Productivity Growth in the Caribbean: A Measure of Key Components

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Abstract: Malmquist indexes of multifactor productivity (MFP) in the agricultural sectors were estimated for the period 1961 to 1991. The selected Caribbean countries were: Cuba, Dominican Republic, Guyana, Jamaica, Suriname and Trinidad & Tobago. The Malmquist indexes were further partitioned into indexes of relative efficiency change and technical change. *All countries* exhibited, on average, a decline in agricultural productivity over the sample period. Jamaica displayed the smallest average productivity fall of 0.7%, followed by Guyana and Trinidad & Tobago (both 0.8%). The largest average decline was by Cuba (3.2%). Out of a total 30 periods of innovation, Cuba lead the set with 16 contributions. This was followed by Trinidad & Tobago and Jamaica, with 14 and 13 contributions, respectively. Guyana made only one contribution to a shift in the production frontier. Estimates of the Malmquist productivity index for Jamaica and Trinidad & Tobago were also compared to Törnqvist-Theil estimates of MFP for 1963 to 1990. The average rate of growth for these two countries were –0.9% and –0.6% respectively.

Keywords: Multifactor Productivity, Malmquist Indexes, Caribbean Agriculture, Relative Efficiency, Technical Efficiency

1. Introduction

For centuries, the economies of Caribbean countries have relied extensively on the production and export of agricultural products, most notably sugar and bananas. In most of these countries, a significant portion of the population still depends on the agricultural sector. Governments often adopt policies that keep large numbers of workers in this sector. These policies have done little to improve productivity in the sector. Consequently, these workers, and their families find themselves in a situation of mean poverty with few prospects for improvement. Productivity increases in agricultural production are needed to improve the well being of farm families, and to free labor to support productive non-agricultural sectors of the economies.

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In planning strategies to enhance the agricultural sector, or in assessing the success of past policies, it is helpful to have some measure of productivity which is easily computed, and which can also provide comparison with other countries. This paper calculates and evaluates Malmquist multifactor productivity indexes for the agricultural sector of selected Caribbean countries, and assesses the source of growth.

Section 2 reviews the Malmquist output-based productivity[1] index, its underlying components and the programming models used for its estimation. Section 3 discusses the values of the indexes derived and their components, and the contribution of each country to innovation. Section 4 compares the Malmquist productivity index to that of the Törnqvist-Theil for Jamaica and Trinidad & Tobago. Some concluding remarks are made in Section 5.

2. Malmquist Indexes

Malmquist productivity indexes, were developed by Caves, Christensen and Diewert (1982), who constructed these measures for technologies with varying returns to scale. They assumed overall efficiency -- as defined by Farrell (1957) -- and a translog structure for the output distance functions, which provides the foundation for the index. Caves *et al.* found that even though the index could not be estimated directly, the geometric mean of two Malmquist productivity indexes was equivalent to a scaled Törnqvist-Theil productivity index.

Subsequently, Färe *et al.* (1992) developed a non-parametric approach for

[1] In this paper, we are using the term productivity to mean multifactor productivity (MFP), which is generally defined as the ratio of a quantitative index of outputs (Y) to a quantitative index of the inputs (X) used. Further, the terms Malmquist productivity index and Malmquist index will be used interchangeably, and will refer to output-based measures, unless otherwise noted.

calculating a Malmquist (input-based) index. Here, inefficiencies in production were allowed, and the underlying production function was not assumed to have a specific functional form. The Malmquist index therefore differentiated between changes in relative efficiency and shifts in the production frontier. This index is based on output distance functions, which are independent of the units of measurement of the data. Furthermore, the requirement of only input and output *quantities*, in general, is a great advantage in most Caribbean countries since assembling good input price data is difficult. It is important to note though, as Perrin and Fulginiti (p. 1356) have pointed out, that productivity is (still) a value-laden concept because we use in its measure only those inputs and outputs that we value.

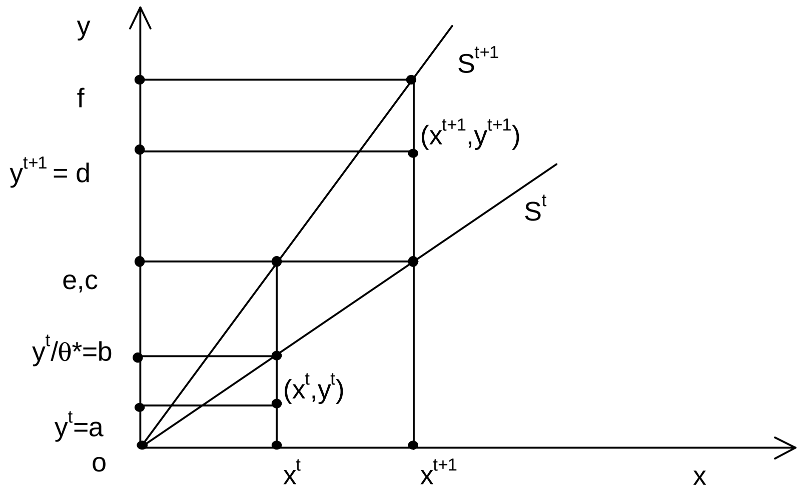
A basic reference for our approach was the work by Färe *et al.* (1994b).[2] A production technology S^t, transforms an input vector $\boldsymbol{x}^t \in \mathbb{R}_+^N$ into a feasible output vector $\boldsymbol{y}^t \in \mathbb{R}_+^M$, where t represents any specified time. The productivity change between consecutive years can be illustrated, using distance functions, in a single input/single output, constant returns-to-scale framework (see Figure 1).

Observed production points are $(\mathbf{x}^t, \mathbf{y}^t)$ and $(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$. The output distance function for period t, $D^t_0(\mathbf{x}^t, \mathbf{y}^t)$, is the reciprocal of the maximum factor θ, given $\mathbf{x}^t$, required to inflate the output vector $\mathbf{y}^t$, such that $\mathbf{y}^t/\theta \in \mathbf{S}^t$ (i.e. the reciprocal of the Farrell measure of technical efficiency). It is defined at t as:

$$(1) \qquad D^t_0(\mathbf{x}^t, \mathbf{y}^t) = \inf\{\theta: (\mathbf{x}^t, \mathbf{y}^t/\theta) \in S^t\} = \{\sup[\theta: (\mathbf{x}^t, \theta\,\mathbf{y}^t) \in S^t]\}^{-1}.$$

So when production is relatively efficient, $D^t_0(\mathbf{x}^t, \mathbf{y}^t) = 1$, and for production inside the boundary, such as point $(\mathbf{x}^t, \mathbf{y}^t)$, in Figure 1, the Farrell measure of technical efficiency is ob/oa (= θ), so that the distance function assumes the value oa/ob, which is < 1.

Figure 1: The Malmquist Index and Output Distance Functions



Source: Färe *et. al.*, 1994b, p.70

In order to appraise productivity changes however, it is necessary to compare actual production in one period with the production possibilities of another. Therefore, two other output distance functions are defined: D^t_0 ($\mathbf{x}^{t+1}$, $\mathbf{y}^{t+1}$) and D^{t+1}_0 ($\mathbf{x}^t$, $\mathbf{y}^t$). The former, using the case shown in Figure 1, represents the maximum deflation, θ, needed on the output vector $\mathbf{y}^{t+1}$, given $\mathbf{x}^{\mathbf{t+1}}$, such that $\mathbf{y}^{t+1}/\theta$ is feasible using technology $\mathbf{S}^t$. Therefore, if $\mathbf{y}^{t+1}$ is outside this set, technical progress has occurred, and D^t_0 ($\mathbf{x}^{t+1}$, $\mathbf{y}^{t+1}$) > 1. The measure of $D^{t+1}_0(\mathbf{x}^t, \mathbf{y}^t)$) follows correspondingly.

The Malmquist index (decomposed) is therefore defined as:

$$(2) \qquad M_o\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{x}^t,\mathbf{y}^t\right)=\left[\frac{D_o^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)}{D_o^t\left(\mathbf{x}^t,\mathbf{y}^t\right)}\right]\times\left\{\left[\frac{D_o^t\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)}{D_o^{t+1}\left(\mathbf{x}^{t+1},\mathbf{y}^{t+1}\right)}\right]\left[\frac{D_o^t\left(\mathbf{x}^t,\mathbf{y}^t\right)}{D_o^{t+1}\left(\mathbf{x}^t,\mathbf{y}^t\right)}\right]\right\}^{1/2}$$

where the ratio outside the curly brackets measure relative efficiency change between years *t* and *t*+1, and that inside measures the shift in the production frontier in that time.

Solutions for the component distant functions: D^t_0 ($\mathbf{x}^t$, $\mathbf{y}^t$); D^{t+1}_0 ($\mathbf{x}^t$, $\mathbf{y}^t$); D^t_0 ($\mathbf{x}^{t+1}$,

[2] Also see Färe *et al.* 1994a.

$\mathbf{y}^{t+1}$); and D^{t+1}_0 ($\mathbf{x}^{t+1}$, $\mathbf{y}^{t+1}$), obtained by solving four different linear programming (LP) problems for each country, k^* ($k^* \in K$) as:

$$\text{Max } \theta^{k^*} = [D^t_0 (\mathbf{x}^{k^*,\, t}, \mathbf{y}^{k^*,\, t})]^{-1}$$

$$\text{s.t.} \quad y_m^{k^*,\, t}\, \theta^{k^*} \leq \sum_{k=1}^{K} y_m^{k,\, t} z^{k,t} \qquad m = 1,\ldots,M$$

$$\sum_{k=1}^{K} x_n^{k,\, t} z^{k,\, t} \leq x_n^{k^*,\, t} \qquad n = 1,\ldots,N$$

$$z^{k,\, t} \geq 0 \qquad k = 1,\ldots,K$$

$$\sum_{k=1}^{K} z^{k,\, t} \leq 1 \text{ (NIRS)}$$

Similarly, D^t_0 ($\mathbf{x}^{k^*,\, t+1}$, $\mathbf{y}^{k^*,\, t+1}$) was solved as:

$$\text{Max } \theta^{k^*} = [D^t_0 (\mathbf{x}^{k^*,\, t+1}, \mathbf{y}^{k^*,\, t+1})]^{-1}$$

$$\text{s.t.} \quad y_m^{k^*,\, t+1}\, \theta^{k^*} \leq \sum_{k=1}^{K} y_m^{k,\, t} z^{k,\, t} \qquad m = 1,\ldots,M$$

$$\sum_{k=1}^{K} x_n^{k,\, t} z^{k,t} \leq x_n^{k^*,\, t+1} \qquad n = 1,\ldots,N$$

$$z^{k,t} \geq 0 \qquad k = 1,\ldots,K$$

$$\sum_{k=1}^{K} z^{kt} \leq 1 \text{ (NIRS)}$$

For distance functions in which the reference technology is time t+1, all t's are replaced with t+1, and vice versa, where applicable. In the LP, non-increasing returns-to-scale (NIRS) was assumed. The $z^{k,t}$ variable is an intensity variable, which forms the technology of the group of countries being studied, based on the observed inputs and outputs.

In the work reported here, 546 LPs were solved using GAMS (Brooke *et al.*, 1992). The four distance functions were computed over the period 1961 to 1991, for: Cuba, Dominican Republic, Guyana, Jamaica, Suriname and Trinidad & Tobago. This group was selected as data[3] were available over the entire study period. Total agricultural production (total value in millions of international dollars[4]) was the output used. The four inputs used were: total arable and permanent cropland (hectares); Total number of tractors; total fertilizer consumption (metric tons); and total number of agricultural workers.

3. Results and Discussion

The six countries together account for a population of 24.27 million persons (1997 mid-year estimate), of which Cuba alone accounts for almost half this sum (11.07 million). All these economies are traditionally agricultural-based, but the current contribution of their agricultural sectors is quite varied. For example, in 1996, the percentage share of agriculture, forestry, hunting and fishing of total GDP (constant 1990 prices) was 2.7% for Trinidad & Tobago, 8.8% for Jamaica, and as high as 49.2% for Guyana (ECLAC, 1998).

The estimated Malmquist productivity change indexes for the study group[5] are reported in Table 1.

[3] These data are entitled "World Agriculture: Trends and Indicators in (TS)-View Format". A description of the data set can be found at: http://usda.mannlib.cornell.edu:70/0/data-sets/ international/91017.
[4] This unit was developed by the FAO to avoid the use of exchange rates. Its purpose is to compute country and regional aggregates by using "international commodity prices". Please refer to the Readme.doc file which describes the data (see Footnote 3), for more details on this unit.
[5] There may be some concern about the inclusion of the Cuban agricultural sector in this analysis, with the obvious differences in the underlying political institutions. However, Malmquist indexes (and its components) for all the countries in our study group, with Cuba excluded, were calculated. We found very

Table 1:

Estimates of Malmquist Productivity Indexes for Selected Caribbean Countries, 1961-1990 [5]

Country/ Year	Cuba	Dominican Republic	Guyana	Jamaica	Suriname	Trinidad & Tobago
1961	0.656	1.142	0.995	0.896	1.029	0.892
1962	0.820	1.135	0.890	1.023	0.840	1.044
1963	0.947	0.927	1.142	0.940	0.976	0.911
1964	1.230	0.806	0.959	1.082	1.026	0.912
1965	0.745	0.934	1.057	1.004	0.958	0.999
1966	1.163	0.946	1.002	1.077	0.914	1.072
1967	0.532	1.007	0.956	0.993	0.956	0.991
1968	0.730	0.923	1.075	0.889	0.891	0.982
1969	1.478	0.955	0.982	1.045	0.885	1.011
1970	0.823	0.937	0.968	1.048	0.586	0.924
1971	0.964	0.888	0.756	0.977	0.880	1.009
1972	0.957	1.062	0.895	0.953	1.062	0.833
1973	1.015	0.903	1.216	0.931	0.978	1.056
1974	0.947	1.071	1.114	1.055	1.143	1.124
1975	1.039	1.112	1.110	1.118	0.965	1.123
1976	1.034	1.193	1.147	0.973	1.013	1.016
1977	1.100	0.976	0.935	1.051	1.034	0.766
1978	1.064	0.884	0.974	0.998	1.482	1.020
1979	0.855	1.104	1.280	0.873	1.333	0.984
1980	1.020	0.958	0.772	0.925	0.685	0.925
1981	1.101	1.153	1.117	1.128	0.996	1.250
1982	0.991	1.124	0.895	0.998	0.958	0.691
1983	1.078	0.817	0.833	0.901	1.074	1.035
1984	0.911	0.929	1.111	1.152	0.955	0.972
1985	0.988	0.951	0.749	0.887	0.933	1.198
1986	1.074	0.955	1.213	0.888	0.956	0.965
1987	1.059	1.151	0.956	1.018	1.176	1.629
1988	1.023	0.937	0.880	0.932	0.969	0.736
1989	1.012	0.879	1.118	1.224	1.242	1.096
1990	1.222	0.964	0.942	0.909	0.995	0.966
Mean[6]	0.968	0.985	0.992	0.993	0.982	0.992
Std. Dev.[7]	0.183	0.107	0.138	0.089	0.169	0.170

[5] One sample year is lost in calculating the inter-year distance functions.
[6] The geometric mean is used here.
[7] This refers to the Standard Deviation of the respective indexes for the entire sample period.

Each country exhibited a decline in its average agricultural productivity over the

similar results. The average change in agricultural productivity for Dominican Republic and Trinidad & Tobago remained unchanged. That for Guyana, Jamaica and Suriname rose by 0.08%, 0.2% and 0.1% respectively.

sample period. Jamaica displayed the smallest average productivity fall of 0.7%, followed by Guyana and Trinidad & Tobago (both 0.8%). The largest average decline was by Cuba (3.2%), a significant value when one considers the compounded effect over time.

The average relative efficiency and technical change indexes, are subsequently presented in Table 2. On average, four of the countries: Cuba, Dominican Republic, Jamaica and Guyana, showed *no change* in average relative efficiency from 1961 to 1991. For each year, the distance functions of these countries (with observed production and reference technology in the same period) exhibited only values of one (not shown). This implied that these countries consistently produced on the "world" technology boundary – the production frontier of the group as a whole.

Table 2:

Average Change in Relative and Technical Efficiency, 1961-90

	Relative Efficiency Change		Technical Change	
	Average	Std. Dev.	Average	Std. Dev.
Cuba	1.000	0.000	0.968	0.183
Dominican Republic	1.000	0.000	0.985	0.107
Guyana	1.002	0.155	0.990	0.092
Jamaica	1.000	0.000	0.993	0.089
Suriname	1.002	0.144	0.980	0.120
Trinidad & Tobago	1.000	0.000	0.992	0.170

The relative efficiency change in agricultural productivity for both Guyana and Suriname showed an average annual increase of 0.2%. Since all the countries exhibited relatively no change in average agricultural relative efficiency, the overall agricultural productivity change was determined largely by each country's ability to contribute to shifts in the production frontier, and for some countries, exclusively by this source.

In order to assess whether a country has contributed to shifting the production frontier from one year to another, looking only at the values of the technical efficiency change index is inadequate. Indeed it is possible for observed production in period *t* to be infeasible using technology from the subsequent period (regression in technology), so to show that this contribution has taken place, the following conditions must exist:

$D^{t+1}_0(\mathbf{x}^t, \mathbf{y}^t) > 1$, Technical Efficiency Change Index >1, and $D^{t+1}_0(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) = 1$.

The contribution of each country to a shift in the "world" technology frontier from period *t* to *t* + 1, over the entire study period is shown in Table 3. Out of a total 30 periods of innovation, Cuba lead the set with 16 contributions. This was followed by Trinidad & Tobago and Jamaica, with 14 and 13 contributions, respectively. Guyana made only one contribution to a shift in the production frontier.

Table 3:
Total Number of Times a Country Contributed to a Shift in the Frontier

Cuba	16
Dominican Republic	11
Guyana	1
Jamaica	13
Suriname	3
Trinidad & Tobago	14

4. A Comparison of Malmquist and Törnqvist-Theil Productivity Estimates

In this section, we compare the Malmquist estimates for Jamaica and Trinidad and Tobago with Törnqvist-Theil (T-T) indexes developed from disaggregated data. For these latter indexes, data are required on quantities of agricultural commodities produced and quantities of inputs used in producing the commodities, by years, along with their respective prices.[6] Using data for 1963 to 1990, the estimated T-T and Malmquist indexes being compared for Jamaica and Trinidad and Tobago are presented in Figures 2 and 3 respectively.

Figure 2: Tornqvist-Theil and Malmquist Indexes of Multifactor Productivity for Jamaica, 1963 - 1990

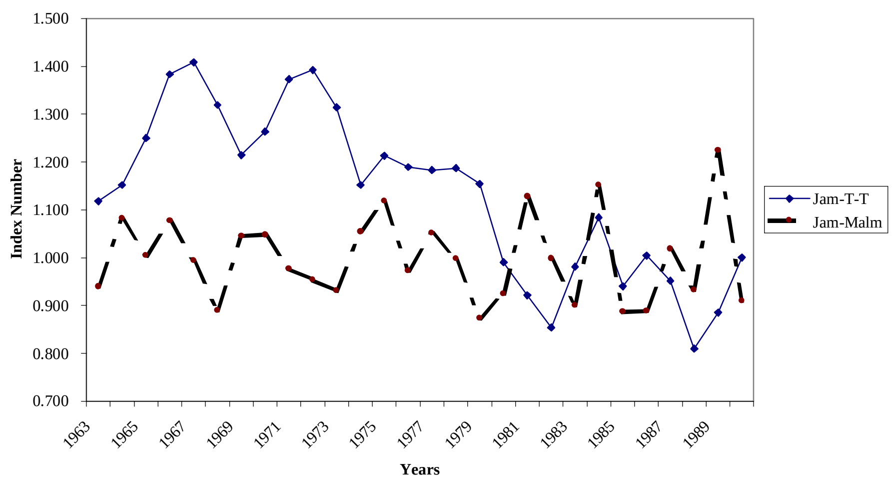
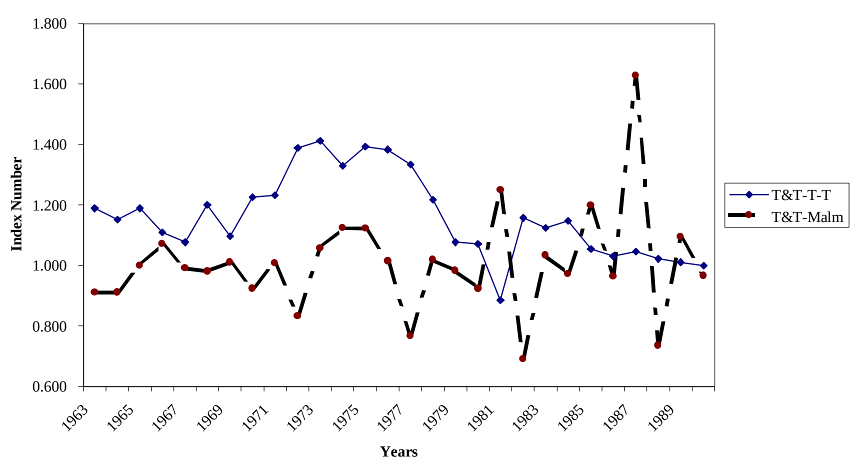


Figure 3: Tornqvist-Theil and malmquist Indexes of Multifactor Productivity for Trinidad and Tobago, 1963 - 1990



[6] These Törnqvist-Theil indexes for the agricultural sectors of Jamaica and Trinidad and Tobago were developed as a component of a broader project entitled "Agriculture, Trade, and the Environment in the Caribbean Basin: Sustainable Development Imperatives" which was carried out under an even broader umbrella provided by a cooperative agreement (CA) among the University of Florida (UF), The University of the West Indies (UWI), and The Caribbean Research and Development Institute (CARDI). Professors Langham, Carlton Davis and Carlisle Pemberton were leading this work.

The reader is cautioned to keep in mind that this comparison is a bit like comparing apples and oranges. The T-T estimates for a country show movements in productivity relative to a base year in that country. The base year was 1992 for both countries. In contrast, Malmquist estimates for any year are relative to that of the country, or countries, that define the production frontier in that year.

Our chief interest in making the comparison of the empirical results was to see how different the measures from the two approaches were for each of the two countries. This is important because a country with high productivity growth using the T-T index may in fact be doing poorly, when compared to other countries with which it competes (as measured by the Malmquist index).

The average rates of growth of the Malmquist indexes for Jamaica and Trinidad and Tobago were –0.7% and -0.8%, respectively. The average rate of growth over the same years for our Törnqvist-Theil indexes were –0.9% and –0.6% respectively[7].

5. Concluding Remarks

The measures of Malmquist productivity change for selected Caribbean countries presented here tell a sad story: a story which is often hidden in reports of rising agricultural GDP, or increased employment in the agricultural sector. All six selected Caribbean countries showed an average decline in annual agricultural productivity change for the period 1961 to 1991. Jamaica exhibited the smallest decline (0.7%), followed by Guyana and Trinidad & Tobago (both 0.8%). The largest fall in average

[7] The rate of growth in the T-T estimates was estimated by regressing the natural logarithm of MFP on time and adjusting the coefficient for discrete time.

agricultural productivity, however, was 3.2% for Cuba. On the brighter side, Cuba showed growth in productivity during the 1986-90 period. Its poor average was due to some difficult years in the 1960s.

Some of the declines in productivity may appear small, or insignificant at first glance, but they represent average annual changes. This implies that over, say a 30 year period, a country with an average decline of 0.7% will have a cumulative fall in its level of productivity of 21%.

Research on changes in productivity indicates that this is a long-term investment process, largely in human capital, in the forms of the education of farmers and agribusiness leaders, and agricultural research and extension support. Large investments in physical infrastructure are also needed. Research in Florida by Langham, Tangka, and Roberts (1997) suggests that increased specialization and larger scale of enterprises occurs along with increased productivity. Each of the ways to improve productivity suggests a move toward a more science based agricultural system with modern management.

There is no free lunch and these investments are only a part of the costs of increasing productivity. The human adjustment costs are paramount simply because a modern science-based agricultural system cannot support large numbers of workers at acceptable wages and hence these human adjustment costs will fall most heavily on the poorest in the countryside. Unless these investments are made, however, the plight of farm families of the Caribbean will continue to worsen.

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