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Timor-Leste quarterly Gross Domestic Product (GDP) indicator

Faviana Bosco de Sousa

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Jeremy Smith (Head of the Department of Economics, University of Warwick) and Michael Ward (Head of the Department of Economics, Monash University)

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Timor-Leste quarterly Gross Domestic Product (GDP) indicator

Name: Faviana Bosco de Sousa

Abstract

This paper evaluates the performance of the Denton method in estimating quarterly GDP using indicators [QGDPi(E)] and explores alternative indicators for GDP components that have big errors. This report uses Timor-Leste quarterly data on GDP expenditure and its components from 2010 to 2019 sourced from GDS (Statistical office of Timor-Leste). The QGDPi(E) is temporally disaggregated through the Denton method, and the results will be evaluated in two ways. Firstly, I compare the Denton results to the Cholette-Dagum results. Secondly, I compare the Denton findings to the published (adjusted) quarterly GDP series. Overall, results show that the Cholette-Dagum approach disaggregates the GDP better than the Denton method, based on the mean absolute error estimation. However, the estimation error of GDP and its components for every quarter are similar for both methods. Therefore, it is concluded that the performance of both procedures is very similar. This result could be used as a guide to disaggregating annual GDP into quarterly series using both approaches, which would be beneficial for Timor-Leste. Finally, this study suggests that GDS continues to use the Denton method in the short term. However, it recommends using a more transparent time series regression-based model to estimate quarterly GDP for a better result in the future.

JEL Classification Number: C22, C61, C82

Keywords: GDP, Proportional Denton Method, Cholette-Dagum Method

1. Introduction

The most common economic indicator used by every country to report its economic performance is Gross Domestic Product (GDP). There are three ways to measure GDP: GDP by production, by income, and by expenditure. Theoretically, all three measures should give the same result. Generally, each country measures GDP using all three approaches and chooses one measure as the headline GDP; the headline GDP can differ across countries. The headline GDP choice depends on the quality of the country's information. For example, Indonesia's headline GDP is GDP production, while Timor-Leste's headline GDP is GDP expenditure. Moreover, the GDP calculation may be on an annual, quarterly, or monthly basis, depending on the availability of data.

Some National Statistics Offices (NSOs) worldwide have implemented quarterly GDP estimation, and some are still developing it (International Monetary Fund (IMF), 2017). The quarterly GDP is considered a stronger indicator for assessing a country's economic situation than the annual GDP. For instance, in Timor-Leste (hereafter TL), the overall GDP is calculated as the sum of the Oil GDP and Non-oil GDP. However, there is often a need for an early indication of non-oil GDP expenditure [non-oil QGDPi(E)] movement before the quarterly figure is available. As a result, within-year information on variables relevant to the GDP estimation and certain assumptions to update the previous annual GDP estimates are used. The bridging solutions are undesirable because of inconsistent data, methods, and the lack of harmonization between the annual and quarterly systems. As a result, the TL General Directorate of Statistics (GDS) has developed non-oil QGDPi (E) since 2014, with some data gaps to meet the local institutions and international agencies' needs.

According to the IMF (2017), quarterly GDP (QGDP) can be seen as a combination of annual GDP and the change of particular short-term indicators. The process of combining the high-

and low-frequency data is called benchmarking in national accounts. It thus offers a combination that is more timely but consistent with the annual GDP. Proper QGDP would be estimated under the direct approach, which means that the quarterly values of the required variables are extracted directly from the source data, as is annual GDP. However, given the current quality of the TL information system, estimating proper QGDP is a challenge. Thus, the non-oil TL QGDP indicator (QGDPi) is limited by its compilation based on the expenditure approach only. It is estimated using an indirect approach, which means an indicator related to the target variable of the annual benchmark is chosen to reflect the quarterly movement.

GDS currently uses the Denton temporal disaggregation method with movement preservation to derive QGDPi by expenditure approach. Various research has been conducted to evaluate the performance of the Denton method compared to Cholette-Dagum, Chow-Lin, and cubic spline methods, and the results vary (Islam, 2014; Marini, 2016).

This study evaluates the accuracy of the proportional Denton method in estimating QGDPi (E) and explores additional indicators that is more accurate in estimating TL quarterly GDP. First, the method will be evaluated by comparing the Denton method's quarterly estimates, using indicators without the annual benchmarks, with the adjusted quarterly GDP series that GDS publishes. Then, in an extension, the Denton method will be compared to the proportional Cholette-Dagum method. The reason is that both Denton and Cholette-Dagum methods have been preprogrammed as an add-in function to Microsoft Excel for disaggregating annual series to quarterly series by IMF, and it can be easily used by the Timor-Leste Statistics officers which compiled GDP based on spreadsheets. Finally, based on the result, the author will explore the high-frequency indicators related to the GDP components that relatively have big estimation error, such as private investment.

2. Literature Review

This study will be the first to assess TL's QGDPi (E) estimation. This research relates to the literature evaluating the accuracy of the Proportional Denton technique (hereafter Denton) in disaggregating national accounts data. Other scholars have attempted to assess the temporal disaggregation method's application on GDP and its components in different countries. For Instance, Islam (2014) evaluated the application of the proportional Denton and Cholette-Dagum method in estimating quarterly exports and found that both methods produced quarterly estimates that are much closer to the actual quarterly exports compared to the additive Denton and Cholette-Dagum method. Moreover, Rashid and Jehan (2013) evaluated the application of the Denton, Chow-Lin, and Cubic Spline methods to derive quarterly GDP, investment, and government spending of Pakistan. The results indicated that both Denton and Chow-Lin perform well by estimating quarterly series accurately.

In contrast, Marini (2016) evaluated the performance of the Denton method, the proportional Cholette-Dagum method with first-order autoregressive (AR (1)) error, and the regression-based Chow-Lin method for both simulated and national accounts data. The author found that the Cholette-Dagum approach offers the most reliable extrapolations when the quarterly indicator and annual benchmarks follow the same pattern. The author also found that in real-life situations where the quarterly indicator is briefly deviating from the yearly benchmark, Denton and Chow-Lin's methods may prevail. Chen and Andrews (2008) discovered that the Denton method performs well if both indicators and annual benchmarks are available.

Another author claimed that the Denton method might not produce satisfactory results when there is a break from the previous quarter of one year to the initial quarter of the next year (Daalmans, 2018). Denton method has been widely known for avoiding steps problem in the

series[1]. However, the evaluation results cannot be generalized because the Denton method performs differently for each dataset. In reviewing the various research, it is noticed that the researchers have used one or two indicators to disaggregate the annual GDP into quarterly series. This might not result in inaccurate quarterly estimation because the information used not sufficient. For instance, Rashid and Jehan (2013) calculated the quarterly GDP, investment, and government spending for Pakistan by using the quarterly consumer price index (CPI) and industrial production index (IPI) as the indicator variables. CPI and IPI might represent parts of the economy, but none can give an aggregate picture of the whole economy by itself. In contrast, this paper will use the Denton approach and the Cholette-Dagum procedures to derive quarterly estimates from annual GDP and its components by utilizing various indicators mentioned in section 3.1. Each component of GDP will be estimated using different indicators that are expected to have more information that could represent the country's whole economy.

3. Methodology

3.1. Overview of QGDPi (E) in Timor-Leste

In general, QGDPi (E) follows the same concepts, definitions, and structure as annual GDP (E) (IMF, 2017). Where GDP (E) is the sum of the Final Consumption Expenditure (FCE) by government, household, and Non-profit institutions serving households (NPISHs) plus gross capital formation (GCF) plus exports less imports (Ministry of Finance of Timor-Leste, 2009). GCF includes Gross Fixed Capital Formation (GFCF), changes in inventories, and acquisitions less disposals of valuables.

The QGDPi (E) is measured using an indirect approach, and it is a temporary disaggregation of the annual national accounts using the accessible quarterly indicator through the

[1] " Discontinuities from the last quarter of one year to the first quarter of the next year" is known as step problem (IMF, 2017, p. 7)

Proportional Denton method. It replicates the annual GDP, but at the quarterly frequency, using the same concepts, sources, and methods as annual. One of the main features required for an indicator is that its yearly growths are closely related to the target variable's annual growth.

The aggregated annual series, which have to be disaggregated into a quarterly series, is the government FCE, NPISHs FCE, Household FCE, GFCF, change in inventories, exports, and imports at constant prices.

The quarterly indicator series are (1) expenditure on salary, wage, goods and services of government and NPISHs, (2) spending on minor capital and capital development of government and NPISHs, (3) imports of consumption goods, (4) imports of capital goods, (5) total exports and imports of goods. The variables that do not have indicators[2], such as a change in inventories, household FCE, private GFCF, will be estimated using Denton with a constant indicator. In contrast, variables that have quarterly indicators can be calculated using Denton with indicators. Finally, TL QGDPi (E) will be the sum of disaggregated series of all GDP components.

3.2. Components of GDP

Household Final Consumption Expenditure

According to GDS (2012), the household FCE is the sum of the expense of resident households plus the expenditure of resident households abroad and excluding expenditure by non-resident households in the country. Moreover, in the System of National Accounts (SNA) 2008, household FCE involves the expenditure by resident households on individual consumption goods and services, including the goods that are produced for their own consumption or not economically significant and consumer goods and services acquired abroad (United Nations, European

[2] Indicator is an observed value of the target variable. It can be either the same measurement of the annual target variable or a proxy on quarterly basis.

Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank, 2009).

Government Final Consumption Expenditure

The government FCE is estimated as the sum of the final consumption spending of the General Government of Timor-Leste (GG), plus purchase of services of The United Nations Integrated Mission in Timor-Leste (UNMIT) and the International Stabilisation Force (ISF) ISF (GDS, 2009).

Non-profit institutions serving households (NPISH) Final Consumption Expenditure

Based on the System of National Accounts (SNA) 2008, the non-profit institutions serving households (NPISHs) sector is a legal entity that is principally involved and voluntarily contributed to the non-market production and services for households or the community (United Nations et al., 2009). Specifically, in TL GDP, the NPISHs FCE covers the expenditure from the development partners' funded projects where the Non-Governmental Organisations (NGOs) and non-resident institutions were recognized as their implementing agencies (GDS, 2012).

Gross fixed capital formation (GFCF)

According to the GDS (2012), the GFCF is obtained as the sum of investment from the private sector, households, NPISHs, and the government. Moreover, the GFCF of NPISHs and government respectively represents expenditure on minor capital and capital and development of NPISHs and the general government of Timor – Leste.

Changes in inventories

In Timor-Leste, the changes in inventories cover only the livestock sector and changes inventories from the Business Activity Survey (BAS) due to the lack of information (GDS, 2012). The livestock treated as inventories include all the young stock of animals that are used as fixed assets or for slaughter and animals that are ready for slaughter.

Acquisition less disposals of valuables

As stated in GDS (2012), the Acquisitions of less disposals of valuables in Timor – Leste only cover the Household sector, and this is reflecting the households' expenditure on Jewelry.

Exports of goods and services

According to the System of National Accounts (SNA), "exports of goods and services consist of sales, barter, or gifts or grants, of goods and services from residents to non-residents" (United Nations et al., 1993, p. 418). According to GDS (2012), in Timor-Leste national accounts, exports of goods cover exports of goods registered in Timor-Leste trade statistics. In contrast, exports of services cover services rendered by Timor-Leste residents to non-residents.

Imports of goods and services

In SNA, "imports consist of purchases, barter, or receipts of gifts or grants, of goods and services by residents from non-residents" (United Nations et al., 1993, p. 418). Additionally, TL's national accounts imports of goods cover imports of goods registered in Timor-Leste trade statistics, and imports of services cover services acquired by Timor-Leste residents from non-residents (GDS, 2012).

3.3. Data

The annual benchmark and indicators data used to evaluate the performance of the existing methods are obtained from the GDS. The dataset will provide an overview of the availability and quality of the quarterly indicators. QGDPi (E) benchmark estimation acquires from the TL-NA 2000 – 2019 publication on GDS's website. The quarterly indicators from 2010 – 2019, such as the government and development partner (including NPISHs), exports, and import data, are obtained upon request. Graph 1 shows the quarterly GDP indicator by expenditure at constant prices from 2010-2019 that has been adjusted or revised to be equal to the annual GDP by GDS.

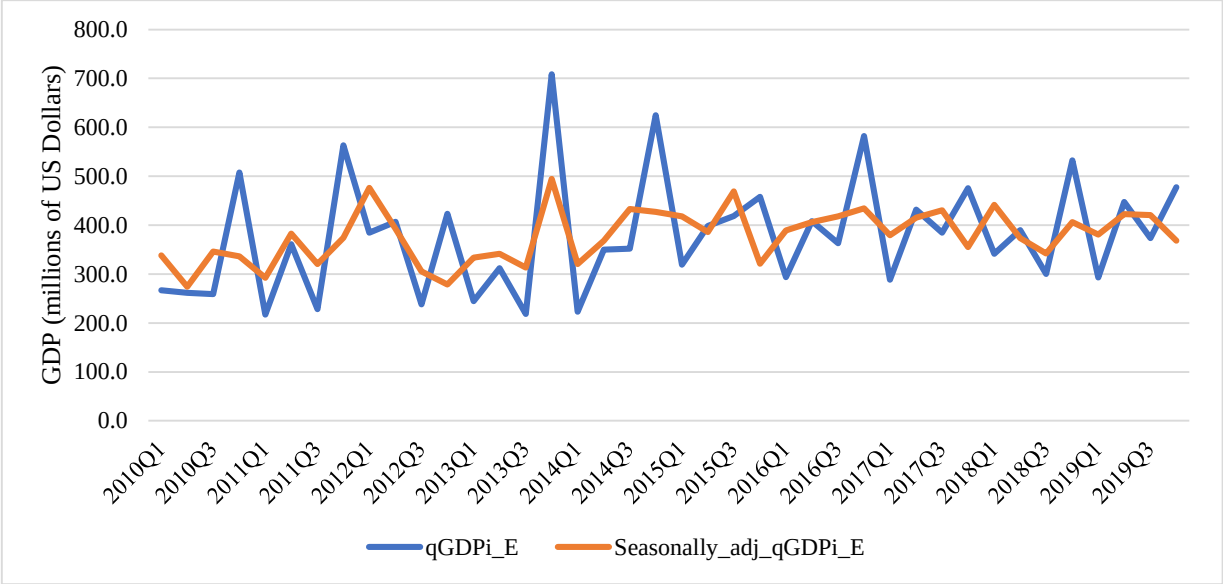

Figure 1. Timor-Leste 2010-2019 qGDP indicator (General Directorate of Statistics, Timor-Leste)

This graph presents both the seasonally and non-seasonally adjusted GDP at constant prices. The non-seasonally adjusted[3] qGDPi shows a similar pattern for every year. The GDP drops in the first quarter and keeps increasing from quarter 2 to quarter 4. This pattern continues for the other years. As shown in the graph, the quarterly GDP of TL fluctuates a lot over the years. Given this, it cannot be compared to the previous quarter in the same year. It will only make sense if a

[3] The non-seasonally adjusted GDP estimation in Figure 1 will be referred to as the adjusted or published series.

given quarter is compared to that of the same quarter in the last year. Thus, there is a need for seasonally adjusted data. However, even after seasonally adjusted the data, it still shows some volatility. The reason might be that the method used for adjusting the seasonality in data is not entirely accurate for the Timor-Leste data. Countries like Cambodia are not adjusting their GDP due to the lack of reliable time series data (National Institute of Statistics Cambodia, 2017). On the other hand, the Lao People's Democratic Republic also produces seasonally adjusted GDP but only on the production side (Viet, 2011).

The quarterly data from 2010-2015 data will be used as benchmark quarterly series to estimate the unadjusted quarterly GDP estimates for 2016 to 2019 using the Proportional Denton method. Additionally, the quarterly unadjusted estimation of the Cholette-Dagum method will also be produced to help in evaluating the performance of the methods. Unadjusted means that the estimation of the quarterly GDP and its component are based only on the previous annual benchmark data and contemporaneous quarterly indicator of GDP and its component. Finally, evaluate the unadjusted Denton's estimation by comparing it with the adjusted or published series in Figure 1 and the unadjusted Cholette-Dagum's estimation. After that, I will explore alternative indicators for the components that have significant mean absolute error.

3.4. Selecting Indicators

The quarterly indicators are selected based on the annual Benchmark-indicator ratio (BI ratio). The BI ratio analyzes the relationship between the annual data and the quarterly indicator by contrasting the benchmark with the annualized indicator. In the IMF working paper, the authors state that the observed BI ratio can help detect the quality of indicator series by tracking annual benchmark movement over the year (IMF, 2017). An indicator is a quarterly measurement of the

same target variable or a proxy variable similar to the unknown quarterly behavior. The annual BI Ratio is defined as:

$$BI = \frac{A_n}{\overline{I_n}}, \qquad \text{n=1,2,…,y} \qquad (1)$$

Where A_n is the level of annual national accounts estimate for year n; $\overline{I_n}$ is the annual sum of the quarterly observation of the indicator for year n; n is the temporal index for the years; and y is the time index for the last available year.

3.5. Brief description of the temporal disaggregation method

3.5.1. Denton method

The Denton method is a benchmarking method that can be used for both interpolation (backward series) and extrapolation (forward series). According to the IMF (2017), the backward series is estimated when both the annual benchmark and related short-term indicator series are available. Additionally, the forward series is calculated when the annual benchmark value is not available and only the quarterly indicators are available.

Generally, the Denton method attempts to minimize the differences between the quarterly Benchmarked and Indicator ratio (BI ratio) to be as constant as possible over time. In other words, the Denton method tries as much as possible to track the change in the quarterly estimation series to be proportional to the movements in the quarterly indicators. Mathematically, the Denton method deals with a linearly constrained quadratic optimization problem, and it follows a random walk process. This method was recommended by the IMF to solve the step or break issues in the economic series, and it has been widely used (IMF, 2017).

For the interpolation, the minimization problem is subject to the constraint that the quarters' sum from quarter 1 to quarter 4 of the respective year must equal the annual benchmarks of that year. Thus, the minimization problem in the Denton method can be formulated as:

$$\min_{X_t} \sum_{t=2}^{q} \left[\frac{X_t}{I_t} - \frac{X_{t-1}}{I_{t-1}}\right]^2 \text{ for t=2, …, q} \qquad (2)$$

Under the following constraint:

$$\sum_{t=4n-3}^{4n} X_t = A_n \qquad \text{for n=1,…,y} \qquad (3)$$

where:

$\frac{X_t}{I_t}$ = quarterly BI ratio

X_t is the unknown quarterly series;

X_{t-1} is the previous quarterly series;

I_t is the level of indicator for the current quarter;

I_{t-1} is the level of indicator in the prior quarter

A_n is the annual data for year n;

t is the temporal index for the quarters;

q is the last quarter for which quarterly source data are available, either the fourth quarter of the last available yearly information (q=4y)

n is the temporal index for the years;

y is the last year for which an annual benchmark is available.

According to the IMF (2017), this method can also be used to extrapolate the annual series into a quarterly series when the last benchmark year is not available. For the extrapolation, the Denton method will perform the same way for the interpolation but without restriction that the quarters' sum must be equal to the annual benchmarks. Nevertheless, it carries forward the last available BI ratio as the forecast BI ratio for the next quarter, as shown in equation 5. Intuitively,

it implies that the following quarterly BI ratio is the fourth quarter's BI ratio of the last benchmark year. For instance, the BI ratio for 2020Q1 is the value of the BI ratio for 2019Q4. Therefore, the Denton method will over or underpredict quarterly series depending on the movement of the last quarterly BI ratio. The minimization problem for extrapolation can be expressed as:

$$\min_{X_t} \sum_{t=2}^{q} \left[\frac{X_{4y+k}}{I_{4y+k}} - \frac{X_{4y}}{I_{4y}}\right]^2 = 0 \text{ for k = 1, 2, 3, 4} \quad (4)$$

When

$$\frac{X_{4y+k}}{I_{4y+k}} = \frac{X_{4y}}{I_{4y}} \quad (5)$$

Where

$4y$ is the fourth quarter of the last benchmark year.

This method might produce inaccurate values. Consequently, the Denton method results will provide a different annual growth rate for the first year of the forward series to the annually aggregated indicator's corresponding growth rate. If the annual national accounts variable grows faster than the indicator, then the yearly BI ratio for the next year will be higher than the last year. On the other hand, when the annual variable grows slower than the indicator, the annual BI ratio of the latest available year is smaller than the previous year's annual BI ratio.

To overcome the downsides of this method, two alternative approaches can be followed. First, the proportional Denton method can be improved in extrapolation when external information is available to expand the annual BI ratio for the year with no yearly benchmark. Second, the Cholette–Dagum method is an alternative benchmarking method that automatically estimates the extrapolation with the bias-adjusted based on the historical relationship between the quarterly indicator and the annual variable. In this report, it will be focused on the second alternative method, the Cholette-Dagum approach.

3.5.2. Proportional Cholette-Dagum method with AR (1) error

The Cholette–Dagum benchmarking method is suitable for interpolation and extrapolation. As mentioned in IMF (2017), this method is an appropriate way to measure QNA series extrapolations when the indicator is an unbiased estimator of the annual variables. The Cholette-Dagum model allows bias in the indicator, autocorrelation, and heteroskedastic errors in the original data. It also generates benchmarks that can be adjusted. Additionally, this method is regression-based; thus, the usual regression diagnostic analysis is needed to be done (European Commission, 2018).

Under specific values for the AR (1) coefficient, The AR (1) model for the error guarantees that movements in the short-term indicator are sufficiently well-preserved in the back series, and the extrapolations of the year with no annual benchmark are adjusted for a bias in the indicators. The specific value of the AR (1) parameter recommends by the IMF is between 0.71 to 0.93. However, most countries use the value of 0.84 for the AR (1) parameter.

The Cholette–Dagum method consists of the following two equations:

$X_t = I_t^a - e_t$ for t = 1, …, q (6)

$A_n = \sum_{t=4n-3}^{4n} X_t$ for n = 1, …, y (7)

where

I_t^a is the original quarterly indicator I_t adjusted for the historical level bias,

X_t is unknown quarterly series or quarterly target series or benchmark series,

e_t is a quarterly autocorrelated and heteroscedastic error,

A_n is the annual benchmark series,

t is the temporal index for the quarters,

q is the last quarter for which quarterly source data are available, either the fourth quarter of the last available of yearly data (q=4y),

n is the temporal index for the years;

y is the last year for which an annual benchmark is available

Equation 6 is used for both interpolation and extrapolation. Equation 7 is valid only for interpolation because both indicators and annual benchmark series need to be available or no missing value under this equation. In order to estimate the unknown quarterly series for interpolation and extrapolation, X_t, the original quarterly indicator, I_t, is needed to be adjusted first. Thus, the bias-adjusted indicator I_t^a is estimated by rescaling the original indicator I_t as follows:

$$I_t^a = d \times I_t \quad (8)$$

Where I_t is the original quarterly indicator, and d is the historical BI ratio. Thus, factor d is obtained as follows:

$$d = \frac{\sum_{n=1}^{y} A_n}{\sum_{t=1}^{4y} I_t} \quad (9)$$

The factor d interpreted as an estimate of the level bias in the indicator I_t in measuring the benchmark A_n.

Moreover, the quarterly error for interpolation and extrapolation follow the AR (1) process, and it is calculated differently for both. For interpolation, the quarterly error is calculated by multiplying the AR (1) parameter by the previous quarterly error observed:

$$e_t = \phi e_{t-1} \quad \text{for t = 2, …, 4y} \quad (10)$$

For instance, the interpolation is done for 2015. Then, the error for 2015Q1 is calculated by multiplying the AR parameter by the error of 2014Q4. Continuously, the error for 2015Q2 will be the multiplication between the AR parameter and the error of 2015Q1. This estimation

continues for all the interpolation processes. Whereas, for extrapolation, the error is estimated by multiplying the AR (1) parameter by the last quarterly error observed:

$e_{4y+k} = \phi e_{4y}$ for k = 1, 2, 3, 4 (11)

Where,

$4y$ is the fourth quarter of the last benchmark year.

k is the temporal index for the quarters that are needed to forecast

For instance, the extrapolation is done for 2016. In this case, the error for 2016Q1 to 2016Q4 is calculated by multiplying the AR parameter by the error of 2015Q4. Additionally, if the extrapolation is done for 2017, the error of 2016Q4 will be used to estimate the error of 2017Q1 to 2017Q4. This estimation continues until the last extrapolation is done.

Theoretically, the Cholette–Dagum method with the AR error method leads, on average, to a more accurate extrapolation than the Denton method. Therefore, the Cholette-Dagum method with AR (1) extrapolation is an alternative solution to the Denton approach, as illustrated in equation 12.

$$\min_{X_t} \left\{ \left(\frac{1}{1-\phi^2}\right) \left(\frac{X_1}{I_1^a}\right)^2 + \sum_{t=2}^{q} \left[\frac{X_t}{I_t} - \phi \frac{X_{t-1}}{I_{t-1}}\right]^2 \right\} \quad (12)$$

The minimization problem in Cholette – Dagum method is closely related to the Denton method. If the AR (1) parameter (ϕ) is close to 1 (e.g., 0.999), equation 12 converges to equation 2, which is simply the Denton method's equation. When ϕ moves away from 1 (e.g., 0.84), equation 12 will adjust the quarterly BI ratio to be smooth as much as possible and offers weaker movement preservation[4] than the Denton method.

This method provides an automatic solution to overcome the drawbacks of the Denton method in extrapolation by adjusting the change in the BI ratio. In the Cholette-Dagum method,

[4] Weaker movement preservation assumes that the next annual discrepancy will be lower than the last one, if the last annual discrepancy is smaller than the previous one, and conversely (Dagum & Cholette, 2006).

the next annual BI ratio is computed by considering the full relationship between the annual series and the indicator in the period. By including the historical BI ratio, it will smooth the movement from one quarter to another quarter. Thus, it is expected that after a boom, GDP for the next quarter will be likely to decline, and after a bust, the quarterly GDP will be likely to rebound.

3.5.3. Evaluating the performance of the temporal disaggregation methods

The performance evaluation of the Denton method is based on the following metrics: i) The QGDPi(E) estimation based on the indicators will be graphically compared to the quarterly benchmark of QGDPi(E) (Islam, 2009), ii) The comparison between the Denton method the Cholette-Dagum method's results will also be made based on the mean absolute error (MAE) (Marini, 2016; Bisio & Moauro, 2018). In this report, the MAE will be measured by taking the average of the differences between the adjusted and unadjusted quarterly series. Thus, MAE can formulate as follows:

$$MAE = \frac{1}{T}\sum_{t=1}^{T}|UA_t - A_t| \quad (13)$$

Where UA_t denotes unadjusted quarterly series for both GDP and its components, and A_t denotes the adjusted quarterly series for both GDP and its components.

The assessment is made for aggregate GDP and its components. First, look at patterns in differences between the unadjusted and adjusted quarterly estimates. Second, looking for systematic biases and the size of the estimation error. Third, look at the patterns in error to evaluate whether this method performs well or worse during the slow economic growth and identify which components were poorly estimated using these methods. Finally, compare the results of both methods, and suggest areas of weakness with the technique or choice of indicators.

4. Results

This section presents the unadjusted quarterly GDP estimation using the Denton (established method) and the Cholette –Dagum method (proposed method). Estimating the quarterly GDP and its component without an annual benchmark is called an unadjusted quarterly GDP series. For example, 2019 GDP is an unadjusted series because it compiles using the quarterly indicators from 2010-2019 with the last available yearly annual benchmark data from 2010-2018.

The adjusted quarterly GDP is the GDP published by GDS, and it estimates based on both annual benchmark and quarterly indicator series using the Denton method. For instance, both yearly and quarterly indicators from 2010-2019 are available to compute 2019 GDP; thus, the 2019 GDP is the adjusted GDP. Usually, the adjusted quarterly series is simultaneously published by GDS with the annual GDP numbers. Align with this, both adjusted and unadjusted quarterly series from both methods will be graphically compared and evaluated used mean absolute error (MAE). However, before that, it is essential to describe the data used briefly to understand Timor-Leste GDP better.

4.1. Brief description of GDP data and its components

Figure 2 shows the private final consumption expenditure from 2010 to 2019, and it illustrates a similar increasing pattern for both adjusted and non-adjusted series. Private consumption mainly estimates from the consumption of imported goods. Generally, it shows a high increase in quarter four and occasionally increases in quarter two and three. It assumes that the business will import more consumption goods during the fourth quarter before All souls' day on the 1st and 2nd of November holiday and Christmas holiday.

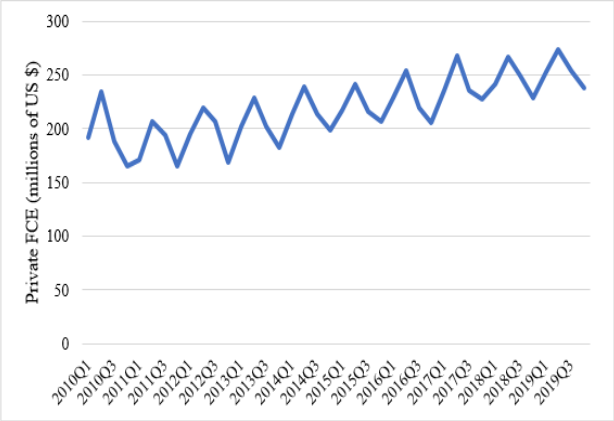

Figure 2. Private Final Consumption Expenditure (FCE) (Adjusted)

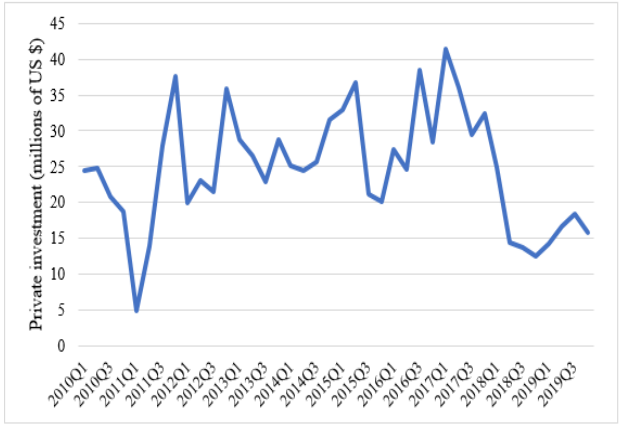

Figure 3. Private Investment (Adjusted)

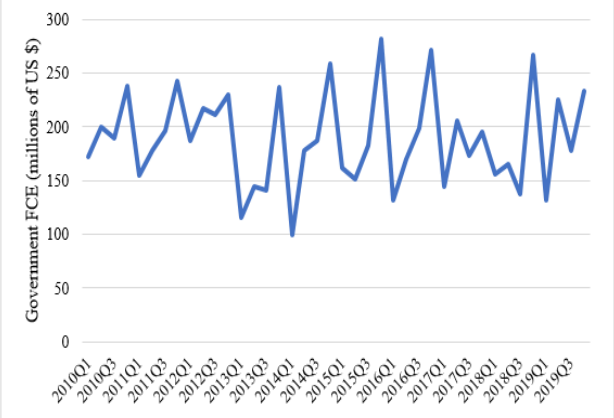

Figure 4. Public Final Consumption Expenditure (Adjusted)

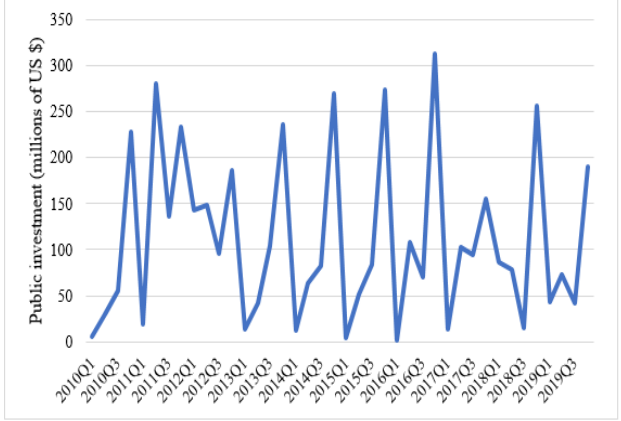

Figure 5. Public Investment (Adjusted)

However, Figure 3 indicates that private investment fluctuates following the fluctuation of public investment in Figure 5. Public companies in the construction and infrastructure area in Timor-Leste are mainly financing by the government. Thus, when there is an increase in government spending on capital development, public investment also will increase. However, the rise in private investment is not as drastic as the changes in public investment. The nature of the government's spending is usually declined in the first quarter and a massive increase at the end of the years. It displays clearly in Figures 4 and 5. The same pattern repeats every year. However, from 2017 to 2018, the public consumption (Figure 4) and investment (in Figure 5) was smaller than in other years due to the Presidential and Parliamentary elections, which leads to the political impasse. First, the public expenditure initially declined for the expectations of a change in the

government (low execution rate), and secondly, the parliament did not approve the budget for 2017 on time. This situation severely constrained the total government spending in 2017 and 2018. As a result, public investment declined, and it negatively affected the construction sector. As a result, there were delays in the implementation of large infrastructure projects in Timor-Leste. This situation continued until the third quarter of 2018.

Besides this, Timor-Leste's economic activity is also supported by aid from the development partners. Figure 6 illustrates that the development partners' data also fluctuated significantly but less than the government data. Development Partners' spending declined because it awaited public strategies that did not come through during 2017. Moreover, it follows a similar pattern as public consumption expenditure and public investment. It assumed that both government and development partner sectors are positively associated in executing their budget to support the TL economy.

Figure 7 shows the exports of goods and services from 2010 to 2019. The graph indicates that exports fluctuated from 2010 to 2014 and were followed by an increase in 2016 and a decreased in 2015, 2017 to 2018. The decrease in exports was determined by the decline of coffee, given supply restrictions. Whereas the increase was due to a rise in coffee supply, and it increased in the last quarter of 2019 were due to additional oil exports in the estimation of exports of goods. Figure 8 showed imports of goods and services from 2010 to 2019. If the public investment data and imports of goods and services data are put side by side, the relationship between these variables will be clearly portrayed. It shows that the pattern in imports follows the government spending's pattern. An increase in government spending on capital and development is highly associated with a rise in imported goods, mainly in capital goods.

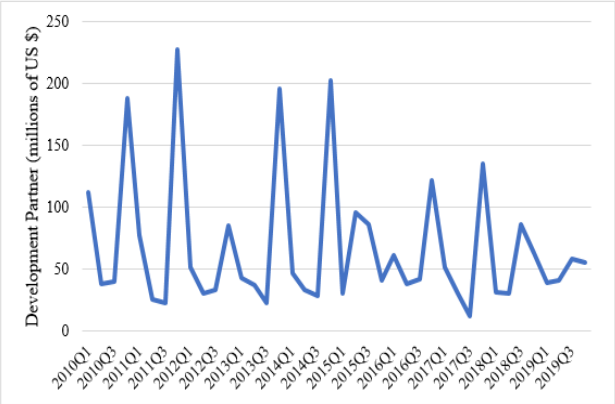

Figure 6. Development Partners FCE and Investment (Adjusted)

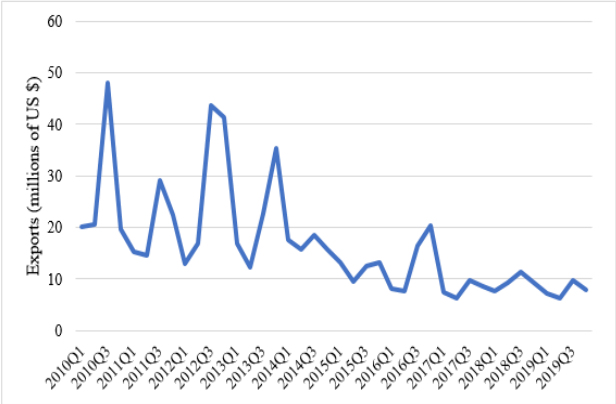

Figure 7. Exports of Goods and Services (Adjusted)

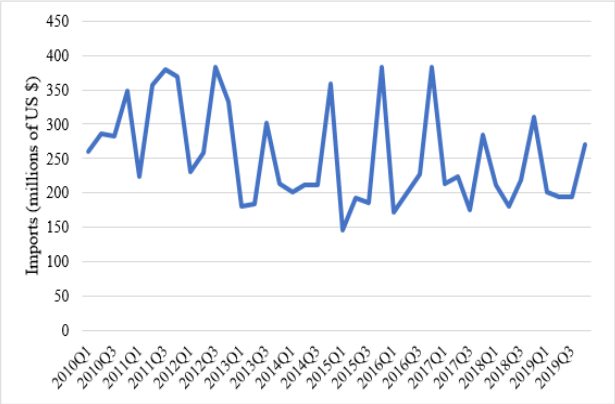

Figure 8. Imports of Goods and Services (Adjusted)

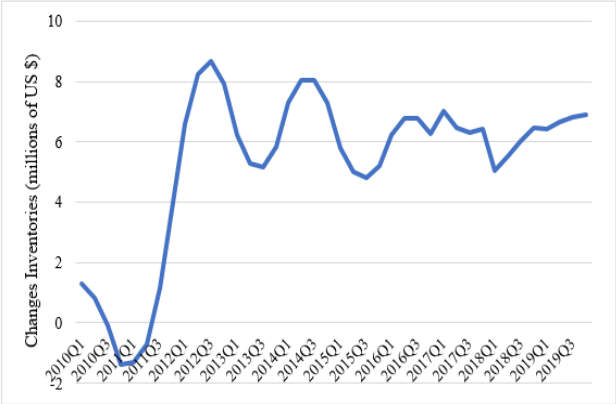

Figure 9. Changes in Inventories (Adjusted)

In Figure 9, the changes in inventories showed an increase in 2011 and maintained around 6 million throughout the years. A massive increase in 2011 was due to a shift in live animals' stocks for slaughter and an increase in the change of inventories of finished goods. A decrease in 2013 and 2015 was due to lower inventories in rice, given the fall in local production. Figure 10 showed the acquisition less disposals of valuables data from 2010 to 2019. This data obtained from the living standard survey of Timor–Leste (TL–LSS) and covered the information about the valuables (Jewelry) of the households. It relatively has a small contribution to the GDP of Timor-Leste.

Finally, Figure 11 showed the GDP (E) at a constant price from 2010 to 2019. The GDP fluctuated greatly over the years due to seasonality in the data set. The seasonality in the GDP series was mainly translated from the government spending, development partners' expenditure,

and exports of goods and services. Obviously, the major contribution to Timor-Leste GDP is the final consumption expenditure and investment from the government.

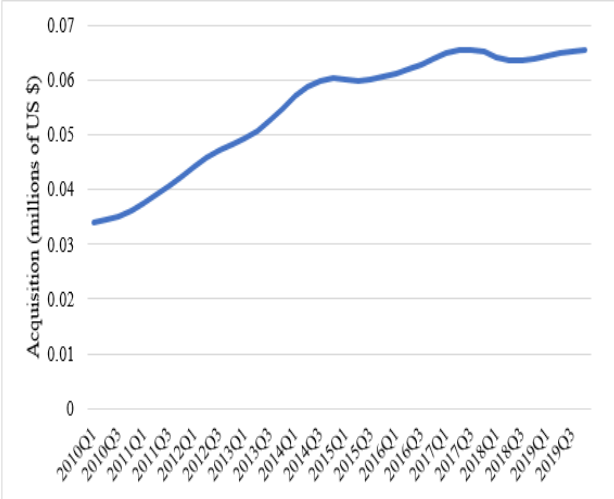

Figure 10. Acquisition less disposals of valuables (Adjusted)

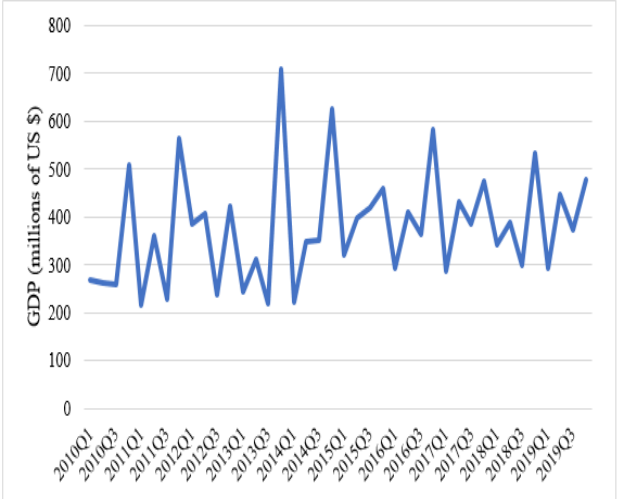

Figure 11. GDP at Constant Prices (Adjusted)

4.2. Denton Method and Cholette - Dagum Method Results

The following graphs present the adjusted and unadjusted GDP and its components estimation using the Denton and Cholette–Dagum method. Notice that the green line indicates the adjusted or publish GDP and its component. The blue line represents the unadjusted GDP and its components using the Denton method. The yellow line denotes the unadjusted GDP and its components using the Cholette – Dagum method.

Figure 12 shows an increasing pattern of private FCE from 2010 to 2019. It indicated that both methods produced a similar pattern of private consumption as the published data. Comparing the unadjusted and adjusted private consumption showed that both methods overpredicted the private consumption in 2016 and underpredicted it for 2017 onwards. These results aligned with the expectation that it will underpredict in the slow economic growth period and overpredict in the positive economic growth period. However, it expects that both methods would overpredict the private consumption for 2019 because the economic growth for 2019 is positive.

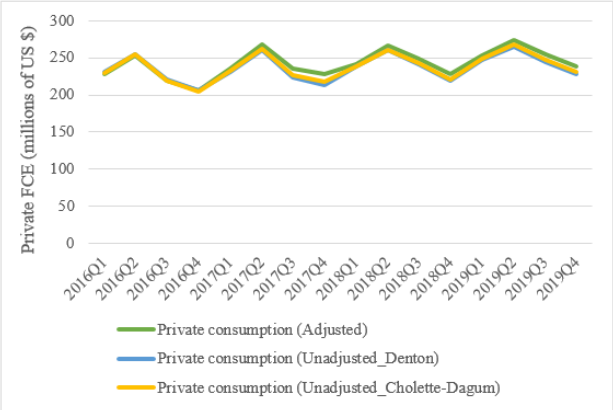

Figure 12. Private Final Consumption

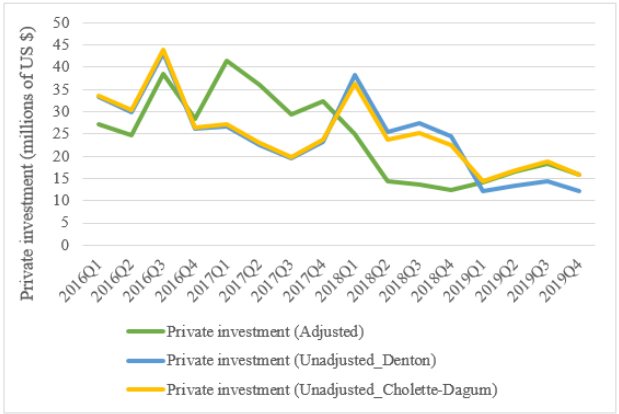

Figure 13. Private Investment

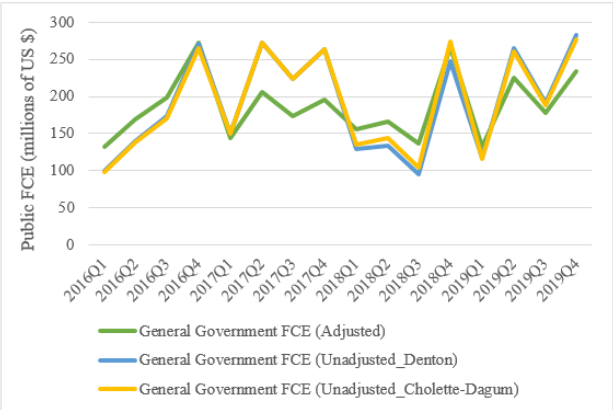

Figure 14. Public Final Consumption

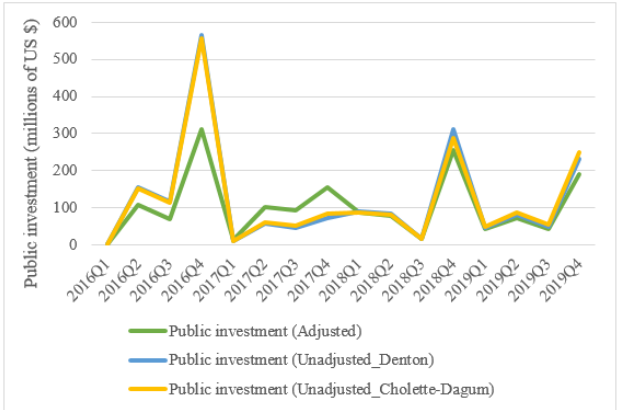

Figure 15. Public Investment

As for private investment in Figure 13, both methods overpredicted it in the first to the third quarter of 2016, 2018, and underpredicted for 2017. In 2019, Denton underpredicted the private investment; in contrast, Cholette-Dagum estimated private investment as relatively similar to the adjusted version. The result from both methods for 2018 and Denton's result for 2019 was not as expected. Additionally, the government FCE was underpredicted by both methods for 2016 and 2018, and it was overpredicted for 2017 and 2019. Notice that the estimation for 2016 and 2017 are not as expected to be. It is likely to underpredict for 2017 because the government expenditure and investment decreased in that year. On the other hand, public investment was overpredicted for 2016 to 2019 except for 2017.

Moreover, the development partners' expenses were mainly overpredicted for 2016 and 2019 and underpredicted for 2017 to 2018. These results aligned with the prior expectation that the methods will overpredict for positive economic growth and underpredict for negative economic growth. Additionally, the Denton method overpredicted exports of goods and services from 2016 until 2019 except for 2018, while the Cholette – Dagum overpredicted the exports for all the years. Nevertheless, the imports of goods and services were underpredicted by both methods for 2016 and 2018. Furthermore, changes in inventories were also underpredicted by Denton for all the years except 2018, while the Cholette – Dagum method underpredicted it for all the years. In contrast, both methods underpredicted the acquisition less disposals of valuables for 2016 to 2019, except that the Cholette - Dagum method overpredicted it for 2018.

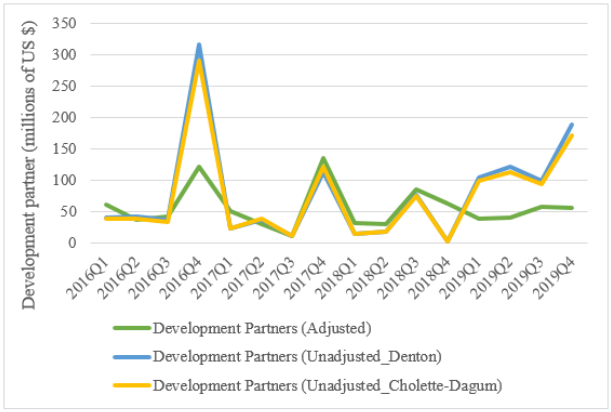

Figure 16. Development Partners FCE and Investment

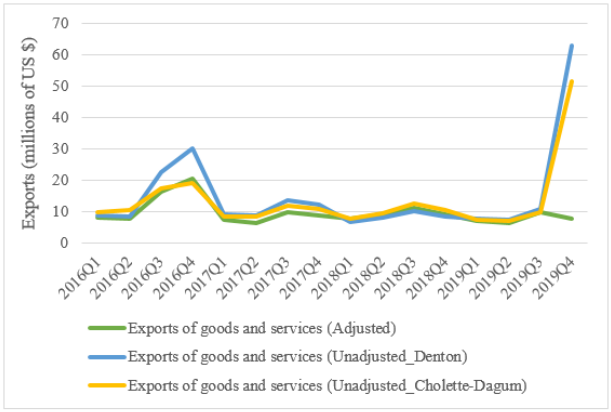

Figure 17. Exports of Goods and Services

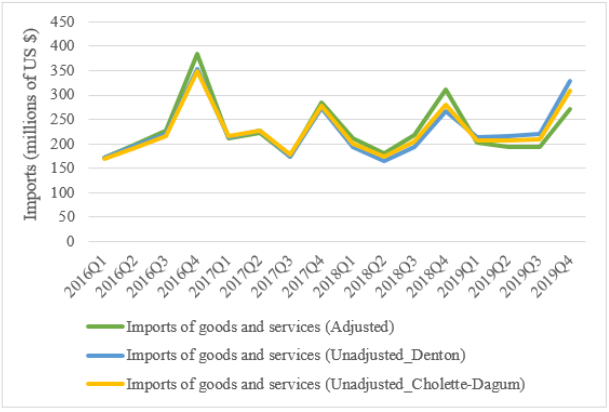

Figure 18. Imports of Goods and Services

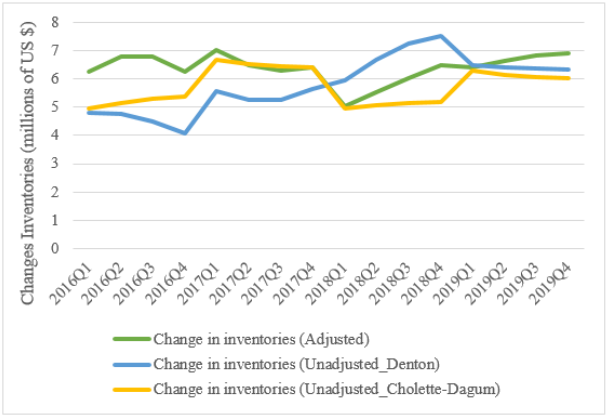

Figure 19. Changes in Inventories

Overall, both methods produced a quarterly GDP estimation with a similar pattern as the adjusted or published quarterly GDP series except for some gaps in 2016Q4. Additionally, on average, the quarterly GDP estimation uses both methods aligned with the expectation that it overpredicted 2016 and 2019 and underpredicted it for 2017 and 2018.

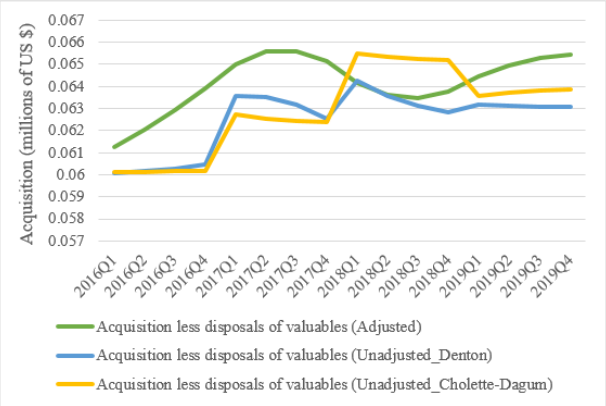

Figure 20. Acquisition less disposals of valuables

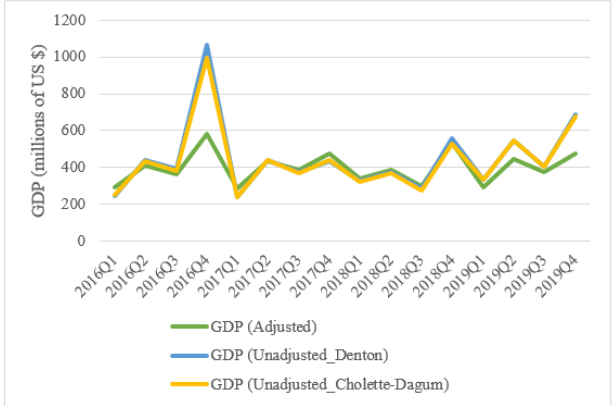

Figure 21. GDP at Constant Prices

4.3. Evaluation

By looking at the pattern in the differences in adjusted and non-adjusted GDP estimations, the GDP's components such as private consumption and investment, development partners, public consumption, and import of goods and services were underpredicted by the Denton and Cholette-Dagum method. From these components, private consumption was consistently undervalued from 2017 to 2019 by both methods. This negative pattern of the estimation can be well-explained by the lack of information on the short-term indicator on private consumption. However, there was not a significant difference between the adjusted and non-adjusted private consumption. On average, the actual (adjusted) value of private consumption from 2016 to 2019 was 243 million, the Denton estimation was 236.6 million, and the Cholette – Dagum estimation was 237.7 million. It implied that the Denton method and Cholette – Dagum respectively underpredicted private consumption by around 5.9 million and 4.6 million. Therefore, it can be inferred that the Cholette

- Dagum method performs better than the Denton method. Additionally, the method produced an estimation that follows a pattern of overestimating for positive economic growth and underestimating for negative economic growth.

Private investment was overpredicted for one year and underpredicted for another year by both methods. A similar pattern was consistently replicated for 2018 and 2019. The actual private investment from 2016 to 2019, on average, was 24.3 million, the Denton estimation was 24.5 million, the Cholette – Dagum estimation was 25.1 million. By looking at the difference between adjusted and non-adjusted private investment estimated using both methods, the differences were less than 1 million. Both methods respectively overpredicted private investment by 220 thousand and 820 thousand. In this case, the Denton method produced private investment closer to the adjusted data. Moreover, the Denton method underpredicted for slower economic growth in 2017 and positive growth in 2019, while the Cholette – Dagum performed as expected in both low and high economic growth.

Public consumption was consistently underpredicted for one year and overpredicted for another year by both methods. However, there is not a relative difference between the adjusted and non-adjusted private consumption. On average, the actual (adjusted) value of public consumption from 2016 to 2019 is 186.59 million, the Denton estimation is 190.94 million, and the Cholette – Dagum estimation is 192.53 million. It implies that the Denton method and Cholette – Dagum were overpredicted public consumption by around 4.35 million and 5.94 million. It can be inferred that the Denton method performs better than the Cholette - Dagum method. Additionally, the methods produce an estimation that is not as expected where overestimating for positive economic growth and underpredict for negative economic growth.

Public investment was not consistently underpredicted by the Denton method, whereas it is systematically underpredicted by the Proportional Cholette – Dagum. The Cholette – Dagum method results' follow a pattern where it underpredicted in the slow economic growth between 2017 to early 2018 and overpredicted for high economic growth, while the Denton method only underpredicted for 2017. In this case, the Denton method's result does not portray Timor – Leste's economic situation from 2017 to 2018. Additionally, on average, the actual (adjusted) value of public investment from 2016 to 2019 is 102.64 million, the Denton estimation is 120.93 million, and the Cholette – Dagum estimation is 121.13 million. It implies that the Denton method and Cholette – Dagum were respectively overpredicted public investment by around 18.29 million and 18.49 million. From this, it can be seen that there is a vast difference between the adjusted and non-adjusted private investments. Moreover, the Denton method performs better than the Cholette - Dagum method. Additionally, the methods produce an estimation that aligns with the prior expectation of overestimating for positive economic growth and underestimating for negative economic growth.

Development partners were consistently underpredicted for slow economic growth from 2017 to 2018 and overpredicted for positive economic growth in 2016 and 2019 by both methods. Both methods are able to produce an estimation that reflects the economic situation in Timor – Leste. Moreover, there is not a significant difference between the adjusted and non-adjusted development partners' expenses. On average, the actual (adjusted) value of development partners' data from 2016 to 2019 is 55.65 million, the Denton estimation is 63.07 million, and the Cholette – Dagum estimation is 61.38 million. It implies that the Denton method and Cholette – Dagum have respectively underpredicted development partners' consumption and investment by around

7.42 million and 5.73 million. It can be inferred that the Cholette - Dagum method performs better than the Denton method.

Exports of goods and services were consistently overpredicted from 2016 to 2019 by the Cholette – Dagum method. The Denton methods did overpredict for all the time but underpredicted for low economic growth. It is believed that even in slow and high economic growth, Timor – Leste will continue to increase their production to export. However, there is not a significant difference between the adjusted and non-adjusted exports. On average, the actual (adjusted) value of exports of goods and services from 2016 to 2019 is 9.57 million, the Denton estimation is 14.74 million, and the Cholette – Dagum estimation is 13.24 million. It implies that the Denton method and Cholette – Dagum have respectively overpredicted exports of goods and services by around 5.18 million and 3.68 million. It can be concluded that the Cholette - Dagum method performs better than the Denton method.

Imports of goods and services were consistently underpredicted for one year and overpredicted for another year by both methods, same as public consumption. The methods perform not as expected for this component. However, there is not a significant difference between the adjusted and non-adjusted imports of goods and services. On average, the actual (adjusted) value of imports of goods and services from 2016 to 2019 is 228.62 million, the Denton estimation is 226.63 million, and the Cholette – Dagum estimation is 225.98 million. It shows that the Denton method and Cholette – Dagum were respectively underpredicted private consumption by around 1.99 million and 2.64 million. It can be interpreted that the Denton method performs better than the Cholette - Dagum method.

Changes in inventories were consistently underpredicted for 2016 to 2019 by the Cholette – Dagum method. It was systematically underpredicted by the Denton method as well, except in

2018. The methods perform not as expected for this component. On average, the actual (adjusted) value of changes in inventories from 2016 to 2019 is 6.38 million, the Denton estimation is 5.80 million, and the Cholette – Dagum estimation is 5.73 million. There is not a significant difference between the adjusted and non-adjusted changes in inventories. Additionally, it shows that the Denton method and Cholette – Dagum were respectively underpredicted private consumption by around 0.58 million and 0.65 million. Intuitively, it can be interpreted that the Denton method performs better than the Cholette - Dagum method.

In contrast, acquisition less disposals of valuables were consistently underpredicted by the Denton method. It was underpredicted for all the years except 2018 by the Cholette – Dagum method. In this case, both techniques did not perform as expected for positive economic growth. However, there is not a significant difference between the adjusted and non-adjusted acquisition less disposals of valuables. On average, the actual (adjusted) value of acquisition less disposals of valuables from 2016 to 2019 is 0.064 million, the Denton estimation is 0.062 million, and the Cholette – Dagum estimation is 0.063 million. It shows that the Denton method and Cholette – Dagum were respectively underpredicted private consumption by around 0.002 million and 0.001 million. It can be interpreted that the Cholette - Dagum method performs better than the Denton method because the difference from the Cholette Dagum method is less than the Denton method estimation.

Based on the results in section 4.2, GDP was consistently underpredicted for slow economic growth and overpredicting positive economic growth. Additionally, there is a significant difference between the adjusted and non-adjusted GDP. On average, the actual (adjusted) value of GDP from 2016 to 2019 is 399.01 million, the Denton estimation is 447.01 million, and the Cholette – Dagum estimation is 437.56 million. It indicates that the Denton method and Cholette

– Dagum were respectively overpredicted GDP by around 48 million and 38.54 million. In this case, it can be inferred that the Cholette - Dagum method performs better than the Denton method. However, if observing more closely on GDP for each quarter and comparing the annual benchmark and the annualized quarterly series, both methods randomly over or underpredict the quarterly GDP series. Both comparisons of GDP estimation respectively can be seen in table 1 and table 2 below. Table 1 shows the actual number and the GDP estimation using the Denton and Cholette-Dagum method from 2016 to 2019.

Table 1. The estimation of Adjusted (published) and non-adjusted Gross Domestic Product (Denton and Cholette-Dagum's estimation)

	GDP (Published)	**GDP (Denton)**	**GDP (Cholette-Dagum)**	**Error Denton**	**Error Dagum**
(1)	*(2)*	*(3)*	*(4)*	*(5)=(3)-(2)*	*(6)=(4)-(2)*
2016Q1	293.90	248.00	248.73	**-45.89**	-45.16
2016Q2	408.53	438.64	432.70	**30.11**	24.17
2016Q3	363.33	395.73	380.87	**32.40**	17.55
2016Q4	582.30	1064.47	995.65	**482.17**	413.35
2017Q1	288.30	240.78	239.12	-47.52	**-49.17**
2017Q2	431.86	439.25	438.84	**7.39**	6.98
2017Q3	384.75	372.98	367.91	-11.77	**-16.84**
2017Q4	475.52	434.73	441.40	**-40.79**	-34.12
2018Q1	341.41	328.86	321.23	-12.56	**-20.18**
2018Q2	389.74	375.69	368.35	-14.05	**-21.38**
2018Q3	300.13	284.62	277.22	-15.51	**-22.91**
2018Q4	532.49	557.63	531.57	**25.14**	-0.92
2019Q1	293.15	331.74	330.89	**38.60**	37.75
2019Q2	447.34	548.42	544.69	**101.08**	97.35
2019Q3	373.70	401.89	403.81	**28.19**	30.11
2019Q4	477.75	688.72	677.93	**210.96**	200.18

Based on the results in table 1, for one quarter, the difference between adjusted and non-adjusted GDP estimation might be smaller for the Denton method. For another quarter, it might be smaller for the Cholette – Dagum method. A similar pattern is repeated on an annual basis, as shown in table 2.

Table 2. The comparison between annual benchmark GDP and the sum of the quarterly GDP from both methods

	GDP Annual	GDP (Annualized Denton)	GDP (Annualized Cholette -Dagum)	Error (Denton)	Error (Dagum)
2016	1648.06	2146.85	2057.96	**498.79**	409.90
2017	1580.43	1487.74	1487.27	-92.69	**-93.16**
2018	1563.77	1546.80	1498.38	-16.98	**-65.40**
2019	1591.94	1970.77	1957.33	**378.83**	365.39

These results contrast with the theory that for extrapolation, the Cholette – Dagum method will perform better than the Denton method. In this particular case, it can be inferred that both methods are relatively not performed well enough in terms of forecasting GDP when the annual benchmark is not available. Alternatively, these estimations can still be improved by using other time series or forecasting methods.

Moreover, the difference between the adjusted (published) and non-adjusted GDP (unpublished) is illustrated in Figure 22.

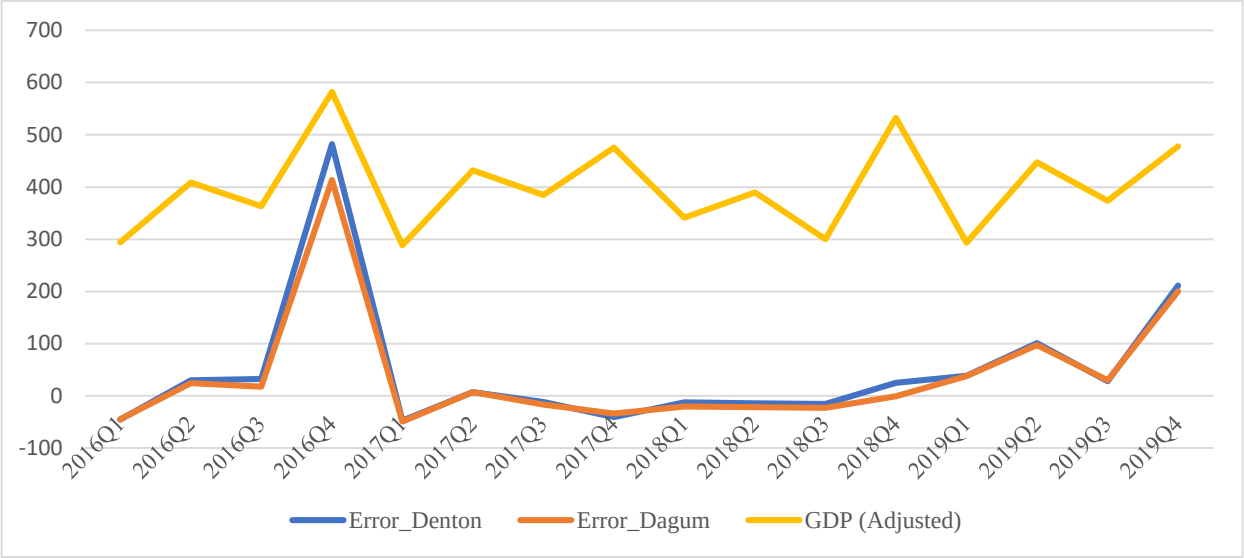

Figure 22. The difference between adjusted and non-adjusted GDP

It is clearly shown that in estimating quarterly GDP from 2016Q1 to 2019Q4, both methods produce relatively similar results except for some gaps in the fourth quarter of 2016 and 2018. Both methods produce a similar pattern due to the slight difference in the AR (1) parameter value.

The Cholette – Dagum uses the value of 0.84 for the AR (1) parameter, and the Denton method implicitly uses the value of 1 for the AR (1) parameter.

Overall, based on the graphical comparison, it is difficult to distinguish which method out of the two methods considered performs better. It is relatively subjective. It shows that the Denton method performs well for some components, and for another component, the proportional Cholette – Dagum outperforms the Denton method. Therefore, a further check is needed. Finally, in terms of minimum MAE, the proportional Cholette – Dagum model outperforms the proportional Denton method for GDP and its components. As shown in Table 1 below, all MAE value for Cholette – Dagum method is smaller than the proportional Denton method.

Table 2. The Mean Absolute Error estimation

	Mean Absolute Error	
	Denton	**Cholette - Dagum**
Private consumption	6.67	**4.94**
Private investment	8.03	**6.72**
Public consumption	22.18	**19.30**
Private consumption	32.42	**29.73**
Development Partner	40.77	**38.50**
Exports of goods and services	5.69	**3.85**
Imports of goods and services	17.25	**12.77**
Changes in inventories	1.13	**0.68**
Acquisition less disposals of valuables	**0.0017**	0.0020
GDP	71.51	**64.88**

4.4. Exploring new indicators

Based on the evaluation, there is a considerable difference between the adjusted and non-adjusted private consumption, exports of goods and services, and public investment. Additionally, both methods also estimate the private investment and changes in inventories for some years quite different from the adjusted series. One reason for miscalculating the change in inventories might be because of not considering any indicator and only using constant (1) as an indicator. However, the contribution of the changes in inventories to the aggregate GDP is considerably small

compared to private consumption and investment. Therefore, this report is only considering exploring the indicators for private consumption and investment. Indicators considered at the moment for estimating private consumption are credit from a bank to the household, and government transfer to the households includes pension for veterans, elderly, and disabled. Moreover, the indicator considers for the private investment is credit from a bank to the private sector.

5. Conclusion

Overall, this study will broaden other data producers' and users' knowledge of estimating Timor-Leste QGDP(E). This study replicates and evaluates the temporal disaggregation of the Timor-Leste quarterly GDP estimation and its components using the Proportional Denton method. It demonstrates that the Denton method does not yield satisfactory results. The measurement error associated with the Denton estimation is relatively high.

This paper has explored the possibility of using the Cholette-Dagum method for TL, showing how the method works and providing quarterly GDP estimates. Graphically, the results from both methods show a similar pattern or trend for non-adjusted quarterly GDP and its component. Those results also follow a similar pattern as the adjusted GDP series and its components except private investment and changes in inventories. By comparing the two estimations, adjusted and non-adjusted GDP and its components, the results show that the differences are relatively high for the GDP and some of the main components of GDP such as public investment, exports of goods and services, private consumption.

Overall, it can be concluded that one method does not over or underperform relative to the other method. It is by chance only that Denton or Cholette – Dagum produce a quarterly estimation

that is closer to the adjusted quarterly series. Another finding is that there is a possibility that the indicators for those variables are not entirely representative or fully cover the economic situation in Timor - Leste. Thus, it is expected to improve the quality of the information for the available indicator or explore better indicators in estimating GDP. Public investment and exports of goods and services are directly measured using the indicators from the direct sources as the annual benchmark sources. Therefore, the indicators for these two components will be maintained, but some smoothing or adjustment to the data or outlier needs to be done. However, the indicator used to estimate private consumption and investment and change in inventories needs to be revised. Based on this, it is possible to use government transfer to the household and credit from the bank to the household as proposed indicators for estimating private consumption. In contrast, the credit from a bank to the private sector may be used as an indicator to estimate private investment.

Based on the results, it is suggested that the Timor-Leste Statistics office can continue to use the existing method and regularly publish the quarterly GDP numbers with revisions made every quarter and year when more information available. However, it is crucial to inform the policymakers and other data users to use the quarterly GDP with some caution that the quarterly numbers are not fixed, and it will change. This quarterly estimation is only early information to show how the Timor-Leste economy situation is going to be in a respective year. Another suggestion is that if the GDS wants to use the Cholette – Dagum method in the future, it will be helpful if the GDS estimates the AR (1) parameter its own AR parameter value based on the Timor – Leste data. The reason is that the Cholette – Dagum is not performed well in this analysis. It might be because the value of the AR parameter recommended by the IMF is not suitable for the Timor – Leste economy.

6. Further Work

One problem with the literature that the Denton and Cholette-Dagum methods are derived from is with the approach: a sequence of papers would start with an idea for a relatively simple proposed method for producing quarterly GDP estimates, then subsequent work discovers some limitation of that method, extensions or adaptations have proposed that address the limitation, and the methods evolve incrementally with increasing complexity. There is a case for going "back to basics" and starting with a model as an assumed data generating process. Based on this model, an implied forecasting method could be used to provide the Quarterly GDP estimates based on the measured values of the relevant indicators.

An obvious starting point is to assume a relationship between each GDP component and its lag for the same quarter from the previous year and contemporaneous values of the quarterly GDP indicators. Then, overall GDP will be the sum of the components. The model is illustrated as follows:

$$y_{i,t} = \mu + \phi y_{i,t-4} + \theta X_t + U_{i,t} \qquad (14)$$

Where, $Y_{i,t}$ is the ith GDP component (9 components); $Y_{i,t-4}$ is the value of that GDP component for the same quarter from the previous year; X_t is the vector of indicators used to estimate the respective components; and t is time index for quarterly series

The estimated quarterly GDP will be:

$$\widehat{Y_t} = \sum_{i=1}^{9} \widehat{y_{\iota,t}} \qquad (15)$$

where the $\widehat{y_{\iota,t}}$ values are predictions based on estimates of equation (14). Historical data and adjusted quarterly GDP values can be used to estimate the parameters of equation (14). The other benefit of this approach is that the relevance of specific indicators can be assessed by testing parameter significance in equation (14). The functional form of the relationship between indicators

and quarterly GDP can be explored using standard nonparametric regression techniques. Other extensions can be developed all within well-established methodologies for regression modeling. This increases the transparency of all the methodologies used, rather than statistical agencies relying on a "black box approach" of the Denton and other methods, with little insight into their statistical foundations.

Unfortunately, there was not enough time to explore this alternative approach in this paper, but it will be considered in subsequent work.

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