Disposable Income, Debt, and Savings: Q1 1980 through Q3 2018

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Abstract

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Background

Americans are on average spending more and saving less over the past decade. As of the fourth quarter 2018, total household debt in the United States has hit a ten-year high at $869B (Federal Reserve Bank of New York Center for Microeconomic Data (2019)). As debt increases, so does household spending, up from $9.7M in 2008 to $12.9M in 2017 (Organisation for Economic Co-operation and Development (2018b)). Total household savings is on the decline, decreasing from 9.1% in 2012 to 6.9% in 2017 (Organisation for Economic Co-operation and Development (2018a)). Wages have increased modestly during this time, and appears largely attributable to inflation (Federal Reserve Bank of St. Louis (2016)).

The objective of this study was to analyze US household real per-capita disposable income, debt service payments, and personal savings over time, to understand trends in personal disposable income, and to determine whether savings can accurately be predicted from debt.

Methods

Data pertaining to disposable personal income, household debt service payments, and personal savings informed the analytic dataset (Table 1). All variables were obtained from the Federal Reserve Bank of St. Louis, all share a common year of valuation ($US 2012), and all have already been seasonally adjusted. The data were limited to a common time horizon (Q1 1980 through Q3 2018), yielding 155 observations for each time series (TS).

Table 1. Analytic Dataset Contents

Variable	**Description**	**Reference**
`fred_disposable`	Per-capita disposable income, adjusted for inflation in chained $US 2012, seasonally adjusted	Federal Reserve Bank of St. Louis (2018c)
`fred_debt`	Household debt service payments as a percent of disposable personal income, seasonally adjusted	Federal Reserve Bank of St. Louis (2018a)
`fred_savings`	Personal savings as a percentage of disposable personal income, seasonally adjusted	Federal Reserve Bank of St. Louis (2018b)

Data Exploration

Each TS was separately explored via the `forecast::autoplot()` function, which yields plots for the raw time series along with its autocorrelation (ACF) and partial autocorrelation (PACF) functions. Differencing was applied where needed. Classical decomposition was performed for each TS via `decompose()` to understand the seasonality, if any, of these time series. Where meaningful seasonality was suspected, a periodogram was generated to determine important frequencies. To understand how savings may be dependent on debt, the cross-correlation function (CCF) was computed and plotted for differenced `fred_savings` vs. differenced `fred_debt`.

Modeling Disposable Income

To model the disposable income data, the `fred_disposable` TS was subset to a "training" dataset capped at Q3 2017, and a suggested fit was obtained via `forecast::auto.arima()`. The suggested model was fit using `forecast::Arima()`, and model fit was assesed both through analysis of residuals using `forecast::checkresiduals()` and by checking p-values via `lmtest::coeftest()`. ACF plots of squared and absolute value residuals were assessed for ARCH/GARCH behavior. Finally, `forecast::forecast()` was used to predict the next three values (i.e., Q1 2018 through Q3 2018) along with a confidence interval, and these predictions were compared to the values found in the full dataset.

Modeling Savings vs. Debt

Since both debt service payments (`fred_debt`) personal savings (`fred_savings`) are expressed as a percentage of disposable personal income, it is reasonable to hypothesize that, as debt payments increase, personal savings may decrease. Under this hypothesis and using the same set of functions as described above, debt was used to predict savings for Q1 2018 through Q3 2018 using training datasets capped at Q3 2017 in an ARIMA model that incorporates both differencing and a lag offset informed by the CCF of differenced savings vs. differenced debt. Predictions were again compared to the observed values available in the full `fred_savings` dataset.

All analyses were performed in R (R v. 3.5.1, R Foundation for Statistical Computing, Vienna, Austria) using packages `forecast` (Hyndman et al. (2019)) and `astsa` (Stoffer (2019)) for specialized time series calculations and plots. All statistical tests were evaluated against a significance threshold of $\alpha = 0.05$.

Results

Text

Data Exploration

Figures 1-3 show the `autoplot()` output for the three time series. A generally increasing trend is seen in the plot of disposable income (Fig. 1). Because these data are adjusted for inflation to $US 2012, this trend represents a true increase in disposable income, not inflation, and thus the time series is not stationary. The ACF plot shows a slow linear decline in $\hat{\rho}(h)$ with increasing h, suggesting nonstationarity. The graphs of debt payments and savings (Figs. 2 and 3 respectively) do not exhibit any simple trend, but do fluctuate over time, though without any apparent seasonality (which is expected, because the data are provided in seasonally adjusted form). Additionally, the ACF plots for both debt payments and savings are suggestive of nonstationarity due to their slow decline, and thus required differencing to achieve stationarity.

Figure 1. Real Disposable Personal Income Per Capita

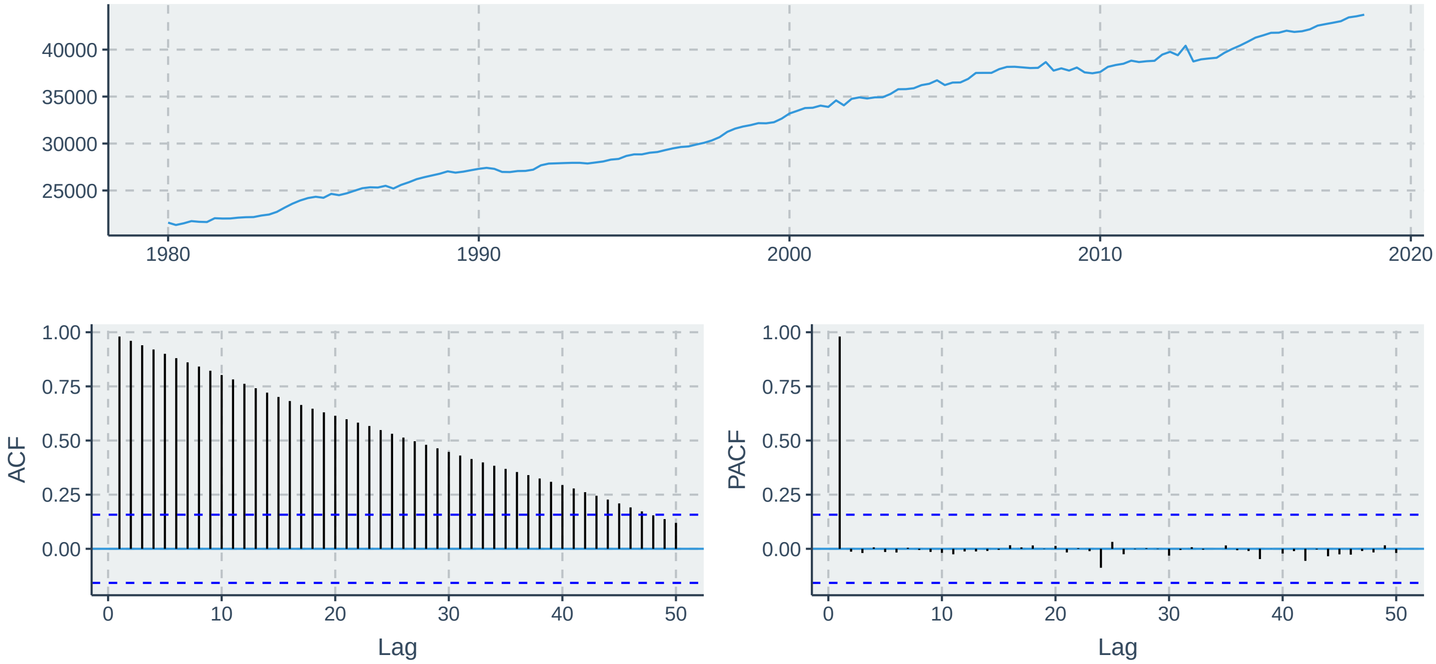


Figure 2. Household Debt Service Payments as a Percent of Disposable Personal Income

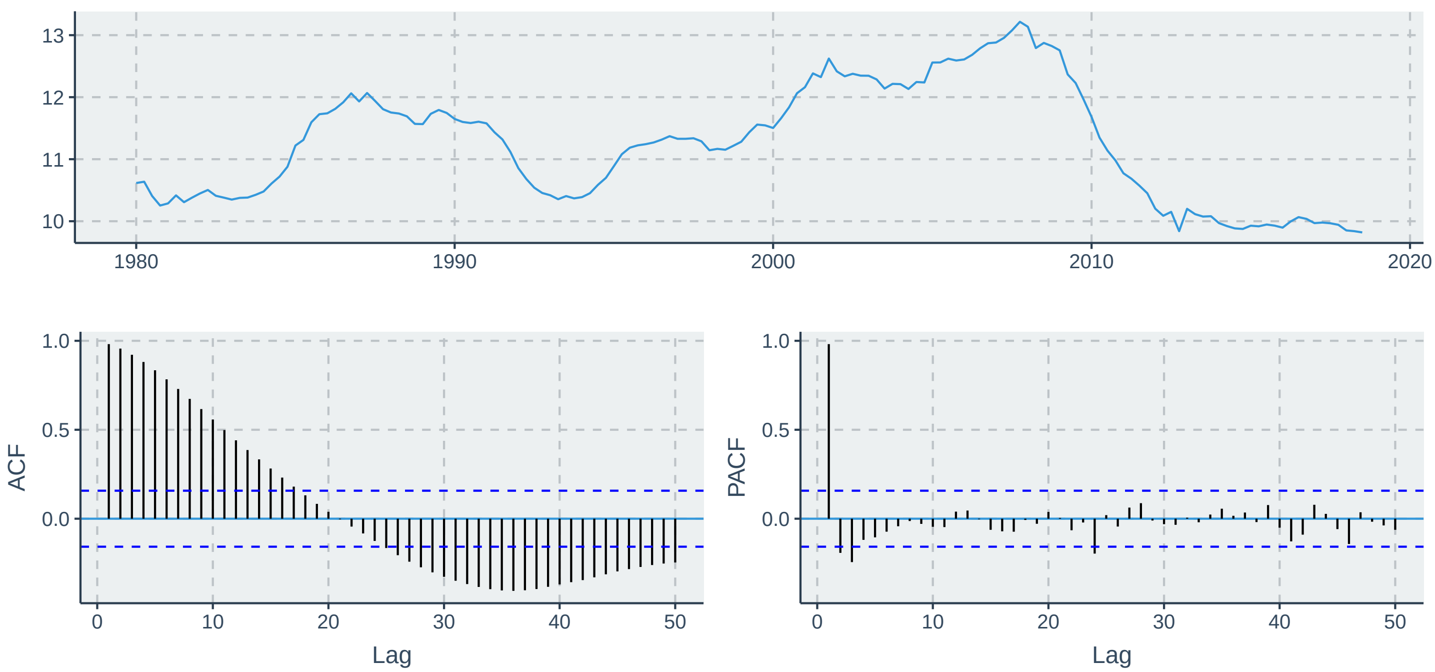
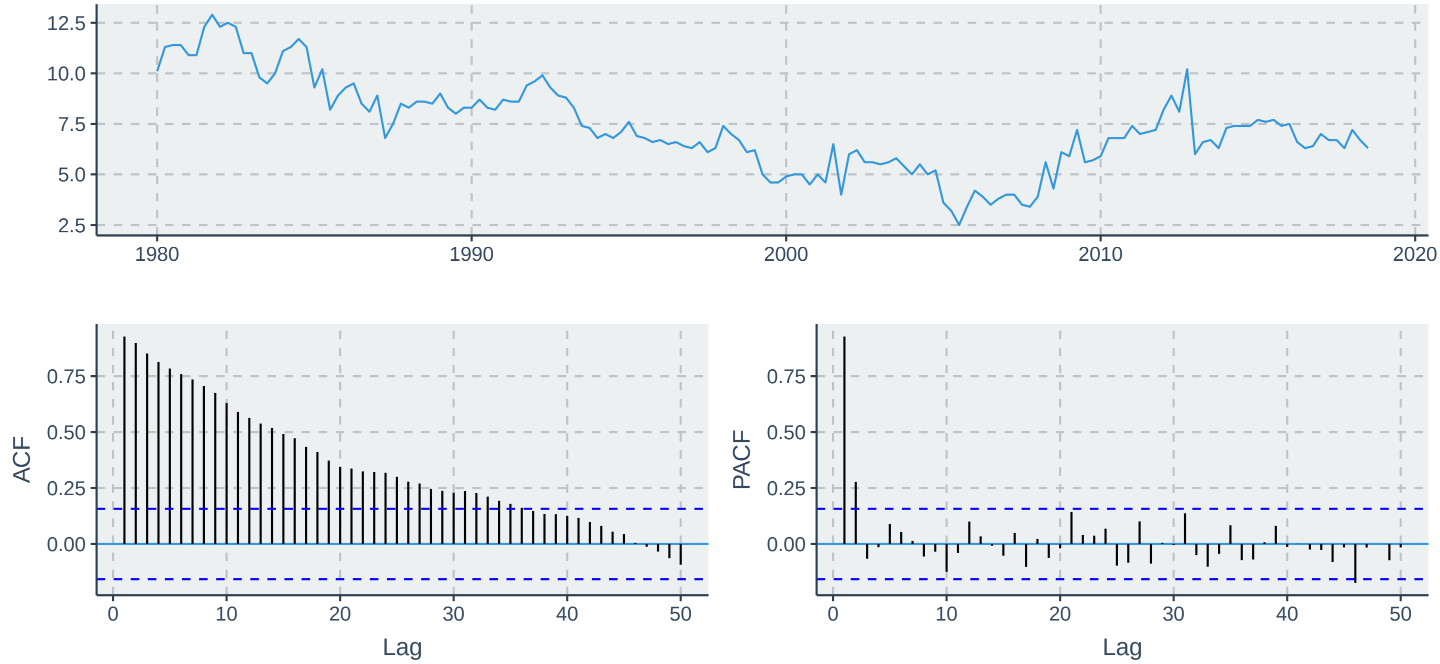


Figure 3. Personal Savings as a Percent of Disposable Personal Income



Figures 4-6 show the results of differencing. After differencing, stationarity appears to be met for all three TS. ELABORATE FURTHER?

Figure 4. Real Disposable Personal Income Per Capita, Differenced Once

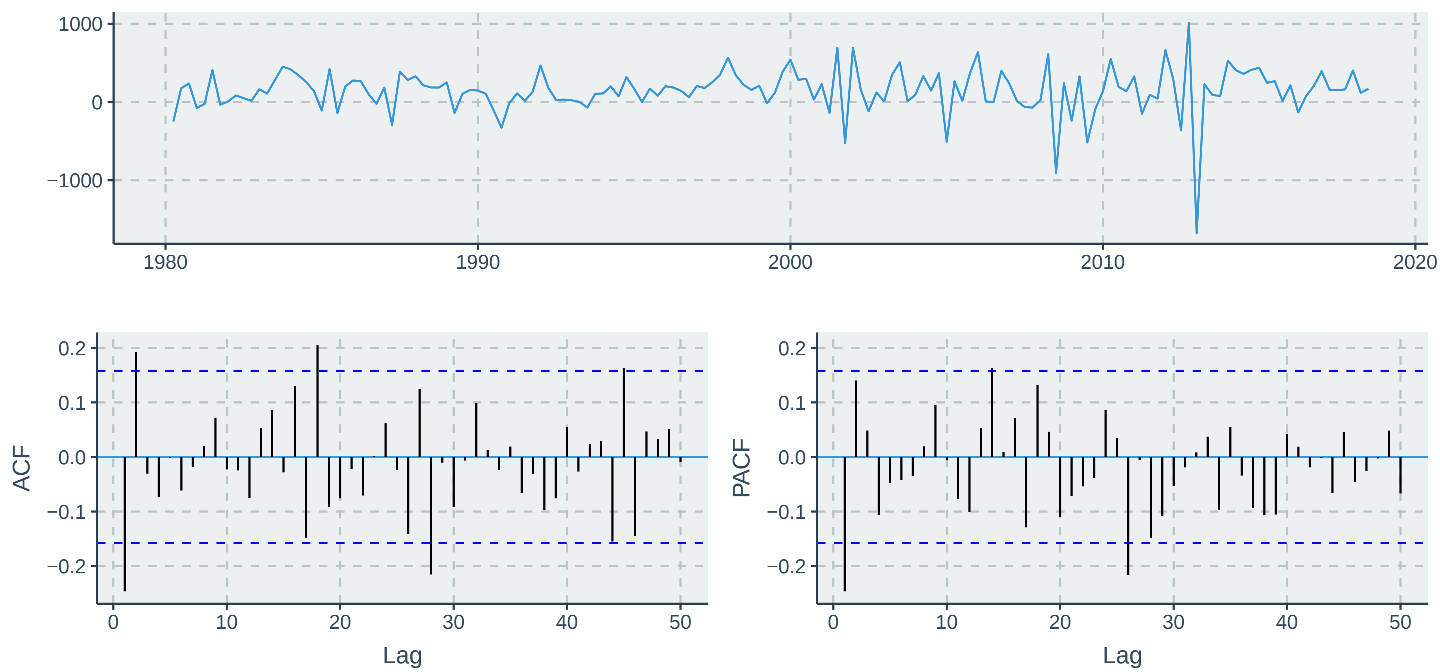


Figure 5. Household Debt Service Payments as a Percent of Disposable Personal Income, Differenced Once

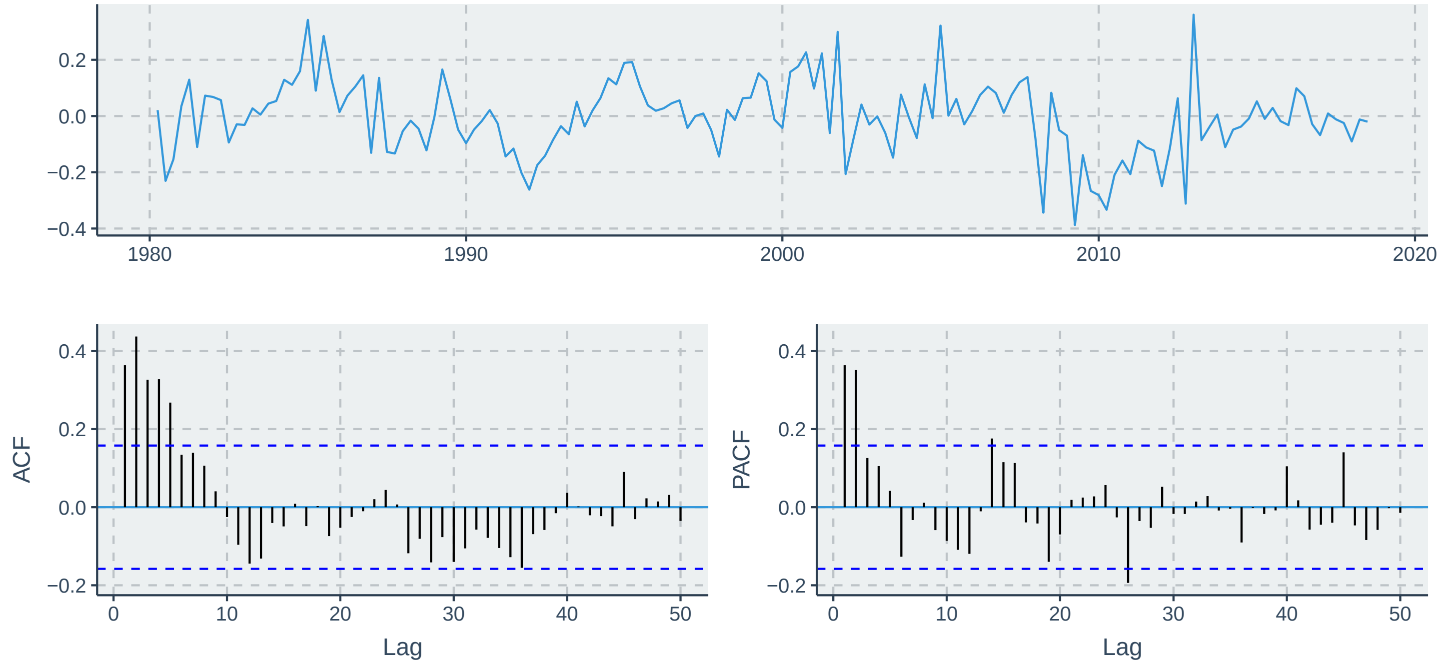
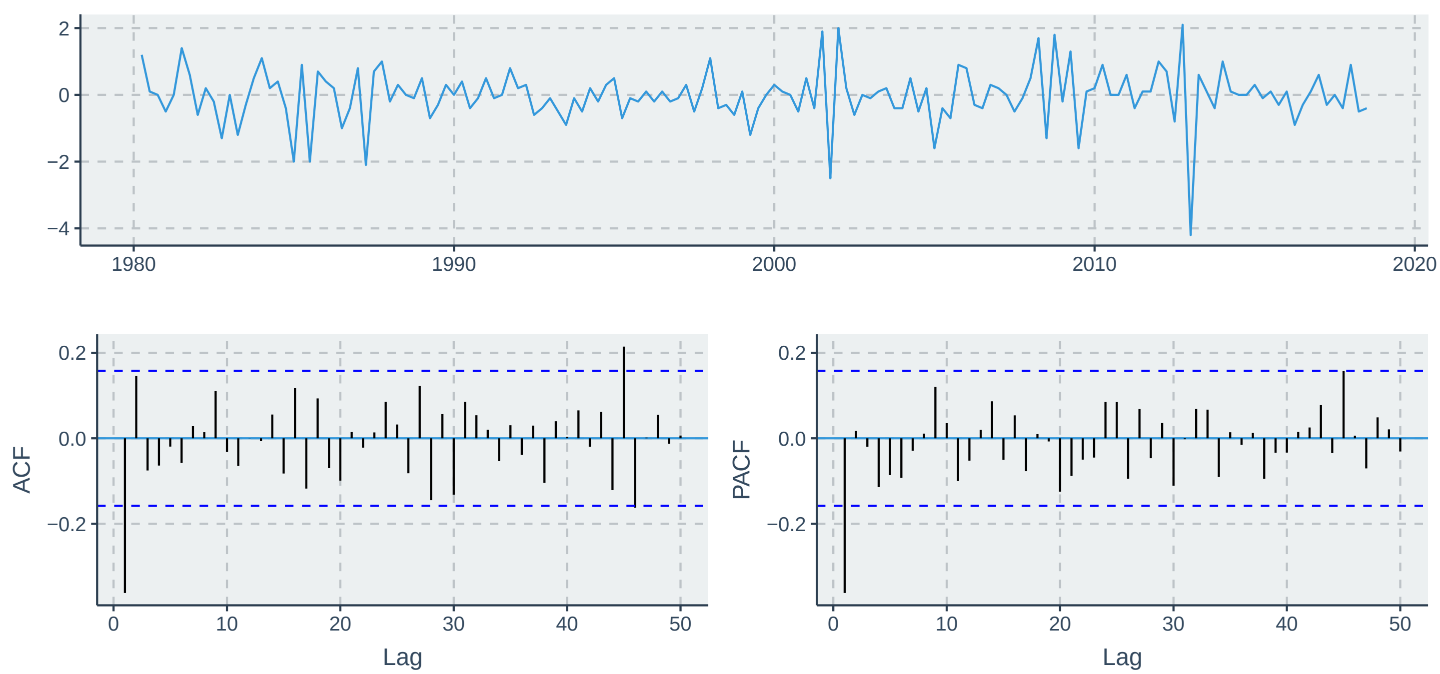


Figure 6. Personal Savings as a Percent of Disposable Personal Income, Differenced Once



Classical decomposition of the debt and savings TS is shown in Figs. 7-8. For both TS, the seasonal component was small in magnitude when compared to the raw TS, with personal savings having the more pronounced seasonal component.

Figure 7. Debt Service Payments, Decomposition

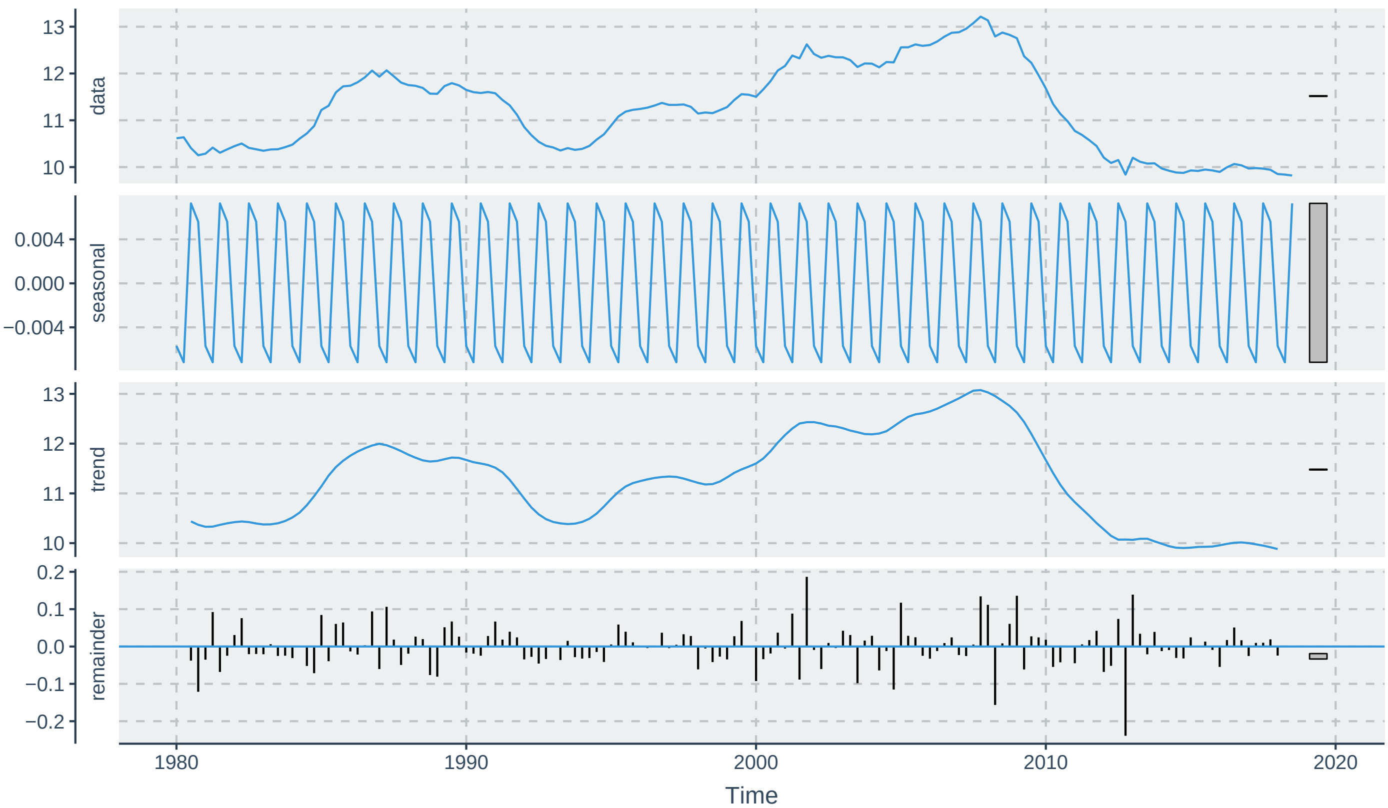
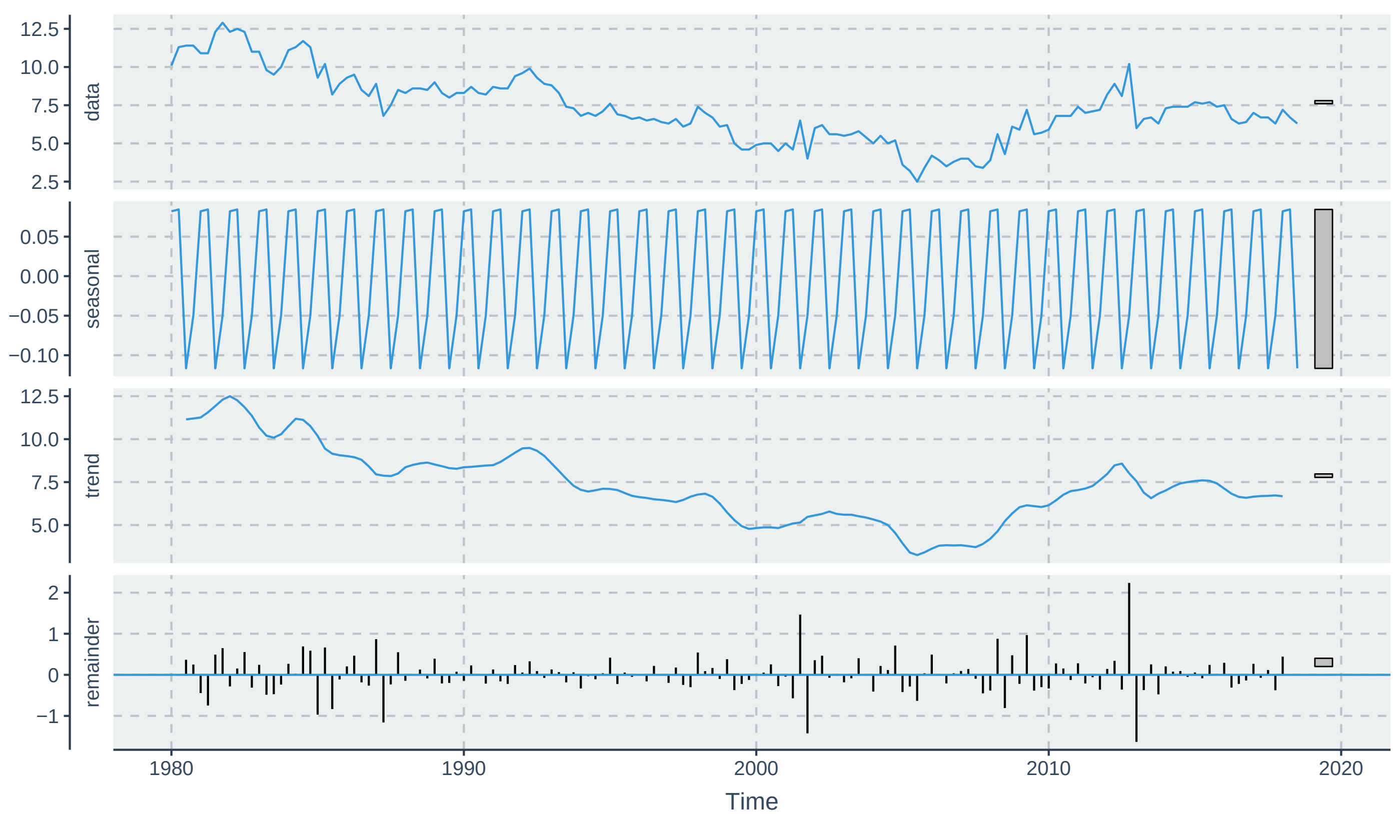


Figure 8. Personal Savings, Decomposition



The scaled periodogram for differenced savings is presented in Figure 9. All peak values in this plot are quite small. Five peaks are seen; key frequencies observed are $\omega_1 = 0.123$, $\omega_2 = 0.377$, and $\omega_3 = 0.448$, with some possible clustering about ω_3, indicating it is not a fundamenal frequency. Because these data are already seasonally adjusted, none of these frequencies are expected to have real meaning; additionally, all peaks observed are of small magnitude, consistent with a weak seasonal component, and thus limiting the usefulness of the frequency domain approach.

Figure 9. Scaled Periodogram for Differenced Savings

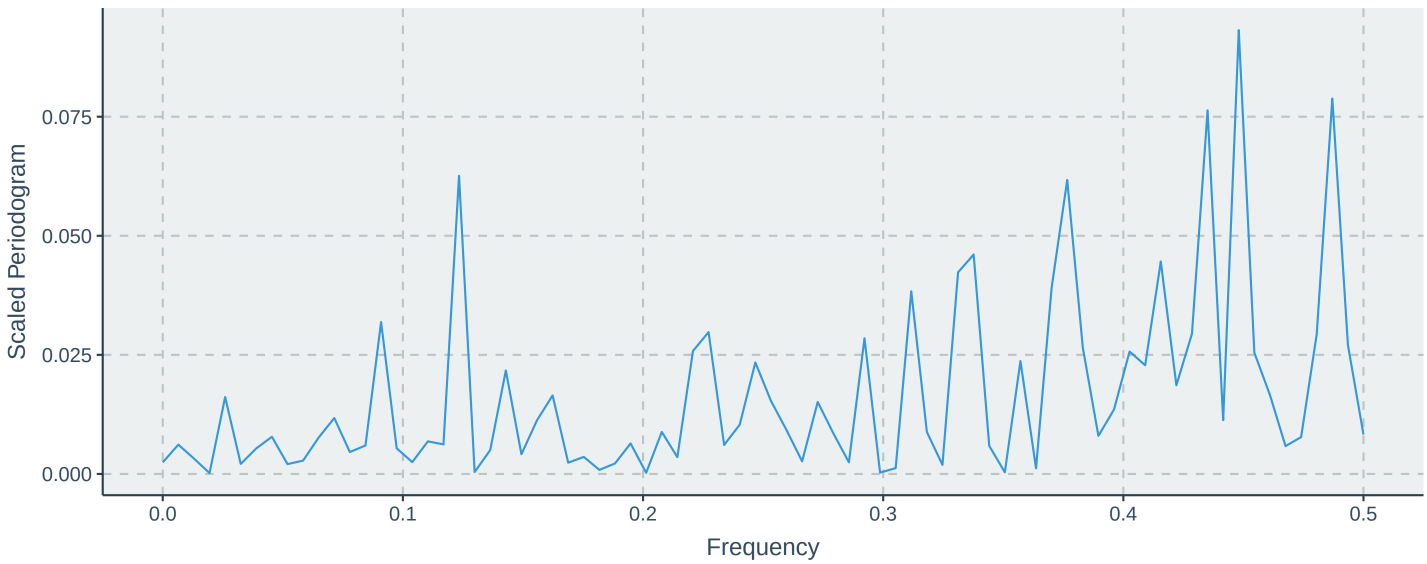
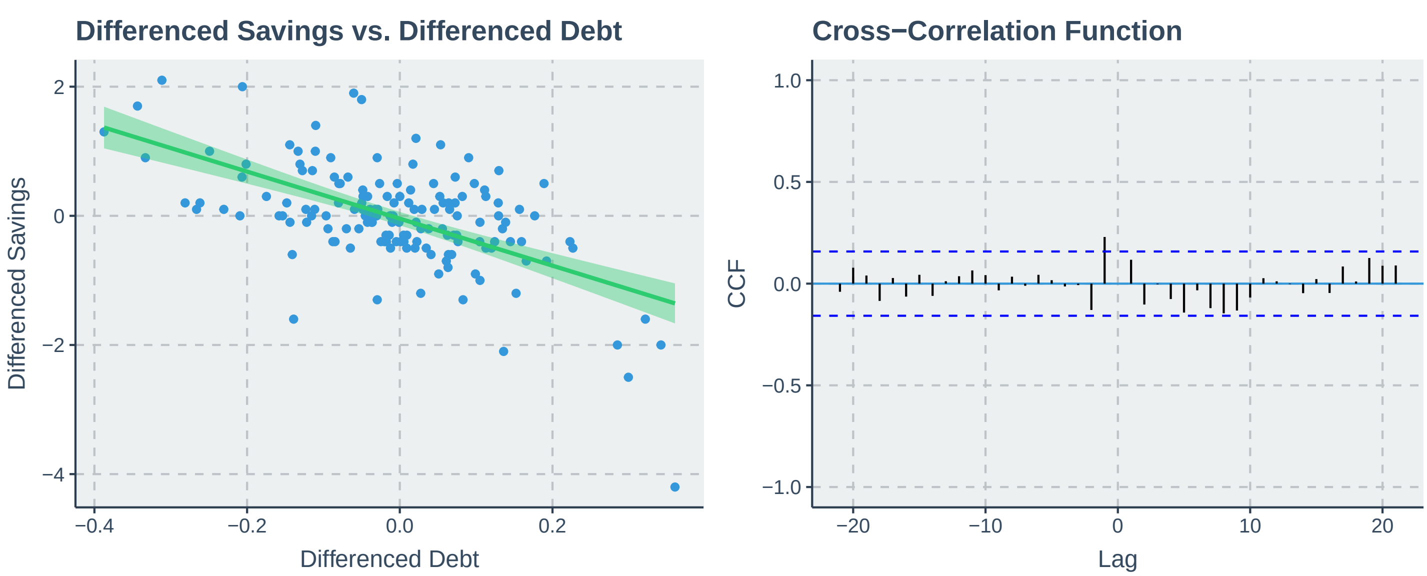


Table 2. Key Frequencies, Scaled Periodogram

Frequency
0.123
0.377
0.435
0.448
0.487

A scatterplot and the cross-correlation function for differenced savings vs. differenced debt are shown in Fig. 10. The scatterplot shows a general decrease in differenced savings as differenced debt increases, but a nontrivial degree of spread is seen in the plotted points. In the CCF plot, a cross-correlation is seen at lag $h = -1$; however, it is small in magnitude which suggests that differenced debt at $h = -1$ may only be weakly predictive of differenced savings.

Figure 10. Relationship between Differenced Savings and Differenced Debt



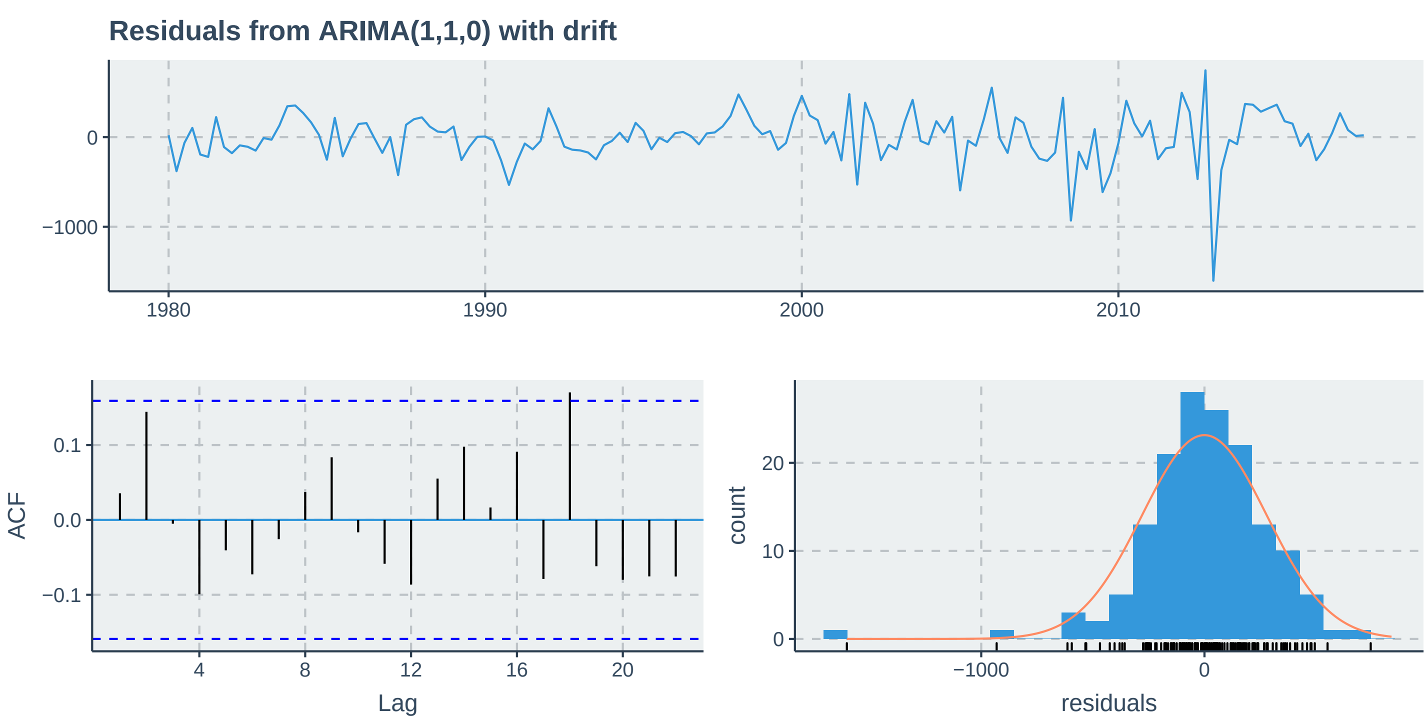
Modeling Disposable Income

For disposable income, the model suggested by `auto.arima()` was ARIMA $(1,1,0)$ with drift; `checkresiduals()` output for the fitted model is shown in Fig. 11. The Ljung-Box test (not shown in Fig. 11) yielded a p-value of 0.3746 over 8 lags, indicating that the residuals are consistent with white noise. This conclusion is supported by the plots in Fig. 11 - namely, the ACF plot looks like white noise, and the histogram demonstrates approximate normality of residuals with nontrivial deviation about the tails. Both the AR(1) and drift parameters in the model are significant at the $\alpha = 0.05$ threshold. Despite the suspected lack of normality in the residuals, this model fits the training dataset reasonably well. Additionally, ARCH/GARCH behavior was not seen in the model residuals (Fig. 12).

```
## Series: fred_disposable_train
## ARIMA(1,1,0) with drift
##
## Coefficients:
##           ar1     drift
##       -0.2489  142.5335
## s.e.   0.0790   18.2321
##
## sigma^2 estimated as 79132:  log likelihood=-1064.84
## AIC=2135.67   AICc=2135.84   BIC=2144.73

##
## z test of coefficients:
##
##         Estimate Std. Error z value  Pr(>|z|)
## ar1    -0.248912   0.079026 -3.1497  0.001634 **
## drift 142.533522  18.232105  7.8177 5.379e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

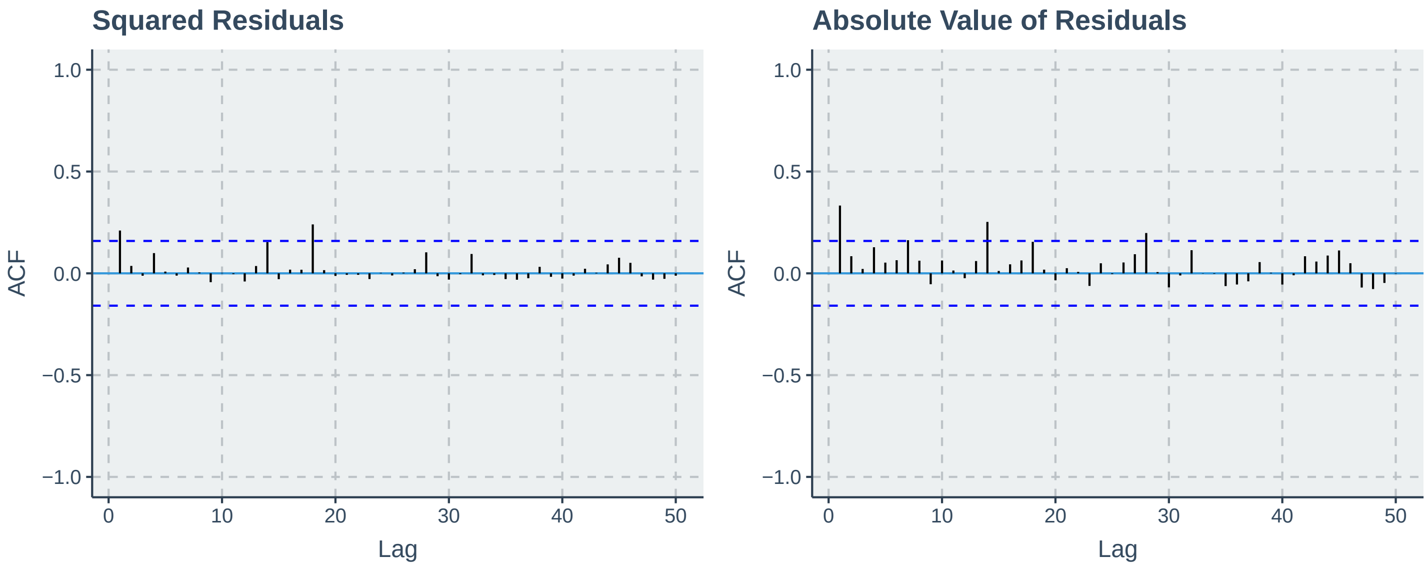
Figure 11. Residual Fit, Disposable Income Model: ARIMA(1, 1, 0) with Drift




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(1,1,0) with drift
## Q* = 6.4507, df = 6, p-value = 0.3746
##
```

```
## Model df: 2.   Total lags used: 8
```

Figure 12. Autocorrelation Function for Residuals

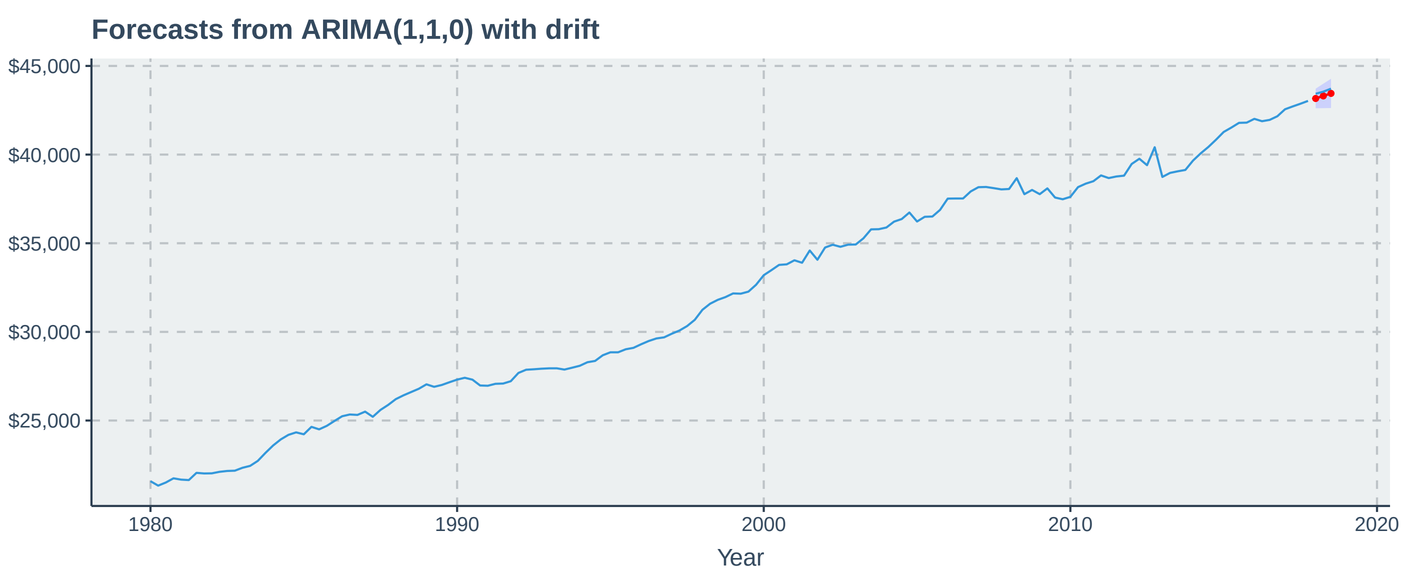


Predicted and observed disposable income values for Q1 through Q3 2018 are shown in Table 3. The observed values are marginally greater than predicted values in each case, and fall within the 95% prediction interval (Fig. 13).

Table 3. Predicted and Observed Values, Disposable Income, Q1 through Q3 2018

Timepoint	Predicted Values	Actual Values	Percent Error
Q1 2018	$43,165	$43,430	-0.61
Q2 2018	$43,309	$43,549	-0.55
Q3 2018	$43,451	$43,718	-0.61

Figure 13. Predicted vs. Actual Values, Disposable Income



Modeling Savings vs. Debt

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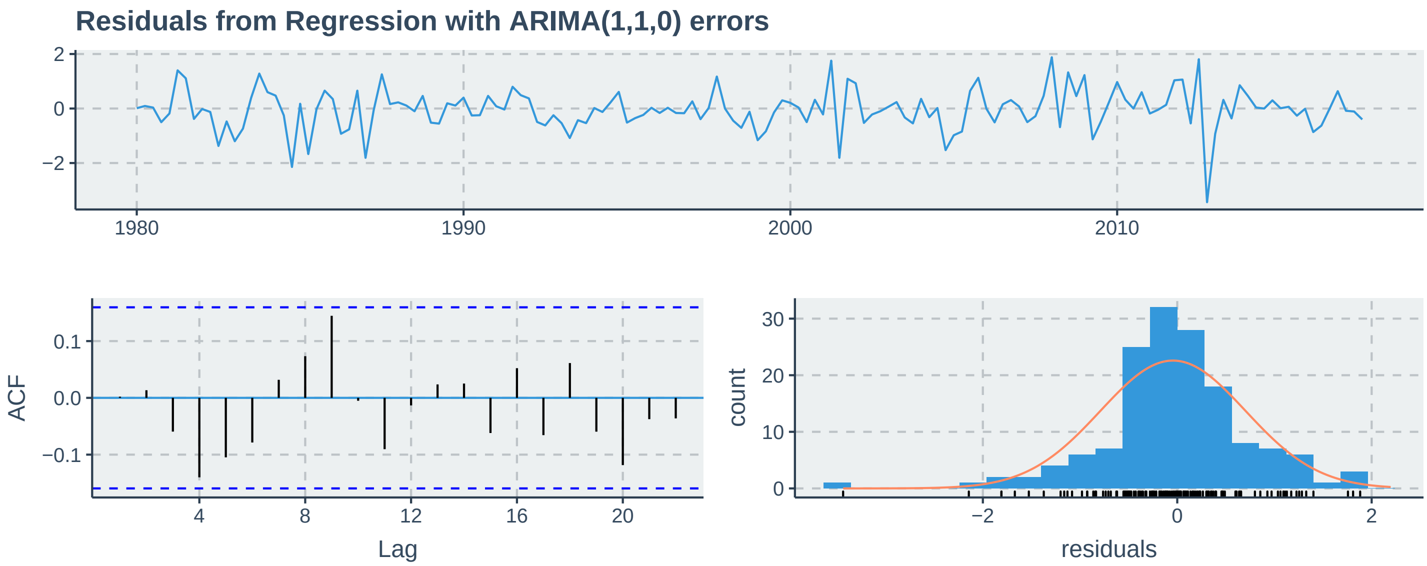
```
## Series: savdebt_ts[, 2]
## Regression with ARIMA(1,1,0) errors
```

```
##
## Coefficients:
##           ar1     xreg
##       -0.3639  -0.0066
## s.e.   0.0858   0.4440
##
## sigma^2 estimated as 0.5671:  log likelihood=-169.36
## AIC=344.72   AICc=344.89   BIC=353.76
```

```
##
## z test of coefficients:
##
##         Estimate Std. Error z value  Pr(>|z|)
## ar1  -0.3638799  0.0857849 -4.2418 2.218e-05 ***
## xreg -0.0065701  0.4439923 -0.0148    0.9882
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 14. Residual Fit, Lagged Regression of Differenced Savings on Differenced Debt




```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(1,1,0) errors
## Q* = 7.4125, df = 6, p-value = 0.2844
##
## Model df: 2.   Total lags used: 8
```

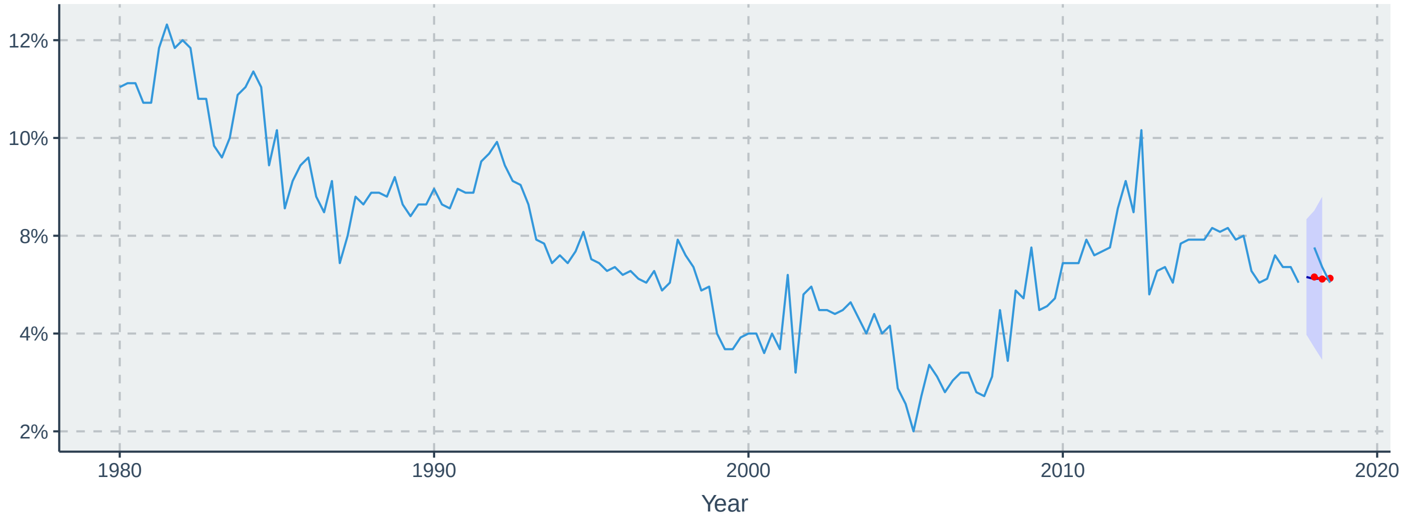
Text

Text

Table 4. Predicted and Observed Values, Savings, Q1 through Q3 2018

Timepoint	Predicted Values	Actual Values	Percent Error
Q1 2018	6.45	7.2	-10.42
Q2 2018	6.39	6.7	-4.63
Q3 2018	6.41	6.3	1.75

Figure 15. Forecast Savings, Lagged Debt Model



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Discussion

Text

Limitations

Text

Conclusion

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References

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