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GROWTH CONSTRAINTS, THE TERMS OF TRADE, AND REGIONAL MODELING

*Hsianghoo Ching and Roger F. Riefler**

Introduction

One of the primary goals of regional macroeconomics has been to analyze regional growth trajectories. Whether the objective has been to describe past growth experience, predict future directions, or to investigate policy impacts, analysts have devoted considerable effort to replicating a region's recent growth path. Models designed to achieve these objectives have ranged (and evolved) from the simple and data-parsimonious to the complex and data-hungry.¹

To oversimplify somewhat, regional growth modeling has proceeded from emphasis on demand-side determinants of growth (for example, export-based and traditional input-output constructs) through supply-side models (especially models emphasizing labor market developments and migration) to more complex models such as sophisticated econometric and extended input-output models. These latter have attempted to integrate both sides of the demand/supply scissors.² Unfortunately, conceptual formulations often have exceeded the existing data base. Further, even when empirically feasible, suggested models exceed time and/or monetary budget constraints. Not surprisingly, the result is often a nostalgic desire to return to the good old days of a less complex view of the regional growth process.

The purpose of this paper is not to advocate a return to the classical period of regional growth modeling. Rather the paper suggests that recent developments in statistical or econometric techniques provide a simple, useful preliminary screening or filtering device to reduce the theoretical and empirical baggage we carry into modeling of regional growth paths. It is hoped that initial identification of actual growth constraints binding on regional growth will focus subsequent modeling

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¹See Richardson (1979) for a comprehensive review. For a more recent review, see the various articles in the *Journal of Regional Science*, 25, no. 4.

²See, for instance, several articles in the *International Regional Science Review*, no. 1 and 2 and *Socio-Economic Development Planning*, 23, no. 5 on recent advances in input-output modeling.

efforts, thereby economizing scarce resources of data, time, and money.

Part II of this paper presents the view of the growth process adopted by this paper. This portion of the paper also discusses the conceptual advantages inherent in the suggested approach. Subsequent sections present, respectively, a discussion of the empirical and statistical problems involved in applying the proposed screening device and a preliminary application of the model. A concluding section summarizes the results, presents a preliminary assessment of the proposed method, and suggests directions for further research.

Suggested Methodology

Our view of the regional growth process is derived from that first put forward by Horst Siebert (1969). In its most general, simplified form, the Siebert model suggests that a region's growth trajectory is attributable to the interaction of supply and demand. If such interaction is equilibrating, then observed growth patterns are likely to resemble those predicted by neoclassical models. (See Smith, 1975; and Borts and Stein, 1964.) If interaction is disequilibrating, either supply- or demand-side forces are likely to dominate and models that emphasize one or the other side of the (in)famous economic scissors are likely to be more congruent with observed growth. Short-run fluctuations in regional growth are likely to reflect these disequilibrating forces; only in the long run are equilibrating forces likely to be found preeminent, and even here cumulative causation could be the rule.

A more specific view of the growth process is found in Chapter 6 of the Siebert text (p. 119) where the following equation is presented:

$$(1) dY_{t-1}^{t+1} = \min[dO_{t-1}^{t+1} + dM_{t-1}^{t+1}] [dD_{t-1}^{t+1} + dX_{t-1}^{t+1}] + \Omega_{t-1}^{t+1}$$

where:

- dY_a = Actual growth in economic activity;
- dO = Internal supply;
- dM = External supply;
- dD = Internal demand;
- dX = External demand; and
- Ω = Regional terms of trade.

Here the actual pattern of regional growth is viewed in a manner similar to the solution of a linear programming problem where supply and

demand elements (and the terms of trade) represent possible binding constraints.

The job of the analyst in applying the Siebert framework in investigating a region's growth trajectory at a point in time is to choose a construct from the tool kit of regional models that encompasses the relevant (e.g., binding) constraint or constraints. The challenge facing the regional practitioner is to identify the current binding constraint(s) on regional growth correctly, choose or design a model appropriate to that (those) constraint(s) relevant, and apply the model to analyze and/or forecast regional growth patterns.

Although much of the extant literature on regional growth economics tends to concentrate on the second and third tasks, it is the contention of this paper that focussing on the first challenge can simplify subsequent tasks significantly. If we can estimate equation (1) empirically, our task of replicating growth trajectories and modeling future growth paths may be eased by concentrating on those constraints that appear to be determining or binding the observed development.

Equation (1), while offering certain advantages for growth analysis—such as separating the effects of real or price-adjusted changes in external and internal demand from fluctuations in regional terms of trade (denoted in subsequent presentation as RTOT)—is, in a sense, deceptively simple. One difficulty is that many of our existing models, while emphasizing either demand or supply sides, fail to distinguish real from price-induced movements. Utilization of equation (1) to indicate growth constraints, therefore, may provide more information than our current tool kit of models can handle.

As an example of this phenomenon, current demand-side models such as export base theory and input-output analysis tend, in application, to confound the growth impact of quantity and price changes. An increase in exports or a change in shipments to final demand is posited (usually in either absolute dollar magnitudes or percentage growth terms). While factor supply curves are assumed elastic at current prices, the precise nature of the demand curve is not specified; only the change in expenditures (the relevant area under the demand curve) is identified. Thus, for instance, a 10 percent increase in export demand may be attributable to a 10 percent increase in either product price or quantity or to some combination of price and quantity change.

Supply-side models, especially if based in the neoclassical tradition, are more likely to consider explicitly the effect of price fluctuations on growth trajectories. The calculation of supply and substitution elasticities from production function-based models highlights, for example, the growth impact of rapidly escalating energy prices in an energy-deficit region. Other supply models emphasizing interregional migration

(of labor, capital, or other inputs) include relative real rates of return as a driving force behind movement, thus again emphasizing the influence of price on growth paths.

We hope that equation (1), by attempting to separate the influence of RTOT from quantity or real changes, will lead to the development of more refined models. Siebert's (1969, chapters 3 and 5) original treatise describes at the conceptual level how the influence of RTOT on the growth process differs from or, more correctly, supplements quantity adjustments. In summary, both external and internal growth determinants not only have a direct impact on regional growth paths, but they also have indirect effects via changes in the terms of trade. Some applied research in this area recently has appeared in the literature (Branson and Love, 1987; Cox and Hill, 1988; Carlino, Cody, and Voith, 1990).

A second difficulty in applying the Siebert framework for analyzing binding growth constraints is more serious. In investigating internal supply constraints, Siebert identifies six possible arguments in the regional production function:

- Labor;
- Transport resources;
- Land;
- Capital;
- Technical knowledge; and
- The regional institutional framework or social system.

Although scholars might debate the precise ordering of these six factors, most would agree that our ability to model these possible constraints empirically declines as we move from labor to the regional institutional framework or social system (Siebert, 1969, p. 25). Unfortunately, recognition of this shortcoming of the literature means our specification of internal supply-side constraints must remain incomplete at this point in time.

A final difficulty encountered in trying to empirically implement equation (1) is the likelihood that any attempt to apply ordinary least squares (OLS) methods to test for binding constraints will violate the assumption of constant error variance inherent in that approach. Luckily, as subsequent analysis will show, recent econometric techniques promise to minimize this difficulty.

Empirical Application

Nebraska was chosen for an initial test of the screening model represented by equation (1). While this choice was made largely for convenience, three factors indicated that Nebraska would be an interesting test for the proposed constraint screening methodology. First,

previous research by one of the authors had suggested that economic development policies had influenced growth favorably in this state (Riefler, 1991). This meant that at least one of the region's growth constraints is expected to be endogenous from the local policy perspective. Second, as demonstrated by its input-output table in comparison to those for other states, Nebraska has a relative paucity of internal linkages (Lamphear and Roesler). This openness of the state, combined with its specialization in products important in international trade, created a presumption that fluctuations in external demand as well as the terms of trade should influence growth trajectories. Finally, being a state largely dependent on agriculture and the processing of agricultural commodities for export, it was easier to generate a proxy for the state's domestic terms of trade.³

Equation (2) presents a preliminary version of the Siebert model as applied in our study. If we assume a linear statistical relationship between the change in the level of regional activity, dY^a , growth in external (internal) demand, dD , change in external (internal) supply, dS , and fluctuations in Nebraska's terms of trade, $dRTOT$, equation (1) can be rewritten in stochastic terms as:

$$(2)dY_i^a = \alpha_1 + \alpha_2 dD_i + \alpha_3 dS_i + \alpha_4 dRTOT_i + \varepsilon_i$$

where:

$i = 1, 2, \dots, t.$

If the alphas are appropriately signed and significant, they would indicate the existence of a binding constraint or constraints on growth for the relevant time period.

Left Hand Side (LHS) Variables

Several measures of regional economic activity are available. Two prime candidates are employment statistics, available on a monthly basis, and personal income data, released on a quarterly basis. Employment data were culled from various issues of the *Nebraska Labor Market Information Report*; state personal income information was obtained from the Bureau of Economic Analysis, Department of

³In 1990 Nebraska's location quotient for agriculture, calculated using income as a measure of activity levels, was 6.71. For the Plains as a whole, the location quotient was 3.11. For food and kindred products Nebraska's 1990 location quotient, calculated in employment terms, was 2.61

Commerce; and state farm income was from the Nebraska Economic Information Program at the UNL Bureau of Business Research. We decided to use Nebraska personal income as our primary LHS variable. Quarterly state real personal income, as published by the Bureau of Economic Analysis, Department of Commerce, was utilized for the period from 1974:1-1991:4. Because the variable enters equation (2) in the form of absolute quarterly growth (dTY), 71 observations were used. Our choice of 1974 as an initiation date for our sample was dictated by the desire to capture the impact of flexible international exchange rates on subsequent growth trajectories. The concluding date was dictated by data availability.

In addition to total state personal income, a second income measure was used as an alternative LHS variable: state farm income. This component of total income was isolated in order to investigate further the impact of real versus price constraints on growth. It is hypothesized that the agricultural sector would be especially sensitive to fluctuations in the state's terms of trade. Further it was felt that an extremely accurate measure of the domestic terms of trade was available for the farm sector.

Right Hand Side (RHS) Variables

The first two variables on the right side of our estimated equation attempt to capture the possible effects of demand constraints on Nebraska's growth. The first variable, TY_{-1} , is simply the level of state real personal income in the previous quarter. This variable was included as a measure of internal demand. The second variable, $dGNP$, is the quarterly growth in gross national product expressed in constant (1982) prices. Given the small size of the Nebraska market, fluctuations in GNP probably reflect changes in interregional and international demand for state output (e.g., external demand). If either (or both) of these demand measures are constraining Nebraska's income growth, a positive coefficient is expected.

Specification of possible supply-side constraints on Nebraska's income growth is by necessity more selective. Two of the myriad of factor inputs entering the state's production function were identified as possible growth constraints: labor and energy. We implicitly are assuming, therefore, that other inputs (e.g., capital) are available to the state at an infinitely elastic supply at nationally determined prices (e.g., interest rates). We also are assuming stability in the state's social and institutional systems.

Considering the time period modeled and Nebraska's geographic position in the middle of the country (and therefore removed from major coastal markets and export points), it is hypothesized that the state's

growth may have been supply constrained by fluctuations in energy availability. It is posited that higher real energy prices during the 1970s may have reduced income growth in the state while the opposite tendency in the 1980s may have removed this constraint on growth. For this reason the average quarterly change in the energy component of the Producer Price Index, dEP , was included in the estimated model as a possible supply-side constraint on growth. If binding, such a constraint would show as a negative coefficient in our estimation.

The possibility of a labor constraint on observed aggregate growth reflects the likely imperfection of migration as a short-run equilibrating factor or mechanism. Two measures of possible labor constrained growth were considered for inclusion in the model: the average quarterly change in the unemployment rate, dUN , and the average quarterly change in weekly hours worked in manufacturing, $dHRS$. Monthly unemployment statistics were derived from various publications of the Nebraska Department of Labor. Average weekly hours in manufacturing by month were found in Nebraska Department of Labor sources for 1977 through 1991 and in U.S. Department of Labor *Employment and Earnings for States and Areas* for 1974 through 1976. Simple monthly averages were used in the computation of average quarterly unemployment or hours.

The shortcomings of the former as a proxy for labor constraints (e.g., failure to adjust for part-time workers) are well-known and especially severe for an agricultural economy such as Nebraska. For these reasons $dHRS$ was felt to be the preferred measure of tightness in the labor market, despite its obvious sectoral coverage limitation. If a tight labor market, indicated by an increase in weekly average hours, were constraining income growth, a negative coefficient on $dHRS$ is expected. Similar analysis would suggest that a lower unemployment rate would be associated with slower income growth if labor were a binding constraint; hence a positive coefficient is anticipated in this case. Subsequent empirical estimation of the two alternatives indicated the superiority of the $dHRS$ measure. Results reported below include only this variable on the right hand side.

In attempting to measure the impact of fluctuations in the terms of trade on growth of farm income, a rather precise measure of the domestic terms of trade is available: Nebraska farm parity. This information is maintained by the Agricultural Statistics Board, Nebraska Agriculture Statistics Service, U.S. Department of Agriculture. Farm parity directly measures the price farmers receive for their output relative to prices paid for purchased inputs. Under the reasonable assumption that the bulk of these inputs are imported, farm parity appears to be a reasonable proxy for the domestic terms of trade facing the agricultural sector. It is anticipated that an improvement in farm parity, a positive value for

dFP, would be associated with more rapid growth in farm income; a positive coefficient is expected.

It is more difficult to construct a measure of the domestic terms of trade for the entire Nebraska economy (and test for impact on growth in total personal income). If data on state interstate exports and imports by commodity or service type were available, such statistics could be used to weight the appropriate components of the Producer Price Index (for exports) and Consumer Price Index (for imports) to construct such a variable. Given the paucity of such information, it is assumed as a first approximation that the bulk of Nebraska's exports fall into two categories: processed and unprocessed agricultural output. This assumption resulted in the numerator for the state's domestic terms of trade (DTOT) measure being calculated by combining the farm products component of the Producer Price Index with the processed foods and feeds classification of that index. The weights used to combine these components of the PPI into a monthly export price index for the Nebraska were the annual percent of total state personal income attributable to agriculture versus that generated by the food and kindred products industry (Bureau of Economic Analysis, U.S. Department of Commerce table "Personal Income and Earnings by Industry for Nebraska"). The resulting export index was divided by the monthly Consumer Price Index (both indices with a 1982 base) to approximate Nebraska's domestic terms of trade. The assumption here is that the overall CPI trend approximates price fluctuations for the state's imports.⁴ Monthly observations for DTOT were averaged to derive quarterly estimates. It is anticipated that the tendency for export prices to decline relative to import prices (e.g., negative values for dDTOT) would act as a constraint on the growth of total personal income; a positive coefficient is expected.

Previous attempts to quantify the impact of changes in the domestic terms of trade on regional growth paths have been precluded (or at least made difficult) by the necessity of specifying a region's export and import mix in order to construct the relevant component price indices. The more diversified the state or region, the more challenging the construction of such an index. The relatively specialized nature of the Nebraska economy minimizes, but does not eliminate, this difficulty.

The final independent or RHS variable measuring possible constraints on Nebraska's growth in total (or farm) personal income is change in the international terms of trade faced by Nebraska producers,

⁴Further improvements in this denominator could be made by excluding components of the CPI (e.g., services) less likely to be imported. Such refinements were not made at this point, given our interest in demonstrating the efficacy of the constraint approach as a first approximation in regional modeling efforts.

dITOT. This variable was estimated using the U.S. dollar per SDR exchange rate (International Financial Statistics table "U.S. \$/SDR Exchange Rate). Monthly data were averaged to construct a quarterly series. Because a decline in the dollar cost of an SDR indicates an improvement in the international terms of trade, a positive relationship between dITOT and income growth is anticipated if this constraint influences growth. Using our preferred measure of the labor constraint and suppressing the error term, our investigation of possible constraints on Nebraska's growth in total personal income entailed econometrically estimating the following equation:

$$(3) dTY_i = \beta_1 + \beta_2 TY_{i-1} + \beta_3 dGNP_i + \beta_4 dEP_i + \beta_5 dHRS_i + \beta_6 dDTOT_i + \beta_7 dITOT_i$$

where:

- $i = 1, \dots, 71;$
- dTY = Change in state total personal income;
- $dGNP$ = Change in real GNP;
- $dHRS$ = Change in weekly hours in manufacturing;
- dEP = Change in energy prices;
- $dDTOT$ = Change in domestic terms of trade;
- $dITOT$ = Change in international terms of trade.

All changes are absolute quarterly increases or decreases. The equation for farm sector personal income growth (dFY_i) was estimated similarly; farm parity (dFP_i) replaces $dDTOT_i$.

Initially equation (3) was estimated for the entire 1974:1-1991:4 period. The longer the time period investigated, the more likely it is that all possible constraints significantly influence growth. To investigate the possibility of binding constraints varying in the short run, the model was reestimated using three subperiods: 1974:1-1979:4, 1980:1-1987:4, and 1988:1-1991:4.

Results

Initial ordinary least squares (OLS) estimation of equation (3) (as well as the equation for farm income) indicated that the assumption of constant error variance was violated. Such heteroscedasticity undoubtedly has limited previous attempts to use the Siebert model as a preliminary screening device to assist in model construction. Recent advances in econometric techniques, however, may help in minimizing this problem.

When heteroscedasticity exists (in the context of time series observations), the model may be improved by utilizing Engle's autoregressive conditional heteroskedasticity (ARCH) model (Cragg, 1982; Engle, 1982). To test whether this was the case, the model containing equation (3) (and its farm income variant) was run using OLS. We first examine the results for serial correlation in residuals, utilizing the Lagrange multiplier test. Application of this test (for first to eighth order serial correlation) found no evidence of serial correlation. We next performed an ARCH test for first and second order heteroscedasticity. The following table summarizes the results of these tests.

Table 1

Order	Chi-Square Statistic	Critical Chi-Square*	AIC**
1	7.588509	3.84146	28.114
2	9.288353	5.99147	28.125

* Upper 5 percent points of the Chi-square distribution

** AIC information statistic (in logs)

Although the results show both orders of the ARCH tests are significant, the AIC information statistic for the first order ARCH was smaller. Hence, a first order ARCH model was chosen for application.

In the first order ARCH process the pattern of disturbance behavior is postulated to be:

$$(4) e_t = u_t(\gamma_0 + \gamma_1 e_{t-1}^2)^{1/2}$$

where:

$$u_t \sim N(0,1);$$

$$E(u_t u_s) = 0 \text{ for } t \neq s.$$

The data therefore are deflated by:

$$(5) (\gamma_0 + \gamma_1 e_{t-1}^2)^{1/2}$$

The original model becomes equation (6), and the log-likelihood function can be written as:

$$(6) \frac{dTY_t}{(\gamma_0 + \gamma_1 e_{t-1}^2)^{1/2}} = \beta_1 \frac{1}{(\gamma_0 + \gamma_1 e_{t-1}^2)^{1/2}} + \beta_2 \frac{dTY_{t-1}}{(\gamma_0 + \gamma_1 e_{t-1}^2)^{1/2}} + \dots + u_t$$

$$(7) L = -\frac{1}{2} \sum_t \log(\gamma_0 + \gamma_1 A_{t-1}^2) - \frac{n}{2} \log(2\pi) - \frac{1}{2} \sum_t \frac{At}{\gamma_0 + \gamma_1 A_{t-1}^2}$$

where:

$$A_{t-1} = dTY_{t-1} - \beta_1 - \beta_2 TY_{t-2} - \beta_3 dGNP_{t-1} - \dots - \beta_7 dITOT_{t-1}.$$

The resulting equation, which represents our best estimate of equation (3), is:

$$(8) \quad dTY_t = 188.24 + 0.00646 TY_{t-1} - 0.34385 dGNP_t + 69.558 dHRS_t +$$

(7.367) (2.638) (1.334) (8.060)

$$1.4176 dEP_t + 2369.4 dDTOT_t + 1816.8 dITOT_t$$

(0.6258) (37.119) (5.3160)

$$\gamma_1 = 4.1642$$

(5.8615)

The figures in parentheses are (absolute) *t* values, and the error term has been suppressed.

For the 1974:1-1991:4 period four RHS variables are significant at commonly accepted confidence intervals. Three of these, TY_{t-1} , $dDTOT_t$ and $dITOT_t$, have the correct sign. An improvement in either the domestic or international terms of trade increases Nebraska's growth in personal income. Both variables, in the sense of the Siebert model, are binding constraints. The growth elasticity of fluctuations in the domestic terms of trade, when evaluated at the mean, exceeds that of the international terms of trade by a factor of 10.

In addition to the terms of trade variables, our term designed to capture internal demand, TY_{t-1} , is also significant and is correctly signed to be a growth constraint. A 10 percent increase in Nebraska total personal income in a given quarter will result in an approximately 3.9 percent increase in the growth of total income in the following quarter.

The positive, significant coefficient on $dHRS$, while reasonable (e.g., an increase in hours increases the growth of total personal income), is not consistent with a tight labor market constraining growth. The result is more indicative of an efficient, flexible labor market. Given net migration from Nebraska for most of this period (also indicating a relatively slack labor market), this result was not unanticipated.

Possibly the most surprising result in equation (8) is the lack of a positive, significant relationship between changes in external (real) demand and Nebraska growth in personal income. Our results suggest that economic growth in the state is less sensitive to the quantity of exports than it is to fluctuations in the prices of those export commodities. In such an environment, traditional export demand models by

failing to distinguish price from real fluctuations are likely to mislead the analyst attempting to isolate growth sources.

If growth in total personal income is replaced with increase in farm income, the results change somewhat. (See Appendix A.) Neither the international terms of trade nor internal income are related significantly-1974:1-1991:4 growth. The lack of significance of internal demand is not surprising given the limited internal demand for Nebraska's crop and livestock production. The failure of the international terms of trade to affect the growth in farm incomes significantly is more surprising. Combining this result with that reported above for total personal income, it appears that fluctuations in the international terms of trade mainly affect the nonagricultural sectors of the state's economy.

Farm parity, our measure of the domestic terms of trade, is positive and significant, indicating that this variable is capturing a constraint on farm income growth. This result is consistent with that reported for total personal income. In the case of farm income, however, external demand (as proxied by growth in GNP) enters the equation with a positive, significant coefficient. This indicates the sensitivity of the agricultural sector to growth in external real demand.

A key benefit to utilizing the Siebert framework to identify growth constraints is the ability of the model to isolate changes in these constraints over time. This is important if analysts wish, following Occam's Razor, to adopt the most parsimonious model capable of tracking growth trajectories. The crucial question is how often these constraints change over time. If such behavior is uncommon, the usefulness of the Siebert formulation is diminished.

To test for changes in growth constraints over time, the 1974-1991 period was partitioned into subperiods; the model contained in equation (8) then was applied. There are an almost infinite number of possible criteria that could be utilized for identifying subperiods. We adopted a rather simple approach: a plot of our main LHS variable (growth in Nebraska total personal income) seemed to show two discontinuities over the 18 year period. (See Figure 1.) This figure indicates the likelihood of structural change in 1980:1 and 1988:1. We therefore decided to divide the entire period into three subperiods: 1974:1-1979:4, 1980:1-1987:4 and 1988:1-1991:4. We then tested for changes in growth constraints using these subperiods. To conserve space Table 2 presents the results of applying the model with this partitioning of the 18 year period. Dummy variables (and interaction terms) were utilized for the 1980:1-1987:4 and 1988:1-1991:4 periods. Appendix B contains the estimated equation and the equations containing significant variables for each period. The columns in Table 2 indicate the time period utilized; the rows indicate the possible constraints. The positive and negative

Figure 1
Total Personal Income for Nebraska

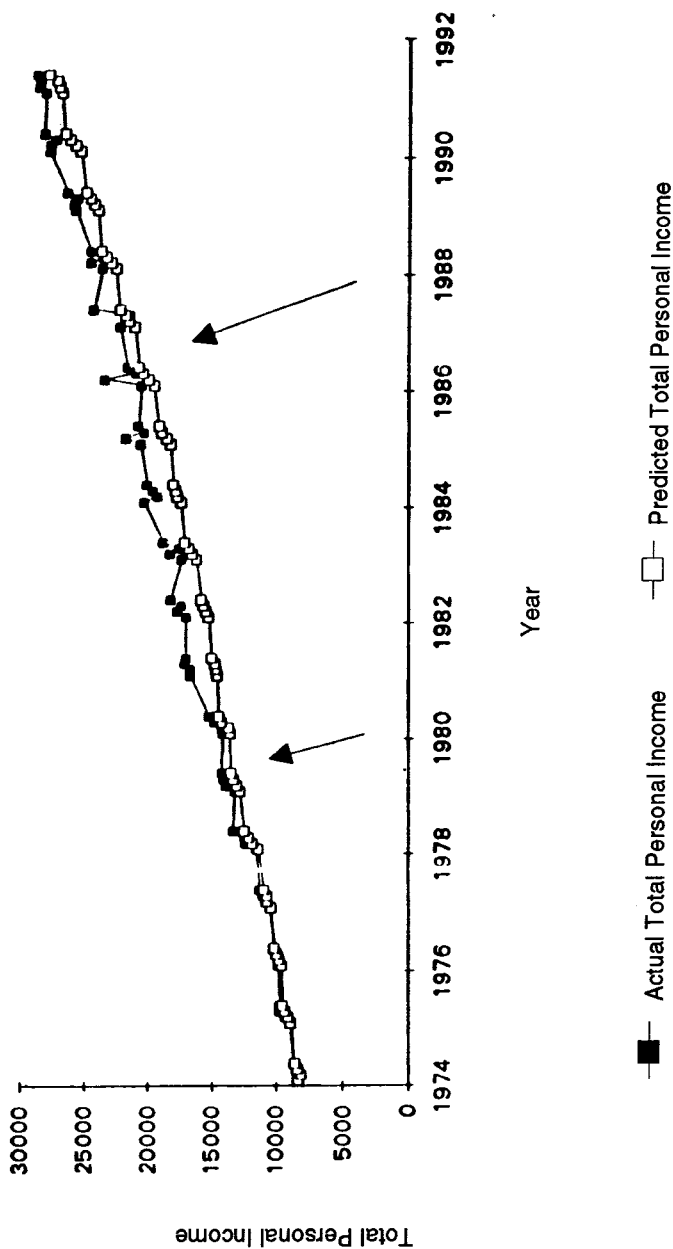


Table 2
Subperiod Constraints on Growth
Nebraska Total Personal Income

Possible Constraint	1974:1- 1979:4	1980:1- 1987:4	1988:1- 1991:4
TY_{t-1}	-	-	-
$dGNP_t$	+	+	+
$dTOT_t$	+	-	-
$dITOT_t$	+	+	+
$dHRS_t$	+	-	-
dEP_t	+	-	-

entries in the table indicate those cases where the relevant row variable was significant at the 90 percent or better confidence interval.

Unlike the results reported above in equation (8), internal demand does not appear to be a binding growth constraint in any of the three subperiods identified. Where significant, the sign on TY_{t-1} is inconsistent with that of a growth constraint. External demand as proxied by change in GNP, on the other hand, is a significant growth constraint in each time period. The estimated coefficient on $dGNP$ is positive and increases in each subsequent time period: 1.2776 (1974-1979), 8.3794 (1980-1987), and 23.2984 (1988-1991). External demand on the demand side of the ledger is an important determinant of Nebraska's growth trajectory, and sensitivity to this variable is increasing over time.

Supply-side constraints appear to have influenced Nebraska's growth during certain episodes of the overall 1974-1991 period. Labor constraints do not appear to have been significant growth determinants in the 1970s, but during the 1980s they come to the fore as a prime growth determinant. Labor shortages especially constrained post-1987 growth. Falling (real) energy prices in the mid-1980s appear to have accelerated growth in Nebraska personal income. The 1979 OPEC-induced run-up in energy prices did reduce state personal income growth significantly in the early '80s; such was not the case with the increase in energy prices in the earlier 1970s. In the post-1988 subperiod the increase in energy prices acted to constrain growth.

Fluctuations in the domestic and international terms of trade also have a differentiated impact on the observed growth Nebraska total personal income. The international terms of trade appear with a positive, significant coefficient in each time period, indicating a constraining influence on growth. The coefficient on this variable is 3795.1 during 1974-1979, but increases to 9952.8 in the early 1980s before falling slightly to 8279.8 in the final period. The domestic terms of trade, in contrast, only affect growth trajectories in the 1974-1979 period. In the 1980s the effect of $dTOT$ is significant but negative, indicating no constraining influence on growth.

For farm income (Appendix C), external demand is a consistent factor constraining growth in all three time periods; internal demand does not affect farm income growth in a constraining fashion. Energy prices appear to have been a constraining factor on farm income growth in the 1970s, but not in the 1980s. Conversely, labor market tightness appears not to have constrained growth in the '70s, but has in the 1980s. Finally both the domestic and international terms of trade have been active constraints on farm income growth. The coefficients on dITOT suggest that farm incomes have become increasingly sensitive to fluctuations in the international economy as we proceed through the three subperiods. Domestic terms of trade fluctuations constrained growth trajectories for farm income in the '70s and late '80s but not during the agricultural slump of the early '80s.

Conclusions

Our results indicate that utilization of a reduced form equation such as that suggested by the Siebert model of regional growth facilitates the identification of regional growth constraints. It is a useful prologue to the choice of a specific model to explain or forecast regional growth paths. Although a regional version of a general equilibrium-based econometric model, if frequently updated and subjected to sensitivity analysis, can be expected to yield similar information to the results reported in equation (8), the above formulation represents a parsimonious attempt to obtain the same information. It seems a necessary prerequisite to the application of models emphasizing either demand- and/or supply-side determinants of growth.

Table 2 and the accompanying text indicates that the constraints determining regional growth trajectories are likely to change over time. While we make no claim that our subperiod delineation is a definitive one for the Nebraska economy, the fact that both the nature and size of the identified constraints on Nebraska's growth pattern change over time clearly indicates that a reduced form model such as that proposed should aid in any continuing effort to explain and/or forecast regional growth.

Our results also suggest the efficacy of separating real from price-induced growth sources. For Nebraska, changes in the domestic terms of trade seem to have an important growth impact. The elasticity of the growth rate of personal income, evaluated at the mean, with respect to dDTOT was roughly 30 percent of that of increases in internal demand (the highest elasticity recorded) for the 1974-1991 period. This demonstrates the importance of this variable in explaining the overall behavior

of Nebraska personal income. Further research on more precisely specifying a region's domestic terms of trade appears warranted.

While fluctuations in the international terms of trade have had less impact on Nebraska's 1974-1991 growth path than those in DTOT, the evidence suggests that the effect has not been insignificant. Subperiod analysis suggests that this variable has become an important growth constraint in the 1980s. Further research on refining this variable, possibly by considering exchange rates between the dollar and currencies of the major countries importing Nebraska-produced goods, also is indicated.

Finally, from a policy perspective our results suggest that supply-side and internal demand variables have been important determinants of Nebraska's economic development (the latter mainly for nonfarm income) at certain crucial junctures. To the extent these variables are amenable or endogenous from the purview of local policy makers, the results are consistent with an expanding role for states in attempting to influence their overall economic development. Final judgments on the design and/or efficacy of such policy initiatives must await further research employing more detailed models than that utilized here.

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Appendix A **Growth Constraints of Farm Income**

Variable	Coefficient	t-ratio	Significant
Constant	-116.98	-2.8661	*
dGNP	2.7377	8.3076	*
TY-1	0.0423	1.4979	
dFP	1722.9	7.7598	*
dITOT	338.87	0.7598	
dEP	3.6078	0.8415	
dHRS	-100.13	-7.3807	*
λ_1	4.477	5.838	*

* Significant (two-tailed) at 5 percent level

Estimation performed with ARCH(1) model

Appendix B Total Income Subperiod Analysis

To allow for a change in the structure of the model, two dummy variables were defined:

$$\begin{aligned} S_2 &= 1 \text{ for } 1980:1 \text{ to } 1987:4, 0 \text{ otherwise} \\ S_3 &= 1 \text{ for } 1988:1 \text{ to } 1991:4, 0 \text{ otherwise.} \end{aligned}$$

We allow the regression coefficients of the original model to interact with these dummy variables in order to test for significant shifts in the structural parameters of the constraints.

Again, the Lagrange multiplier test was applied to check for serial correlation. The LM statistics for first through eighth order serial correlation indicated that there is no serial correlation. The first order ARCH effect is significant; the Chi-square statistic was 5.45341, which is higher than the critical value (at the 95 percent confidence level) of 3.84146. The second order ARCH effect was not significant (Chi-square value, 5.28535; critical value, 5.99147). Therefore, there is no first order serial correlation effect in the residuals themselves, just their variances.

The following table contains the estimates of the complete model utilizing the three subperiods. It is a first order ARCH model.

Table B1

Variable	Coefficient	t-ratio	Significant
Constant	495.7	17.735	*
S_2	2702.7	8.588	*
S_3	-632.8	-1.749	
dGNP	1.278	6.779	*
dGNP * S_2	7.102	9.079	*
dGNP * S_3	14.919	25.543	*
dHRS	85.456	12.668	*
dHRS * S_2	-460.240	-7.539	*
dHRS * S_3	-1110.00	-23.549	*
dDTOT	2850.10	37.402	*
dDTOT * S_2	-6999.70	-9.415	*
dDTOT * S_3	-8978.60	-21.840	*
dITOT	3795.70	7.178	*
dITOT * S_2	6157.10	4.477	*
dITOT * S_3	-1673.00	-2.912	*
dEP	9.280	2.371	*
dEP * S_2	-55.409	-7.073	*
dEP * S_3	31.157	5.648	*
TYL1	-0.025	-6.940	*
TYL1 * S_2	-0.154	-7.998	*
TYL1 * S_3	0.039	2.868	*
λ_1	4.3437	5.837	*

d indicates difference and TYL1 means a lag of one period on TY

Utilizing these results, the estimated models for the three time periods are:

1974:1 to 1979:4:

$$dTY_i = 495.7 + 1.2776dGNP_i + 9.2798dEP_i + 85.4564dHRS_i \\ + 2850.1dDOT_i + 3795.1dITOT_i - 0.025178TY_{i-1}$$

1980:1 to 1987:4:

$$dTY_i = 3198.4 + 8.3794dGNP_i - 46.1292dEP_i - 374.784dHRS_i \\ - 4149.6dDTOT_i + 9952.8dITOT_i - 0.1788TY_{i-1}$$

1988:1 to 1991:4:

$$dTY_i = 3198.4 + 23.2984dGNP_i - 14.9722dEP_i - 1484.784dHRS_i \\ - 13128.2dDTOT_i + 8279.8dITOT_i - 0.1400TY_{i-1}$$

Appendix C
Farm Income
Subperiod Analysis

Table C.1

Variable	Coefficient	t-ratio	Significant
Constant	362.84	11.209	*
dGNP	1.6553	6.328	*
dGNP * S ₂	2.8258	8.621	*
dGNP * S ₃	7.8250	14.408	*
TY-1	-.03371	-7.363	*
TY-1 * S ₂	-.01384	-1.891	
TY-1 * S ₃	.02906	2.764	*
dFP	3049.8	22.965	*
dFP* S ₂	-4106.7	-9.454	*
dFP* S ₃	557.1	2.006	*
dITOT	1681.9	2.298	*
dITOT* S ₂	887.0	1.434	
dITOT* S ₃	639.5	0.703	
dEP	-25.250	-4.437	*
dEP* S ₂	25.607	5.538	*
dEP* S ₃	48.916	8.108	*
dHRS	44.766	2.640	*
dHRS* S ₂	-241.84	-11.867	*
dHRS* S ₃	-862.69	-29.152	*
S ₂	463.68	4.960	*
S ₃	-299.14	-1.225	
λ ₁	9.5887	5.8115	*

Note: Estimation performed with ARCH(1) model

* Significant (two-tailed) at 5 percent level

The estimated models for the three time periods are as follows:

1974:1 to 1979:4:

$$dFY_i = 362.84 + 1.6553dGNP_i - 25.25dEP_i + 44.766dHRS_i + 3049.8dFP_i \\ + 1681.9dITOT_i - 0.03371TY_{i-1}$$

1980:1 to 1987:4:

$$dFY_i = 826.52 + 4.4811dGNP_i + 0.357dEP_i - 197.074dHRS_i - 1056.9dFP_i \\ + 1681.9dITOT_i - 0.03371TY_{i-1}$$

1988:1 to 1991:4:

$$dFY_i = 826.52 + 12.3061dGNP_i + 49.273dEP_i - 1059.764dHRS_i \\ - 499.8dFP_i + 1681.9dITOT_i - 0.00465TY_{i-1}$$

Table C.2
Summary of Constraints

Possible Constraints	1974:1- 1979:4	1980:1- 1987:4	1988:1- 1991:4
TY_{i-1}	-	-	-
$dGNP_i$	+	+	+
dFP_i	+	-	-
$dITOT_i$	+	+	+
$dHRS_i$	+	-	-
dEP_i	-	+	+