An Application of the Disequilibrium Adjustment Framework to Small Area Forecasting and Impact Analysis

Geoffrey J. D. Hewings (hewings@illinois.edu)
Regional Economics Applications Laboratory, University of Illinois at Urbana-Champaign

Jae Hong Kim (jaekim@k-state.edu)
Department of Landscape Architecture / Regional & Community Planning, Kansas State University

Abstract: Regional disequilibrium adjustment frameworks, pioneered by Carlino and Mills (1987) and further extended by Boarnet (1994a), have been widely adopted for empirical assessments of a broad range of development issues, including 1) whether jobs follow people or people follow jobs; 2) how urban – suburban – rural areas interact with each other; 3) what policy and other factors are essential for local and regional development; etc. This study identifies key advantages of the framework, particularly its dynamic nature, and then presents an application of the model to small area population and employment forecasting and impact analysis, beyond existing uses of the framework for empirical assessments. The present application uses data for the Chicago metropolitan area and shows that the framework can be a powerful tool for small area studies, when it is combined hierarchically with another model that describes regional macroeconomic growth trajectories. Combined with the regional growth model, it projects small area growth trajectories under several different conditions. The paper also discusses some methodological challenges in this type of application.

Key Words: Forecasting, Spatial Adjustment, Econometric Input-Output Model

JEL Codes: C53, R12, R15

1. Introduction

Regional disequilibrium adjustment frameworks, pioneered by Carlino and Mills (1987), have been widely employed for a broad range of regional and more disaggregated level research. Particularly, the method has been more extensively used, after Boarnet (1994a) extended the original form of the adjustment model by introducing a spatial weight matrix into the equation system in order to explicitly consider the intrinsic spatial interdependence. So far, the applications include a variety of empirical analyses of growth dynamics, ranging from the examinations of the population-employment interaction (see e.g. Carlino and Mills 1987; Boarnet 1994b; Clark and Murphy 1996; Vias 1999) to the studies on the spatial linkages (see e.g. Henry *et al*. 1997, 1999, and 2001; Feser and Isserman 2005) and the investigations on development policy issues (see e.g. Bollinger and Ihlanfeldt. 1997; Edmiston 2004; Ke and Feser 2010).

This study identifies key advantages of the disequilibrium adjustment model, particularly its dynamic nature, and explores a possibility of the further expansion of the model applications, beyond its existing uses for empirical assessments. An attempt is made to exploit a spatial econometric version of the regional disequilibrium adjustment model (Boarnet 1994a) for small area socio-economic forecasting and impact analysis. Rather than using the adjustment model as it stands for a forecasting purpose, the study presents rationales as well as an idea of combining it hierarchically with a regional econometric input-output model (REIM) which provides a long-term growth trajectory of economic growth that is hardly reflected by the adjustment model alone. Further it demonstrates an application of the combined framework for a small area population and employment forecasting under various scenarios.

The remainder of this paper is structured as follows. Section 2 briefly explains the disequilibrium adjustment model and review existing model applications for various analysis. In section 3, attention is paid to the dynamic nature of the adjustment model and its potential for being a tool to support socio-economic forecasting and dynamic impact analysis. Section 4 presents a strategy for combining the adjustment model with REIM to construct an integrated forecasting and dynamic impact analysis framework. Finally, a small area population and employment forecasting based upon the integrated framework is demonstrated in section 5, followed by a conclusion where some challenges in this type of the application are discussed.

2. Regional Disequilibrium Adjustment Model

2.1. Logic & Formulation

Like some other applied analysis frameworks in regional studies, generally the disequilibrium adjustment model describes growth dynamics of certain geographic areas, particularly population and employment changes. The most critical feature of the model is that it characterizes the population and employment changes in the real world as an incremental adjustment process, rather than assuming that the observed patterns of population and employment distributions are a sort of spatial equilibrium state. In other words, it recognizes not only the equilibrating forces arising from the rational behaviors of economic agents but also difficulties of attaining equilibrium in reality. Even though this characterization (i.e., the denial of the assumption of the equilibrium status) somewhat complicates the model formulation and estimation, this way of the understanding the process is appealing, given that there are many factors (e.g., irreversible investments, moving costs, etc.) that prevents households and businesses from relocating frequently in response to the evolving environments. In addition, the model is a more general framework that can include the case of a perfect adjustment (i.e., the equilibrium state) depending on the data.

The fundamental concepts of this model had been expressed by the following two sets of the equations (i.e., equations 1 thru 4). The equations basically imply a) that the equilibrium level of population and employment can be determined by household and business location choice factors and their influences on each other and b) that actual population and employment changes in reality are the result of adjustment processes from a current state towards an equilibrium state that are hardly attained.

$$P^*_{i,t} = f(H_{i,t-1}, E^*_{i,t}) \tag{1}$$

$$E^*_{i,t} = g(B_{i,t-1}, P^*_{i,t}) \tag{2}$$

$$\Delta P_{i,t} = P_{i.t} - P_{i.t-1} = \lambda_P \cdot (P^*_{i,t} - P_{i.t-1}) \tag{3}$$

$$\Delta E_{i,t} = E_{i.t} - E_{i.t-1} = \lambda_E \cdot (E^*_{i,t} - E_{i.t-1}) \tag{4}$$

where $P^*_{i,t}$ and $E^*_{i,t}$ represent the equilibrium level of population and employment in area *i* in year *t*, while $P_{i.t}$ and $E_{i.t}$ indicate actual population and employment (i.e., observations). $H_{i,t-1}$ and $B_{i,t-1}$ are exogenous variables, representing household and business location choice factors, respectively. λ_P and λ_E are

adjustment rates of population and employment towards the equilibrium points (i.e., $P^*_{i,t}$ and $E^*_{i,t}$). The two adjustment rates, between 0 and 1 by definition, represent the essence of this model. They are also the parameters, among many others, to be estimated.

To extend this form of the framework, Boarnet (1994a) suggested that population and employment in a certain area can also have effects on adjacent zones. In other words, for instance, $P^*_{i,t}$ is not only influenced by $E^*_{i,t}$ but also by $E^*_{j,t}$, as workers may decide to live in zone *i*, because they are working in zone *j* close to *i*. Boarnet (1994a) expressed this point by replacing equations (1) and (2) with the following formulation.

$$P^*_{i,t} = f(H_{i,t-1}, \bar{E}^*_{i,t}) \tag{5}$$

$$E^*_{i,t} = g(B_{i,t-1}, \bar{P}^*_{i,t}) \tag{6}$$

where $\bar{P}^*_{i,t}$ and $\bar{E}^*_{i,t}$ represent the equilibrium level of population and employment in the local labor market centered on zone *i* in year *t*.

Boarnet (1994a) further specified the population and employment in the larger labor shed area, centered on each zone, using a typical spatial weight matrix (W), as follows.

$$\bar{P}^*_{i,t} = (I + W) \cdot P^*_{i,t} \tag{7}$$

$$\bar{E}^*_{i,t} = (I + W) \cdot E^*_{i,t} \tag{8}$$

Based upon these basic settings, an estimable disequilibrium adjustment model can be derived. In detail, from (3), (4), (7), and (8), the following set of equations can be stated.

$$\bar{P}^*_{i,t} = (I + W) \cdot P_{i.t-1} + {}^{1}/_{\lambda_P} \cdot (I + W) \cdot \Delta P_{i,t} \tag{9}$$

$$\bar{E}^*_{i,t} = (I + W) \cdot E_{i.t-1} + {}^{1}/_{\lambda_E} \cdot (I + W) \cdot \Delta E_{i,t} \tag{10}$$

In addition, from (3), (4), (5), and (6), the observed population and employment can be written as follows, assuming a linear relationship in equations (5) and (6).

$$\Delta P_{i,t} = H_{i,t-1} \cdot \beta_P \cdot \lambda_P + \lambda_P \cdot \theta_P \cdot \bar{E}^*_{i,t} - \lambda_P \cdot P_{i.t-1} + u_{i,t} \tag{11}$$

$$\Delta E_{i,t} = B_{i,t-1} \cdot \beta_E \cdot \lambda_E + \lambda_E \cdot \theta_E \cdot \bar{P}^*_{i,t} - \lambda_E \cdot E_{i.t-1} + v_{i,t} \tag{12}$$

whereβ_P, β_E, θ_P, and θ_E indicate the parameters for corresponding determinants of the level of population and employment; and both $u_{i,t}$ and $v_{i,t}$ are the independent and identically distributed random error terms.

If (9) and (10) are plugged into (11) and (12), a spatial econometric version of the disequilibrium adjustment model, which is a structural equation system, can be derived, as shown by Boarnet (1994a).

$$\Delta P_{i,t} = H_{i,t-1} \cdot \beta_P \cdot \lambda_P + \lambda_P \cdot \theta_P \cdot (I + W) \cdot E_{i.t-1}$$
$$+ {}^{\lambda_P \cdot \theta_P}/_{\lambda_E} \cdot (I + W) \cdot \Delta E_{i,t} - \lambda_P \cdot P_{i.t-1} + u_{i,t} \qquad (13)$$

$$\Delta E_{i,t} = B_{i,t-1} \cdot \beta_E \cdot \lambda_E + \lambda_E \cdot \theta_E \cdot (I + W) \cdot P_{i.t-1}$$
$$+ {}^{\lambda_E \cdot \theta_E}/_{\lambda_P} \cdot (I + W) \cdot \Delta P_{i,t} - \lambda_E \cdot E_{i.t-1} + v_{i,t} \qquad (14)$$

It needs to be noted that population and employment *densities*, as opposed to the absolute *numbers*, are often used as the dependent variables (e.g., Carlino and Mills 1987; Clark and Murphy 1996). Sometimes, a log linear form of the model specification is also adopted (e.g., Carruthers and Mulligan 2007 and 2008). Moreover, a considerable number of studies, using the framework, include third or more dependent variables (e.g., land area, housing, wage, employment by industry, etc.) in the simultaneous equation system, in addition to population and employment (e.g., Carruthers and Mulligan 2008; Vermeulen and Ommeren 2009). However, the fundamental logic (i.e. characterizing the changes as a disequilibrium adjustment process) and the simultaneous structural equation form are the common grounds of this methodology. Mulligan *et al*. (1999), Vias and Mulligan (1999), and Boarnet *et al*. (2005) have provided meaningful suggestions on how this model can be used in a more effective and appropriate manner.

2.2. Applications

Although the model requires a special treatment in estimation due to the simultaneity involved, it is useful for a variety of research purposes, thus employed for a wide range of empirical analyses. Among others, the model's explicit consideration of the population – employment interactions enable researchers test a) whether jobs follow people, b) people follow jobs, or c) reciprocal causality exists. Here, of interest are the sign and significance of $(\lambda_P \cdot \theta_P)/\lambda_E$ and $(\lambda_E \cdot \theta_E)/\lambda_P$ in equations (13) and (14) that show the influences of population changes on employment and vice versa. Carlino and Mills (1987), one of the pioneering studies applying the adjustment model, looks at this

population – employment interaction issue. They analyze county-level population and employment changes in the United States from 1970 to 1980, and find a positive reciprocal interrelationship between population and total employment. They also pay attention to the interaction between population and manufacturing employment. According to the analysis result, population shows a significant negative effect on manufacturing employment growth, while the relationship the other way around is positive. Boarnet's (1994b) study, using municipality-level data in a part of New Jersey, also examines the population – employment interaction. The estimation result (p.93) suggests that jobs are likely to follow people rather than vice versa, like a well-known study by Steinnes (1977). Using the adjustment model, many other studies also have empirically investigated the issue in other contexts. For instance, Vias (1999) looks at the rural Rocky Mountain region and reports a similar conclusion that jobs tend to follow people, whereas the effect of employment changes on population appears weak. Clark and Murphy (1996) conduct a county-level analysis with 1980s data in the United States. Their analysis suggests that the effects of population on employment change vary by sector.[1] Although population change exhibit positive estimates on the employment in all five sectors that they test (i.e., Manufacturing, Construction, Service, Trade, and FIRE: Finance, insurance and real estate), only the effects are found statistically significant only in the Construction and FIRE.

In addition to the investigation of the population-employment interactions, the spatial econometric version of the disequilibrium adjustment model has been employed to analyze how the growths or declines in different areas are interrelated. Henry, Barkley, and Bao's (1997) study on the spread vs. backwash effects is a notable example of this kind. They analyze how the growth in urban core and fringe areas affects the population and employment changes in surrounding hinterlands based upon the disequilibrium adjustment model and find a mix of spillover and backwash effects from the case of southern regions in the United States (covering parts of Georgia, North Carolina and South Carolina). Specifically, according to their analysis, rural hinterlands are more likely to grow faster, as the adjacent urban fringes are rapidly growing, with a slower pace of growth in the core. In such a context, employment in the hinterlands is also

[1] By conducting a large number of experiments, Hoogstra et al. (2011) finds that the outcomes of the empirical studies on this population – employment interactions can differ by many other factors, such as measurements and spatial weight matrix specification.

found to increase more. Later, the authors (Henry et al. 1999; Henry, Schmitt and Piguet 2001) analyze the urban – rural linkage in France. By testing various specifications of the adjustment model, Henry, Schmitt and Piguet (2001) detect a strong spillover effect of urban growth on rural areas in terms of population, but not that much significant impact on employment. Feser and Isserman (2005) investigates the case of 48 states using a more recent (i.e., 1990~2000) county-level data. Their empirical analysis also indicates a sort of mixed effects, namely positive spillovers from the growth in highly urbanized counties to rural areas, but a competition with suburban (i.e., mixed urban + rural) counties.

The disequilibrium adjustment model has also been widely adopted for a variety of policy and impact analyses. As it properly separates the influences arising from population – employment and spatial linkages out of the other factors of growth, the model can be used for a more precise assessment of population and employment changes in relation to many potential growth factors and policies of interest. For instance, Bollinger and Ihlanfeldt (1997) measure the impact of Atlanta's MARTA rail transit system on census tract level growth. Using employment by industry data with the adjustment model, their analysis examines not only whether population and total employment are affected by the transit stations but also how the industrial structure is influenced. They find no substantial effect of the transit system on the growth (i.e., population and total employment), while it appears that the system "has altered the composition of employment in favor of the public sector … in those areas with high levels of commercial activity" (p. 202). Henry, Barkley, and Bao (1997), mentioned above, pay attention to rural development factors as well as the spatial linkages among urban, suburban, and rural areas. In the study, a variety of local amenity features (infrastructure, public service, housing, labor force, school quality, etc) are considered using a set of representative variables (p.486-487), in order to come up with policy recommendations for rural area development. Among others, the provision of key public service, housing, and school quality are found significant for population growth in rural areas. There are many other applications of the adjustment model for the policy and impact analysis purposes, particularly those aiming to understand the growth determinants in rural areas and to test the role of infrastructure and amenity. The policy-related studies include Duffy-Deno (1998), Deller et al. (2001), Edmiston (2004), Vermeulen and Ommeren (2009), Ke and Feser (2010), etc.

3. Forecasting with a Disequilibrium Adjustment Model

As explained in the previous section, the regional disequilibrium adjustment framework has been widely used as a powerful analytic method for the empirical analyses of population – employment interaction, spatial interlinkages, the real effects of various potential growth factors or policy instruments, and so on. In addition to its usefulness in such empirical assessment, the model's dynamic nature would present an opportunity to be employed as a tool for forecasting and dynamic impact analysis. The model's explicit description of population and employment changes as well as relatively flexible formation may be other merits to be recognized. Particularly, the model can well fit to socio-economic forecasting and analysis for small areas where population and employment often change dramatically due to the dynamic relocation process.

Once the model is properly estimated, it is possible to derive the predicted values of the dependent variables of equations (13) and (14) (i.e., population and employment changes in each zone between *t-1* and *t*) from the state in *t-1*. In addition, we can estimate the impact of a particular shift in an explanatory variable on population and employment changes, using the estimated model.

Few studies have attempted to generate a sort of projections using this approach. Mills and Lubuele (1995) estimate a simultaneous three equation model (in which population, employment, and wage are dependent variables) with 1970, 1980, and 1990 data for the U.S. metropolitan statistical areas (MSA) and project the changes in the three variables for a following time span (i.e., 1990~2000) to see how the MSAs' growth pattern will be in future. In the case of Carruthers and Mulligan (2007), a different set of three variables, 1) acres of developed land per person, 2) acres of developed land per employee, and 3) acres of developed land, are modeled. Then, using the model estimated with 1982, 1987, and 1992 data for metropolitan counties in the United States, the future (i.e., 1992~1997) pattern of land absorption is projected.

Although technically the estimated model can be used for projection purposes, the adjustment model alone is hard to be a plausible long-term forecasting method. The framework is not designed to describe a fundamental driving force of growth (e.g., increasing demands; labor or capital accumulation; technology advancement), whereas it reflects the adjustment process and the effects of location factor differentials on the population and employment changes at a certain level of geography. Therefore, if the model is used as it stands to

project the future, the captured adjustment processes will be iterated without the full consideration of the essential growth momentum. This can be very problematic from a long-term forecasting perspective, while it may be still meaningful for short-term projections. Maybe due to this reason, the previous studies generate the predicted values only for the next time span rather than extending the projection period, when they use the estimated adjustment model for the future analysis.

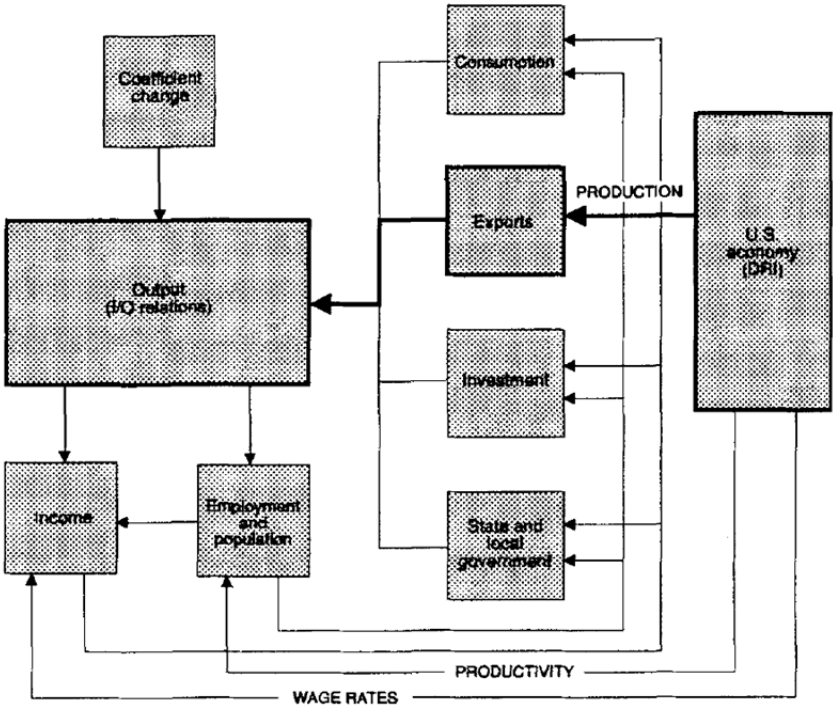
This challenge to utilizing the model for a forecasting purpose, could be addressed by using the model together with another framework that can describe the fundamental growth forces more effectively. In other words, it may be more appropriate to construct an integrated framework in which the adjustment model is combined with a growth model that can generate a long-term trajectory of economic growth or decline. The next section presents an idea of integrating the disequilibrium adjustment model hierarchically with a REIM to forecast municipality-level population and employment changes under a metropolitan wide economic growth forces.

4. Integrating REIM and Disequilibrium Adjustment Model

As indicated above, the disequilibrium adjustment model can be better used for a forecasting and dynamic impact analysis, when it is combined with a growth model. Among others, REIM can be a good partner of the disequilibrium adjustment model, as it well captures the changes in the demands for regionally produced goods and services, which is a main driving force of regional economic growth. REIM can also benefit from the adjustment model. As a macro-economic framework, generally REIM is dealing with spatially aggregated variables (i.e., region-wide values as opposed to the distribution within a region), thus as it stands has limited usefulness in spatial analysis. If the variables can be spatially disaggregated in an appropriate manner, being combined with the adjustment model, the REIM can become a method for a more complete forecasting and empirical analysis.

As well explained in West (1995), West and Jackson (1998), and Rey (2000), REIM describes growth and structural changes of a regional economic system with explicit consideration of the dynamic regional industrial structure. The integration of econometrics, namely the structural time-series equation modeling,

and regional input-output makes it possible to simulate the complex behavior of a regional economic system.[2] For instance, the Chicago REIM (Israilevich *et al*. 1997; Hewings et al. 1998), which will be combined with a disequilibrium adjustment model, depicts the structure of economic system, as shown in figure 1.



Source: p.570, Israilevich *et al*. (1997)

Figure 1. Chicago REIM Structure

The simplest way to feed the adjustment model may be to determine the long-term regional growth forecasts from the REIM and to use the numbers in adjustment modeling. However, a consistency issue can arise, if this strategy of loose coupling is adopted. To be consistent, the sum of the population and employment in individual zones from the adjustment model need to be fixed at the predetermined numbers from the REIM. In other words, the integration needs to be accomplished in a top-down manner (from the REIM to the adjustment model). Although the consistency can be ensured, the strict top down approach is not desirable, as it does not attain the full potential of the integrated framework. As discussed in Kim and Hewings (2011, p.1010)

[2] Given the methodological advantages, REIM has long been widely used for regional socio-economic forecasting and various types of advanced policy and/or impact analyses (Kim and Hewings 2011).

"Because the integration [approach] neglects the effect of spatial structure and other subregional conditions on the performance of the regional economy or the regional demographic changes, the forecasting or simulation outcomes may be challenged in the sense that they may under- or overstate the more probable outcomes. Moreover, the framework based on the top-down integration inevitably has limited usefulness in the sense that the macroeconomic effects of different land-use policies or other actions at the subregional level cannot be appropriately assessed due to the lack of the bottom-up or feedback linkages."

A better integration approach is to derive the potential regional growth momentum, as opposed to the determined region-wide population and employment changes, from the REIM and incorporated the potential growth variable into the disequilibrium adjustment model that describes the changes of the subzones within the region. Then, the adjustment model can project individual subarea's future with consideration of long term regional economic growth forces, but not strictly bounded by a certain number. This strategy of the integration can allow the adjustment model to modify the region-wide values with the consideration of a variety of subregional conditions, including the efficiency of the spatial structure of the region, resource constraints, etc, whereas under the top-down approach it will merely act as an allocation tool, assuming that the predetermined changes from the REIM will be realized regardless of the intraregional conditions.

This approach to a better integration can be implemented using the concept of expected growth that exists in some types of REIM. For instance, adopting Conway's (1990) idea, Chicago REIM deals with expected output as well as actual output to simulate the evolution of regional input output coefficients over time. The expected output by industry (Z), that is the potential level of outputs, derived from the base year's input-output matrix, is defined as below

$$Z = A \cdot X + F \tag{15}$$

where A is a base year's input-output matrix; X represents a vector of the actual output (i.e., real amount of production); and F indicates final demands.

Using the expected output (Z), the expected level of regional employment by industry (ZE) can be calculated with the projected industry-specific productivity in the region.[3] This expected regional employment growth can be

[3] See Kim and Hewings (2010) for a more detailed explanation about this computation.

used in the combined adjustment model to address the lack of the consideration of the fundamental growth momentum. More specifically, for each subregional zone (e.g., counties, municipalities, census tracts) that is the unit of the analysis with the adjustment model, the expected level of employment can be computed using ZE from REIM as follows.

$$ze_t^k = \sum_i ze_{i,t-1}^k \cdot \left(\frac{ze_{i,t}}{e_{i,t-1}}\right) \quad (16)$$

where e and ze indicate the actual and expected level of employment. In addition, i, t, and k denote industry, year, and zone within the region, respectively.

Given ze available for every zone, the dependent variable of the disequilibrium adjustment model (i.e., equation (13)) can be modified for a forecasting purpose, as below.

$$\Delta e_i^k - \left(ze_t^k - e_{t-1}^k\right) = e_t^k - ze_t^k \quad (17)$$

This new variable indicates each zone's achievement beyond the expected level of growth, that is derived considering the long-term growth momentum of the regional economy from REIM. In the same vein, a new dependent variable for the population change equation (i.e., equation (14)) can be used. In this case, the expected growth can be estimated applying birth and death rates. Then, the adjustment model can act as a module of an integrated framework that effectively describes the real changes in small areas with consideration of long-term growth forces as well as many location choice factors, population - employment interactions, spatial linkages, etc.

5. Forecasting & Impact Analysis with an Applied Model

The presented idea to develop an integrated framework, where REIM and a disequilibrium adjustment model are hierarchically combined, had been first implemented for the Chicago metropolitan area (Kim and Hewings 2010). The study area of the applied model consists of seven counties and 296 municipalities in Illinois, USA (figure 2). The individual municipalities and seven unincorporated areas of the counties are the units of disequilibrium adjustment modeling. In other words, there are total 303 (=296+7) small areas, included in the modeling.

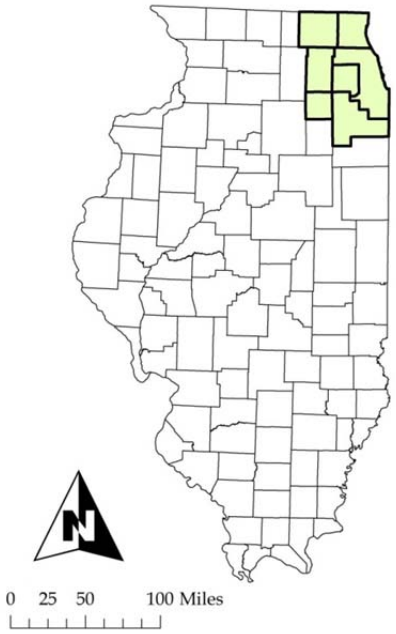


Figure 2. Study Region and the State of Illinois

The adjustment model part of the calibrated framework, presented in table 1 and Kim and Hewings (2010), can be used for small area (i.e., municipality level) population and employment forecasting. Furthermore, the framework can support dynamic impact analysis, showing how the growth trajectories will differ under various conditions of interest. Admittedly, population and employment projections under a set of scenarios are essential for a broad range of development policy making and regional or community level planning practices.

Table 1. Disequilibrium Adjustment Model Part Estimation Outcomes

Variable	Description	Pop. Change Eq. Dependent Var.: *p–zp*		Emp. Change Eq. Dependent Var.: *e–ze*	
		Estimated Coefficient	Std. Error	Estimated Coefficient	Std. Error
C	Intercept	201.06 ***	37.92	176.18 ***	44.34
IWECH	(*I+W*) · (Employment Change)	0.0185 *	0.0081		
IWPCH	(*I+W*) · (Population Change)			0.0804 **	0.0247
P0	Population in *t-1*	-0.0124 ***	0.0001		
E0	Employment in *t-1*			-0.0177 ***	0.0002
IWP0	(*I+W*) · *P0*			0.00050 **	0.00016
IWE0	(*I+W*) · *E0*	0.00027 **	0.00009		
HISPR	Hispanic population ratio	109.50 ***	17.04	116.64 ***	24.07
MHOHINC	Median household income	101.47 *	44.09		
EDU	Educational attainment level	194.15 ***	31.30	207.49 ***	40.39
MHV	Median value of specified housing units	-276.38 ***	38.72	-142.79 ***	38.36
UNIV	Presence of universities or colleges	54.74 ***	15.53		
LU_UDL	Developable land area	214.50 ***	18.39		
HINTERLA	Surrounding hinterland area	256.23 ***	18.82		
GOV	Presence of major government offices			74.23 **	22.90
DUMMYREC	Recession year dummy	85.96 *	41.48		
R-squared		0.885		0.872	
Adjusted R-squared		0.884		0.871	

Notes: – *** 0.1% level Significant | ** 1% level Significant | * 5% level Significant
– The adjustment model has been estimated using spatial generalized moments approach (Kelejian and Prucha 1998 and 1999)
– Many dependent variables (i.e., *HISPR, MHOHINC, EDU, MHV, UNIV, LU_UDL, HINTERLA, GOV*) are used in the form of a normalized index value as opposed to their absolute magnitudes for a more effective forecasting. See Kim and Hewings (2010) for a detailed explanation of this treatment.

Using the applied model, this study projects small area population and employment changes under three different scenarios, that represent diverse future economic performance of the U.S. economy – 1) High growth, 2) Baseline, and 3) low growth national economic. For the baseline scenario, national economic forecasts, produced by *Global Insight*, are adopted; and for two other scenarios, ±0.3% of variation in growth rates is considered. The three scenarios have 2.4%, 2.7%, and 3.0% of the compound annual GDP (Gross domestic products) growth rate for the following 30 years, respectively. Since a wide range of national economic indicators (GDP, investments, unemployment rate, etc) are used in the Chicago REIM as key explanatory variables, the regional

economic growth projection depends on the performance of national economy, as it certainly does in reality. Further, different trajectories of potential regional economic growth, projected by the Chicago REIM under different scenarios, will result in the shifts in small area population and employment.

Figures 3 and 4 show how total regional population and employment (i.e., the aggregated values of all 303 units of analysis) will grow in future under the three scenarios and reveal the net impact of the changes in national economic conditions. Under the growth scenarios with varying growth rates in national macroeconomic variables, it appears that municipalities' employment growth trajectories can be influenced significantly, while population growth shifts are somewhat modest. More specifically, ±0.3% of variation in national economic growth rates causes ±0.1% in population and ±0.4% in employment growth rate in the study area, according to this projection using the integrated framework. As the national economy grows faster, first the Chicago region's economy can enjoy increasing demands for exporting goods and services. This stimulates an expansion of the regional production and further generates the ripple effects through inter-industrial linkages. A greater amount of production expansion certainly induces larger employment growth; and increasing job opportunities promotes population growth but not as much as the rate of employment increase.

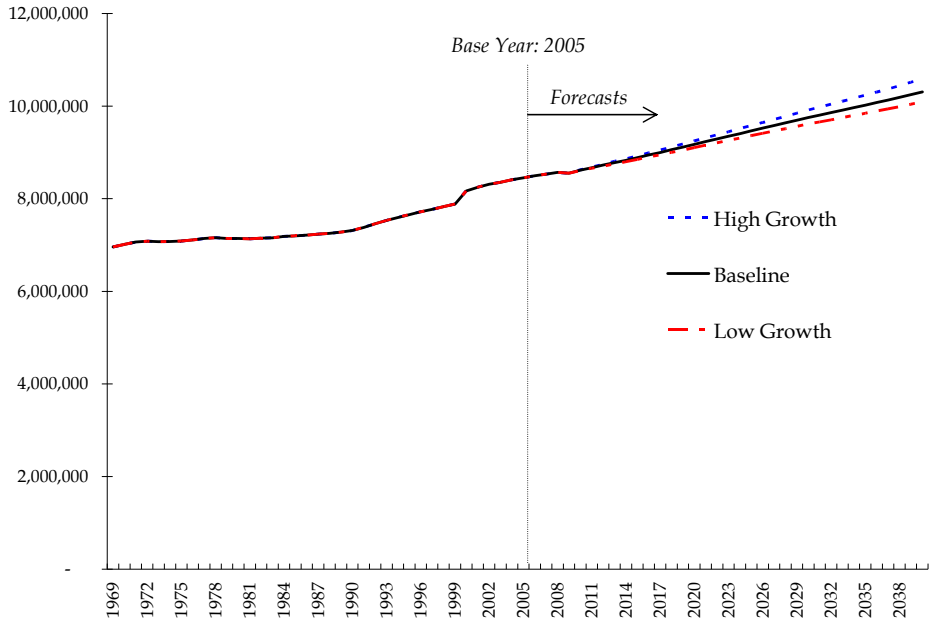


Figure 3. Aggregated population growth under three scenarios

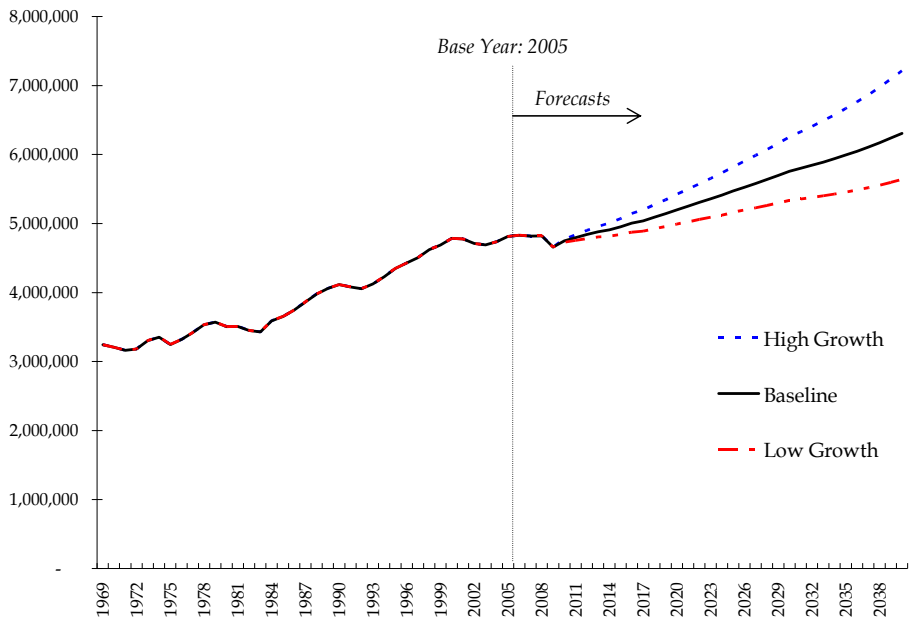


Figure 4. Aggregated employment growth under three scenarios

Figures 5 and 6 present how individual municipalities will grow differently under different national economic situations by demonstrating the gaps in compound annual population and employment change rates between high and low growth scenarios. Although most municipalities exhibit faster growth rates under higher national economic growth conditions, the effects are not the same across space. Particularly, a large degree of variation is found in the changes in municipality-level population growth rates, according to this simulation.

A close look at the simulation outcomes reveals that the places adjacent to the City of Chicago, that have experienced decline in recent years, are likely to get relatively larger benefits in population increase than suburban or exurban communities. This is at least partly attributable to a significant number of employment increases in the City of Chicago under the high growth scenario. In other words, the spillover effects of the Chicago's great performance in employment tend to benefit the municipalities whose main comparative advantage is the proximity to Chicago, a dominantly large job center in this metropolitan region.

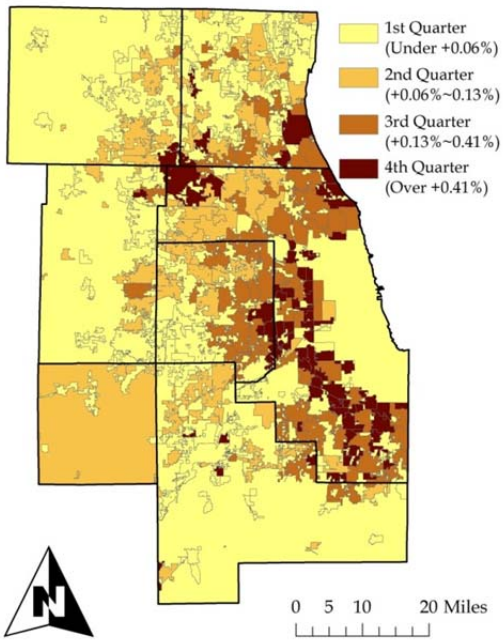


Figure 5. Differences in the forecasted annual population change rates between high and low growth scenarios

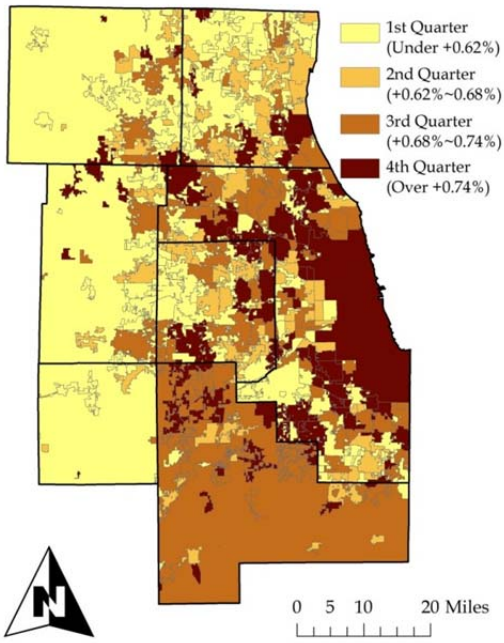


Figure 6. Differences in the forecasted annual employment change rates between high and low growth scenarios

In contrast to such places, suburban and/or exurban communities attract development based on different comparative advantages that they have abundant developable land within the jurisdictions and incorporable hinterlands, which are found significant in the estimation of the population change equation of the disequilibrium adjustment model. As the potential regional growth rate shifts up in respond to favorable national economic conditions, first their growth will be accelerated. However, as developable land and hinterland areas are depleted more rapidly (i.e., as the areas are built out faster), they will tend to lose the driving forces for growth earlier. As a result, in a longer term, the benefits that these communities can get are not as much as expected with a reform of development pattern, unlike the municipalities next to the central city.

This point is clearly illustrated in figures 7 and 8, showing the population forecasts under high and low growth scenarios for two different cities. Whereas the Village of Elmwood Park (figure 7), located right next to the City of Chicago, consistently obtains the benefits from the high growth scenario conditions, the Village of Monee (figure 8), a suburban town in Will County, may not be able to keep the benefits in a long term. In fact, according to the forecasts generated by the integrated framework, 2040 population in this village is greater under the low growth scenario than high growth scenario. The rapid economic growth merely shifts the utilization of the development opportunities ahead rather than promoting sustainable growth.

The advantages of using the disequilibrium adjustment model, combined with REIM, are well highlighted in this application. The growth trajectories of small areas seem to be effectively described and simulated with the consideration of various critical determinants, ranging from the potential regional growth forces to population – employment interactions, the interlinkages among the small areas, and other spatially explicit conditions (e.g., developable land stock).

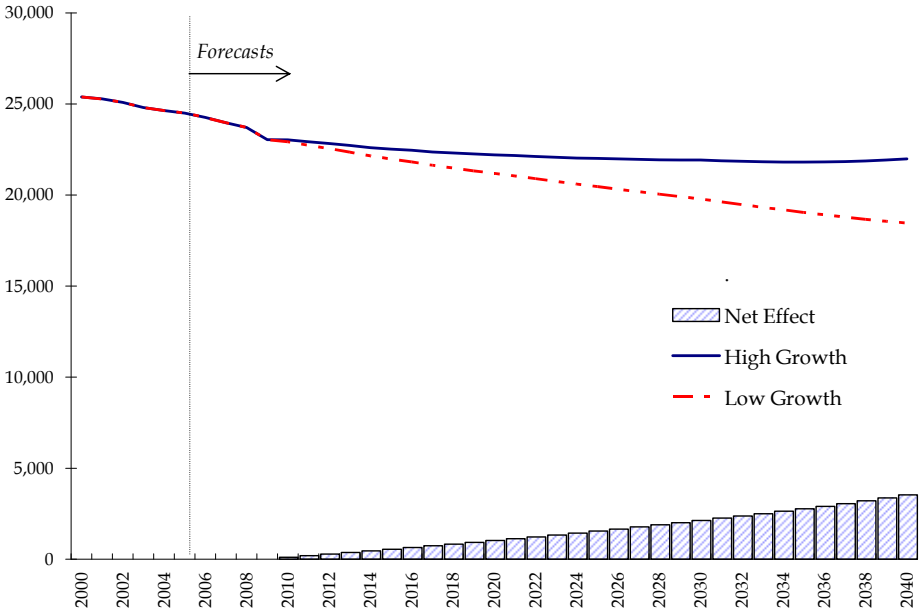


Figure 7. Population forecasts for the Village of Elmwood Park

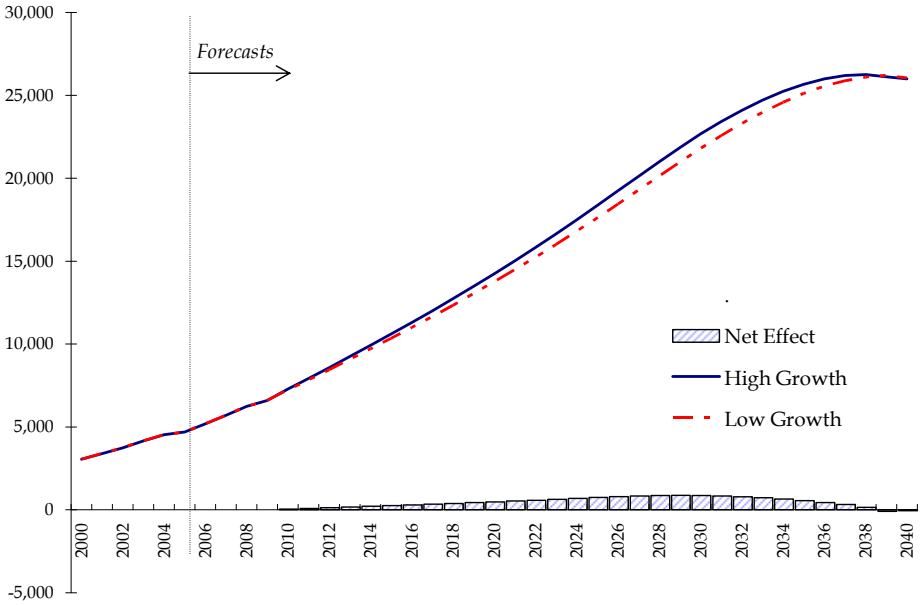


Figure 8. Population forecasts for the Village of Monee

6. Summary & Discussion

This study presents an idea of using the disequilibrium adjustment model for small area socio-economic forecasting and impact analysis, beyond its existing uses for empirical assessment. The adjustment model can be used as a part of an integrated multi-level framework where it is combined with REIM which describes the fundamental long-term growth drivers of a regional economy. As shown in the presented application, the integration of the multi-level variables in a single framework expands the capabilities of the adjustment model and provides a possibility of a more systematic examination small area growth dynamics.

Some challenges, however, do exist. Data availability for the small area is one obstacle for most empirical disaggregated level analysis, including the application of the presented methodology. Some important determinants of small area growth, particularly government policy variables are hardly considered, simply because such information over past years is not available. In the same vein, model calibration often has to be made with a short period of observations, although long-range data series are required for a more robust long-term forecasting.

Besides data availability problem, the linear fashion of the disequilibrium adjustment model adopted here may not be ideal for describing the intrinsic non-linearity of a dynamic metropolitan system. Another notable challenge is model stability, which is critical in forecasting. As all adjustment model equations (i.e., 303 population change and 303 employment equations in the case of the presented application) are interlinked with each other, it is much more difficult to generate reasonable future growth trajectories than the case of modeling individual variables separately. This is especially challenging, when the areas considered have a large degree of variation in terms of the size.

Finally, it needs to be noted that there is an issue associated with the use of traditional spatial weight matrix, which is fixed and assumed to represent the spatial interdependence correctly. Given that the pattern of spatial interaction may evolve over time, it would not be desirable to use the fixed weight matrix for a long forecast period. A significant decline in transportation cost has raised the connection between the areas with a fairly long distance; and this trend will persist in future. Attention needs to be paid to how we can address this issue by reconciling the conflicts between the weight matrix requirements in econometric

estimation and an increasing need for describing the evolution of spatial interdependence in long-term forecasting or simulation. Little is known about how we can better consider and handle this temporal variation of the spatial relation, although recently many studies have attempted to carefully choose a spatial weight matrix among many possible ways of constructing the matrix (e.g., contiguity-based, distance-based, flow-data-based, etc.) in empirical analysis (see e.g. Boarnet et al. 2005; Hoogstra et al. 2011). The use of spatio temporal weight matrices (see e.g. Sun et al. 2005; Maddison 2009) and few other exceptions (e.g., Cheng et al. 2011) recently emerged in the literature could be a meaningful step towards a more robust consideration of the dynamic spatial dependence.

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