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Does California Drive the West? An Econometric Investigation of Regional Spillovers

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This paper measures linkages between the California economy and its neighbors, and the extent to which economic shocks to California spill over to its neighbor states, through vector autoregression techniques. Leading and lagging relationships between California and other western states are identified through Granger causality tests. Then, under certain identifying assumptions, the economic importance of these relationships is measured. Finally, the sources of the linkages are then considered by examining the effect of California on specific sectors within a state. In general, the results suggest that the California economy does have important spillover effects on other western states—particularly those in close geographic proximity to it.

In terms of population, output, and diversity, California dwarfs its neighbors in the Twelfth Federal Reserve District—which includes Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, Utah, and Washington. In July 1990, the 12.9 million jobs in California accounted for almost two-thirds (63 percent) of total employment in the District. For comparison, it had five times as much employment as the next largest District state, Washington, which has 2.2 million jobs.

This paper examines the extent to which the California economy drives the western region. In particular, it attempts to measure linkages between the California economy and its neighbors, and the extent to which economic shocks to California spill over to its neighbor states.

The topic is relevant to the most recent recession, which hit California and the nation in mid-1990. Most District states, however, were not affected until much later, with employment declines becoming evident only in early 1991. To the extent that systematic spillovers from California occur with a lag of two to three quarters, this pattern of regional recession would not be surprising. Accounting for these spillovers would yield better forecasts of economic developments in western states.

A more general motivation is that information on linkages and spillovers between states adds to the understanding of how regions operate and when regional analysis is appropriate. A model of regional linkages due to trade flows, for example, results in different predictions from a model of linkages due to factor flows. Positive shocks that increase economic activity in one state may stimulate trade with other states, inducing positive spillovers. If the increased economic activity induces labor to migrate, however, a negative effect on neighbor states might result. Furthermore, if regional economies are relatively open and driven by national shocks, a broad macroeconomic perspective might be appropriate for monetary or fiscal policy analysis. If regional economies are closed to spillovers from the nation or other states, however, a region-by-region approach to policy analysis might be called for. Finally, if particular sectors (such as housing or finance) are shown to be more closed than others, policies targeted toward those sectors can be implemented on a regional rather than national basis.

This paper measures linkages through vector autoregression (VAR) techniques. Employment growth rates (used as a proxy for growth in economic output) in Twelfth District states are estimated as a function of lagged growth in own employment, lagged growth in California employment, and lagged growth in national employment. The goal is to explore the extent to which economic fluctuations in a state are driven by the state's own economy or by linkages to California or national markets.

Leading and lagging relationships between California and other western states are tested through Granger causality tests. A standard decomposition of the forecast error variance then measures the economic importance of these relationships. The sources of the linkages are then explored through examining the effect of California on specific sectors within a state.

In general, the results suggest that the California economy has important spillover effects on its neighboring states in the Twelfth District, namely, Arizona, Nevada, Oregon, Utah, and Washington, but not on Alaska, Hawaii, and Idaho. In the reverse direction, Granger causality tests suggest that only Arizona has significant spillover effects on California.

The variance decomposition results indicate that the measured spillovers from California to its neighbors is relatively large and statistically significant through three quarters. The state with the largest measured linkages is Arizona, followed by Nevada, Oregon, Washington, and Utah.

The sectoral breakdowns suggest varied sources of linkages. Shocks to California affect manufacturing in Arizona, Oregon, and Utah, while the service sectors appear to respond in Arizona, Nevada, Oregon, and Utah.[1] No spillovers are observed in finance. The observed spillovers in manufacturing are consistent with a model of linkages propagated through trade flows of manufactured products between firms, while spillovers in the service sector suggest that trade flows also exist in nonmanufacturing sectors—possibly tourism and recreation.

In sum, the results indicate that shocks to California influence its neighbor states, and suggest the magnitude of spillovers that can be expected given this historical relationship. The estimates should be treated with caution, however. In particular, the VAR modeling approach does not capture structural change or adequately measure factor flows. Moreover, it may not control adequately for shocks common to western states (perhaps due to common industries). The spillovers identified in this paper, however, indicate that these problems merit further research.

This paper is organized as follows. Section I reviews the theory of linkages between regions and considers the strengths and weaknesses of using VARs to model them. Section II presents the basic results. Section III explores which sectors are most affected by spillovers. Section IV concludes and considers areas for future research.

I. Modeling Regional Linkages with VARs

While linkages among states may exist for several reasons, this paper is concerned with measuring spillovers of economic shocks to the California economy to its neighbor states. As such our focus is on linkages that are principally economic in nature: flows of goods (trade) and factors of production.[2] What then is the nature of the economic shocks, and how are they transmitted through these linkages?

Positive economic shocks to California could come from the demand side (for example, due to jumps in national demand for California products like computers, entertainment, aerospace), or from the supply side (for example, from technological innovations that enhance productivity or result in new products). Negative shocks, of course, also have occurred and are of current concern. Falling national demand for California defense products is reducing manufacturing activity. Recent natural supply shocks include the 1989 Loma Prieta earthquake, freezes, and drought. Supply constraints induced by environmental problems, inadequate infrastructure, or regulatory burdens also may become binding.

Trade flows of goods and services between regions are an obvious mechanism for transmission of economic shocks from California to its neighbors. Increases in economic activity in California heighten the demand for imports of raw materials, intermediate inputs, and final products from other states. Raw materials could include minerals, electricity, or water. Intermediate inputs could range from lumber and wood products for housing, to electronic components for defense and aerospace. Final products could include the whole range of consumer goods. Economic growth in California also can affect the consumption of services in other states, including entertainment (skiing in Utah or casinos in Nevada).

[1]While Washington exhibits a significant overall linkage, no one sector is significantly affected.

[2]Linkages other than trade or factor flows also may exist. First, multiregional government institutions (such as Federal Reserve Districts) or multiregional firms may exist. Second, information flows may give rise to differential adaption rates of innovations across regions. Third, physical flows of pollutants such as acid rain across regional boundaries could occur.

The transmission of shocks through trade should occur relatively quickly, as California factories place orders for goods, or as consumers plan vacations. If the shocks are measured as changes in growth rates from trend, however, they should be short-run in nature. A jump in demand from California would permanently raise the *level* of economic activity in a neighbor state, but the period of higher growth would be of relatively short duration.

In general, if positive (negative) economic shocks to California spill over to other states through trade flows, they should have a positive (negative) short-run effect on growth in the state that dampens down relatively quickly. Furthermore, since transportation costs increase with distance, I expect more trade to be conducted between California and states in close geographic proximity. As such, states contiguous to California should be subject to greater spillover effects than those at greater distance.

If the linkages between states are through factor flows as well as trade, the expected spillover effects of shocks to California become less clear. Positive shocks to California that raise the demand for labor might attract workers from other states, leading to a negative effect on economic activity as the population and labor emigrates. Alternatively, a positive shock that raises demand for California products might lead firms to consider moving production facilities to other states if supply constraints in infrastructure (or environment) become binding. Negative shocks to productivity also could lead firms to relocate. Much attention is currently being given to California firms relocating production facilities to other western states due to regulatory burdens and other perceived costs of operating in California.

If the predominant mechanism for regional linkages is factor flows, then I have no clear prediction of how shocks to California will affect neighbor states. Spillovers propagated through factor flows, however, will likely occur over a longer time horizon than those propagated through trade flows. (Relocating a firm takes longer than placing orders.)

A further problem, however, is that spillovers involving factor flows entail long-run structural change in regional economies that will result in changed trade flows. The VAR model assumes that structural patterns are fixed and cannot distinguish between long-run and short-run influences in the data. This limits our ability to distinguish between trade and factor flows.

A final note is that trade and factor flows should be reciprocal. The relative size of the California economy to its neighbors, however, suggests that the neighbors' effect on California growth will be smaller than California's effects on its neighbors. Though theory predicts that a relationship exists, in practice it may be difficult to pick up a small effect in noisy data.

The VAR Approach

This paper uses a VAR approach to model linkages between states in the Twelfth District. The advantages of this method include its parsimonious use of data, allowance for top-down effects from the nation to the region, allowance for feedbacks (with a lag) from the region to the nation, and identification of leading and lagging relationships between pairs of states. The drawbacks include the lack of an explicit structural model to explore the mechanism of linkages and the need for untestable identifying restrictions to measure the economic importance of spillovers.

A vector autoregression is a relatively simple modeling approach that has become widely used by economists to gather evidence on business cycle dynamics. Typically, these models focus on a limited number of random variables at the national level, such as money, interest rates, prices, and output. Each variable is expressed as a linear function of past values of itself, past values of the other variables, and nonrandom constant terms and time trends. After estimating the model (equation by equation with ordinary least squares) the results can be used to identify leading and lagging relationships between variables and, with further identifying restrictions, to measure the economic importance of these dynamic relationships.

The identification of leading and lagging relationships is accomplished through causality tests. For example, if there are two time series m and y, the series y fails to Granger-cause m according to the Granger (1969) test if, in a regression of m on lagged m and lagged y, the latter (lagged y) takes on a zero coefficient. If y fails to Granger-cause m, that m is said to be exogenous with respect to y. Furthermore, if in addition m does Granger-cause y, m is said to be causally prior to y.[3]

While statistical leading and lagging relationships can be identified through Granger tests, measuring the economic importance of these relationships requires further identifying restrictions. The standard approach developed by Sims (1980a,b) uses the estimated VAR results to measure the dynamic interactions among variables in two different ways. First, from a moving average representation of a VAR model, each variable can be written as a function of the errors. A tabulation of the response of the ith variable to an innovation in the jth variable is called an impulse response function and shows how one variable

[3]See Cooley and Leroy (1985). In another approach presented by Sims (1972), y fails to Granger-cause m if in a regression of y on lagged y and future m, the latter takes on a zero coefficient. Jacobs, Leamer, and Ward (1979) show that the Granger and Sims tests are implications of the same null hypothesis.

responds over time to a single surprise increase in itself or another variable. Second, a forecast error variance decomposition (or innovation accounting) can be used to analyze the errors the model would make if used to forecast. It determines the proportion of each variable's forecast error that is attributable to each of the orthogonalized innovations in the VAR model.

Identification of a VAR system is achieved by assuming a recursive chain of causality among the surprises in any given period. This identification (or ordering of equations), however, is justified only under a predeterminedness assumption. If y_t is predetermined with respect to m_t, the conditional correlation between y_t and m_t is attributed to the contemporaneous effect of y_t on m_t; the contemporaneous effect of m_t on y_t is restricted to zero. This assumption, however, is untestable in the absence of prior restrictions derived from theory. In particular, since Granger noncausality (which tests for the effect of lagged as opposed to contemporaneous variables) is neither necessary nor sufficient for predeterminedness, predeterminedness is not tested by the Granger or Sims tests.[4]

Identifying Assumptions for Regional Modeling

Previous research using VARs to measure national-regional linkages by Sherwood-Call (1988) and Cargill and Morus (1988) has used the identifying assumption that growth in the (large) national economy is predetermined with respect to any particular (small) state. The observed contemporaneous correlation of errors stems from the national economy affecting the region, and not vice versa.[5]

To achieve identification between California and its neighbors, I extend this assumption as follows: The national economy is predetermined with respect to states, and the large California economy is predetermined with respect to its smaller neighbors. (The orders of magnitude involved are displayed in Table 1 which shows payroll employment figures for the nine states in the Twelfth District in July 1990, the most recent business cycle peak.) Any observed contemporaneous correlation of shocks between California and its neighbors is due to California affecting the neighbors, rather than vice versa.

Table 1

Twelfth District State Payroll Employment, July 1990

State	Payroll Employment (thousands)	As a Percent of California	As a Percent of U.S.
Alaska	239	1.9	0.2
Arizona	1,486	11.6	1.3
California	12,861	100.0	11.7
Hawaii	529	4.1	0.5
Idaho	384	3.0	0.3
Nevada	625	4.9	0.6
Oregon	1,255	9.8	1.1
Utah	725	5.6	0.7
Washington	2,157	16.8	2.0
U.S.	110,078		100.0

An alternative explanation and potentially serious objection, however, would be that the correlation of the errors represents some joint regional shock common to both California and its neighbors. For example, if California and Nevada both rely heavily on the same industry (perhaps tourism), an industry-specific shock could cause the observed error pattern. Exploring such possibilities is beyond the scope of this paper and is left for future research.

A final cautionary note to the VAR analysis is the extent to which results are robust. A criticism of the Sims analysis of monetary intervention, for example, is that the results often changed for seemingly arbitrary redefinitions of variables, time periods, and periods of observations. In this analysis I test the robustness of the results for different time periods, but because of data limitations, I cannot test for the robustness of the results across different measures of economic activity.[6]

[4]See Cooley and Leroy (1985) for a detailed review of the applications and pitfalls of vector autoregression.

[5]Sherwood-Call (1988) uses the portion of the forecast error for an individual state attributable to national innovations as her measure of linkage between the nation and state. Among Twelfth District states, she found California to be most linked to the national economy. In modeling the Nevada economy, Cargill and Morus (1988) also assume that the nation is predetermined with respect to Nevada. Furthermore, they recognize the proximity and interrelatedness of the California and Nevada economies and include California civilian employment in the system of VAR equations. VARs also have been used to generate regional forecasts, as with the VAR model of Ninth District states run by the Federal Reserve Bank of Minneapolis (Todd 1984).

[6]See Todd (1990) and Spencer (1989).

II. Model and Estimation

I examine the linkages between California and its neighbor states using a three-equation VAR model with employment growth rates for the nation (NATEMP), California (CALEMP), and neighboring states (STEMP) as the random variables. Several specifications are tested. First, I include all Twelfth District states (except California) in STEMP. Second, I include only states contiguous to California (Oregon, Nevada, and Arizona) in STEMP to examine the importance of geographic proximity. Finally, I estimate eight separate VARs (one each for the Twelfth District states other than California) to examine state-by-state spillovers from California. In all specifications, NATEMP excludes CALEMP and STEMP, and employment growth rates are taken from trend by including a constant term in the regression.

Economic activity is measured with quarterly payroll employment data. This variable is chosen as a proxy of economic activity for several reasons. First, it is measured consistently over time and across states from state-level payroll records. Second, other state-level variables (such as personal income) are in part derived from the payroll employment data. Some alternative measures of state-level economic activity (such as state gross product) are not considered reliable at present. Third, employment data are broken into sectors, allowing for the examination of the source of spillovers between states. Finally, employment fluctuations should adequately capture relative output fluctuations between states over time if relative capital-labor ratios across states change little over time.

The estimation period is from 1947.Q1 to 1991.Q4 (except for Alaska and Hawaii). To test for robustness I also break the sample period into two segments.

The basic form of the VAR is shown in equations (1) through (3). The growth rate (in log difference form signified by a dot) of each variable is estimated as a function of 6 lags of itself and the other two variables using ordinary least squares.[7]

$$\dot{\text{NATEMP}}_t = a_1 + \sum_{i=1}^{6} \beta_1 \, \dot{\text{NATEMP}}_{t-i} + \sum_{i=1}^{6} \beta_2 \, \dot{\text{CALEMP}}_{t-i} + \sum_{i=1}^{6} \beta_3 \, \dot{\text{STEMP}}_{t-i} + e_{nt} \tag{1}$$

$$\dot{\text{CALEMP}}_t = a_2 + \sum_{i=1}^{6} \beta_4 \, \dot{\text{NATEMP}}_{t-i} + \sum_{i=1}^{6} \beta_5 \, \dot{\text{CALEMP}}_{t-i} + \sum_{i=1}^{6} \beta_6 \, \dot{\text{STEMP}}_{t-i} + e_{ct} \tag{2}$$

$$\dot{\text{STEMP}}_t = a_3 + \sum_{i=1}^{6} \beta_7 \, \dot{\text{NATEMP}}_{t-i} + \sum_{i=1}^{6} \beta_8 \, \dot{\text{CALEMP}}_{t-i} + \sum_{i=1}^{6} \beta_9 \, \dot{\text{STEMP}}_{t-i} + e_{st} \tag{3}$$

The estimated coefficients and standard errors of the individual coefficients are numerous and difficult to interpret. Following standard procedure I instead report summary statistics from the Granger tests, forecast error variance decomposition, and impulse response analysis.

First, I consider whether California has a Granger causal effect on its neighbor states. Granger causation is tested through an F test of the joint significance of the lagged STEMP variables in the CALEMP equation. An F statistic greater than the critical value of 2.10 results in rejection of the null hypothesis of non-Granger causation. Results of these tests are shown in the first column of Table 2.

When the other Twelfth District states are aggregated together into STEMP, California does not appear to have a leading predictive relation. The F statistic for non-Granger causation is 1.09, which is below the critical value of 2.10. When only contiguous states are included in STEMP, however, the F statistic is 3.55, suggesting that developments in California do have predictive power. Likewise, when individual states are examined, shocks to California appear to have predictive power for Arizona, Nevada, Oregon, Utah, and Washington, but not for Alaska, Hawaii, and Idaho.

Second, I consider the reverse relationship, that is, whether growth in neighboring states has a Granger causal effect on California. The results (Table 2, second column) show that, except for Arizona, the null hypothesis of non-Granger causation is not rejected for all states when tested either individually or together. Since this reverse effect is not significantly different from zero, the results show that California is causally prior to Nevada, Oregon, Washington, and Utah, and to the contiguous states when aggregated. In other words, changes in California employment growth have a predictive power for employment growth in these neighboring states. California and Arizona appear to be jointly determined, with employment growth in each state having predictive power for the other.

While the tests identify a statistical leading effect of California on its neighbors, measuring the magnitude (or economic importance) of these dynamics requires identifying assumptions regarding the causal ordering of the contemporaneous errors. As discussed in the previous

[7] The choice of lag length is somewhat arbitrary. A lag of over one year was desired to accommodate seasonal fluctuations. Alternative lag lengths yield qualitatively similar short-run effects, though different long-run dynamics. As I am interested in short-run spillovers, a relatively short lag length is chosen. Long-run dynamics, of course, may be biasing our short-run estimates.

Table 2

Results of Granger Causality Tests

State	California "Granger-Causes" State	State "Granger-Causes" California
Other 12th District States	No 1.09	No 0.51
Contiguous States (OR, NV, AZ)	Yes 3.55	No 1.24
Alaska	No 1.87	No 0.50
Arizona	Yes 5.02	Yes 2.69
Hawaii	No 0.44	No 0.91
Idaho	No 1.63	No 0.82
Nevada	Yes 3.10	No 1.32
Oregon	Yes 3.75	No 1.44
Utah	Yes 2.81	No 2.00
Washington	Yes 3.47	No 1.08

Note: *F* test statistic of null hypothesis of non-Granger causality. The critical value for rejecting the null hypothesis is 2.10.

Table 3

Contemporaneous Correlation and Variance Decomposition

		Variance Decomposition (%)		
State	Contemp. Correlation (%)	California	Nation	California (Reverse Order)
All Other 12th District States	0.45	17.1	21.0	5.4
Contiguous States	0.65	32.3	30.9	11.5
Arizona	0.39	28.3	16.1	17.8
Nevada	0.46	27.5	10.5	11.0
Oregon	0.60	25.8	24.6	17.5
Washington	0.48	24.9	27.6	16.2
Utah	0.33	21.0	25.9	18.9
Idaho	0.40	17.7	18.4	16.9
Alaska	0.20	9.1	7.0	7.8
Hawaii	0.14	3.0	25.2	2.9

Note: Percent of forecast error variance attributable to California after 24 quarters

section, the causal ordering I assume is that contemporaneous shocks flow from the nation to California and its neighbors, and from California to the neighbor states.

The first column of Table 3 reports the contemporaneous correlation of errors between California and its neighbors from the estimated covariance matrices. The correlation between California and all other District states is 0.45. For contiguous states the correlation is 0.65. For individual states, the correlation ranges from 0.60 in Oregon to 0.14 in Hawaii. In general these correlations are large, and point out the importance of the identifying assumption. The contemporaneous shocks are assumed to be due to the impact of California on its neighbors. If the reverse is true, or if some unobserved common factor is affecting both states, the VAR results will be inconsistent.

Subject to this identifying assumption, the forecast error the model makes for a neighbor state can be decomposed into the error due to the state's own lags, the error due to the nation, and the error due to California. I use this variance decomposition as a measure of how states are linked to California. Column 2 in Table 3 reports the proportion of the forecast error at 24 quarters attributable to California. For all other Twelfth District states, 17.1 percent of the forecast error variance is attributable to California. In contrast, the linkage to the nation is 21.0 percent. For contiguous states, however, the proportion of the forecast error attributable to California rises to 32.3 percent (30.9 percent for the nation).

Among individual states, Arizona exhibits the largest degree of linkage: 28.3 percent of the error the model would make in forecasting Arizona is attributable to errors (innovations) in the California equation. Arizona is followed closely by Nevada (27.5 percent), then Oregon, Washington, Utah, (all in the 21 to 26 percent range), then by Idaho, Alaska, and Hawaii, which exhibit relatively little linkage to California.

The sensitivity of these results to the predeterminedness assumption is tested by reversing the ordering of the equations, that is, assuming that the neighbor states are predetermined with respect to California. These results are shown in the final column of Table 3. When the states are aggregated, reversing the ordering reduces the measured linkage by over half. For all Twelfth District states it falls from 17.1 to 5.4, and for contiguous states it falls from 32.3 to 11.5. The results for the aggregate measures of neighboring states thus are very sensitive to the ordering assumption. For individual states, however, changing the ordering assumption has less of an effect. Arizona's linkage falls from 28.3 to 17.8, Oregon from 25.8 to 17.5, and Washington from 24.9 to 16.2. Utah and Idaho change relatively little. Nevada, however, drops more than half (from 27.5 to 11.0). The sensitivity of the results points out the importance of the contemporaneous correlations in measuring spillovers.

An alternative measure of the effects of California on its neighbors is obtained through impulse response analysis. The effects of a one-standard-deviation shock to California on neighboring states over 24 quarters is graphically shown in Charts 1 through 3.

For all Twelfth District states (shown in Chart 1) a one-standard-deviation shock to quarterly employment growth in California of 0.0043 (in log difference form, or approximately 0.43 percent) results in a 0.29 percent higher growth rate in the rest of the District in the first quarter. The response goes away by quarter 5. (It slightly overshoots, then dampens to zero by quarter 18.) For contiguous states (shown in Chart 2) the response to a shock to California is

Chart 1
Response of All Twelfth District States and California to One-Standard-Deviation Shock to California

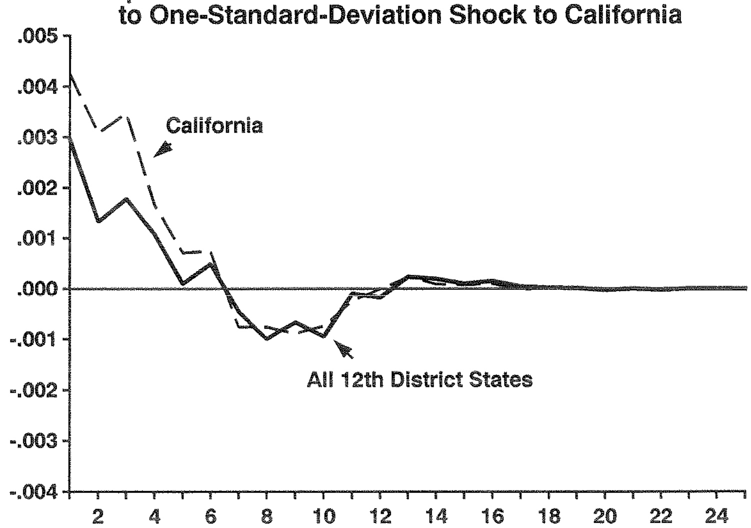
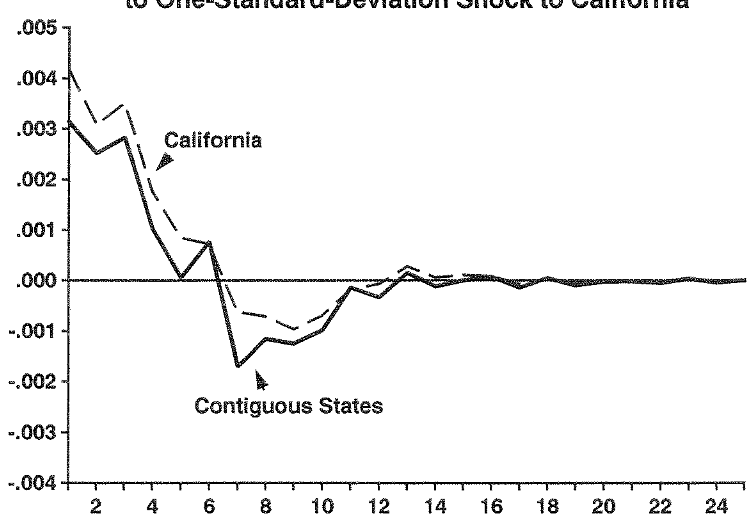


Chart 2
Response of Contiguous States and California to One-Standard-Deviation Shock to California



larger. The response rises to 0.31 percent in the first quarter, and remains above the response for the all-Twelfth-District aggregate until quarter 4. This suggests that the magnitude of spillovers from California is larger for contiguous states.

Responses for individual states are shown in Chart 3. These results also suggest that spillovers are larger in states that are geographically closer to California. The largest peak responses are seen in Oregon (0.38 percent in quarter 1) and in Arizona and Nevada (both at 0.35 percent in quarter 3). In contrast, smaller responses are seen in Washington and Utah. (Idaho, Alaska, and Hawaii exhibit small responses but are not shown for clarity of exposition.) Nevada shows the largest sustained spillover (remaining positive through quarter 6), while Oregon's is of short duration, reaching zero by quarter 4. As with the aggregate measures, the responses in the individual states slightly overshoot, then dampen to zero by quarter 18.

Are these spillovers statistically significant? Charts 4 and 5 report the impulse responses for the all-District and contiguous states, respectively, with 95 percent confidence bounds calculated through a Monte Carlo simulation. The confidence bound for the all-District response is greater than zero in quarter 1, touches zero in quarter 2, is just above zero in quarter 3, then contains zero from quarter 4 on, suggesting that the measured spillover is not significantly different from zero beyond three quarters. The results for contiguous states, however, suggest that the impulse is estimated more precisely. The confidence bound is well above zero through three quarters, then as with the all-District response, contains zero from quarter 4 on. Results

Chart 3
Response of Neighbor States to One-Standard-Deviation Shock to California

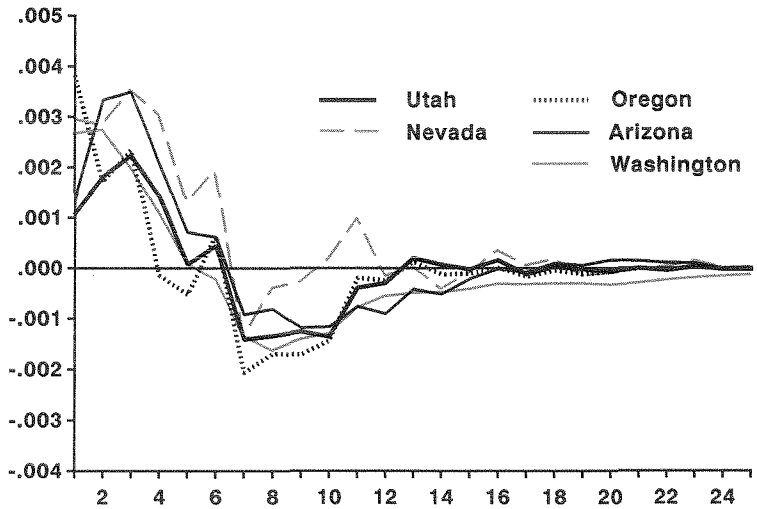
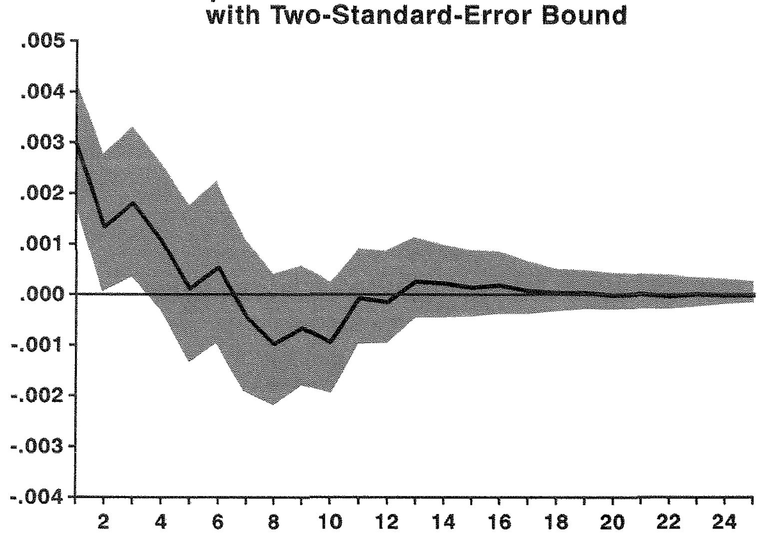


Chart 4
Response of All Twelfth District States with Two-Standard-Error Bound



for individual states reveal statistically significant spillovers in Nevada (through quarter 6), Arizona (through quarter 4), and Oregon, Washington, and Utah (through quarter 3).

The robustness of the results is tested by splitting the sample into two periods (1947.Q1-1970.Q1 and 1970.Q2-1991.Q4). This tests for structural change, at the cost, however, of reducing the degrees of freedom. In general, splitting the sample period lowers the value of the *F* statistics for Granger causality, with the leading relationship becoming insignificant in certain states. While the overall qualitative pattern of the results does not change, for most states the measured linkage to California appears larger in the first period than in the second, while the measured linkage to the rest of the nation rises. This suggests that western states are becoming more integrated into the national economy over time, while the relative linkage to California is falling. The impulse responses in both sample periods, however, both reveal significant spillovers for three quarters following a shock to California.

For the aggregate of states contiguous to California, for example, the *F* statistic for Granger causality is 2.90 for the first period, but only 0.6 in the second period, and the measured linkage to California declines from 38.2 to 25.9. The linkage to the nation, however, rises from 34.1 to 40.9, suggesting some substitution in linkage from California to the nation. The pattern of the impulse responses (shown in Chart 6) to a shock from California, however, is little changed between the two sample periods and remains significantly greater than zero for three quarters. While these results are suggestive of structural change, testing for this will involve a modeling approach that allows for time-

Chart 5
Response of Contiguous States with Two-Standard-Error Bound

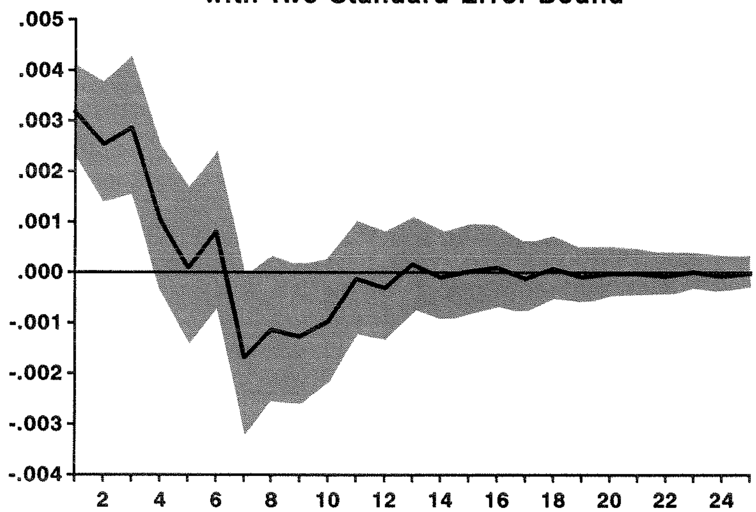
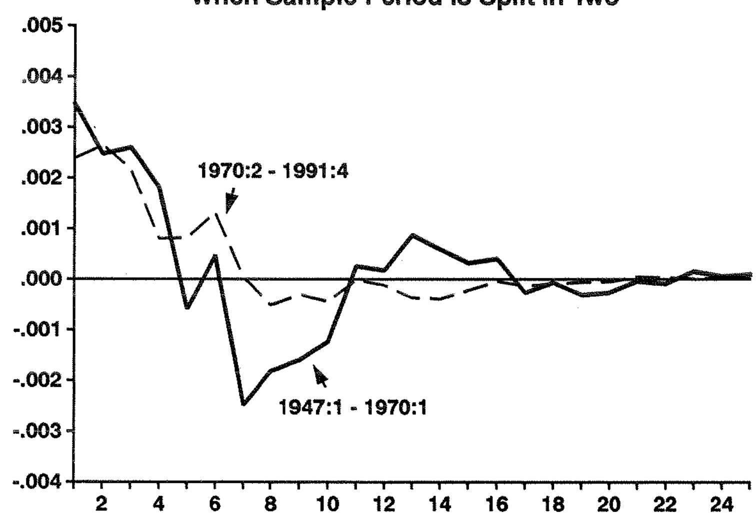


Chart 6
Response of Contiguous States When Sample Period is Split in Two



varying coefficients and represents an area for future research.

To summarize these initial results, California has statistically significant leading relationships for several neighboring states, including Arizona, Nevada, Oregon, Washington, and Utah. With the exception of Arizona, a reverse effect on California is not seen. Furthermore, under the identifying assumption that observed contemporaneous shocks flow from California to its neighbors, California appears to have significant economic spillovers to its neighbor states. The largest spillovers appear in states geographically near California. The results are sensitive, however, to the assumption of predeterminedness and the choice of sample period. There is some indication that the linkage of California to neighboring economies may be decreasing over time relative to their linkage to the national economy.

III. Sectoral Linkages

To explore linkages between sectors in California and sectors in its neighbors, I expand the three-equation VAR model estimated in Section II to a six-equation system. NATEMP and CALEMP remain unchanged from the initial period. STEMP, however, is divided up into the following sectors: manufacturing, services, "other," and finance. An equation is included for each sector. As before, each of these six components then is regressed on lagged values of itself and lagged values of the other components. I conduct this analysis only on states for which California had a significant overall Granger causal effect.

The results are reported in Table 4. California appears to have a leading effect on manufacturing in Arizona, Oregon, and Utah. California also appears to have a leading effect on the service sectors of its neighbors, with significant results seen for Arizona, Nevada, and Oregon. Of particular interest is the strong result for Nevada, showing the expected impact of California on the casino-related service sector of the state. A significant effect is also seen for the "other" sectors in Utah and Oregon. (Service employment is included in the "other" sector for Utah due to data availability.) California does not appear to have an effect on any specific sector in Washington, though the "other" sector has the strongest measured effect with an F statistic of 1.9 that is significant at the 80 percent level. Finally, the California economy does not have a Granger causal effect on the financial sectors of its neighbors.

To estimate the magnitude of these linkages, a causal ordering is again needed. I again assume that the nation is predetermined with respect to California and its neighbors, and that California is predetermined with respect to its neighbors. More problematic, however, is determining the direction of causality among the sectors. The results for the linkage to California, however, are invariant to the ordering of sectors.

The forecast error variances of the state sectors due to California shocks are shown in Table 5. Note that in a six-

Table 4

California vs. Sectors in Neighbor States

Results of Granger Causality Tests

State	Manufacturing	Services	Other	Finance
Arizona	Yes 3.4	Yes 3.5	No 1.5	No 0.6
Nevada	No 1.1	Yes 4.3	No 2.1	No 1.2
Oregon	Yes 4.3	Yes 2.3	Yes 4.1	No 1.1
Utah[a]	Yes 2.2		Yes 3.3	No 0.6
Washington	No 1.3	No 1.1	No 1.9	No 0.4

Note: F test statistic for null hypothesis of non-Granger causality. The critical value for rejecting the null hypothesis is 2.10.
[a]For Utah, no service sector data are available, so Services are included in Other.

Table 5

Percent of Forecast Error Variance in State Sector Attributable to California after 24 Quarters

	Variance Decomposition			
State	Manufacturing	Services	Other	Finance
Arizona	26.4	11.6	17.1	10.0
Nevada	9.4	8.1	9.8	7.2
Oregon	16.2	11.9	11.3	9.7
Utah[a]	9.8		14.6	6.0
Washington	10.3	5.5	10.1	5.8

[a]For Utah, no service sector data are available, so Services are included in Other.

equation system, the observed linkage to California declines because shocks in the other sectors affect the forecast variance. The results are thus not strictly comparable to the three-equation model, but are used to suggest relative strengths of linkages across states and across sectors.

In general, manufacturing displays a higher degree of linkage to California than the other sectors. Arizona manufacturing appears to be most linked to California, followed by Oregon and Washington. In services, Arizona and Oregon display the greatest linkage. The "other" category displays large linkages in Arizona and Utah. In spite of the significant Granger-test of California on Nevada, the estimated linkage is of relatively small magnitude.

The observed spillovers in manufacturing are consistent with a model of linkages propagated through trade flows between firms. The spillovers in the service sector suggest that linkages also exist in sectors such as tourism and recreation. This is particularly true in the case of Nevada, where growth in California has strong effects on the casino-dominated recreation sector. The lack of spillovers in finance suggests that growth in this sector is largely determined by developments internal to the state, rather than spillovers from California.

IV. Conclusion and Future Research

Using a set of three-equation VAR models of the nation, California, and other Twelfth District states, this paper established that California has a statistically significant leading relationship with employment growth in several of its neighbor states—Arizona, Nevada, Oregon, Utah, and Washington. The sectors affected are manufacturing in Arizona, Oregon, and Utah, and services in Arizona, Nevada, and Oregon. The financial sectors of these states are not affected.

The magnitude of these linkages were then measured through VAR variance decomposition and impulse response analysis. This measurement requires identifying assumptions regarding the observed correlation of contemporaneous shocks. I assume that the causal ordering flows from the nation to California and other states, and from California to its neighbors. Under this assumption, the measured spillovers appear to be important, but dampen relatively quickly.

These results are broadly consistent with a model of regional linkages occurring through trade of goods and services. Positive shocks to California have positive short-run spillovers. The spillovers in manufacturing can be attributed to orders for goods, while spillovers in services potentially are due to demand for recreation and tourism.

An extension of this research will further explore these linkages and the reasonableness of the identifying assumptions. Alternative explanations for the joint regional shocks to California and its neighbors could include industrial mix (aerospace or tourism, for example), or shocks associated with being located on the Pacific Rim. An explicit accounting for aerospace between Washington and California, for example, could explore whether this industry is driving the observed overall linkage in manufacturing.

This paper also suggests, however, that simple VAR modeling of regional economies can be pushed only so far. The results are sensitive to structural change, and imposing a standard model on unique states results in dynamic patterns that suggest problems in specification. While VAR modeling may effectively pick up trade flows, measuring longer-run factor flows suggests a modeling approach that explicitly accounts for structural change.

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