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A Vector Autoregression Model of the Nevada Economy

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A vector autoregression time series model of the Nevada economy is developed and used to forecast key measures of economic activity for a two-year period beyond the third quarter of 1986. The results have three important implications. First, a relatively simple forecasting model can be developed for a regional economy that incorporates considerable economic theory and flexibility. Second, the forecasting performance of such a model appears promising. Third, the vector autoregression approach should generate a reconsideration of traditional approaches to modeling and forecasting the regional economy.

A vector autoregression (VAR) forecasting model of the Nevada economy is developed in this article. The use of the VAR in the context of analyzing this region is motivated by two considerations. First, Nevada's economy has attracted considerable attention because of its structure uniquely based on gaming and the fact that it has been, and continues to be, one of the fastest growing states in terms of employment and income. At the same time, the economy has become increasingly sensitive to national influences, the gaming industry is exhibiting signs of slower growth and feeling the effects of increased competition, and in response, the state has embarked on an extensive effort to diversify the economy away from gaming. Understanding the future prospects for Nevada's economy and having a mechanism for forecasting changes in the economy thus are important.

Second, the VAR method of modeling offers a number of advantages over traditional alternatives based on structural equation systems. It is both more parsimonious in its use of data and offers theoretical advantages over structural representations.

The remainder of the paper is organized into four sections. The next section outlines key elements of the Nevada economy. Section II presents the basic features of the VAR approach. Section III outlines the development steps of the Nevada VAR model and reports in-sample and out-of-sample performance of the model. A short concluding section summarizes the main results of the study and compares the model's forecasts with the most recent data available at the time of this writing.

I. Nevada's Economy

Nevada's gaming-based economy was established by legislation in 1931 that permitted casino gaming statewide. Not until after World War II, however, did the gaming industry come to dominate the state's economy.[1] Estimates indicate that gaming activity directly and indirectly accounts for over 60 percent of Nevada employment. Gaming tax revenues provide about 45 percent of state revenues to the general fund in any given year.

The dominant role of gaming and the service orientation of the Nevada economy sharply differentiates it from other regional economies. In 1985, the service sector in Nevada accounted for 44.0 percent of total industrial employment, of which 64.0 percent was employed in the hotel-gaming-recreational sector. The service sector in Nevada is proportionately almost twice as large as that in the U.S.

There are five characteristics of the Nevada regional economy that make it unique and interesting to study. First, the state is less diversified than most other states and remains highly dependent on the gaming industry as its economic base. Second, the geography and the uneven spatial distribution of economic activity present policymakers with a set of problems that are simultaneously urban and rural. Despite the physical size of the state, population and economic activity are concentrated in three regions: Las Vegas (Clark County) in the southern part of the state, and, in the northern part, Reno-Sparks (Washoe County) and South Lake Tahoe (Douglas County and Carson City).

Third, the federal government owns approximately 87 percent of the land in Nevada. Nevada is viewed as a likely location of the high-level nuclear waste facility just as it was several years ago for the controversial MX missile system. As a result, the role of the federal government as a large landowner adds a unique economic and political dimension to the state's future economic growth.

Fourth, the gaming industry is exhibiting signs of market saturation as it matures in Nevada and as new competitors emerge in the forms of casino gaming in Atlantic City, New Jersey and state lotteries such as that in California lottery introduced in late 1985.

Fifth, despite the recent slowdown in the gaming industry, Nevada has had and is projected to have one of the highest employment growth rates through the end of the century. Total civilian employment grew at an average annual rate of 5.5 percent from 1960 to 1985, compared to an employment growth rate of 2.0 percent for the U.S. In 1986, employment in Nevada was the fastest growing among the states making up the Twelfth Federal Reserve District (Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, Utah, and Washington).

In fact, the past and projected performance of the Nevada economy have been used to rationalize proposals to initiate or expand gaming activities in other regions to solve local employment and/or fiscal problems. In addition, gaming often has been portrayed as an activity less sensitive to national influences than others. These are mistaken views.

Gaming has not rendered Nevada recession-proof[2] nor has gaming provided a stable revenue base. A close reading of Nevada's performance suggests that gaming will neither be a panacea for fiscal problems nor a means of insulating other regions from national cyclic swings. Nevada's economic performance in the late 1970s and especially in 1981 and 1982 demonstrated once and for all that the region was not immune to changes in the national economic environment. The sharp national recession from July 1981 to November 1982 was clearly reflected in reduced economic activity in Nevada. The unemployment rate increased from 6.7 percent in July 1981 to 10.8 percent in November 1982.

The growing sensitivity of Nevada's economy to national economic forces and the lower prospects for growth in the gaming sector have led to efforts throughout the state to diversify the economy away from dependence on gaming. There is now widespread recognition within Nevada that gaming no longer is capable of supporting stable long-term growth and stable tax revenues for an expanding economy. Thus, other regions that look to gaming as a solution to their economic problems should be less optimistic about the economic benefits of gaming.

II. Approaches to Modeling the Nevada Economy

Structural and time series methods represent two possible ways of classifying the variety of methods that have been employed or could be employed to model and forecast Nevada's economy.

Structural economic models are loosely defined as systems of equations that specify behavioral, technological, institutional, definitional, and equilibrium relationships among a given set of economic variables. In these models certain variables — "exogenous variables" — are seen as affecting, but not being affected by, economic behavior as defined in the model. The affected — or "endogenous" — variables are linked to the exogenous variables by behavioral equations. Thus, the structural approach imposes an explicit causal ordering among the variables and predicts future values of the endogenous variables by relating them to other variables in which the causal relationships are explicitly defined by the structure of the model.

Traditionally, structural models of the regional economy have followed the Keynesian macroeconomic framework of sectoral aggregate demand analysis. They look much like national macroeconomic models, modified to fit the available data set or to deal with issues specific to the regional aspect of the economy, such as migration. Multi-equation Keynesian models, input-output models, economic base models, and a variety of demographic models incorporate the structural approach. Structural models are used not only to forecast but also to explore the features of the underlying behavioral relationships.

Time series methods, in contrast, are designed primarily to *forecast,* and rely on either the past behavior of the variable and/or correlations with other variables to generate those forecasts. Time series methods are not "structural" since they rely on autocorrelations and cross correlations to forecast future values rather than specified, causal behavioral relationships among the variables. In addition, they adopt a methodology using few parameters to simplify modeling and estimation, and to limit errors associated with the statistical specification.

In the 1970s, a class of linear time-series models introduced by G. E. P. Box and G. M. Jenkins (1970) referred to as autoregressive-integrated-moving-average (ARIMA) models found wide application in economic and business forecasting. These models essentially rely on the assumption that the process that causes an economic variable to move can be described by a properly weighted sum of past values of the variable plus a random disturbance of some kind.

Previous Efforts to Model the Nevada Economy

The overwhelming majority of modeling and forecasting applications in Nevada have used the structural approach. S. Chu (1974) provided the first large (42 equation) structural model of Nevada's economy. Thomas F. Cargill and James Walker (1981) estimated single equation models using national variables to forecast Nevada's state revenues. Robert Barone (1979) and Barone *et al* (1979) applied a modeling framework incorporating an extensive demographic sector for a rural area of Nevada. John Hester and William Rosen (1981) and Steve Ghiglieri (1986) constructed large structural models of Washoe County (Reno, Sparks, and Lake Tahoe area).

To date, Cargill and William Eadington (1978) provide the only application of time series modeling to the Nevada economy. They estimated ARIMA models for gross gaming revenues for the three major regions of Nevada, and these models were subsequently used for a limited period by the Budget Division in Nevada to forecast gaming revenues.

These various efforts have provided important insights into the Nevada economy and have been used on occasion to develop forecasts of key measures of economic activity. At the same time, they have not proven flexible enough to meet the requirements of timely and accurate forecasts. The ARIMA models possess the advantage of cost effectiveness and flexibility, relying as they do on a simple, weighted sum only of past values of a variable. They ignore, however, important relationships *among* variables and have little basis in economic theory. In addition, they can be nonlinear in form, a fact that causes some estimation and statistical inference problems.

Recently, the VAR method of time series analysis has attracted considerable attention because it possesses advantages in a number of dimensions over both ARIMA models and traditional structural approaches.[3] In addition, the forecasting performance of VAR models of the national economy has been good relative to several well-known structural models (Stephen K. McNees, 1986), suggesting that the VAR method offers considerable potential as a forecasting instrument for the regional economy as well.[4]

The VAR Approach

A VAR model represents a vector of variables as a general autoregressive structure in which the relationship between a number of variables and their past values is employed. The general mathematical structure of a VAR model is:

$$Y(t) = D(t) + B_1 Y(t-1) + \dots + B_m Y(t-m) + e(t) \quad (1)$$

where Y is an $n \times 1$ vector of variables, D is an $n \times 1$

vector of deterministic components, B is an $n \times n$ matrix of coefficients, e is an $n \times 1$ vector of residuals, and m is the lag length. Deterministic ("exogenous") components include a constant term, seasonal dummies, or other dummy variables that represent discrete shifts in the relationships at a specific point in time.

Equation 1 is an unconstrained or UVAR model since the equations are estimated without any constraints on the coefficients or the lag pattern. Unfortunately, even relatively small UVAR models (those with few variables and short lag lengths) can quickly become quite large in terms of the number of parameters that need to be estimated. For example, each equation of a UVAR system using a 3×1 matrix of variables and just 4 lags of each variable would have 12 parameters to estimate, plus any parameters on deterministic variables. This poses problems not only of data availability (a particular crucial issue in regional modeling) but also of the resultant quality of the forecasting device. Too many parameters typically cause UVAR models to have large out of sample forecast errors.

Using an approach developed by Robert B. Litterman (1979) and Thomas A. Doan and Litterman (1986), the modeler can improve the forecast performance of a VAR model by restricting its parameters in a particular manner. Using such restrictions is known as "imposing a prior" on the model. This terminology is rooted in Bayesian statistical theory, which provides guidance to a modeler who wishes to combine optimally the sample data with which the model will be estimated with information or beliefs known independently of the sample.

In Bayesian parlance, the modeler is said to know this independent information "prior to" any knowledge of the informational content of the unrestricted model. Litterman, in fact, goes as far as to call a UVAR model, upon which he has imposed such a prior, a Bayesian vector auto-regression, or BVAR model.

While in principle almost any kind of restriction could be imposed upon a UVAR model, when Litterman speaks of BVAR models, he has a particularly clever choice of prior in mind. This prior is known as the random walk prior. (It is also known as a "Minnesota prior" since it has been used extensively in the modeling efforts of the Federal Reserve Bank of Minneapolis.)

The random walk prior is based on the empirical finding that the simple time series model $x(t) = x(t-1) + u(t)$ is a reasonable representation of a large number of economic variables. Notice in equation 1 that there are n variables appearing in Y, the $n \times 1$ matrix of variables. Each of these n variables will appear once as the dependent variable in one of the n equations that forms the vector autoregressive system.

To begin with, the random walk prior sets equal to 1.0 the value of the first "own" lag in each individual equation. ("Own lags" are the lagged values of the dependent variables in the equation under consideration.) All other coefficients on lagged variables in that equation, called "other lags", as well as own lags of more than one period, are restricted to zero. The value to which individual coefficients have been restricted is known as those coefficients' point value.

The second step in forming a random walk prior is to set the degree to which the coefficients in each equation will be allowed to vary away from their point values. This is known as setting the "tightness" of the prior. An extremely tight prior allows little or no variance from the pre-selected point values. Conversely, an extremely loose prior allows the full freedom inherent in a completely unrestricted VAR.

The modeler's beliefs about the suitability of the random walk model is reflected in the tightness set for the prior. A modeler can, by adjusting the prior's overall tightness, adjust the degree to which the model responds in general to the randomness in the data set over which the model is estimated. Obviously, setting most of the parameters in each equation to point values of zero would also greatly alleviate the problem of too many parameters.

Further sophistication can be achieved by fine tuning the relative tightness of groups of parameters. Within each equation, a different relative tightness can be assigned to coefficients on own lags versus other lags. This procedure is known as cross-weight tightness, and it reflects the degree to which the other variables are implicitly employed in predicting the dependent variable of each equation. (In essence, the researcher is making a judgment about how much useful information is contained in other variables.)

A second kind of variation in tightness operates on lags of the same variable in each equation and may be called a distributed lag prior. The intuition here is that higher numbered lags should contain less useful information about the dependent variable, and hence should be assigned greater relative tightness. For example, the third lag of any variable will be set tighter than the second, and so on. The tighter the prior on a particular parameter, the more its coefficient is pushed towards its point value. Hence, except for the first own lag of each equation, the coefficients of lags are increasingly pushed towards zero as the lags increase in length.

The ability to set both point values and tightness is one crucial feature that distinguishes BVARs from traditional structural models. While structural models often will restrict coefficients to specific point values, they typically do not have the ability to allow any variance away from those values. VAR models by their very nature allow the inclusion of a large number of variables. BVAR techniques then give the modeler the ability to adjust *the degree* to which the many variables influence forecast performance. In contrast, traditional structural techniques also force the modeler to control *the number* of included variables. This restriction is equivalent to setting the excluded variables to a point value of zero with infinite tightness, which is rarely a realistic reflection of the modeler's knowledge or beliefs.

Structural techniques, as their very name suggests, also require the modeler to specify equations that mirror as closely as possible the actual structure of the economic system under study. Again, it is rarely realistic to believe that the modeler knows the structural details of an economic system in sufficient detail to make such specifications. Likewise, the initial prior imposed on a BVAR model is, at best, an educated guess. In practice, a very large number of estimations are performed, in each of which the prior varies slightly. A choice among the numerous estimations is made by identifying the setting that minimizes the BVAR model's out-of-sample forecast error. In this way, the modeler uses a BVAR model subtly to exploit the statistical regularities hidden in the available data. An explicit knowledge of the structure of the economic system is not necessary, although, to the extent it is known, it can be used to shape the imposed prior.

III. VAR Model of Nevada's Economy

Three sets of variables constitute the eight-vector Nevada VAR Model. The first set consists of three variables that represent key measures of economic activity: total industrial employment, taxable sales, and gross gaming revenues. Gross gaming revenues are the net winnings of gaming operations, and, together with taxable sales, provide the major tax base for the state. Establishment-based employment is used rather than civilian employment because civilian employment depends on population estimates, which themselves are subject to question in the Nevada context. Because of its proximity and the interrelatedness of their economies, some measure of the influence of California on Nevada's economy is included in the second set of variables. We include California civilian employment in the system of VAR equations. Four national variables assumed to influence Nevada's economy comprise the third set of variables: real gross national product, the annualized rate of inflation measured by the GNP deflator, total civilian employment, and the 6-month commercial paper rate.

The development of the Nevada VAR model can be summarized by considering the types of interactions between the Nevada variables and the national variables, data transformations, specific priors imposed on the estimation process, model evaluation, and forecasts for the period from the fourth quarter of 1986 to fourth quarter of 1988.

Interaction with the National Economy

The role of national variables in the Nevada VAR model raises two considerations: first, the extent to which they influence economic performance in Nevada, and second, how they should be treated in generating forecasts of Nevada variables beyond the estimation interval.

The coefficient estimates of VAR models are not subject to straightforward interpretation. However, the influence of national variables on the Nevada economy can be investigated by estimating the model and analyzing the interactions among the eight variables. A useful approach is to forecast the VAR model beyond the estimation interval and then to decompose the observed variance in the forecast error of a given variable into the parts due to the shocks in each variable in the vector.

The UVAR Model is based on quarterly, seasonally adjusted data over the period from the first quarter of 1965 to the fourth quarter of 1984, with forecasts generated for the period from the first quarter of 1985 to the third quarter of 1986. The variance decomposition is sensitive to the order of the variables in the vector since a variable in the first few elements of the matrix has fewer opportunities to interact with other variables than a variable further down the order. By definition, the variable placed first in the ordering explains all of its own variance for the first quarter forecast.

Table 1 presents the variance decomposition for each of the eight variables for forecasts 1, 4, and 8 quarters beyond the fourth quarter of 1984. They suggest several important observations. First, the Nevada and California variables play a less important role in explaining the variance of the national variables than the national variables play in explaining the variance of the Nevada and California variables. This suggests that the statistical causation runs from the national economy to the regional economy.

Second, the Nevada variables are less sensitive than the California variable to national variables. This implies that, although both are closely linked to national developments, Nevada's economy is less closely linked

Table 1

Decomposition of Variance for Each Variable in the Eight-Vector UVAR Nevada Model

		Percentage of Variance of Error due to Disturbance to:							
Forecasted Variable	Quarters Ahead	Real GNP	GNP Deflator	6-Mo. Comm. Paper Rate	U.S. Employ	CA Employ	Gross Gaming Revenues	Taxable Sales	Total Industry Employment
Real GNP	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	67.6	5.7	13.4	1.6	1.4	1.3	0.2	8.8
	8	27.0	10.1	43.9	1.1	4.8	1.3	3.0	8.9
GNP Deflator	1	0.1	99.9	0.0	0.0	0.0	0.0	0.0	0.0
	4	8.5	44.2	13.1	4.3	3.6	14.6	7.1	4.6
	8	10.4	29.5	11.1	12.9	6.6	12.1	14.4	3.1
6-Month Commercial Paper Rate	1	0.8	17.4	81.8	0.0	0.0	0.0	0.0	
	4	10.3	7.8	52.2	2.8	2.9	0.5	4.7	18.8
	8	9.0	4.9	40.4	4.6	8.9	1.7	3.9	26.5
U.S. Employment	1	28.7	3.5	0.1	67.6	0.0	0.0	0.0	0.0
	4	41.5	4.4	5.9	33.2	5.9	1.8	2.5	4.8
	8	14.6	12.6	42.3	12.9	3.5	1.3	2.7	10.1
CA Employment	1	8.3	8.4	9.2	3.1	71.0	0.0	0.0	0.0
	4	10.8	7.5	20.1	1.4	47.9	6.7	0.9	4.7
	8	10.0	3.3	34.2	7.2	23.8	6.4	5.7	8.5
Gross Gaming Revenues	1	1.3	0.0	11.0	0:0	0.5	87.2	0.0	0.0
	4	7.1	2.0	8.2	6.0	15.5	52.5	4.6	4.1
	8	4.8	4.0	11.5	4.7	10.5	41.0	4.8	18.9
Taxable Sales	1	2.3	1.9	2.9	0.8	0.9	0.0	91.0	0.0
	4	12.6	2.7	4.5	1.0	5.0	4.7	67.9	1.4
	8	6.1	3.5	13.0	10.1	4.0	1.9	32.3	29.1
Total Industry Employment	1	0.1	1.0	3.7	0.1	0.3	3.5	22.0	69.4
	4	19.1	1.6	1.5	2.7	0.9	2.2	31.8	40.2
	8	18.4	2.1	17.6	3.6	2.2	1.8	24.7	29.6

Note: Estimation period: First quarter 1965 to fourth quarter 1984
Forecast period: First quarter 1985 to fourth quarter 1986
Seasonally adjusted data (Except 6-Month Commercial Paper Rate)

than California's economy. Third, the California variable contributes to the forecast variance of the Nevada variables. This verifies the notion that the large, prosperous neighbor state is influential in Nevada's economic life.

Fourth, despite the influence of the national and California variables in explaining the forecast errors for each of the Nevada variables, the forecast errors of each variable are significantly explained by their own innovations. The inference from this finding is that the random walk model is not an unreasonable approximation for Nevada time series data.

The issue of the direction of causation is usually not raised in single sector VAR models such as national models or models of a single large region. However, general considerations suggest that national variables should play a larger role in explaining the forecast errors of Nevada and California variables than the reverse. That is, it seems reasonable to suppose that national economic events have a greater impact on a small region than the reverse, and the results reported in Table 1 lend some support to this supposition. Because Nevada's economy is so small compared to the nation's, there is little question about the direction of causation between Nevada and national variables.

Unfortunately, the VAR method treats all variables as endogenous, and typical VAR forecasts are based on dynamically forecasted values of all variables in the system. While the direction of causation is not a problem in the estimation stage, allowing a sizable amount of feedback from Nevada variables to national variables can be viewed as at least a conceptual problem in the forecasting stage. The solution adopted in this study was to employ a separate BVAR model of the national economy to generate forecasts of the four national variables used in the Nevada model.[5] The four national variables are thus treated as exogenous when the Nevada model is used to generate forecasts beyond the interval of estimation.

The national model itself consists of a vector of nine variables: real GNP, the GNP deflator, U.S. employment, the commercial paper rate. Standard and Poor's 500 stock index, nonresidential fixed investment, import unit value index, export unit value index, and the monetary aggregate M3. This national model incorporates a fairly complex set of priors and specifications, and is, of course, a modeling exercise that we could discuss at length on its own. We will not do so here, however. Suffice it to say that this national BVAR model is capable of forecasting real GNP growth and inflation with reasonably small forecast errors over the period from the first quarter of 1982 to the third quarter of 1986.

Model Estimation and Evaluation: Two Stages

There were two stages to the estimation and evaluation of the Nevada model in terms of the forecast period selected to evaluate the model: the first stage focused on the period from the first quarter of 1982 to the third quarter of 1986, whereas the second stage focused on the period from the first quarter of 1985 to the third quarter of 1986 for reasons to be explained below.

First Stage A large number of variations of the Nevada model were estimated that differed in terms of data transformations, lag length, treatment of seasonality, and type and tightness of the priors imposed on the coefficients. The models were evaluated in terms of absolute mean errors, root mean square errors, and other statistics or measures of performance over the forecast interval. They were estimated over the period from the first quarter of 1965 through the fourth quarter of 1981, and forecasted over the period from the first quarter of 1982 through the third quarter of 1986, which was the most recent data available at the time.

The most promising version of the Nevada VAR model from the first stage estimation and evaluation process was a six-lag model of seasonally adjusted data with an overall random walk tightness prior of .075, a harmonic decay pattern on the distributed lags with a decay parameter of 2.0, and a cross weight prior of .4. The final priors were consistent with the UVAR model results (Table 1) and with prior understanding of Nevada's economy.[6]

Second Stage The second stage estimation and evaluation focused on a more recent period, from the first quarter of 1985 through the third quarter of 1986. This was a period of increased economic uncertainty in Nevada resulting partly from the October 1985 introduction of a statewide lottery in California. The behavior of key measures of economic activity in Nevada during 1986 suggest that the California lottery is indeed affecting Nevada's economy.

The data suggest that the shift toward gaming in California has had a greater impact than the 1978 introduction of casino gaming in Atlantic City, New Jersey. The impact of casino gaming in Atlantic City was mitigated by the East Coast's distance from the western states, which constitute Nevada's most significant market area. The California lottery in contrast represents a more direct competitive threat since California is the major state in Nevada's market area. The rapid growth of the California lottery (1986 gross sales of slightly more than $2 billion), the introduction of a parimutuel lotto game in late 1986, and indications that the California Lottery Commission is considering expanded gaming activities throughout the state have raised considerable concern in Nevada. Focusing the VAR model on this more recent period therefore would provide meaningful information on the impact of the California lottery on the Nevada economy.

Initial regressions for the more recent period — from the first quarter of 1985 to the third quarter of 1986 — suggested that some improvement could be achieved by tightening the random walk prior. Table 2 presents the percentage forecast error for each quarter forecasted based on the actual values of the national variables.[7] The forecast errors are reasonable with the exception of gross gaming revenues which is consistently overestimated, with the size of the error increasing over the forecast period. This growing overestimation is likely due to the failure to incorporate any measure of the California lottery.

Table 3 provides additional information about the forecast performance of the VAR model without the influence of the California lottery. The model in Table 3 was estimated through the fourth quarter of 1984, and then used to develop forecasts for each of seven quarters by re-estimating the coefficients of the model for each quarter via the Kalman filter method. A resultant statistic — the Theil U statistic — provides insights into the forecasting performance of the model by giving a comparison of the root mean square error for each forecast step to the root mean square error of a no change or "naive" forecasting model.[8] With the exception of gross gaming revenues, the Theil U statistics are less than one and tend to decline the longer the forecast period.

The Theil U statistics for gross gaming revenues suggest that the VAR model does a poor job of forecasting a key measure of economic activity in Nevada; however, two considerations indicate that concluding the model does a poor job would be premature. First, for every variation of the model used in the first stage of model estimation and evaluation, the Theil U statistics for gross gaming revenues were less than one. Secondly, the failure to incorporate some measure of the influence of the California lottery could be expected, a priori, to cause negative and increasingly large forecast errors for gaming revenues.

Thus, the influence of the California lottery should be incorporated into the estimation process before the VAR model is used to forecast beyond the third quarter of 1986. This can be accomplished by including a dummy variable (DUMMY = 0 before the fourth quarter of 1985 and DUMMY = 1 from the fourth quarter of 1985 on) as a deterministic component of the model. The California lottery has existed for too short a period of time to permit useful forecast evaluation information such as reported in Tables 2 and 3.

Table 2

Forecast Errors of Nevada Variables

Quarter	Percent Forecast Error [(Actual — Forecast)/Actual] × 100 Gross Gaming Revenues	Taxable Sales	Total Industry Employment
1985 First	0.5%	−0.9%	−1.1%
Second	−1.0	0.4	1.0
Third	−4.7	−4.1	−0.2
Fourth	−8.0	−4.3	−2.4
1986 First	−8.3	−4.9	−3.8
Second	−9.1	−7.8	−2.3
Third	−13.0	−5.0	−3.3

Note: Estimation period: First quarter 1965 to fourth quarter 1984

Seasonally adjusted data (Except 6-Month Commercial Paper Rate)

Table 3

Theil U Statistics for Nevada VAR Model

Forecast Horizon	Number of Forecasts	Theil U Statistics: Gross Gaming Revenues	Taxable Sales	Total Industry Employment
1	7	1.3	0.8	0.8
2	6	1.5	0.6	0.7
3	5	2.1	0.7	0.7
4	4	2.8	0.7	0.7
5	3	2.4	0.7	0.7
6	2	2.0	0.6	0.3
7	1	2.1	0.4	0.4

Note: Estimation period: First quarter 1965 to fourth quarter 1984

Seasonally adjusted data (Except 6-Month Commercial Paper Rate)

Forecasts for the Period 1986 to 1988 Prior to developing forecasts for the Nevada variables, it was necessary to generate forecasts of the four required national variables since they are treated as exogenus to the Nevada and California variables. According to forecasts made by the U.S. VAR model of the Federal Reserve Bank of San Francisco, real GNP will grow at approximately 3.5 percent per year over the two-year period, civilian employment will grow approximately 3.2 percent per year, interest rates are to remain fairly constant, and inflation will increase gradually to an annual rate of 5.89 percent in the fourth quarter of 1988.

The VAR Nevada model was re-established from the first quarter of 1965 to the third quarter of 1986 with a California lottery dummy for the fourth quarter of 1985 and beyond. Forecasts of gross gaming revenues, taxable sales, and employment along with California employment were generated, treating the national forecasted variables as exogenous. The forecasted values of the seasonally adjusted data were transformed into annualized quarterly growth rates reported in Table 4 with and without the influence of the California lottery.

The effect of the California lottery is clearly reflected in the results in Table 4. The dummy variable significantly lowers the forecasted growth rates of gross gaming revenues and employment as anticipated. The forecasted growth of employment is reduced because gaming represents about 25 percent of industrial employment. It was also anticipated that the growth rate of taxable sales would not be as significantly affected by the California lottery because statistics on such characteristics as traffic flows, airport activity, and special events suggest that there has been a continued increase in the number of visitors to the state. It does appear, however, that the visitors are spending less on gaming activities than in the past.

Table 4

Forecasted Growth Rates of Nevada Variables and the California Lottery Dummy Variable

(Annual)

	California Dummy Excluded			California Dummy Included		
Quarter	Gross Gaming Revenue	Taxable Sales	Total Industry Employment	Gross Gaming Revenue	Taxable Sales	Total Industry Employment
1986 Fourth	10.3%	12.1%	6.6%	3.9%	12.0%	4.3%
1987 First	10.3	12.4	6.7	4.2	12.2	4.5
Second	10.1	12.2	6.6	4.2	11.9	4.4
Third	10.4	12.5	6.7	4.7	12.2	4.7
Fourth	10.5	12.8	6.8	5.1	12.5	5.0
1988 First	10.5	12.7	6.8	5.2	12.3	5.1
Second	10.4	12.5	6.7	5.2	12.0	5.1
Third	10.5	12.6	6.8	5.6	12.1	5.3
Fourth	10.6	12.8	6.8	5.9	12.2	5.5

Note: Estimation period: First quarter 1965 to third quarter 1986
Seasonally adjusted data (Except 6-Month Commercial Paper Rate)

IV. Concluding Comments

The technical problems with estimating large structural models combined with the lack of a detailed and reliable data base at the regional level strongly argue that an alternative modeling methodology be applied to regional economic forecasting. Time series techniques offer an alternative that deserves consideration. While the enthusiasm for ARIMA time series models has waned, the VAR method offers many of the same advantages with the additions of being more flexible and capable of incorporating economic considerations about the underlying structure of a regional economy.

In this paper we have developed a vector autoregressive time series model of the Nevada economy and used it to forecast key variables out to the fourth quarter of 1988. The forecasts suggest continued growth in Nevada. However, the California lottery is anticipated to have a negative impact on the growth rate of Nevada employment and gaming revenue, at least in the short run. Taxable sales, in contrast, appear only slightly affected by the lottery, perhaps because tourists still visit Nevada to enjoy its many recreational attractions despite having spent some of their gaming dollars elsewhere. These results also suggest that gaming may no longer be the engine of economic growth it once was, and that other regions looking for relief from fiscal distress may be well-advised to consider options beyond gaming.

Intuition and the results presented in Tables 3 and 4 suggest that the influence of the California lottery should be incorporated into developing forecasts of gaming revenues, taxable sales, and employment in Nevada. The need to consider the lottery's impact becomes more apparent when the forecasts presented in Table 4 are compared with recent performance of the forecasted variables (Table 5). That comparison suggests that the dummy variable used to represent the influence of the lottery may have overemphasized the lottery's adverse impact.

Table 5

Actual Growth Rates of Nevada Variables
(Annual)

Quarter	Gross Gaming Revenues	Taxable Sales	Total Industry Employment
1986 Fourth	11.8%	14.0%	5.9%
1987 First	14.4	11.3	6.9

Note: Growth rate calculated as one-year quarter percentage change.

Gaming revenues have grown much faster than forecasted with the influence of the California lottery incorporated into the VAR model. In fact, the forecasted gaming revenue growth is fairly close to the forecast generated when the lottery variable was omitted. The same observation can be made for employment, although the difference between forecast (with lottery influence) and actual growth is not as large as it is for gaming revenue. The taxable sales forecast was not significantly influenced by the inclusion or exclusion of the lottery variable and, in either case, the VAR model provided a reasonable forecast of taxable sales growth.

These different impacts suggest that additional work needs to be directed toward incorporating the effects of the California lottery. Unfortunately, the short time period for which the lottery has been in existence limits the number of ways one can incorporate its influence. The dummy variable will likely overemphasize the lottery's influence since it is incapable of differentiating between short run and long run impacts. One would reasonably anticipate a difference between the short run and long run response of gaming revenues to the initiation of the California lottery. Perhaps gaming has recovered from the initial impact of the California lottery, or perhaps the lottery never had a significant effect on gaming revenues, although the latter explanation is difficult to accept on a priori grounds.

The growth of gaming revenue in the fourth quarter of 1986 and the first quarter of 1987 has surprised most observers in Nevada and it is too early to determine whether Nevada will continue to experience such high gaming growth rates. In any event, Tables 4 and 5 illustrate the difficulty of forecasting a regional economy on a quarter-by-quarter basis.

While it may be too early to assess fully the merits of the Nevada VAR model, the initial results are promising and the areas of future research are well-defined. Considering that there presently exists no other quarterly forecasting model for Nevada that is widely accepted or has proven as flexible, the Nevada VAR model can be regarded as a meaningful forecasting framework for the regional economy.

FOOTNOTES

1. The Nevada economy and Nevada gaming are discussed in more detail in Thomas F. Cargill (1982) and William R. Eadington (1982), respectively. Recent developments are discussed in various issues of the *Nevada Review of Business and Economics,* published by the Bureau of Business and Economic Research, College of Business Administration, University of Nevada, Reno.

2. Thomas F. Cargill (1979) analyzed growth rates of various categories of industrial employment over business cycle phases from 1960 through 1975 and found that Nevada employment was sensitive to national swings in the economy.

3. A general discussion of VAR methods is provided by Richard M. Todd (1984) while a theoretical discussion is provided by Robert B. Litterman (1979). Christopher Sims (1980), Thomas J. Sargent and Sims (1977), and Sargent (1979) provided early applications. T. F. Cooley and S. F. LeRoy (1985) provide a critical appraisal of VAR methods.

4. There are several regional VAR models in existence; for example, see Hossain Amirizadeh and Richard M. Todd (1984) and Anatoli Kuprianov and William Lupoletti (1984).

5. The national model was developed at the Federal Reserve Bank of San Francisco by Bharat Trehan with the assistance of one of the authors (Morus). The authors express appreciation to Bharat Trehan and Jack Beebe, Director of Research, for permission to use the national model in this paper.

6. Calculations were performed on an IBM PC-AT using the RATS econometric software package (Thomas A. Doan and Robert A. Litterman, 1986).

7. Actual values of the national variables were employed rather than forecast values because of the desire to use the best available information to evaluate the Nevada VAR model. The relative ranking of various versions of the model would not be affected by the use of forecasted national variables.

All data with the exception of the rate of inflation were transformed into natural logs. The Nevada and California variables were seasonally adjusted via the Commerce Department's X-11 method. Seasonally adjusted values of the national variables (except the interest rate) were used as they are provided by the Commerce Department or other sources.

8. The Theil U statistic is the ratio of the root mean squared error (RSME) of the VAR model to the RSME of the naive model. Thus, values less than one suggest the VAR model outperforms a very simple forecast procedure.

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