

Final Draft

Forecasts of River Traffic on the
Inland Waterway System
(Phase 1, Task 3)

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1. Final Draft of “Forecasts of River Traffic on the Inland Waterway System” by Wesley W. Wilson and Mark A. Thoma.

**Forecasts of River Traffic on the
Inland Waterway System**

by

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ABSTRACT

Forecasts of River Traffic on the Inland Waterway System

**by
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Wesley W. Wilson**

This paper uses time-series techniques to forecast total tons moved annually on the inland waterway and on segments of the Mississippi river using data from 1953-2001. The paper first examines the time-series properties of individual variables and finds the variables used here, measures of industrial production, lock capacity, and a measure of tons moved, are first order integrated processes. The paper next establishes that the variables are co-integrated, and an error-correction model is estimated and used to provide out-of-sample forecasts at short time-horizons. Forecasts at longer horizons are obtained in two ways, from the estimated error-correction model and from the estimated co-integrating relationship. In the first case forecasts of future variables needed to produce forecasts of river traffic are generated endogenously within the model. This produces forecasts of average annual growth rates for tons moved as 1.68% for the system as a whole, and 1.45%, 3.33%, and 2.97% for the upper, mid, and lower Mississippi river segments. In the second case, forecasts of future variables needed to forecast tons moved are derived from other sources such as the CBO forecast of potential GDP or from assuming a variety of lock capacity growth rates. An interesting finding is that up until 1990 industrial production, measured lock capacity, and tons moved varied quite closely. However, after 1990 the growth rate in industrial production has surpassed the growth rate in both tons moved and lock growth indicating that capacity constraints may have limited the growth in tons moved. The results indicate that a growth rate of 2% in system capacity in the future is needed to allow total tons moved to grow at approximately the same rate as industrial production and GDP, and a growth rate higher than 2% is needed to return measured capacity, tons moved, and industrial production to the relationship that existed prior to 1990.

1. Introduction

Forecasts of river traffic over long time horizons play a key role in determining the potential benefits of projects to increase the volume of traffic over time. Thus, these forecasts are essential components of the Army planning models. Most previous attempts to forecast river traffic rely upon structural modeling in one guise or another. These models often forecast future supply and demand for river transportation from forecasts of the supply and demand for products that use river transportation such as grains and industrial products.¹ Forecasting the supply and demand for these products requires forecasts for each of the determinants of supply and demand for each of the products that are transported on the river. This is a large and complicated task that often requires questionable simplifying assumptions, a task that is further complicated by lack of available data on each of the many influences on the supply and demand for each of the products transported on the river. This study proposes an alternative approach that avoids structural modeling of complicated real-world behavioral relationships, an approach common in the time-series econometrics literature.

Economists commonly use time-series techniques to forecast variables of interest, particularly when the forecast horizon extends far into the future. Such techniques often rely upon vector autoregression (VAR) models. These models can be interpreted as very general reduced form structural models.² The genesis of VAR

¹ Two examples are "Evaluation of the U.S. Army Corps of Engineers Forecasts of U.S. Grain Exports," May, 2000, by C. Phillip Baumel and "Upper Mississippi River and Illinois Waterway Navigation Study," May 1, 2002, by Sparks Companies Inc.

² Structural models embody behavioral relationships, identities, and equilibrium conditions containing both endogenous and exogenous variables. For example, supply and demand equations are behavioral equations, and the equilibrium condition is that quantity demanded equal quantity supplied. Both equations generally contain both endogenous variables, price and quantity, as well as exogenous variables such as income, the price of substitutes, and the price of inputs. Reduced form equations express the endogenous

models³ arises from the idea that the identification restrictions present in most structural econometric models are arbitrary and not supported by underlying theoretical models. If the identification restrictions used to estimate structural econometric models are suspect, then it is not surprising that these models do not produce reliable multi-step ahead forecasts. An alternative is to rely on a different identification scheme and forego the troublesome identification restrictions present in structural econometric models.

This led researchers to consider VAR models as an alternative to structural modeling of behavioral relationships. Under the VAR approach, a very general reduced form is posited which allows each endogenous variable to depend upon every other endogenous variable in the model as well as any exogenous variables.⁴ Estimation of VAR models allows the data to impose restrictions as required to achieve the best fit. Dynamic forecasts of the endogenous variables can then be derived from the estimated VAR models.

For short horizons, those of approximately six months or less, VAR models are able to produce reliable forecasts and have proved very useful within this limitation. The second stage of this research project exploits this feature of these models. However, for longer forecasts, those beyond six months, VAR models often do not fare much better than traditional structural models. Fortunately, a potential solution to the long-run forecasting problem arrived with the discovery of co-integration and its connection to

variables solely in terms of the exogenous and predetermined variables. Thus, for supply and demand, price and quantity are each expressed solely as a function of the exogenous and predetermined variables.

³ A seminal article in this area is "Macroeconomics and Reality" by Christopher A. Sims which appeared in *Econometrica*, vol. 48, No.1 (Jan., 1980), 1-48.

⁴ Thus, there are no exclusion restrictions as would exist under the structural approach.

error-correction models.⁵ Many economic time-series contain trends as they move systematically upward or downward through time through random or deterministic trend processes. GDP is an example of a variable that trends upward over time. In some cases, the variables both trend upward or downward and, furthermore, they follow or share the same trend. When trending variables or, more precisely, integrated variables⁶ move together in the long-run then the variables are said to be co-integrated. For example, consumption and disposal income are generally believed to be co-integrated variables.

Co-integrating relationships can involve any number of integrated variables. By exploiting the co-integrating relationships among the variables, it is possible to produce better multi-step ahead forecasts than with VAR or structural models.⁷ One reason for the improvement in forecasting is that if two variables are co-integrated, then so are forecasts of those variables. The co-integrating relationship ties the two variables together over time which in turn ties the forecasts together. The research proposed here uses time-series techniques to identify co-integrating relationships useful in forecasting long-run river traffic.

This study uses this relationship between forecasts in co-integrated systems to produce short-run and long-run out-of-sample forecasts for total river traffic on the inland waterway system and for the upper, mid, and lower Mississippi river segments. Long-run forecasts are based upon the co-integrating relationship among the variables and are derived in two different ways. The first uses the estimated error correction model to

⁵ Nobel Prize winners in economics, C.W.I. Granger and Robert F. Engle, discuss co-integration and error correction models in "Co-integration and Error Correction: Representation, Estimation, and Testing" which is in *Econometrica*, vol. 55, No.2 (March, 1987), 251-276.

⁶ See "Developments in the Study of Co-integrated Economic Variables" by C.W.J. Granger in *Oxford Bulletin of Economics and Statistics*, 48, vol. 3, (1986) 213-228 for a discussion of integrated variables.

⁷ See Engle, Robert F. and Yoo, B.S., "Forecasting and Testing in Co-Integrated Systems," *Journal of Econometrics*, vol. 35 (May 1981), 143-160.

dynamically generate out-of-sample forecasts for all variables in the model. The second uses forecasts of variables that are involved in the estimated co-integrating relationship to generate forecasts for tons moved.⁸ Two methods are used to generate forecasts of measured lock capacity. The first assumes that measured lock capacity grows according to its historical relationship to potential GDP and uses forecasts of potential GDP from the Congressional Budget Office to generate forecasts of measured lock capacity. The second method assumes that measured lock capacity will grow at various rates from .5% to 4%, rates consistent with either historical rates of growth or projected rates of growth in demand from other sources.

More particularly, the study proceeds as follows. The first condition for a variable to be co-integrated is that it be integrated, or trend deterministically or stochastically over time. Using standard augmented Dickey-Fuller unit root tests, the time-series describing total tons moved, measured lock capacity, industrial production, and the gap between potential and actual industrial production⁹ are examined and all but the IP gap are shown to contain unit roots. An examination of the co-integrating relationships between the variables reveals that up until 1990, total tons moved, industrial production, and measured lock capacity all move closely together and tests indicate that the three variables are co-integrated.¹⁰ This means that there is a long-run relationship

⁸ For example, suppose that the co-integrating relationship is $Y_t = \hat{a} + \hat{b}X_t + \hat{c}W_t$. Then forecasts of Y_t can be obtained from forecasts of X_t and W_t .

⁹ This is a standard measure of overall demand conditions in the economy and is included so that demand conditions can impact short-run movements in tons moved.

¹⁰ The techniques described in Johansen, S. "Statistical analysis of co-integration vectors", *Journal of Economic Dynamics and Control*, Vol. 12, (1988), 231-254, are used to determine the existence and number of co-integrating relationships. When there are K variables, there can be as many as K-1 independent co-integrating relationships, and Johansen tests can be used to determine how many co-integrating relationships exist among a particular set of variables, and what the relationship is for each co-

between these variables tying them together over time. However, after 1990 industrial production begins to drift upward more quickly than measured lock capacity and tons moved indicating a break in the co-integrating relationship. Potential reasons for this break are examined and binding capacity constraints cannot be rejected as an explanation for this break in the relationship.¹¹ Indeed, as stated in the UMR-IWW System Navigation Study “Waterway Traffic Forecasts for the Upper Mississippi River Basin” (1997):

“The 1988 Inland Waterway Review identified five locks on the Mississippi River (locks 20, 21, 22, 24 and 25) and three of the eight locks on the Illinois Waterway (La Grange, Peoria, and Marseilles locks) as being among the 17 locks in the country with the highest average delays, total delays, highest total barge transit processing and lockage times, and highest rate of lock utilization. In 1992, tows at Locks 20-25 were delayed a total of 87,000 hours at a cost of \$35 million while waiting to be locked through. Lock 22 was the most congested lock in the study area. The average delay for the 3,306 tows that used the lock in 1992 was seven hours. Assuming a cost of \$400 per hour (industry figures), this delay cost \$2,800 per tow processed at Lock 22. In addition, 80 percent of these tows had to double lock; a process that added an additional hour to each lockage. During the period 1988-1992, river traffic grew an average of 4 percent per year. If this rate continues, delays at Lock 22 will increase to about 56 hours per tow by the year 2000. All other locks on the waterways will also experience increased delays as a result of this traffic growth.”

Having determined a stable co-integrating relationship between tons moved and measured lock capacity, the next step is to use this relationship to forecast tons moved at long time horizons. As noted above, two exercises are performed. The first exercise uses the estimated error correction model to dynamically generate out-of-sample forecasts for all variables in the model. This produces average annual forecasted growth rates for tons

integrating relationship. In addition, hypothesis tests can be conducted concerning the co-integrating relationships.

¹¹ A potential explanation for the departure of output growth from growth in tons moved is the movement towards a more service based economy. However, this is unlikely given that the measure used here is IP rather than GDP and the IP index does not reflect such compositional changes.

moved of 1.68% for the system as a whole, and 1.45%, 3.33%, and 2.97% for the upper, mid, and lower Mississippi river segments. Thus, growth on the lower and mid Mississippi river segments is projected to be about twice as large as for the upper Mississippi and for the system as a whole.

The second exercise uses forecasts of measured lock capacity derived in two ways, one from forecasts of potential GDP and one from assumed lock capacity growth rates from .5% to 4%, rates consistent with either historical rates of growth or projected rates of growth in demand from other sources. Obtaining forecasts of measured lock capacity from forecasts of potential GDP is useful because the CBO's forecast of potential GDP has a known forecasting record, is easily obtained, and because it captures forecasted future demand conditions. The second method is useful because it is a supply based assumption that assumes measured lock capacity grows at various rates. Combining these exercises leads to the conclusion that a growth rate of approximately 2% in measured lock capacity is needed to meet projected demand growth as indicated by the growth in potential GDP and potential industrial production, and a higher growth rate is needed to overcome capacity constraints.

2. Unit Root and Co-Integration Tests

The first step is to test for unit roots in the variables used here, total tons moved on the inland waterway system¹², total tons moved on the upper, mid, and lower Mississippi river system, lock capacity as measured by lock length and lock area for the

¹² The total is for all segments. The segments are the Upper Mississippi, Middle Mississippi, Missouri, Lower Mississippi, Arkansas, Illinois, Ohio, Monongahela, Kanawha, Cumberland, Tennessee, GIWW, BWT, AIWW, and Columbia.

system overall and for the Mississippi segments,¹³ industrial production, potential industrial production as derived from potential GDP, and the industrial production gap.

The data are annual and cover the years 1953 through 2001.

The long-run trend properties of total tons moved, upper, mid, and lower Mississippi total tons moved, total system lock length, and total lock length for the Mississippi and rivers feeding into are examined in Table 1. Using an augmented Dickey-Fuller test, the results with four autoregressive lags allowed in the testing equation (i.e. assuming the model in levels contains five lags) indicate the presence of a unit root, i.e. the null of a unit root is not rejected, in all variables listed in the table.¹⁴ Thus, these variables all trend upward stochastically over time and are thus potentially co-integrated.

The unit root properties of industrial production and deviations of industrial production from potential, i.e. the gap, are well known and the tests are not repeated here. It is generally agreed that industrial production and potential production have unit roots, while the gap does not.¹⁵

The next step is to examine potential co-integrating relationships among the total and Mississippi river system variables. Co-integrating relationships between total tons moved, measured lock capacity, and industrial production are examined first. It is helpful to begin with Figure 1 which graphs these three variables over time. Two features of

¹³ Lock length is total lock length for the inland waterway system and for the Mississippi and its feeders. The data are available at <http://www.iwr.usace.army.mil/ndc/lockchar/pdf/lkgenrl.pdf>. The lock length and lock area variables move together very closely and the choice is arbitrary. All results below are completely robust to interchanging the two variables as a measure of lock capacity.

¹⁴ The regressions start in 1958 since five observations are lost in the testing process, one when the data are differenced and the other four when four lags are allowed in the model specified in differences. The results are generally robust if the number of included lags varies from 0 to 8 lags so that the four lag assumption is not important for the results.

¹⁵ Construction of potential industrial production from potential GDP and the industrial production gap is discussed below.

Figure 1 are particularly noteworthy. First, up until around 1980, the three series track each other very closely. Starting around 1980, industrial production begins to drift upward a bit and in 1990 begins an even more rapid increase over and above the rate of growth of the other two series, measured lock capacity and total tons moved. Thus, it appears likely that any co-integrating relationship between industrial production, total tons moved, and lock capacity breaks down after 1990. Co-integration tests confirm this.

Table 2 presents the outcome of a test for a co-integration relationship between industrial production and total tons moved for both total river traffic and traffic on the three segments of the Mississippi. The test is performed by first regressing total tons moved on a constant and either industrial production (IP) or measured lock capacity though 1990 and 2001 separately, then conducting a unit root tests on the residuals from these regressions.¹⁶ Measured lock capacity is for the system as a whole is used when total tons is examined in the first column of the table, and for the Mississippi river system when the total tons moved on the three Mississippi river segments are examined in the remaining columns.

The results shown in Figure 1 are evident in the first column of the results in Table 2. Prior to 1990, there is a co-integrating relationship between both tons moved and IP, and between tons moved and measured lock capacity. When the full sample is examined, the co-integration relationship between IP and total tons breaks down, but the relationship between total tons and measured lock capacity does not. This is important because it indicates that capacity constraints may have played a role in the departure of IP

¹⁶ Since there are only two variables in the model, this simplified procedure is used to test for co-integration. The gap is not included because it is stationary. When more than two variables are present, Johansen or similar tests are necessary. Unlike the variables in levels, where four lags are used in the augmented unit root tests and a constant and trend are included in the tests, only two lags are needed to augment the unit root tests for the residuals and no constant or trend is included.

from the other two variables around 1990. That is, for IP, the failure to reject for the full sample indicates that when the sample is extended from 1990 to 2001, co-integration is no longer present. However, the co-integrating relationship between measured lock capacity and total tons remains. This is expected if capacity growth is limiting the growth in tons moved to a level below the growth in industrial production around 1990, though other explanations are possible.

The results for the Mississippi river segments are also shown in Table 2. The results for the upper Mississippi are qualitatively identical, but the results are weaker for the mid and lower Mississippi. However, close inspection shows that there is only one co-integrating relationship, the relationship between measured lock capacity and total tons for the full sample, that appears in every case. That is, a comparison of rows three and four in the table, which show the results for the full sample, shows the breakdown in the co-integration relationship between IP and tons moved as compared to the relationship between measured lock capacity and tons moved. Thus, these results support the result that a more stable co-integrating relationship exists between measured lock capacity and total tons moved than between industrial production and total tons moved.

3. Forecasts

In this section, an error-correction model is estimated and used to produce out-of-sample forecasts of total tons moved on the inland waterway system and on the Mississippi river system. Formally, a four lag, three variable error-correction model is estimated and used to produce out-of sample forecasts at various short-run and long-run

time horizons. Forecasts for long-run horizons are also obtained from the co-integrating relationship directly.¹⁷

The variables used are total tons moved, measured lock capacity, and the industrial production gap. The lock capacity measurement captures supply-side considerations while the gap is included to capture demand side influences. Four versions of the model are estimated, one for total tons moved, and one for each of the three Mississippi river segments.

Short-Run Forecasts from the Error-Correction Model

Short-run forecasts using the error-correction model are obtained by first estimating the model through 1974:1, then producing out-of sample forecasts at various horizons, then re-estimating the model through 1975:1, obtaining out-of-sample forecasts, and so on until the end-of-the sample is reached. Estimation of the error-correction model for the total system variables, and using the model to produce 1, 2, 3, 4, and 5 year ahead out-of-sample forecasts yields the results in Figures 2-6.¹⁸

¹⁷ When the goal of econometric estimation is to test theoretical propositions and to discover the values of important theoretical quantities, it is important to have unbiased estimators. Thus, including too many variables, which in general only reduces power but does not bias estimates, is preferred to including too few variables in the model, which can bias estimates. Thus, the tendency is to include too many rather than too few variables when there is uncertainty as to the best empirical specification of a model. The situation is different when a model is used for forecasting. Here, the goal is to produce forecasts as close as possible to the actual values and, if large gains in efficiency can be obtained by accepting small bias in estimation, such tradeoffs are generally adopted. Including too many variables in a model, i.e. simply “throwing in the kitchen sink” can produce poor forecasts even if no biases are introduced in the process. This is because the extra variables will, to some extent, explain the in-sample variation in the dependent variable even if, in fact, the variables are unrelated simply due to statistical chance causing the two variables to co-vary. This means that out-of-sample forecasts will be inappropriately sensitive to these variables and the forecasts will deteriorate. When the goal is precise forecasts, it is desirable to produce as parsimonious a model as possible, in this case a three variable model, to avoid this pitfall. This is particularly true when the degrees of freedom in estimation are small.

¹⁸ The forecasts are out-of-sample so, for example, the one-step ahead forecast labeled 1998:1 is based upon the model estimated through 1997:1, while a five step ahead forecast labeled 1998:1 is based upon a model estimated through 1993:1. The actual values are plotted for comparison and since the purpose here

The fifteen graphs in Appendix A repeat this exercise for each of the three Mississippi river segments for each of the five forecasting horizons. The results are very similar to the total river movements. The bottom line is that forecasts of one or two years ahead, perhaps as many as three, are very good. However, beyond horizons the forecasts become increasingly noisy, though even at five years they appear to be fairly accurate during stable time periods. Forecasts at one and three years from Appendix A for the three river segments are shown in Figures 7-12.

Long-Run Forecasts from the Error-Correction Model

Long-run forecasts to fifty years ahead are obtained from the estimated error-correction model for total tons moved on the entire river system, and for tons moved on the three river segments. The results of this exercise are presented in Figures 13-16 and imply that the estimated annual growth rates from 2002 for total tons moved is 1.68%. For the individual river segments the estimated growth rates for total tons moved are 1.45% for the upper Mississippi, 3.33% for the mid Mississippi, and 2.97% for the lower Mississippi.¹⁹ Thus, growth rates for tons moved are projected to about twice as large for the lower and mid Mississippi as compared to the upper Mississippi and as compared to the system as a whole.

is to evaluate the ability of the model to predict out-of-sample, forecasts beyond the end of the sample are not presented here. Forecasts that extend beyond the end of sample are presented below.

¹⁹ Since the two series shown in each of the graphs use different scales, one on the right-hand side of the graph and one on the left. The gap between the two series, which for example is smaller in Figure 16 than in Figure 15, is an artifact of the scaling and does not have any interpretation.

Long-Run Forecasts from the Co-Integrating Relationship

Long-run forecasts can also be obtained directly from the estimated co-integrating relationship. For example, for total system traffic, the relationship for the full sample is

$$Total\ Tons_t = -6.77 + .014 * Gap_t + 1.11 * Lock\ Capacity_t$$

so that forecasts of total tons can be obtained from forecasts of the gap and of lock capacity. Long-run forecasts of the gap are easy to obtain since the long-run effect of a demand shock is zero. That is, in models of the type used here, demand shocks arising from the stationary gap measure have short-run, but not long-run effects on real variables such as total tons moved or industrial production. Thus, the long-run forecast of the gap is zero.²⁰ Long-run forecasts of lock capacity are obtained in two separate ways, one attempting to capture various supply scenarios, and one attempting to capture future demand characteristics.

For the supply based approach, forecasts of future lock capacity are obtained by assuming various lock capacity growth rates. In particular, growth rates of .5%, 1%, 2%, and 4% are examined. The .5% lower bound is chosen because it is consistent with recent growth in lock capacity. A growth rate of 1% allows lock capacity to grow with the growth rate of demand in exhibits 19 and 20 of the UMR-IWW System Navigation Study “Waterway Traffic Forecasts for the Upper Mississippi River Basin” (1997). A growth rate of 2% causes lock capacity and the forecast of total tons to grow at approximately the same rate as the CBO’s forecast of potential GDP. The upper bound of 4% is selected based upon the quote above from the UMR-IWW System Navigation

²⁰ This assumes that in the long-run, actual and potential industrial GDP are equivalent.

Study where it is noted that river traffic grew at a 4% rate from 1988-1992, and because sustained growth in either demand or capacity in excess of 4% seems unlikely.

For the approach that bases the growth in capacity on the growth in demand, the procedure is to estimate lock growth from potential industrial production growth. This is accomplished by regressing industrial production on the potential GDP series from the CBO

$$IP_t = \alpha + \alpha_1 Potential\ GDP_t + e_t$$

and then using the estimates to forecast potential IP through 2014, the last period for which CBO estimates of potential GDP exist.²¹ Next, the estimated value for potential IP is used to set the growth in lock capacity using the estimated relationship between the two series from the equation

$$Capacity_t = \beta_0 + \beta_1 Potential\ IP_t + v_t.$$

By plugging forecasts of potential IP through 2014 into this equation, forecasts of capacity can be obtained and used to derive estimated growth rates.

The results for total river system tons are in Figures 17-20. Each graph shows two forecasts, one based upon an assumed lock capacity growth rate from .5% to 4%, and one based upon the projected growth in potential IP as derived from the CBO potential GDP estimates. The series labeled CBO GDP Forecast can be interpreted as the value of total tons had they continued to grow at the rate IP and GDP grew after 1990. Thus, the jump in the series at 2002 shown in the figures is a measure of how much capacity constraints have reduced tons moved.

²¹ The industrial production gap, measured as the difference between potential and actual industrial production, is very similar to the deviation of the unemployment rate from the natural rate provided by the CBO.

The graphs show that a .5% growth rate is consistent with recent growth in lock capacity and results in lock capacity growing at a slower rate than potential GDP and IP growth projections. The 1% growth rate for capacity, which accords with the growth in demand projected in other studies such as the UMR-IWW System Navigation Study, results in a growth rate faster than in recent years, though not as fast as in the more distant past or as fast as the growth in potential IP. At a 2% rate of growth, the growth in lock capacity is close to the growth rate in capacity implied by the growth in IP and GDP. At this rate of growth, lock capacity would approximately match projected demand. Finally, at a 4% rate of growth, lock capacity growth catches the growth in IP around 2010. Thus, if lock capacity grows at 4% for approximately nine or ten years,²² and for around 2% thereafter, lock capacity would return to its pre 1990 relationship with industrial production, that is, the two series would track each other closely once again just as they did prior to 1990. Lastly, results of identical exercises for the three Mississippi river segments are in Appendix B and are consistent with the results for the total system.

4. Conclusions

This paper uses time-series techniques to forecast total tons moved annually on the inland waterway system and on segments of the Mississippi river system using data on industrial production, potential GDP, and lock capacity from 1953-2001. The paper first examines the time-series properties of individual variables and finds the variables are first order integrated processes, i.e. they have a unit root. The paper next establishes that total tons and lock capacity are co-integrated, and that industrial production is also co-integrated with total tons prior to 1990. This appears to be true for both system wide

²² When counting the number of years, recall that the sample ends in 2001.

variables and for variables limited to particular segments on the Mississippi river system, but the results are stronger for the total system and for the upper Mississippi than for the mid and lower Mississippi river system. After 1990, the co-integrating relationship between total tons and industrial production appears to break down. A possible explanation for this finding is that capacity constraints began to bind after 1990 limiting expansion of river traffic to a growth rate below that of industrial production.

The error-correction model and the co-integrating relationship are used to produce forecasts of total tons moved on the river system. Two types of forecasts are produced, forecasts based upon the error-correction model and forecasts based upon the estimated co-integrating relationship. Out-of-sample forecasts based upon the error-correction model are close to actual values at short-run horizons.

For longer horizons, forecasts based upon the error-correction model produce average annual forecasted growth rates for tons moved as 1.68% for the system as a whole, and 1.45%, 3.33%, and 2.97% for the upper, mid, and lower Mississippi river segments. Thus, growth on the lower and mid Mississippi river segments is projected to be about twice as large as for the upper Mississippi and for the system as a whole.

Using an alternative method based upon the estimated co-integrating relationship, forecasts are anchored in two ways, from the CBO forecast of potential GDP through 2014, and from various assumed lock capacity growth rates from .5% to 4%, rates consistent with historical patterns or other forecasts of river traffic. The results indicate that a growth rate of 2% in system capacity in the future will allow total tons moved to grow at approximately the same rate as industrial production and GDP. A growth rate faster than this will allow the relationship between total tons and lock capacity to return

to historical levels, while a slower growth rate of .5% to 1% is consistent with recent growth in lock capacity.

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Table 1

Augmented Dickey-Fuller Unit Root Tests

	Test Statistic
Total Tons Moved	-0.96
Upper Miss. Total Tons	-0.02
Mid Miss. Total Tons	-0.42
Lower Miss. Total Tons	-1.01
System Lock Length	-0.55
<u>Mississippi Lock Length</u>	<u>-0.51</u>
Critical values: 1% = -4.173 (***) , 5% = -3.511 (**), and 10% = -3.185 (*).	

Table 2

Augmented Dickey-Fuller Unit Root Tests

	Total	Upper	Mid	Lower
<i>1953-1990</i>				
Total Tons, IP	-2.16**	-2.27**	-1.47	-0.84
Total Tons, Capacity	-2.22**	-2.80***	-1.32	-1.14
<i>1953-2001</i>				
Total Tons, IP	-1.32	-0.96	-1.70*	-1.54
<u>Total Tons, Capacity</u>	<u>-2.49**</u>	<u>-2.77***</u>	<u>-1.79*</u>	<u>-1.73*</u>
Critical values: 1% = -2.626 (***) , 5% = -1.950 (**), and 10% = -1.620 (*).				

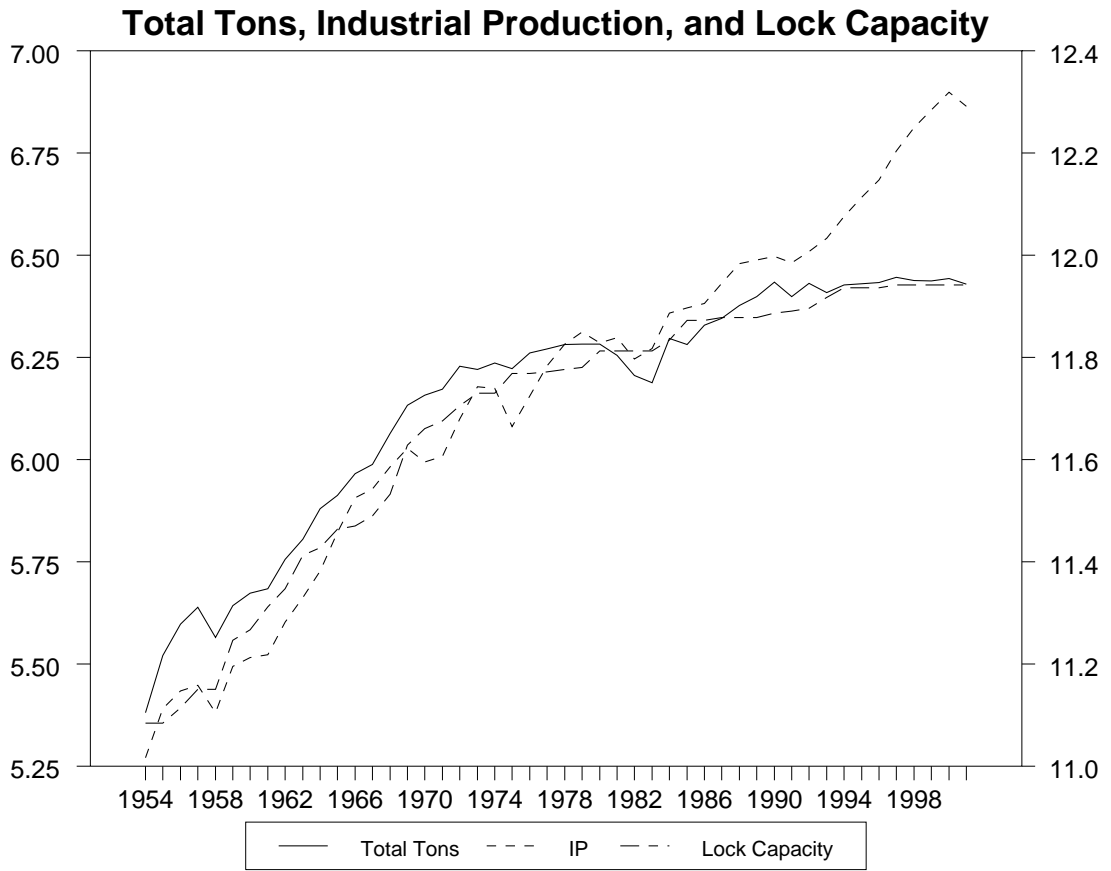


Figure 1

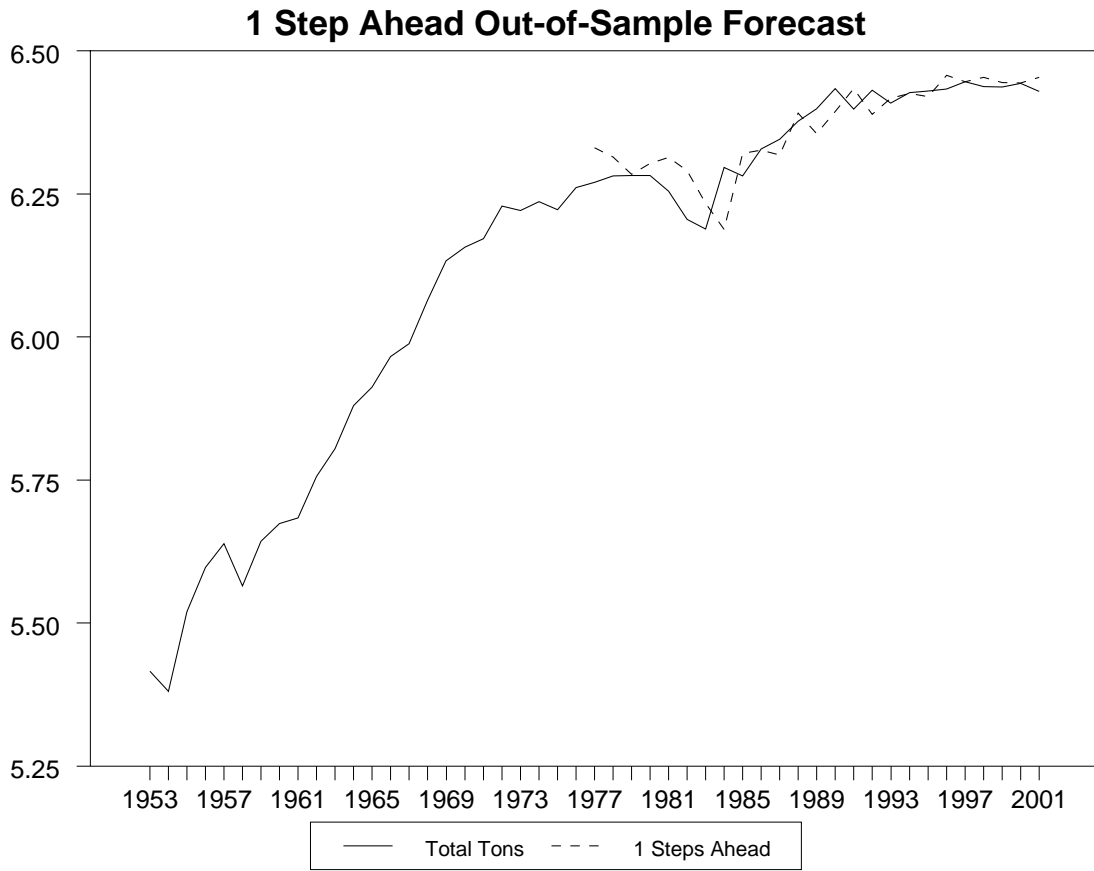


Figure 2

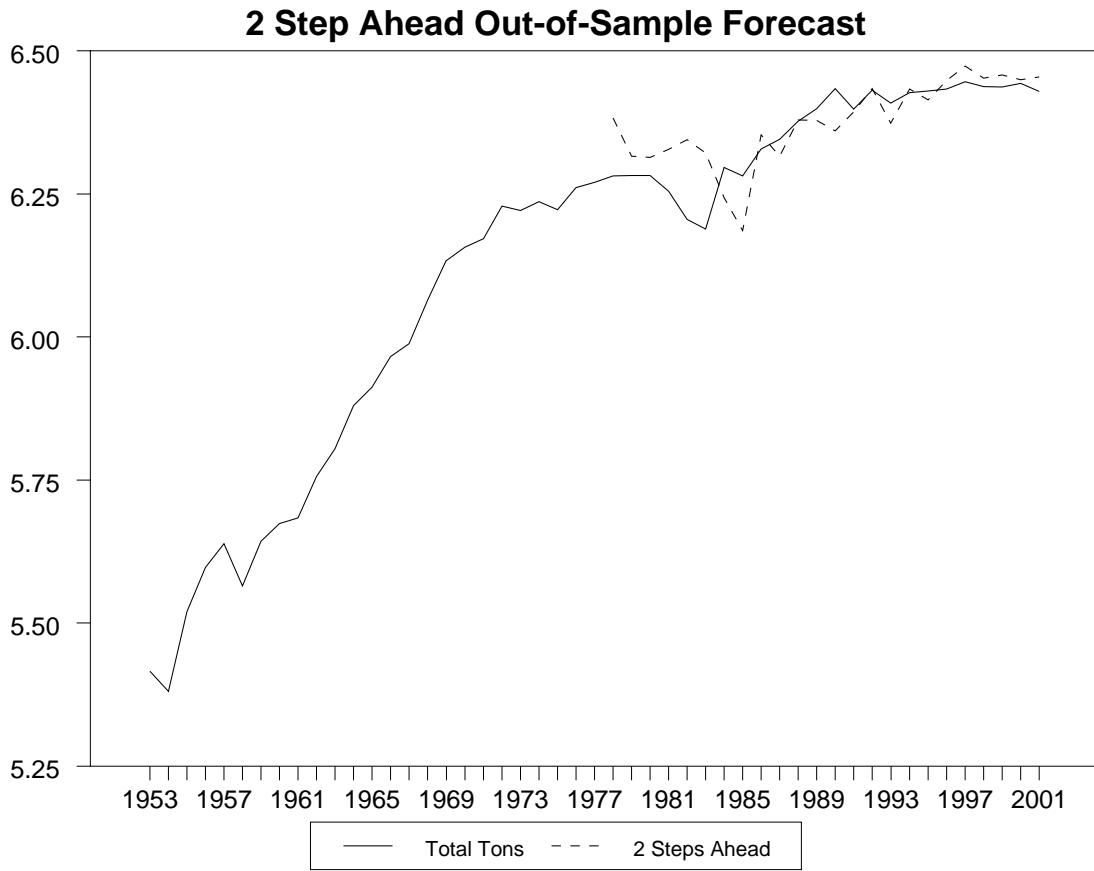


Figure 3

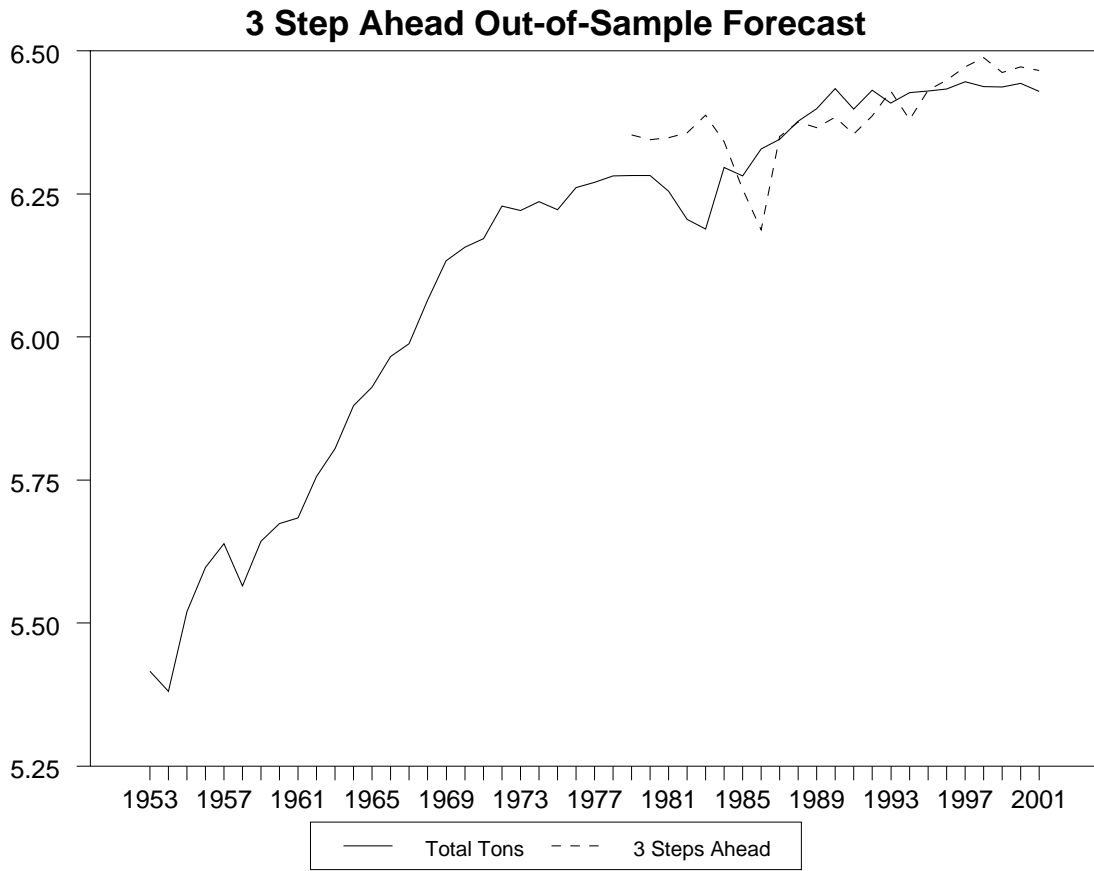


Figure 4

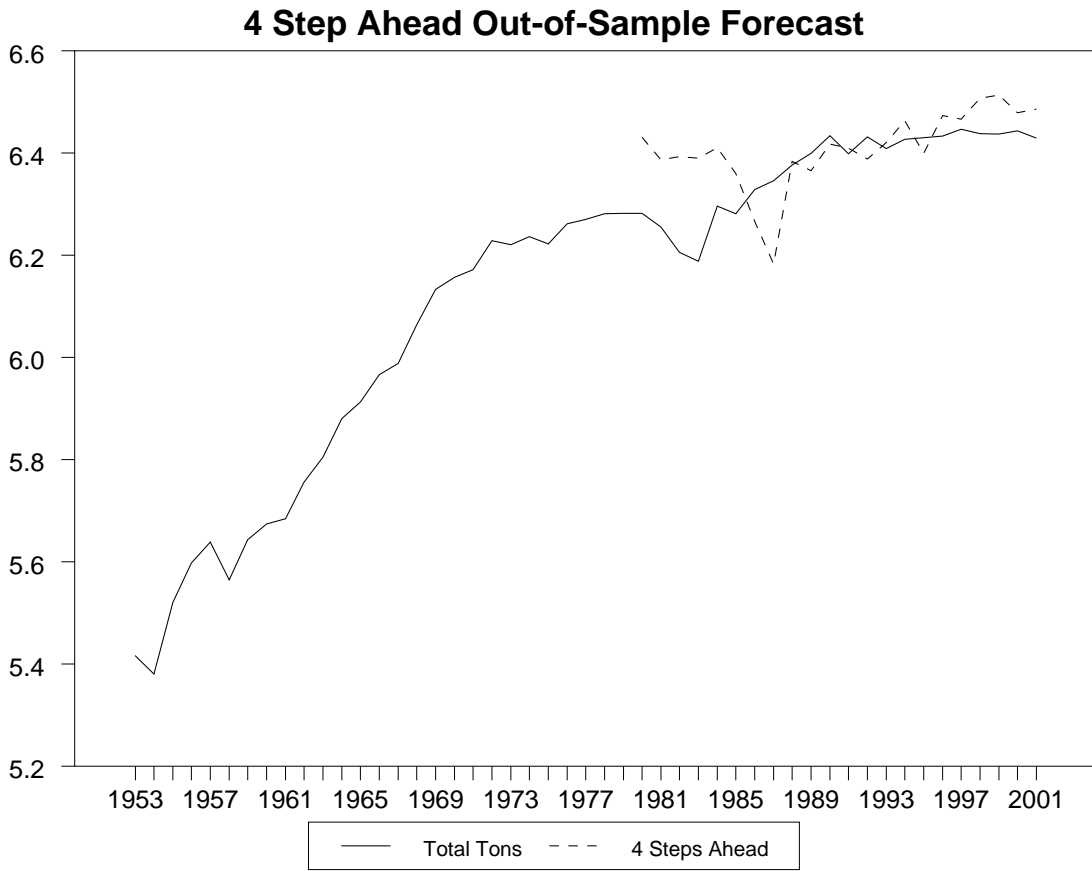


Figure 5

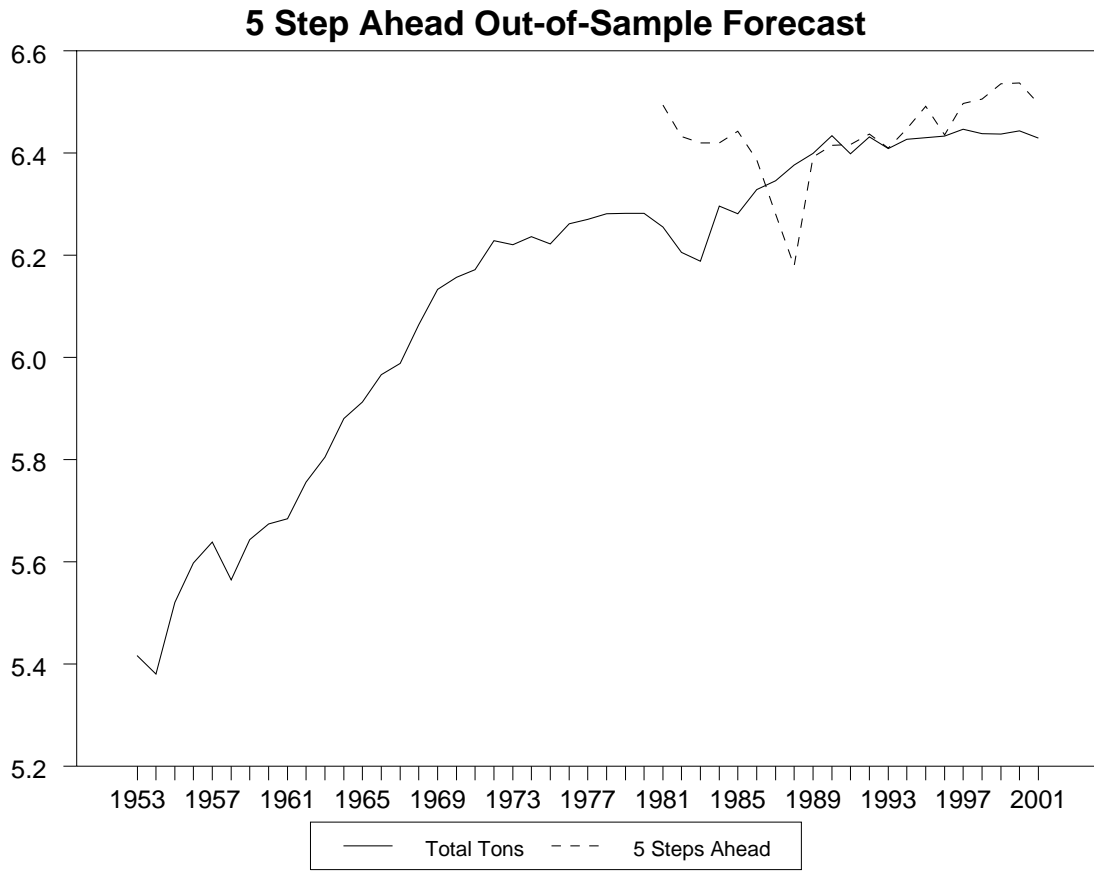


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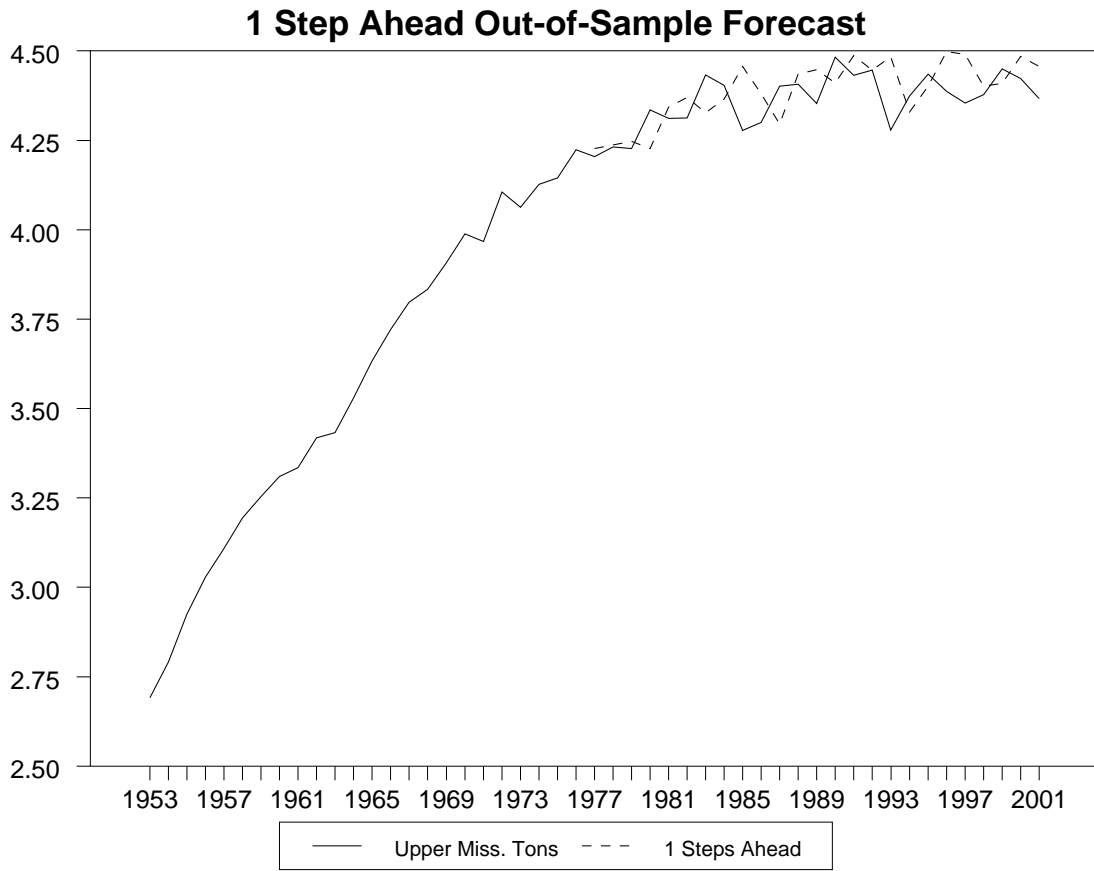


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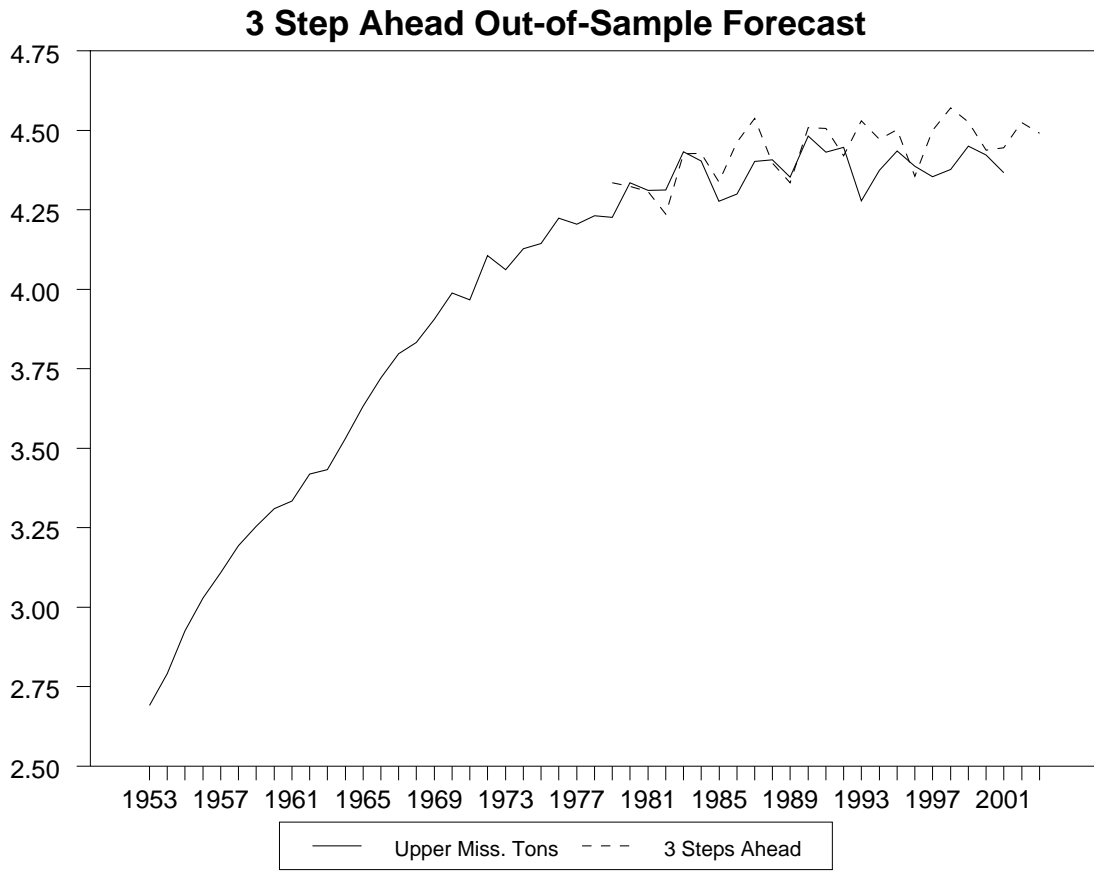


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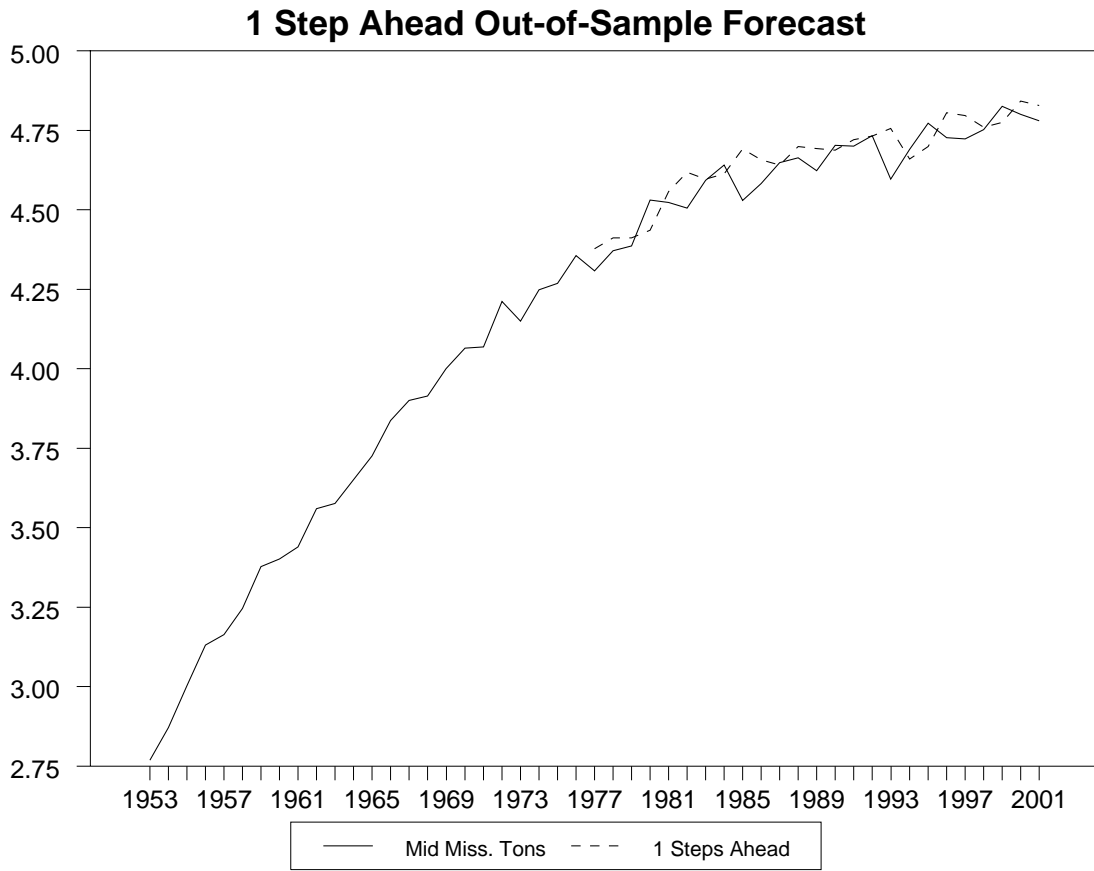


Figure 9

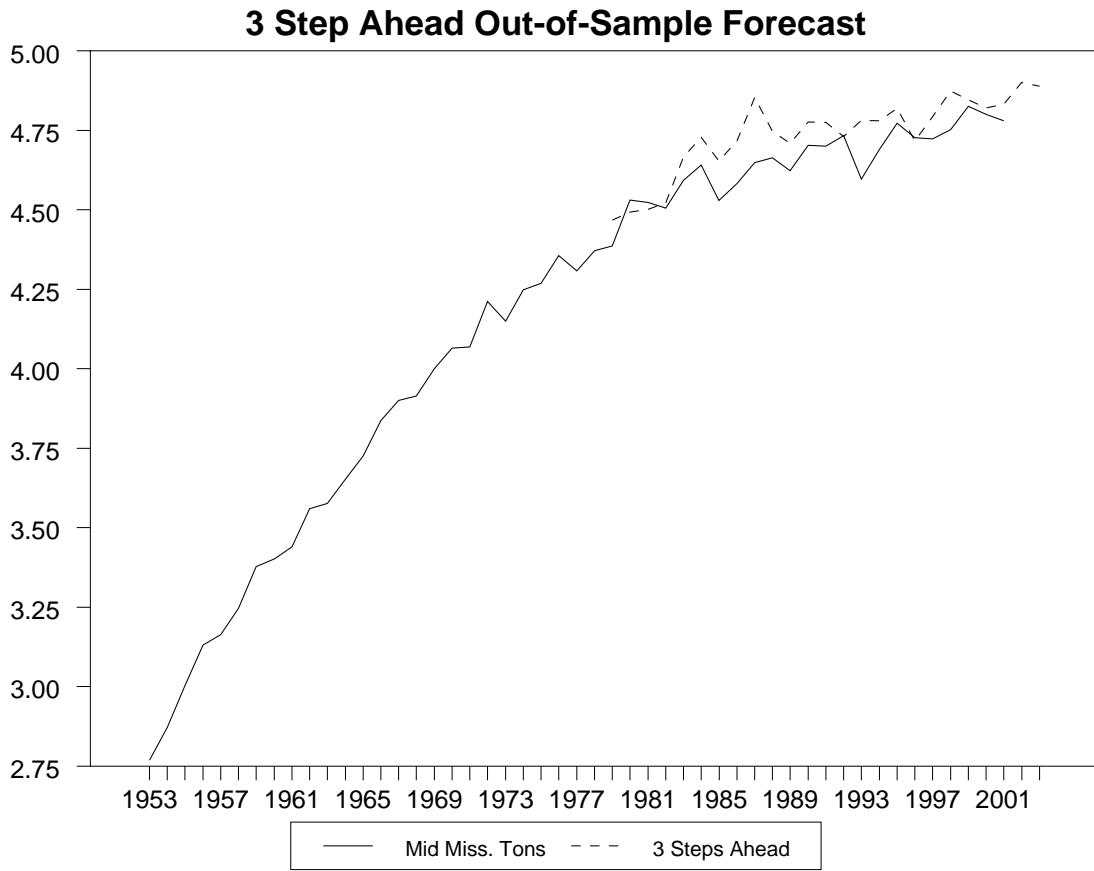


Figure 10

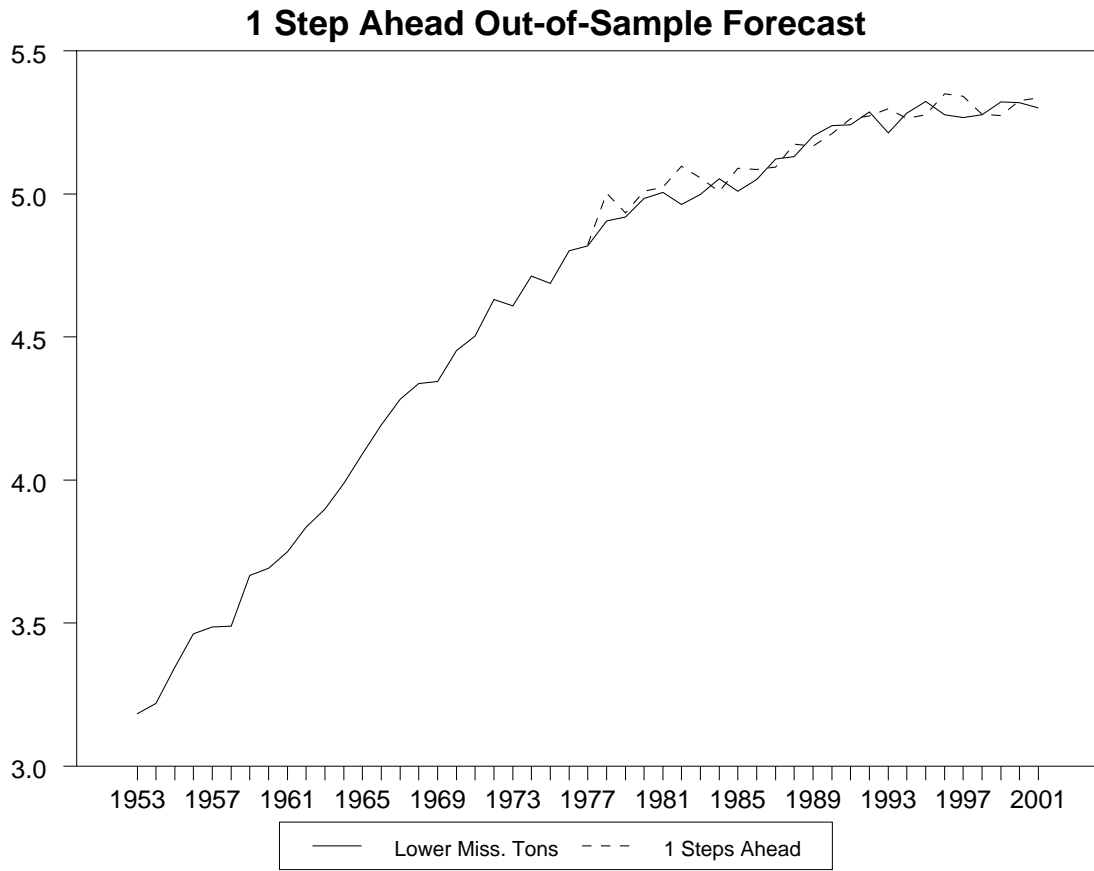


Figure 11

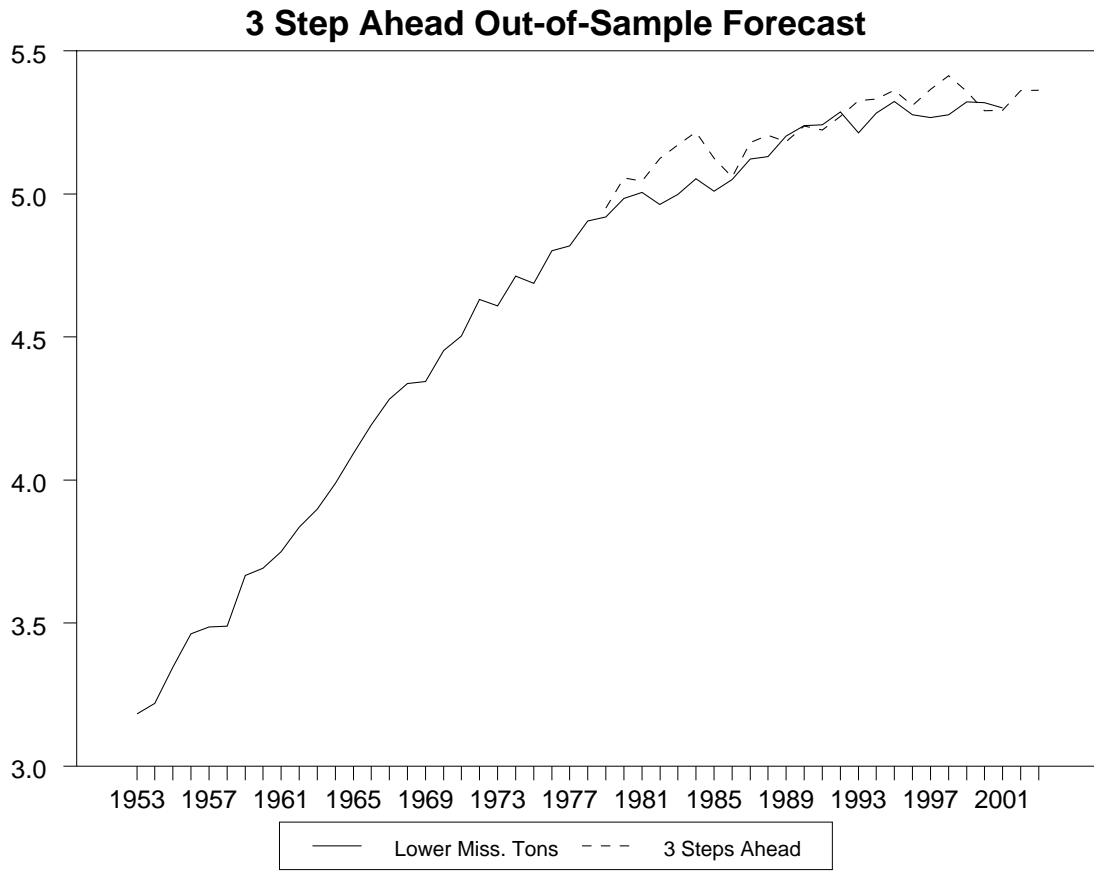


Figure 12

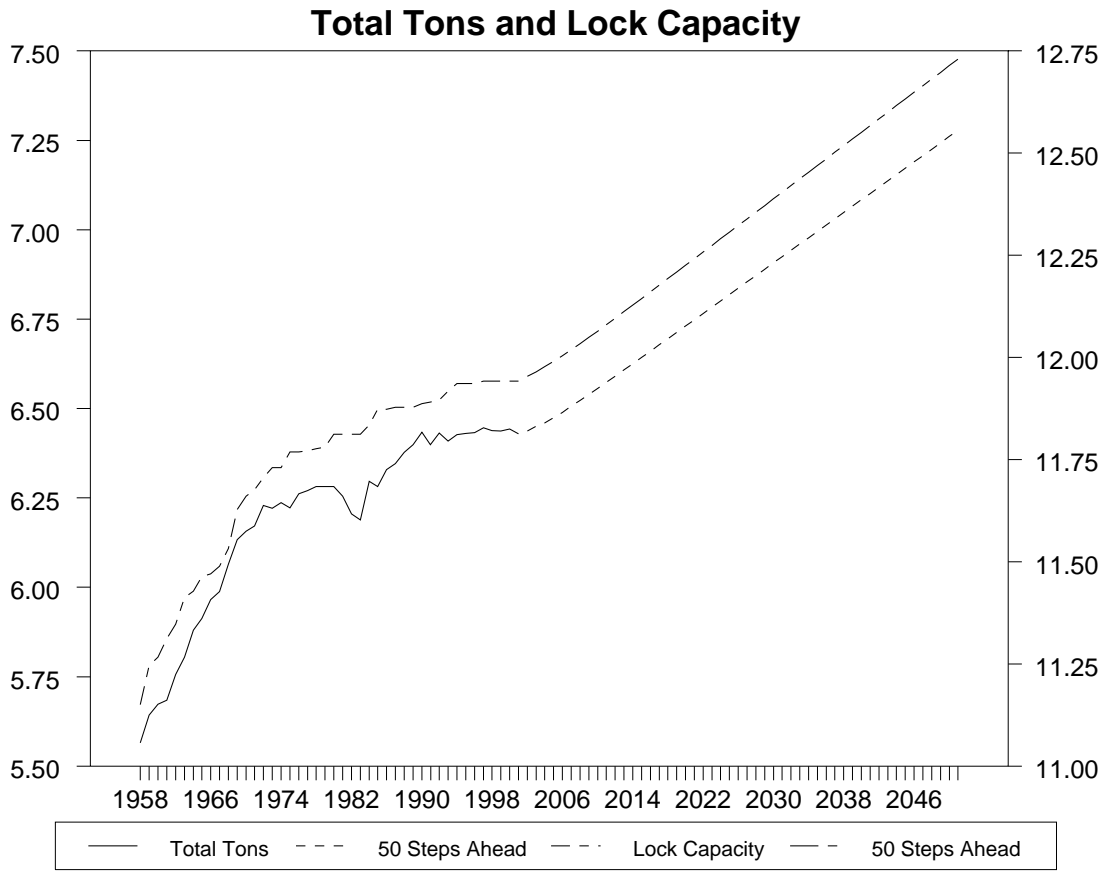


Figure 13

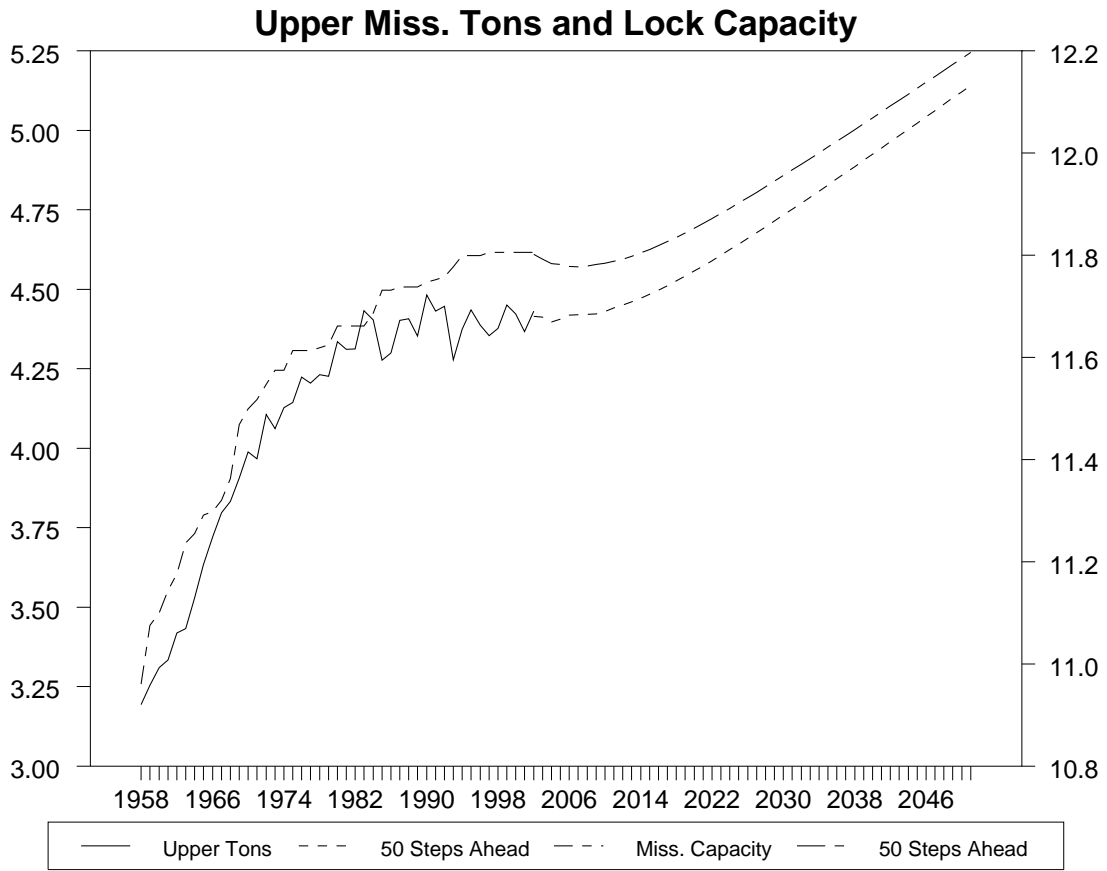


Figure 14

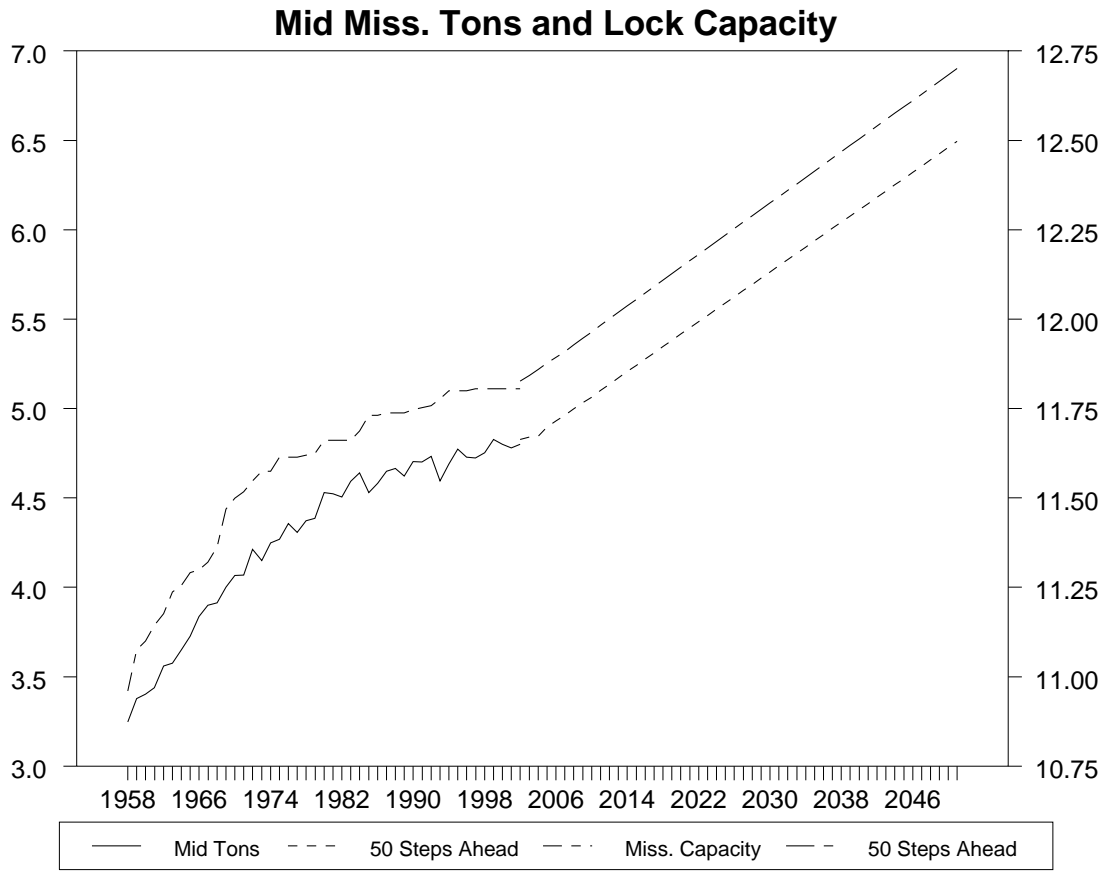


Figure 15

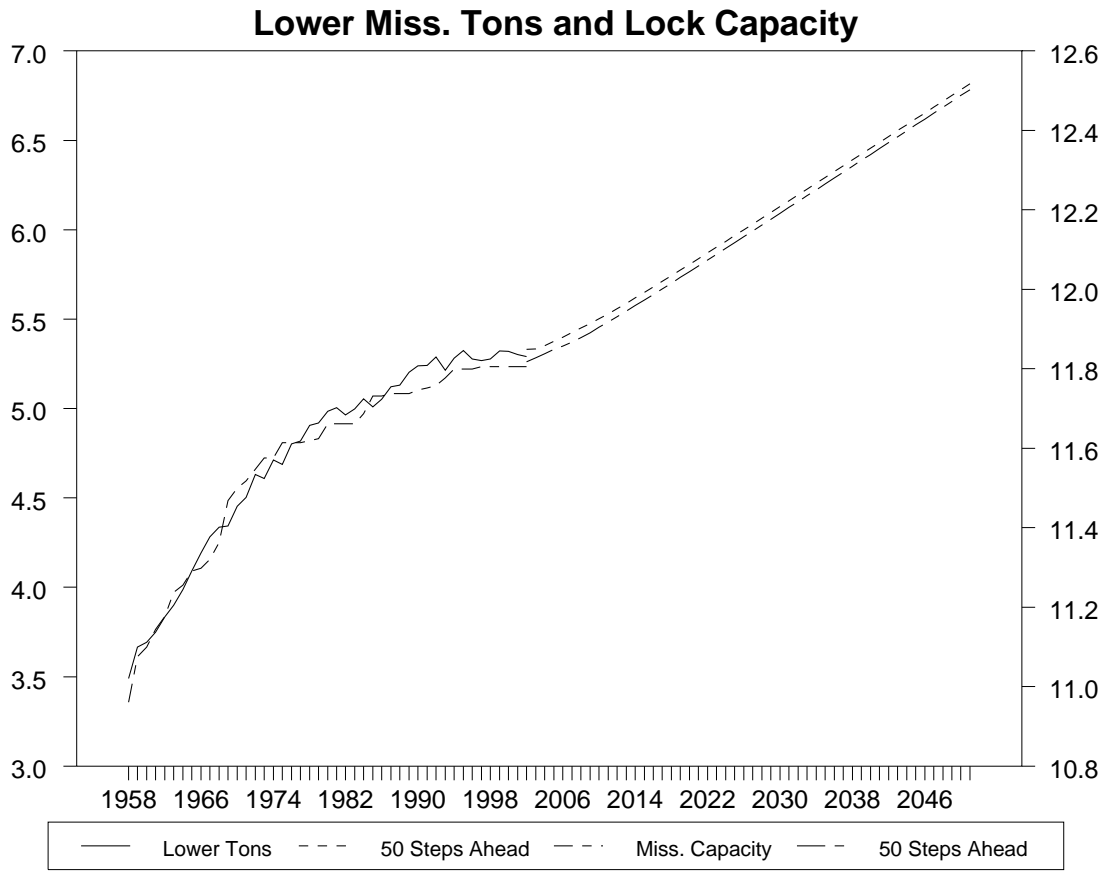


Figure 16

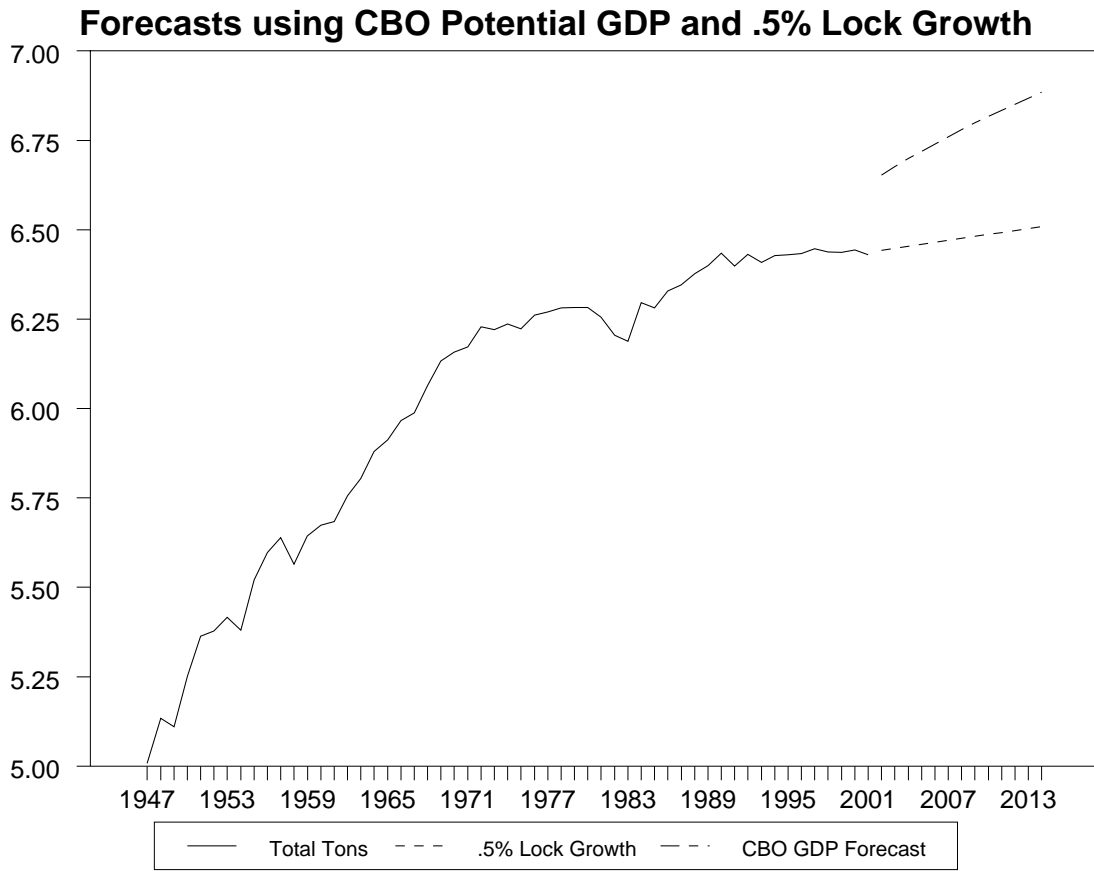


Figure 17

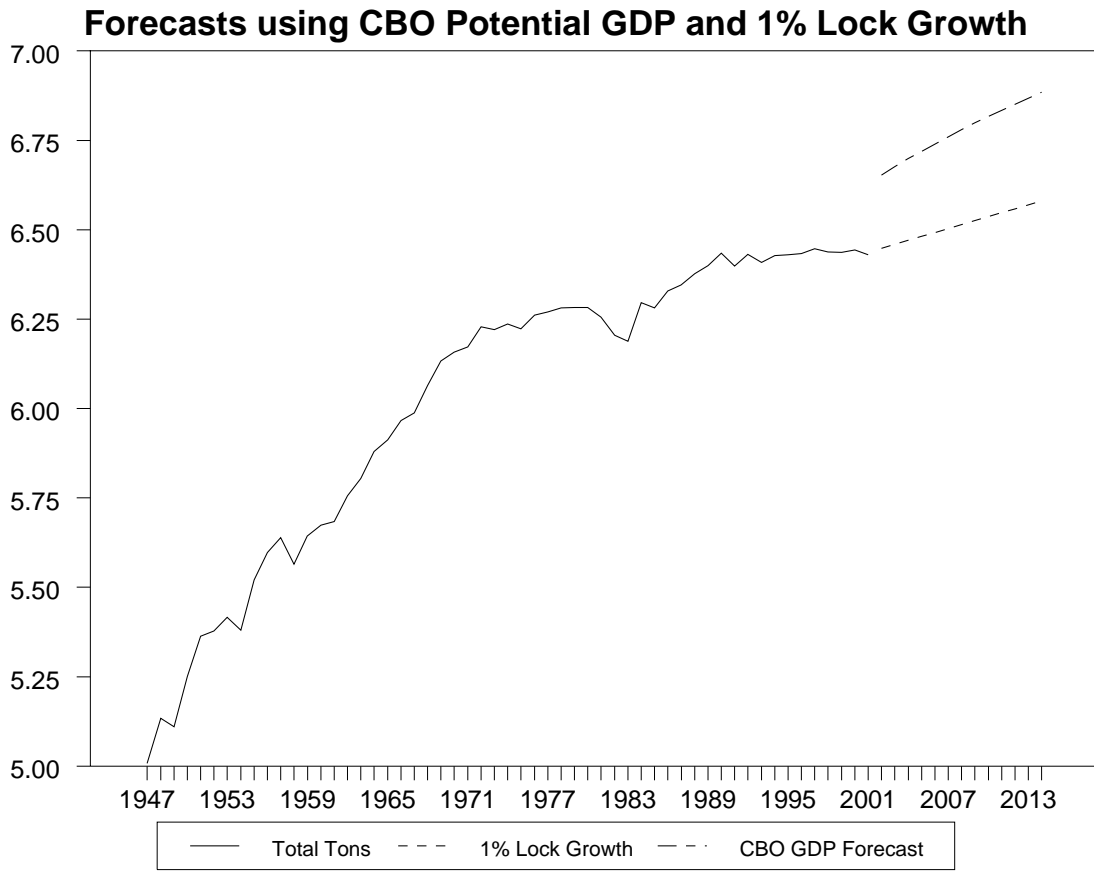


Figure 18

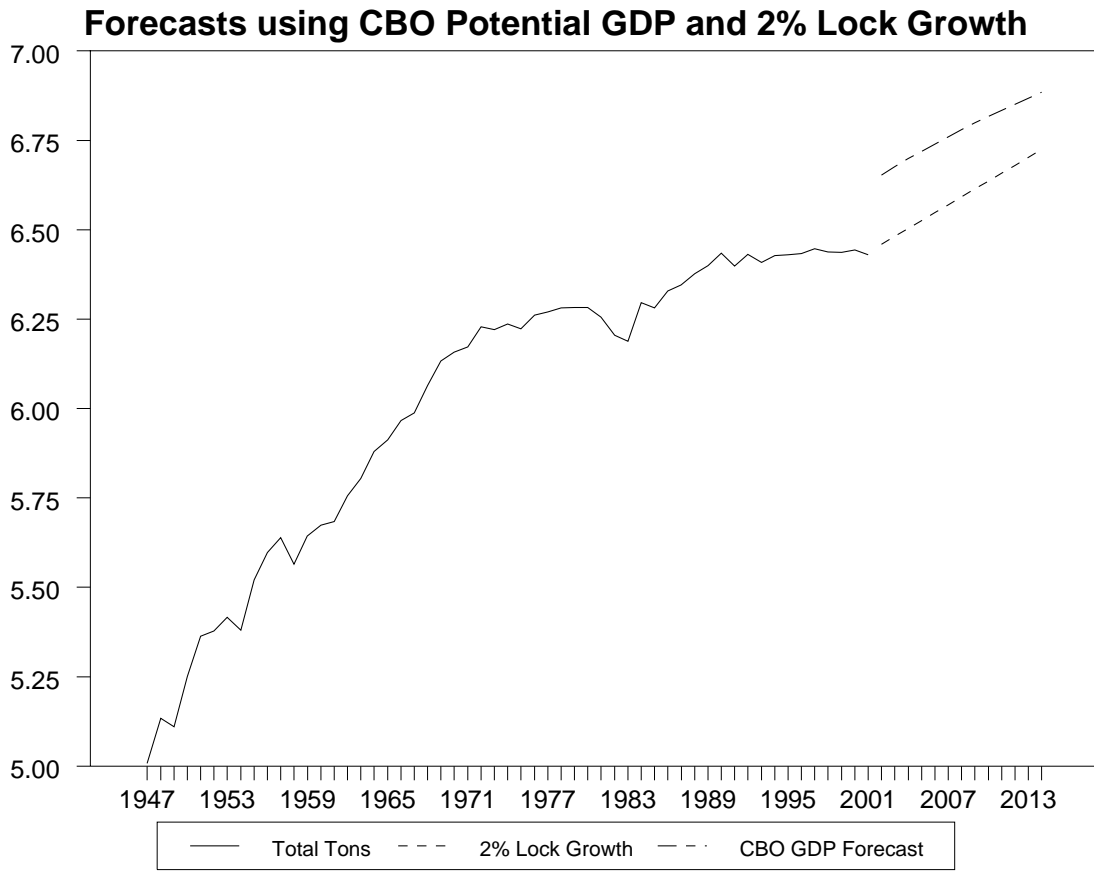


Figure 19

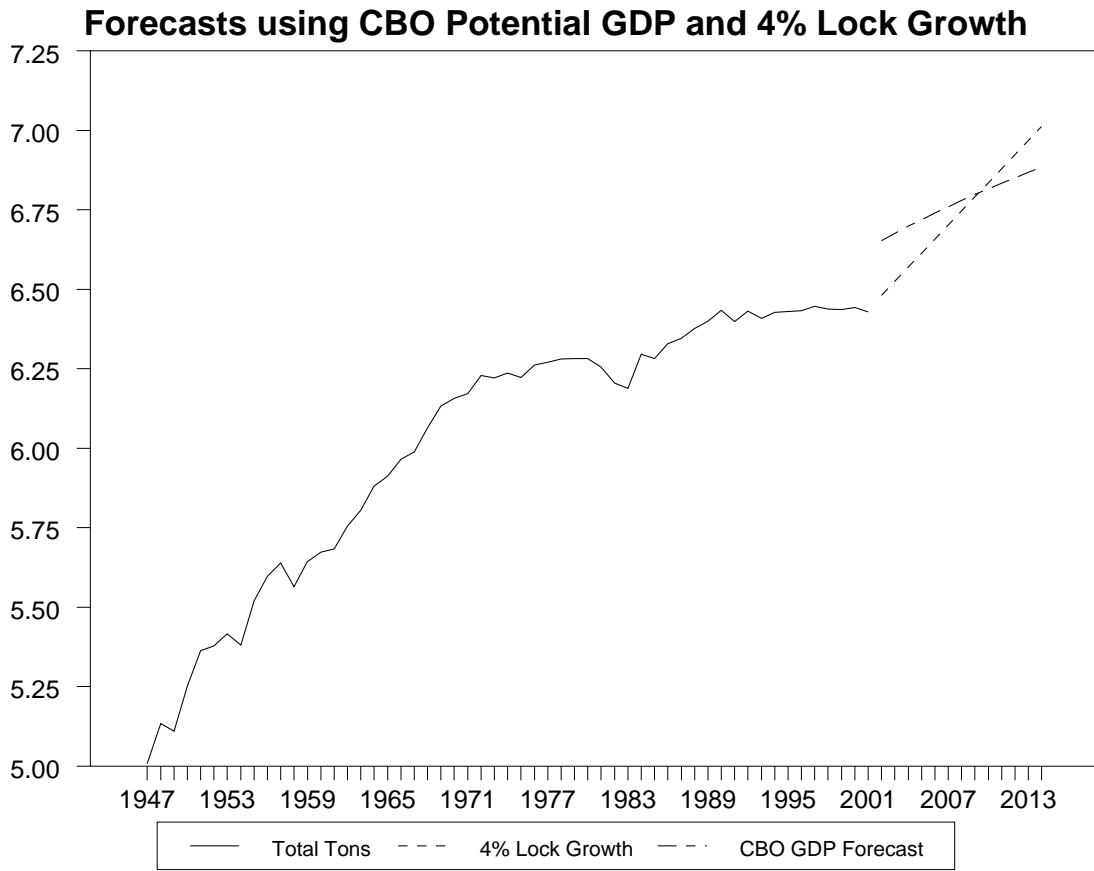
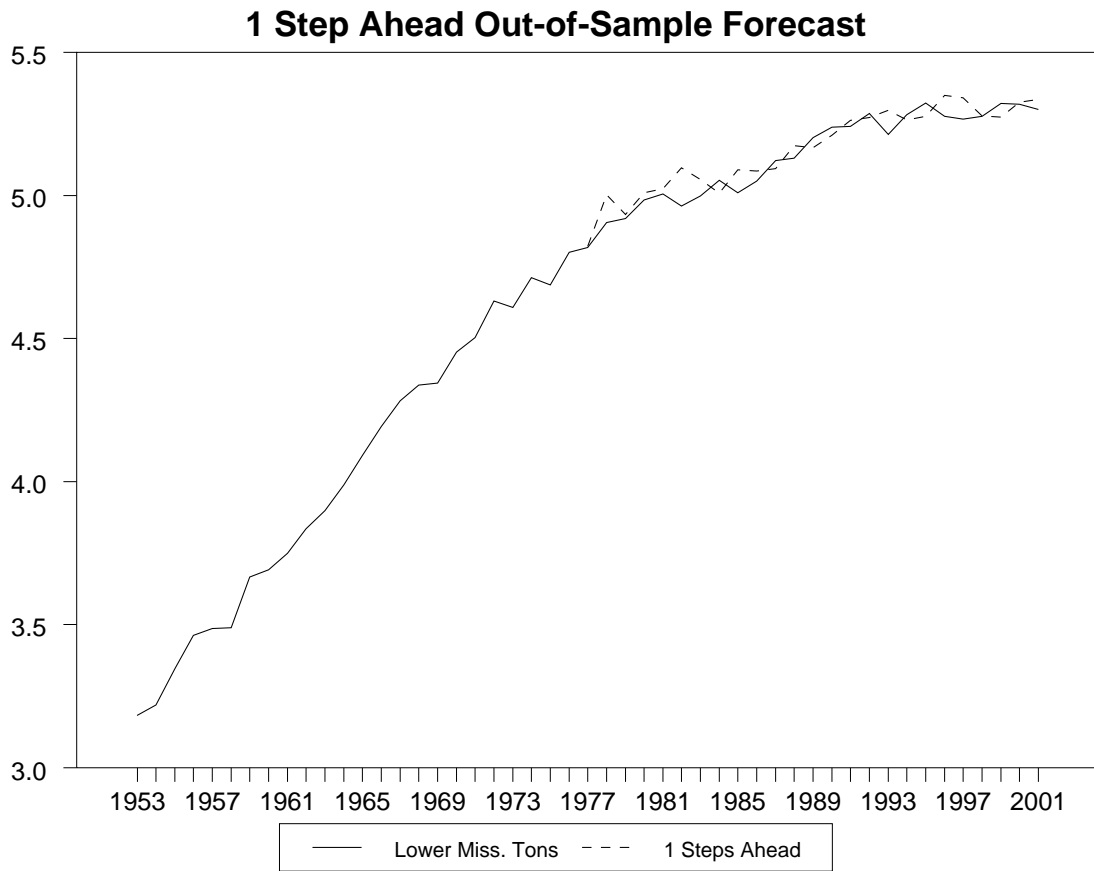
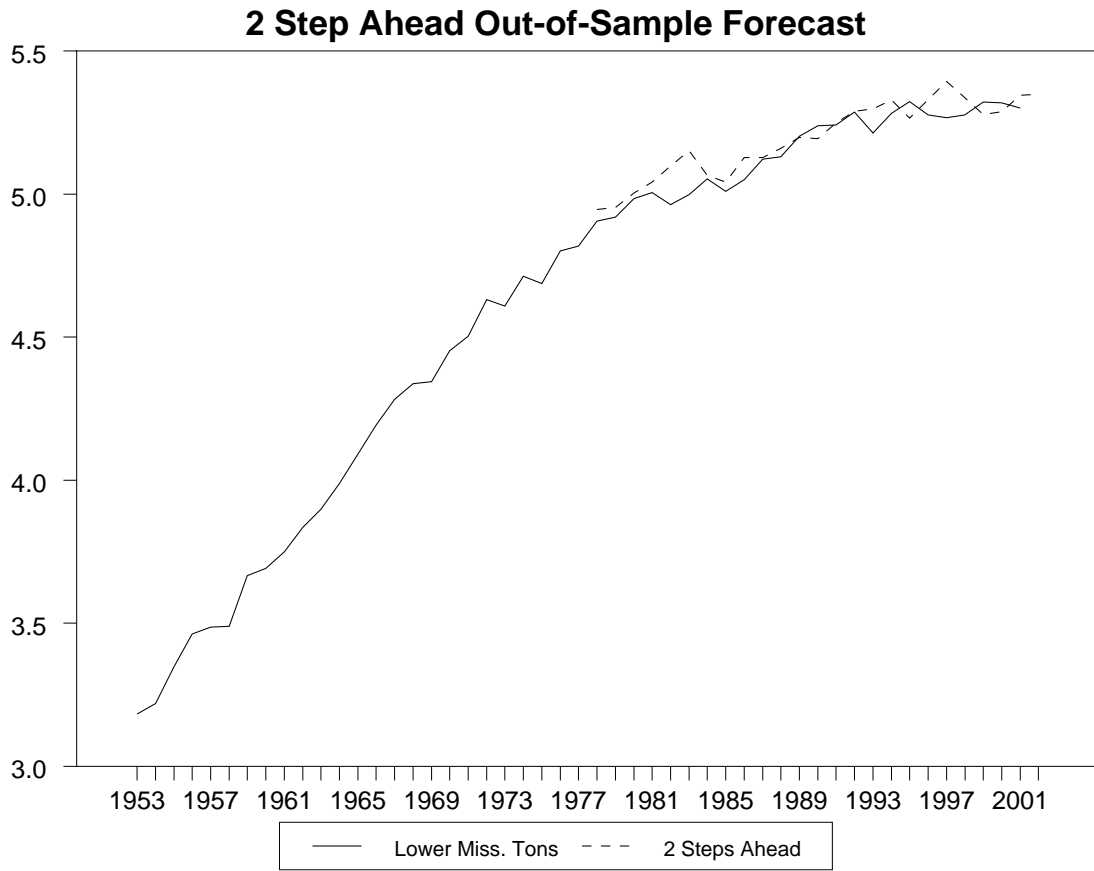


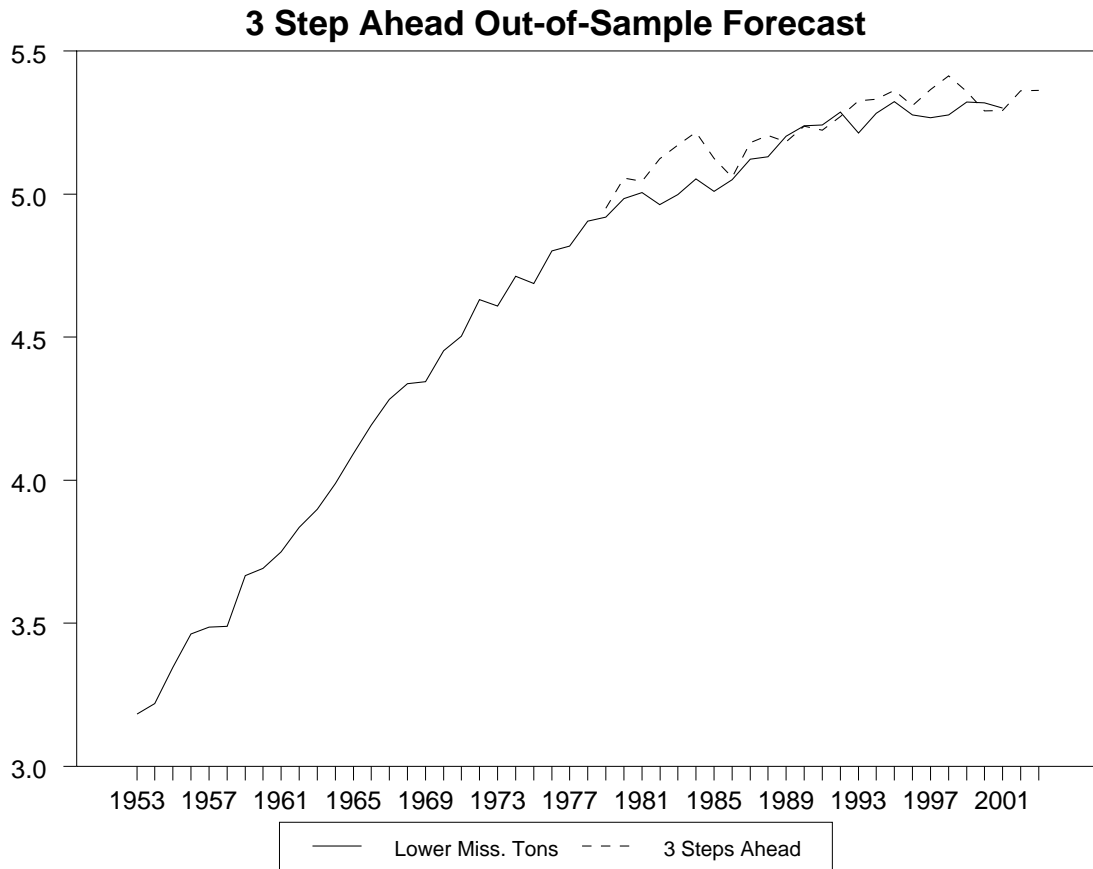
Figure 20

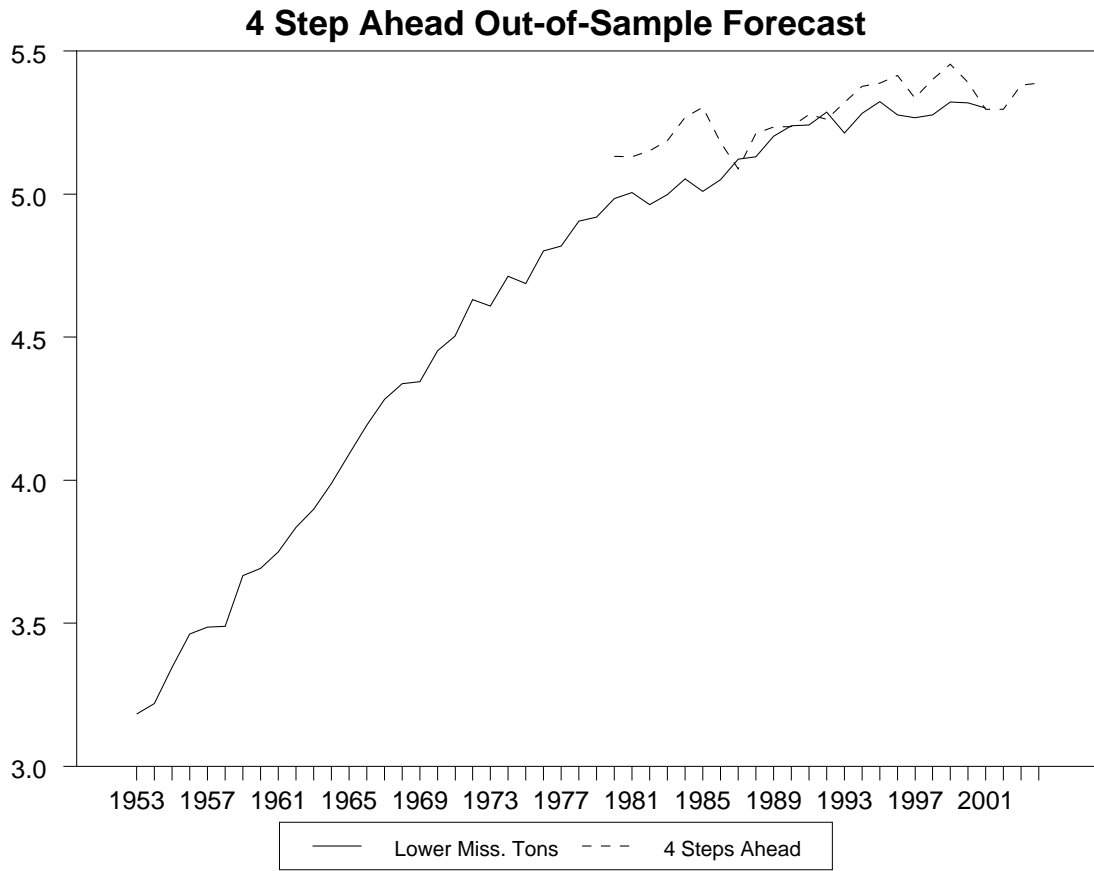
APPENDIX A

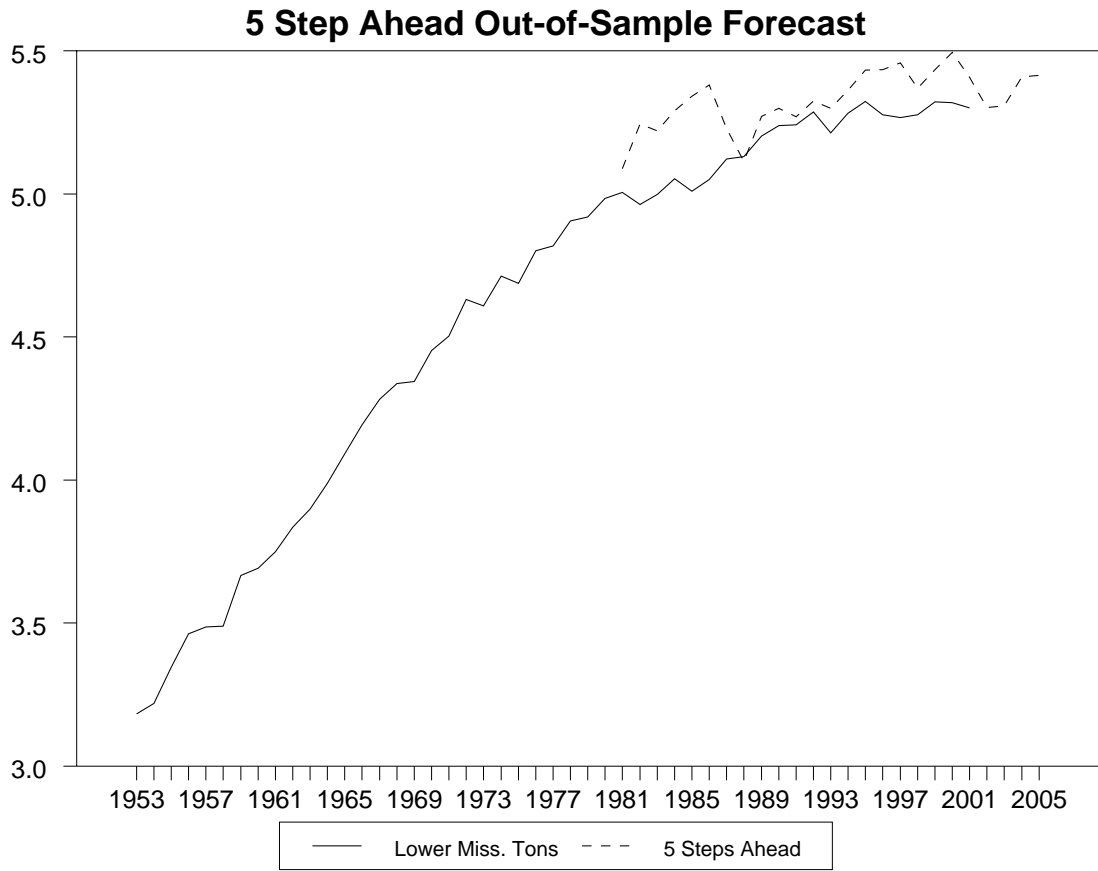
**Out-of-Sample Forecasts at the 1, 2, 3, 4, and 5, Year Horizons
based upon the Estimated Error-Correction Model for the
Upper, Mid, and Lower Mississippi River System**

Lower Mississippi

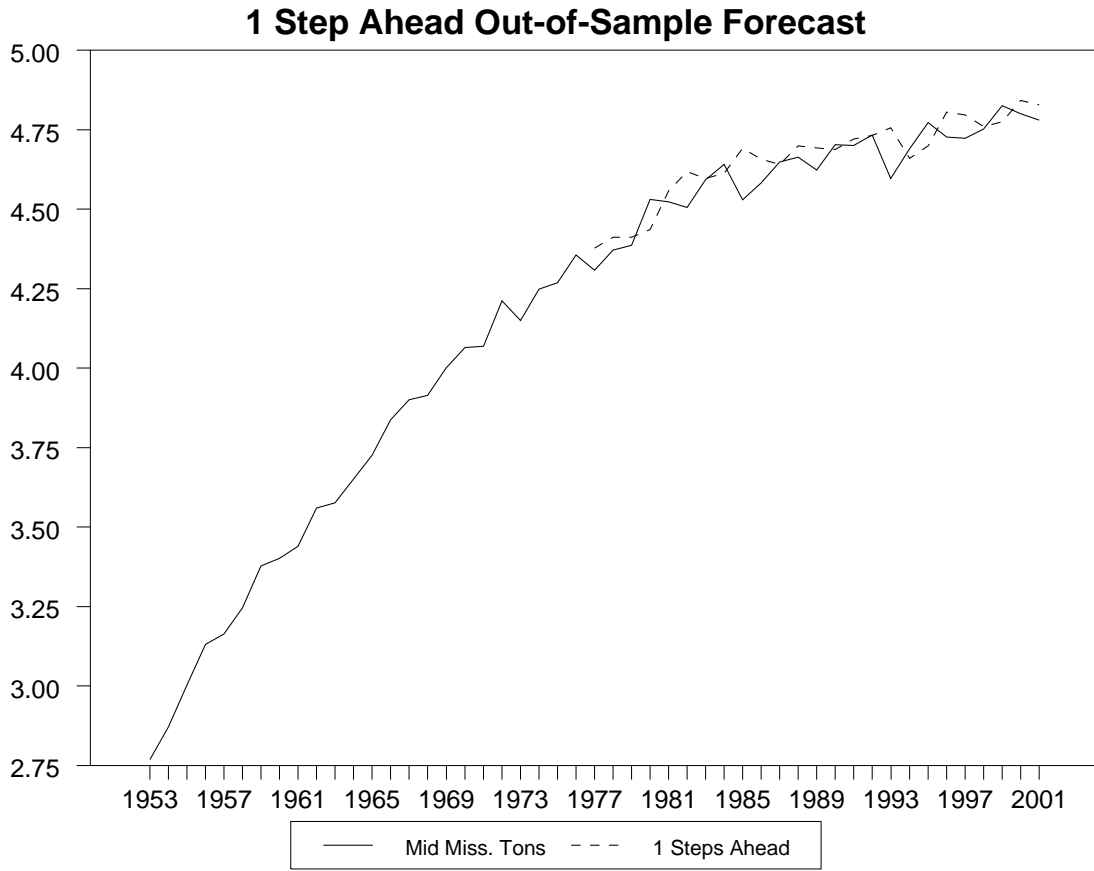




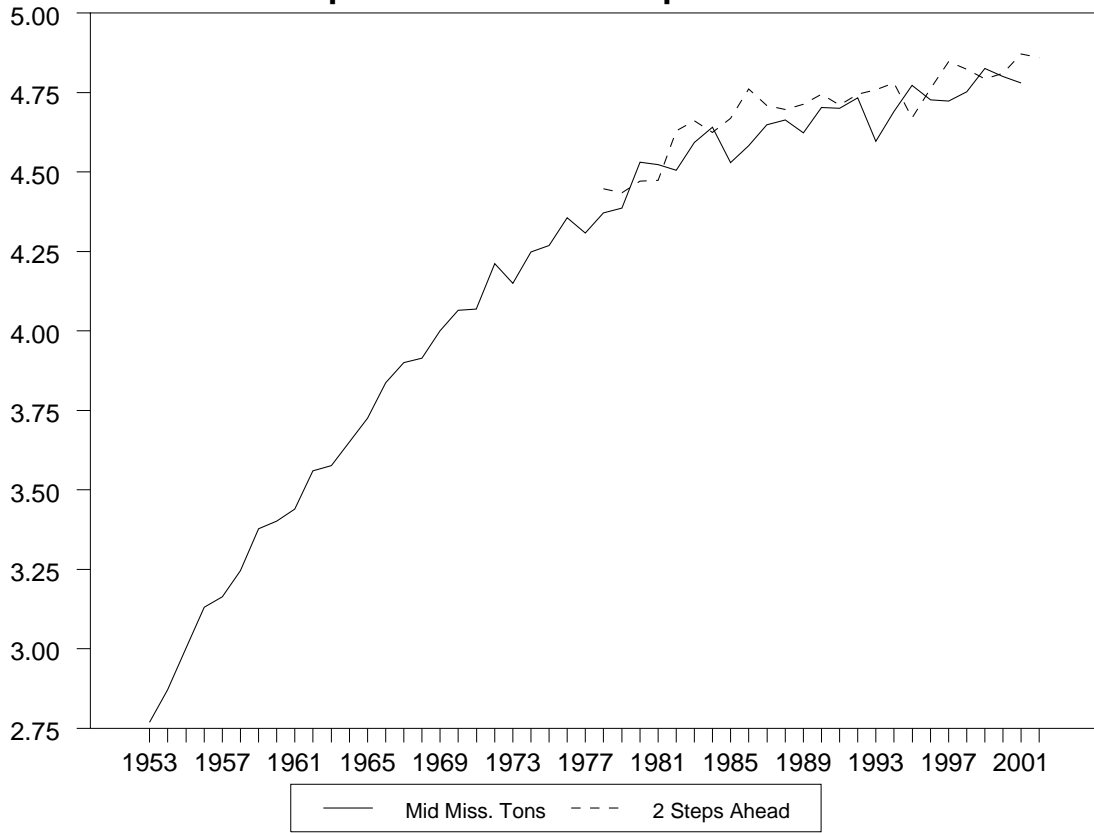




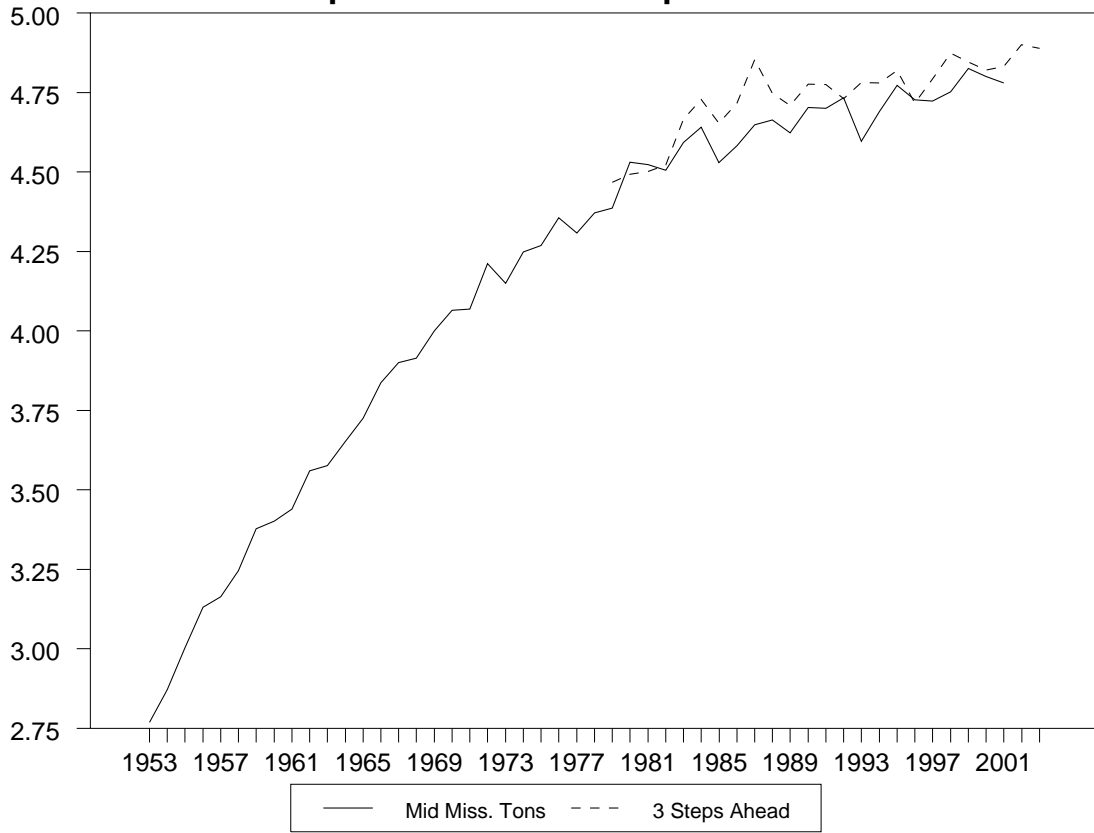
Mid Mississippi

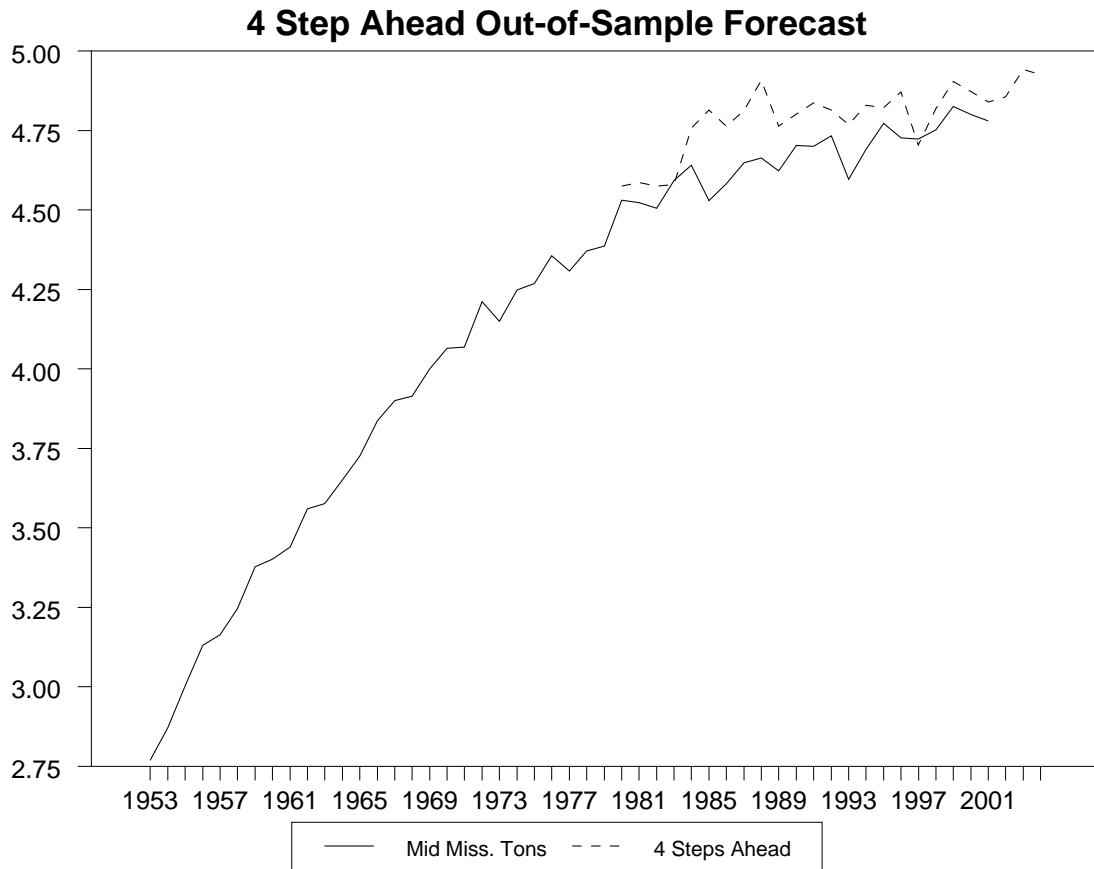


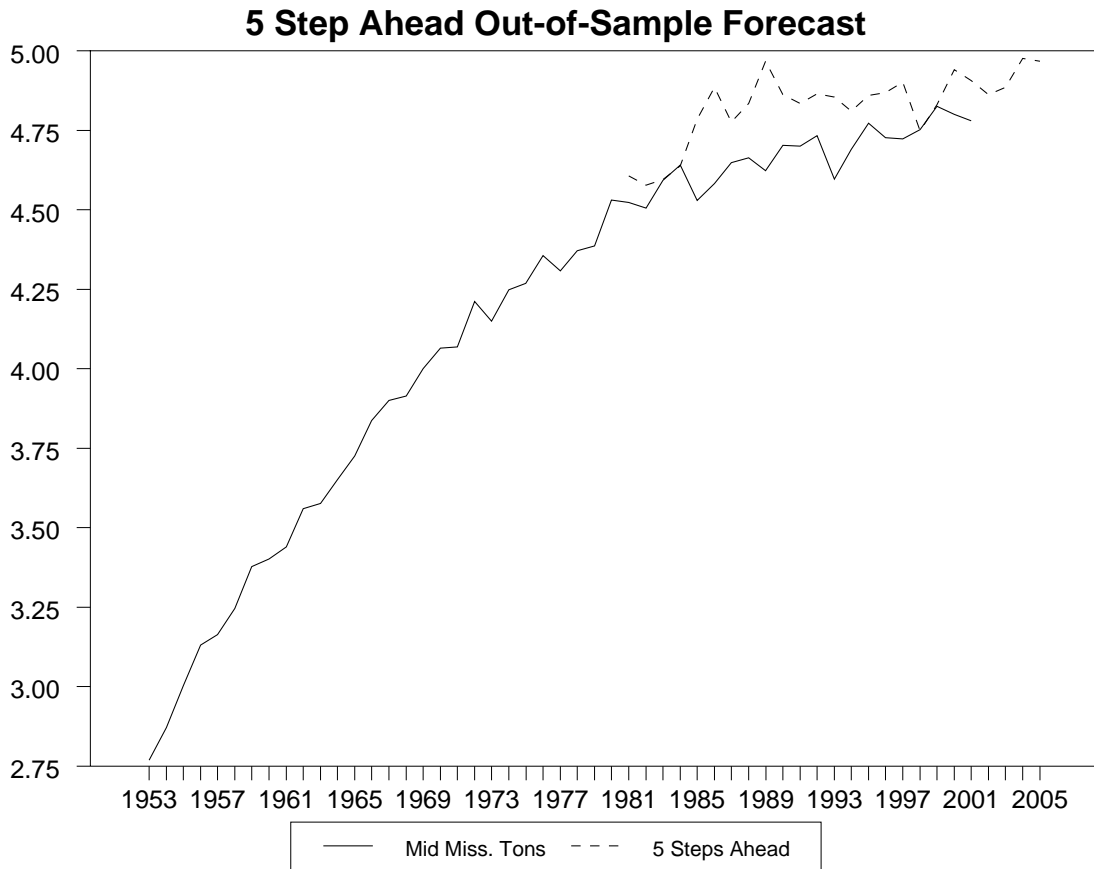
2 Step Ahead Out-of-Sample Forecast



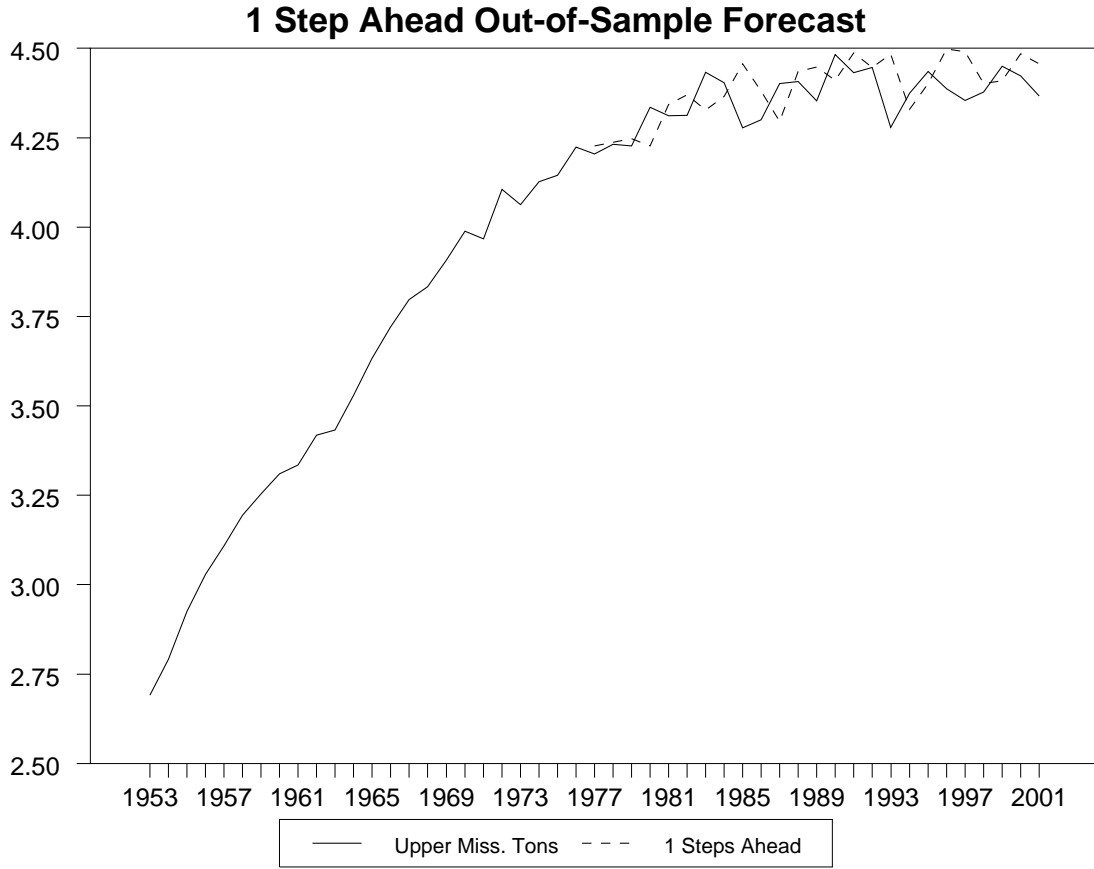
3 Step Ahead Out-of-Sample Forecast



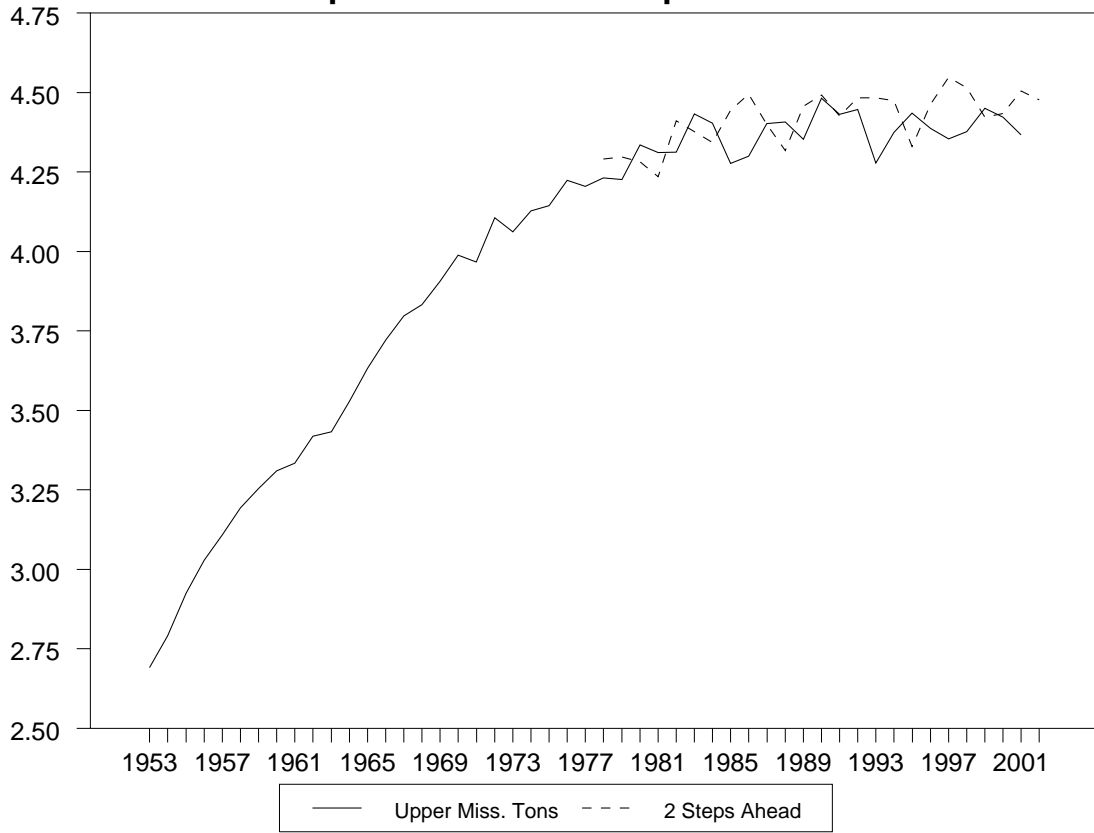




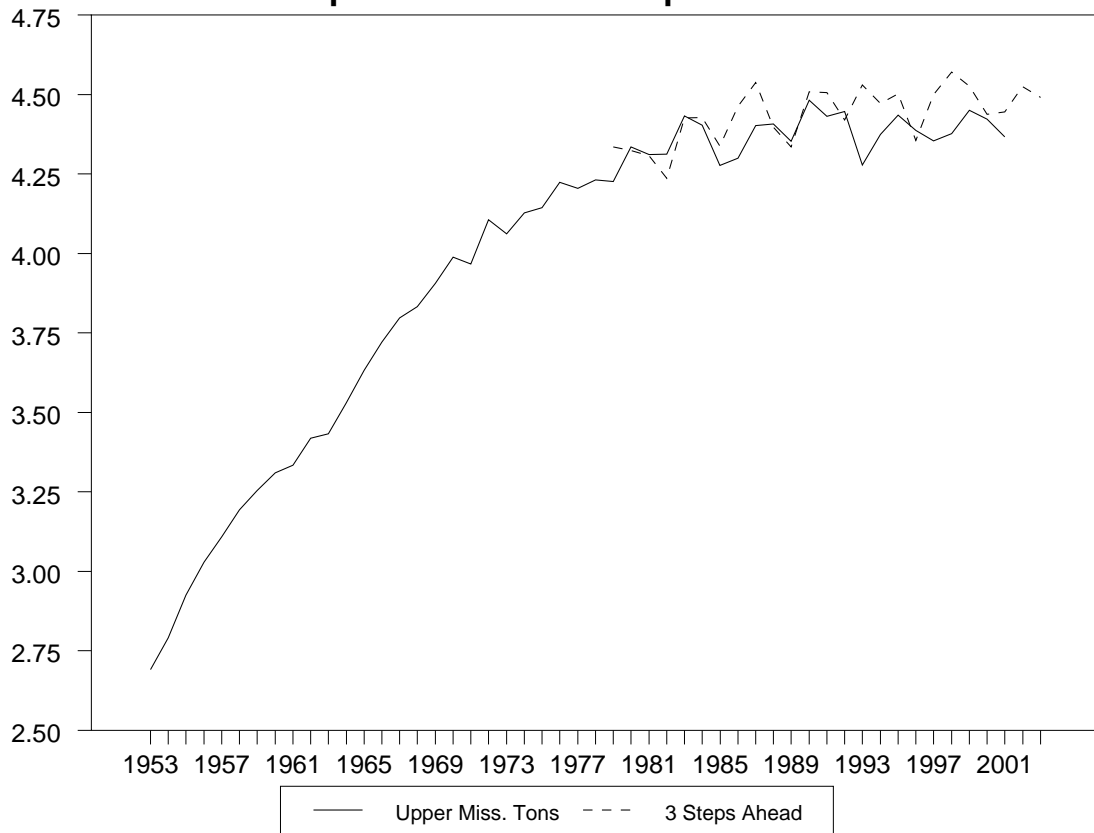
Upper Mississippi



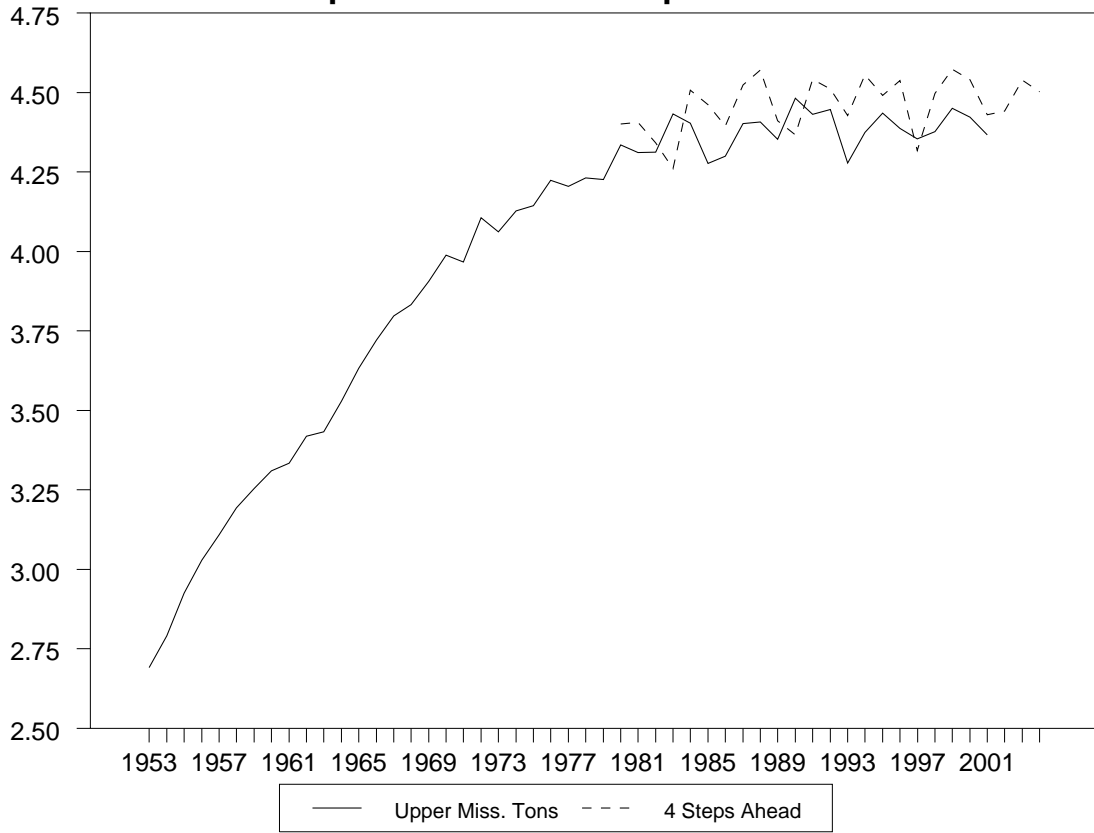
2 Step Ahead Out-of-Sample Forecast



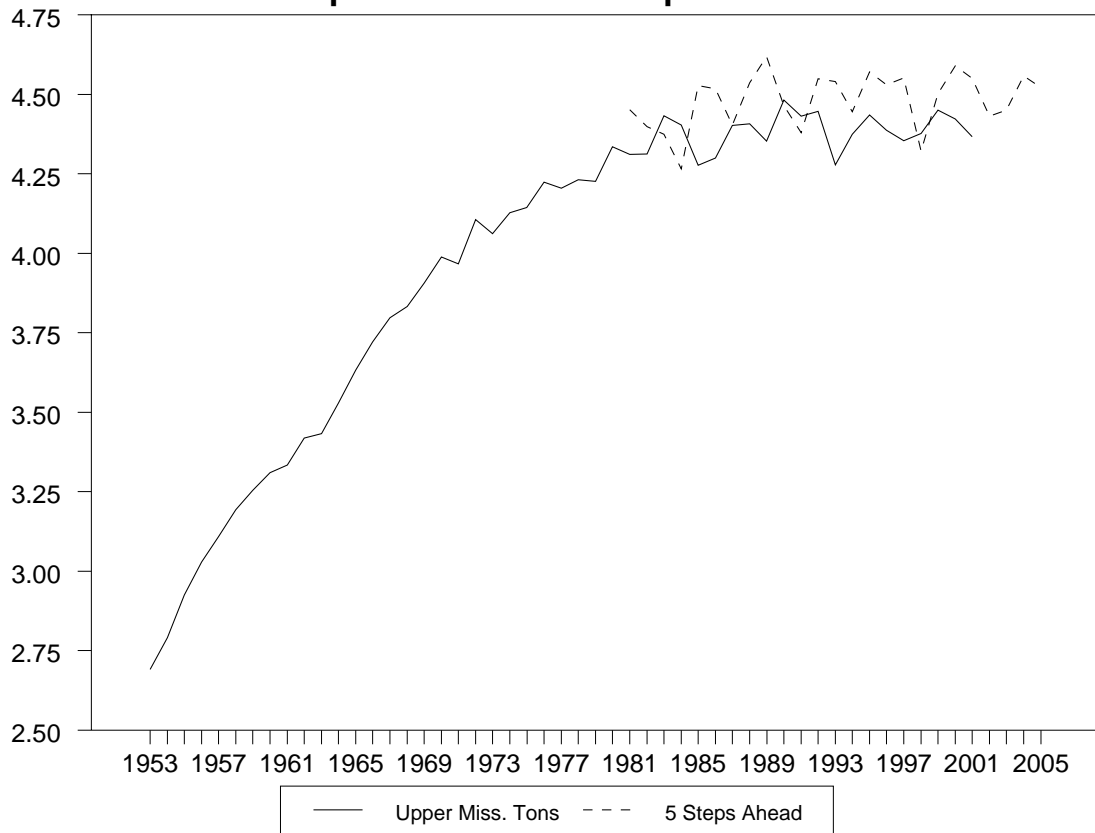
3 Step Ahead Out-of-Sample Forecast



4 Step Ahead Out-of-Sample Forecast



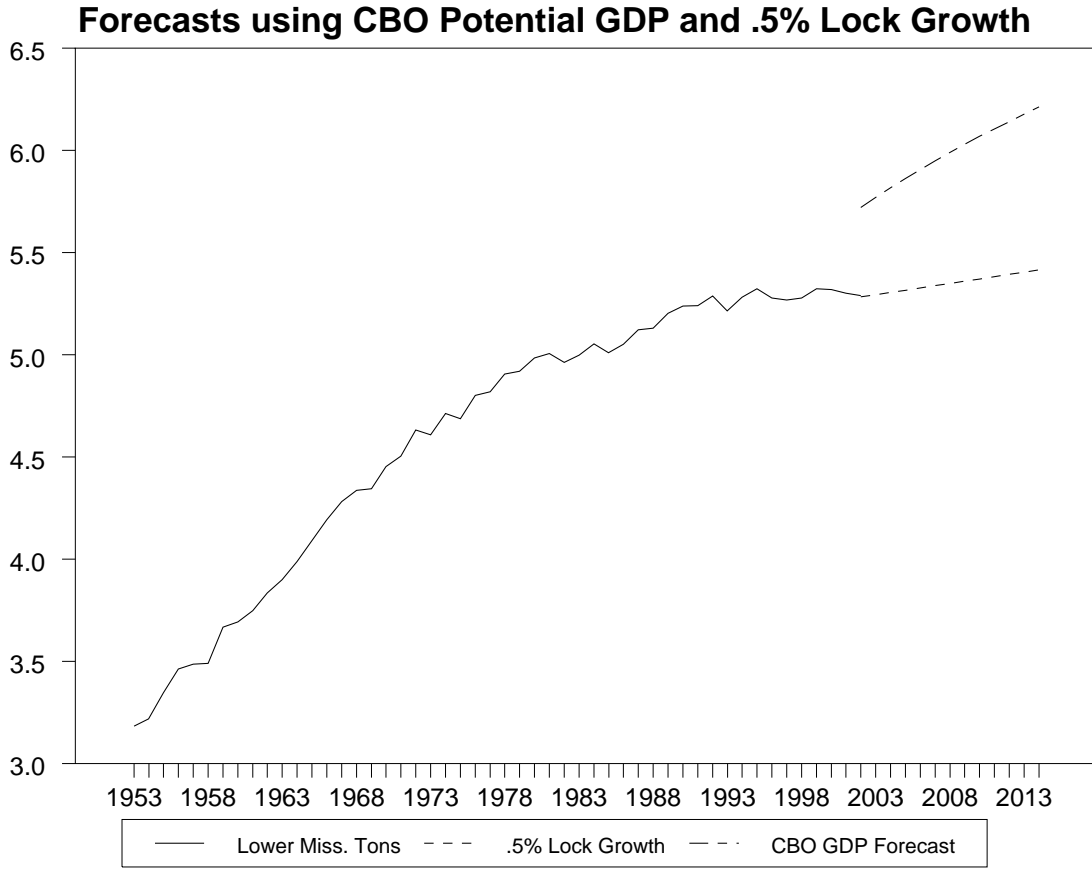
5 Step Ahead Out-of-Sample Forecast



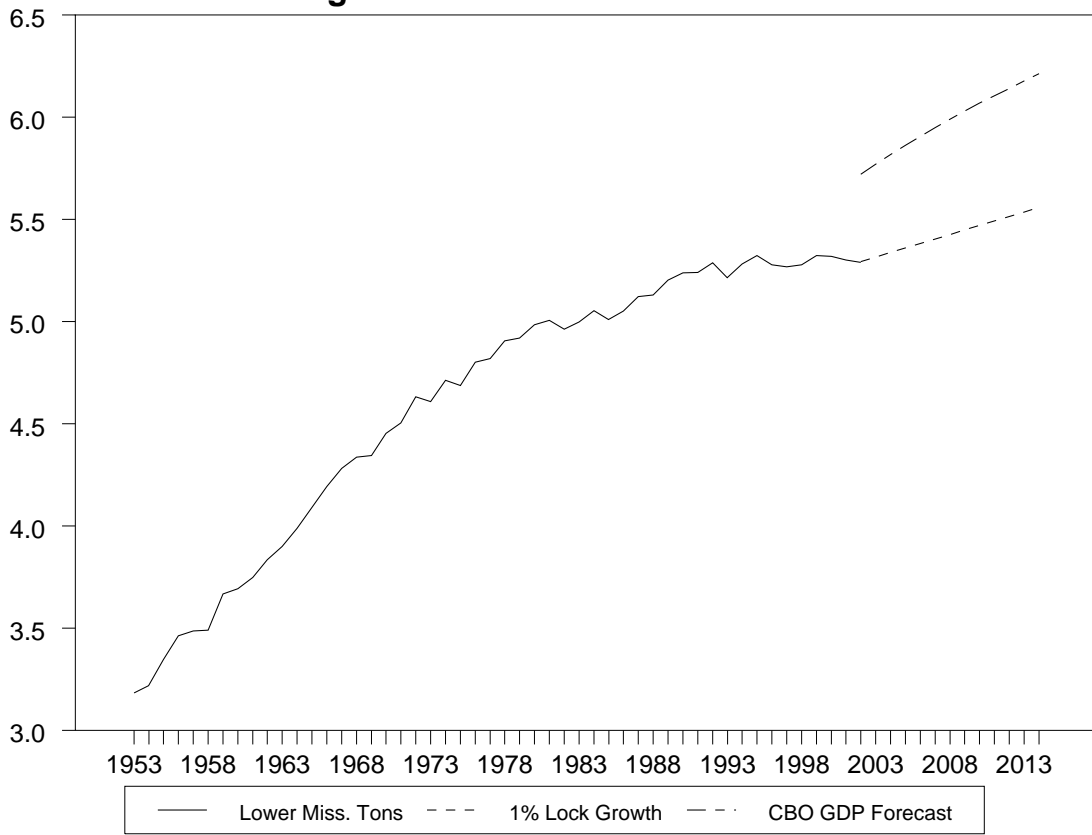
APPENDIX B

**Long-Run Forecasts based upon the
Estimated Co-Integrating Relationship for the
Upper, Mid, and Lower Mississippi River System**

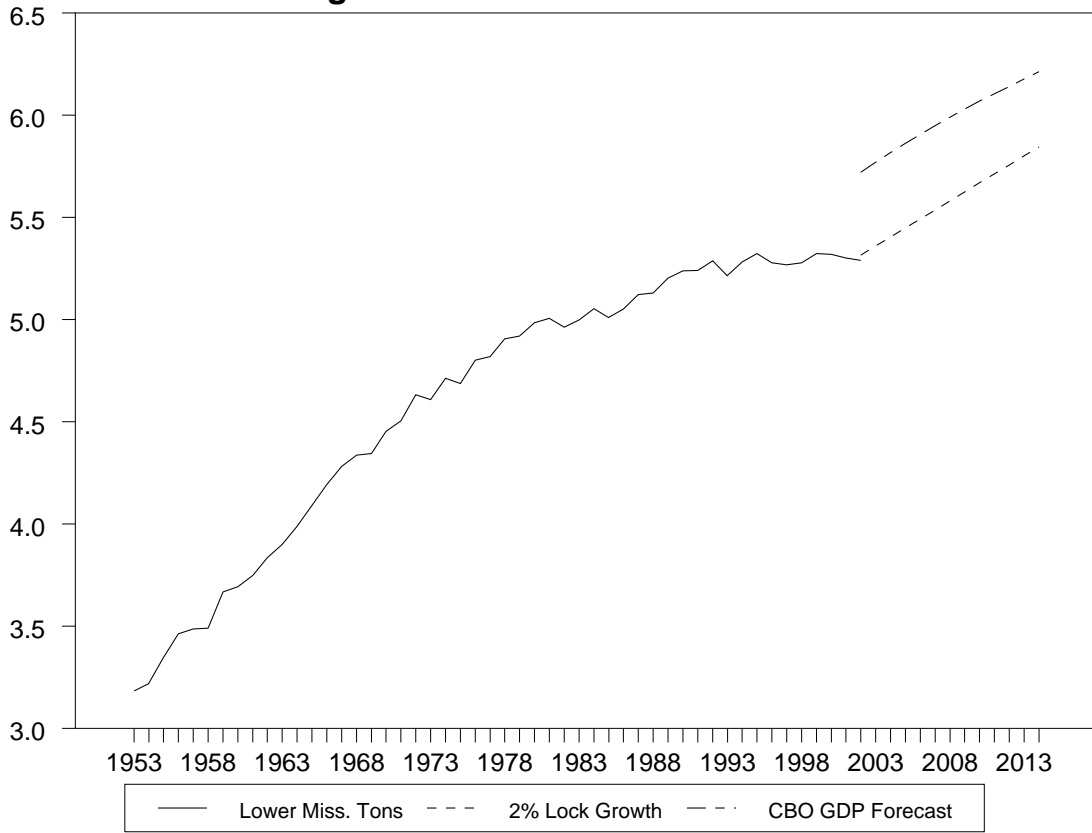
Lower Mississippi



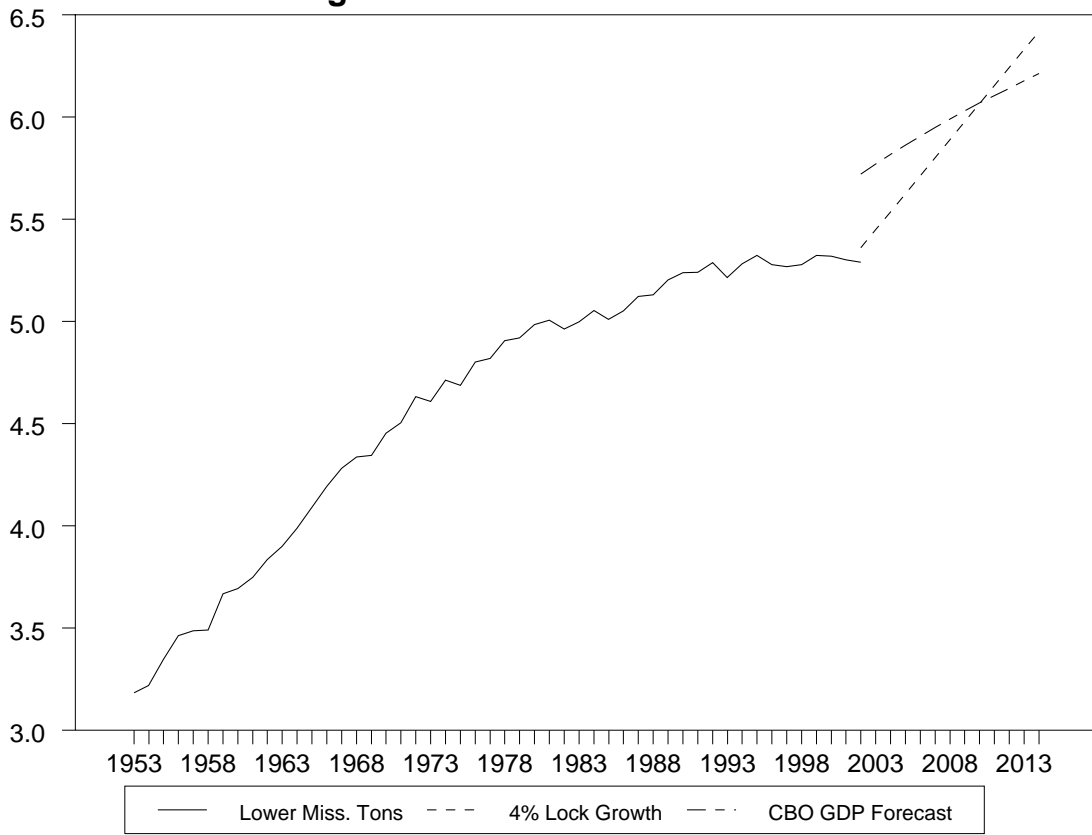
Forecasts using CBO Potential GDP and 1% Lock Growth



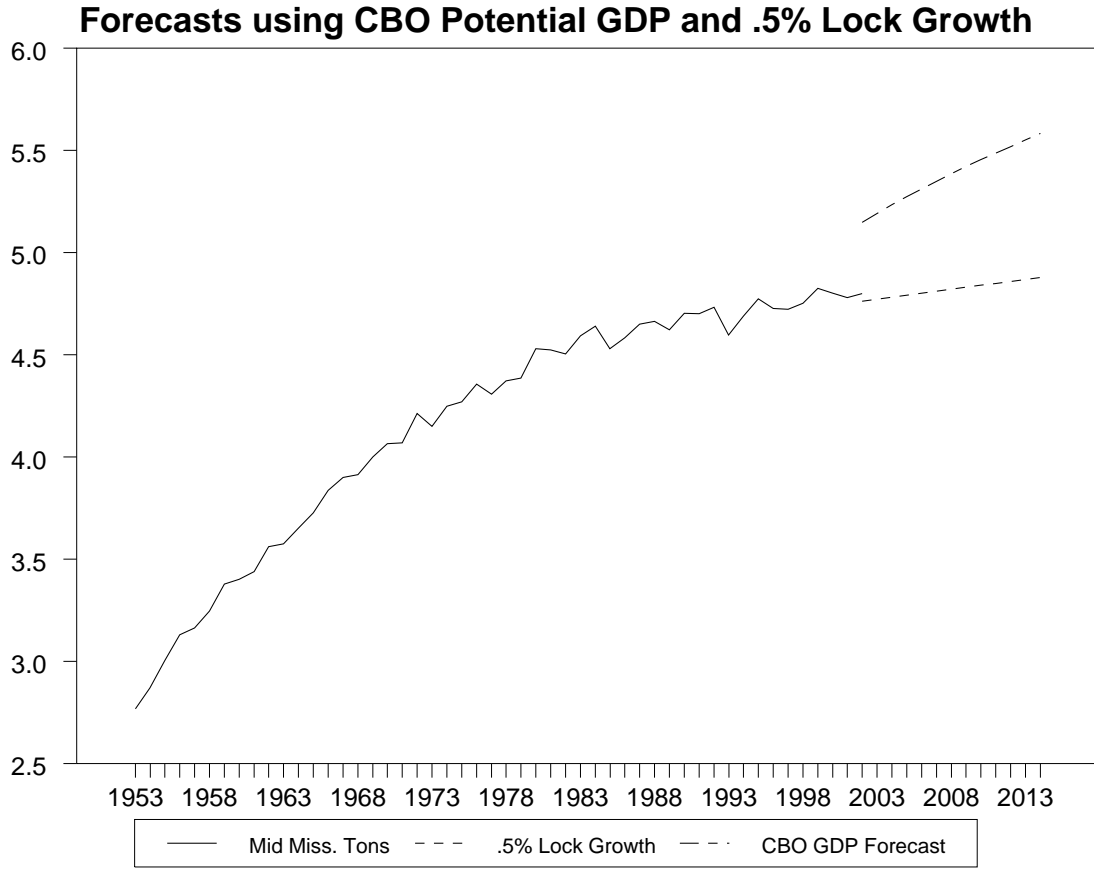
Forecasts using CBO Potential GDP and 2% Lock Growth



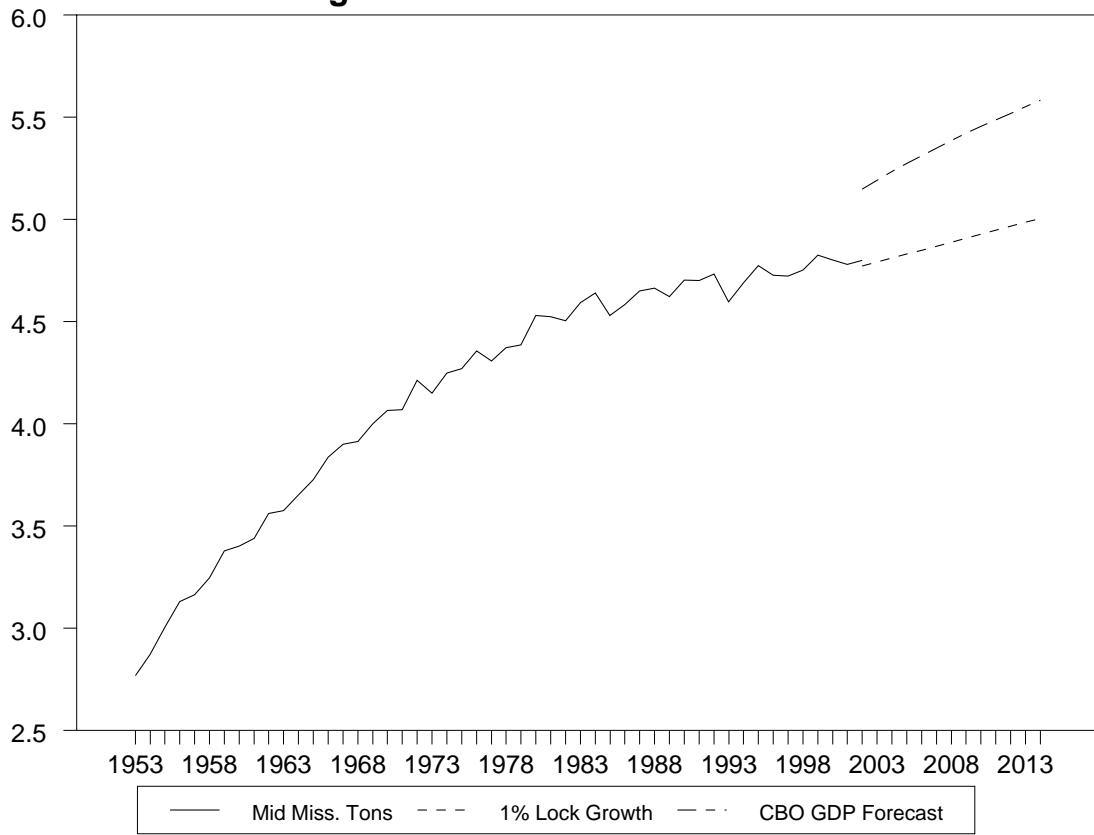
Forecasts using CBO Potential GDP and 4% Lock Growth



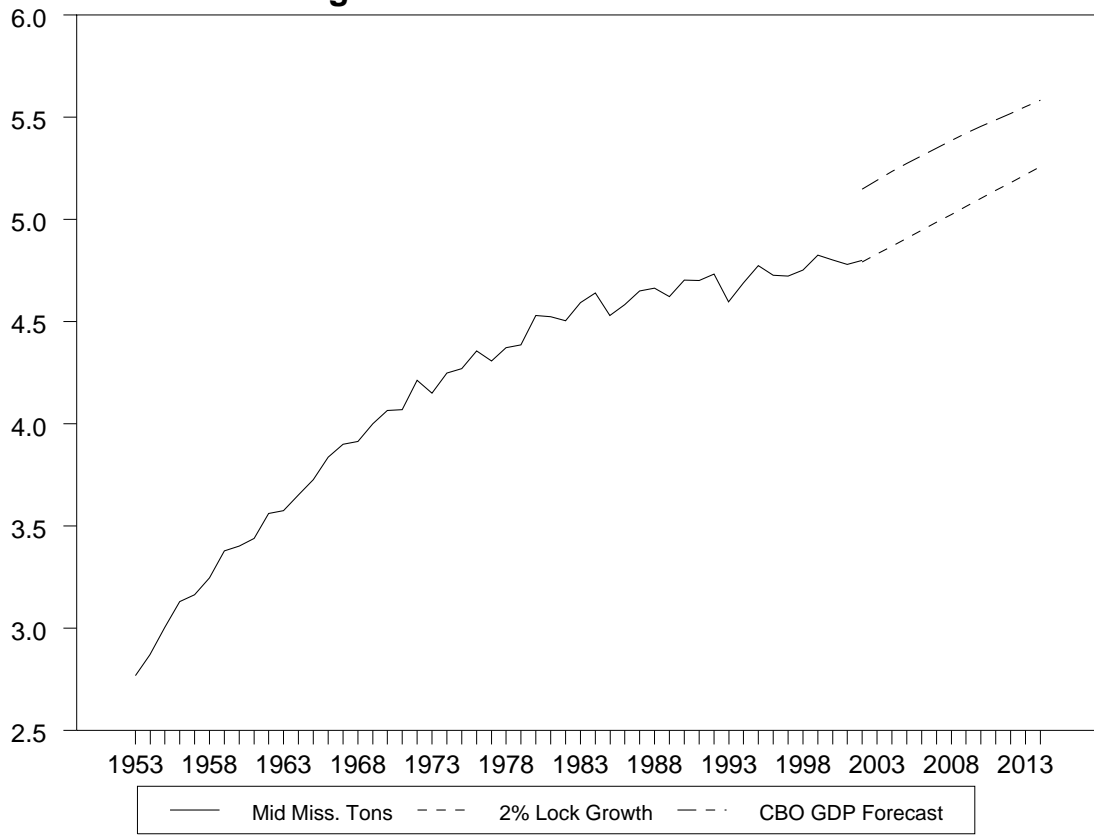
Mid Mississippi

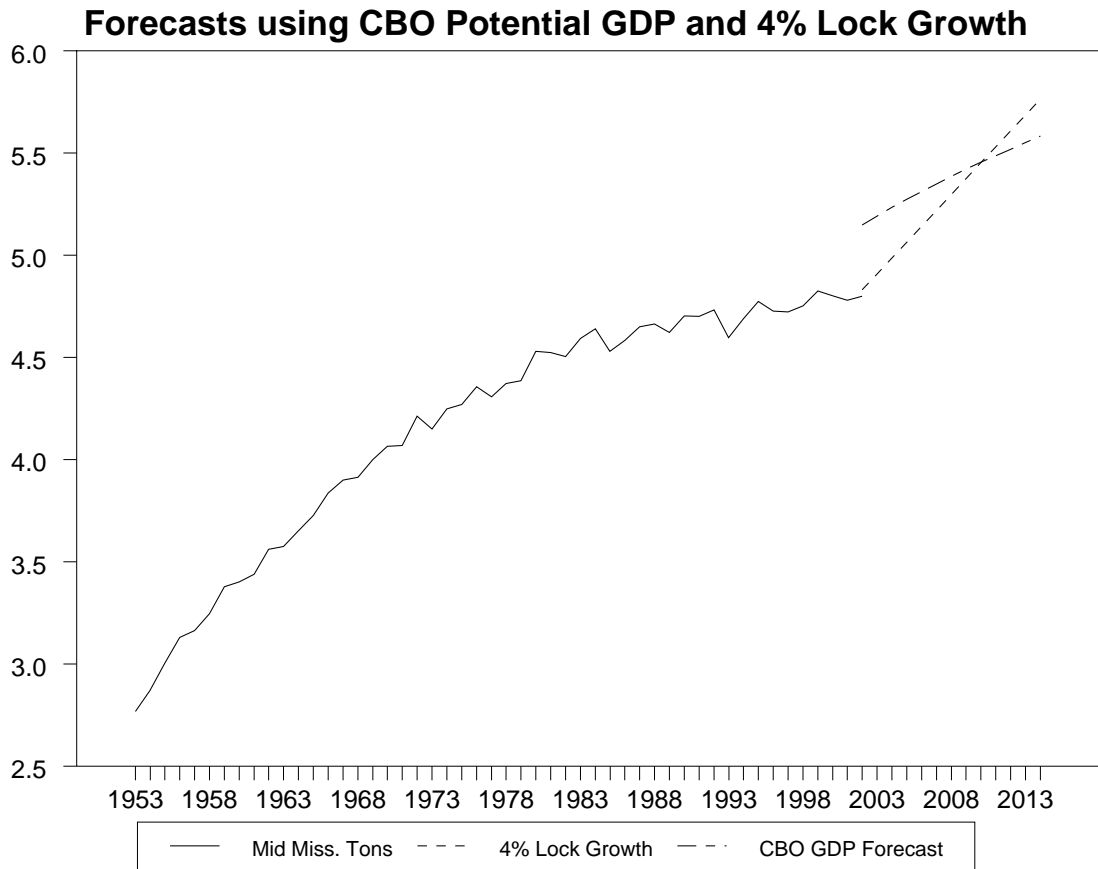


Forecasts using CBO Potential GDP and 1% Lock Growth

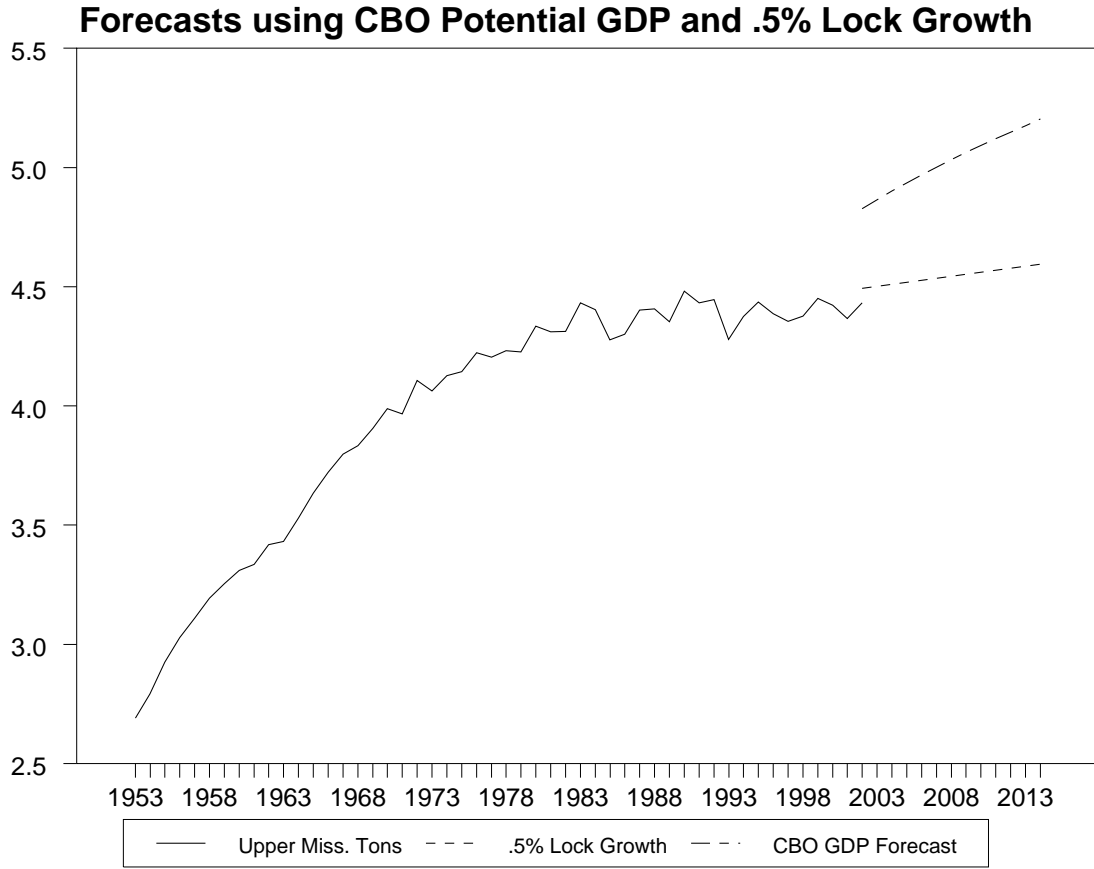


Forecasts using CBO Potential GDP and 2% Lock Growth



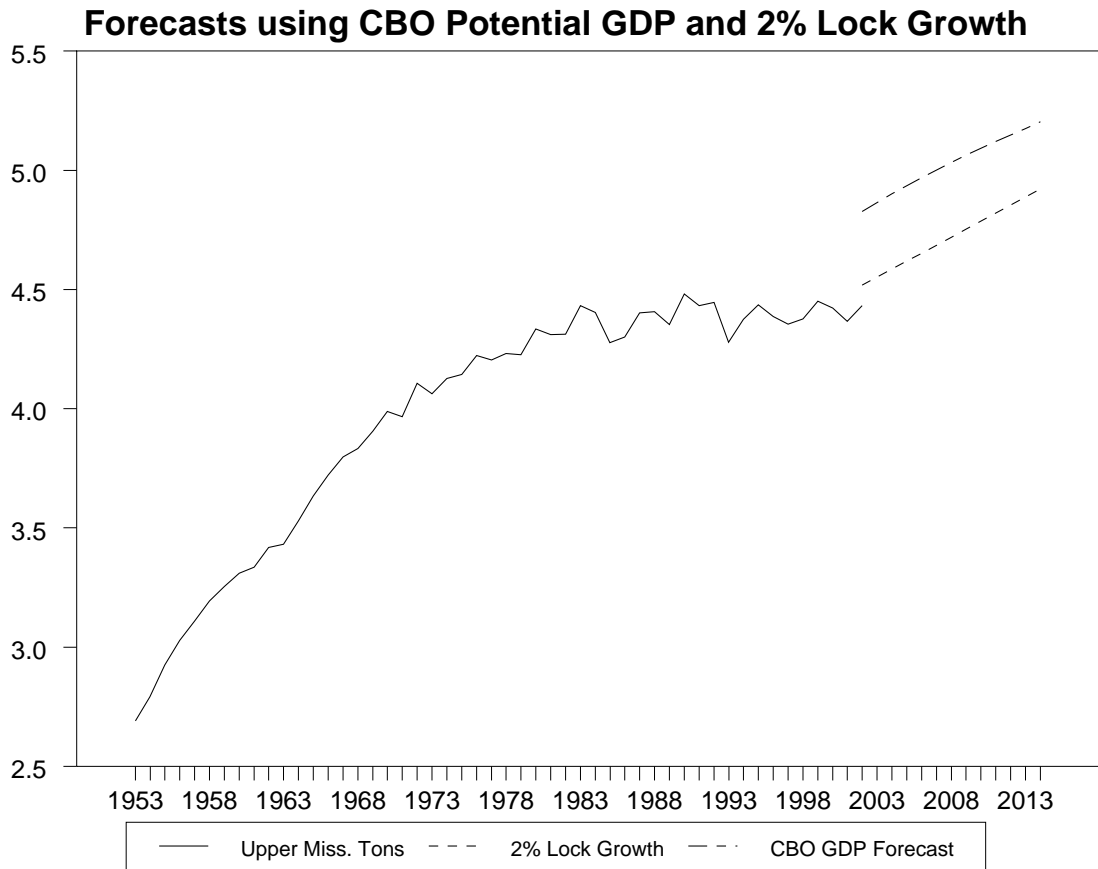


Upper Mississippi



Forecasts using CBO Potential GDP and 1% Lock Growth





Forecasts using CBO Potential GDP and 4% Lock Growth

