rising interest in plant-based diets, leading to a maintained or even increased intake of starchy foods. Therefore, North America's mixed dietary landscape, influenced by economic disparity and health trends, creates an environment where Bennett's Law only partially applies, as both high- and low-income groups exhibit different staple consumption patterns (Liu et al., 2020).

Oceania includes both high-income countries, such as Australia and New Zealand, and smaller Pacific island nations with varying economic statuses. This economic diversity limits the general applicability of Bennett's Law because dietary shifts tied to income growth may manifest differently across these diverse settings. Smaller island nations often face geographic and infrastructural constraints that restrict access to imported or nutrient-diverse foods and lead to continued reliance on locally available starchy staples. Additionally, the high cost of importing fresh produce and animal-based proteins to island nations sustains the preference for affordable, energy-dense starchy foods (Thow et al., 2011). However, Australia has the most considerable influence on trends in the entire region. The historical emphasis on staple crops, particularly wheat, underlines Australia's cultural reliance on grains, a result of both British influence and longstanding agricultural practices (Argent, 2002). Wheat remains central to Australian farming due to its established role in local diets and export markets. This cultural and economic connection to grains persists, even as income rises, aligning with the arguments that productivism - focused on staple output - does not necessarily encourage dietary diversification (Lawrence et al., 2013). Deregulation and a competitive export market lead to heavy reliance on cost-efficient staple crops, limiting policy incentives for diversified food production that could otherwise shift consumption patterns away from staples as incomes rise (Dibden and Cocklin, 2005).

Conclusion

Our analysis supports Bennett's Law to varying degrees across different continents, confirming that economic development often correlates with dietary diversification away from starchy staples. In line with Bennett's prediction, continents with higher GDP per capita, such as North America and Oceania, display significantly lower consumption of starchy foods compared to less economically developed continents. In Africa and parts of Asia, however, starchy staples continue to dominate diets, reflecting persistent structural and economic limitations that restrict access to diverse food options even as incomes rise.

In South America, the study finds a clear inverse relationship between GDP per capita and the proportion of calories from starchy staples, suggesting that economic growth encourages dietary shifts toward higher-quality, nutrient-dense foods. This aligns well with Bennett's Law and may be influenced by urbanization, market accessibility, and changing consumer preferences toward Western dietary patterns. Europe presents an unexpected deviation from Bennett's Law, where an increase in starchy food consumption accompanies rising income. This phenomenon may reflect unique cultural factors, such as the rise in health and environmental consciousness, which promote plant-based diets that include a substantial share of grains and other starches.

Overall, the findings emphasize the importance of region-specific factors - including cultural dietary preferences, infrastructure, policy interventions, and socioeconomic conditions - that influence the applicability of Bennett's Law in different contexts. While economic growth broadly supports dietary diversification, as Bennett's Law suggests, local variables often modify this relationship, leading to distinct regional dietary trends. The study thus reinforces that while Bennett's Law provides a valuable framework for understanding global dietary transitions, its applicability must be viewed within individual regions' complex socioeconomic and cultural landscapes. Future research should investigate these factors further, particularly in areas where economic development alone does not predict dietary shifts, to enhance our understanding of food security and nutrition transitions in a rapidly globalizing world.

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References

[1] Ansah, I. G. K., Marfo, E. and Donkoh, S. A. (2020) "Food demand characteristics in Ghana: An application of the quadratic almost ideal demand system", *Scientific African*, Vol 8, p. e00293. ISSN 2468-2276. DOI 10.1016/j.sciaf.2020.e00293.

[2] Argent, N. (2002) "From pillar to post? In search of the post-productivist countryside in Australia", *Australian Geographer*, Vol. 33 No. 1, pp. 97-114. ISSN 0004-9182. DOI 10.1080/00049180220125033.

[3] Azzam, A. (2021) "Is the world converging to a 'Western diet'?", *Public Health Nutrition*, Vol. 24, No. 2, pp. 309-317. E-ISSN 1475-2727. DOI 10.1017/S136898002000350X.

[4] Bajan, B., Genstwa, N. and Smutka, L. (2021) "The similarity of food consumption patterns in selected EU countries combined with the similarity of food production and imports", *Agricultural Economics*, Vol. 67, No. 8, pp. 316-326. ISSN0169-5150. DOI 10.17221/307/2020-AGRICECON.

[5] Bajan, B. and Sowa, K. (2019) "Food consumption models around the world in the context of globalization", *Intercathedra*, Vol. 3, No. 40, pp. 219-226. ISSN 1640-3622. DOI 10.17306/J.INTERCATHEDRA.2019.00081.

[6] Bennett, M. K. (1941) "Wheat in national diets", *Wheat Studies of the Food Research Institute*, Vol. 18, No .2, pp. 37-76. ISSN 0097-3467.

[7] Chang, X., DeFries, R. S., Liu, L. and Davis, K. (2018) "Understanding dietary and staple food transitions in China from multiple scales", *PloS one*, Vol. 13, No. 4, p. e0195775. ISSN 1932-6203. DOI 10.1371/journal.pone.0195775.

[8] Choudhury, S., Headey, D. D. and Masters, W. A. (2019) "First foods: Diet quality among infants aged 6-23 months in 42 countries", *Food Policy*, Vol. 88, p. 101762. ISSN 0306-9192. DOI 10.1016/j.foodpol.2019.101762.

[9] Dibden, J. and Cocklin, C. (2005) "Sustainability and agri-environmental governance", In: Cocklin, C. and Dibden, J. (Eds.) "*Agricultural Governance Globalization and the New Politics of Regulation*", pp. 151-168. London, Routledge. ISBN 9780415543910.

[10] Dokova, K. G., Pancheva, R. Z., Usheva, N. V., Haralanova, G. A., Nikolova, S. P., Kostadinova, T. I. and Aleksandrova, K. (2022) "Nutrition transition in europe: East-west dimensions in the last 30 Years—A narrative review", *Frontiers in Nutrition*, Vol. 9, p. 919112. ISSN 2296-861X. DOI 10.3389/fnut.2022.919112.

[11] Douyon, A. Worou, O. N., Diama, A., Badolo, F., Denou, R. K., Touré, S., and Tabo, R. (2022) "Impact of crop diversification on household food and nutrition security in southern and central Mali", *Frontiers in Sustainable Food Systems*, Vol. 5, p. 751349. ISSN 2571-581X. DOI 10.3389/fsufs.2021.751349.

[12] Drewnowski, A. (2024) "Alternative proteins in low- and middle-income countries face a questionable future: Will technology negate Bennett’s Law?", *Current Developments in Nutrition*, Vol. 8, p. 01994. ISSN 2475-2991. DOI 10.1016/j.cdnut.2023.101994.

[13] Drewnowski, A. and Popkin, B. M. (1997) "The nutrition transition: New trends in the global diet", *Nutrition Reviews*, Vol. 55, No. 2, pp. 31-43. ISSN 0029-6643. DOI 10.1111/j.1753-4887.1997.tb01593.x.

[14] Durbin, J. and Watson, G. S. (1951) "Testing for Serial Correlation in Least Squares Regression II", *Biometrika*, Vol. 38 No.1/2, pp. 159-178. ISSN 0006-3444. DOI 10.1093/biomet/38.1-2.159.

[15] Durbin, J. and Watson, G. S. (1971) "Testing for Serial Correlation in Least Squares Regression III", *Biometrika*, Vol. 58, No. 1, pp. 1-19. ISSN 0006-3444. DOI 10.1093/biomet/58.1.1.

[16] FAO (2024) "*Food Balance Sheet*". Food and Agriculture Organization of the United Nations. [Online]. Available: http://www.fao.org/faostat/en/#data/FBS [Accessed: 19 Feb. 2024].

[17] Filippini, M. and Srinivasan, S. (2019) "Impact of religious participation, social interactions and globalization on meat consumption: Evidence from India", *Energy Economics*, Vol. 84, p. 104550. ISSN 0140-9883. DOI 10.1016/j.eneco.2019.104550.

[18] Fraval, S., Hammond, J., Bogard, J. R., Ng'endo, M., van Etten, J., Herrero, M. and van Wijk, M. T. (2019) "Food access deficiencies in sub-Saharan Africa: prevalence and implications for agricultural interventions", *Frontiers in Sustainable Food Systems*, Vol. 3, No. 104. ISSN 2571-581X. DOI 10.3389/fsufs.2019.00104.

[19] Fuglie, K. O. (2004) "Challenging Bennett's Law: The new economics of starchy staples in Asia", *Food Policy*, Vol. 29, No. 2, pp. 187-202. ISSN 0306-9192. DOI 10.1016/j.foodpol.2004.03.003.

[20] Gouel, C. and Guimbard, H. (2019) "Nutrition transition and the structure of global food demand", *American Journal of Agricultural Economics*, Vol. 101, No. 2, pp. 383-403. ISSN 0002-9114. DOI 10.1093/ajae/aay030.

[21] Greene, W. H. (2018) "*Econometric analysis*", 8th ed., New York, Pearson. ISBN 978-1-292-23113-6.

[22] Grigg, D. (1996) "The starchy staples in world food consumption", *Annals of the Association of American Geographers*, Vol. 86, No. 3, pp. 412-431. ISSN 0004-5608. DOI 10.1111/j.1467-8306.1996.tb01760.x.

[23] Hausman, J. A. (1978) "Specification Tests in Econometrics", *Econometrica*, Vol. 46, No. 6, pp. 1251-1271. ISSN 0012-9682. DOI 10.2307/1913827.

[24] Huang, J. and Bouis, H. (2001) "Structural changes in the demand for food in Asia: Empirical evidence from Taiwan", *Agricultural Economics*, Vol. 26, No. 1, pp. 57-69. ISSN 0169-5150. DOI 10.1111/j.1574-0862.2001.tb00054.x.

[25] Janssen, M., Busch, C., Rödiger, M. and Hamm, U. (2016) "Motives of consumers following a vegan diet and their attitudes towards animal agriculture", *Appetite*, Vol. 105, pp. 643-651. ISSN 0195-6663. DOI 10.1016/j.appet.2016.06.039.

[26] Lawrence, G., Richards, C. and Lyons, K. (2013) "Food security in Australia in an era of neoliberalism, productivism and climate change", *Journal of Rural Studies*, Vol. 29, pp. 30-39. ISSN 0743-0167. DOI 10.1016/j.jrurstud.2011.12.005.

[27] Levin, A., Lin, C.-F. and Chu, C.-S. J. (2002) "Unit root tests in panel data: asymptotic and finite -sample properties", *Journal of Econometrics*, Vol. 108, No. 1, pp. 1-24. ISSN 0304-4076. DOI 10.1016/S0304-4076(01)00098-7.

[28] Lipoeto, N. I., Lin, K. G. and Angeles-Agdeppa, I. (2013) "Food consumption patterns and nutrition transition in South-East Asia", *Public Health Nutrition*, Vol. 16, No. 9 , pp. 1637-1643. ISSN 1368-9800. DOI 10.1017/S1368980012004569.

[29] Liu, J., Rehm, C. D., Micha, R. and Mozaffarian, D. (2020) "Quality of meals consumed by US adults at full-service and fast-food restaurants, 2003–2016: persistent low quality and widening disparities", *The Journal of Nutrition*, Vol. 150, No. 4, pp. 873-883. ISSN 2211-9124. DOI 10.1093/jn/nxz299.

[30] Maddala, G. S. and Wu, S. (1999) "A comparative study of unit root tests with panel data and a new simple test", *Oxford Bulletin of Economics and Statistics*, Vol. 61, No. S1, pp. 631-652. ISSN 0305-9049. DOI 10.1111/1468-0084.0610s1631.

[31] Manannalage, K. M. L. R., Chai, A. and Ratnasiri, S. (2023) "Eating to live or living to eat? Exploring the link between calorie satiation, Bennett's Law, and food preferences", *Journal of Evolutionary Economics*, Vol. 33, pp. 1197-1236. ISSN 0936-9937. DOI 10.1007/s00191-023-00828-4.

[32] Mancino, L. and Kuchler, F. (2012) "Demand for whole-grain bread before and after the release of dietary guidelines", *Applied Economic Perspectives and Policy,* Vol. 34, No. 1, pp. 76-101. ISSN 2040-5804. DOI 10.1093/aepp/ppr035.

[33] Meixner, O., Malleier, M. and Haas, R. (2024) "Towards Sustainable Eating Habits of Generation Z: Perception of and Willingness to Pay for Plant-Based Meat Alternatives", *Sustainability*, Vol. 16, No. 8, p. 3414. ISSN 2071-1050. DOI 10.3390/su16083414.

[34] Monteiro, C. A., Moubarac, J.-C., Cannon, G., Ng, S. W. and Popkin, B. (2013) "Ultra-processed products are becoming dominant in the global food system", *Obesity Reviews*, Vol. 14, No. S2, pp. 21-28. ISSN 1467-7881. DOI 10.1111/obr.12107.

[35] Mughal, M. and Fontan Sers, C. (2020) "Cereal production, undernourishment, and food insecurity in South Asia", *Review of Development Economics*, Vol. 24, No. 2, pp. 524-545. ISSN 1363-6669. DOI 10.1111/rode.12659.

[36] Newey, W. K. and West, K. D. (1987) "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix", *Econometrica*, Vol. 55, No. 3, pp. 703-708. ISSN 0012-9682. DOI 10.2307/1913610.

[37] Otero, G., Pechlaner, G., Liberman, G. and Gürcan, E. (2015) "The neoliberal diet and inequality in the United States", *Social Science & Medicine*, Vol. 142, pp. 47-55. ISSN 0277-9536. DOI 10.1016/j.socscimed.2015.08.005.

[38] Pingali, P. (2007) "Westernization of Asian diets and the transformation of food systems: Implications for research and policy", *Food Policy*, Vol. 32, No. 3, pp. 281-298. ISSN 0306-9192. DOI 10.1016/j.foodpol.2006.08.001.

[39] Rae, A. N. (1998) "The effects of expenditure growth and urbanisation on food consumption in East Asia: A note on animal products", *Agricultural Economics*, Vol. 18, No. 3, pp. 291-299. ISSN 0169-5150. DOI 10.1111/j.1574-0862.1998.tb00506.x.

[40] Reardon, T. and Timmer, C. P. (2014) "Five inter-linked transformations in the Asian agrifood economy: Food security implications", *Global Food Security*, Vol. 3, No. 2, pp. 108-117. ISSN 2211-9124. DOI 10.1016/j.gfs.2014.02.001.

[41] Ricciuto, L. E. and Tarasuk, V. S. (2007) "An examination of income-related disparities in the nutritional quality of food selections among Canadian households from 1986–2001", *Social Science & Medicine*, Vol. 64, No. 1, pp. 186-198. ISSN 0277-9536. DOI 10.1016/j.socscimed.2006.08.020.

[42] Sibhatu, K. T., Krishna, V. V. and Qaim, M. (2015) "Production diversity and dietary diversity in smallholder farm households", Proceedings of the National Academy of Sciences, Vol. 112, No. 34, pp. 10657-10662. ISSN 0027-8424. DOI 10.1073/pnas.151098211.

[43] Thow, A. M., Heywood, P., Schultz, J., Quested, C., Jan, S. and Colagiuri, S. (2011) "Trade and the nutrition transition: strengthening policy for health in the Pacific", *Ecology of Food And Nutrition*, Vol. 50, No. 1, pp. 18-42. ISSN 0367-0244. DOI 10.1080/03670244.2010.524104.

[44] Timmer, C. P., Falcon, W. P. and Pearson, S. R. (1984) "*Food Policy Analysis*", Baltimore, Johns Hopkins University Press. ISBN 0-8018-3072-9.

[45] Unar-Munguía, M., Monterubio Flores, E. and Colchero, M. A. (2019) "Apparent consumption of caloric sweeteners in¬creased after the implementation of NAFTA in Mexico", *Food Policy*, Vol. 84, pp. 103-110. ISSN 0306-9192. DOI 10.1016/j.foodpol.2019.03.004.

[46] Vandevijvere, S., De Ridder, K., Fiolet, T., Bel, S. and Tafforeau, J. (2019) "Consumption of ultra-processed food products and diet quality among children, adolescents, and adults in Belgium", *European Journal of Nutrition*, Vol. 58, No. 8, pp. 3267-3278. ISSN 1436-6207. DOI 10.1007/s00394-018-1870-3.

[47] Wooldridge, J. M. (2002) "*Econometric Analysis of Cross Section and Panel Data*", London, MIT Press. ISBN 0-262-23219-7.

[48] Wooldridge, J. M. (2010) "Econometric Analysis of Cross Section and Panel Data", 2nd ed., London, MIT Press. ISBN 978-02-622-3258-6.

[49] Zhou, Y. and Staatz, J. (2016) "Projected demand and supply for various foods in West Africa: Implications for investments and food policy", *Food Policy*, Vol. 61, pp. 198-212. ISSN 0306-9192. DOI 10.1016/j.foodpol.2016.04.002.