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Long-Run Forecasts of River Traffic on the Inland Waterway System
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by

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ABSTRACT

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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 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 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. In the second, forecasts of future variables 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 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 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 approach that avoids structural modeling of complicated real-world behavioral relationships, an approach common in the time-series econometrics literature. The approach is intended to complement existing structural based micro level forecasting models. Suppose, for example, micro level structural based econometric forecasts are made for the next fifty years for a variety of individual commodities on the middle Mississippi. The aggregate approach developed in this paper provides a gauge to assess these forecasts. By averaging the individual forecasts of the growth of river traffic, an average growth of traffic over all commodities can be obtained fairly easily. If this average agrees with the growth projections for the next fifty years

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[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.

derived from aggregate data, then this enhances the confidence in the forecasts. Using two independent approaches that incorporate data gathered independently at different levels of aggregation is a useful cross-checking device. If there is substantial disagreement between the two approaches, then this is a signal that more investigation is needed to see why the two approaches produce conflicting results.

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. The genesis of VAR models[2] arises from the idea that the exclusion restrictions used to identify 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.[3] Structural supply and demand shock can still be identified, but identification relies upon restrictions regarding contemporaneous or long-run relationships grounded in theory rather than through arbitrary exclusion restrictions. Estimation of VAR models allows the data to

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[2] 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.

[3] Thus, there are no exclusion restrictions as would exist under the structural approach.

impose exclusion and other 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 error-correction models.[4]

Many economic time-series follow random or deterministic trend processes as they move systematically upward or downward over time. GDP is an example of a variable that trends upward over time. In some cases, trending variables follow or share the same trend. When trending variables or, more precisely, integrated variables[5] move together in the long-run then the variables are said to be co-integrated. 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.[6] 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

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[4] 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.

[5] 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.

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

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. The forecasts are intended to illustrate the use of time-series data to produce forecasts using aggregate rather than micro level data. As noted in the introduction, this is useful as a means of cross-checking the average of the microeconomic structural forecasts. In addition, the model used here also illustrates the feasibility of moving to the more detailed level, e.g. forecasting wheat or coal moved on a particular segment of the river. The results obtained from the prototype aggregate investigation presented below demonstrate the model's ability to forecast effectively and suggest that similar results are feasible for specific commodities along specific stretches of rivers.[7]

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 dynamically generate out-of-sample forecasts for all variables in the model. The second uses forecasts of measured lock capacity, which is shown to be co-integrated with tons moved, to generate forecasts for tons moved.[8] Two methods are used to generate forecasts of measured lock capacity. The first assumes that lock capacity will grow according to its historical relationship to potential GDP and uses

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[7] At the time the econometric model was constructed and estimated, commodity level time-series data were not available.

[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.

forecasts of potential GDP from the Congressional Budget Office to generate forecasts of measured lock capacity. The second method assumes that 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. It is shown that a lock capacity growth of approximately 2% will allow lock capacity to grow at the same rate that GDP is projected to grow by the CBO and thus accommodate potential demand growth.

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 production[9] 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 lock capacity all move closely together and tests indicate that the three variables are co-integrated.[10] However, after 1990 industrial production begins to drift upward more quickly than lock capacity and tons moved indicating a break in the co-integrating relationship. Potential reasons for this break are examined and binding capacity constraints emerges as one explanation for this break in the relationship. Indeed,

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

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 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 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 inland waterway system as a whole.

The second 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 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 lock capacity grows at various assumed growth rates. Combining these exercises leads to the conclusion that a growth rate of approximately 2% in 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 any capacity constraints that exist.

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 system[11], total tons moved on the upper, mid, and lower Mississippi river system, lock capacity as measured by lock length and lock area for the system overall and for the Mississippi segments,[12] 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

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[11] 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.

[12] 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 capacity.

Dickey-Fuller test, the results with four autoregressive lags allowed in the testing equation (i.e. assuming the model in levels contains five lags) are

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
Mississippi Lock Length	-0.51

Critical values: 1%= -4.173 (***), 5%= -3.511 (**), and 10%= -3.185 (*).

which indicates the presence of a unit root, i.e. the null of a unit root is not rejected, in all variables listed in the table.[13]

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.[14]

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, lock capacity, and industrial production are examined first. It is helpful to begin with Figure 1 which graphs these three variables over time.

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[13] 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.

[14] Construction of potential industrial production from potential GDP and the construction of the industrial production gap are discussed below.

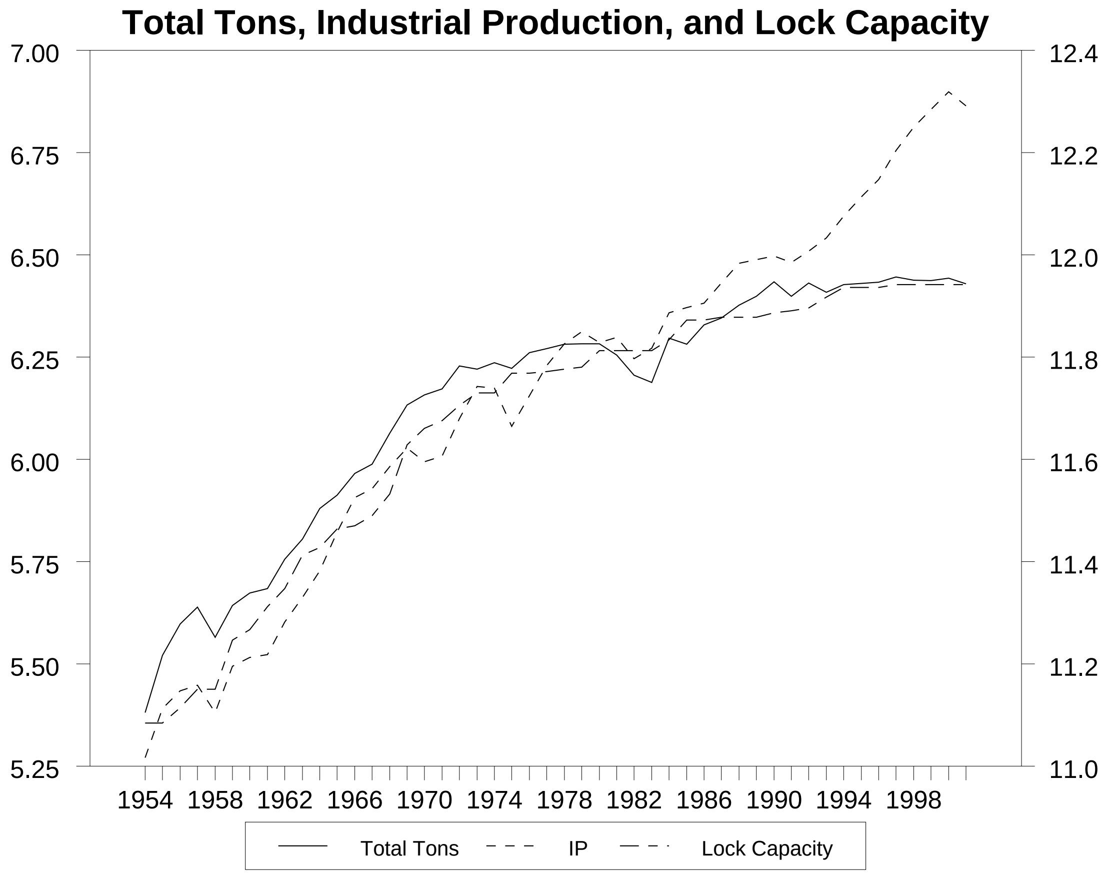

Figure 1

Two features of 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, 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.

The following table 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 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.[15] This approach yields:

Table 2

Augmented Dickey-Fuller Unit Root Tests

	Total	Upper	Mid	Lower
1953-1990				
Total Tons, IP	-2.16**	-2.27**	-1.47	-0.84
Total Tons, Capacity	-2.22**	-2.80***	-1.32	-1.14
1953-2001				
Total Tons, IP	-1.32	-0.96	-1.70*	-1.54
Total Tons, Capacity	-2.49**	-2.77***	-1.79*	-1.73*

Critical values: 1%= -2.626 (***), 5%= -1.950 (**), and 10%= -1.620 (*).

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 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 lock capacity does not. This indicates that capacity constraints

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[15] 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.

may have played a role in the departure of IP 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 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.[16]

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 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 capacity and tons moved. Thus, these results support the proposition that a more stable co-integrating relationship exists between lock capacity and total tons than between industrial production and total tons.

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

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[16] 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.

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

Error-correction models, which are used in both microeconomic and macroeconomic applications, are so named due to their ability to capture long-run equilibrium relationships while allowing short-run deviations from the long-run equilibrium conditions. The error-correction term in the model corrects a proportion of any deviation from the long-run equilibrium each period so that in the long-run the equilibrium relationship is maintained. Thus, the error-correction model used below captures the tendency of river traffic to move to equilibrium in the long-run, but allows for deviations from the long-run relationship due to changes in supply and demand changes at particular points in time. In general, structural based microeconomic forecasting models are not as general in that such models require that all markets be in equilibrium at all points in time, a potentially restrictive assumption. Error-correction models allow all market to clear continuously as a special case, but allow for more general short-run behavior as well.

Changes in supply and demand conditions are captured by the variables used in the error-correction model. The variables used are total tons moved, measured lock capacity, and the industrial production gap. The lock capacity measurement captures supply-side considerations. Changes in measured lock capacity are interpreted as supply shocks within the model. The gap captures and efficiently summarizes demand conditions. For example, suppose there is an increase in foreign demand for grain exports from the U.S. coupled with a decline in domestic demand for coal. The gap variable effectively summarizes the net impact of these offsetting effects on demand.

Since it is the net impact of all the underlying microeconomic influences that determines variables such as aggregate river traffic, a summary measure of demand is useful. In addition, the particular form of the variable used in the econometric model has strong theoretical foundations. Deviations of GDP and IP from potential are, by definition, due to demand side influences and the gap variable is a summary measure of demand-side conditions.

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 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 waterway 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.[17]

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[17] 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 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.

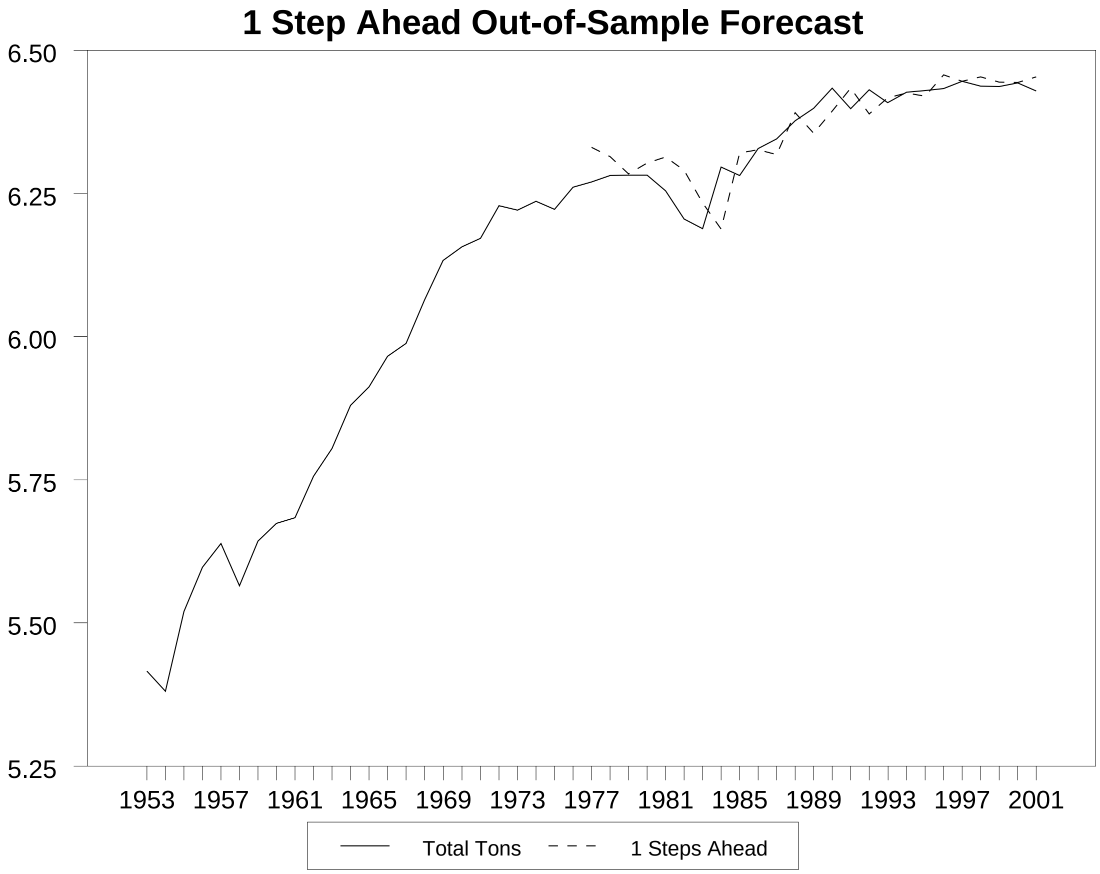

1 Step Ahead Out-of-Sample Forecast
6.50
6.25
6.00
5.75
5.50
5.25
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Total Tons
1 Steps Ahead

Figure 2

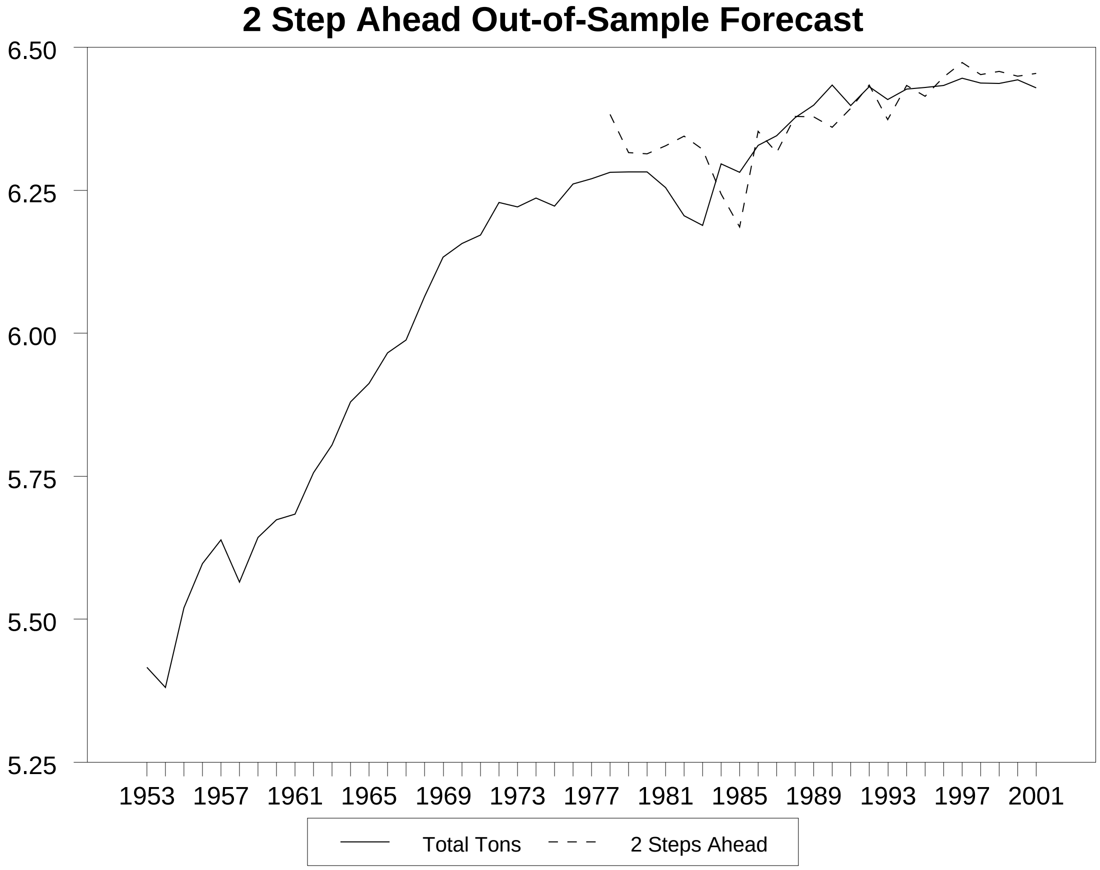

2 Step Ahead Out-of-Sample Forecast
6.50
6.25
6.00
5.75
5.50
5.25
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Total Tons
2 Steps Ahead

Figure 3

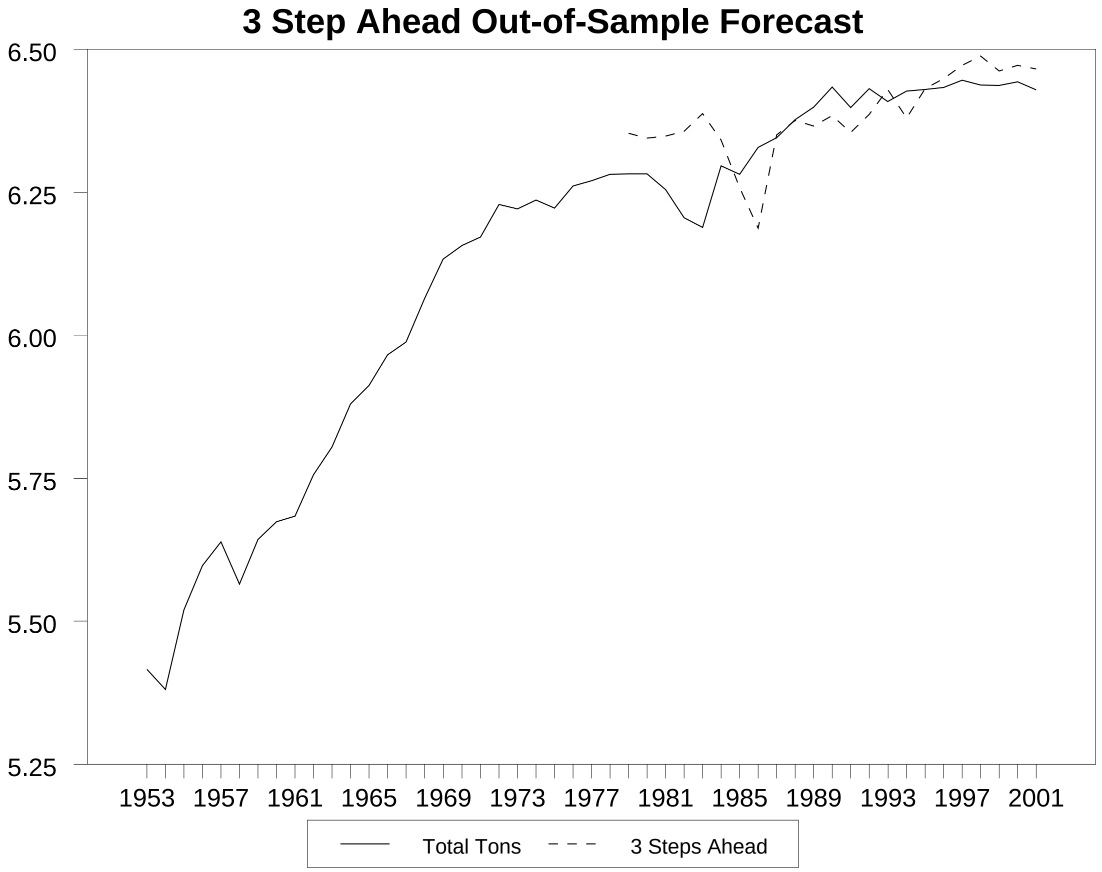

3 Step Ahead Out-of-Sample Forecast
6.50
6.25
6.00
5.75
5.50
5.25
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Total Tons
3 Steps Ahead

Figure 4

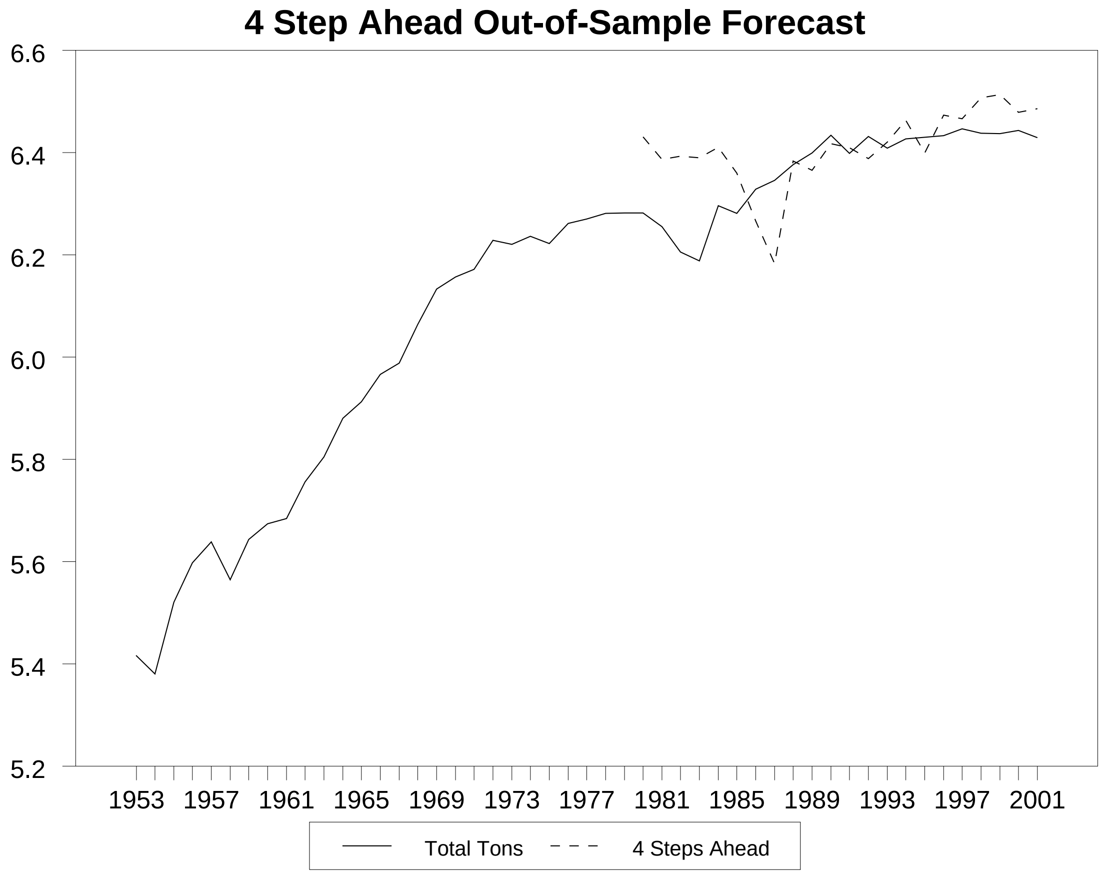

4 Step Ahead Out-of-Sample Forecast
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Total Tons
4 Steps Ahead

Figure 5

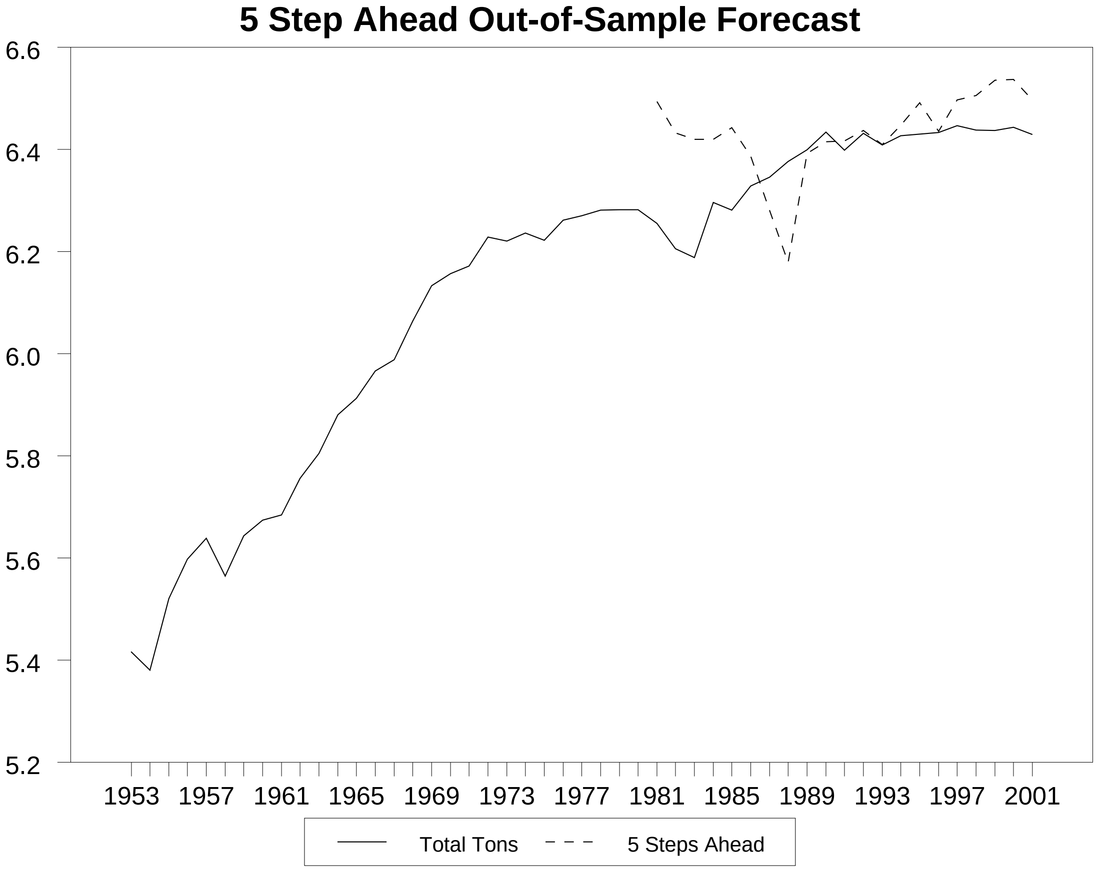
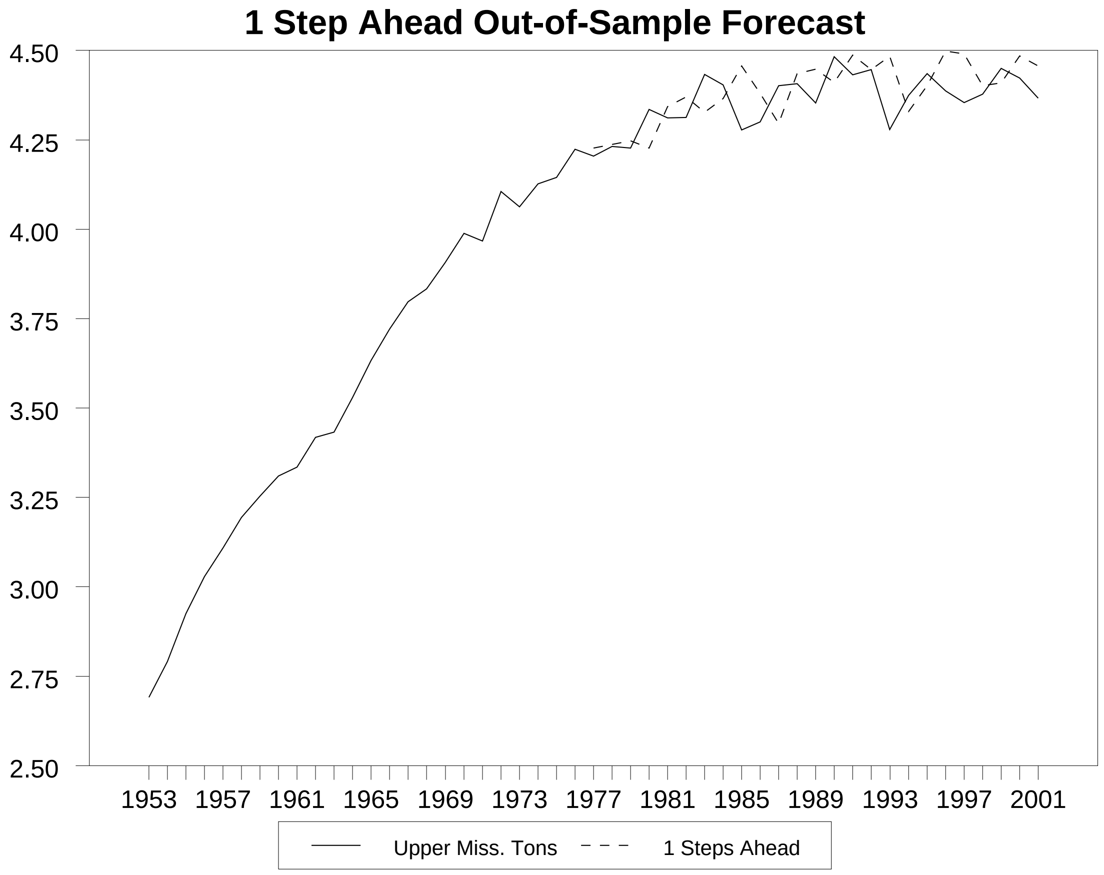


Figure 6

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 a few years ahead, perhaps as many as three, are close to the actual values. Beyond horizons of a few years, the forecasts become increasingly unreliable, though even at five years they remain fairly accurate. Forecasts at one and three years from Appendix A for the three river segments are shown in Figures 7-12.


1 Step Ahead Out-of-Sample Forecast
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
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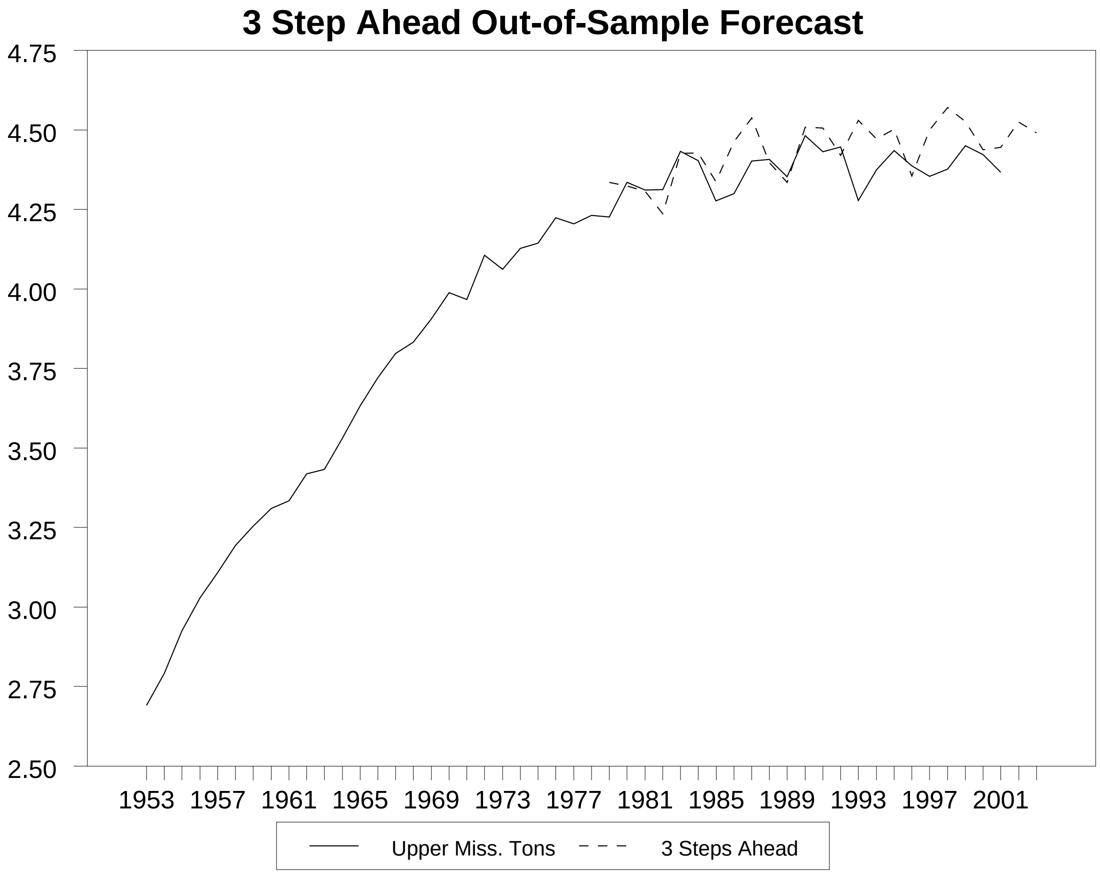
1989
1993
1997
2001
Upper Miss. Tons
1 Steps Ahead

Figure 7


3 Step Ahead Out-of-Sample Forecast
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
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1953
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1993
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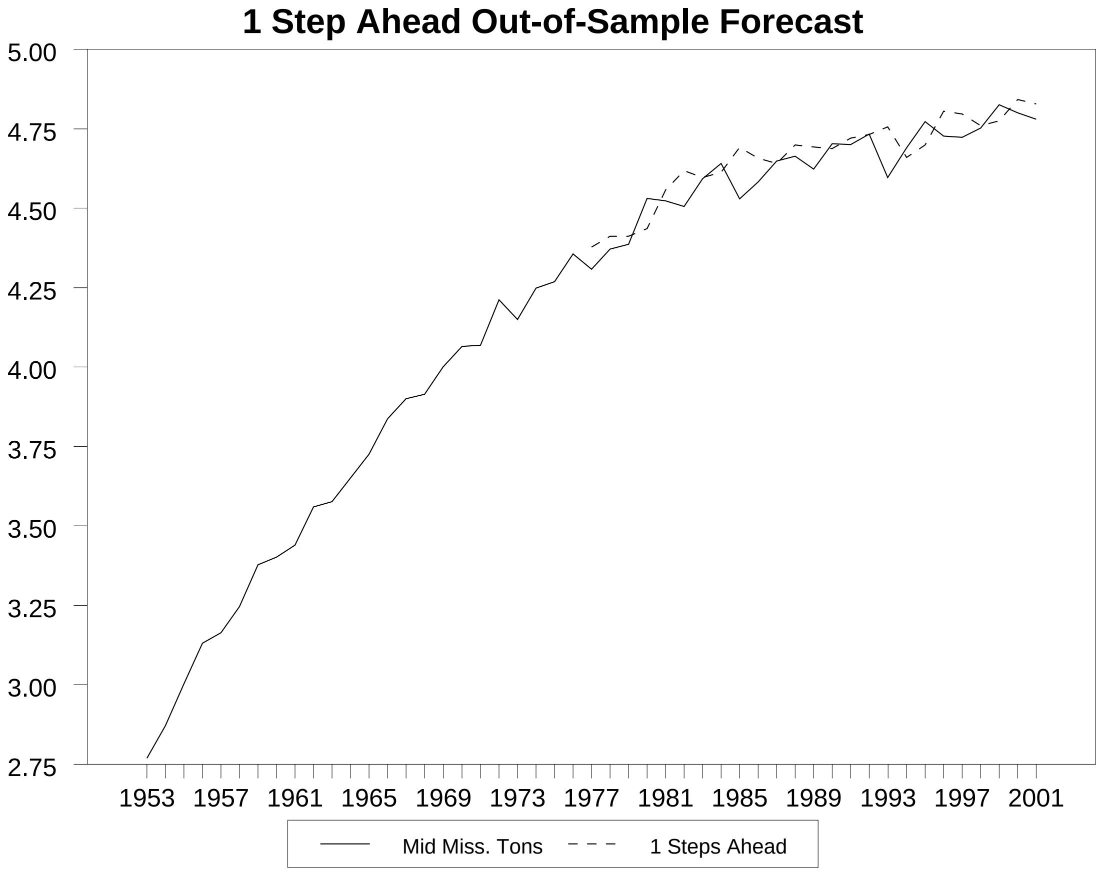
2001
Upper Miss. Tons
3 Steps Ahead

Figure 8


1 Step Ahead Out-of-Sample Forecast
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
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1977
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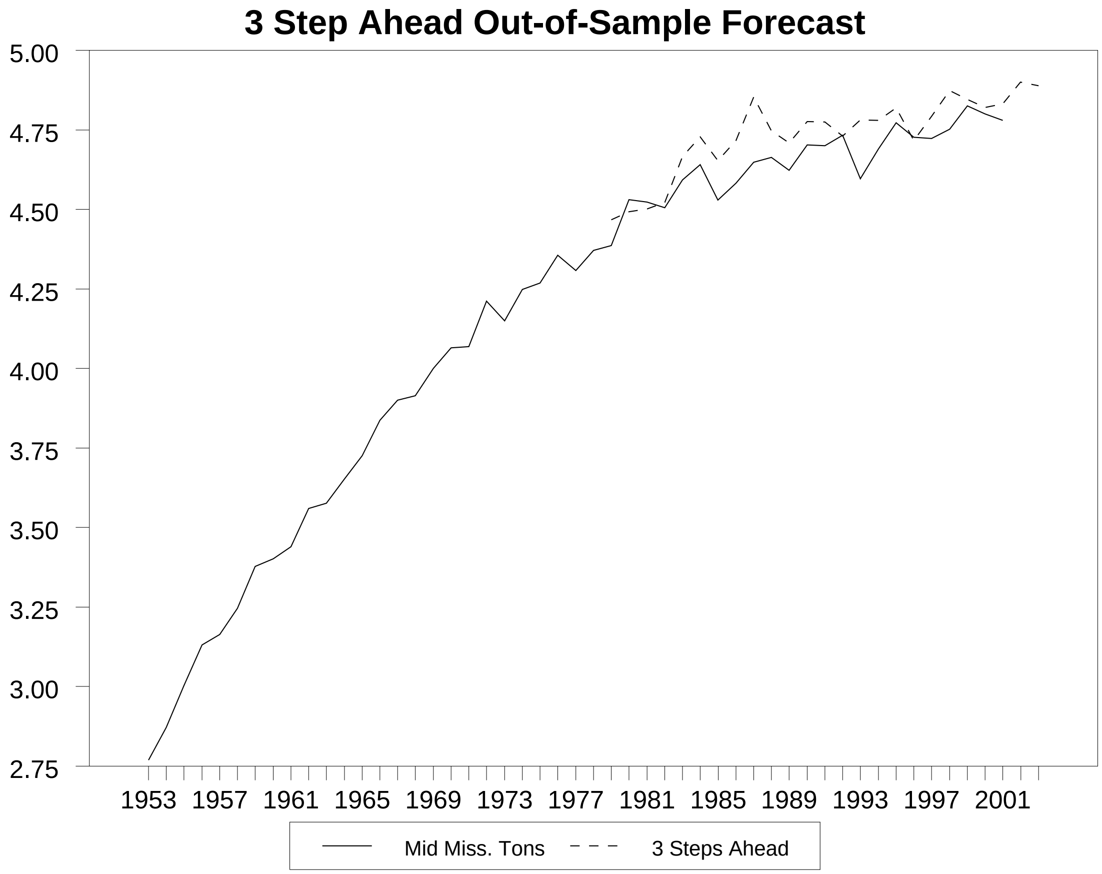
1989
1993
1997
2001
Mid Miss. Tons
1 Steps Ahead

Figure 9


3 Step Ahead Out-of-Sample Forecast
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
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1981
1985
1989
1993
1997
2001
Mid Miss. Tons
3 Steps Ahead

Figure 10

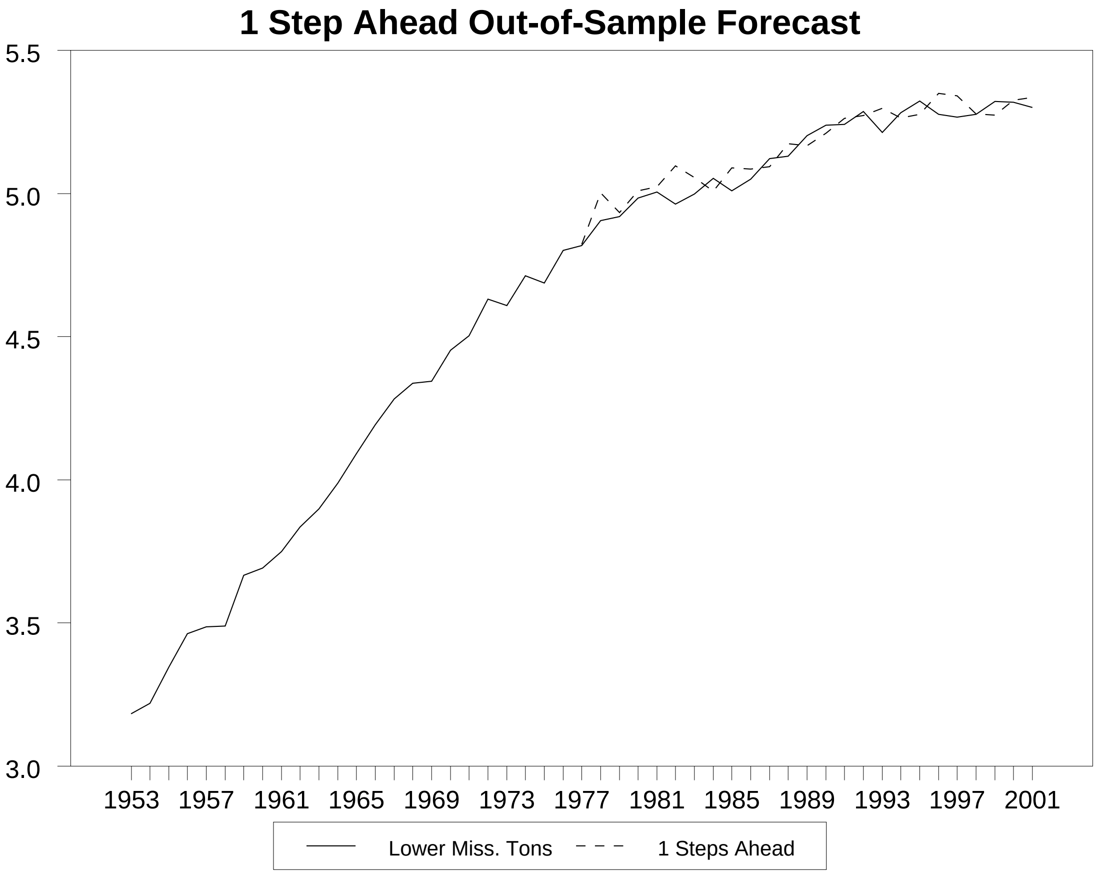
1 Step Ahead Out-of-Sample Forecast
5.5
5.0
4.5
4.0
3.5
3.0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Lower Miss. Tons
1 Steps Ahead

Figure 11

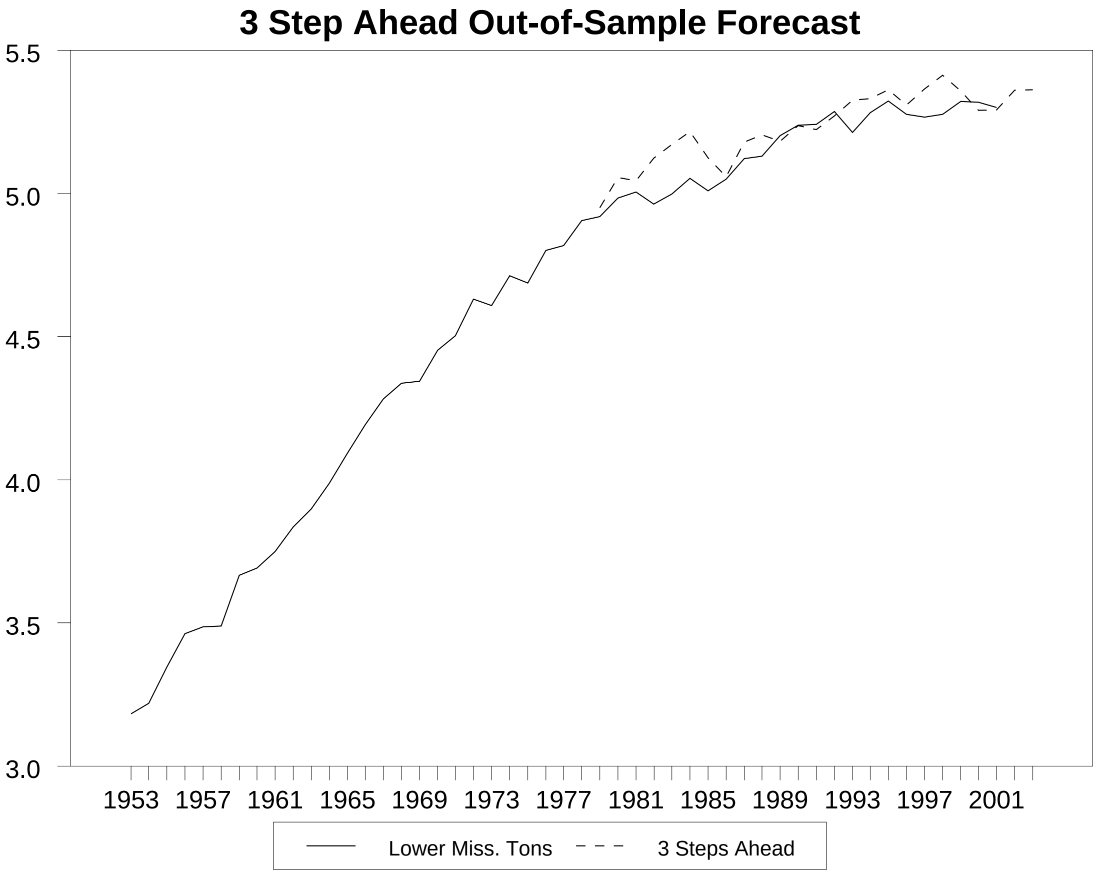

Figure 12

Long-Run Forecasts from the Error-Correction Model

Long-run forecasts up to fifty years ahead are obtained from the estimated error-correction model for total tons moved, and for the three river segments. The results of this exercise are presented in Figures 13-16.

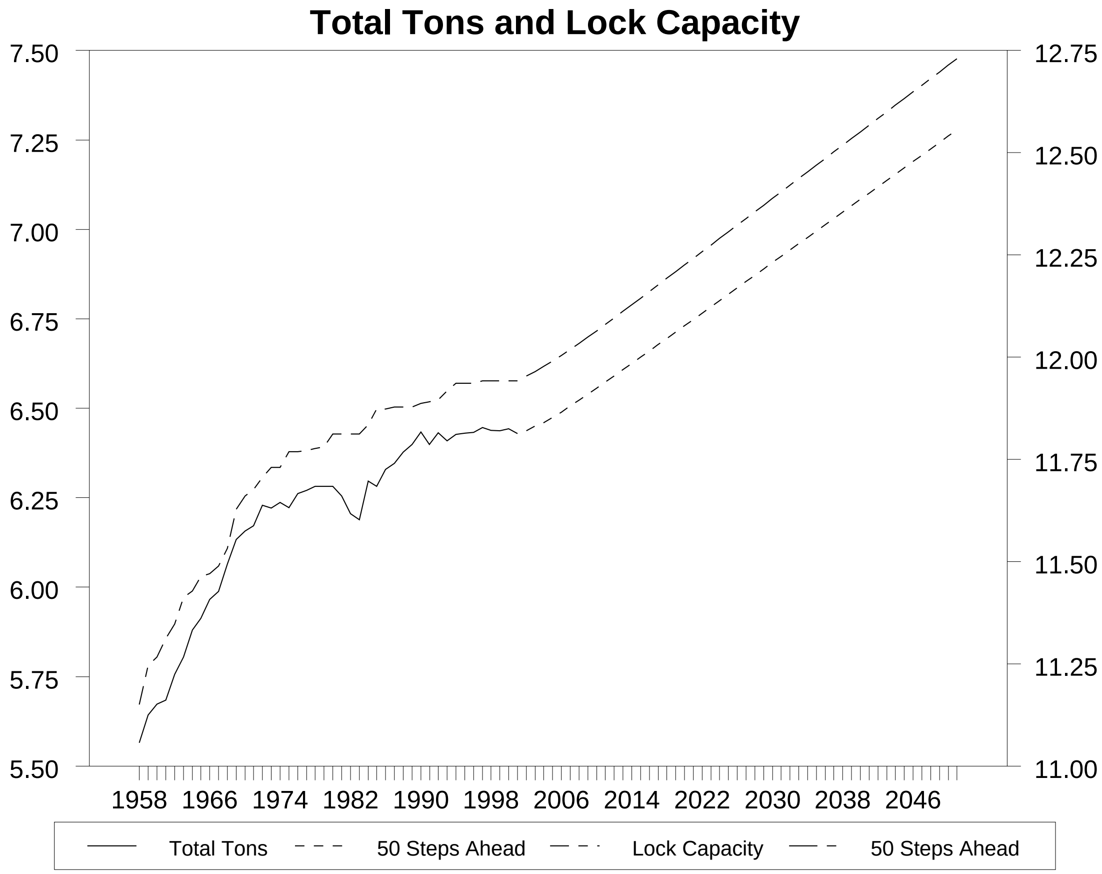
Total Tons and Lock Capacity
7.50
7.25
7.00
6.75
6.50
6.25
6.00
5.75
5.50
12.75
12.50
12.25
12.00
11.75
11.50
11.25
11.00
1958
1966
1974
1982
1990
1998
2006
2014
2022
2030
2038
2046
Total Tons
50 Steps Ahead
Lock Capacity
50 Steps Ahead

Figure 13

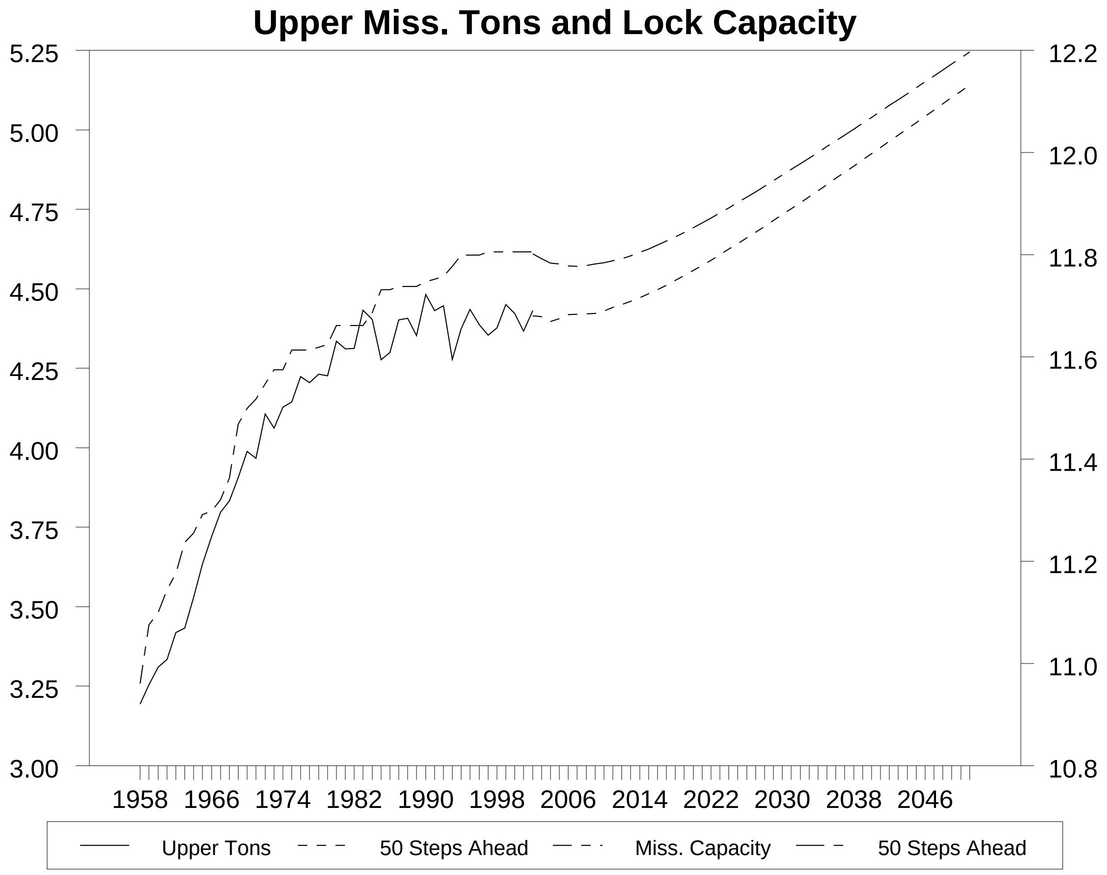
Upper Miss. Tons and Lock Capacity
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
12.2
12.0
11.8
11.6
11.4
11.2
11.0
10.8
1958
1966
1974
1982
1990
1998
2006
2014
2022
2030
2038
2046
Upper Tons
50 Steps Ahead
Miss. Capacity
50 Steps Ahead

Figure 14

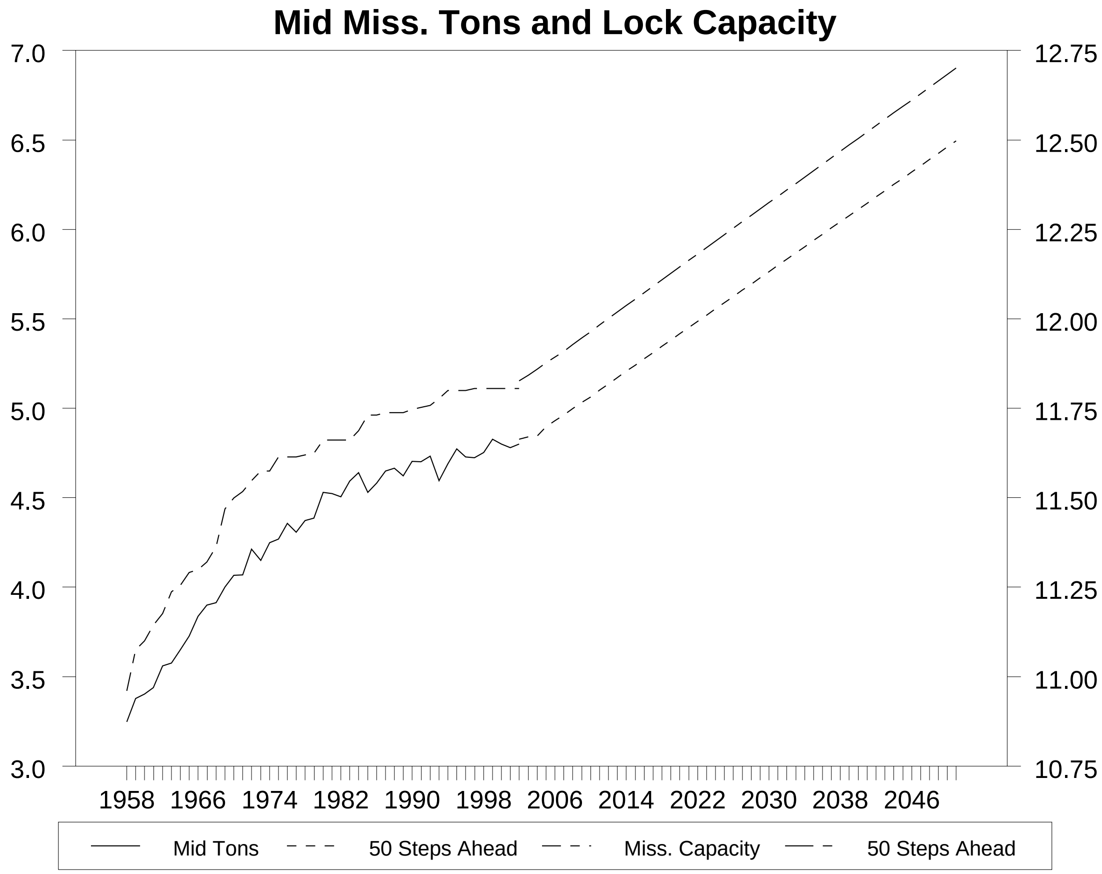
Mid Miss. Tons and Lock Capacity
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
12.75
12.50
12.25
12.00
11.75
11.50
11.25
11.00
10.75
1958
1966
1974
1982
1990
1998
2006
2014
2022
2030
2038
2046
Mid Tons
50 Steps Ahead
Miss. Capacity
50 Steps Ahead

Figure 15

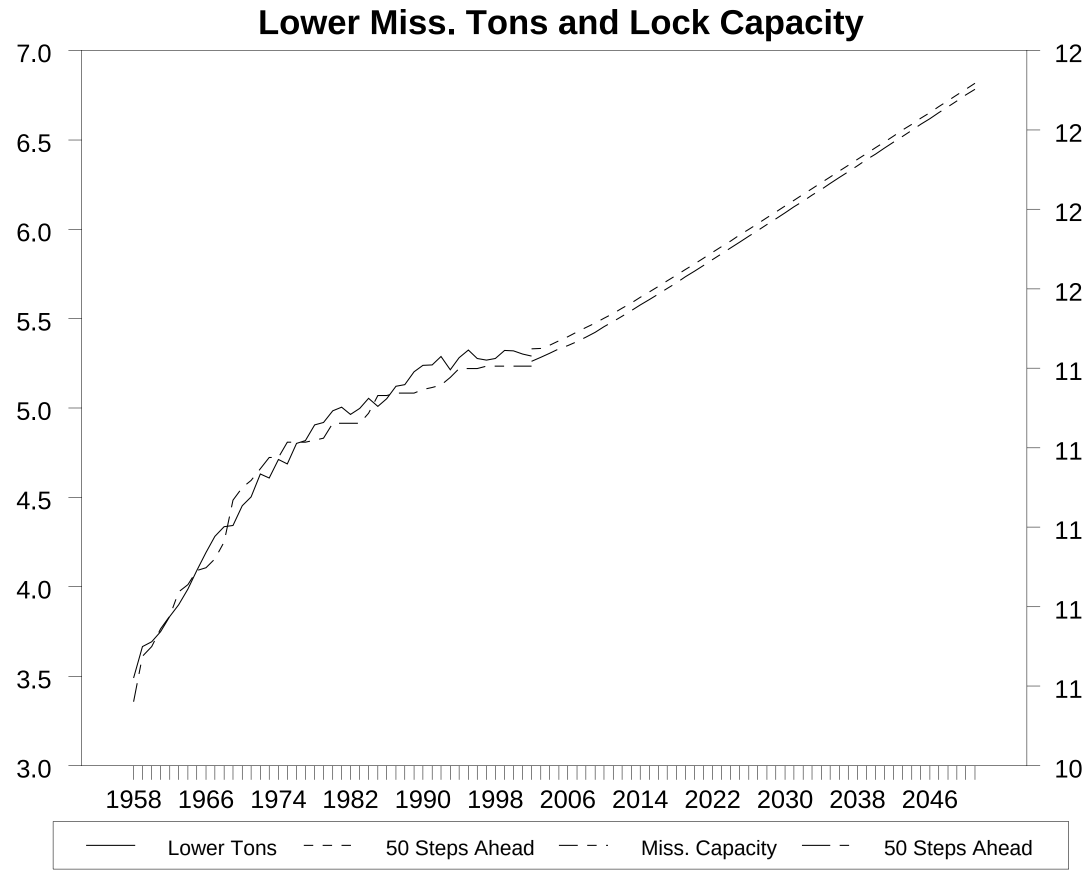

Figure 16

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. Thus, growth rates are projected to about twice as large for the lower and mid Mississippi as compared to the upper Mississippi and compared to the system as a whole.

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 total tons moved or industrial production. Thus, the long-run forecast of the gap is zero. 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 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

$$IP_t = \alpha + \alpha_1 PotentialGDP_t + e_t$$

and then using the estimates to forecast potential IP through 2014, the last period for which CBO estimates of potential GDP exist.[18] 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

$$Capacity_t = \beta_0 + \beta_1 PotIP_t + v_t$$

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 is a measure of the effect of capacity constraints on tons moved.

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[18] 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.

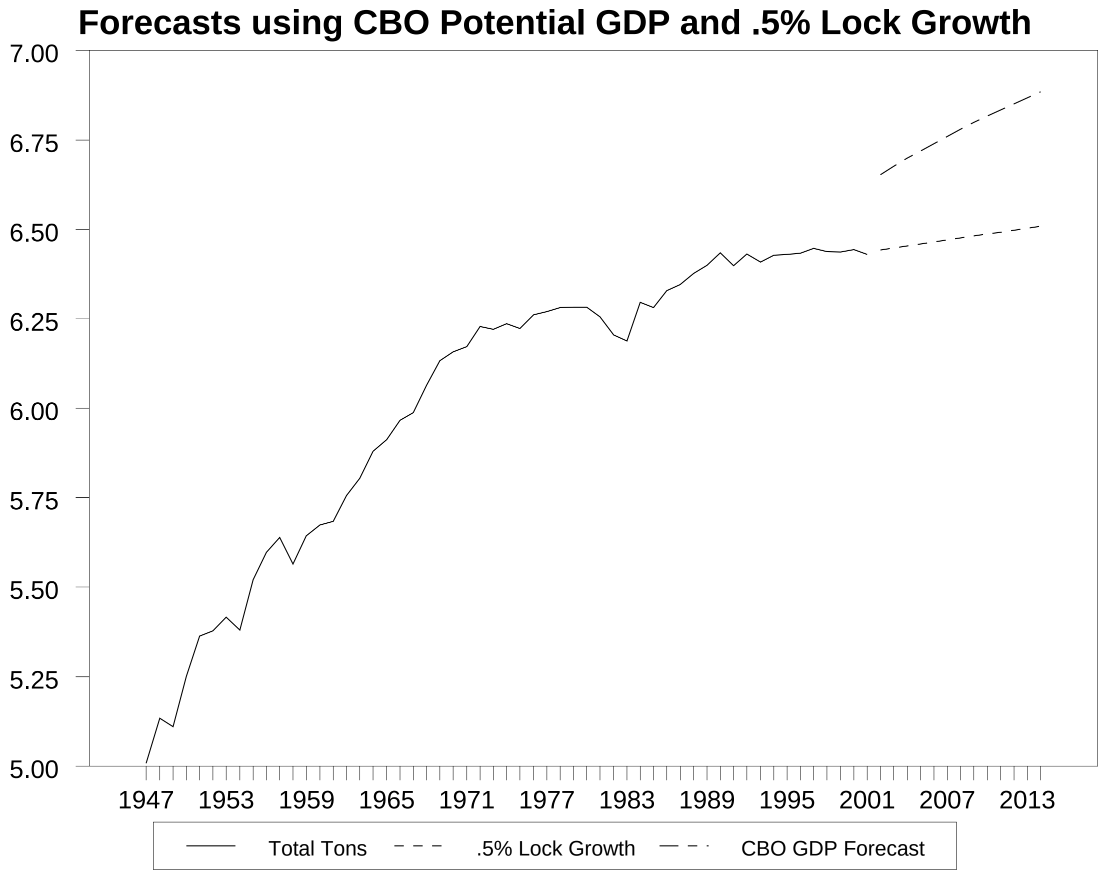

Forecasts using CBO Potential GDP and .5% Lock Growth
7.00
6.75
6.50
6.25
6.00
5.75
5.50
5.25
5.00
1947
1953
1959
1965
1971
1977
1983
1989
1995
2001
2007
2013
Total Tons
.5% Lock Growth
CBO GDP Forecast

Figure 17

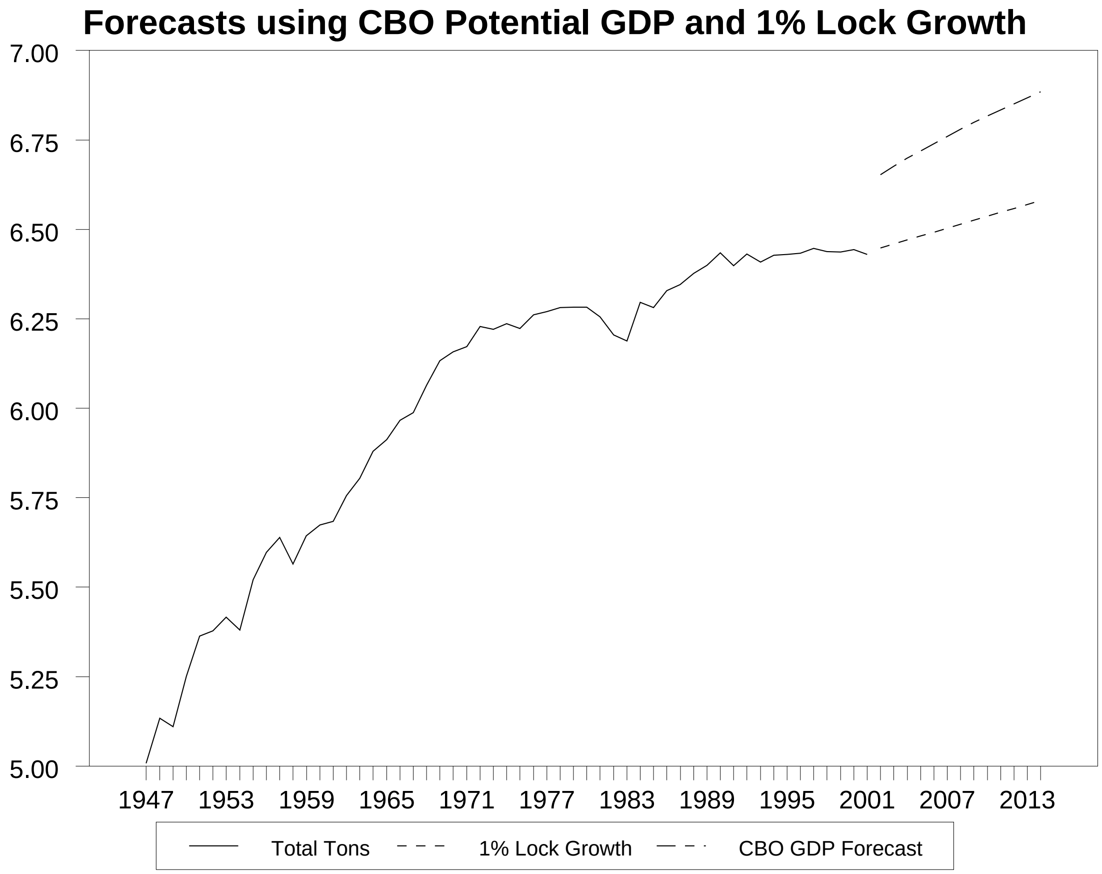

Forecasts using CBO Potential GDP and 1% Lock Growth
7.00
6.75
6.50
6.25
6.00
5.75
5.50
5.25
5.00
1947
1953
1959
1965
1971
1977
1983
1989
1995
2001
2007
2013
Total Tons
1% Lock Growth
CBO GDP Forecast

Figure 18

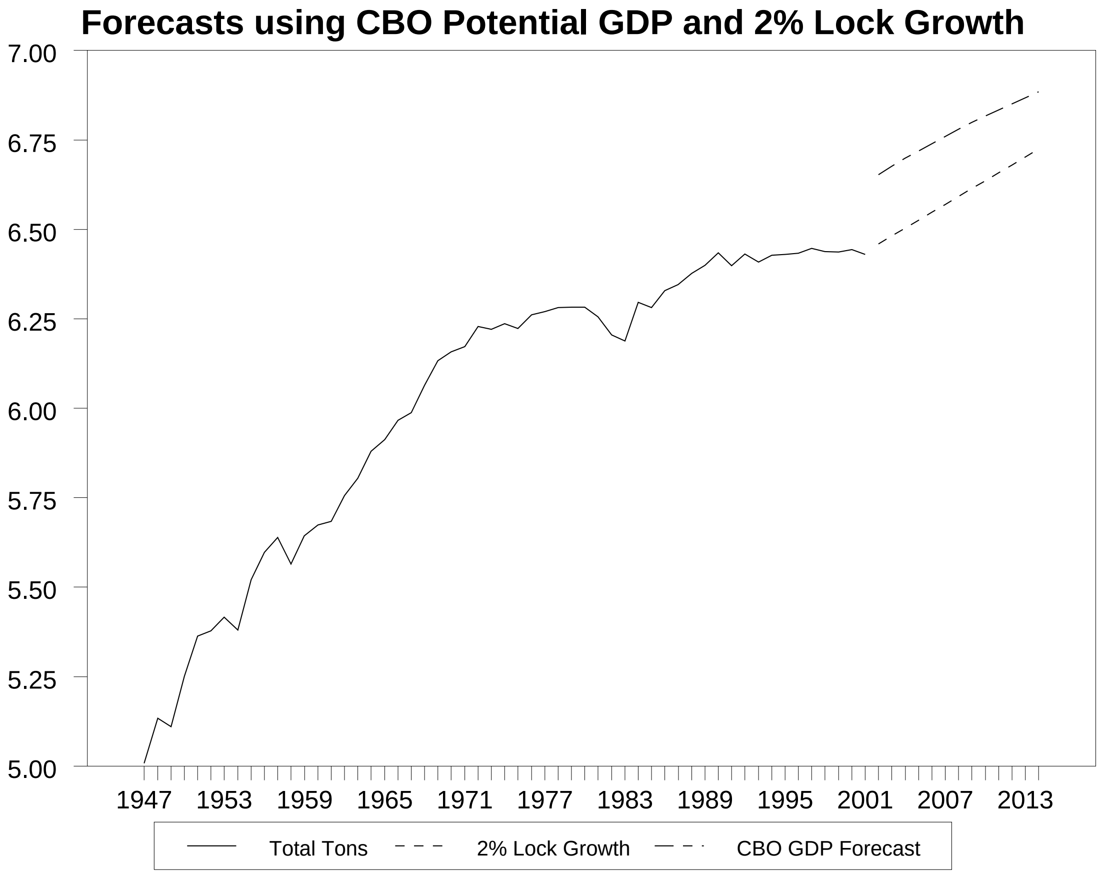

Forecasts using CBO Potential GDP and 2% Lock Growth
7.00
6.75
6.50
6.25
6.00
5.75
5.50
5.25
5.00
1947
1953
1959
1965
1971
1977
1983
1989
1995
2001
2007
2013
Total Tons
2% Lock Growth
CBO GDP Forecast

Figure 19

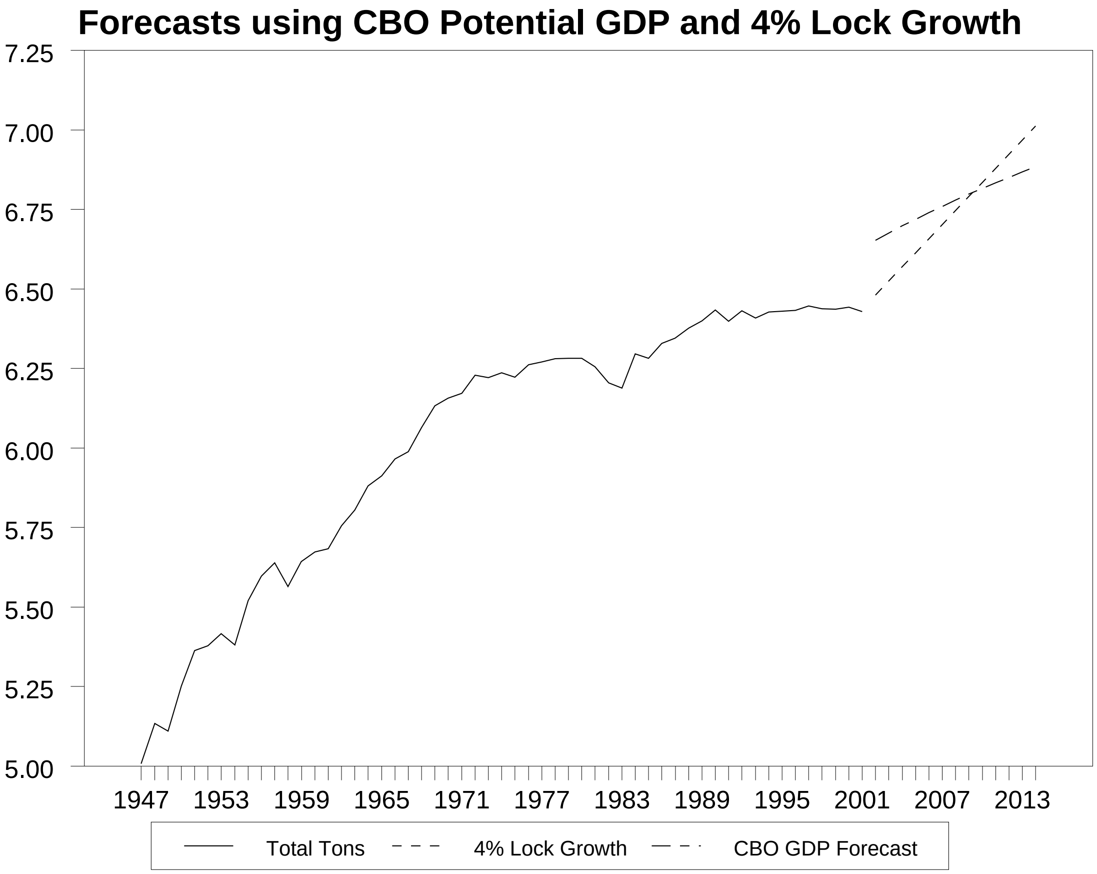


Figure 20

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,[19] 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 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,

---

[19] When counting the number of years, recall that the sample ends n 2001.

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.

The econometric model and results presented above have several uses. First, the approach complements structural based detailed microeconomic forecasts. The average of the micro forecasts derived by other researchers using different models and data should agree with the forecasts for river traffic growth derived from the more aggregative time-series approach illustrated in this paper. The process used to produce aggregate data, weighted averaging, can eliminate noise in the underlying data thereby sharpening forecasts. If the two sets of forecasts are similar, confidence in both is increased. If there is substantial disagreement in the two sets of forecasts, then that is a signal that more investigation is needed.

Second, the model presented above is intended to illustrate the methodology for extending the results to more disaggregated levels. For example, instead of total tons of all commodities moved, the variable used in the model could be total grain moved on a particular segment of a river. Forecasts from this model could then be used as an independent means to cross-check the average of micro based forecasts of grain movement for the same region of the river, i.e. the average for wheat, corn, and so on.

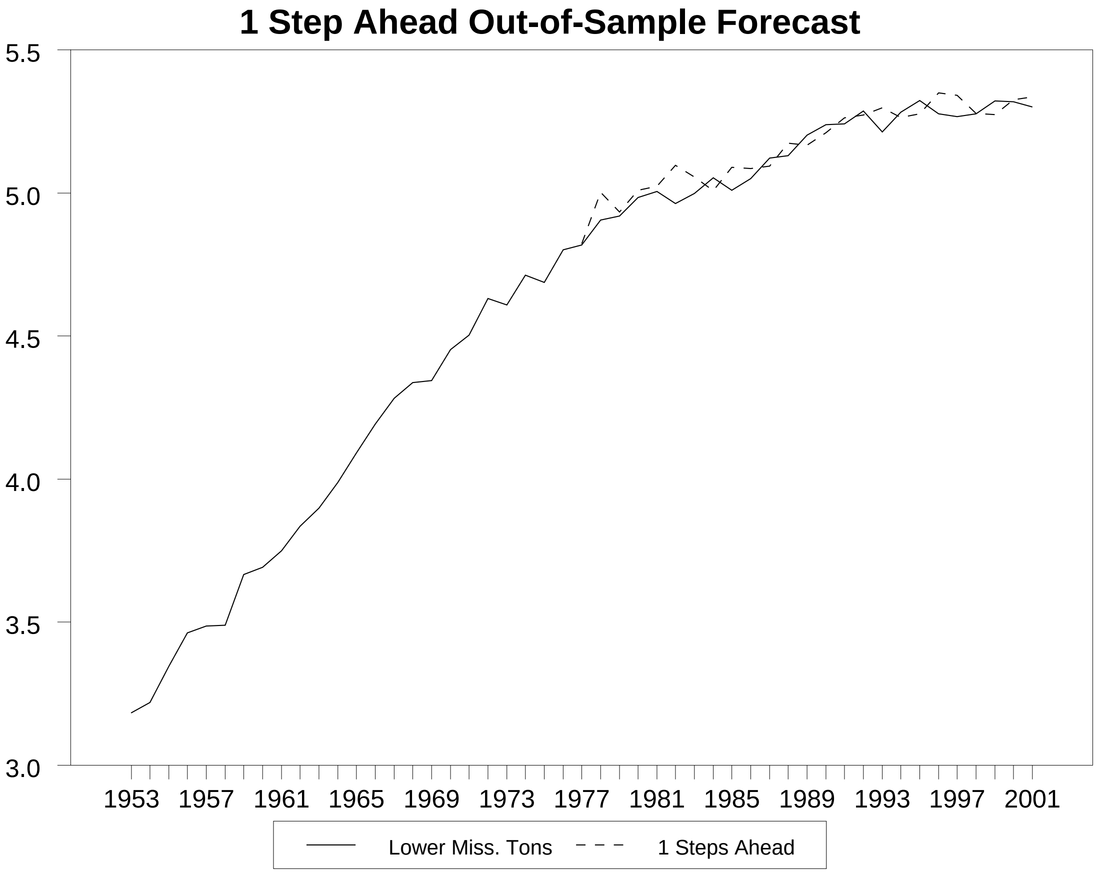
Third, the error-correction model allows deviations from equilibrium relationships in the short-run, but insists that such relationships hold in the long-run. Thus, in the short-run, these models are more general than their standard microeconomic counterparts where markets are modeled as continuously in equilibrium. While such behavior is possible in error-correction models, i.e. nothing prevents equilibrium at every point in time, other more general possibilities are also allowed.

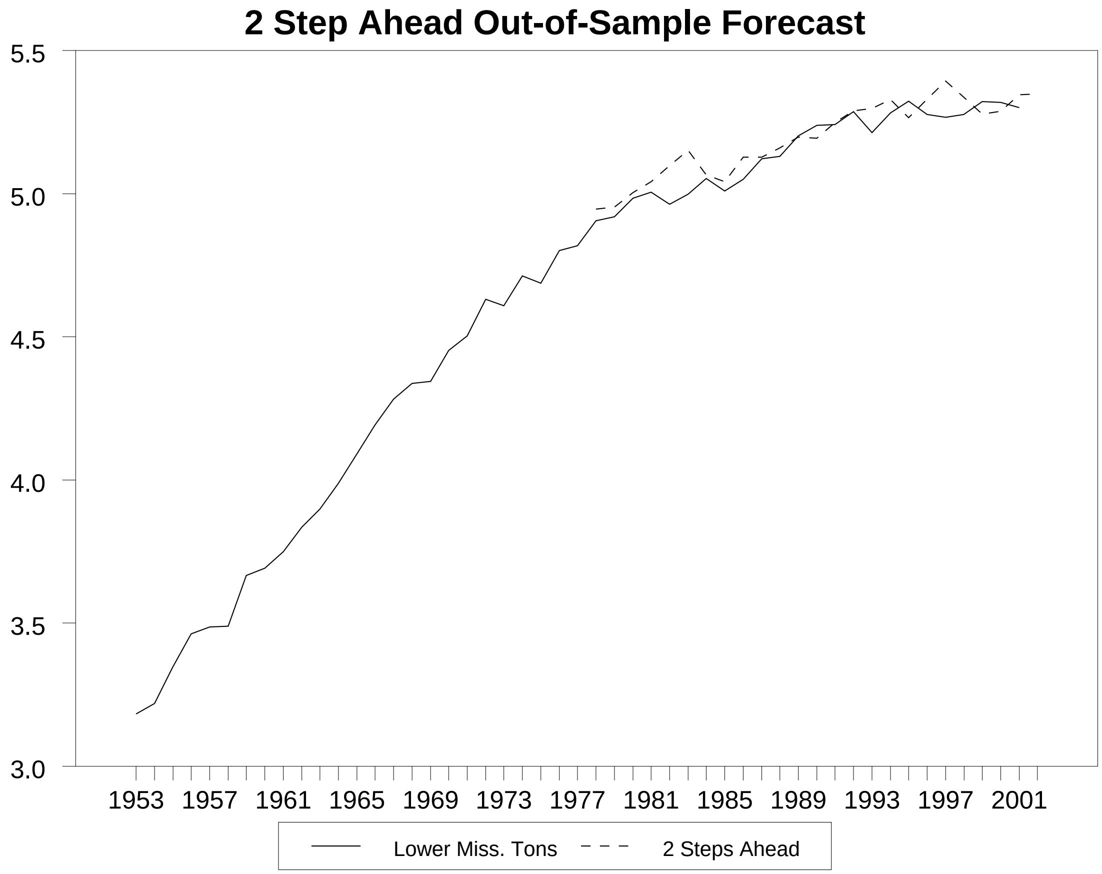
Fourth, the models do not require that forecasts of other variables be used as inputs. Unlike most structural based micro models, forecasts of future variables can be generated endogenously from within the model. There is no need to forecast the variables separately. However, as noted and illustrated in the presentation in this paper, by using the estimated co-integrating relationship among the variables, it is still possible to use independent forecasts as inputs if such an approach is desired. For example, forecasts of industrial production derived from CBO estimates of GDP growth are used to forecast river traffic in the results presented above.

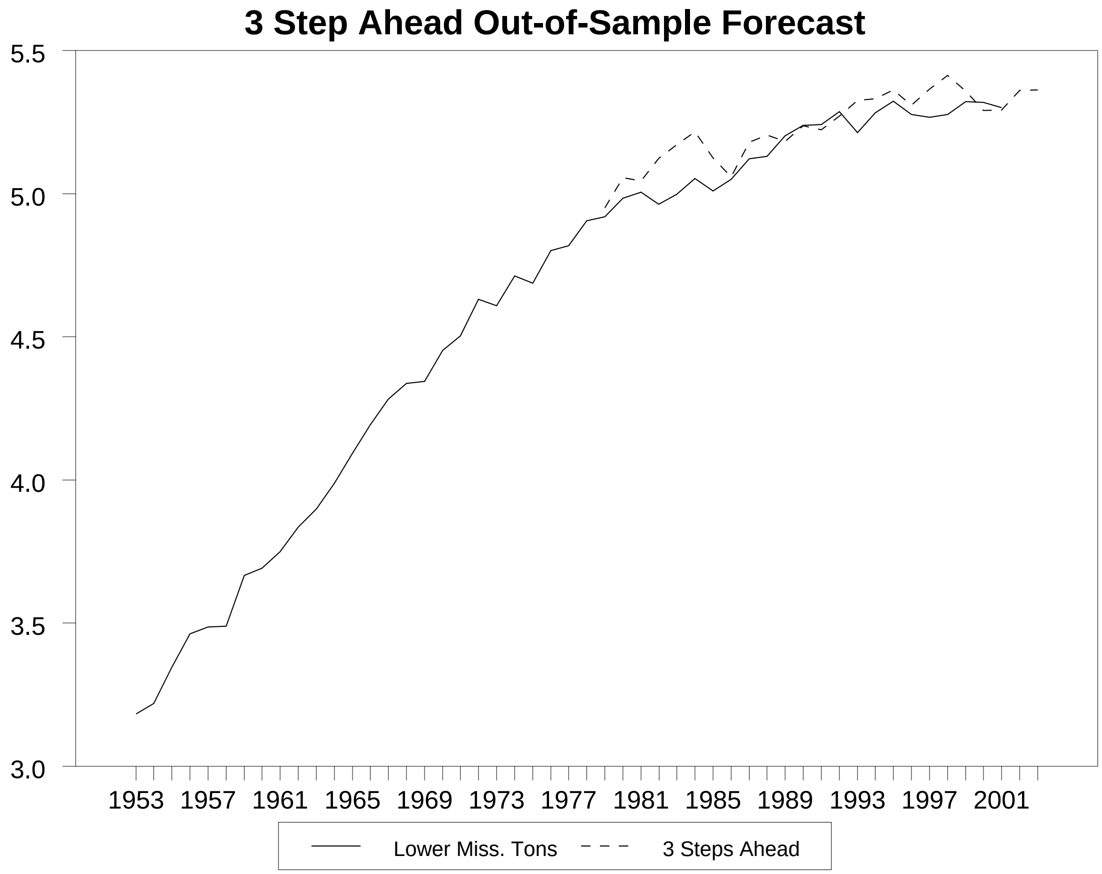
APPENDIX A

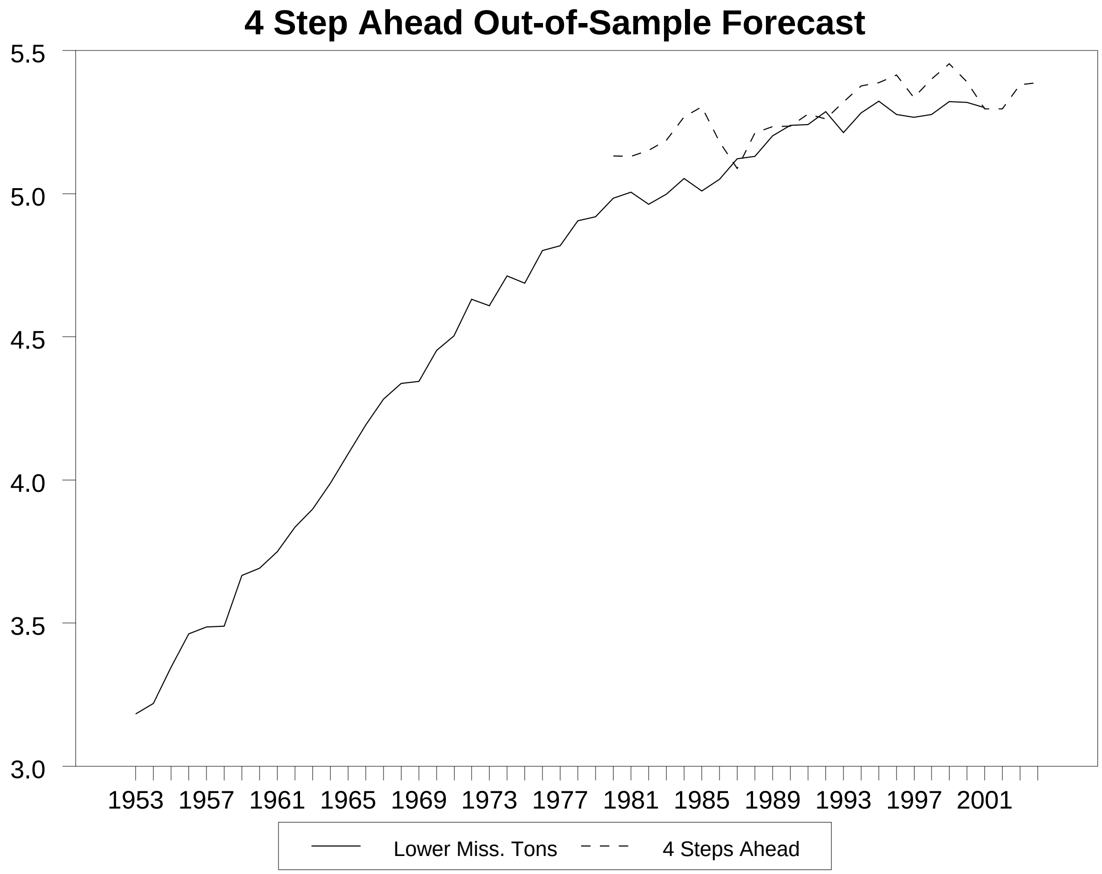
Out-of-Sample Forecasts at the 1, 2, 3, 4, and 5, Year Horizons based upon the Estimated Error-Correction Model for the Upper, Mid, and Lower Mississippi River System

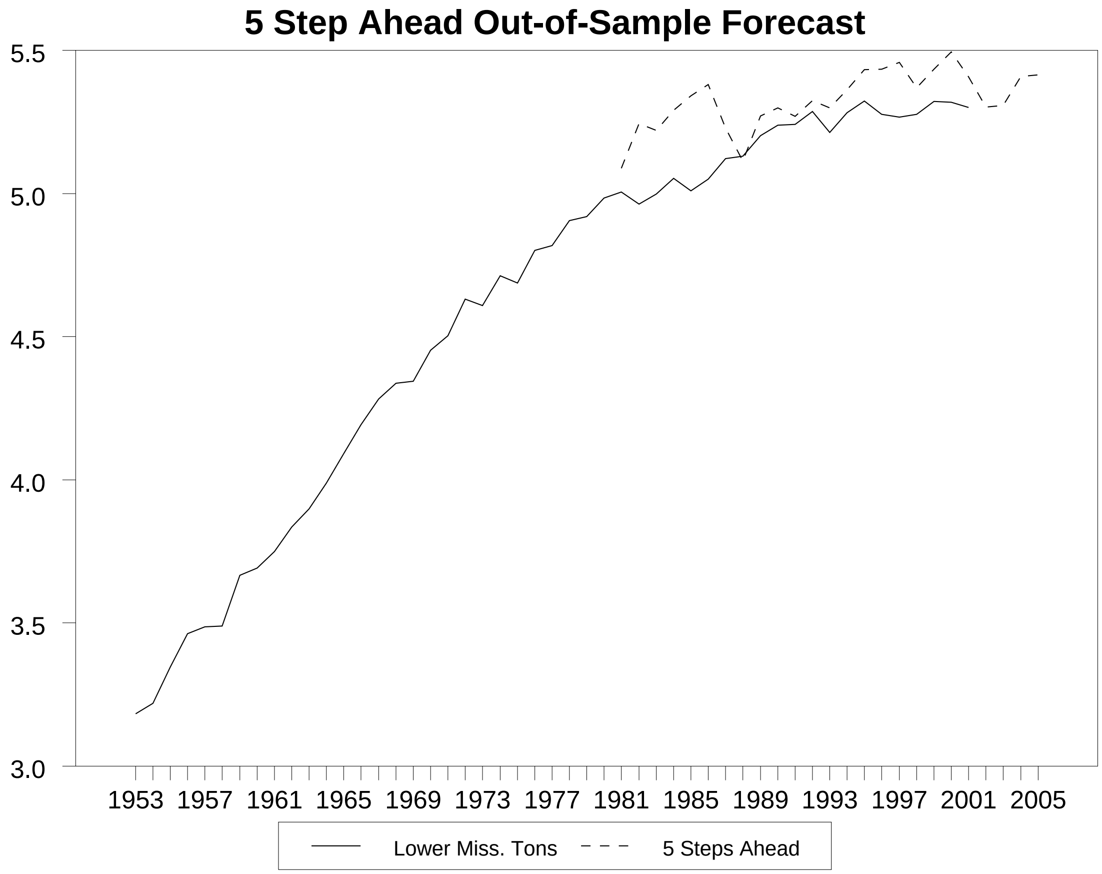
Lower Mississippi



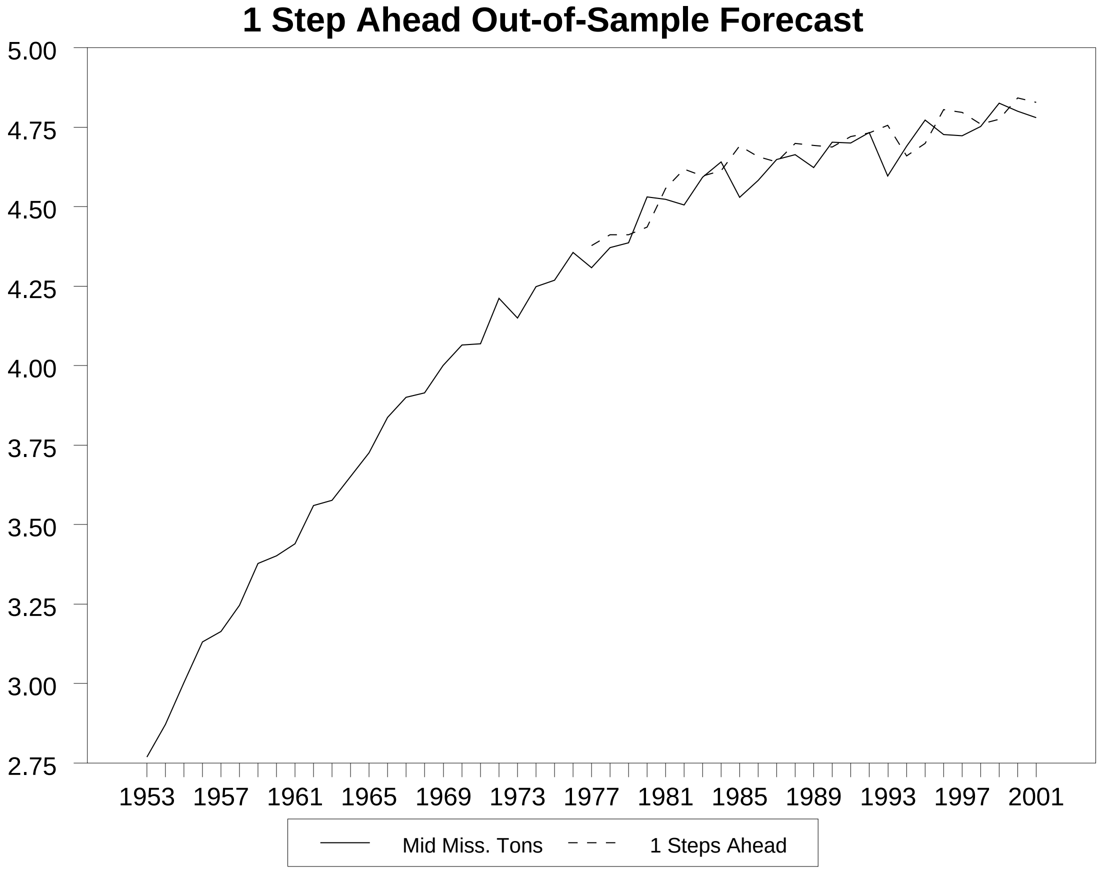

2 Step Ahead Out-of-Sample Forecast
5.5
5.0
4.5
4.0
3.5
3.0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Lower Miss. Tons
2 Steps Ahead

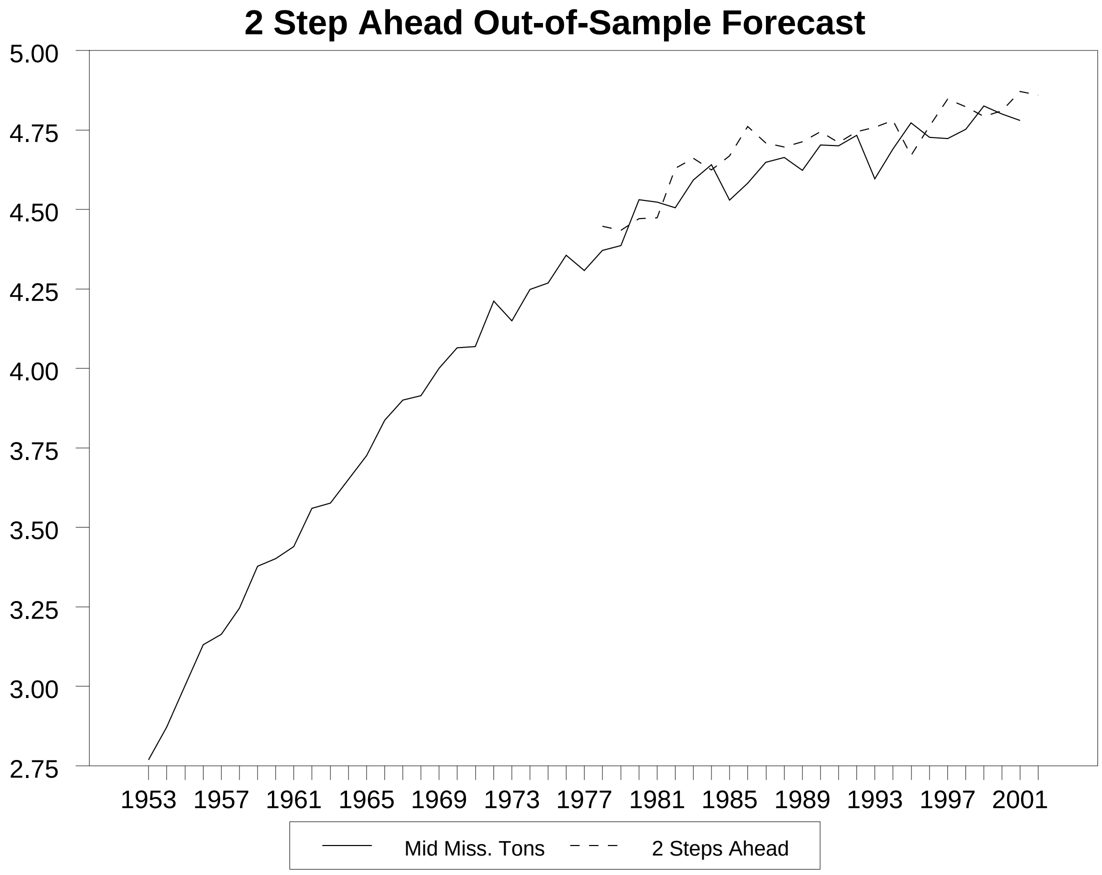

3 Step Ahead Out-of-Sample Forecast
5.5
5.0
4.5
4.0
3.5
3.0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Lower Miss. Tons
3 Steps Ahead

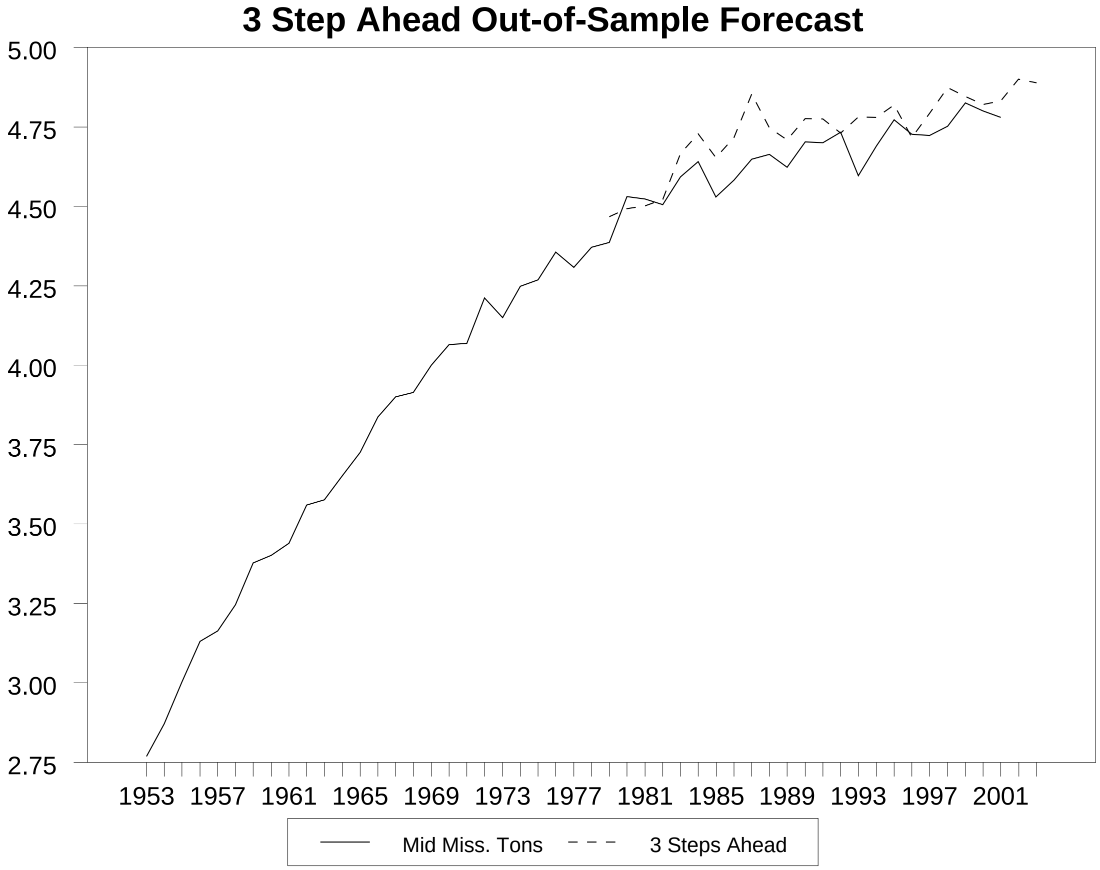

4 Step Ahead Out-of-Sample Forecast
5.5
5.0
4.5
4.0
3.5
3.0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Lower Miss. Tons
4 Steps Ahead

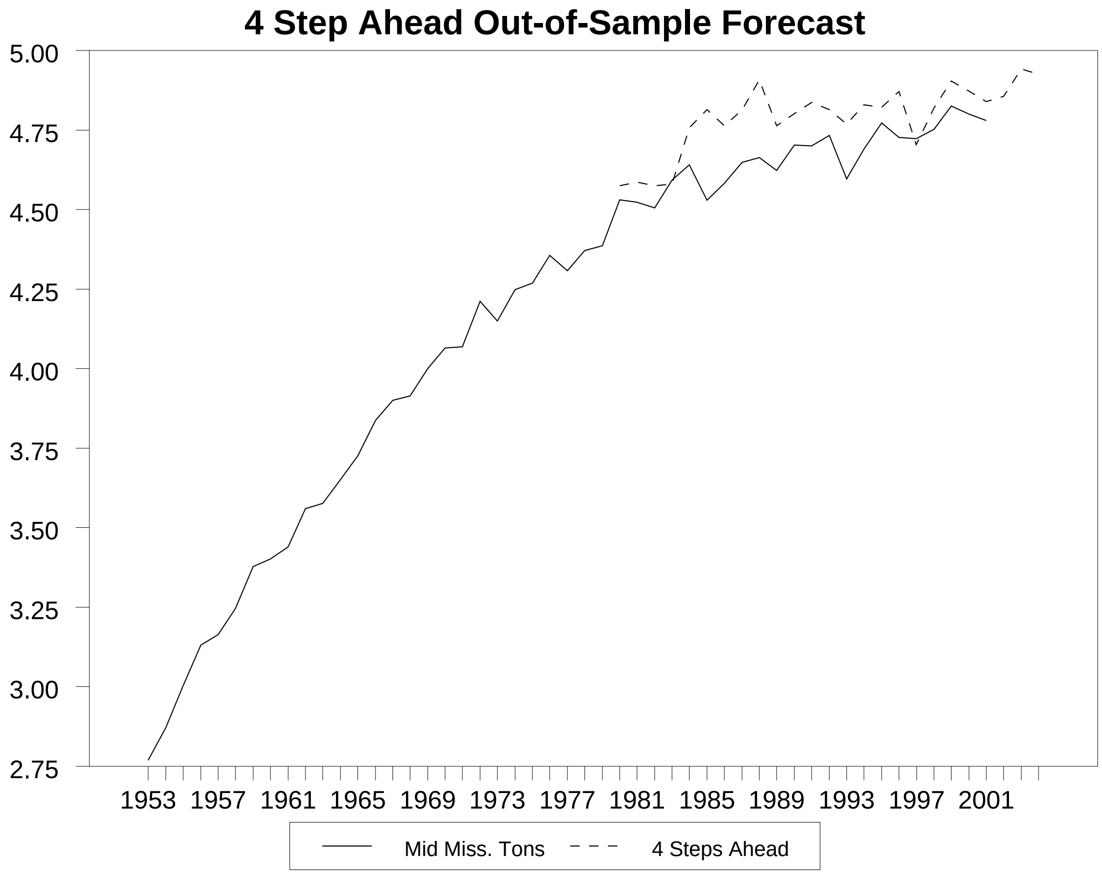

5 Step Ahead Out-of-Sample Forecast
5.5
5.0
4.5
4.0
3.5
3.0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
Lower Miss. Tons
5 Steps Ahead

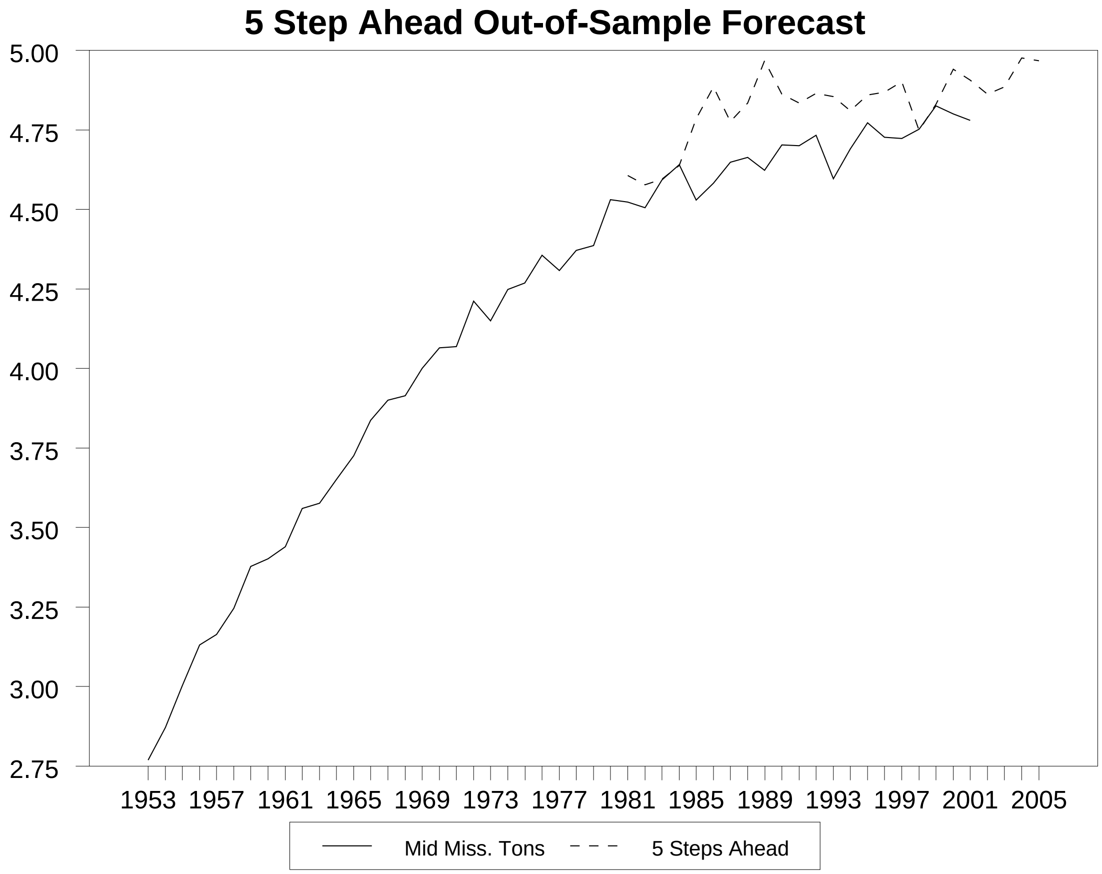
Mid Mississippi



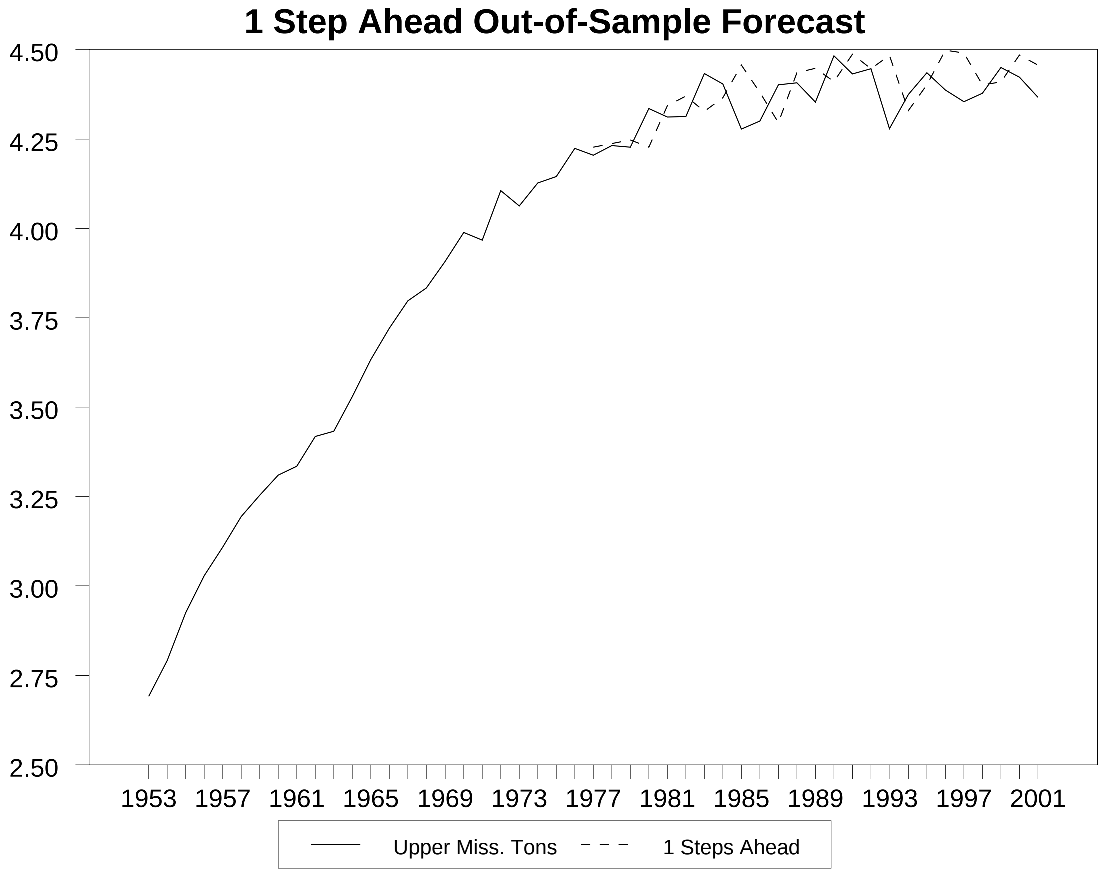

2 Step Ahead Out-of-Sample Forecast
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Mid Miss. Tons
2 Steps Ahead

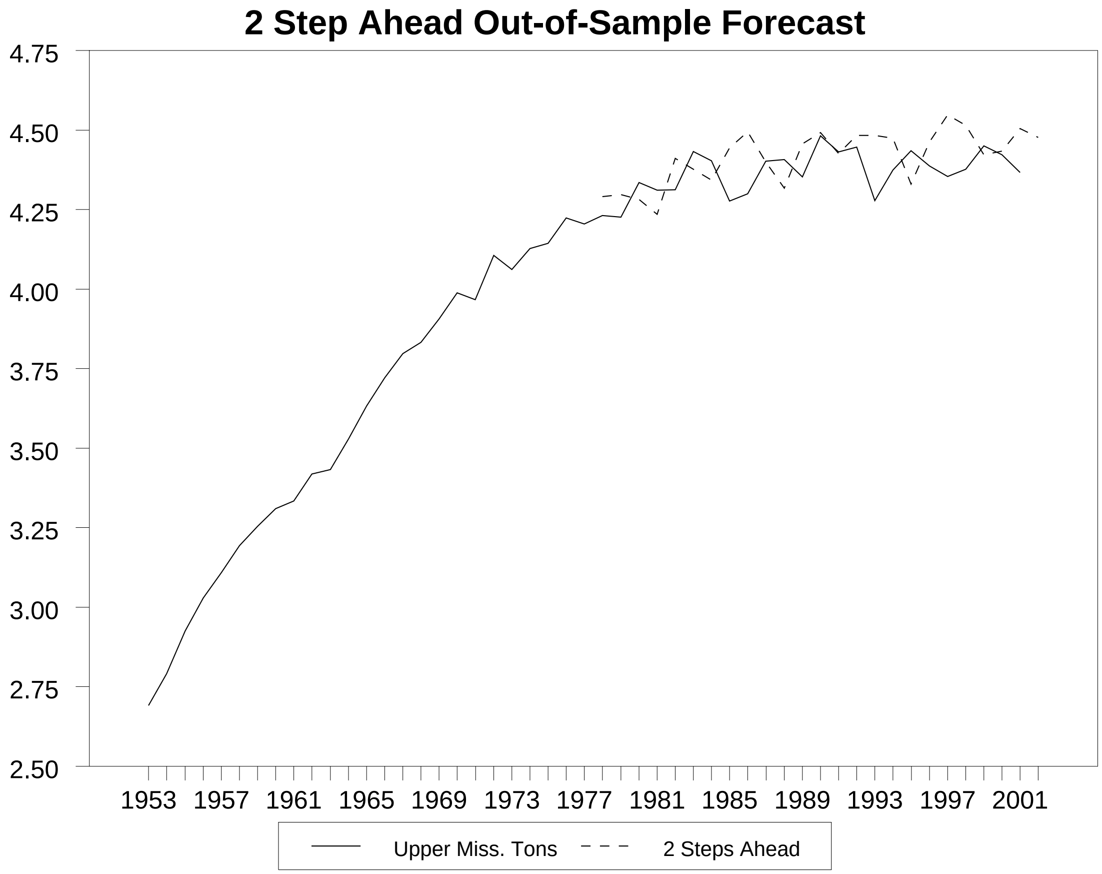

3 Step Ahead Out-of-Sample Forecast
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Mid Miss. Tons
3 Steps Ahead

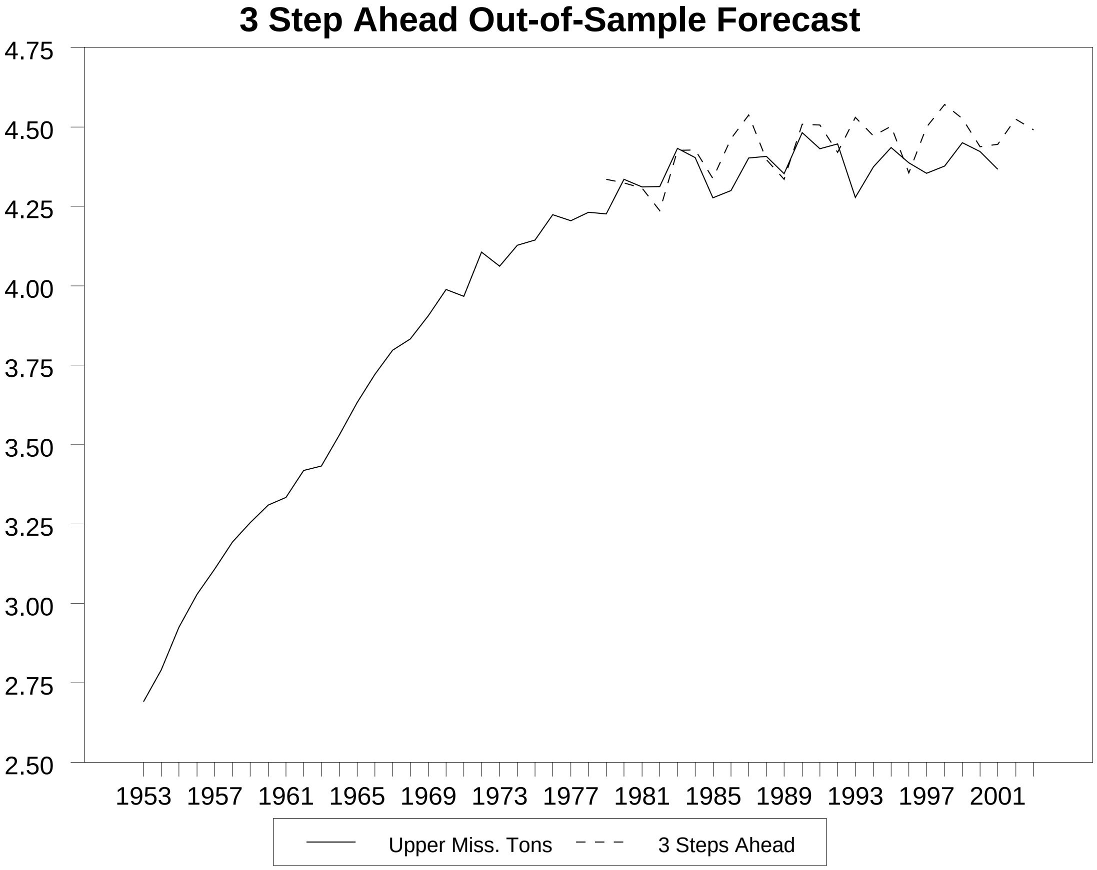

4 Step Ahead Out-of-Sample Forecast
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Mid Miss. Tons
4 Steps Ahead

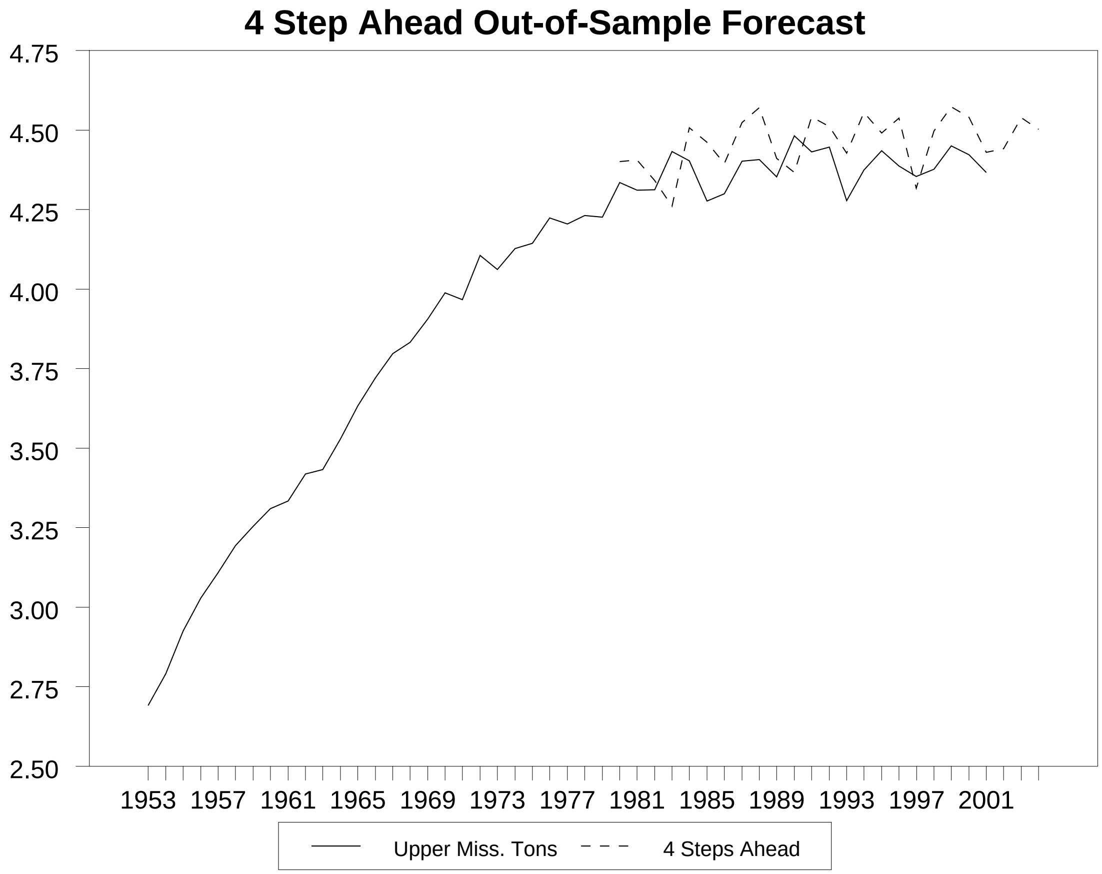

5 Step Ahead Out-of-Sample Forecast
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
Mid Miss. Tons
5 Steps Ahead

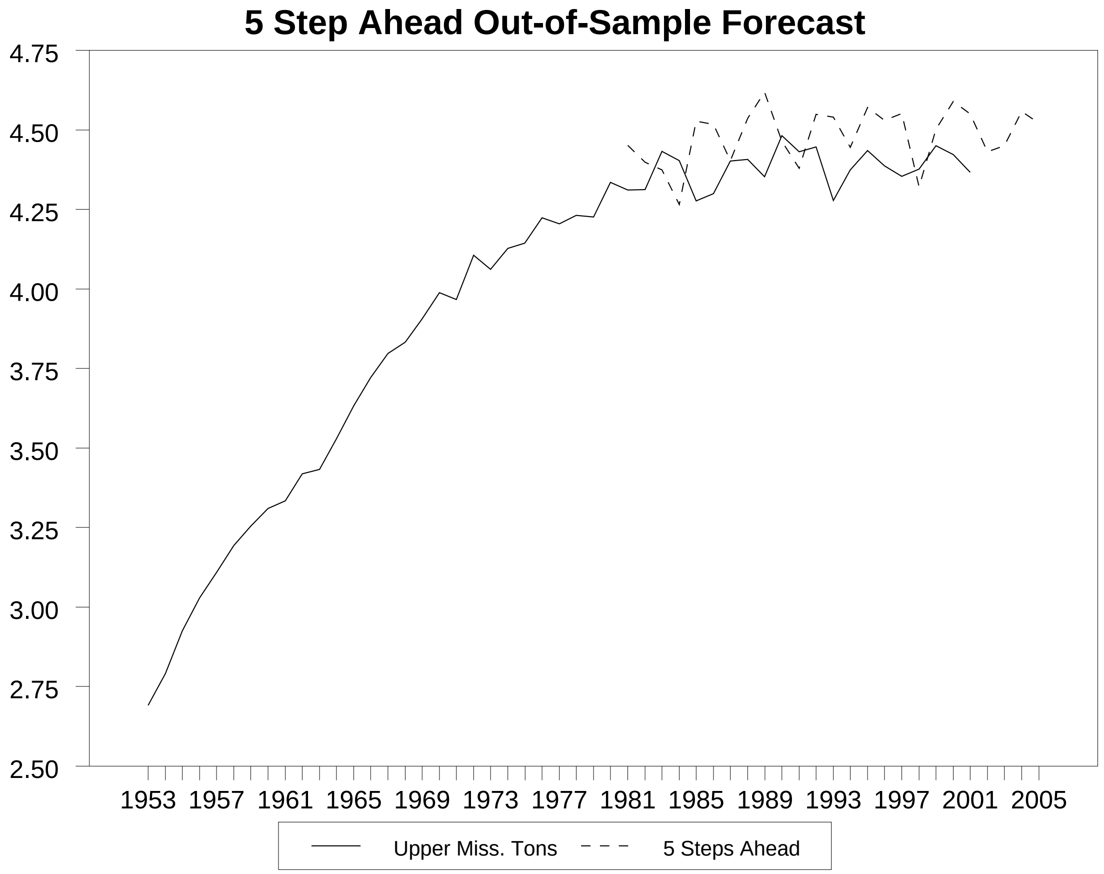
Upper Mississippi




2 Step Ahead Out-of-Sample Forecast
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Upper Miss. Tons
2 Steps Ahead


3 Step Ahead Out-of-Sample Forecast
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Upper Miss. Tons
3 Steps Ahead

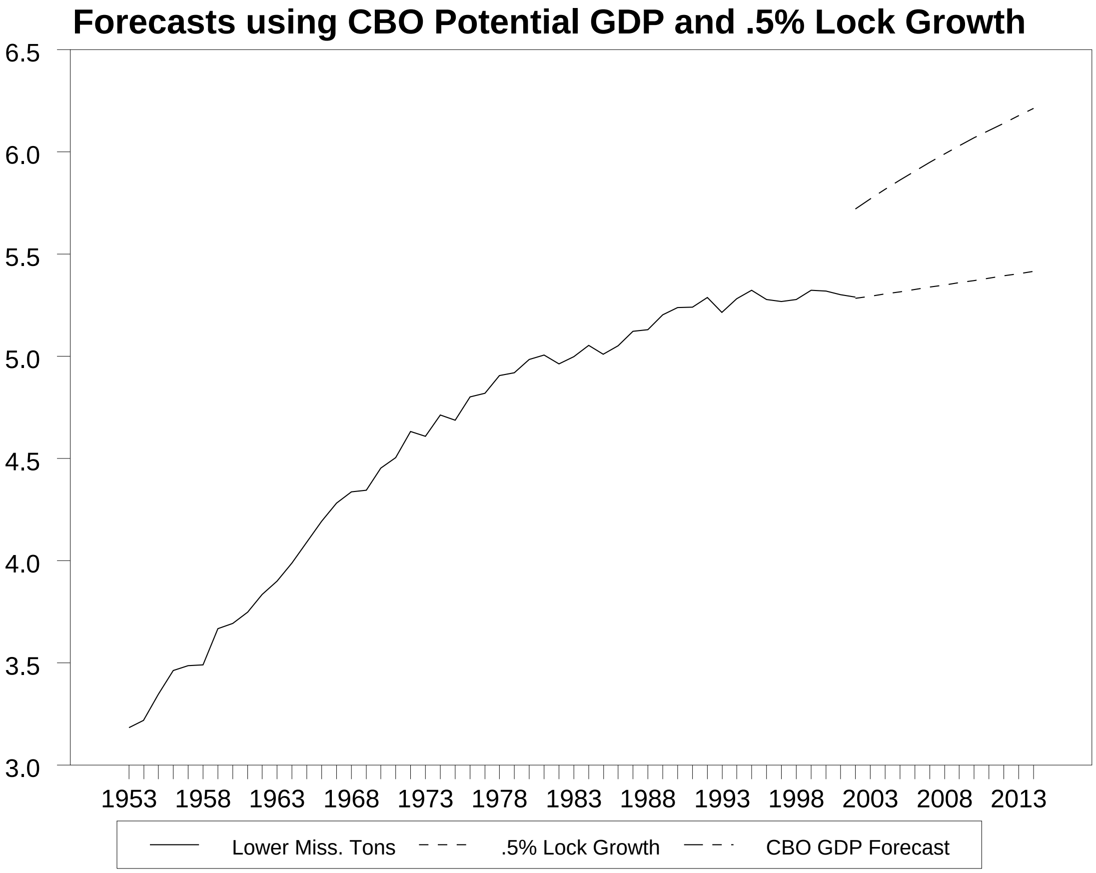

4 Step Ahead Out-of-Sample Forecast
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
Upper Miss. Tons
4 Steps Ahead

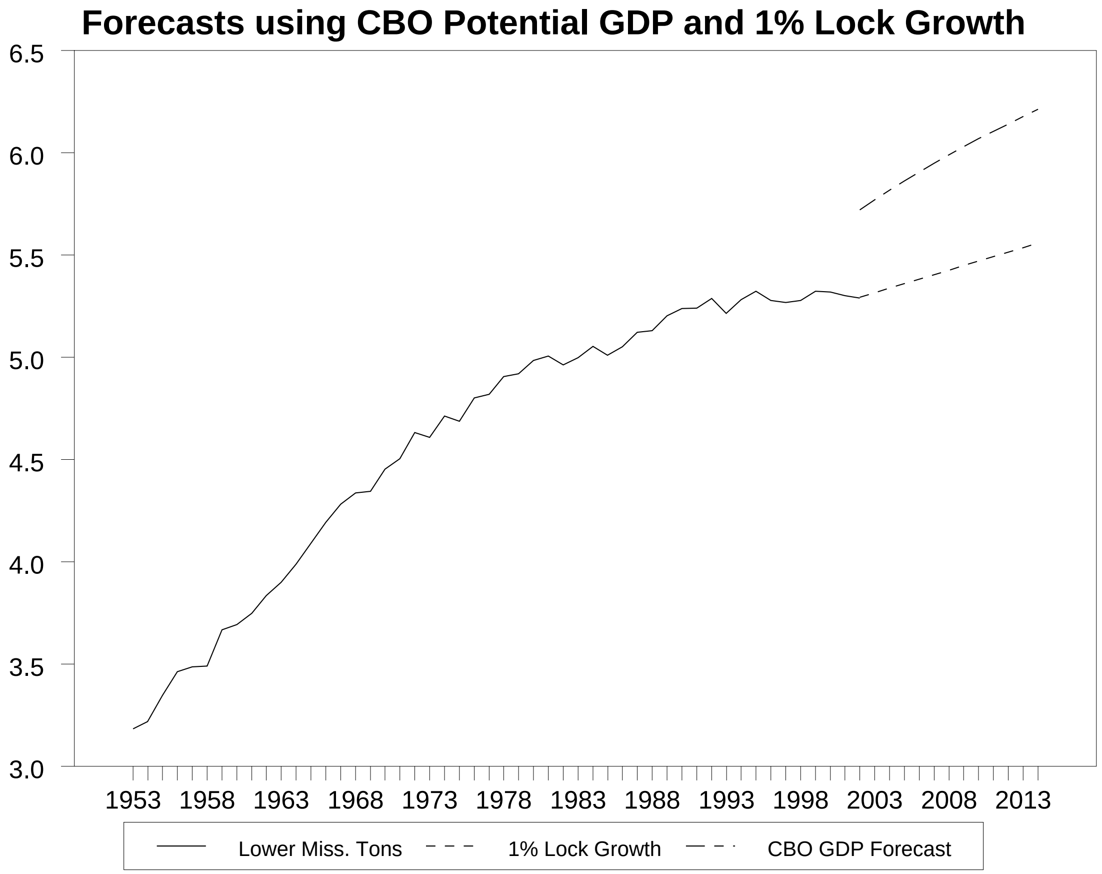

5 Step Ahead Out-of-Sample Forecast
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
Upper Miss. Tons
5 Steps Ahead

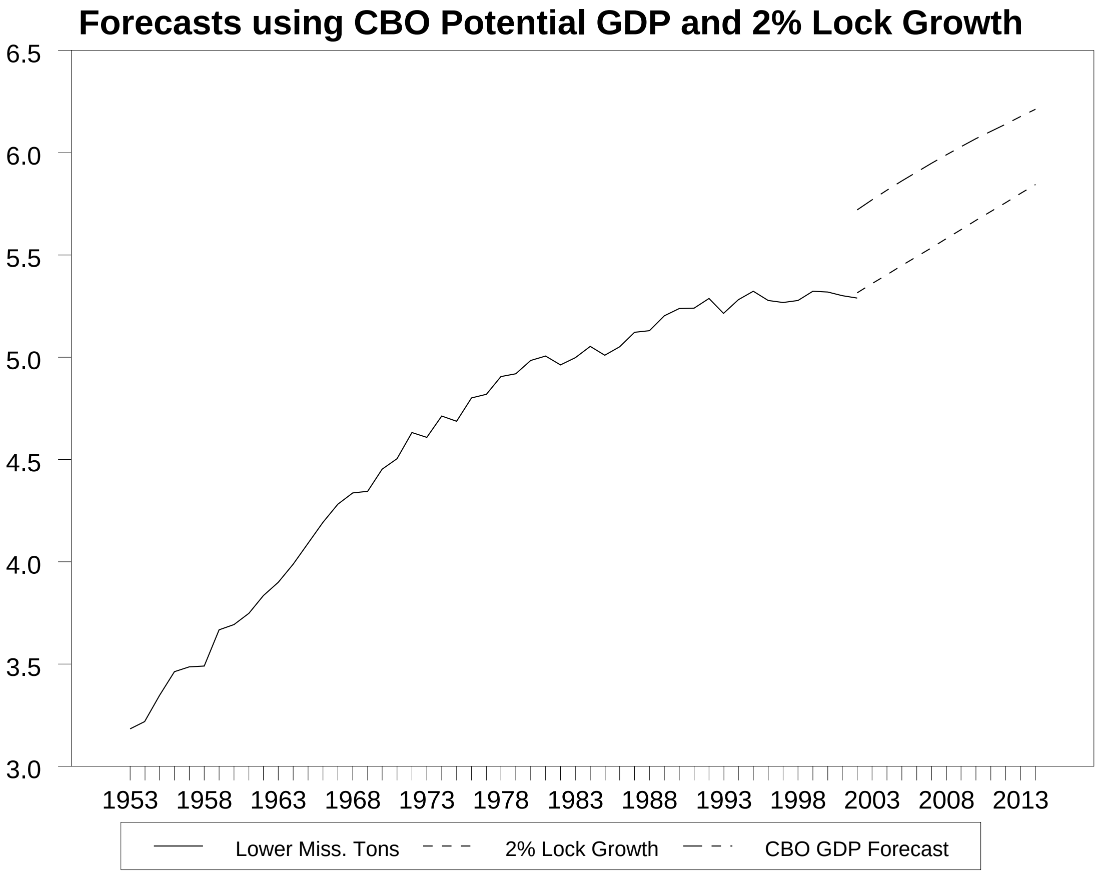
APPENDIX B

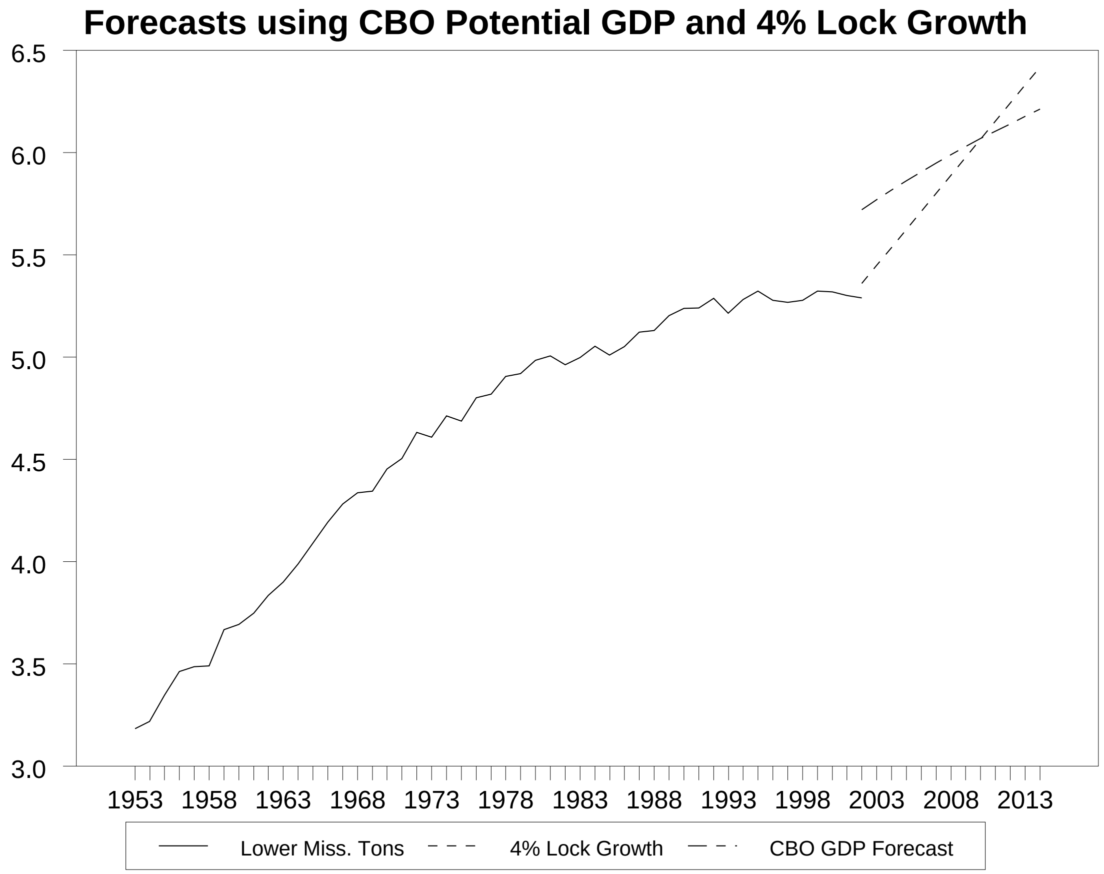
Long-Run Forecasts based upon the Estimated Co-Integrating Relationship for the Upper, Mid, and Lower Mississippi River System

Lower Mississippi

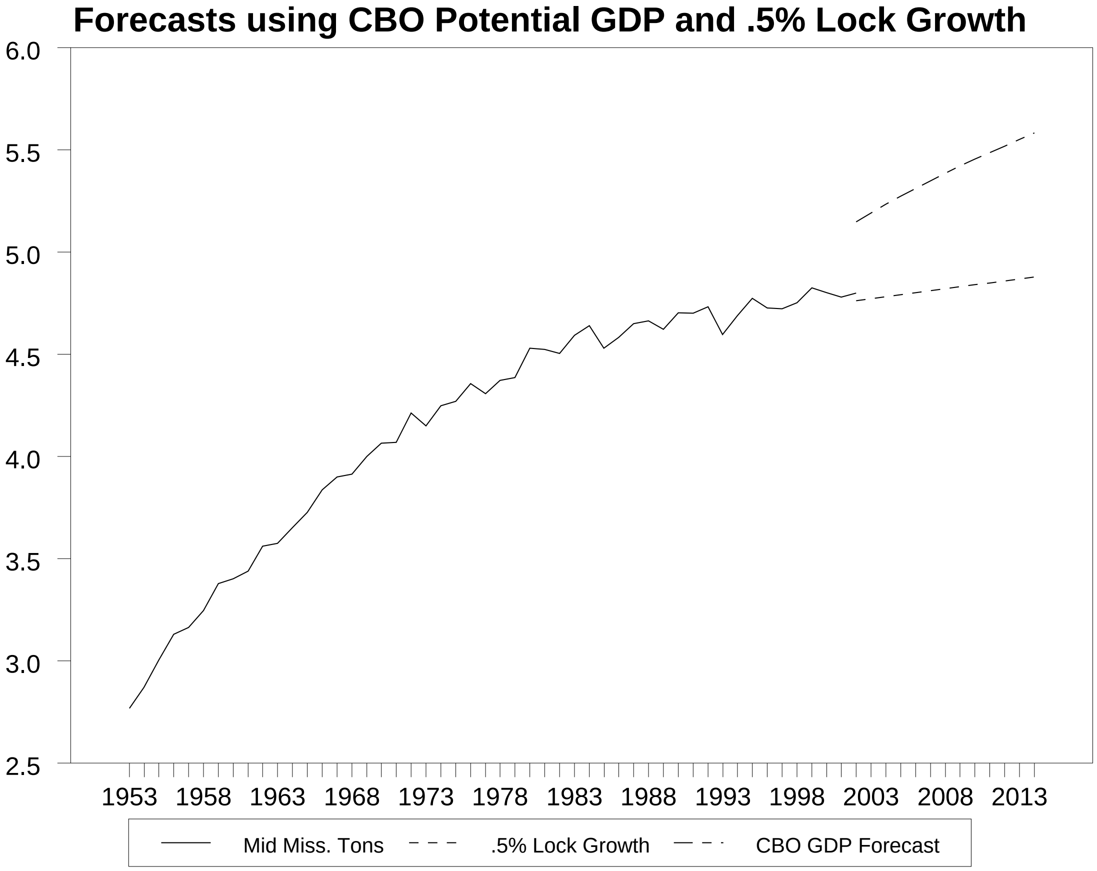


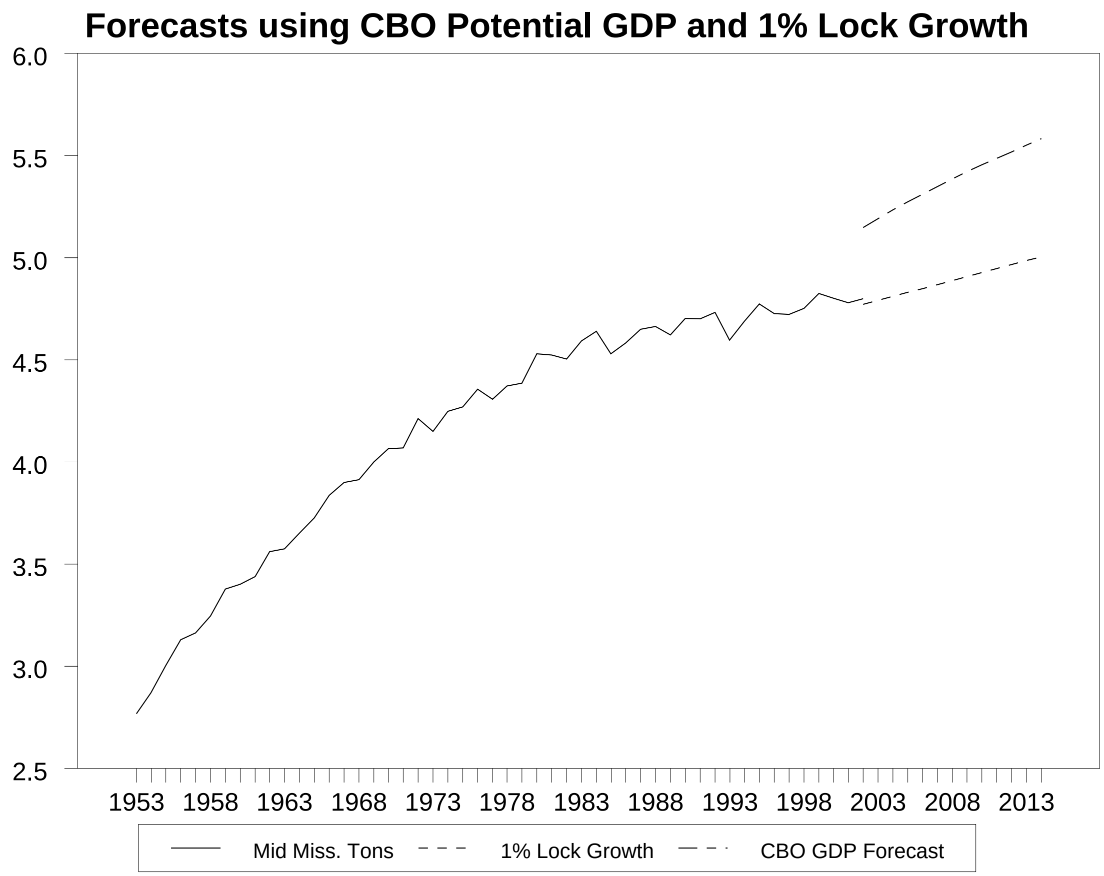

Forecasts using CBO Potential GDP and 1% Lock Growth
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Lower Miss. Tons
1% Lock Growth
CBO GDP Forecast

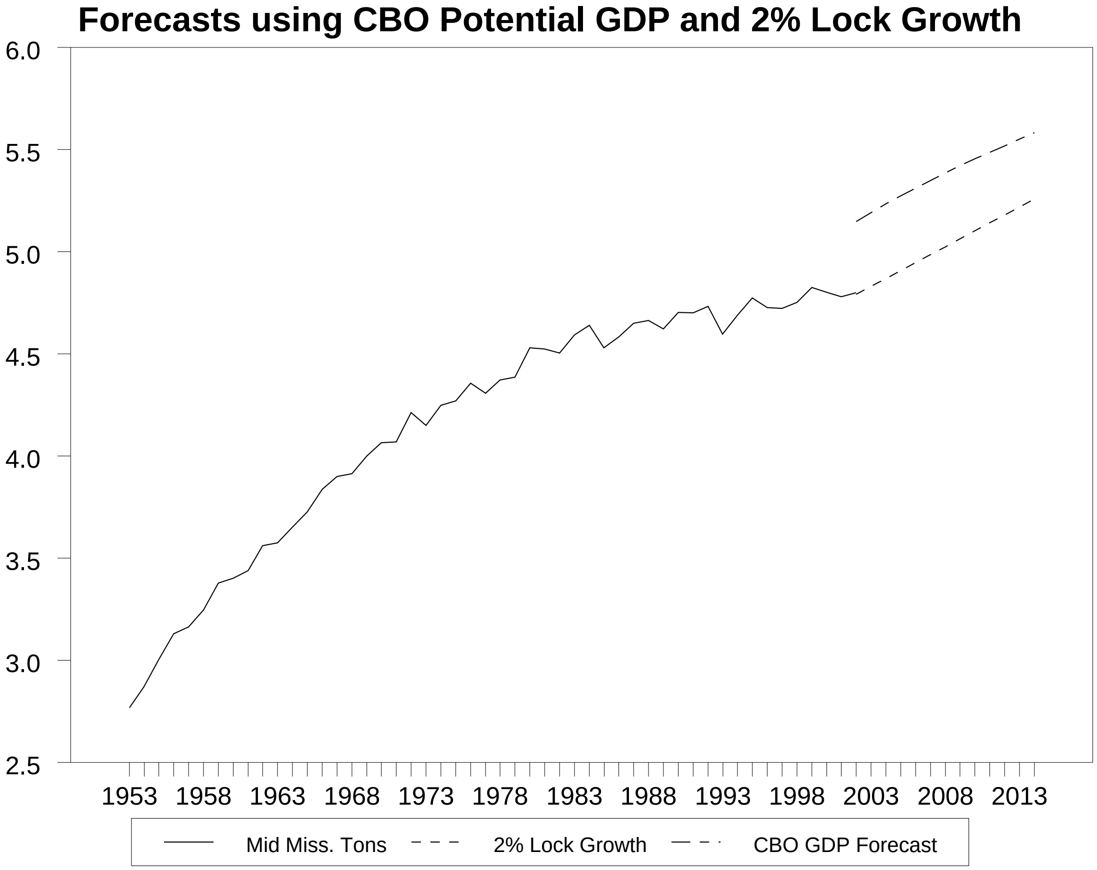

Forecasts using CBO Potential GDP and 2% Lock Growth
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Lower Miss. Tons
2% Lock Growth
CBO GDP Forecast

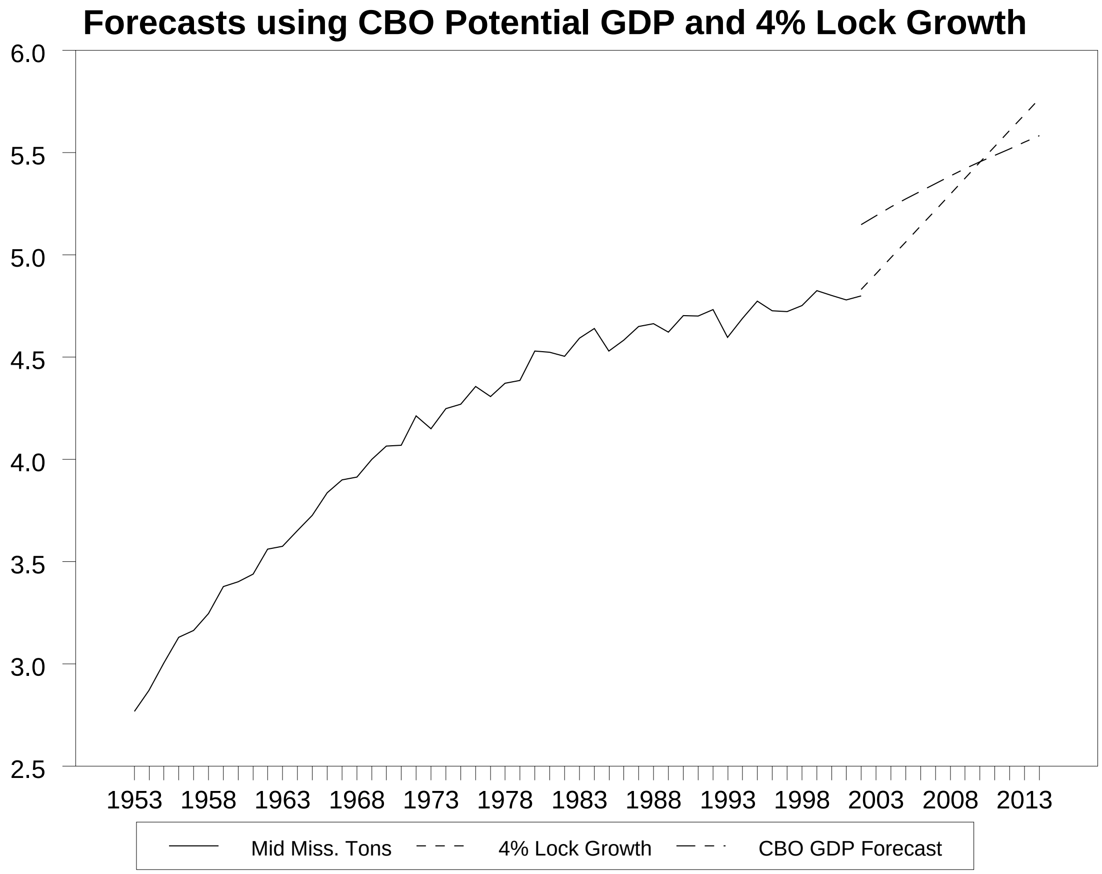

Forecasts using CBO Potential GDP and 4% Lock Growth
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Lower Miss. Tons
4% Lock Growth
CBO GDP Forecast

Mid Mississippi

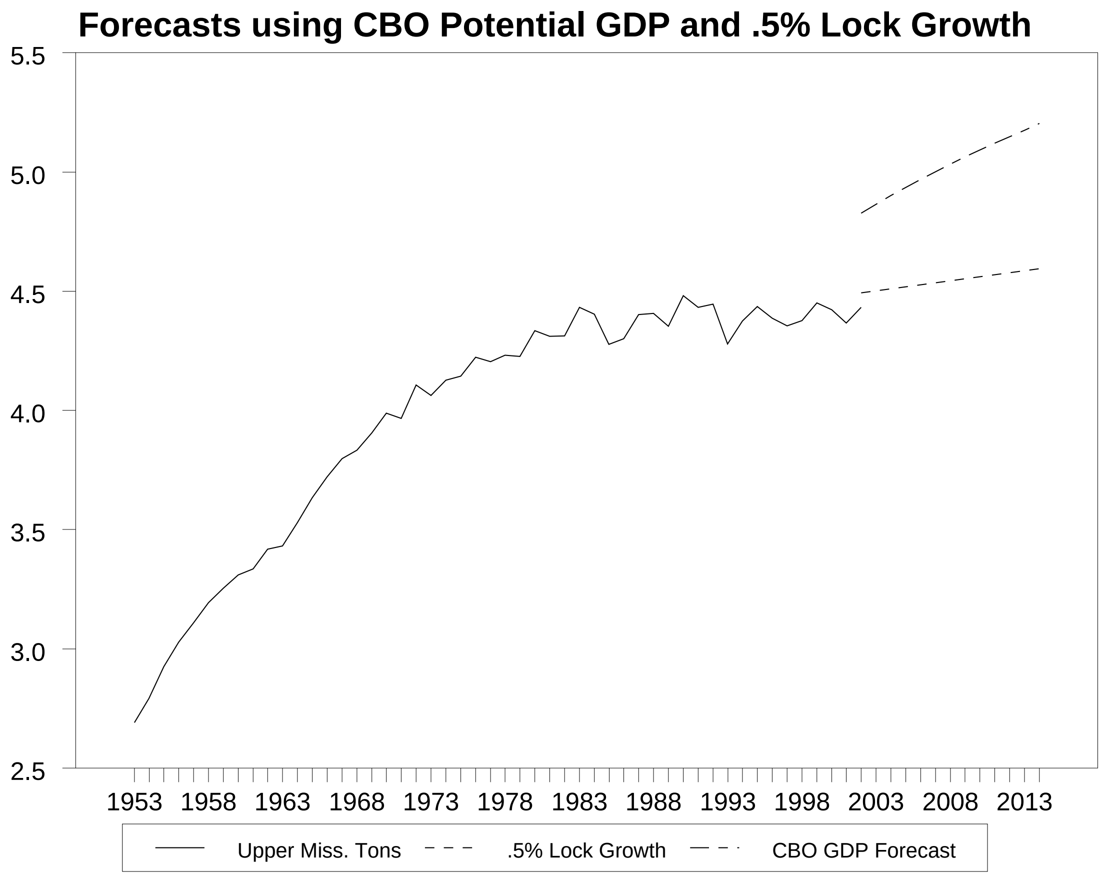


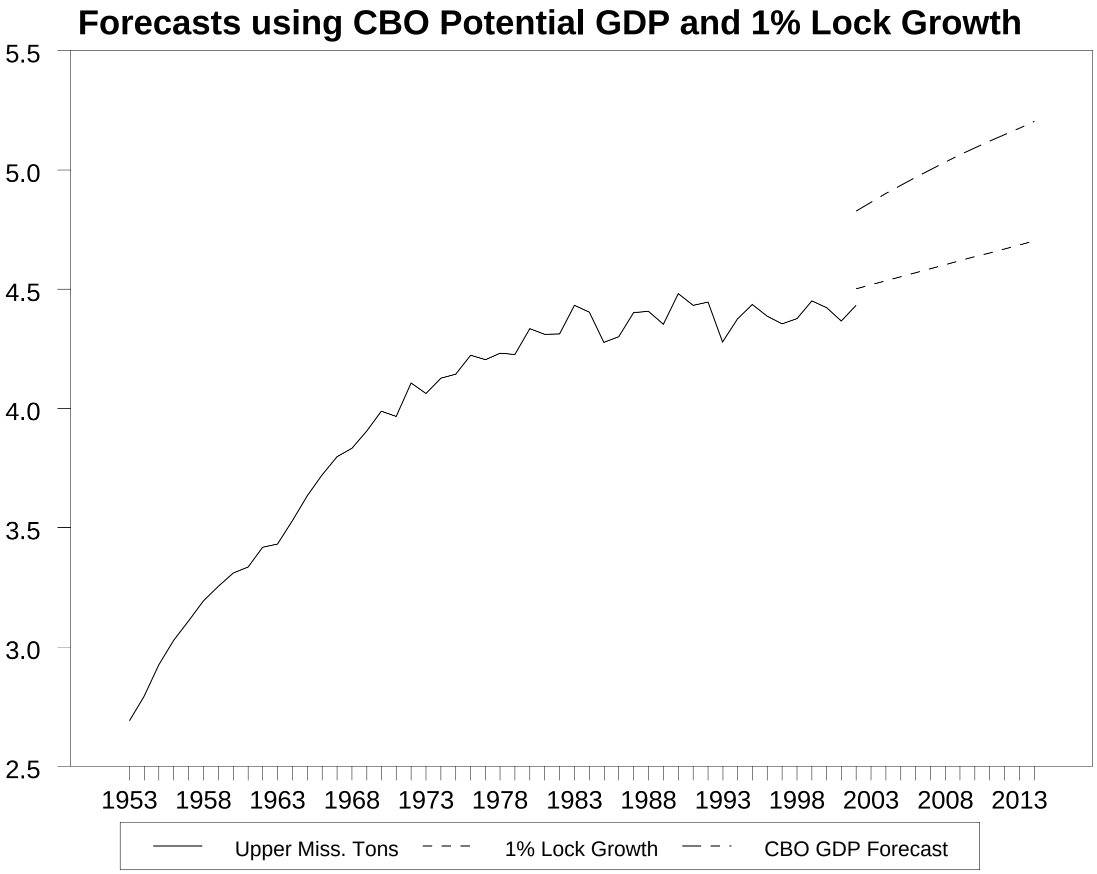

Forecasts using CBO Potential GDP and 1% Lock Growth
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Mid Miss. Tons
1% Lock Growth
CBO GDP Forecast

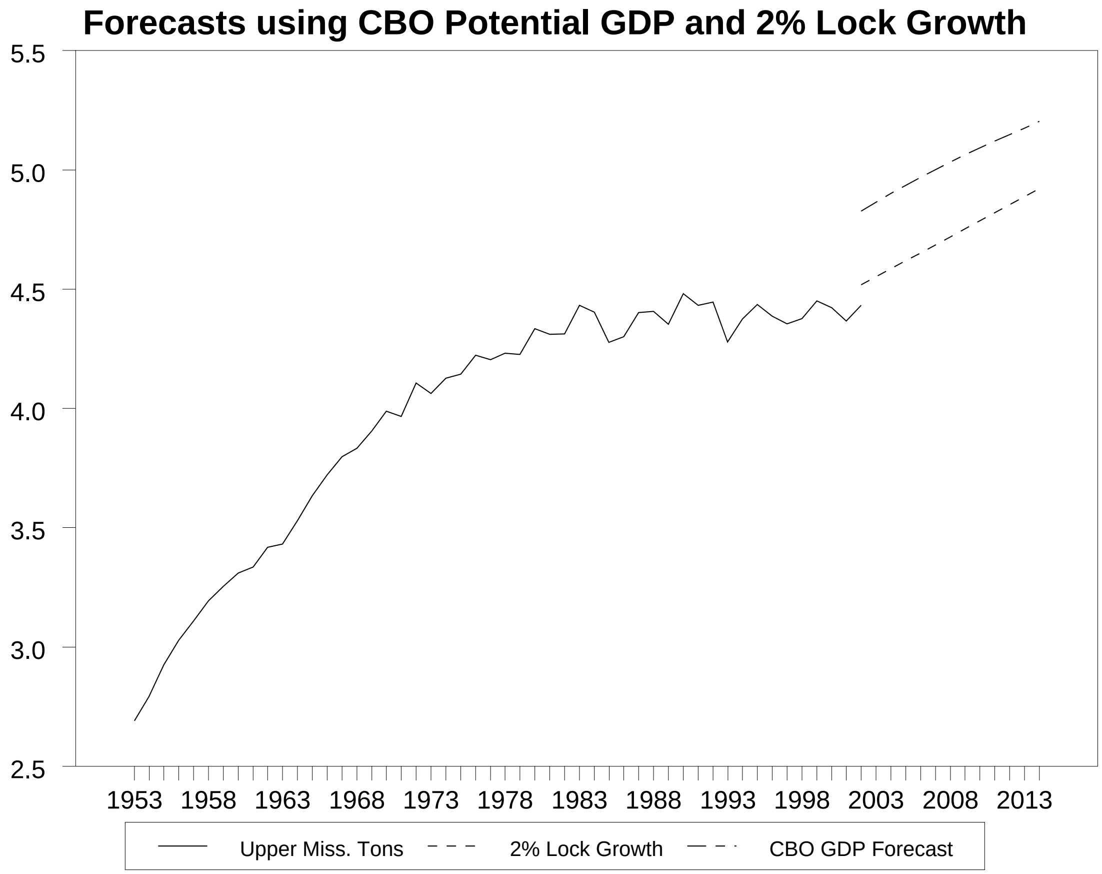

Forecasts using CBO Potential GDP and 2% Lock Growth
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Mid Miss. Tons
2% Lock Growth
CBO GDP Forecast

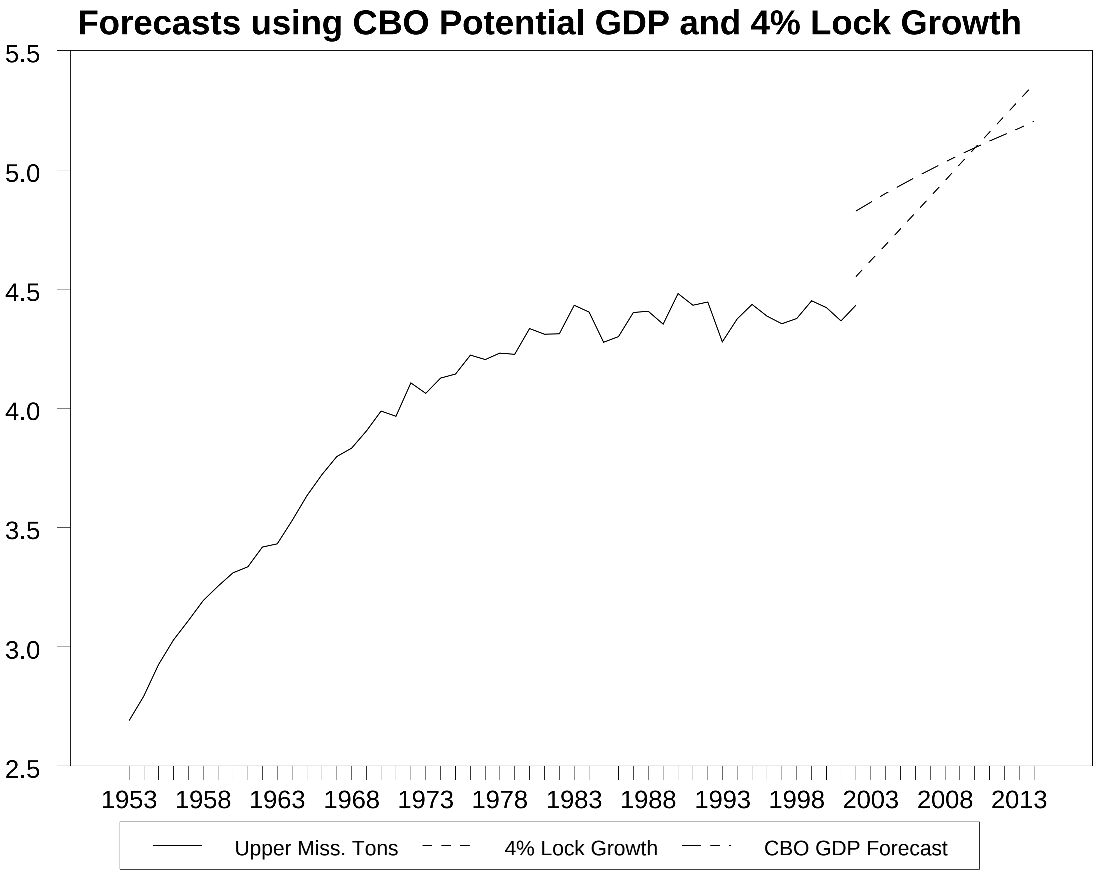

Forecasts using CBO Potential GDP and 4% Lock Growth
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Mid Miss. Tons
4% Lock Growth
CBO GDP Forecast

Upper Mississippi




Forecasts using CBO Potential GDP and 1% Lock Growth
5.5
5.0
4.5
4.0
3.5
3.0
2.5
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Upper Miss. Tons
1% Lock Growth
CBO GDP Forecast


Forecasts using CBO Potential GDP and 2% Lock Growth
5.5
5.0
4.5
4.0
3.5
3.0
2.5
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Upper Miss. Tons
2% Lock Growth
CBO GDP Forecast


Forecasts using CBO Potential GDP and 4% Lock Growth
5.5
5.0
4.5
4.0
3.5
3.0
2.5
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
Upper Miss. Tons
4% Lock Growth
CBO GDP Forecast