Title: Comparing Price Forecast Accuracy of Natural Gas Models and Futures Markets

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Abstract:

The purpose of this article is to compare the accuracy of forecasts for natural gas prices as reported by the Energy Information Administration's *Short-Term Energy Outlook* (STEO) and the futures market for the period from 1998 to 2003. The analysis tabulates the existing data and develops a statistical comparison of the error between STEO and U.S. wellhead natural gas prices and between Henry Hub and U.S. wellhead spot prices. The results indicate that, on average, Henry Hub is a better predictor of natural gas prices with an average error of 0.23 and a standard deviation of 1.22 than STEO with an average error of -0.52 and a standard deviation of 1.36. This analysis suggests that as the futures market continues to report longer forward prices (currently out to five years), it may be of interest to economic modelers to compare the accuracy of their models to the futures

market. The authors would especially like to thank Doug Hale of the Energy Information Administration for supporting and reviewing this work.

Keywords: Natural Gas Price, Pricing

1. Introduction

It is important for policy purposes to accurately forecast natural gas prices. Many policy decisions such as regulatory action in technologies (i.e., appliance efficiency standards), use of public lands (i.e., mineral exploration) and foreign policy may all be influenced by changing expectations about natural gas prices. For example AEO natural gas price forecasts have consistently over-estimated the price every year since 1982, never falling below 68%.[1] The inaccuracy of these forecasts has encouraged economists and energy policy makers to seek alternative methods to forecast natural gas prices.

The natural gas futures market provides an alternative forecast of natural gas prices determined by the interaction of numerous buyers and sellers in the natural gas market. Natural gas futures markets were set up in 1989 to help insure buyers against the risk of energy price fluctuations. In theory, futures market prices summarize privately available information about natural gas supply and demand. As a result, some economists believe that prices determined in the futures markets provide accurate price forecasts.

Policy makers can turn to two primary sources of information about future natural gas prices – price forecasts based upon economic models of energy supply and demand and price forecasts derived from the natural gas futures market. Historically, policy makers have relied almost exclusively upon forecasts based upon economic models.

[1] Cited from Energy Information Administration's *Annual Energy Forecast Evaluation* on June 2, 2005

AEO calibrates its natural gas price forecasts to the Energy Information Administration's Short-Term Energy Outlook (STEO) [2], a monthly publication of 15 to 24 month energy forecasts produced by the Short-Term Integrated Forecasting System (STIFS). AEO price forecasts have constituted the natural benchmark forecast since the early 1980s and are the primary source of forecasts used in federal energy policy making. [3]

This article tests the hypothesis that the futures market is a more accurate predictor of natural gas prices than STEO. This paper is divided into four sections. The first section provides an overview other natural gas price forecasts. An overview of the existing literature is provided in the second section. The third section evaluates the accuracy of price forecasts obtained from the STEO and from the Henry Hub futures market and the fourth section recommendations for future directions.

2. Overview of Other Natural Gas Price Forecasts

Researchers and policy makers utilize natural gas price forecasts to inform a range of government energy policy options. The continued effectiveness of government policies

[2] National Gas Transmission and Distribution Module (NGTDM) of NEMS regional supply and demand curves are adjusted to determine a price for "delivered" gas (well head price + pipeline transportation (including any storage fees) + any "shortage" premium due to an imbalance of local demand with available supply. The adjustment, the STEO scale factor, change each iteration in such a way as to cause the sum of NEMS regional price forecast for the forecast year to approximate closely the STEO natural gas price. The STEO scale factors are phased out over the five years following the last STEO year, this is not done for the wellhead prices because the prices that define the supply curves are predominantly based on the solved-for prices in the previous forecast year; this structure results in a relatively smooth transition into the forecast.

[3] In 1978 the Natural Gas Policy Act was passed which essentially created a single nation-wide natural gas market, equalizing supply with demand and allowing market forces to determine the price of natural gas at the wellhead. In 1982, the first AEO was published based on the Intermediate Future Forecasting System (IFFS), replacing the Annual Report to Congress (published from 1977-1981) which satisfied a 1977 Department of Energy Organization Congress Act mandate which required energy forecasts to be provided and updated annually. A the request of Congress and with the assistance of the National Academy in the early 1990s, the Energy Information Administration (EIA) began developing the National Energy Modeling System (NEMS), which improved upon the IFFS model "representation of electricity and natural gas markets, demand-side management programs, development of renewable sources, and environmental policies." (Calvin, K., 2004)

are predicted on accurate price information to insure that energy saving benefits exceed consumer costs.

Private organizations regularly issue other price forecasts (Table 1). Typically, the analytical core of these models includes energy supply equations estimated from historical mineral abundance, exploration and capital investment data, and energy demand equations estimated from macro-economic models of the economy. The data used in such equations may represent the best information available to researchers at the time, but is by definition, historical (Budzick, P, 2004).

[Insert Table 1]

3. Literature Review

The poor track record of energy price forecasting models has encouraged analysts to turn to other sources of information about future energy prices, including most prominently, energy futures markets. Energy futures markets are 'hubs' that price and market natural gas.

Walls (1995), examining several years of spot prices finds that, in general, gas futures are unbiased predictors of future spot prices whereas Herbet (1993) finds bias in natural gas futures prices where futures prices are greater than realized spot prices. Chinn et al (2005) finds futures prices to be unbiased predictors of future spot prices, with the exception of those in the natural gas market at the three month horizon and they slightly outperform time series models. This study builds upon the existing literature by investigating the accuracy of forecast methods up to the 24 month horizon.

3. Comparison of STEO Natural Gas Price Forecasts and Henry Hub Foreward Prices

Several futures markets exist but for the purposes of this study we selected the Henry Hub market, reported on the New York Mercantile Exchange (NYMEX). Henry Hub prices are more widely accessible and have been reported over a longer time period than other futures markets in the country.

As described above, the STEO price forecasts are generated from analytical tools applied to historical data while Henry Hub foreward prices are generated from the expectations about changes in the natural gas market.

STEO and Henry Hub report their natural gas prices in different units, for the purposes of this study the price data has been converted to a single unit, dollars per thousand cubic feet averaged across quarters. A comparison of STEO versus Henry Hub is based on a two year ahead January price forecasts from STEO's U.S. Energy Price table and Henry Hub's historical documents. The daily and monthly price "forecasts" from these sources were transformed into quarterly price forecasts, using simple averages. Thus, a two year ahead STEO quarterly price forecast could be directly compared with a similar two year ahead quarterly Henry Hub forward price.[4]

The accuracy of these two quarterly price forecasts is measured by the forecast error, which is defined in this study as the difference between the forecasted price and the price. Table 2 shows the futures market error and STEO error by quarters for the first 12 months of the two year ahead forecast. Table 3 shows the futures market error and STEO error by quarters for months 13-24 of the two year ahead forecast. The futures market

[4] For example, in quarter four of 1997 forward prices are produced for a 24 month period beginning January 1998 and extending out to December 1999. Henry Hub reports forward prices daily for each month, so in quarter four of 1997 we averaged all of the forward prices made for January 1998, February 1998, etc. We then averaged those values over three month periods to obtain data for four quarters until we matched STEO's timeline. From now on, the first four quarters will be referred to as the "first year forecast" and the last four quarters are the "second year forecast".

"forecast" error averaged over the six year period of the study has an average error of -0.23 and a standard deviation of 1.22. The STEO forecast of error for the same period is an average error of -0.52 and standard deviation of 1.36.

[Insert Tables 2 and 3]

Fig. 1 shows the first 12 months of the two year ahead forecasts for six forecast years (1998 to 2003). This figure reveals that the futures market is significantly more accurate than the STEO. The futures market "forecast" average error is 0.08 with a standard deviation of 1.20. The STEO forecast average error is -0.30 with a standard deviation of 1.31. Fig. 2 shows months 15-24 of the two year ahead forecasts for six forecast years (1998 to 2003). This figure reveals that the futures market is significantly more accurate than STEO. The futures market "forecast" average error is -0.53 with a standard deviation of 1.22. The STEO forecast average error is -0.74 with a standard deviation of 1.43.

[Insert Fig. 1 and 2]

4. Recommendations for Future Directions

Overall, the results suggest that the futures market is a more accurate predictor of natural gas prices than STEO for a 24 month forecast period. Naturally, the next step is to determine how these results can inform researchers and policy makers who utilize natural gas prices to develop federal energy policy. The analysis presented in this article is only possible because the futures market began to produce forward prices longer than a 12 month horizon in the mid-1990s. Allowing researchers to investigate this overlap with forecast models such as STEO to determine which approach, those based on economic models or on the market, is more accurate and unbiased. Recently, the futures market has

begun producing forward prices out to the five year horizon. This longer period of overlap may interesting to AEO and STEO to compare the accuracy of the futures market compared to their economic model.

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Appendix

A.1 Natural Gas Price Data for Futures Market and STEO (Months 1-12)

Forecast Year	Quarter	Futures Market ($/Mcf)	STEO ($/Mcf)	Actual Price ($/Mcf)	Futures Market Error	STEO Error
1998	1998-1	2.79	2.15	1.99	0.79	0.16
	1998-2	2.31	1.94	2.04	0.27	-0.10
	1998-3	2.28	1.96	1.87	0.41	0.09
	1998-4	2.46	2.29	1.92	0.55	0.37
1999	1999-1	1.84	1.84	1.77	0.06	0.07
	1999-2	1.88	1.62	2.07	-0.19	-0.45
	1999-3	1.98	1.74	2.44	-0.46	-0.70
	1999-4	2.22	2.13	2.48	-0.26	-0.35
2000	2000-1	2.71	2.24	2.75	-0.04	-0.51
	2000-2	2.53	2.16	3.55	-1.02	-1.39
	2000-3	2.57	2.20	4.19	-1.62	-1.99
	2000-4	2.75	2.42	5.66	-2.91	-3.24
2001	2001-1	6.31	6.82	5.42	0.89	1.40
	2001-2	4.92	4.82	4.22	0.70	0.60
	2001-3	4.79	4.38	3.20	1.59	1.18
	2001-4	4.94	4.89	3.20	1.74	1.69
2002	2002-1	3.07	2.14	2.36	0.71	-0.22
	2002-2	3.03	1.93	2.95	0.09	-1.02
	2002-3	3.15	1.92	2.88	0.26	-0.96
	2002-4	3.38	2.22	3.60	-0.22	-1.38
2003	2003-1	4.49	4.45	1.48	3.02	2.97
	2003-2	4.13	3.89	5.49	-1.36	-1.60
	2003-3	4.14	3.65	5.09	-0.95	-1.44
	2003-4	4.30	4.01	4.46	-0.16	-0.45

A.1 Natural Gas Price Data for Futures Market and STEO (Months 13-24)

Forecast Year	Quarter	Futures Market ($/Mcf)	STEO ($/Mcf)	Actual Price ($/Mcf)	Futures Market Error	STEO Error
1998	1999-1	2.52	2.16	1.77	0.75	0.39
	1999-2	2.26	1.89	2.07	0.19	-0.18
	1999-3	2.25	1.92	2.44	-0.20	-0.52
	1999-4	2.40	2.25	2.48	-0.08	-0.23
1999	2000-1	2.36	2.23	2.66	-0.30	-0.43
	2000-2	2.16	1.93	3.22	-1.06	-1.29
	2000-3	2.17	1.98	3.94	-1.77	-1.96
	2000-4	2.34	2.28	4.92	-2.57	-2.64
2000	2001-1	2.78	2.29	4.66	-1.87	-2.37
	2001-2	2.52	2.17	3.83	-1.32	-1.66
	2001-3	2.54	2.21	3.01	-0.48	-0.80
	2001-4	2.72	2.42	2.28	0.44	0.14
2001	2002-1	4.74	5.20	2.36	2.38	2.84
	2002-2	4.17	4.34	2.95	1.22	1.39
	2002-3	4.18	4.15	2.88	1.29	1.27
	2002-4	4.29	4.59	3.60	0.70	0.99
2002	2003-1	3.59	2.60	5.48	-1.89	-2.88
	2003-2	3.37	2.43	4.88	-1.52	-2.45
	2003-3	3.45	2.62	4.71	-1.26	-2.09
	2003-4	3.64	2.95	4.45	-0.81	-1.50
2003	2004-1	4.37	4.51	4.85	-0.48	-0.34
	2004-2	3.90	4.10	5.11	-1.21	-1.01
	2004-3	3.89	3.96	5.69	-1.81	-1.73
	2004-4	4.08	4.43	5.22	-1.15	-0.79

Tables

Table 1. Energy Models

Model Name	Symbol	Proprietor	Energy Markets	Description
U.S. MARKAL	MARKAL	U.S. Department of Energy; Brookhaven National Laboratory	All U.S. energy markets including imports and exports	Large national model that represents detailed technologies or groups of technologies in all the end-use sectors. Each technology competes with other options on the basis of initial capital costs and its energy performance.
Energy 2020	E2020	Canadian Energy Research Institute	All Canadian and U.S. energy markets	A systems dynamics approach similar to that used n a former U.S. Department of Energy Model called FOSSIL2 and later IDEAS.
National Energy Modeling System	NEMS	U.S. Energy Information Administration	All U.S. energy markets including imports and exports	A large engineering-economy models of all energy markets. This model combines considerable detail about technology options with a representation of end-use demand and the energy market and policy structure.
Policy Office Electricity Modeling System	POEMS	U.S. Department of Energy	All U.S. energy markets including exports and imports	Developed initially to conduct electricity restructuring analysis in greater regional detail than is available in NEMS. The natural gas market is represented the same as in the 2002 version of the NEMS system.
NANGAS/IPM	NANGAS	U.S. Environmental Protection Agency; ICF consulting	U.S. electricity and gas markets including exports and imports	The system uses a natural gas model (NANGAS) and an integrated planning model for electricity (IPM) jointly to conduct the environmental impacts of fuel market changes.
North American Regional Gas	NARG	California Energy Commission	Canadian and U.S. gas markets	This model covers numerous natural gas regions. Plays close attention to recent electricity trends and their potential effect on the natural gas market
Model for U.S. and International Natural Gas Simulations (MUSINGS)	CRA	Charles River Associates	Canadian and U.S. gas markets	Calibrating natural gas supply and demand conditions with NEMS for the United States ad with Canadian sources and the National Petroleum Council for Canada.

Table 3. Futures Market and STEO Error from 1998 to 2003 (Months 1-12)

Forecast Year	Quarter	Futures Market Error	STEO Error
1998	1998-1	0.79	0.16
	1998-2	0.27	-0.10
	1998-3	0.41	0.09
	1998-4	0.55	0.37
1999	1999-1	0.06	0.07
	1999-2	-0.19	-0.45
	1999-3	-0.46	-0.70
	1999-4	-0.26	-0.35
2000	2000-1	-0.04	-0.51
	2000-2	-1.02	-1.39
	2000-3	-1.62	-1.99
	2000-4	-2.91	-3.24
2001	2001-1	0.89	1.40
	2001-2	0.70	0.60
	2001-3	1.59	1.18
	2001-4	1.74	1.69
2002	2002-1	0.71	-0.22
	2002-2	0.09	-1.02
	2002-3	0.26	-0.96
	2002-4	-0.22	-1.38
2003	2003-1	3.02	2.97
	2003-2	-1.36	-1.60
	2003-3	-0.95	-1.44
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Table 3. Futures Market and STEO Error from 1998 to 2003 (Months 13-24)

Forecast Year	Quarter	Futures Market Error	STEO Error
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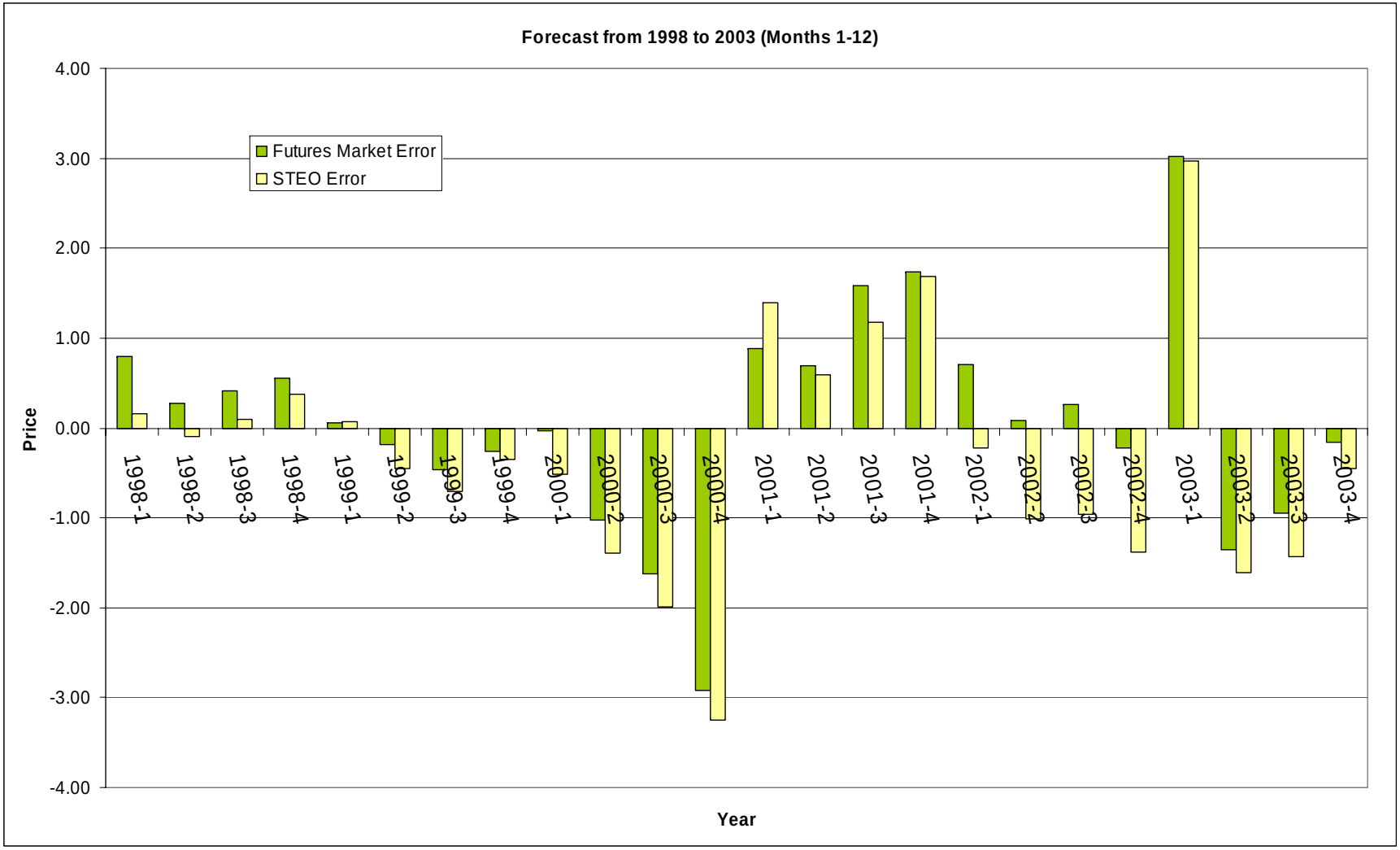
	1999-2	0.19	-0.18
	1999-3	-0.20	-0.52
	1999-4	-0.08	-0.23
1999	2000-1	-0.30	-0.43
	2000-2	-1.06	-1.29
	2000-3	-1.77	-1.96
	2000-4	-2.57	-2.64
2000	2001-1	-1.87	-2.37
	2001-2	-1.32	-1.66
	2001-3	-0.48	-0.80
	2001-4	0.44	0.14
2001	2002-1	2.38	2.84
	2002-2	1.22	1.39
	2002-3	1.29	1.27
	2002-4	0.70	0.99
2002	2003-1	-1.89	-2.88
	2003-2	-1.52	-2.45
	2003-3	-1.26	-2.09
	2003-4	-0.81	-1.50
2003	2004-1	-0.48	-0.34
	2004-2	-1.21	-1.01
	2004-3	-1.81	-1.73
	2004-4	-1.15	-0.79

Figure Captions

Fig. 1 Futures Market and STEO Error Forecast Error from 1998 to 2003 (Months 1-12)

Fig. 2 Futures Market and STEO Error Forecast Error from 1998 to 2003 (Months 13-24)


Forecast from 1998 to 2003 (Months 1-12)
Futures Market Error
STEO Error
Price
Year
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3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
1998-1
1998-2
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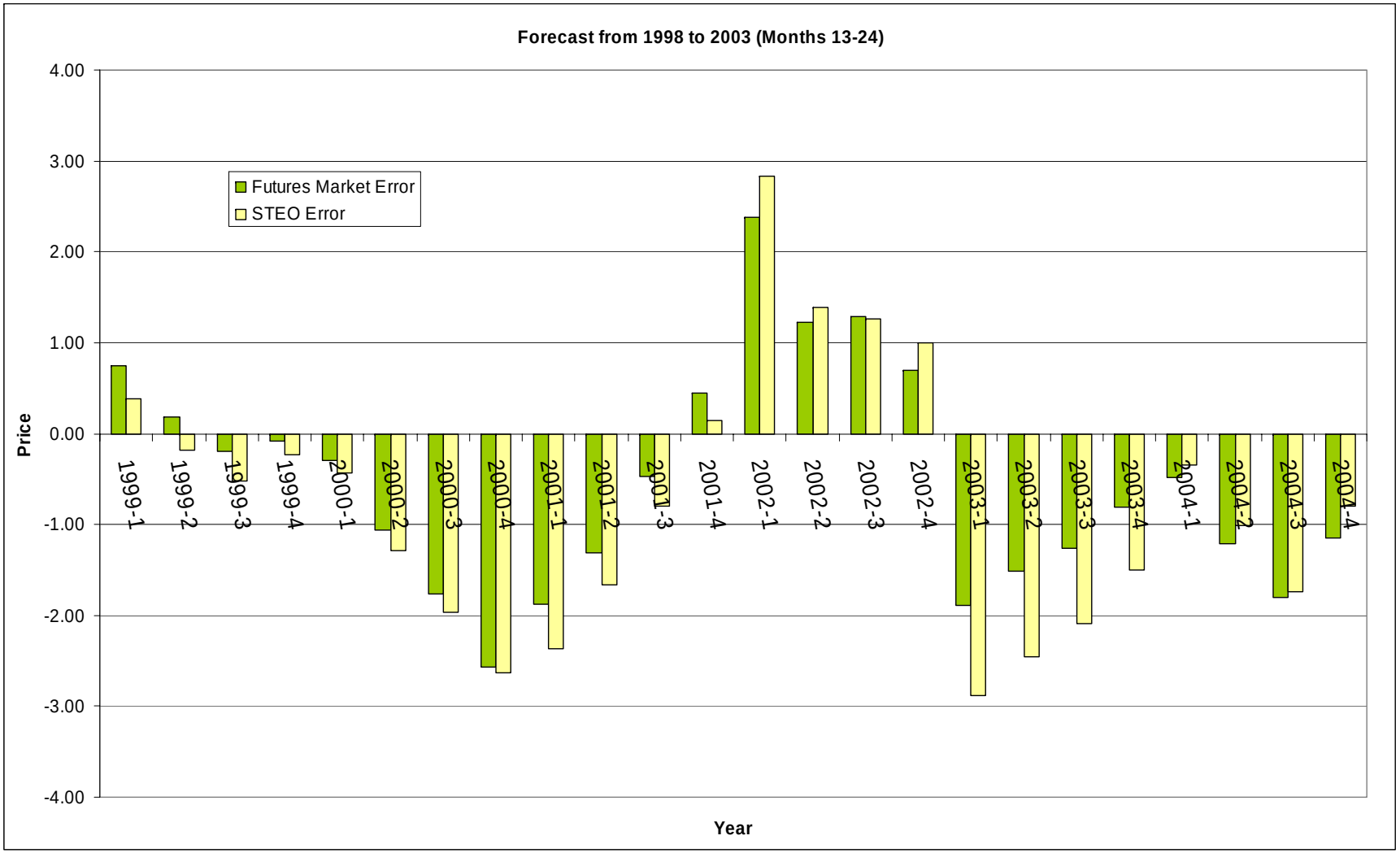
Forecast from 1998 to 2003 (Months 13-24)
Futures Market Error
STEO Error
Price
Year
4.00
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-1.00
-2.00
-3.00
-4.00
1999-1
1999-2
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