Macrothink Institute™

International Journal of Regional Development
ISSN 2373-9851
2025, Vol. 12, No. 1

Computable General Equilibrium Modeling for Regional Factor Demand: Policy Impacts and Factor Mobility in Economic Development

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Received: March 12, 2025 Accepted: April 2, 2025 Published: April 8, 2025

doi:10.5296/ijrd.v12i1.22710 URL: http://dx.doi.org/10.5296/ijrd.v12i1.22710

Abstract

The choice among various politically feasible policies requires the analysis of each policy's general economic and social impacts and analyzing how different these impacts are on other system components. The Regional Computable General Equilibrium model is the most appropriate tool to analyze the effects of alternative policies for rural development on the socioeconomic structure of a social accounting matrix for a multimarket model. Assumption enables a small number of parameters the model requires and a calibration procedure to replicate a base year. One of the shortcomings of this assumption is that the CGE results are only good for relative comparison of alternative policies but not for forecasting. Third, such resources as labor and capital are mobile from sector to sector and region.

Keywords: Regional and Urban Development, Computable General Equilibrium, Factor mobility, Compensating variation (CV) and Equivalent variation (EV)

1. Introduction

A rural area comprises firms and households, various sectors, numerous factor markets, and commodity markets. All these components are interdependent and interactive with each other. Furthermore, this system is open because it allows capital/labor flows and commodity trade with other regions. Rural development always involves policy decisions, so the question of choice among alternative policies often arises to obtain one or several specific development goals. The choice among various politically feasible policies requires the analysis of each policy's general economic and social impacts and analyzing how different these impacts are on other system components (Dieli, Osho, Ojumu, & Opara 2020). and (Pan et al., 2022).

The Regional Computable General Equilibrium model is the most appropriate tool for analyzing alternative policies' impacts on rural development due to the partial socioeconomic structure of SAM and the multimarket model (Sadoulet & de Janvry, 1995) and (Pan, Failler, & Du, 2022). As with other analytical methods, the assumptions of the regional CGE model are essential to understand to make the judgment about when to use this model and how to interpret its results. Only the main assumptions and their corresponding implications are discussed here. First, regional CGE is fundamentally an equilibrium model. General equilibrium means that demand equals supply in all markets; in other words, markets are transparent, or there is no buoyant excess demand (Varian H.R., 1992). The conditions for markets to be transparent are competitive market structure and variable prices that can freely adjust to equate demand with supply to bring the market system to a new equilibrium after a shock hits the system. Therefore, this model is often considered a medium-term model with an extended period for disequilibrium Adjustment (Sadoulet E. and A. de Janvry, 1995). The essential assumption of equilibrium rests on the idea that market equilibrium corresponds to a point of maximum welfare and efficiency (Tweeten, 1989).

Based on this assumption, the data provided by SAM is the initial equilibrium. What is interesting to the researchers and policymakers is the change of this equilibrium point after a policy is introduced to the model as a shock. Second, the rigorous theoretical basis of all decisions in the model is the profit maximization of producers and utility maximization of consumers who are also price responsive (Sadoulet E. and A. de Janvry, 1995). This assumption enables a small number of parameters the model requires and a calibration procedure to replicate a base year. One of the shortcomings of this assumption is that the CGE results are only good for relative comparison of alternative policies but not for forecasting (Uwakonye, Osho & Ajuzie 2010). Third, such resources as labor and capital are mobile from sector to sector and region. The assumptions of factor mobility are made differently under both short and long runs in the CGE model. Labor and capital should be based on sectors and regions, and land should be fixed in the long and short run (Madden, 2020).

The interregional movement of labor and capital plays a critical role in the theory of regional growth and development (Armstrong and Taylor). The rental rates of a factory are treated according to whether it is fixed or mobile. If a factor is assumed to be fixed, its rental rates differ across regional sectors; by contrast, if a factor is considered mobile, only one rental rate prevails across all industries. The difference in factor prices between regions or sectors induces a factor's mobility (labor, capital). This study aims to illustrate how the above assumptions are processed in a regional CGE model regarding factor markets, emphasizing the labor market. The study will examine, among others, an equilibrium condition in factor markets and factor mobility, a theoretical derivation of labor demand, and a framework for calibration processes of labor demand parameters for a partial equilibrium analysis in the labor market (Anthony, Osho & Sen 2017).

2. Factor Mobility and Market

The following tables present different assumptions of factor mobility under short-run and long-run. This study will focus on the short-run model; therefore, under the short-run assumption, only the labor market deserves profound studies since labor is the only mobile factor and its equilibrium condition is subject to price changes, held in the corresponding row of labor, capital, and land in the initial SAM. Furthermore, all factors are homogenous, and their markets are assumed to be perfectly competitive.

2.1 Market Clearing Condition for Labor

Labor is assumed to be mobile; therefore, only one wage rate prevails across sectors. There are three sources of labor supply: initial equilibrium stock of labor, endogenous labor supply provided by local households, and determined by the labor-leisure choice model. Labor migration: Labor will out-migrate from the region if the wage rate is higher in the rest of the country, and labor in-migration will occur if the wage rate is lower (Kim, Hewings, & Lee 2022). The sensitivity of labor supply concerning the difference in wage rates between the region and the rest of the world is expressed by the elasticity of labor migration. Let γ Is elasticity of labor migration, and the labor migration can be written as:

$$\partial L = \eta \, L \, \partial[(PL/PLO)/(PL/PLO)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where L is the initial equilibrium stock of labor, PL is the wage rate in the region, and PLO is the wage rate in the rest of the country. The market equilibrium condition for the labor market where demand equals supply can be written as follows:

$$\text{LHSO} + \text{LHMG} = \text{LHDI} + \text{LHDE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

LHSO is the total initial household labor, LHMG is the labor migration, LHDI is the total industry labor demand, and LHDE is the erogenous demand for labor demanded by government subagencies. The market clearing condition for capital can be written as

$$\text{CAPi} = \text{CAPOi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(3)}$$

where *CAPOi* is the fixed supply of capital in sector *i* and *CAPi* is the demand for capital in industry *i*. The market clearing conditions for land can be written as follows:

$$LANDi = LANDOi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where *LANDOi* is the fixed supply of land in sector *i* and *LANDi* is the demand for land in industry *i*.

2.2 Theoretical Derivation of Labor Demand

Labor is provided by households that maximize their utility. In the labor-leisure choice model, the worker-consumer aims to maximize the utility by choosing an arrangement of leisure (*Qo*) and combined market commodities (*Qi*), which include both imports and regionally produced products subject to the constraint of the household's full income (*FY*). Full income consists of non-labor income (*YNL*) and imputed value of time (*wT*)

$$Max\ U = \beta_o \ln(Q_o + \gamma_o) + \sum_i^m \beta_i \ln(Q_i + \gamma_i) \quad \text{(5i)}$$

$$HE = \sum_i^m P_i Q_i \quad \text{(5ii)}$$

Where $S.T.FY = YNL + wT = HE + wQo$ and HE is the household money income or household expenditure, T is the aggregate time. The resulting LES for leisure as a commodity is:

$$Q_{oh} = \gamma_o + \left(\frac{\beta_o}{w}\right)\left(FY_h - \sum_i^n p_j \gamma_j\right) \quad \text{(6)}$$

If j = 0 then $P0$ = w, then γ_o is the minimum required amount for leisure, and Bo is the marginal budget share for leisure. Substitute (5) into (6), and rearranging terms, we have *HH* labor demand function:

$$LS_h = MT_h - \left(\frac{\beta_{oh}}{w}\right)\left(\frac{HE_h - \sum_i^n P_j \gamma_{jh}}{1 - \beta_{0h}}\right) \quad \text{(7)}$$

Where $LSh + Q0h$ is Th, and Th is the total time endowment, and $Th - \gamma_o$ is MTh equals aggregate work time for a household. Since γ_{oh} is not observable, the maximum hours available for work (MTh) is calibrated as follows:

$$MT_h = LS_h + \left(\frac{\beta_{oh}}{w}\right)\left(\frac{HE_h - \sum_i^n P_j \gamma_{jh}}{1 - \beta_{0h}}\right) \quad \text{(8)}$$

3. Calibration Process of Labor Demand Parameters

The data sources for the calibration process: First, data was provided from the Aggregated Social Accounting Matrix (SAM) for Oklahoma in 1993, particularly from the Households column and the Labor row. This is the benchmark data, of which *LMG* is supposed to be zero. Thus, the following equilibrium condition is held in SAM:

$$\text{LSO} = \text{LDI} + \text{LDE} \quad \text{(9)}$$

Second, exogenous parameters consist of ε_h^{LY} is income elasticity of labor demand, ε_{ih}^{LY} Does the income elasticity of household consumption (i = 1,2,3,4) and the Frisch coefficient measure the marginal utility of income? The calibration process is for calibrating. β_{oh} , β_{ih} , and γ_{ih} (Uwakonye & Osho, 2008). These values are then substituted into (5), which would yield the same value given by SAM.

Step 1: Calibrating the Marginal Budget Share for Leisure, β_{oh} ,

From (5), take the derivative of LSh with respect to HE, then substitute it into the formula.

$$\varepsilon_h^{LY} = \frac{\partial LS_h}{\partial HE_h} \cdot \frac{HE_h}{LS_h} \quad (10)$$

The income elasticity of labor supply:

$$\varepsilon_h^{LY} = \frac{-\beta_{oh} HE_h}{(1 - \beta_{oh}) wLS_h} \quad (11)$$

Since ε_h^{LY} is exogenous and available from other studies. Rearranging terms in (12) yields:

$$\beta_{oh} = \frac{-wLS_h \varepsilon_h^{LY}}{wLS_h \varepsilon_h^{LY} - HE_h} \quad (13)$$

Step 3: Calibrating the Minimum Subsistence Requirement, γ_{ih}

An exogenously specified *Frisch* parameter of -1.60 (From Abbot & Ashenfelter, 1979) is used to calibrate γ_{ih}

$$Frisch_h = -\frac{HE_h}{HE_h - \sum_i^n P_i \gamma_{ih}} \quad (14)$$

Rearranging terms in (14) then γ_{ih} Which is interpreted as the minimum subsistence requirements, was calculated from the following equation:

$$\gamma_{ih} = Q_{ih} + \left(\frac{\beta_{ih}}{1 - \beta_{oh}}\right) \cdot \left(\frac{HE_h}{Frisch_h}\right) \quad (15)$$

3.1 Commodity Substitution of Imports for Domestic Product

Households choose optimal combinations of imports and locally produced goods according to relative prices and pre-specified elasticities of substitution. Regional and imported goods are imperfect substitutes due to product differentiation. In addition, the substitution possibilities are represented by the parameters of the CES function, corresponding to the Armington specification. Finally, the shares in the composition of regional and imported goods are determined by cost minimization.

$$Q_i = \phi_i^Q (\delta_i^Q QM_i^{\rho_i^Q} + (1-\delta_i^Q) QR_i^{\rho_i^Q})^{\frac{1}{\rho_i^Q}} \quad \text{and} \quad \sigma_i^Q = \frac{1}{1-\rho_i^Q} \quad \text{(16)}$$

Where ϕ_i^Q is the household consumption efficiency parameter (ϕ_i^Q >0), δ_i^Q where (0< δ_i^Q <1), QM_i Denotes demand for imports by households, QR_i denotes demand for imports households, σ_i^Q is the responsiveness of substitution and ρ_i^Q is the substitution coefficient (-1< $\rho_i^Q \neq 0$). Consumers minimize cost and maximize utility subject to their budget by optimizing purchases from regionally produced and imported goods:

$$\text{Minimize } PMQM_i + PR_i QR_i \quad \text{(17)}$$

$$\text{Subject to: } Q_i = \phi_i^Q (\delta_i^Q QM_i^{\rho_i^Q} + (1-\delta_i^Q) QR_i^{\rho_i^Q})^{\frac{1}{\rho_i^Q}} \quad \text{(18)}$$

Where PM_i is the price of imported commodities and PR_i is the price of regionally produced commodities from sector i. Using the substitution calculus for the above minimization, the equation gives equation (18).

$$\frac{QR_i}{QM_i} = \left[\left(\frac{1-\delta_i^Q}{\delta_i^Q} \right) \left(\frac{PM_i}{PR_i} \right) \right]^{-\sigma_i^Q} \quad \text{(19)}$$

The region's welfare change is measured by compensating variation (CV) and equivalent variation (EV) consistent with the linear expenditure demand system. Compensating variation determines the new prices while equivalent variation the current prices. Substituting commodity demand functions into the utility function will yield the indirect utility function that represents the maximum utility obtainable:

$$V = \prod_i^n \left(\frac{\beta_i}{p_i} \right)^{\beta_i} \left(HE - \sum_j^m p_j \gamma_j \right) \quad \text{(20)}$$

$$\sum_{i=0}^{n}\beta_i = 1, \quad \text{...} (21)$$

$$V = \prod_i^n \left(\frac{\beta_i}{p_i}\right)^{\beta_i} \left(HE - \sum_j^m p_j \gamma_j\right) \quad \text{...............................} (22)$$

where V is the indirect utility function. Solving equation (21) for HE_h to obtain the expenditure function:

$$HE = E(p,V) = \prod_i^m \left(\frac{p_i}{\beta_i}\right)^{\beta_i} \left[V + \prod_i^m \left(\frac{\beta_i}{p_i}\right)^{\beta_i} \sum_j^m p_j \gamma_j\right] \text{..................} (23)$$

$$E(p,V) = \prod_i^m \left(\frac{p_i}{\beta_i}\right)^{\beta_i} V + \sum_j^m p_j \gamma_j \quad \text{.............................} (24)$$

The CV and EV measures are now defined as follows:

$$CV = HE^1 - E\{P^1, IU(P^0, HE^0)\} \text{.................................} (25)$$

$$EV = E\{P^0, IU(P^1, HE^1)\} - HE^0 \text{ ....} (26)$$

Substituting equation (23) into (24) and (25):

$$CV = HE^1 - \prod_i^m \left(\frac{p_i^1}{\beta_i}\right)^{\beta_i} V(p^0, HE^o) - \sum_j^m pj^1 aj \text{ ....} (27)$$

$$EV = \prod_i^m \left(\frac{p_i^o}{\beta_i}\right)^{\beta_i} V(p^1, HE^1) + \sum_j^m pj^1 aj - HE^0 \text{ ....} (28)$$

Substituting equation (25) into (26) and (26)

$$CV = HE^1 - \sum_j^m p_j{}^1 a_j - \left[\prod_i^m \left(\frac{p_i^1}{p_i^0}\right)^{\beta_i} \left(HE^o - \sum_j^m p_j{}^0 \gamma_j\right)\right] \text{........................} (29)$$

$$EV = \prod_i^m \left(\frac{p_i^0}{p_i^1}\right)^{\beta_i} \left(HE^0 - \sum_j^m p_j{}^1 \gamma_j\right) - \left(HE_h^o - \sum_j^m p_j{}^0 \gamma_j\right) \text{ ....} (30)$$

Where equation (28) and (29include leisure with household expenditure, not full income. Then, substitute this equation obtained from the labor and leisure relationship.

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ISSN 2373-9851
2025, Vol. 12, No. 1

$$HE - \sum_{j}^{m} p_j \gamma_j = \frac{HE - \sum p_j \gamma_j}{1 - \gamma_0} \quad \text{.....................................} (31)$$

Equation (28) into equations (29) and (30), we obtain:

$$CV = \left(\frac{1}{1-\beta_0}\right)\left[\left(HE^1 - \sum_{j=1}^{n} P_j^1 \gamma_j\right) - \left(HE^0 - \sum_{j=1}^{n} P_j^0 \gamma_j\right)\prod_{i=0}^{n}\left(\frac{P_i^1}{P_i^0}\right)^{\beta_i}\right] \text{............} (32)$$

$$EV = \left(\frac{1}{1-\beta_0}\right)\left[\left(HE^1 - \sum_{j=1}^{n} P_j^1 \gamma_j\right)\prod_{i=0}^{n}\left(\frac{P_i^0}{P_i^1}\right)^{\beta_i} - \left(HE^0 - \sum_{j=1}^{n} P_j^0 \gamma_j\right)\right] \text{............} (33)$$

All the variables in the welfare measures of equations (37) and (38) are observable, so we take these CV and EV as measures of the welfare change resulting from a rural development policy. In addition to the previous equations, the labor supply function is used in calibration.

$$LS = MAXHOURS - \left(\frac{\beta_0}{w}\right)\left(\frac{HE - \sum_{j=1}^{n} p_j \gamma_j}{1 - \beta_0}\right) \text{.................................} (34)$$

Where *MAXHOURS* represents maximum available time. The parameters needed to calibrate are β_0, β_i and γ_i. The system's remaining variables and parameter values are obtained from the SAM tabular economy snapshot for a particular year. Finally, to obtain the parameter γ_i, an exogenously specified "*Frisch* parameter" is needed. The Frisch coefficient determines the sensitivity of the additional utility of income. The Lagrangian to the utility maximization problem when deriving the demand function by using the Klein-Rubin utility function is

$$L = \sum_i \beta_i \ln(Q_i - \gamma_i) + \lambda(HE - \sum_i P_i Q_i) \text{..........................} (35)$$

Frisch is the elasticity of λ with respect to *HE*. Solving the first-order conditions for the above Lagrangian results in:

$$\lambda = \frac{\sum_i \beta_i}{HE - \sum_i P_i \gamma_i} = \frac{1}{HE - \sum_i P_i \gamma_i}, \qquad \sum_i \beta_i = 1 \text{.....................} (36)$$

The elasticity of λ with respect to *HE*, which is the Frisch parameter:

$$Frisch = -\frac{HE}{HE - \sum_i P_i \gamma_i} \text{................................} (37)$$

Hence, the parameter γ_i, which is interpreted as the minimum subsistence requirements, was calculated from the following equation.

$$\gamma_i = Q_i + \left(\frac{\beta_i}{(1-\beta)p_i}\right)\left(\frac{HE}{Frisch}\right) \quad \text{..............................} \quad (38)$$

The maximum hours available for work, $MAXHOURS$ is calibrated by rearranging (34):

$$MAXHOURS = LS + \left(\frac{\beta_0}{w}\right)\left(\frac{HE - \sum_{j=1}^{n} p_j \gamma_j}{1-\beta_0}\right) \quad \text{..........................} \quad (39)$$

4. Conclusion

Applying the Computable General Equilibrium (CGE) Model in regional factor demand analysis provides an essential framework for evaluating the economic impact of various policies. This study has illustrated how regional CGE models integrate labor, capital, and land markets while emphasizing factor mobility. The model's ability to account for interregional labor migration and sectoral capital allocation highlights its effectiveness in assessing policy-induced economic shifts. A key strength of the CGE approach is its ability to model general equilibrium conditions, where supply and demand interact dynamically across multiple sectors. By relying on Social Accounting Matrix (SAM) data, this model provides a benchmark equilibrium that allows researchers and policymakers to simulate economic shocks and analyze their effects on different market components. The model's theoretical foundation in profit maximization for producers and utility maximization for consumers ensures that it aligns with standard economic principles, reinforcing its reliability for policy evaluation (Waters & Seung, 2010).

Despite its advantages, the CGE model has limitations. The assumptions of perfect competition, market transparency, and full-factor mobility may not always hold in real-world economies, particularly in developing regions where market frictions and policy constraints influence economic behavior. Additionally, the calibration process relies on predefined parameters, which may introduce bias or restrict the model’s predictive accuracy. Nevertheless, this study underscores the value of CGE modeling in regional economic policy analysis. It enables comparative analysis of alternative policies rather than precise forecasting, allowing policymakers to make informed decisions about regional labor dynamics, capital allocation, and economic welfare. Future research should explore hybrid models that integrate agent-based or dynamic stochastic general equilibrium (DSGE) models to enhance forecasting capabilities and address the limitations of static CGE models. By advancing regional economic analysis, the CGE framework contributes significantly to policy planning, resource allocation, and economic sustainability, reinforcing its role as a vital tool for rural and urban development strategies.

Finally, the application of Computable General Equilibrium (CGE) modeling in regional factor demand analysis provides valuable insights into the economic effects of various policy interventions. Policymakers rely on CGE models to evaluate how changes in taxation, subsidies, labor regulations, trade policies, and infrastructure investments impact different sectors and regions. CGE models illustrate shifts in employment, wage levels, capital allocation, and overall economic welfare by simulating policy shocks. One of the most significant advantages of CGE modeling is its ability to capture spillover effects, showing how changes in one sector influence others through market linkages. Additionally, CGE models help determine the distributional effects of policies, highlighting disparities between urban and rural areas or different income groups. However, while these models provide relative comparisons of policy alternatives, their forecasting ability is limited due to underlying assumptions about market efficiency and factor mobility. CGE models should be used alongside empirical validation and sensitivity analysis to enhance policymaking, ensuring that economic policies are practical and equitable in promoting regional development and long-term economic sustainability.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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