Modern Macroeconomics and Regional Economic Modeling

by

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prepared for presentation in the
JRS 50th Anniversary Symposium at the
Federal Reserve Bank of New York

1. Introduction

- Regional forecasting and policy models historically have been patterned after models originally developed for country-level analysis
  - Leontief's input-output model
  - Walrasian applied general equilibrium model
  - Cowles Commission macroeconometric equation system approach
- These models continue to be widely used both at the regional and national levels

- Numerous criticisms of the macroeconometric equation system approach:
  - lack of microeconomic underpinnings
  - ad hoc equation specification (e.g., insufficiently tested exclusion restrictions)
  - suffer from the Lucas critique
  - forecast failures during the stagflation period of the 1970s because of demand-side orientation
- Led to subsequent refinements of Cowles-style models

- Two macroeconomic paradigms also emerged which attempt to overcome these critiques:
  - Vector Autoregression (VAR) approach
  - Dynamic Stochastic General Equilibrium (DSGE) approach
- Explosion of related studies in macroeconomics
- Yet to be fully embraced by regional economists: (i) limited use of VARs; and (ii) absence of regional DSGE models
- In this paper, I discuss potential gains from greater use of modern macroeconomic methodology in regional economic modeling

2. DSGE and VAR Macroeconomic Methodology

- Vector Autoregression (VAR) Modeling
  - VAR approach began as an atheoretical alternative to structural econometric equation modeling
  - reduced-form VAR

    (1) $x_t = \mathbf{A(L)}x_{t-1} + e_t$

    endogenous variables *x*, lag operator L, matrix of reduced-form coefficients **A(L)**, errors *e* with covariance matrix Σ_e

- Reduced-form VAR avoids imposing exclusion restrictions which often were criticized as being ad hoc and untested (Sims, 1980)
- Yet large number of parameters requiring estimation in large systems easily leads to over parameterization and poor out-of-sample forecasting performance
- Also reveals little about the underlying economic structure, allowing for a number of different inferences to be drawn from the same data
- Two important extensions of the reduced-form VAR have been pursued: (1) Bayesian vector autoregression (BVAR); and (2) structural vector autoregression (SVAR)

- Bayesian Vector Autoregression (BVAR)
  - originally developed by Litterman, Doan, and Sims in series of related articles
  - imposed Theil-Goldberger inexact restrictions on the VAR coefficients (**A(L)**) through use of hyperparameters; Pseudo-Bayesian approach
  - prior reflected belief that economic systems generally follow a multivariate random walk; Minnesota Prior
  - improved forecast performance over the unrestricted VAR both by reducing the inefficiency associated with over parameterization and in correcting coefficient bias resulting from series nonstationarity
  - also enjoyed some forecasting success when compared to more traditional forecasting approaches (Ashley, 1988; Artis and Zhang, 1990)

- Structural Vector Autoregression (SVAR)
  - use of VARs to examine macroeconomic structure
  - early attempts typically examined time-series Granger-causality between variables and used mechanical methods to orthogonalize innovations to compute impulse response functions and variance decompositions
  - Granger-causality not consistent with Cowles notion of causality
  - mechanical orthogonalization makes structural interpretation problematic
  - this led to explicit use of economic theory in deriving restrictions on VAR

- SVAR corresponding to the reduced-form VAR in Equation (1) can be written as

(2) $\mathbf{B}x_t = \boldsymbol{C(L)}x_{t-1} + \boldsymbol{D}\varepsilon_t$

  - **B**, contemporaneous response (structural) matrix
  - **C(L)** is a matrix of polynomials relating contemporaneous to lagged variables
  - **D** measures the contemporaneous responses of endogenous variables to exogenous shocks, typically normalized as a diagonal matrix
  - pre-multiplying by $\mathbf{B}^{-1}$ (assuming invertibility) produces the reduced-form VAR in Equation (1); $\mathbf{A(L)}=\mathbf{B}^{-1}\mathbf{C(L)}$, and $e_t=\boldsymbol{B}^{-1}\varepsilon_t$
  - ε_t, unobservable shocks, replace Cowles' exogenous variables
  - under identified system, theoretical restrictions are imposed to identify the structural parameters in **B** and hence the ε_t
  - two common forms of restrictions: (i) contemporaneous exogeneity (delay) restrictions and (ii) long-run neutrality restrictions

- SVAR comparisons
  - contrast to BVARs: restrictions derived from theory are imposed on **B**, not on **A** in the reduced form; difficulties in finding theoretically-based restrictions, delay restrictions often ad hoc
  - contrast with Cowles Commission models which imposed structure (e.g., on Equation 1) by assuming exogeneity of the policy variables and by imposing exclusion (zero coefficient) restrictions for model identification
  - over-identification tests in Cowles models couched within the identifying structure of the model; does not test the statistical adequacy of the model itself

- Dynamic Stochastic General Equilibrium (DSGE) Modeling
  - earliest DSGE models were formulated in an attempt to provide an internally-consistent framework to investigate real business cycle (RBC) theory
  - RBC models underpinned by neoclassical general equilibrium economic theory (Kydland and Prescott, 1991b)
    - rational, infinite-lived, identical households maximize intra- and inter-temporal utility over consumption and leisure
    - constant-returns-to-scale in use of capital and labor
    - markets clear each period
    - net investment in each period determines the change in capital stock

- In contrast to computable general equilibrium (CGE) models, agent maximization takes place within a stochastic environment
- Technological progress assumed to follow an AR(1) process
- Focus on the role of supply shocks, long-run neutrality of demand, & absence of frictions, implied no role for macroeconomic policies
- Like CGE models, early models primarily relied on the method of calibration rather than estimation for parameterization

- Explicit decision rules are derived which relate the choice variables to the predetermined and exogenous variables
- Typical absence of closed form solution leads to use of dynamic programming, obtaining nonlinear stochastic difference equations
- Solution of the model equations typically obtained by log-linearization or second-order approximation around the steady state of the economy
- Computational experiments can then be performed by perturbing the economy and observing the adjustment back to the steady-state path

- DSGE models have become more complex as the number of structural shocks considered has increased and frictions have been added on both the real and monetary sides of the economy for added realism and improved empirical fit to the data
- Alternative procedures also have been developed to more formally parameterize DSGE models (Canova, 2007): full-information maximum likelihood estimation, generalized method of moments (GMM) estimation, Bayesian estimation, and matching VAR and DSGE dynamic responses to structural shocks
- Work also continues on evaluating the validity of policy experiments in macroeconomic models, such as overcoming the Lucas critique for likely policies of interest (Kremer et al., 2006)

- Empirical evaluation of the DSGE facilitated by recognition it can be reasonably approximated with a VAR with sufficiently long lags
- DSGE can be thought to impose restrictions on the VAR in Equation (2) (Diebold, 1998; Canova and Pina, 2005)
- Rather than using theory solely to impose limited restrictions on **B** in Equation (2) as in the SVAR approach, or on **A** in Equation (1) as in the BVAR approach, the DSGE implies a richer set of cross-equation restrictions on **B**, **C** and **D** in Equation (2)(Canova, 2007)

- Integrated DSGE and VAR Modeling
  - because of misspecification, data simulated from DSGE models may not be reflective of the DGP (Schorfheide, 2000), invalidating classical maximum likelihood estimation
  - while VARs with sufficiently long lags can be made to generally reflect the DGP they typically lack sufficient structure for policy analysis
  - recognition of the restrictions imposed by the DSGE model on the VAR representation naturally leads to a Bayesian approach in which the restrictions of the DSGE are used to construct priors for the VAR (Del Negro and Schorfheide, 2003; 2004)
  - advantages of Bayesian estimation: (i) does not rely on asymptotic properties that require the DSGE model to be correctly specified; (ii) can be used with sparse data, and (iii) the parameter space can be restricted to regions where the DSGE model is well-behaved
  - use DSGE-VAR approach to: construct improved BVAR forecasting models, and evaluate and refine DSGE models (Del Negro and Schorfheide, 2006)

3. Implications for Regional Economic Modeling

- Regional Computable General Equilibrium Modeling
  - DSGE approach borrowed heavily from CGE modeling both in terms of specification and computation
  - both grounded in microeconomic assumptions about tastes, technology, constrained optimization, and equilibrium
  - early RBC models used the method of calibration ubiquitously used to parameterize CGE models (Partridge and Rickman, 1998a).

- a primary difference though is that CGE models are deterministic rather than stochastic
- stochasticity makes DSGE models more difficult to solve; leading to fewer variables and greater aggregation
- advantage of the stochastic specification is it naturally leads to estimation and the fitting to time series data
- even dynamic CGE models are routinely calibrated to cross-sectional data with the dynamic properties given by steady-state growth extrapolation of the initial static equilibrium or solution of a reasonable path based on initial conditions

- DSGE models naturally better suited for studying dynamics of the aggregate economy and cyclical fiscal and monetary policy effects, while CGE models are used more for long-run microeconomic policy analysis (e.g., international trade or tax policies)
- despite differences, there are lessons to be learned for regional CGE modeling from the estimation and/or dynamic fitting of DSGE models
- for greater quantitative policy use CGE models have to be demonstrated to more accurately reflect the workings of regional economies and provide empirically-based time dimensions to policy responses (Partridge and Rickman, 1998a; forthcoming)
- have been limited attempts using time series information in parameterizing CGE models

- Borrow from DSGE-VAR methodology
  - recursive dynamic CGE models could be used to simulate time paths of key regional variables for use in the imposition of restrictions on a VAR representation of the same variables
  - provide alternative priors to the Minnesota prior in BVAR forecasting while also serving as a means for checking how consistent the restrictions are with the data
  - restrictions from alternative CGE models for the same region could be compared for their accuracy; e.g., akin to the comparison of two competing DSGE models by Schorfheide (2000)

- competing views of labor mobility, unemployment, labor force participation responsiveness and wage flexibility could be incorporated and evaluated, CGE model could be modified appropriately in response
- current regional BVAR literature includes imposition of restrictions from input-output models (LeSage and Magura, 1991; Partridge and Rickman, 1998b); spatial contiguity models (LeSage and Krivelyova, 1999); two-sector economic base and general equilibrium (Rickman et al., 2009)
- need for restrictions derived from richer structural models: DSGE or CGE

- Regional Simultaneous Econometric Equation Modeling
  - workhorse model for regional policy analysis has been the partial adjustment simultaneous equation model of regional employment and population (e.g., Carlino and Mills, 1987)
  - two equations are a subset of a location optimization-based structural model (e.g., prices are solved out of the model), making them a “semi-structural” representation of the full model (Steinnes and Fisher, 1974, p. 70)

- Semi-structural formulation makes identification and interpretation of the equation coefficients problematic
  - are not reduced-form as the measure of labor demand is regressed on labor supply and vice versa
  - not completely structural, as employment and population are outcome variables, wages absent from model

- Critiques leveled at (Cowles Commission) macroeconometric models apply here:
  - use of exclusion/identifying restrictions which typically are untested
  - where tested, occur within an imposed structure which may not reflect the DGP
  - instability of coefficients and problems of interpretation
  - policy analysis subject to the Lucas Critique
  - describes co-movement, not causality: “the central premise is that the distribution of population and employment is constantly adjusting toward an unknown spatial equilibrium and, along the way, the two are jointly determined” Carruthers and Mulligan (2007, p. 81)

- Alternatives

  SVAR models

  – Blanchard and Katz (1992) implement an SVAR model of state employment, wages, the unemployment rate and wages
    - assumed long-run stationarity of employment rates and wages
    - assumed employment represented labor demand
    - drive the conclusion regarding role of demand shocks and dominant role of migration in regional labor market equilibration

  – Partridge and Rickman (2003, 2006) implement SVAR of employment, population and wages
    - imposed long-run neutrality restrictions of labor supply shocks on wage rates
    - conclude role of labor demand in driving labor market fluctuations and migration in smoothing out asymmetry in regional cycles overstated by B&K
    - also note the inability of the econometric equation approach to address the sources and dynamics of state cycles

- Coulson (1993) uses contemporaneous exogeneity restrictions inspired by the regional shift-share model
- Carlino, Defina and Sill (2001) use with contemporaneous restrictions among local industries based on input-output linkages
- in an alternative to spatial econometric approach, Chang and Coulson (2001) use contemporaneous restrictions in an SVAR to examine spatial spillovers between central cities and suburban areas of selected U.S. metropolitan areas

- Rappaport (2008a, 2008b) implements a calibrated static general equilibrium model of a representative U.S. metropolitan area economy
    - simulates the model to examine the likely variations in quality of life (2008a) and productivity (2008b) that underlie differences in U.S. metropolitan area population density
    - model alternatively could be formulated in a dynamic context in which regional fluctuations would be driven by productivity and quality-of-life shocks (Rappaport, 2008a)
    - DSGE model formulated along these lines could become a serious competitor to regional SVAR models and simultaneous econometric equation models in quantitative regional policy analysis

4. Conclusion

- Significant potential exists for greater use of VAR and DSGE macroeconomic methodology in regional economic modeling
  - provide insights into how regional CGE models might be formulated to become much more widely used for regional quantitative policy assessment
  - DSGE models also could be used as substitutes to CGE and regional simultaneous econometric approaches for forecasting and policy analysis

- Numerous challenges remain in terms of empirical identification, parameterization and verification (Canova and Sala, 2006; Canova, 2007)
- Issues could be explored within the context of regional economic applications and much would be learned about regional economies along the way
- Approaches which are technically the most virtuous may not be those making the greatest contribution to knowledge (Summers, 1991)
- But we do not know what would be gained until we try!