Macroeconomic Policy and Analysis
An Investigation into China's GDP and GDP Deflator

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Contents

1 Introduction

Analysing changes in both economic growth and prices is fundamental to an understanding of the Chinese economy. Chinese Gross Domestic Product (GDP) data can be used to evaluate both metrics.

In this paper, I present an overview of the drivers of changes in GDP and concurrent changes in the GDP deflator, one measure of price changes. Analysing the long time period of 1960s through to present provides breath but at the comprise of depth. In correction, I provide a detailed analysis of the quarterly data available from 2011. Identifying trends and their source is obscured by data quality concerns. Thus I comment on the causes of the observed patterns in-so-far as the available data permits.

To further aid my analysis, I apply time series econometrics in fitting and predicting an AR(1) model for the GDP deflator and an ARIMA (5,1,0) for GDP. Using these models I make best guess predictions for eight quarters in advance but once again, data quality concerns limit confidence placed in these forecasts. All data presented in this paper is obtained from the National Bureau of Statistics.

In summary, this paper finds underlying the evident patterns in Chinese economic growth and price evolution is a multitude of concurrent determinants inclusive of investment cycles, consumption growth, monetary policy, expectations, exchange rate and exogenous shocks from the global system at large.

2 China's GDP

2.1 Definitions and Methododology

Gross Domestic Product (GDP) is used as a general measure of economic health. It is defined as the market value of all final goods and services produced within a country in a given year. In relative terms, China's GDP adjusted by purchasing power parity is the second largest in the world, second only to the US. Some commentators argue Chinese GDP is undercounted by up to 50 percent when measured at market exchange rates, with some speculation that the Chinese economy will soon become the world's largest.

Definitional Distinction 1: Aggregate GDP vs GDP Per Capita

The first important definitional distinction is by what scale GDP is measured in. Aggregate GDP considers the total value of all goods and services in the visible economy as a whole. GDP per capita scales aggregates GDP by the nation's population giving a more accurate metric of average individual income. Under this measure, China drops from 2nd largest to rank 72nd. Figure 1 presents the path of aggregate and per capita GDP in China from 1960-2017. It demonstrates that both have followed similar paths. This may be reliant strict demographic policy in the past few decades since if population growth exceeds GDP growth, GDP per capita falls.

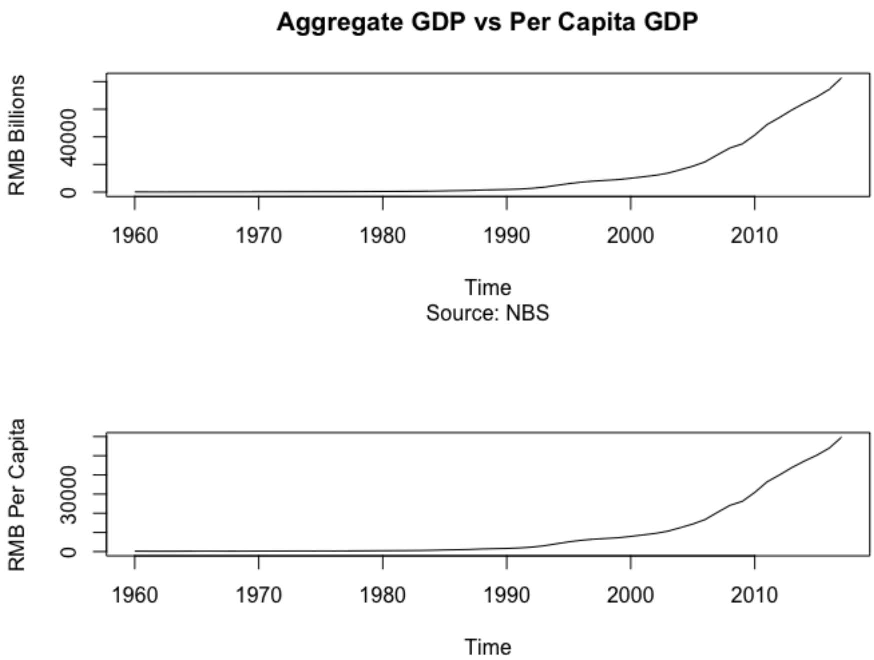
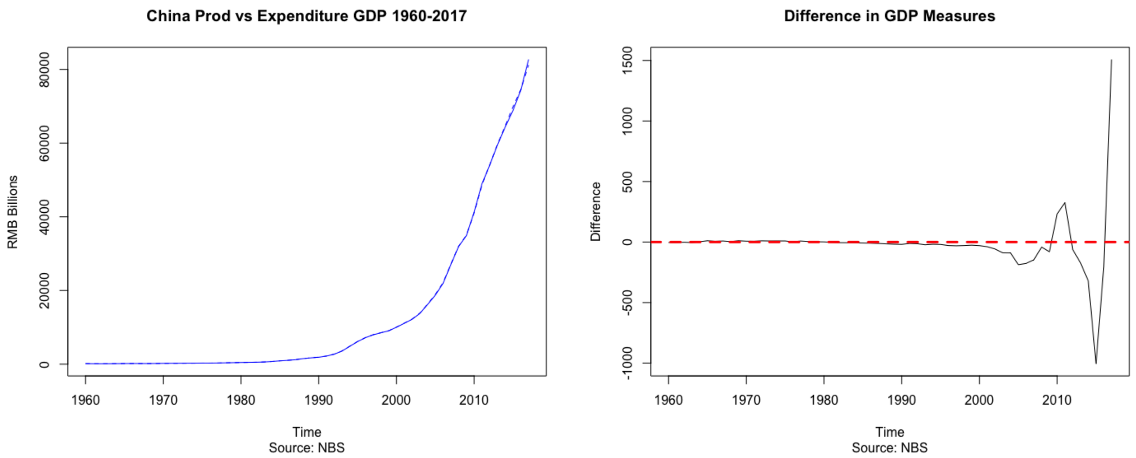


Figure 1: China GDP by Aggregate and Per Capita

Figure 2: Comparing China GDP as Measured by Production vs Expenditure Method



Definitional Distinction 2: Calculation Method

GDP can be measured in three ways which should all be identical in result despite differences in method. Firstly, the **expenditure method** defines GDP as the expenditure on all final goods and services within the year. Secondly, the **production method** aggregates value added at every stage of intermediate production by each industry with an adjustment for taxes and subsidies. Finally, the **income method** measures all income earned in the economy including wages, production taxes, profits and less subsidies and costs. In theory and application of a circular flow model, each method should produce consistent figures. In China, the production method is favoured by official statisticians. Figure 2 presents a plot of GDP as measured by production vs expenditure. **A priori**, to the naked eye, it shows a near identical co-movemement. However, by plotting the difference in the two series, it becomes clear this identicality breaks down in the mid 2000s. The cause of this discrepancy is unclear. My hypothesis would attribute it to either a change in calculation methodology or poor quality of data. This difference interests me greatly and influences the trust I place in the GDP data used throughout this report. As such, I would like to investigate the cause of such discordance between data and theory.

Definitional Distinction 3: Real vs Nominal GDP

The distinction between nominal and real GDP lies in price adjustment. Real values are adjusted for inflation thus measured in constant price while nominal values are measured in unadjusted current price. Resulantly, nominal GDP appears higher than real GDP but the latter gives better indication when comparing purchasing power across time periods. Changes in the differences between the series thus gives a

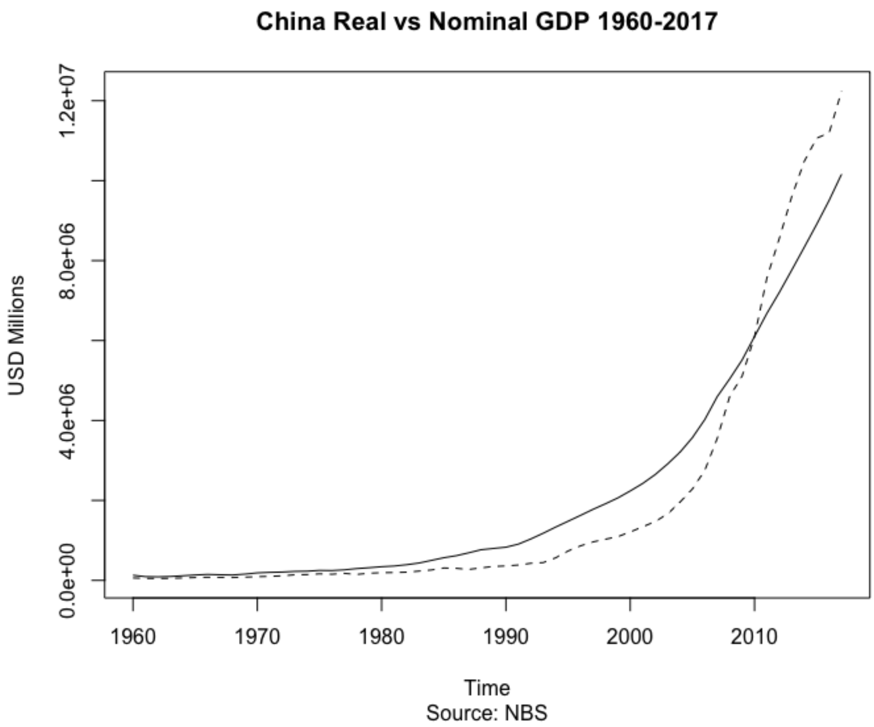


Figure 3: China GDP Real vs Nominal

measure of changes in the price index. Figure 3 plots the real and nominal GDP of China from 1960-2017. Taking the ratio between the volume in each measure gives a metric called the GDP Deflator which will be explained subsequently.

3 China's GDP Deflator

3.1 Definitions and Methododology

The GDP Deflator is one possible way to measure changes in the price index. The price index (P_t) is a normalised average adjusted by weights of price relatives for a basket of goods or services. Inflation is subsequently defined as a change in the price level:

$$\pi = \frac{P_t - P_{t-1}}{P_{t-1}} \tag{1}$$

Given the nominal GDP subsumes changes in the price level and real GDP does not, the difference between the two series provides a proxy for inflation. If the GDP deflator is greater than 100, nominal GDP is greater than real GDP implying inflation.

On the converse, when the GDP deflator falls below 100, this indicates deflation. The GDP deflator is defined as the following ratio:

$$\text{GDP Deflator} = \frac{\text{Nominal GDP}}{\text{Real GDP}} \times 100 \tag{2}$$

Inflation as measured by the GDP deflator incorporates change in all prices of all goods and services, in contrast to the Consumer or Producer Price Index which only covers the respective basket of goods. This breadth of inclusion is an advantage of using the GDP Deflator to measure inflation. However, the calculated GDP deflator inherits the data quality issues plaguing GDP measurement. There is a plentidude of literature from both inside and outside of China citing the unreliability of its GDP figures. Thus, any comment is limited by the authenticity and accuracy of its data foundation.

3.2 Analysis

3.2.1 An Overview from 1960-2017

Figure 4 presents the GDP deflator calculated from annual data in USD. It is important to note the GDP deflator is most commonly calculated in local currency to avoid containmination of domestic inflation with imported exchange rate effects. Correspondingly, some of the discrepancy between the GDP Deflator calculated with China GDP in USD versus that calculated in RMB may in part be due to changes in the dollar/yuan exchange rate over the past decade which includes both periods of relative stability and periods of dramatic change due to devaluations and modifications to how the yuan is valued.

3.2.2 Identifying Primary Cycles

The Chinese economy has displayed fluctuations since open market reforms in 1978. These cycles displayed in the period as measured by peaks and troughs can be explained through both GDP growth and inflation changes. These two measures incorporate wider changes in other economic metrics such as job creation, investment plans, consumer spending and policy influence.

The rising GDP Deflator in 1978 can be attributed to post-Mao reformist policies in spending and agricultural reform, affirming an 'Adjustment' period. Such reforms

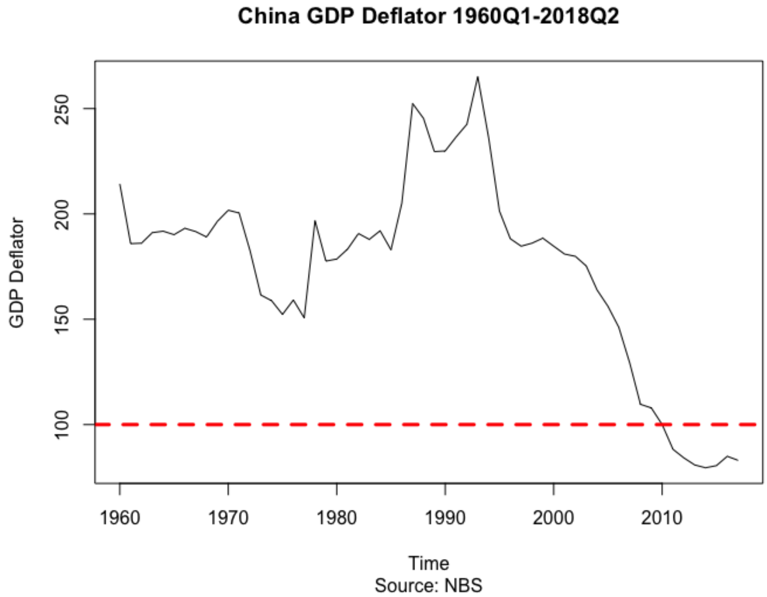


Figure 4: China GDP Deflator Calculated from Nominal and Real GDP (USD)

increased spending and investment thus increasing inflation. The underlying mechanism can be attributed to either a neo-keynesian explanation (via menu costs and imperfect competition, Mankiw (1985), Yellen (1985)) or to expectations augmented phillips curve effect (via the wage setting process) or by the Lucas Imperfect Information approach (Lucas 1972). During this period, wages were set centrally by the government limiting wage inflation.

Progressing into the 1980s, the rural and industrial reform boom create peaks in inflation while corrections for budget imbalances and industrial overheating moderates inflationary pressure. A key change occurred 1985 where the government implemented a wage indexing system linked directly to the price level (Yueh 2004). This reform initiated run away inflation through a feedback loop of higher wages to higher inflation. Banking panics in 1987-88 further stakes this loop. Growth in the money supply exacerbated inflationary pressure.

The introduction of a price stabilisation program, concurrent to urban price reforms and below trend investment rate cause a slower growth period in the early 1990s. However, the subsequent abolition of company price regulation which previously obscured inflation and a period of price liberalisation once again cause inflation to soar.

In response to high inflation in the mid 1990s, a form of price control (the Price Law) was more rigorously introduced and a new wage reform divorced wages from inflation and instead indexed to productivity, thereby breaking the previously problematic feedback loop. The quest for monetary tightening intensified with confirmed legal status of the PBOC by 1995 and continued switch of focus from credit to inflation policy.

At the turn of the century and in the aftermath of the 1999 Asian Crisis, inflationary pressures begin to ebb. Scholar attribute this period of stabilising inflation to an improvement in policy regime (Guerineau and Guilldamont 2005). In the earlier 2000s, deflationary concerns took precedence engendering expansionary monetary policy. Interestingly, this expansion did not boost inflation. The cause of this discordance is attributed to China's preferential credit policy whereby consumer and SME spending is crowed out by favourable credit lines to heavy industry. Such discordance illustrates the importance of compositional analysis obscured in aggregate by the GDP deflator. It matters not only what monetary policy is implemented but whom it affects.
The 2008/2009 Global financial crisis has effect in China, with an imported stagnation in export demand, investment plans and consumer spending. This dip in economic growth generates a response in policy towards expansion. In the USD calculated, the GDP deflator falls below 100 implying real GDP is less than nominal GDP and thus purchasing power falls compared to the period before.

3.2.3 Focus on the Past Decade

Analysing higher frequency quarterly GDP better attributes observation to event. However, it also introduces more scope for data issues of measurement quality and manipulation. I have my suspicions on the validity of this quarterly analysis. These suspicions are deepened by the increasing decoupling of the GDP deflator with CPI statistics produced by the NBS. Such widenening could be explained innocently by differences in baskets of goods and services included in each measure but a more cynical observer may doubt the trustworthiness of the data.
In order to cross examine the path of China's GDP data, an annual metric is constructed. Figure 6 presents the GDP deflator calculated from annual data downloaded from Global Datasets, CEIC. This data is based in 2015 prices.

Figure 5: China GDP Deflator Calculated from Quarterly Nominal and Real GDP (RMB)

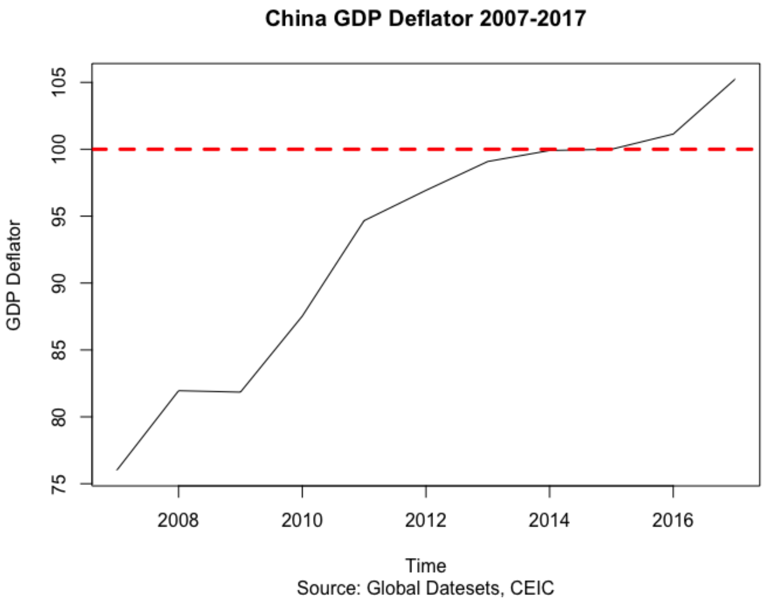


Figure 6: China GDP Deflator Calculated from Annual Nominal and Real GDP (RMB)

3.2.4 Identifying Determinants of Recent Developments

As previously identified, the dip in 2009 corresponds to the 2009 global recession and its consequences on the Chinese economy. Inflation recovered in 2010 and in fear of over-heating, the PBOC decided to abate some growth by restricting credit lines. Inflation slowed in line with the reduction in money growth in 2011. Continued slowing in 2013 was driven by a slowdown in investment - a solid and sustained driver of growth in the past. As aforementioned, distortions of preferential credit policy previously lead to the growth of investment as a share of GDP but the collaspe in household consumption and labour income shares. A deepening of capital through these specific channels initially lead to strong GDP growth but also underpins the current slowdown. The lack of linkage of investment income to households implies the investment boom was an unsustainable long-term driver of growth. The resultant unbalanced growth gave rise to both low consumption and labour income growth twinned with overcapacity of industry and debt fragility.

In recent commentary, there has been a consistent theme of excessive credit growth in China. Such concerns were borne out by Moody's downgrade of the sovereign credit rating. However, in the analysis presented in figures 6 and 7 it appears the 2017 downgrade had little effect on this measure of price level. This corroborates with the alternative side taken in recent literature which argues the Chinese government are aware of the risk and applying relevant policy changes evinced by the fall in Chinese nonfinancial corporate credit over the year. This slowdown in corporate leverage lead to a spike in the price level thus boosting nominal GDP, raising the GDP Deflator and lowering the debt-to-GDP ratio.

The inflationary effect of this year's SOE reforms and changes in soft monetary policy stance on 2018 data remains to be seen. Generally, the effect of monetary policy rebalancing in China depends crucially on how the government policy tools. The government determines both the loan and deposit interest rates which, if set artifially low, causes a reallocation of wealth from saver to borrower. As aforementioned, this compositional allocation explains why despite continuing expansive monetary policy, consumer spending and inflation is slow to respond. The key point is that monetary policy can be simultaneously loose for producers and restrictive for consumers. A reversal of this shift will likely hit the economy hard due to increasing the value of interest rate payments made by firms, resulting in more firm failures, a drag on investment rates and a general slow down in economic growth.

4 AR(1) Model: GDP Deflator Modelling and Forecasting

In order to extend my analysis, I use time series econometrics to fit a model to the GDP deflator series, allowing me to tentatively make overarching predictions for the coming two years. I use the GDP Deflator in quarterly terms giving more variation on which to fit the model.

4.1 Theory

An autoregression (AR) model represents a stochastic time-varying process. It specifies the output variable (GDP deflator) depends on previous values and a random error component. The $AR(p)$ model is specified as:

$$\textbf{AR(p):}\ X_t = \alpha + \sum_{i=1}^{p} \beta_i X_{t-i} + \varepsilon_t \tag{3}$$

In essence, the current value of X is compried of a constant (α), previous values of X multiplied by the estimated parameters of the model (β) plus a white noise normally distributed error term ε.

4.2 Model

Figure 7 presents the first difference of GDP deflator. From this is is unclear if the system is stationary. Stationary is required to fit a correctly specified model. Table 1 presents the statistical tests conducted. The KPSS tests for stationary and the Augmented Dickey-Fuller test is a standarised method for identifiying the presence of a unit root. These tests confirm the first differenced series is stationary.

Test	T-Statistic	P-Statistic	Result
KPSS Test for Level Stationary	0.135	0.1	Reject H_0, series is stationary
ADF Test for Unit Root	-2.491	0.3845	Reject H_0, there is no unit root, series is stationary

Table 1: Tests for Stationary of the First Differenced GDP Deflator Series

Following the result of these tests, the sample autocorrelation functions and partial autocorrelation functions are used for guidance on how to fit the correct model. Figure 8 presents the ACF and PACFs. From these plots which display the appropriate

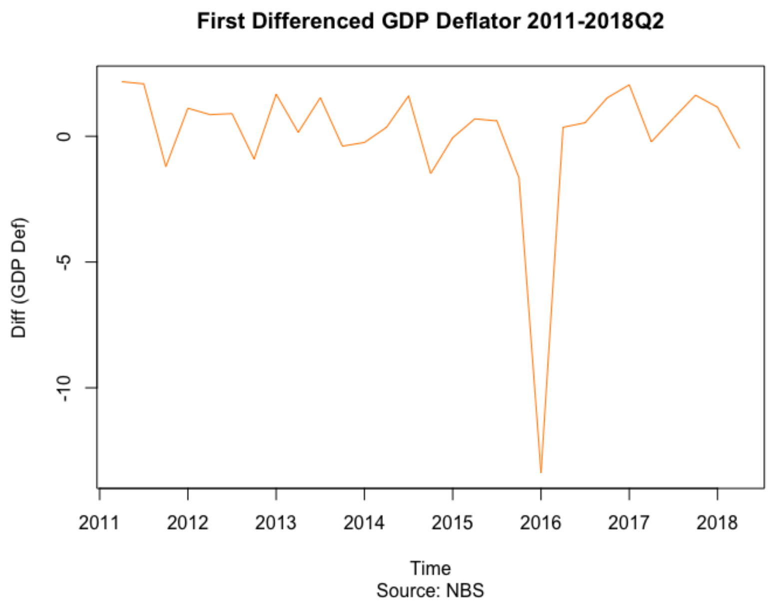


Figure 7: First Differenced GDP Deflator

95% confidence intervals, it is clear the spike at lag1 in the ACF and lack of statistically significant spikes in the PACF imply an AR(1) model is appropriate. This implies the GDP Deflator depends on its previous term plus an error term but the effect of other terms decays.

Thus, this AR(1) model for the GDP Deflator (GD_t) can be summarised as:

$$\textbf{AR(p):}\ GD_t = \alpha + \beta_1 GD_{t-1} + \varepsilon_t \tag{4}$$

This model is estimated by a maximum likelihood method employed by RStudio software. The estimated coeffcients are presented in Table 2.

Lag	Coefficient	SE
Intercept	108.7432	2.2379
AR1	0.8114	0.0971

Table 2: Estimated Coefficients for AR(1) GDP Deflator Model

The validity of this model depends on the assumption the residuals are random. The model residuals are plotted in Figure 8. The Box-Pierce test provides confirmation the residuals are random implying our assumption on ε being independent and identically distributed is valid. Table 3 presents the box-test results.

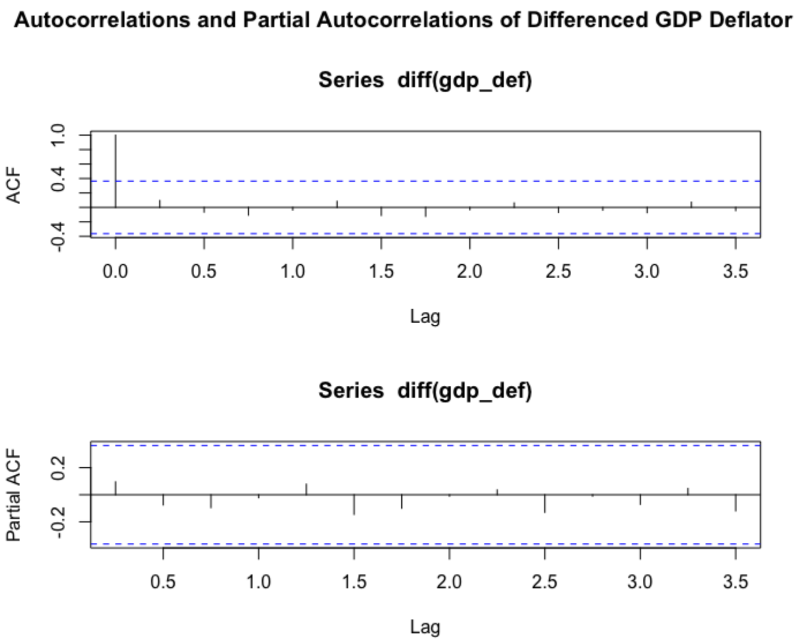


Figure 8: Autocorrelation and Partial Autocorrelations to Determine $AR(p)$ model

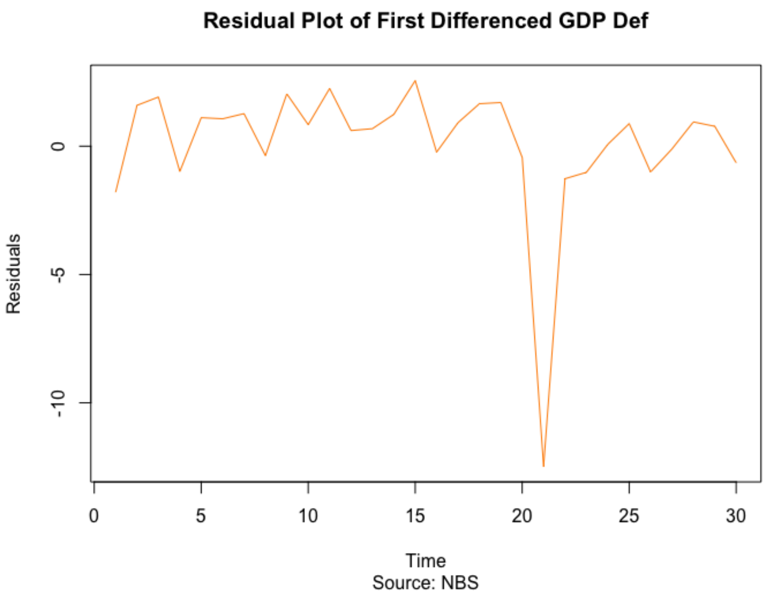


Figure 9: Residuals of $AR(1)$ model

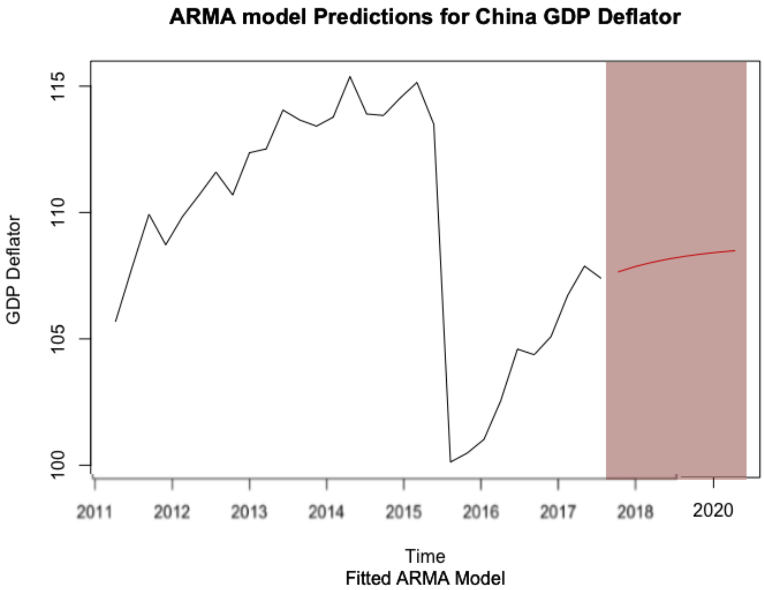


Figure 10: Predictions of $AR(1)$ model

Test	T-Statistic	P-Statistic	Result
Box-Pierce Test	0.74632	0.3876	Do Not Reject H_0, residuals are iid

Table 3: Tests for the Model Residuals

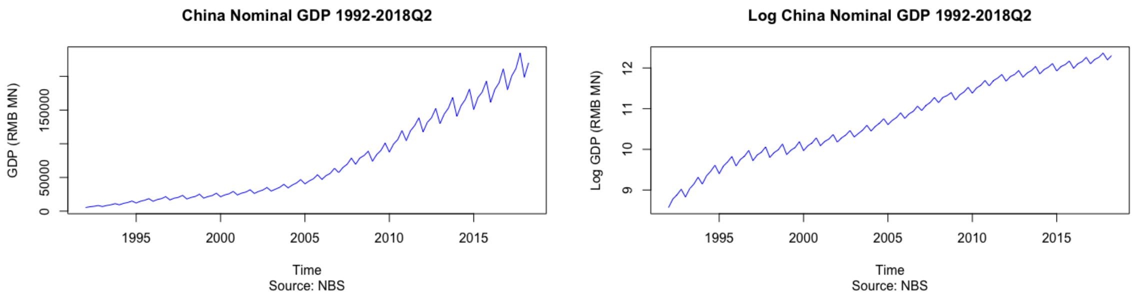
4.3 Forecasts

This model is strife with error given the frequency, short-time period of data and possibly unreliability of the data. Thus, the predictions as presented in Figure 9 are a methodological exercise to show how predictions for the next 8 quarters of China's GDP deflator can be calculated. Under this elementary forecasting model, the prediction is that the GDP deflator will continue to increase but at a flatter rate.

5 ARMA (5,0,1) Model: GDP Modelling and Forecasting

In a more convincing attempt at modelling and forecasting, I use China quarterly GDP data from 1991 to 2018Q2. Figure 11 presents nominal GDP and log nominal GDP both of which have been on a rising trend over the period evaluated.

Figure 11: China Nominal GDP 1991-2018



5.1 *Theory*

An Autoregressive integrated moving average ARIMA(p, q)model is a general form of autogressive moving average models combing both an autoregressive (AR) term and a moving average (MA) term. The latter allows the error term to be linearly dependent on contemporarous or past errors. The $ARIMA(p, q)$ model is specified as:

$$\textbf{ARIMA(p,q):}\ X_t = \alpha + \sum_{i=1}^{p} \beta_i X_{t-i} + \sum_{j=1}^{q} \omega_i \varepsilon_{t-j} + \varepsilon_t \tag{5}$$

5.2 *Model*

Figure 11 presents the first difference of GDP. Table 4 presents a repeat of the statistical tests required. These tests confirm the first differenced series is stationary.

Test	T-Statistic	P-Statistic	Result
KPSS Test for Level Stationary	0.19366	0.1	Reject H_0, series is stationary
ADF Test for Unit Root	-2.6817	0.294	Reject H_0, there is no unit root, series is stationary

Table 4: Tests for Stationary of the First Differenced GDP Series

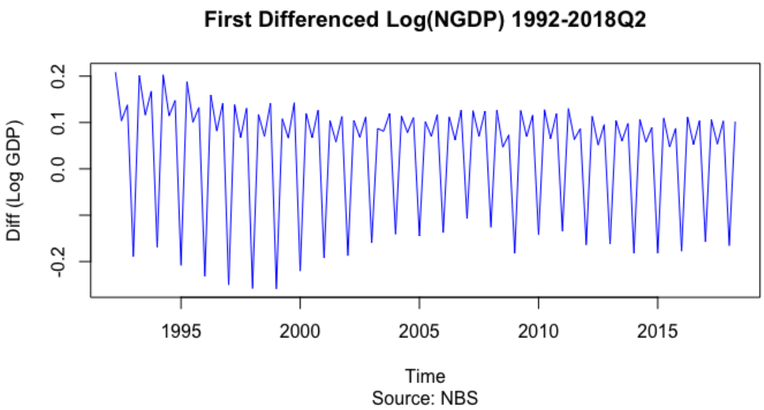


Figure 12: First Differenced Log GDP

Following the result of these tests, the sample autocorrelation functions and partial autocorrelation functions are used for guidance on how to fit the correct model. This time, as Figure 13 shows, both the ACF and the PACFs display signficant lags. From the PACF, a spike at lag5 and subsequently dimishing later lags implies an AR(5) model is appropriate. The ACF plot shows a MA(∞) is suitable. Thus the appropriate fitted model is ARMIA(5,1,0).

Thus, this ARIMA(5,0,1) model for the GDP Deflator (Y_t) can be summarised as:

$$\textbf{AR(p):}\ Y_t = \alpha + \beta_1 Y_{t-1} + +\beta_2 Y_{t-2} + \beta_3 Y_{t-3} + \beta_4 Y_{t-4} + \beta_5 Y_{t-5} + \varepsilon_t \quad (6)$$

This model is estimated by a maximum likelihood method employed by RStudio software. The estimated coeffcients are presented in Table 5.

Lag	Coefficient	SE
Intercept	108.7432	2.2379
AR1	0.8114	0.0971
AR2	-0.0094	0.0087
AR3	-0.0171	0.0106
AR4	0.9937	0.0085
AR5	-0.4741	0.0871

Table 5: Estimated Coefficients for ARIMA(5,0,1) GDP Deflator Model

Once again, the model relies on the assumption the residuals are random. The model residuals are plotted in Figure 14. The Box-Pierce test provides confirmation the residuals are random implying our assumption on ε being independent and identically distributed is valid. Table 6 presents the box-test results.

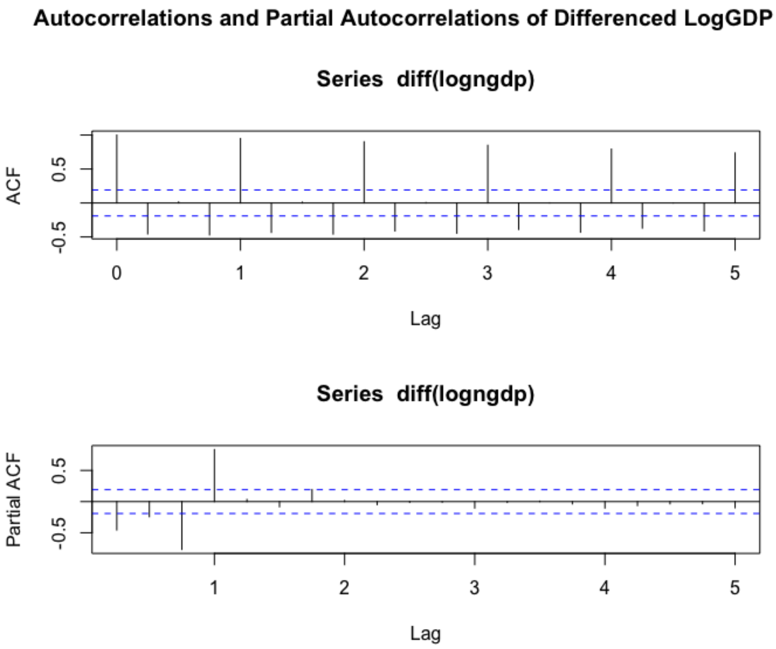


Figure 13: Autocorrelation and Partial Autocorrelations to Determine $ARIMA(p, q)$ model

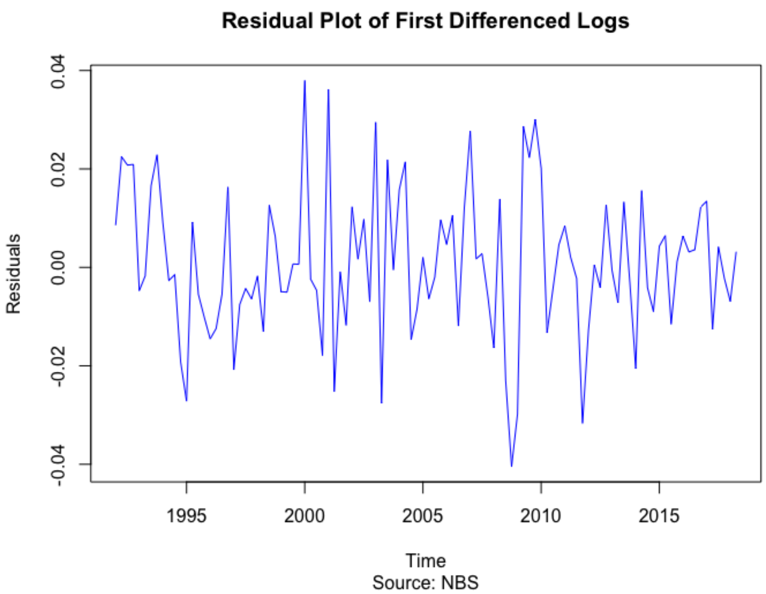


Figure 14: Residuals of $ARIMA(5, 0, 1)$ model

Test	T-Statistic	P-Statistic	Result
Box-Pierce Test	0.5675	0.476	Do Not Reject H_0, residuals are iid

Table 6: Test for the Model Residual

5.3 *Forecasts*

While limited in external validity, the model predictions as presented in Figure 15 show a best guess forecast of the evolution path of the next 8 quarters of China's GDP.

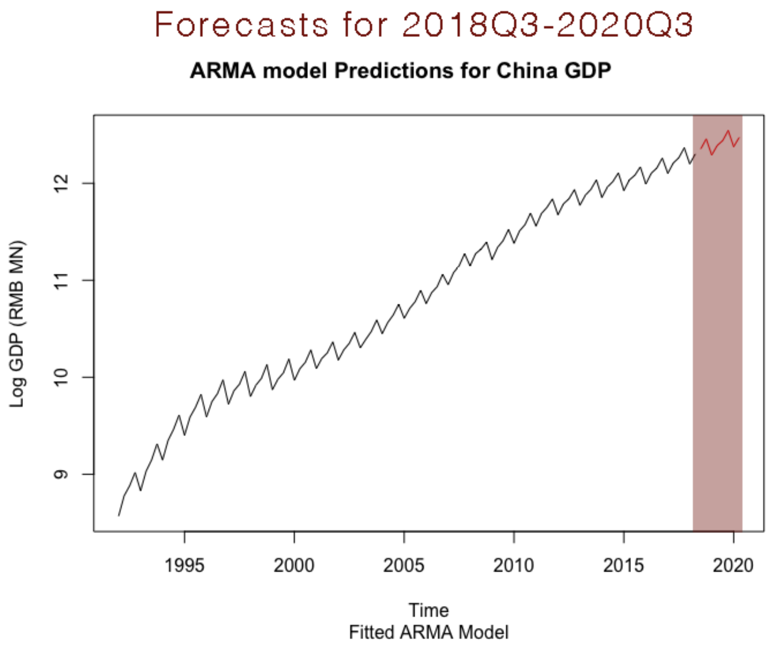


Figure 15: Residuals of $ARIMA(5,0,1)$ model

6 Conclusion

This paper has covered both the definitional approaches to GDP metrics and their use in identifying cyclical fluctuations and in measuring changes in the price level. A broad analysis of the Chinese evolution of GDP and the GDP deflator is provided but concerns remain in the quality and reliability of sourced data. As a methodological exercise, this paper further demonstrates how ARIMA models can be fitted to stochastic, time-varying series like those investigated.

7 References

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