Draft Technical Paper: Australian State and Territory Quarterly Gross State Product

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Introduction

Gross Domestic Product (**GDP**) is a common measure of economic activity in a country's economy. The Australian Bureau of Statistics (**ABS**) describes GDP as:

> *The conceptual underpinning of GDP is that it measures gross value added for all resident institutional units for the whole economy. Gross value added is the difference between output and intermediate consumption for each institutional unit and thereby measures the value created by production. Value added represents the contribution of labour and capital to the production process.*

ABS (2021a)

The equivalent measure to GDP at the Australian state and territory (**state**) level is Gross State Product. (**GSP**, ABS, 2021b)

The Australian Bureau of Statistics (**ABS**) publishes quarterly national GDP (ABS, 2022a) from the September quarter 1959 onward.

It also publishes annual state Gross State Product (ABS, 2022a) and quarterly State Final Demand (**SFD**, ABS, 2022b) four times a year but does not publish quarterly GSP.

While SFD makes up a major portion of GSP from the demand side, SFD excludes international trade in goods and services and the GSP balancing item (ABS, 2020). The balancing item reflects: changes in inventories; interstate trade in goods and services; and the balancing item discrepancy.

This paper uses the benchmarking statistical method to allocate annual GSP to a quarterly basis using quarterly industry indicator data. This is done for current price, or nominal, data and chain volume, or constant-price, data.

Benchmarking and Extrapolation

Benchmarking

Benchmarking is a common procedure to estimate quarterly economic data when a high-quality quarterly estimate of the data is not available. For example, the ABS notes that its annual GDP estimates are superior in quality to its quarterly GDP estimates (ABS, 2015, p98).

Benchmarking is a mathematical procedure that calculates a final quarterly estimate of a data series. It maintains as closely as possible the patterns in the low-quality quarterly data, called the indicator series, while constraining the final quarterly estimate to summing to the high-quality annual data, called the benchmark series.

Benchmarking need not to be applied to quarterly to annual data and is applicable to any high frequency data within the constraint of the final series adding to lower frequency data.

This paper uses the proportional variant method, which aims to keep the slope of the final benchmarked quarterly series as close to the slope of the quarterly indicator series while summing to the annual indicators (Cholette, 1984, p39). The Cholette method has the advantage over methods used by the ABS (ABS, 2021d) in that the first data point in the quarterly indicator series and the final quarterly series need to be the same (Cholette, 1984, p39).

Minimise:

1) $$p(x) = \sum_{t=2}^{n} (\Delta(x_t - z_t)/z_t)^2 = \sum_{t=2}^{n} \left(\Delta(x_t/z_t)\right)^2$$

Subject to:

2) $$\sum_{t=(i-1)k+1}^{ik} x_t = y_i, i = 1,2, \dots, m$$

Where:

x is the desired quarterly benchmarked data point in time t, t=1,….,n

z is the quarterly indicators data point in time t, t=1,….,n

y is the annual benchmark data point in time i, i=1,   ,k

n = k*m is the number of indicator observations, 80 in this case

m is the number of annual benchmarks available, 20 in this case

k is the number of indicators to benchmarks, 4 in this case

This constrained minimisation is solved using Lagrangean maximisation on the vectors of each variable (Cholette, 1984, p40):

3) $$\begin{bmatrix} \underline{x} \\ \underline{g} \end{bmatrix} = \begin{bmatrix} Z^{-1}AZ^{-1} & B \\ B' & 0 \end{bmatrix}^{-1} \begin{bmatrix} Z^{-1}AZ^{-1} & 0 \\ B' & I \end{bmatrix} \begin{bmatrix} \underline{z} \\ \underline{r} \end{bmatrix} = \begin{bmatrix} I & W_x \\ 0 & W_1 \end{bmatrix} \begin{bmatrix} \underline{z} \\ \underline{r} \end{bmatrix}$$

Where:

$\underline{x}$ is the vector containing the desired quarterly benchmarked data series

$\underline{z}$ is the vector containing the vector of quarterly indicators

$\underline{g}$ is the vector containing the Lagrangean multipliers

$\underline{y}$ is the vector containing the annual benchmark series

$\underline{r}$= B'$\underline{z}$-$\underline{y}$ is the vector containing the annual discrepancies

$$\frac{x}{n*1} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{bmatrix} \quad , \quad \frac{z}{n*1} = \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ \vdots \\ xz_n \end{bmatrix} \quad , \quad \frac{y}{m*1} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \vdots \\ y_m \end{bmatrix} \quad , \quad \frac{g}{mx*1} = \begin{bmatrix} g_1 \\ g_2 \\ g_3 \\ \vdots \\ g_m \end{bmatrix}$$

$$\frac{A}{n*n} = D'D \quad , \qquad \frac{D}{(n-1)*n} = \begin{bmatrix} -1 & 1 & 0 & \dots & 0 \\ 0 & -1 & 1 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

$$\frac{B}{nxm} = \begin{bmatrix} \underline{j} & 0 & \cdots & 0 \\ 0 & \underline{j} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \underline{j} \end{bmatrix} . \ \frac{\underline{j}}{k*1} = \begin{bmatrix} 1 \\ 1 \\ \vdots \end{bmatrix}, n = k*m$$

This calculation can be performed easily in modern programming software.

Un-benchmarked Observations

Benchmarking calculations can only be applied to data where the number of annual benchmarks is the number quarterly observations divided by four. For example, in the calculations in this paper, there are 20 annual benchmarks from 2002/03 to 2021/22, and 80 quarterly indicators from September 2002 to July 2022.

However, there are frequently more quarterly indicator data available than applicable benchmarks. In the current case, quarterly indicator data are released by the ABS throughout each year, so there are often part-year data available for which there is no annual benchmark.

In this paper, quarterly indicator data for the September and December quarters of 2022 are available, but these cannot be benchmarked to an annual data because: a minimum of four indicators is needed against which to compare with an annual benchmark; and no such annual benchmark exists.

However, timely quarterly GSP in the latest quarter available are of interest to policymakers and forecasters, so another method of adjusting quarterly indicators to final quarterly data is needed.

The un-benchmarked indicators are adjusted by the same weights as the corresponding quarter in the last benchmarked year. Formally, if the vector of quarterly indicators is given by:

4) $$\underline{z} = [z_1, z_2 \dots, z_n, \dots, z_{n+b}], 1 \le b \le k$$

And the final quarterly data series vector is:

5) $$\underline{x} = [x_1, x_2 \dots, x_n, \dots, x_{n+b}], 1 \le b \le k$$

Where there are b quarterly observations after the last benchmarkable indicator. The variable b can be between 1 and four for quarterly data. If b is four, there is a complete year of quarterly indicator data, but the annual benchmark has not yet been released.

The final benchmarked quarterly data points are calculated by the following formula.

6) $$x_c = z_c * \left(\frac{x_{c-k}}{z_{c-k}}\right), c \in \{1, b\}$$

For example, the final value of GSP for each state in the September quarter 2022 equals the quarterly indicator for the September quarter 2022 multiplied by the ratio of GSP the for the September quarter 2021 to quarterly indicator for the September quarter 2021.

Available Data and Implementation in Python

Data

This paper utilises publicly available ABS data and the Cholette benchmarking procedure, to construct a quarterly GSP series for Australian States. The ABS data used in this paper are:

- Quarterly **Gross Domestic Product (GDP):** Is the total market value of goods and services produced in Australia within a given period after deducting the cost of goods and services used up in the process of production but before deducting allowances for the consumption of fixed capital. Gross domestic product, as here defined, is 'at market prices'. It is equivalent to gross national expenditure plus exports of goods and services less imports of goods and services (ABS, 2021c).
  - These data are published on an annual basis in ABS in Cat No. 5220.0 (ABS, 2022b) and quarterly in in ABS in Cat No. 5206.0 (ABS, 2022a).
- **Annual Gross State Product (AGSP, State):** Defined equivalently to GDP but refers to production within a state or territory rather than to the nation as a whole (ABS, 2021c).
  - These data are published by the ABS in Cat No. 5220.0 on an annual basis (ABS, 2022b).
- **Quarterly National Industry Gross Value Added (QNIGVA, Industry):** The value of output at basic prices minus the value of intermediate consumption at purchasers' prices. The term is used to describe gross product by industry and by sector. Basic prices valuation of output removes the distortion caused by variations in the incidence of commodity taxes and subsidies across the output of individual industries (ABS, 2021c).
  - These data are published quarterly at a national level in ABS in Cat No. 5206.0 (ABS, 2022a) for each of the 19 Industry Divisions in the Australian and New Zealand Standard Industrial Classification (**ANZSIC**) system (ABS, 2013).
- **Annual State Industry Total Factor Income (ASITFI, State, Industry):** That part of the cost of producing GDP which consists of gross payments to factors of production (labour and capital). It represents the value added by these factors in the process of production and is equivalent to gross domestic product less taxes plus subsidies on production and imports (ABS, 2021b).
  - These data are published annually at the State level by the ABS in Cat No. 5220.0 on an annual basis (ABS, 2022b) for each of the 19 Industry Divisions in the ANZSIC system.

The benchmarking procedure is applied to original (i.e. not seasonally adjusted or trend) data, with seasonal adjustment later applied to the benchmarked quarterly state GSP series. All data are available in current price (nominal) and chain-volume (real or inflation adjusted) terms (ABS, 2003), and an individual benchmarking procedure is performed on each to form GSP in both price formats.

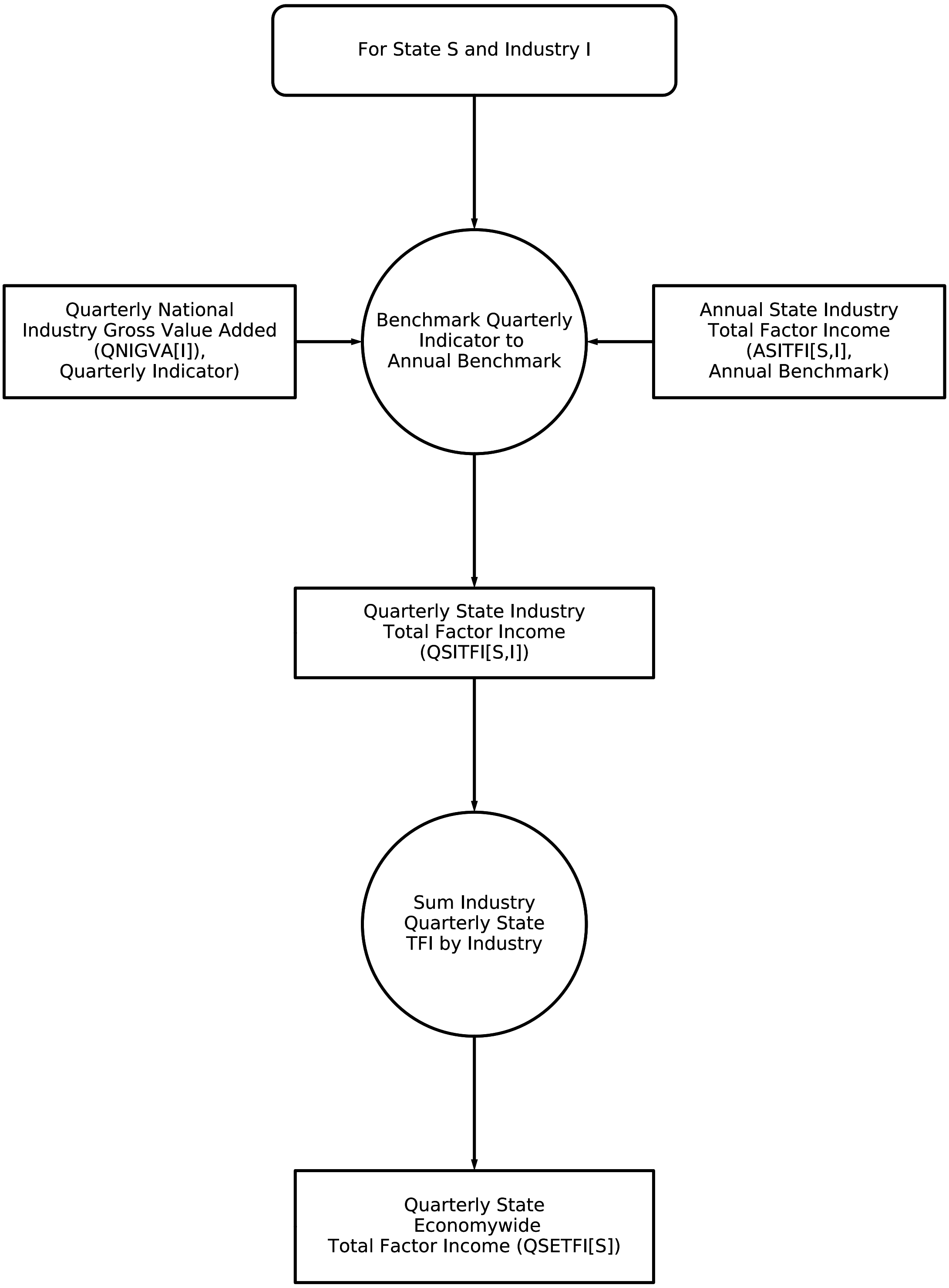
While the quarterly allocation of annual GSP is done using industry TFI, the final quarterly GSP data are not GSP as measured from the production side. It is the final quarterly measure of GSP as measured from the average of the production, income and expenditure sides (ABS, 2020).

In this paper, there are 20 annual benchmarks from 2002/03 to 2021/22, which 80 quarterly indicators from September 2002 to July 2022, and two un-benchmarked observations for the September and December quarters 2022.

Implementation

The calculations in this paper are implemented in the Python (Python, 2023) software package. The first part of the benchmarking procedure is shown in Figure 1 below.

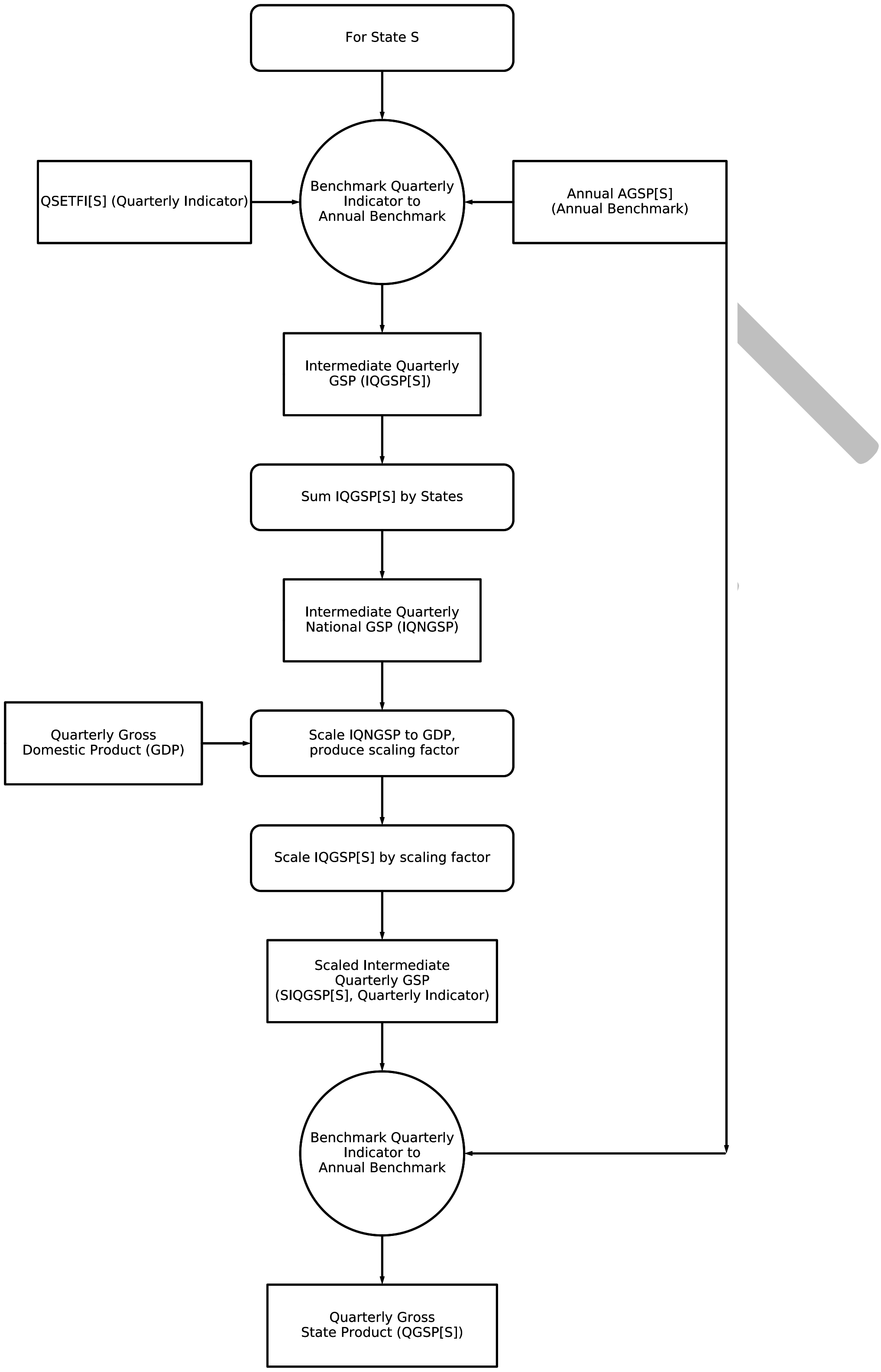
Figure 1: Stage 1, Benchmark Quarterly GVA to Annual TFI.



The process takes QNIGVA as the quarterly industry indicator for each State, which is benchmarked against ASITFI, to form **Quarterly State Industry TFI (QSITFI)**

Even though the initial quarterly GVA indicator is the same for each industry in every state, the benchmarked quarterly TFI output data series will diverge to the extent that the annual change in TFI for each industry in each State diverges.

Figure 2: Stage 2, Benchmark Quarterly Total Factor Income to Annual Gross State Product, Scale to Gross Domestic Product, Produce Quarterly Gross State Product



The advantage of using readily available quarterly GVA data from the ABS is that the calculations outlined in this paper can be coded and quickly run every time the ABS releases new data.

In the final part of Stage 1, Quarterly industry TFI by state is summed by industry to form **Quarterly State Economywide Total Factor Income (QSETFI)**.

The second stage of the calculations takes place when, for each state and price type, QSETFI is benchmarked against annual GSP, to form **Intermediate Quarterly GSP (IQGSP)**.

IQGSP is summed across states to form a national figure of **Intermediate Quarterly National GSP (IQNGSP)**. A scaling factor is calculated by dividing each quarter's GDP by Intermediate National Quarterly GSP. For example, the Intermediate IQNGSP figure for the December quarter 2022 is 1.002888 below the GDP figure for the same quarter, the scaling factor for the September quarter 2021 is 0.288%.

Each individual state GSP series is then adjusted by this scaling factor, to form **Scaled Intermediate Quarterly GSP (SIQGSP)**. For example, all individual state GSP figures for the September quarter 2021 are adjusted upwards by 0.288%. SIQNGSP forms the new quarterly indicator for GSP for each state and for both current and chain volume prices.

Finally, each state SIQNGSP series is benchmarked to Annual GSP. This forms **Quarterly GSP (QGSP)** for each state and for current and chain volume prices.

The sub-components of chain volume data, such as state GSP, do not add to aggregate data, such as GDP, particularly as the data become further from the reference year, which is 2020/21 in this paper. The ABS notes:

> *As weights of a chain volume index change from year to year, chain volume indexes have no base period in the sense of a fixed–weight index base period and therefore non–additivity exists in the chain volume measures. Non–additivity occurs because the values of component chain volume measures expressed in dollar terms do not generally add up to the dollar value of the aggregate chain volume measure.*

ABS (2003), p23

Therefore, scaling IQGSP data to chain volume quarterly GDP as in the first part of Stage 2, which constructs SIQNGSP, produces a data series that is not realistic, as the data points furthest from the benchmark year are not scaled correctly. However, re-benchmarking SIQNGSP to annual GSP in the second part of Stage 2, will re-introduce the divergence of the sum of states GSP relative to GDP.

This process is undertaken for original data, with seasonal adjustment performed on the final data obtained from the process.

Seasonal Adjustment of chain volume final quarterly GSP data are undertaken using the X13 seasonal-adjustment process (United States Census Bureau, 2022), as implemented in the Python Statsmodels package (Statsmodels, 2023).

This is a different method to that used by the ABS, which applies the X12 procedure (ABS 2021d), which so causes some difference between seasonally-adjusted growth of GSP summed across states and ABS seasonally-adjusted GDP growth.

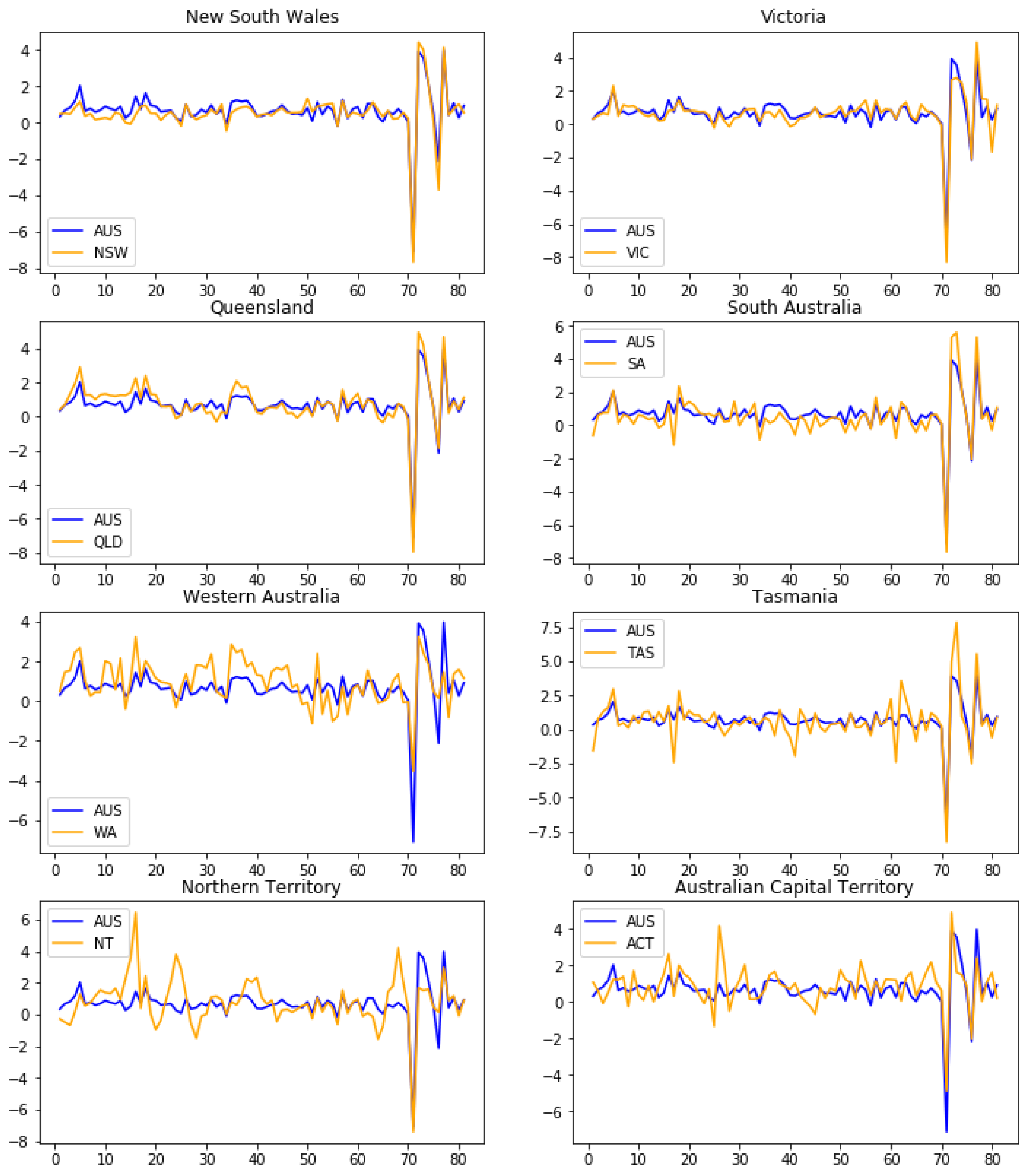
Additionally, the disruptions to the Australian economy caused by the COVID-19 border closures and lockdowns in 2020 and 2021 cause problems to smoothing of original data for analysis purposes. In particular, the large shocks in the June and September quarters of 2020 may have too much weight when seasonal-adjustment factors are calculated.

The ABS has, given the large swings in 2020 and 2021 due to the COVID lockdowns, announced a review of its seasonal-adjustment and trend data estimation process in 2023 (ABS, 2022a).

Results

Growth in seasonally-adjusted chain-volume GSP for each state since the September quarter 2002 is shown in Figure 3 below. The impact of the COVID lockdowns throughout 2020 and 2021 is the standout feature of each series.

Figure 3: Australian State and Territory GSP Growth, July 2022 to December 2022, Chain Volume, Seasonal Adjusted



Growth for the December quarter 2022 and for the year to the December quarter 2022 are shown in Table 1 below. National GSP growth in the December quarter 2022 was 0.92%, compared to official ABS GDP growth of 0.5% (ABS, 2022a). This is caused by differences in seasonal adjustment methods.

Table 1: December Quarter 2022 Practical Economics Gross State Product, Percentage Changes, Chain Volume Data

State	Quarterly Growth Sep-22 to Dec-22 (seasonally-adjusted data)	Year-on-year Growth Dec-21 to Dec-22 (original data)
NSW	0.54	2.74
VIC	1.14	2.44
QLD	1.12	2.66
SA	1.05	1.96
WA	1.15	3.46
TAS	0.88	1.43
NT	0.91	2.95
ACT	0.22	2.97
AUS	0.92	2.72

Source: Practical Economics' calculations

Annual year-on-year GSP growth and GDP growth were both 2.7%.

Table 2 shows the simple correlations of quarterly GSP growth to quarterly GDP growth for the entire sample and for the sample prior to the COVID-19 lockdowns.

Prior to the lockdowns, quarterly and annual GSP for the states had little correlation with the national figure. However, the large swings experienced by all states apparent in Figure 3 led to a large increase in the correlations.

Table 2: Table of Correlations: Seasonally Adjusted, Chain Volume, Percentage Change

	Quarterly GSP to GDP	Quarterly GSP to GDP, pre-Lockdowns (to Dec-2019)	Annual GSP to Annual GDP
NSW	0.96	0.64	0.48
VIC	0.94	0.68	0.58
QLD	0.96	0.83	0.89
SA	0.93	0.67	0.49
WA	0.68	0.71	0.62
TAS	0.85	0.54	0.49
NT	0.60	0.26	0.06
ACT	0.73	0.33	0.06
AUS	1.00	1.00	1.00

Source: Practical Economics' calculations

Conclusion and Future Development

The Practical Economics' quarterly GSP series provides an estimate of a data series that the ABS does not produce, but which has value to economists studying and forecasting state economic conditions. Once coded, it gives researchers a suitable series on which to undertake analysis which can be quickly updated once the ABS releases new input data.

However, the there are areas where the final output could be improved, which include:

- Constructing individual TFI indicators for each industry in each state using other ABS data or data held by state governments; and
- Improving the seasonal adjustment of the data, including aligning the Practical Economics' method with those of the ABS, and incorporating improvements in accounting for outliers as they become available.

However, each of these improvements involves considerable time and cost and it is not clear whether improvements in the usefulness of the final data outweighs this cost.

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