Examining the Solow Growth Model: An Empirical Analysis of Economic Growth in Australia

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Abstract

This paper explores the suitability of the Solow Growth Model in interpreting Australia's economic growth over the past 46 years, with a specific emphasis on total factor productivity (TFP). By leveraging data from April 1978 to January 2024, this research conducts an empirical analysis to estimate TFP and evaluate its relationship with Australia's economic conditions. The results indicate that the Solow Growth Model effectively explains the real-life economic growth in Australia, thus confirming the applicability of established fundamental theories of economic growth in this rapidly developing world. This also highlights the significance of technological progress and efficiency enhancements in fostering economic development (the factors of TFP).

1. Introduction

The pursuit of sustainable and robust economic growth has never ceased, and the applicability of established fundamental theories has become uncertain in this rapidly evolving global economy. In this paper, the Solow Growth Model, introduced in the mid-20th century, has been viewed as a foundational theory for the study of modern economic growth, attributing a significant portion of economic growth to technological progress and improvements in efficiency. Unlike factors such as capital and labor force, which have been widely recognized as contributors to economic growth, total factor productivity (TFP) accounts for approximately two-thirds of GDP growth in OECD countries (Robert Shackleton, 2013). As the world has become increasingly interconnected and technologically advanced, the relevance of this model in explaining growth patterns, without being limited by its capability issues in developed economies like Australia, is both timely and significant.

Australia, with its dynamic economy and significant economic transformation over the past decades, serves as an exemplary case for examining the capability of economic theories. This paper prompts an investigation of traditional growth theories in light of contemporary realities over the past 46 years of Australia's economy and explores the applicability of the Solow Growth Model with a particular focus on TFP. It contrasts the economic growth patterns observed in Australia during this period with predictions from TFP, aiming to find whether the Solow Growth Model, with its focus on TFP, can effectively explain the economic growth patterns observed in Australia over the past 46 years.

The structure of this paper is designed to provide a comprehensive analysis for all people to understand. Following this introduction, the paper will provide a background review of the Australian economy, as well as the Solow Growth Model and its relevance to economic growth in terms of TFP. Subsequent sections will delve into the data and methodology used to estimate TFP in the Australian context, employing Gross Domestic Product(GDP), labor, and capital formation data. The empirical analysis will then be presented, examining whether the model's predictions based on the data align with real-world economic events and trends in Australia.

2. Background

Australia is the world's sixth-largest country, stretching from its vast and arid outback to its bustling urban centers. Its economy is characterized by resilience and adaptability, maintaining economic growth over the past decades. This literature review aims to provide an overview of Australia's economic condition, including its growth period as a background to further introduce the topic of this paper, which examines the alignment of the Solow Growth Model within a real economic situation.

Australia's most notable feature of economic growth is its transformation from an economy primarily reliant on agriculture and resources to a more diverse one, based on different types of industries, mainly services and innovation.

Australia's participation in international trade agreements, foreign investment, and regional economic blocs such as the Asia-Pacific Economic Cooperation (APEC) and the Australia-New Zealand Free Trade Agreement (ANZFTA) has given it strong and stable connections with other economies. This integration has ensured that its productivity remains generally strong and stable. Despite fluctuations in commodity prices and the impact of the global financial crisis, the country has maintained a relatively stable economic trajectory, underpinned by prudent fiscal and monetary policies, ensuring its ability to adapt to global market dynamics and internal challenges, making it an ideal target for analyzing the relationship between total factor productivity and economic growth within the framework of the Solow Growth Model.

3. Solow Growth Model

This section introduces the fundamental basis of the most basic theory that supports this paper, the Solow Growth Model. It includes the derivation of the entire theory. In this research, the Solow Growth Model will be applied under the assumption that it considers four variables: Y, which is output; I, which is investment; N, which is labor; K, which is capital; and C, which is consumption. However, all the variables cannot change by themselves; instead, there must be some external factors that influence the variables: S, which represents the savings rate, ranges from 0 to 1, since people cannot save more than they earn; and d, which means the depreciation rate, that is, the loss of value over time for capital and the cost for it to maintain the best function. Also, in this model, the goods market is assumed in a closed economy, meaning that there is no government control over the market. As GDP is equal to C, I, NX, and G, in an economy without government or net exports, Y is solely determined by C and I. I is represented by SY, as savings directly translate into investment. Consumption, conversely, is (1 - S)Y, reflecting the portion of income not saved. This paper stands on the assumption that all terms are in per capita values to eliminate the effect of the population, thus considering y (output per capita), k (capital per capita), and c (consumption per capita). Therefore, $y = c + i$, $i = sy$, $c = (1 - s)y$. Later, this paper will discuss the production function, which elucidates the process of economic output generation.

In the functional format, $Y = f(K, N)$, where K and N are the factors of production. From basic economic principles, several conclusions can be drawn from the production function. First, there is the concept of diminishing marginal returns, which suggests that as inputs increase beyond a certain point, their effectiveness in increasing output decreases. Second, there is the principle of constant returns to scale, which means that if both factors are increased proportionally, the output will also increase proportionally. Third, we have the case where f of K and zero equals zero, indicating that without human labor, there is no production. Fourth, we have the case where f of zero and N equals zero, which means that without capital, there is no production. Moving forward, we will implement a theory known as the Cobb-Douglas Function, which is

$$Y = K^{\alpha}N^{1-\alpha};$$

α represents the capital share. Since all things are in general terms, it needs to be transferred into per capita terms, which means dividing all parts of the function by N. Therefore, $y = k^{\alpha}N^{1-\alpha-1} = \frac{K^{\alpha}}{N^{\alpha}} = k^{\alpha}$. Now, adding a variable A in the Cobb-Douglas function to represent the total factor productivity (TFP), that is, $Y = A \cdot K^{\alpha}N^{1-\alpha}$, and

$$y = A \cdot k^{\alpha}N^{1-\alpha-1} = A \cdot \frac{K^{\alpha}}{N^{\alpha}} = A \cdot k^{\alpha}.$$

Here, when two different countries have the same capital and labor, there can still be a difference in terms of production between the two. A reflects this difference, considering the other factors that influence the country. However, it is a conceptual idea means to represent their productivity. This paper estimates the total factor productivity in determining the countries' growth.

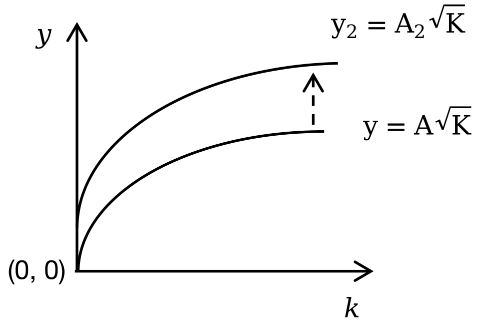


Figure. 1 Increase in TFP

As observed in Figure 1, the graph illustrates a shift attributable to A, which represents the change in total factor productivity, leading to an increase in the output variable, y. With an increase in k, the graph can be horizontally expanded, underscoring the significance of A. While all the above shows the Solow Growth Model in a static case, the dynamics of the model will be introduced below, referred to as the "Capital Evolution Equation (the Law of Motion of K)." This equation predicts how k will change over time:

$$K_{t+1} = K_t + I_t - dK_t$$

This means that tomorrow's capital will be equal to today's capital plus today's investment, minus the cost of maintenance (depreciation) of today's capital. $K_{t+1} - K_t = sY_t - dK_t$ can be found from a simple algebraic transformation; and $K_{t+1} - K_t$ is ΔK. As with the above, since this paper considering per capita terms and want to eliminate the influence of population growth, these values should be divided by N. Therefore, $k_{t+1} = k_t + i_t - dk_t$ thus,

$$k_{t+1} - k = sy_t - dk_t.$$

Now the application of the term known as "steady state" can be introduced. Steady state occurs when output y, capital k, and consumption c are constant over time. This means that ΔK remains the same, indicating that there is no capital growth over time, thus ΔK is equal to 0. Therefore, economic growth is also zero. The steady state is essential since we can identify strategies to stimulate growth when we understand the conditions under which the economy stops growing. While $\Delta K = 0$, so $sy_t - dk_t = 0$, meaning that $sy_t = dk_t$. This suggests that the amount of new investment should be equal to the amount of capital being depreciated.

Since $y = A \cdot k^{\alpha}$ is already known, the left side of the equation becomes $sAk^{\alpha} = dk_t$ under steady state. As A, s, α, and d are all exogenous, k can be solved in terms of parameters. Since parameters remain constant and variables fluctuate within the model, the changes of the variables in response to changes in the parameters can be discovered. After some maths transformations, $\frac{sA}{d} = k_t^{\ 1-\alpha}$ is obtained, finally $k_t = (\frac{sA}{d})^{\frac{1}{1-\alpha}}$. When it is under steady state, k remains constant over time, which implies that t within the equation can be eliminated. Therefore,

$$k_t = k_{ss} = (\frac{sA}{d})^{\frac{1}{1-\alpha}}.$$

This equation illustrates how capital in the steady state behaves if parameters change.

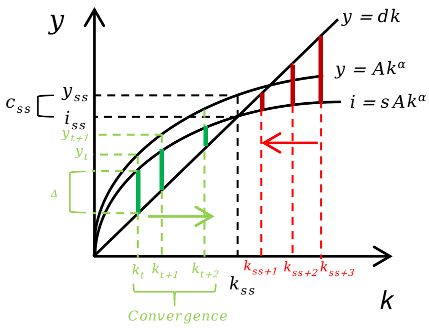


Figure 2. Capital Increase and Steady State

Since $y_{ss} = Ak_{ss}^{\ \alpha}$, it can be implied to get $y_{ss} = A(\frac{sA}{d})^{\frac{a}{1-\alpha}}$, as ss means steady state.

By implementing all the results, $i_{ss} = sy_{ss} = sA(\frac{sA}{d})^{\frac{a}{1-\alpha}}$, and $c_{ss} = (1-s)y_{ss} = (1-s)A(\frac{sA}{d})^{\frac{a}{1-\alpha}}$. All of these reflect the changes from the parameters to the variables. After obtaining this result, the model's consideration of the dynamic condition could begin. Figure 2. displays all the points of the steady state on the graph. When the current capital of the economy is less than the steady-state level, as indicated in the graph, the economy will increase its capital accumulation the following day. This is because the investment for the next day exceeds the depreciation of the capital today, as $sAk_t^{\ \alpha} > dk_t$ if represented mathematically. In Figure 2, the bold green line (Δ) represents the additional capital increase for the next day; and as each "next day" passes, the economy accumulates additional capital, $y_{t+1} > y_t$, thus representing the economic (GDP) growth.

However, if examining this graph closely, we can observe that over time, the marginal increase of the capital diminishes, approaching zero as it nears the steady state. This explains why developed countries tend to grow at a slower rate compared to developing countries, a phenomenon known as convergence. This is the prediction of the dynamic aspect of the Solow Growth Model, which suggests that continuous growth of capital without the development of other factors, such as technological innovation, will eventually lead to zero growth. In Figure 2, the bold red line and the points at which the capital exceeds the steady state level will experience negative economic growth, since ${sAk_t}^{\alpha} < dk_t$.

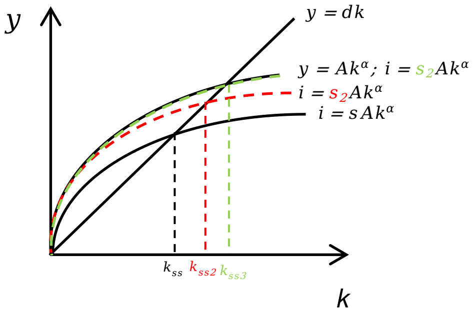


Figure 3. Increase in Savings

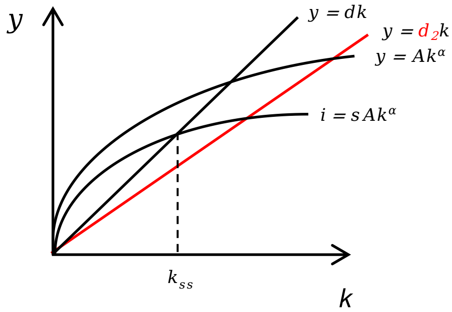


Figure 4. Decrease in Capital Depreciation Rate

Figure 3 illustrates the condition where the economy incentivizes an increased savings rate to boost investment in the capital for the "next day." As depicted, this can increase output and, in turn, foster economic growth. However, there are limitations, as indicated by the green line in Figure 3. Since $s \in [0, 1]$, the maximum amount of savings for the entire economy cannot exceed the total output of the economy, even under the ideal assumption that no one spends any of their savings for any purpose. Clearly, an economy cannot function solely with no spending.

It is also inefficient to decrease the depreciation rate of the existing capitals. However, even definitively $d \in [0, 1]$, the depreciation rate has a lower bound; it is also difficult to control through government policies since it is decided by the nature instead of human. Therefore, to increase their capital and promote economic growth, the economy should be focused on improving the total factor productivity. This is because all of the considered parameters contain A, in the Cobb-Douglas function above, as a factor.

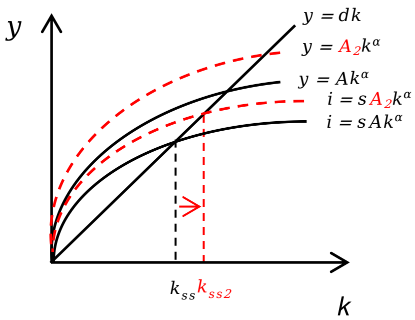


Figure 5. Increase in TFP

The situation where total factor productivity is increased is shown in Figure 5. Since both y and i are influenced by the total factor productivity A, when A increases, both output and the savings rate will rise automatically. Unlike changes in i or y , which could lead to a stag or decrease in economic growth, altering the total factor productivity does not have this limitation. As A changes, the steady-state capital point also increases, enhancing the economy's capabilities and boosting the total output without necessitating an increase in capital. Internet, automation, and AI can be considered as examples that increase total factor productivity, thereby raising the steady state and creating more room for economic growth.

The stronger mathematical connection is needed to calculate the influence factor of total factor productivity. From the previous result, $y = Ak^{\alpha}$is found; by applying the natural logarithm to each side of the equation: $\ln y = \ln (Ak^{\alpha})$, and performing the mathematical transformation based on properties of natural logarithm, $\Delta \ln (y) = \Delta \ln (A) + \alpha \cdot \Delta \ln (k)$ can be obtained. Therefore,

$$\%\Delta y = \%\Delta A + \alpha \cdot \%\Delta k.$$

This converts a per capita Cobb-Douglas production function into a growth rate Cobb-Douglas production function. The equation explains the contribution of total factor productivity A and capital growth to the output (GDP). As $\alpha \in [0, 1]$, it serves as a capital share, representing the weight of its importance for the capital to contribute to GDP growth. However, its significance is also contingent upon the type of economy. For instance, in a labor-intensive country, the growth of capital may not be as crucial.

4. Data Description

This dataset provides a collection of economic indicators (Real GDP, Real Investment, and Labor Force Level) for Australia, spanning from April 1978 to January 2024. It includes variables related to GDP, capital, labor, and total factor productivity, which are essential for the application of the Solow Growth Model.

All the resources are from the Federal Reserve Economic Data of the Federal Reserve Bank of St. Louis.[1] All the data was downloaded from online access, recorded in quarterly intervals, and seasonally adjusted. For this group of data, 183 proper samples were collected and analyzed. The data on Australia's economic factors is from April 1978 to January 2024.

Variables Y, K, and N are directly accessed from the data, representing the real GDP of Australia, the fixed capital formation of Australia, and the total labor force aged 15 to 64 for Australians (in persons). Secondly, Y(B) and K(B) are the Y and K in units of billions, while Y and K are in units of trillions; this is achieved by dividing Y and K by 1,000. Thirdly, variables y and k are the output Y and capital K per labor force, which were converted from billions to single units and then divided by the total labor force. Then, variables $d\ln y$ and $d\ln k$ came from the subtraction of the natural logarithms of two values of y and k. The calculation of $d\ln y$ and $d\ln \mathrm{k}$ is the difference between the natural logarithms of two values of y and k in continuous periods, $d \ln \frac{y}{k} = \ln (\frac{y}{k_1}) - \ln (\frac{y}{k_2})$.

5. Empirical Analysis

5.1 Regression Line

In the last part of the Solow Growth Model section, the growth of an economy can be delineated by the following equation, $\%\Delta y = \%\Delta A + \alpha \cdot \%\Delta k$. Originally presented as an algebraic production function, it now transforms into a linear regression line, making it amenable to calculation. In linear regression, x represents independent variables, and y represents dependent variables. The focus here is on the causation between these variables.

[1] FRED: https://fred.stlouisfed.org

This approach extends from the linear function $y = mx + b$, acknowledging that real-life data cannot perfectly align fit the linear line, resulting in an error (residual). Consequently, the sum of all the error terms should be concerned, which is represented by e. Given that the error terms can be both positive and negative, it is important to consider their squared values.

In that case, R^2, a measure of model fit, needs to be employed. As certainty is not guaranteed, the concept of a confidence interval, which provides an estimated range for the true value, should be utilized. Therefore, $y_i = \beta_0 + \beta_1 x_i + e_i$. Once the samples of x and y are obtained, the software STATA generates the results $\hat{\beta}_0$ and $\hat{\beta}_1$, which include the confidence interval.

Given the equation from the Solow Growth Model: $\Delta ln(y) = \Delta ln(A) + \alpha \cdot \Delta ln(k)$, which is the Cobb-Douglas Production Function, and the regression line $y_i = \beta_0 + \beta_1 x_i + e_i$, the percentage change in the dependent variable $\Delta \ln y$ is y_i, and the percentage change in the independent variable $\Delta \ln k$ is x_i; α, the capital share is β_1, and the percentage change in total factor productivity, known as the Solow Residual, $\Delta \ln A$, is e_i. $\Delta \ln A$ is a changing factor while β_0 is constant. Total factor productivity encompasses the aspects not accounted for by capital, which is the error of the linear line, or the Solow Residual.

5.2 Result

Here are the linear regression results. STATA was used to generate the summary of the data $dln(y)$ and $dln(x)$, despite the data not being used in the final conclusion. Also, the predicted value A (estimation of total factor productivity) was found by using STATA, generating the best fit linear function for the $y - k$ relationship. β_1 was first generated by using STATA regression function for variable $dln(y)$ *and* $dln(k)$, representing a regression coefficient which demonstrates the relationship between capital and GDP growth; 95 Conf.int was subsequently generated, representing the range within which we can be 95% confident that the true regression coefficients lie; and R^2 was generated, which measures the degree to which the data points are close to the fitted regression line.

In this run of STATA, α in Solow Growth Model, as well as $\hat{\beta}_1$ is 0.1409022; the 95 Conf.int is between 0.0995157 and 0.1822887; the R^2 is 0.2015, which means that 20% of the y could be explained by x, indicating that 20% change of the y could be explained by k, the capital.

A (Total Factor Productivity) Estimation Result	
$\hat{\beta}_1$	0.1409022
95 Conf.int	0.0995157 0.1822887
R^2	0.2015

Table 1. Result of the estimation of TFP

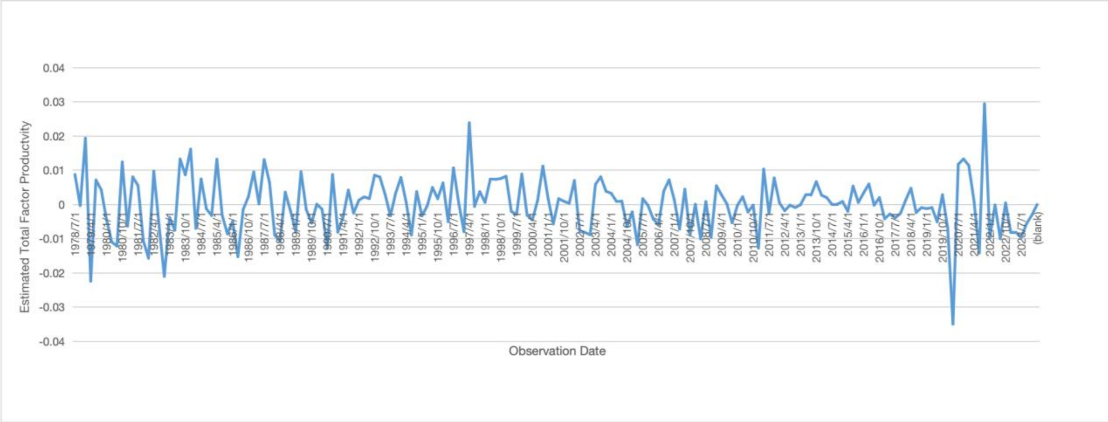


Figure 6. TFP of Australia from 1978-2024[2]

Figure. 6 shows the estimated and predicted value of Solow residual, derived from $\mathrm{dln}(y)$ and $\mathrm{dln}(k)$. This paper will use empirical analysis to test several peaks and troughs in the graph above to see if the estimated total factor productivity reflects the real positive/negative economic growth in the Australian economy as predicted by using the Solow Growth Model.

5.3 1978 Agricultural Growth

In October 1978, farm production in Australia rose strongly, particularly in wheat production. Prices for farm products were generally stable, and rural incomes grew rapidly. From 1977–78 to 2022–23, national productivity growth in the broadacre industries averaged 1.0% yearly (ABS, 1978). However, since 1977–78, the broadacre productivity growth in Australia has been driven by declining input use and modest output growth. We found that at the moment, the composition of the broadacre industry has changed significantly. The output have experienced growth, while others have reduction; there has been a decrease in the number of farms, but an increase in their overall size, and the geographical distribution of specific industries has undergone changes. All these changes have contributed to the overall trend in broadacre productivity growth, and such shifts within the industry have changed the capital formation of Australia's agriculture, proving that they were able to focus on production but with less competition. Also, in the 1980s, the strong productivity growth in the agricultural industry has been attributed to developments in technology. Because of that, the dairy productivity growth from 1978–79 has varied significantly, and the overall increase in productivity has been propelled by an expansion in output coupled with a slight reduction in the use of inputs. This combination has led to a peak in total factor productivity, based on Australia's data.

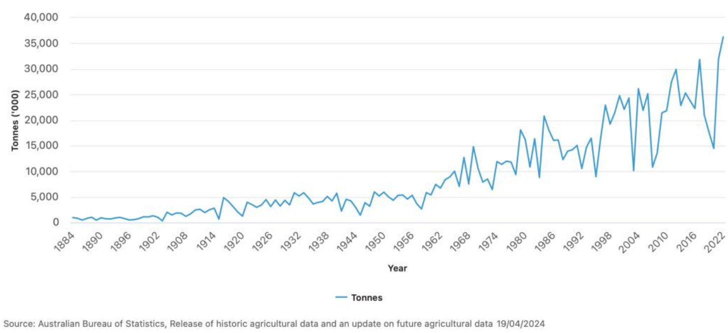


Figure 7. Wheat Production of Australia from 1882 to 2022

[2] See detailed data at https://docs.google.com/spreadsheets/d/19-fkBP5Be5YSxJ4HfCJfbfbcDMk1_AEo/edit?usp=sharing&ouid=110729579799595767408&rtpof=true&sd=true

5.3 2008 Financial Crisis

The Australian economy displayed an unusual feature during 2008, during a worldwide severe financial crisis: it was less affected and had a 0.4 percent growth in the whole Australian economy in the March quarter of 2009. In response to the global financial crisis, the Australian Government and the Reserve Bank took swift and coordinated actions to mitigate its effects. The Reserve Bank lowered the cash rate target, reducing it from 7 percent in September 2008 to 3.25 percent in 2009, in an effort to stimulate demand (Reserve Bank of Australia, 2009). Simultaneously, the Australian Government implemented an expansionary fiscal policy, including a series of stimulus packages totaling over $52 billion. These packages were aimed at alleviating the contraction in private spending, with nearly 30 percent allocated as cash handouts to households, particularly in the real estate sector, which was most affected. Additionally, $29.4 billion was directed towards infrastructure projects and $1.5 billion to housing construction to support the economy and secure jobs. The government also guaranteed deposits up to $1 million held by deposit-taking institutions to reassure depositors and maintain banks' access to capital markets (Chesters, 2022). Furthermore, the Australian Prudential Regulation Authority (APRA) and the Australian Securities and Investments Commission strengthened lending standards and implemented robust global banking regulations to enhance the resilience of the financial and private sectors. These measures were designed to stabilize the system, ensure the trustworthiness of banks, and support the production of capital in key industries reliant on the financial system, keeping the trust of the public and preventing an influence on productivity, which aligns with the estimation of Total Factor Productivity (TFP).

Second, Australia's trade composition and orientation have provided it with a buffer against the global economic downturn, particularly in the sharp decline of discretionary spending and trade in manufactured goods that affected many economies, including those in Asia. While these economies saw exports fall by as much as 50% within six months, Australia's manufactured goods make up only about 20% of its total exports (Eslake, 2009). The decline in these goods has been less severe than in other countries, and overall exports have increased since the financial crisis began, driven by strong demand from China. As reflected in Figure 8, China and Hong Kong receive one-third of Australia’s whole exports, ensuring strong support for its economy's output. This demand reflects the effectiveness of China's stimulus measures on Australia's economy and opportunistic buying by Chinese importers. Australia's economy, heavily intertwined with Asia and especially China, has continued to benefit from China's growth during a period of global slowdown. China's economy remained robust during the 2008 crisis, making it one of the least affected countries and a significant export market for Australia, accounting for nearly one-third of its exports. Despite the greater risks often associated with investing in emerging economies, which are less integrated with global capital markets, Australia's trade with these economies, particularly China, has ensured a steady input of necessary materials and machinery. The financial market relationship between China and Australia is expected to strengthen further, especially in comparison to the relationship with the U.S. Australia's capital was well protected during the crisis, largely due to its substantial trade with China, which maintained a good economic performance and provided a reliable source of demand for Australian exports.

Third, Australia has not experienced the same level of distress in its residential property market as has occurred in the United States, the United Kingdom, Canada, and some other European countries. (Eslake, 2009). This outcome comes from Australia building fewer houses than required to meet the growth in the number of households over the past decades, resulting in “a shortage of housing of at least 85,000 dwellings and a rental dwelling vacancy rate since mid-2006 of less than 2 percent” (Eslake, 2009). The boom in the residential property market was not overwhelming during that time; instead, it was an opportunity to fill the property industry's capital where it was lacking. The situation stands in stark difference to that of the United States, where the real estate bubble during the initial years of the decade was characterized by both a "price bubble" and a "quantity bubble," and where the rental vacancy rate has consistently hovered around or exceeded 10 percent since the year 2003.

All these reasons kept the Australian economy in good shape, where its essential ability to produce, the TFP, was not negatively affected. Although its labor and capital were damaged, its TFP remained, allowing it to experience ups and downs during the 2008 global financial crisis without forming a trough.

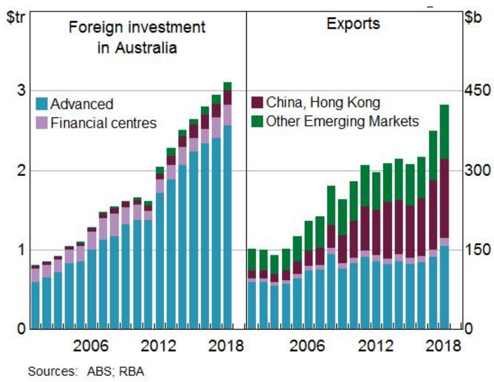
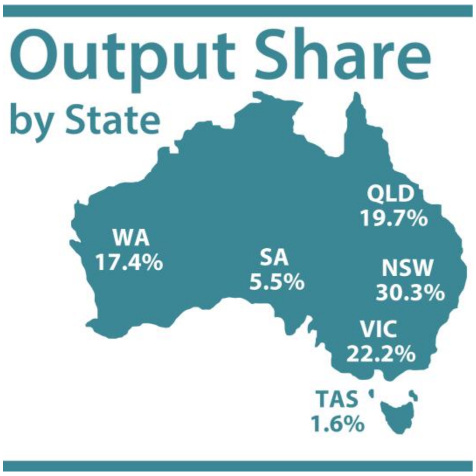


Figure 8. Australia’s Financial and Trade Linkages

5.5 2011 Australia Flood

In late 2010 and early 2011, Australia experienced a severe trough in the TFP graph (Figure 6) due to natural disasters. Australia faced one of its most devastating natural disasters when unusually heavy, prolonged rains, caused by a strong La Niña event. This led to widespread flooding across the eastern states, primarily affecting Queensland, New South Wales, and Victoria, the economic centers of the country. As shown in Figure 9, those three states, which were mainly influenced by the flood, contribute to 77.1% of Australia’s total output share, indicating a substantial impact on the national economy. The majority of the states responsible for the economy were frustrated by the flood and needed time to recover, forming a dramatic downfall in the productivity of Australia. The flood, which claimed 35 lives and resulted in billions of dollars in property damage and economic losses, was further intensified by Tropical Cyclone Tasha on December 25, 2011, which added another 6 to 10 inches of rain to the already saturated east coast(Murray, 2023).

The economic impact was profound, with key sectors such as agriculture and coal production in Queensland suffering massive setbacks due to ruined crops and disruptions in mining and transport caused by mine closures and damaged rail lines. At that time, agriculture and minerals took a major portion of Australia’s total output, meaning that most of its capital of production was damaged because of the flood. The money for cleanup and recovery that was used to balance the severe depreciation rate of the capital from the previous year was extremely high, resulting in a significant effect on the investment from the upcoming year. According to the Solow Growth Model, investment from the next year is a huge factor that contributes to the increase in capital the following year, meaning that not only was its TFP damaged due to the flood, but also the capital for the next year, the second biggest factor of economic growth of the economy, was decreased. Australia had to slow down its growth to adapt to the impact of the flood. The flood extended throughout the time. By late January, more than 40 towns across Victoria had been affected, with thousands of people evacuating their homes (Murray, 2023). The Prime Minister, Julia Gillard, proposed a temporary "flood levy" to help fund the recovery efforts, which did boost the GDP marks but also reduced its potential investment in capital development for long-term growth, and finally resulted in a noticeable downfall in Australia’s TFP.



Sources: Reserve Bank of Australia, Composition of the Australian Economy SNAPSHOT

Figure 9. Output Share by States of Australia

5.6 2020 COVID-19

In April 2020, the Australian economy was significantly impacted by the COVID-19 pandemic, resulting in a disaster for capital and economic growth, evident as a severe trough on the Total Factor Productivity (TFP) graph. The L-strain of COVID-19 led to Australia-wide lockdowns starting on March 23, 2020. Initial restrictions included the closure of public venues such as pubs, clubs, cafes, and restaurants, and a shift to remote work where possible, severely impacting discretionary service spending. As shown in Figure 10, firms employing from 0 to more than 200 people all had to pause trading due to government restrictions. The situation escalated in Victoria with a second lockdown in July 2020 and stage 4 restrictions in August(ABS, 2020); 48% of companies reported significant operational restrictions, and 870,000 workers lost their jobs, not due to industry demand but because of the dire financial circumstances faced by all companies. Workers were confined to their homes and unable to perform their jobs physically, which decreased the use of capital at that time, thereby decreasing productivity.

Despite government subsidies to support households and businesses, the pandemic's toll was manifested in weakened business investment, particularly in skilled labor, new technologies, and international ventures, and a decrease in government expenditure due to falling tax revenues. Since investment also plays a significant role in capital growth and subsequently economic growth, the reduction in investment, along with the government's revenue which would be transferred into investment for the next year, had an extremely negative impact on the country's production and the growth of Australia's economy.

However, amidst these challenges, the Gross Operating Surplus and Mixed Income (GOSMI), which means the government started to subsidize disabled workers, surprisingly recorded an estimated cumulative gain of $185 billion (ABS, 2020). This was propped up by government support, sustained demand, and robust commodity prices, illustrating a potential recovery of TFP from the pandemic, which is discussed in the next paragraph.

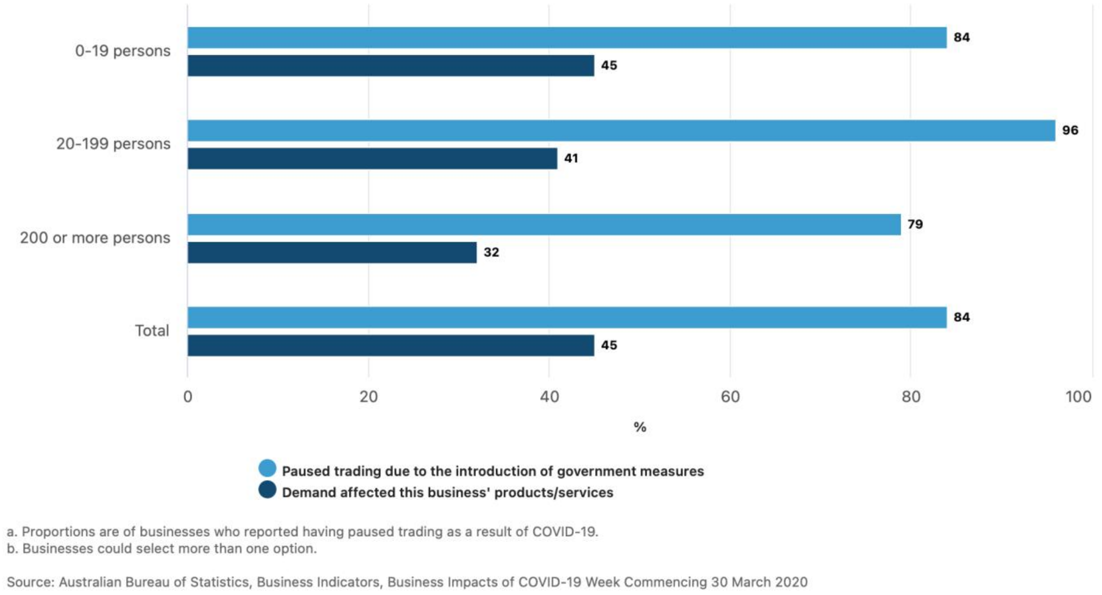
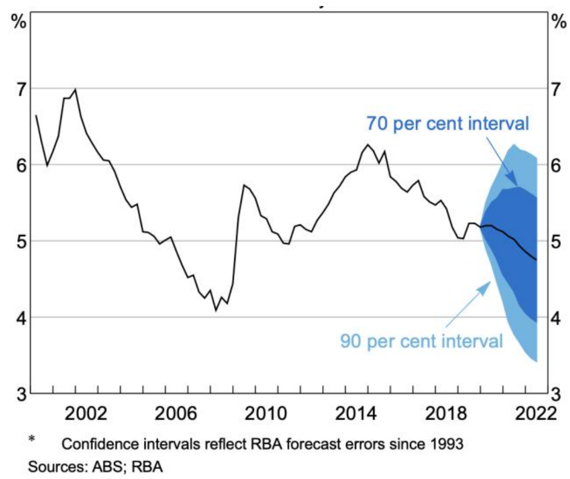


Figure 10. Selected reasons for having paused trading during COVID-19, by employment size, Australia



Sources: Reserve Bank of Australia, Statement on Monetary Policy-February 2020

Figure 11. Unemployment Rate Forecast of Australia, Quarterly

5.7 2021 COVID Recovering

In October 2021, Australia recovered from the COVID-19 pandemic, making TFP start to increase. It was marked by a flexible medium-term inflation target set by the government, aiming for consumer price inflation between 2 and 3 percent, in partnership with the Council of Financial Regulators (CFR) agencies, and the maintenance of Australian banknotes' capacity (Reserve Bank of Australia, 2021). Business conditions improved significantly, as evidenced by a drop from 47% to 38% in the proportion of businesses reporting decreased revenue by September 2020. As Figure 11. demonstrates, the unemployment rate also started to decrease by 0.5%, and was expected by the Australian Bureau of Statistics to continuously decrease. As TFP starts recovering and all the capitals resumed operations, productivity rose strongly. The GDP saw a further increase of 3.1% by December 2020, and by January 2021, Australian employment had almost fully recovered, with 93% of jobs lost during the pandemic being regained. Despite the Delta strain's emergence and subsequent short-term lockdowns, restrictions began to ease, facilitating a recovery phase. The Omicron variant's arrival in November 2021 did not lead to new lockdowns, as high vaccination rates allowed for the gradual easing of travel and trading restrictions. As for that, the remnants of the relatively high TFP keeps the economy to growth, despite the private investment had declined in the pandemic's first year due to operating restrictions and risk uncertainty. In 2021, spurred by improved business conditions and government tax incentives, investment in machinery and equipment increased. Dwelling investment also rose, supported by low interest rates and the federal government's HomeBuilder scheme, highlighting the recovery of capital and the overall economic resurgence. And all those factors finally built a peak in Australia's total factor productivity, maintaining its high-speed economic growth.

6. Conclusion

The empirical analysis has demonstrated that the Solow Growth Model's focus on Total Factor Productivity (TFP) continues to be a relevant framework for understanding economic growth in developed economies like Australia. The findings suggest that the model's predictions align with the country's economic trajectory, and the results of this research conclude that the empirical findings underscore the Solow Growth Model's explanatory power in the context of Australia's economic growth. The estimation of TFP, as predicted by the model, has shown a significant correlation with the observed economic patterns of Australia's economy over the past 46 years. This study has confirmed the applicability of the established fundamental theories of economic growth in our rapidly developing world, highlighting the importance of technological progress and efficiency improvements in driving economic growth, even amidst a rapidly changing global landscape.

However, this research paper acknowledges its limitations, such as using a simplified Solow Growth Model and examining only five events (which include significant changes in peaks and troughs) over the past 46 years. This limitation suggests potential areas for future research, including delving deeper into the accuracy of the Solow growth model's alignment and conducting empirical analysis on a larger number of samples to enhance the accuracy of examining the model's fit.

Works Cited

Bruno, Angelina, et al. *Recent Trends in Australian Productivity | Bulletin – September 2023*. Sept. 2023. https://www.rba.gov.au/publications/bulletin/2023/sep/recent-trends-in-australian-productivity.html.

Chesters, Jenny. *The Global Financial Crisis in Australia*.

Commonwealth Parliament; Parliament House, Canberra. *Impact of COVID-19 on the Australian Labour Market*. https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook47p/COVID-19AustralianLabourMarket. Australia. Accessed 20 Aug. 2024.

Cottrell, Allin. *The Cobb–Douglas Production Function*.

Eslake, Saul. “The Global Financial Crisis of 2007–2009 – An Australian Perspective.” *Economic Papers: A Journal of Applied Economics and Policy*, vol. 28, no. 3, 2009, pp. 226–38. *Wiley Online Library*, https://doi.org/10.1111/j.1759-3441.2009.00034.x.

Hoefer, Florian. “Can Regulation Stop Financial Crises? An Evaluation of Banking Laws in the USA, the UK and Australia after the Financial Crisis 2007/2008 in the Light of What Lesson Can Be Learned and How Such a Crisis Can Be Prevented in the Future -

Part One." *International Journal of Liability and Scientific Enquiry*, vol. 6, no. 1/2/3, 2013, p. 79. *DOI.org (Crossref)*, https://doi.org/10.1504/IJLSE.2013.057752.

Jacobs, David. *How Do Global Financial Conditions Affect Australia? | Bulletin – December 2019*. Dec. 2019. *www.rba.gov.au*, https://www.rba.gov.au/publications/bulletin/2019/dec/how-do-global-financial-conditions-affect-australia.html.

McKinnon, Scott. "Remembering and Forgetting 1974: The 2011 Brisbane Floods and Memories of an Earlier Disaster." *Geographical Research*, vol. 57, no. 2, May 2019, pp. 204–14. *onlinelibrary-wiley-com.ezproxy.oberlin.edu*, https://doi.org/10.1111/1745-5871.12335.

Novik, Vitaliy. "The Countries Most and Least Affected by the 2008 Financial Crisis." *Big Economics*, 1 Nov. 2020, https://bigeconomics.org/the-countries-most-and-least-affected-by-the-2008-financial-crisis/.

OECD. *The 2008 Financial Crisis – A Crisis of Globalisation?* OECD, 11 Apr. 2013, pp. 126–43. *OECD iLibrary*, https://doi.org/10.1787/9789264111905-9-en.

Schmidt, Dirk. *The Financial Crisis and Its Impact on China*.

Shackleton, Robert. *Total Factor Productivity Growth in Historical Perspective*.

Sheng, Yu, et al. "Productivity and Farm Size in Australian Agriculture: Reinvestigating the Returns to Scale." *Australian Journal of Agricultural and Resource Economics*, vol. 59, no. 1, 2015, pp. 16–38. *Wiley Online Library*, https://doi.org/10.1111/1467-8489.12063.

Statistics, AU; Commonwealth of Australia; Australian Bureau of. *Australian Bureau of Statistics Web Site*. AU; Commonwealth of Australia; Australian Bureau of Statistics, https://www.abs.gov.au/websitedbs/D3310114.nsf/home/Measuring+Labour+Market+COVID19. Accessed 20 Aug. 2024.

Sinnamon, Myles. "2011 Queensland Floods - History in Pictures." *State Library of Queensland*, 11 Jan. 2016, https://www.slq.qld.gov.au/blog/2011-queensland-floods-history-pictures.

Anderson, Kym. *Agricultural Development in Australia: 1845–2015 | SpringerLink*. https://link.springer.com/chapter/10.1007/978-3-319-66020-2_14. Accessed 20 Aug. 2024.

Murray, Lorraine. "Australia floods of 2010–11". Encyclopedia Britannica, 1 Sep. 2023, https://www.britannica.com/event/Australia-floods-of-2010-2011. Accessed 20 Aug. 2024.

United States Department of Agriculture. *Australia Wheat Production by Year (1000 MT)*. https://www.indexmundi.com/agriculture/?country=au&commodity=wheat&graph=production. Accessed 20 Aug. 2024.

Steven, Kennedy. *Australia's Response to the Global Financial Crisis | Treasury.Gov.Au*. https://treasury.gov.au/speech/australias-response-to-the-global-financial-crisis. Accessed 12 Aug. 2024.

Australian Bureau of Statistics. *Business Indicators, Business Impacts of COVID-19, September 2020 | Australian Bureau of Statistics*. 24 Sept. 2020, https://www.abs.gov.au/statistics/economy/business-indicators/business-conditions-and-sentiments/sep-2020.

Bottelier, Pieter. *China and the International Financial Crisis | The National Bureau of Asian Research (NBR)*. https://www.nbr.org/publication/china-and-the-international-financial-crisis/. Accessed 12 Aug. 2024.

Reserve Bank of Australia. "Composition of the Australian Economy Snapshot | Education." *Reserve Bank of Australia*, https://www.rba.gov.au/education/resources/snapshots/economy-composition-snapshot/index.html. Accessed 20 Aug. 2024.

Australian Bureau of Statistics. *COVID-19 Mortality in Australia: Deaths Registered until 31 January 2024 | Australian Bureau of Statistics*. 27 Feb. 2024, https://www.abs.gov.au/articles/covid-19-mortality-australia-deaths-registered-until-31-january-2024.

Australian Bureau of Statistics. *Economic Gains and Losses over the COVID-19 Pandemic | Australian Bureau of Statistics*. 9 July 2022, https://www.abs.gov.au/articles/economic-gains-and-losses-over-covid-19-pandemic.

Australian Bureau of Statistics. *Effects of COVID-19 Strains on the Australian Economy | Australian Bureau of Statistics*. 6 Jan. 2022, https://www.abs.gov.au/articles/effects-covid-19-strains-australian-economy.

Dobbie, Phil. *How Australia Ducked the Crisis - CBS News*. https://www.cbsnews.com/news/how-australia-ducked-the-crisis/. Accessed 12 Aug. 2024.

Cheshire, Lynda. *"'Know your neighbours': disaster resilience and the normative practices of neighbouring in an urban context."* Environment and Planning A, vol. 47, no. 5, 2015, pp. 1081-1099. OhioLINK Electronic Journal Center, doi:10.1177/0308518X15592310. Accessed 20 Aug. 2024.

Kevin. *Map of Australia - Guide of the World*. https://www.guideoftheworld.com/map-of-australia.html. Accessed 20 Aug. 2024.

Australian Bureau of Statistics. *One Year of COVID-19: Aussie Jobs, Business and the Economy | Australian Bureau of Statistics*. 17 Mar. 2021, https://www.abs.gov.au/articles/one-year-covid-19-aussie-jobs-business-and-economy.

Reserve Bank of Australia. "Recession | Explainer | Education." *Reserve Bank of Australia*, https://www.rba.gov.au/education/resources/explainers/recession.html. Accessed 20 Aug. 2024.

Australian Bureau of Statistics.*Release of Historic Agricultural Data and an Update on Future Agricultural Data | Australian Bureau of Statistics*. 19 Apr. 2024, https://www.abs.gov.au/articles/release-historic-agricultural-data-and-update-future-agricultural-data.

Sheng, Yu. *Resource Reallocation and Its Contribution to Productivity Growth in Australian Broadacre Agriculture - Sheng - 2017 - Australian Journal of Agricultural and Resource Economics - Wiley Online Library*. https://onlinelibrary.wiley.com/doi/full/10.1111/1467-8489.12137. Accessed 20 Aug. 2024.

Singh, Manoj. *The 2007–2008 Financial Crisis in Review*. https://www.investopedia.com/articles/economics/09/financial-crisis-review.asp. Accessed 12 Aug. 2024.

Rauchway, Eric. *The 2008 Crash: What Happened to All That Money? | HISTORY*. https://www.history.com/news/2008-financial-crisis-causes. Accessed 12 Aug. 2024.

Lim, Guay. *The Australian Economy in 2020–21: The COVID-19 Pandemic and Prospects for Economic Recovery - Lim - 2021 - Australian Economic Review - Wiley Online Library*. https://doi.org/10.1111/1467-8462.12405. Accessed 20 Aug. 2024.

Novik, Vitaliy. *The Countries Most and Least Affected by the 2008 Financial Crisis - Big Economics*. https://bigeconomics.org/the-countries-most-and-least-affected-by-the-2008-financial-crisis/. Accessed 20 Aug. 2024.

Reserve Bank of Australia. *The Economy and the Reserve Bank | Reserve Bank of Australia Annual Report – 1978*. no. December, 1978. *www.rba.gov.au*, https://www.rba.gov.au/publications/annual-reports/rba/1978/economy-and-the-reserve-bank.html.

What Really Went Wrong in the 2008 Financial Crisis? https://www.ft.com/content/e5ea9f2a-8528-11e8-a29d-73e3d454535d. Accessed 12 Aug. 2024.