Stationarity Tests on Medical Net Discount Rates

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Abstract

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Medical net discount rates (MNDRs) are formulated for the post-1980 era using the various available Treasury instruments of between 3-month and 10-year duration. Net discount rate series for the medical care CPI and each of its two main subcategories (medical care commodities and medical care services) are constructed and their time series properties are examined. Stronger stationarity evidence exists for subsets of the data compared to the entire sample frame. Using a diagnostic technique to identify potentially stationary subsets, MNDRs for overall medical care costs and medical care services are found to possess strong stationary properties for series beginning in middle or late 2000 depending on the particular series. For MNDRs using medical care commodities, there are strong stationary properties for data sets beginning in late 2008. Total offset, which posits offsetting influences of the medical cost growth and discounting factors in MNDRs, is tested and yields mixed results.

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Introduction

This research investigates the time series properties of several medical net discount rates (MNDRs), which are used by some forensic economists to calculate the present value of medical costs associated with an injury that requires long-term medical care. In time series analysis, the salient statistical property is stationarity. Without it, the data set suggests that the series will eventually drift to positive or negative infinity. The MNDR is pushed in opposite directions by the two components of its formula: a discount rate and a growth rate of medical prices. A non-stationary MNDR implies that one of these components is boundlessly pulling away from the other, and this is not realistic in the long run as macroeconomic forces prevent interest and growth rates from separating without bound.

Nevertheless, previous studies illustrate that a MNDR can be non-stationary depending on the time frame, type of interest rate, or medical cost growth rate. Using short term Treasury security interest rates and the growth rate in overall medical care consumer prices, Baumann and Schap (2015) find little support for stationarity for a data set beginning in 1981. By comparison, there is strong support that MNDRs are stationary if the data starts in early 2001.

The question of MNDR stationarity evolves over time as more data become available even when the same interest rate and growth rate are used. The analysis presented here updates the work in Baumann and Schap (2015) by adding roughly three and-a-half years of monthly MNDR data while also testing for two additional interest rate terms of MNDRs. Our conclusions are largely similar to the earlier analysis. First, we find stronger stationarity evidence for subsets of the data compared to the entire sample frame. Using a diagnostic technique to identify potentially stationary subsets, we find that MNDRs for overall medical care costs and medical care services have strong stationary properties if they begin in middle or late 2000 depending on the series. For MNDRs using medical care commodities, there are strong stationary properties for data sets beginning in late 2008. Second, our tests of total offset (testing whether the difference between the discount rate and the medical cost growth rate is statistically different from zero) vary depending on the sample frame. Specifically, nearly all MNDRs starting in 1981 that we test appear to support total offset. By comparison, almost none of the stationary subsets that we identify within the larger sample frame suggest total offset between interest rates and the growth in medical costs. We conclude that stationary and total offset testing are evolving processes that must be revisited as more data become available.

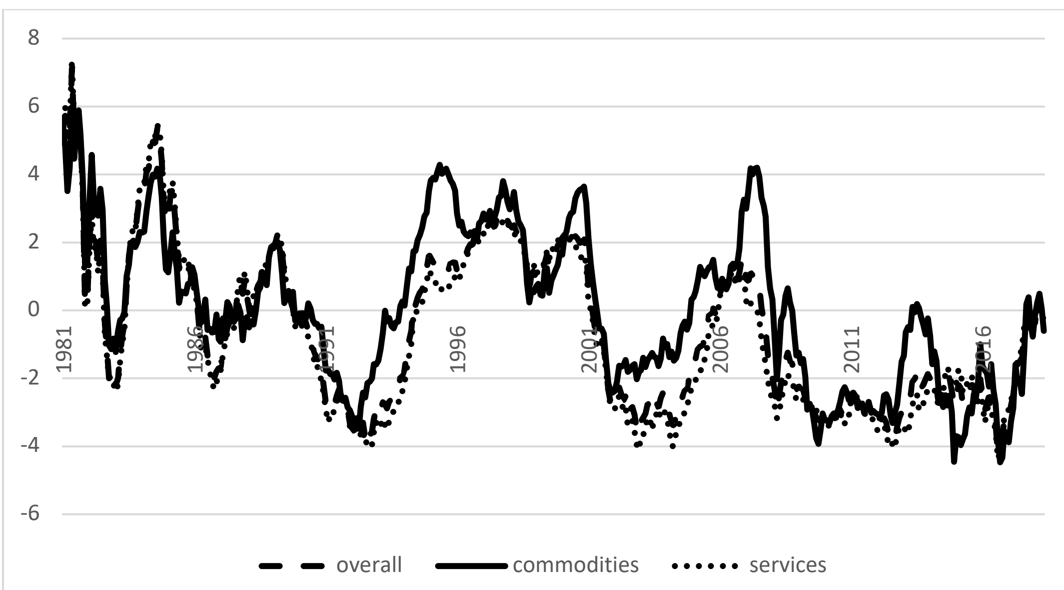
Medical Net Discount Rate Data

The MNDR combines data on an interest rate r and a medical cost growth rate g using the formula $(r - g)/(1 + g)$. All interest rate data are for constant maturity Treasury securities and only differ by term: 3-month, 6-month, 1-year, 3-year, and 10-year. These are available online at the Federal Reserve Economic Data (FRED) series hosted by the Federal Reserve Bank of St. Louis. The 3-month and 6-month rates are converted to effective yields as suggested in Fjeldsted (2000) before they are used in the MNDR formula. We use consumer price index (CPI) data (all urban consumers, U.S. city average, not seasonally adjusted) for overall medical care, medical care commodities, and medical care services, all of which are available from the Bureau of Labor Statistics website. The 12-month growth rate in these prices creates g.

In recognition of the shift in monetary policy during the Paul Volcker regime, we use data beginning in January 1980. Since we use 12-month growth rates for medical prices, this means the sample frame of MNDRs begins one year later in January 1981. The sample frame ends in May 2018. By comparison, Baumann and Schap (2015) use the same starting point, but with data series ending in November 2014 and based on discounting instruments of short duration only, namely 3-month, 6-month and 1-year.

Figure 1 illustrates MNDRs for overall medical care, medical care services, and medical care commodities. Each uses the 6-month interest rate. The most striking feature is the similarity between the three MNDRs, suggesting that these three types of medical care costs are highly correlated. In addition, MNDRs are predominantly negative since 2008, which is evidence that interest rates have been below medical price growth since the start of the Great Recession. MNDRs after November 2014, which is the last data point in Baumann and Schap (2015), remain negative in all three series but return to near zero by the end of this sample frame.

Figure 1: Plot of Selected Medical Net Discount Rates



Full Series Tests

We turn to stationary testing of each MNDR. We follow Baumann and Schap (2015) and use three standard stationary tests: augmented Dickey and Fuller (1979 and 1981; henceforth ADF), Phillips and Perron (1988; PP), and Kwiatowski, Phillips, Schmidt, and Shin (1992;

KPSS). In each, we test for a stationary series around a constant rather than a trend line. In addition, the lag structure is critical to the test statistic as the length of autocorrelation can vary across MNDRs. We use a method from Ng and Perron (1995), which begins with an ADF estimation using the maximum number of lags defined by a widely-used formula in Schwert (1989). The method sequentially shortens the lag structure until the final lag has a statistically significant fit. For brevity we omit these results here, but they are available upon request. Details for each technique can be found at Appendix A of Baumann and Schap (2015).

Table 1 provides the test statistic, *p*-value, and lag length for each ADF test. In these tests, the null hypothesis is that the data are formed with a unit root, i.e. a non-stationary series. All but four tests reject the null hypothesis at five percent or lower, suggesting that most MNDRs are stationary given data from January 1981 to May 2018.

Table 1: Stationary Test; Augmented Dickey-Fuller Technique

	Overall Medical Care	Medical Commodities	Medical Services
3-month rate	-3.369 ($p = 0.012$) lags = 15	-3.704 ($p = 0.004$) lags = 13	-3.360 ($p = 0.012$) lags = 15
6-month rate	-3.736 ($p = 0.004$) lags = 13	-3.534 ($p = 0.007$) lags = 13	-3.268 ($p = 0.016$) lags = 15
1-year rate	-3.510 ($p = 0.008$) lags = 13	-3.271 ($p = 0.016$) lags = 13	-3.139 ($p = 0.024$) lags = 17
3-year rate	-2.848 ($p = 0.052$) lags = 17	-2.839 ($p = 0.053$) lags = 13	-2.855 ($p = 0.051$) lags = 17
10-year rate	-2.866 ($p = 0.049$) lags = 17	-2.476 ($p = 0.121$) lags = 14	-2.893 ($p = 0.046$) lags = 17

Table 2 presents the test statistic and fit of a PP test for a stationary series. This test is similar in structure to ADF, but differs in its handling of autocorrelation. In ADF, autocorrelation is modeled with additional independent variables. In PP, a Newey-West adjustment is made to the standard errors to correct autocorrelation. The results are largely similar to ADF testing. Of the 15 MNDRs tested, only three tests suggest the MNDR is non-stationary using a five percent threshold.

Table 2: Stationary Testing; Phillips-Perron Technique

	Overall Medical Care	Medical Commodities	Medical Services
3-month rate	-3.584 ($p = 0.006$) lags = 15	-3.579 ($p = 0.006$) lags = 13	-3.559 ($p = 0.007$) lags = 15
6-month rate	-3.252 ($p = 0.017$) lags = 13	-3.305 ($p = 0.015$) lags = 13	-3.274 ($p = 0.016$) lags = 15
1-year rate	-2.945 ($p = 0.040$) lags = 13	-3.023 ($p = 0.033$) lags = 13	-2.992 ($p = 0.036$) lags = 17
3-year rate	-2.735 ($p = 0.068$) lags = 17	-2.790 ($p = 0.060$) lags = 13	-2.773 ($p = 0.062$) lags = 17
10-year rate	-2.961 ($p = 0.039$) lags = 17	-3.023 ($p = 0.033$) lags = 14	-3.003 ($p = 0.035$) lags = 17

The final stationary test is KPSS, which is presented in Table 3. This test differs from ADF and PP in multiple ways. Most critically for interpretation, the roles of the null and alternative hypotheses are switched. In KPSS, the null hypothesis is a stationary time series. In addition, *Stata*, the statistical software package used in this analysis, only provides ranges for the *p*-values at the statistical significance levels of one, two-and-a-half, five, and ten percent.

Unlike the ADF and PP results, KPSS firmly rejects the null hypothesis of a stationary in all 15 MNDRs. We conclude that the stationarity evidence of MNDRs from January 1981 to May 2018 is mixed. This is similar to the conclusions of Baumann and Schap (2015), which also found support for MNDR stationarity with ADF and PP testing but not KPSS.

Table 3: Stationary Testing; Kwiatowski-Phillips-Schmidt-Shin Technique

	Overall Medical Care	Medical Commodities	Medical Services
3-month rate	0.988 ($p < 0.01$) lags = 15	0.966 ($p < 0.01$) lags = 13	0.999 ($p < 0.01$) lags = 15
6-month rate	1.15 ($p < 0.01$) lags = 13	1.01 ($p < 0.01$) lags = 13	1.04 ($p < 0.01$) lags = 15
1-year rate	1.23 ($p < 0.01$) lags = 13	1.10 ($p < 0.01$) lags = 13	1.02 ($p < 0.01$) lags = 17
3-year rate	1.21 ($p < 0.01$) lags = 17	1.36 ($p < 0.01$) lags = 13	1.20 ($p < 0.01$) lags = 17
10-year rate	1.12 ($p < 0.01$) lags = 17	1.12 ($p < 0.01$) lags = 14	1.11 ($p < 0.01$) lags = 17

Even though there is limited evidence of MNDR stationarity, we proceed to a test of total offset. Rather than use a *t*-test of the sample mean, we use an estimation technique from Prais and Winsten (1954) that uses feasible generalized least squares to correct the standard errors for first-order autocorrelation. Table 4 presents these results. With one exception, the tests suggest that total offset is appropriate for MNDRs between January 1981 and May 2018. In addition, each MNDR rises as the interest rate term lengthens, suggesting that the yield curve of Treasury securities is upward sloping during the sample frame.

Table 4: Total Offset Test; Prais and Winsten Technique

	Overall Medical Care	Medical Commodities	Medical Services
3-month rate	-0.1775 ($p = 0.815$)	0.2545 ($p = 0.719$)	-0.2956 ($p = 0.714$)
6-month rate	-0.0119 ($p = 0.989$)	0.3899 ($p = 0.617$)	-0.1249 ($p = 0.891$)
1-year rate	0.0763 ($p = 0.937$)	0.4762 ($p = 0.572$)	-0.0368 ($p = 0.971$)
3-year rate	0.4757 ($p = 0.631$)	0.9022 ($p = 0.277$)	0.3577 ($p = 0.734$)
10-year rate	1.0931 ($p = 0.147$)	1.6053 ($p = 0.010$)	0.9615 ($p = 0.238$)

Subseries Tests

Our next task uses a diagnostic technique based on Zivot and Andrews (1992; ZA) break point testing to find a stationary series within the sample frame. ZA estimates an ADF model with a dummy variable (i.e., the break) at each time period except for those near the beginning or end of the data set where identification of a potential break is difficult. The ADF test with the strongest evidence for stationarity identifies a potential break point for the entire series. Rather than incorporating a ZA identified break point into the entire sample frame of a MNDR, we use this break point as the beginning of a new sample and test whether this subseries of the data is stationary. If the subseries is not stationary, then this step is repeated until a stationary series is located or the end of the sample frame is reached. A full series with breakpoint would not be used for forecasting purposes; only the sub-series post-breakpoint would be useful in forecasting.

For most MNDR series, this diagnostic technique requires two iterations to identify a stationary subseries of the data. Tables 5, 6, and 7 summarize the stationary testing for a subseries discovered by the ZA diagnostic technique for overall medical care, medical care commodities, and medical care services, respectively. We once again use the Ng and Perron (1995) technique to find the optimal lag length for each MNDR.

Table 5: Sub-Series Stationary Testing; Overall Medical Care

	Start Date	ADF	PP	KPSS
3-month rate	Dec. 2000	-3.820 (p = 0.003) lags = 13	-3.316 (p = 0.014) lags = 13	0.203 (p > 0.1) lags = 13
6-month rate	Dec. 2000	-3.656 (p = 0.005) lags = 13	-3.192 (p = 0.021) lags = 13	0.209 (p > 0.1) lags = 13
1-year rate	Dec. 2000	-3.469 (p = 0.009) lags = 13	-3.069 (p = 0.029) lags = 13	0.229 (p > 0.1) lags = 13

3-year rate	June 2000	-3.058 (p = 0.030) lags = 13	-2.984 (p = 0.036) lags = 13	0.431 ($0.05 < p < 0.1$) lags = 13
10-year rate	June 2000	-3.617 (p = 0.054) lags = 12	-3.698 (p = 0.041) lags = 12	0.533 ($0.25 < p < 0.05$) lags = 12
Hypothesis Test		H0: unit root	H0: unit root	H0: stationary

Table 6: Sub-Series Stationary Testing; Medical Care Commodities

	Start Date	ADF	PP	KPSS
3-month rate	Sept. 2008	-4.376 ($p < 0.001$) lags = 12	-3.092 (p = 0.027) lags = 12	0.100 ($p > 0.1$) lags = 12
6-month rate	Sept. 2008	-4.232 (p = 0.001) lags = 12	-3.073 (p = 0.029) lags = 12	0.100 ($p > 0.1$) lags = 12
1-year rate	Sept. 2008	-4.196 (p = 0.001) lags = 12	-3.087 (p = 0.028) lags = 12	0.102 ($p > 0.1$) lags = 12
3-year rate	Sept. 2008	-3.941 (p = 0.002) lags = 12	-3.156 (p = 0.023) lags = 12	0.076 ($p > 0.1$) lags = 12
10-year rate	Nov. 2008	-3.424 (p = 0.010) lags = 12	-3.137 (p = 0.024) lags = 12	0.139 ($p > 0.1$) lags = 12
Hypothesis Test		H0: unit root	H0: unit root	H0: stationary

Table 7: Sub-Series Stationary Testing; Medical Care Services

	Start Date	ADF	PP	KPSS
3-month rate	Dec. 2000	-4.103 (p = 0.001) lags = 13	-3.290 (p = 0.015) lags = 13	0.124 ($p > 0.1$) lags = 13
6-month rate	Dec. 2000	-3.875 (p = 0.002) lags = 13	-3.170 (p = 0.022) lags = 13	0.131 ($p > 0.1$) lags = 13
1-year rate	Dec. 2000	-3.670 (p = 0.005) lags = 13	-3.046 (p = 0.031) lags = 13	0.143 ($p > 0.1$) lags = 13
3-year rate	June 2000	-3.851 (p = 0.002) lags = 13	-3.454 (p = 0.009) lags = 13	0.276 ($p > 0.1$) lags = 13

10-year rate	June 2000	-3.913 ($p = 0.002$) lags = 12	-3.877 ($p = 0.002$) lags = 12	0.233 ($p > 0.1$) lags = 12
Hypothesis Test		H0: unit root	H0: unit root	H0: stationary

Of the 15 MNDRs presented at Tables 5, 6, and 7, the ZA diagnostic technique identifies a stationary subseries in all but one MNDR (10-year overall medical) using a significance level of five percent. For this MNDR, further iterations of this diagnostic fail to identify a subseries that passes the three stationary tests. Of the remaining MNDRs, the overall medical care and medical care services MNDRs are stationary if the sample frame begins in December 2000 (for 3-month, 6-month, and 1-year interest rate terms) or June 2000 (for 3-year and 10-year interest rate terms). For MNDRs based on medical care commodities, the stationary subset begins in late 2008. This illustrates that subseries can be stationary even when the entire sample frame proves to be non-stationary.

These results are also largely similar to Baumann and Schap (2015), which uses the same diagnostic on the 3-month, 6-month, and 1-year overall medical care MNDRs but a sample frame that ends roughly three-and-a-half years sooner in November 2014. In that research, a stationary subseries is found when the sample frame begins in January 2001, or one month later than the above results. We conclude there remains considerable evidence of stationarity for overall medical care MNDRs that begin in late 2000 or early 2001.

Given these stationary subseries, we now test for total offset. We again employ the Prais and Winsten method to account for first-order autocorrelation in the data, and Table 8 presents these estimations. We eschew from these tests the two MNDRs that did not pass all three stationary tests at Table 5.

Table 8: Total Offset Test; Prais and Winsten Technique

	Overall Medical Care	Medical Commodities	Medical Services
3-month rate	-1.383 (*p* = 0.029) start: Dec. 2000	-1.985 (*p* < 0.001) start: Sept. 2008	-1.604 (*p* = 0.015) start: Dec. 2000
6-month rate	-1.237 (*p* = 0.069) start: Dec. 2000	-1.858 (*p* = 0.001) start: Sept. 2008	-1.461 (*p* = 0.038) start: Dec. 2000
1-year rate	-1.181 (*p* = 0.082) start: Dec. 2000	-1.728 (*p* = 0.001) start: Sept. 2008	-1.413 (*p* = 0.043) start: Dec. 2000
3-year rate	-0.778 (*p* = 0.121) start: June 2000	-1.237 (*p* = 0.009) start: Sept. 2008	-1.026 (*p* = 0.038) start: June 2000
10-year rate	did not pass all three stationarity tests	0.0522 (*p* = 0.912) start: Nov. 2008	-0.189 (*p* = 0.504) start: June 2000

In general, we find little support for total offset for these subsets of the data. Of the 14 MNDRs that are tested, only four do not reject the null hypothesis of total offset. By comparison, the total offset tests of the entire sample frame presented at Table 4 did not reject total offset in 14 out of the 15 MNDRs. Similar to stationary testing, it is clear that whether a MNDR has total offset can fluctuate with the sample frame. Given a non-inverted yield curve, the medical commodities series exhibiting a negative MNDR based on the 3-year rate and positive MNDR based on the 10-year rate suggests that a series based on either the 5-year or 7-year rate could pass total offset testing (not conducted here).

References

Baumann, R. and D. Schap, 2015. "Medical Net Discount Rates: Updated and Re-examined," *Journal of Forensic Economics*, 26(1): 1-16.

Dickey, D. A., and W. A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series With a Unit Root." *Journal of the American Statistical Association*, 74:427-431.

Dickey, D. A., and W. A. Fuller. 1981. "Likelihood Ratio Statistics for Autoregressive Time Series With a Unit Root." *Econometrica*, 4(9): 1057-1072.

Fjeldsted, Boyd L. 2000. "A Nontrivial (Though Seemingly Not Uncommon) Error in Calculating the Discount Rate Used to Reduce Future Losses to Present Value." *Journal of Legal Economics*, 10(1): 73-80.

Kwiatowski, Denis, Peter C. B. Phillips, Peter Schmidt, and Yongcheoi Shin. 1992. "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root." *Journal of Econometrics*, 54:159-178.

Ng, S., and P. Perron. 1995. "Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of the Truncation Lag." *Journal of the American Statistical Association*, 90: 268-191.

Phillips, P. C. B., and P. Perron. 1988. "Testing for Unit Root in Time Series Regression." *Biometrika*, 75:335-346.

Prais, S. J., and C. B. Winsten. 1954. "Trend Estimators and Serial Correlation." Working Paper 383, Cowles Commission. Available http://cowles.econ.yale.edu/P/ccdp/st/s-0383.pdf.

Schwert, G. W. 1989. "Tests for Unit Roots: A Monte Carlo Investigation." *Journal of Business and Economic Statistics*, 2:147-159.

Zivot, E., and D. W. K. Andrews. 1992. "Further Evidence on the Great Crash, the Oil-

Price Shock, and the Unit-Root Hypothesis." *Journal of Business and Economic Statistics*, 10:251-270.