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Interaction of Regional Population and Employment: Identifying Short-Run and Equilibrium Adjustment Effects

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Abstract:

We investigate the interaction of regional population and employment in a simultaneous model, allowing for interregional commuting. The proposed dynamic specification distinguishes between short-run and equilibrium adjustment effects and it encompasses the lagged-adjustment specification that is standard in the literature. We interpret the long-run relationship between levels of population and employment as a labour market equilibrium. The model is estimated on a panel of 1973 - 2000 annual data for 40 regions in The Netherlands, controlling for region and time-specific heterogeneity. Identification of the model is improved by decomposing population growth into net interregional migration and exogenous natural population developments. We find that employment growth responds quite strongly to deviations from regional labour market equilibria. Net migration is dominated by housing market developments and in the short run only slightly affected by increases in regional employment. The main implication is that equilibrium on regional labour markets is obtained through adjustment of employment instead of population. We test and reject the lagged-adjustment specification.

1. Introduction

There is nowadays a large literature on the spatial interaction of population and employment, both on urban and regional scale. It has been recognised that labour and consumer markets are among the essential mechanisms that lead local population and employment to adjust to one another. From a theoretical point of view, the interaction of population and employment would be simultaneous. However, it is fair to say that theoreticians have usually started from the idea that employment is exogenous to population. In particular in the urban economic literature, the monocentric model introduced by Alonso (1964) that presumes employment is exogenously located in the Central Business District, has become standard. Furthermore, most regional economic text books extensively discuss the role of the export base, regional multipliers and input-output linkages. A fundamental presumption underlying such theories is that there are no restrictions on labour supply, which implies that regional population adjusts to demand (cf. McCann, 2001)[1]. The idea that population is exogenous to employment has always been less attractive to economic theory. Exceptions include Borts and Stein (1964), who where among the first to argue that it is labour supply, and therefore regional population, that determines employment rather than demand (see also Muth, 1991).

To resolve the issue empirically, simultaneous equations models for population and employment have been estimated both at the level of counties or states (e.g. Greenwood and Hunt, 1984, Carlino and Mills, 1987) and at a more local level such as for urban economies (e.g. Muth, 1971, Steinnes and Fisher, 1974, Steinnes, 1977, 1982, Greenwood, 1980, and Boarnet, 1994a, b). In the latter case, the defined regions are small, so population growth in one region and employment growth in another are interrelated, because of commuting between these regions[2]. In spite of the popular view that regional labour supply adjusts to demand, most of these studies reject exogeneity of employment.

[1] Similarly, in some New Economic Geography models it is assumed that in the long run people migrate to regions where the real wage is highest, so that labour supply adjusts to demand. See for example the model put forward in chapters 4 and 5 of Fujita et al. (1999).

[2] The resulting spatial relationships were first modelled explicitly by Steinnes and Fisher (1974), and endogenized by Boarnet (1994a, 1994b). Many studies have estimated variants of the latter model for different periods, areas and spatial aggregation levels (see e.g. Bollinger and Ihlanfeldt, 1997, Henry et al. 1997, Henry et al. 1999 and Schmitt and Henry, 2000).

A common feature of virtually all studies on the interaction of regional population and employment is that they ignore the distinction between short-run and long-run effects, adopting *lagged adjustment dynamics* as introduced by Steinnes and Fisher (1974). Our present paper innovates on the dynamic analysis of the population-employment interaction. Encompassing a lagged adjustment specification, the simultaneous model we derive measures both the instantaneous interaction of population and employment growth and their response to deviations from a long-run relationship between levels of population and employment[3]. This distinction yields substantive insights into regional adjustment processes. Interpreting population as labour supply and jobs as labour demand, one may view the long-run relationship as a regional labour market equilibrium. Our analysis therefore sheds light on the extent to which population and employment adjust to equilibrate local labour markets. The identification of short-run and equilibrium adjustment effects is relevant to spatial policy as well, given the long-term horizon that spatial or urban planning usually requires[4].

The reliability of our estimates is largely enhanced by the inclusion of region and time-specific fixed effects[5]. The econometric model controls *fully* for unobserved regional heterogeneity that affects average regional population and employment growth. In other words, it controls for average growth for every region, as well as for national trends. This minimises specification biases due to omission of (unobserved) explanatory variables, which are a problem in many empirical studies. For example, Boarnet (1994a, p. 150) speculates that omitted regional land use policy variables obscure identification of the population-employment interaction in his study. To the extent that such policies

[3] Our analysis bears similarity to Treyz et al. (1993), who measure migration responses to stock equilibrium changes in, amongst other variables, relative employment opportunities. However, we extend the analysis to employment growth and its response to disequilibrium. Furthermore, we allow for interregional commuting, which makes our model applicable for investigation of population-employment interaction at an intrametropolitan scale.

[4] Through spatial policies like zoning, governments may involve in the location and size of residential and business estate areas.

[5] Although the Steinnes (1977) paper has been of seminal importance in the debate on causality and intrametropolitan population and employment location, remarkably little studies have adopted the time series approach introduced here. His call for the use of panel data techniques (p. 79) has remained largely unanswered in the urban economic literature, though exceptions include Cooke (1978) and Thurston and Yezer (1994). Note however that these papers model urban density gradients, which yields a perspective that differs from the multiregional approach taken here and in the literature following Carlino and Mills (1987) and Boarnet (1994a, b).

are time-invariant, a fixed-effects model is unaffected by the omission of this type of variables.

Another novelty of this paper is that we decompose population growth into *endogenous* net migration, which responds to developments in population and employment, and *exogenous* natural population growth[6]. The population growth equation in the simultaneous model can then be rewritten as a net migration equation, allowing us to estimate the interaction of population and employment more accurately. This explicitly links the literature following Carlino and Mills (1987) and Boarnet (1994a, b) to the migration literature, and particularly to simultaneous analyses of internal migration and employment growth, such as Greenwood and Hunt (1984).

The model we derive will be estimated on 40 regions in The Netherlands, using annual data between 1973 and 2000[7]. Instead of one large metropolis, the country contains a number of relatively small cities that are not strictly separated by rural areas. We would therefore describe its geographical structure as *overlapping urban areas*. The regions we analyse may be considered as overlapping labour market areas, because about thirty percent of the working labour force on average has a job outside the residential region. This explains the need to incorporate commuting in the model explicitly.

The remainder of the paper is structured in the following way. In the next section, we will derive a simultaneous model for regional population and employment growth that allows for commuting between regions. We will interpret this model in terms of regional labour market dynamics and extend the analysis by incorporating fixed effects. In section 3 we will discuss the range of explanatory variables to be included in a model for population-employment interaction in The Netherlands. Estimation issues and empirical results are discussed in section 4 and the final section concludes.

[6] It is common in the demographic literature to decompose population growth into net migration and natural population growth, the latter stemming purely from birth and death processes (e.g., Plane and Rogerson, 1994).

[7] The regional unit (the so-called COROP region, European NUTS III level) contains roughly 350,000 inhabitants and 150,000 jobs on average. These regions are substantially larger than US municipalities (e.g., Boarnet, 1994a, b), but smaller than US counties (e.g., Carlino and Mills, 1987).

2. Modelling regional labour market dynamics

Population and employment are often assumed to be interrelated. There are a number of explanations for the mutual dependency of population and employment within the same region, the most fundamental one being probably that jobs are occupied by people living within an acceptable commuting distance. By definition, employment changes can only be realised through population changes (migration or natural increase), a shift in net interregional commuting or adjustment of labour participation[8]. This underlines the importance of labour market processes in explaining regional population and employment interaction. Hence we interpret population as potential *labour supply* and employment as realised *labour demand*. The simultaneous model for population and employment may thus be considered a regional labour market model.

Another popular explanation for population-employment interaction is that consumer markets are determinants of the location choice of people and firms. For example, many households prefer to live close to shops, which in turn gives an incentive to firms (with their jobs) to locate close to households. However, since this can be assumed to hold for a relatively small part of total employment, we focus on labour market interaction.

2.1 Derivation of a simultaneous error correction model

We derive the regional labour market model from a general specification of population and employment interaction:

$$\begin{aligned} POP_{i,t} &= f\left(A_1(L)POP_{i,t}, A_2(L)\overline{EMP}_{i,t}, X_{i,t}, u_{i,t}\right), \\ EMP_{i,t} &= g\left(A_3(L)EMP_{i,t}, A_4(L)\overline{POP}_{i,t}, Y_{i,t}, v_{i,t}\right), \end{aligned} \tag{2.1}$$

where $POP_{i,t}$ and $EMP_{i,t}$ denote the levels of population aged between 15 and 65 and employment in region *i* during period *t*. The lag polynomials $A_k(L)$ account for a dynamic adjustment process. For example, a first-order lag polynomial includes only one time lag, so $A_k(L) = \alpha_0 + \alpha_1 L$, which applied to population $POP_{i,t}$ yields

$\alpha_0 POP_{i,t} + \alpha_1 POP_{i,t-1}$. Exogenous variables are represented by $X_{i,t}$, $Y_{i,t}$[9]. Furthermore, $u_{i,t}$, $v_{i,t}$ are independently distributed disturbances, and the functions *f* and *g* can take arbitrary forms.

When regional labour markets are open, as will be the case in our empirical analysis, commuting between regions has to be taken into account. People and firms in one region may supply and demand labour in other regions, which implies that regional labour supply depends on the spatial distribution of population, whereas regional labour demand depends on the spatial distribution of employment. We therefore weight population using a matrix W^1 and employment using a matrix W^2, obtaining *weighted* regional population $\overline{POP}_{i,t}$ and employment $\overline{EMP}_{i,t}$[10]. Note that in the absence of commuting between regions, $\overline{POP}_{i,t} = POP_{i,t}$ and $\overline{EMP}_{i,t} = EMP_{i,t}$.

Both linear (e.g. Carlino and Mills, 1987 and Boarnet, 1994a, b) and log linear (e.g. Luce, 1994) specifications have been employed in the literature. However, from a time series perspective it is preferable to specify a log linear model. Population and employment growth are multiplicative rather than additive processes, in the sense that changes are proportional to lagged levels[11]. This implies the need to model growth rates, which are obtained by first-differencing the logarithms of population and employment. Applying the convention that variables are written in capitals and their logarithms are written in lower-case letters, model (2.1) is then rewritten as follows:

$$pop_{i,t} = \alpha_1 pop_{i,t-1} + \alpha_2 \overline{emp}_{i,t} + \alpha_3 \overline{emp}_{i,t-1} + \mu X_{i,t} + u_{i,t},$$

$$emp_{i,t} = \beta_1 emp_{i,t-1} + \beta_2 \overline{pop}_{i,t} + \beta_3 \overline{pop}_{i,t-1} + \nu Y_{i,t} + v_{i,t}, \qquad (2.2)$$

[8] Participation is defined throughout this paper as the share of the potential labour force (the population aged between 15 and 65) that has a job, so the unemployed do not participate in our definition.

[9] Labour and consumer markets are by no means the only determinants of location choice. For example, housing and product markets may also be relevant. Inclusion of exogenous variables in the simultaneous system reflects this.

[10] These spatial weighting matrices reflect interregional commuting probabilities, which are estimated employing data on interregional commuting and distances between regions (see Appendix 1). Although the approach is similar, our weight matrices deviate slightly from the ones used by Boarnet (1994a, b).

where we require that $\alpha_1 \leq 1$ and $\beta_1 \leq 1$. For simplicity of exposition, only first-order lag polynomials are included in this equation[12].

We write system (2.2) as a simultaneous *error correction model* by substituting $pop_{i,t} = \Delta pop_{i,t} + pop_{i,t-1}$ and $emp_{i,t} = \Delta emp_{i,t} + emp_{i,t-1}$, and rearranging terms[13]:

$$\Delta pop_{i,t} = \alpha_2 \Delta \overline{emp}_{i,t} - (1-\alpha_1)\left(pop_{i,t-1} - \frac{\alpha_2 + \alpha_3}{1-\alpha_1} \overline{emp}_{i,t-1} \right) + \mu X_{i,t} + u_{i,t},$$

$$\Delta emp_{i,t} = \beta_2 \Delta \overline{pop}_{i,t} - (1-\beta_1)\left(emp_{i,t-1} - \frac{\beta_2 + \beta_3}{1-\beta_1} \overline{pop}_{i,t-1} \right) + \nu Y_{i,t} + v_{i,t}. \qquad (2.3)$$

The explanatory variables $X_{i,t}$, $Y_{i,t}$ can be rewritten in a similar way[14]. Because both population and employment time series generally portray strong autocorrelation, this procedure will reduce multicolinearity of the endogenous explanatory variables and their time lags (e.g., $\overline{emp}_{i,t}$ and $\overline{emp}_{i,t-1}$ in the population equation). A more substantive advantage of model (2.3) is its *interpretation*. Responses of changes in population and employment are decomposed into an instantaneous reaction (response to changes) and an adjustment towards long-run equilibrium (response to lagged levels).

Regional population and employment are considered to be in (steady-state) equilibrium at time *t* when $\Delta pop_{i,t+1} = \Delta \overline{emp}_{i,t+1} = 0$ and $\Delta emp_{i,t+1} = \Delta \overline{pop}_{i,t+1} = 0$. When we ignore the exogenous explanatory variables X_{it} and Y_{it}, this implies that the following conditions must hold:

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[11] This is obvious for population growth, because new members of the population are born from existing members.

[12] The number of time lags in this derivation can be extended to an arbitrary level in a straightforward way.

[13] The model takes the form of an error correction model (ECM), which has become a standard model in time series econometrics since the study by Davidson et al. (1978). This derivation can be found in Harvey (1990), or in other textbooks on econometric analysis of time series. It may be argued that regional population and employment are co-integrated time series (eg. Freeman, 2001). In the empirical part of this paper however, we control for national developments so that nonstationarity is not an issue. Co-integration is not a condition for modelling time series by means of an ECM.

$$pop_{i,t} - \left(\left(\alpha_2 + \alpha_3\right)/\left(1-\alpha_1\right)\right)\overline{emp}_{i,t} = 0\,,$$

$$emp_{i,t} - \left(\left(\beta_2 + \beta_3\right)/\left(1-\beta_1\right)\right)\overline{pop}_{i,t} = 0\,. \tag{2.4}$$

In these two conditions, the parameters $\left(\alpha_2 + \alpha_3\right)/\left(1-\alpha_1\right)$ and $\left(\beta_2 + \beta_3\right)/\left(1-\beta_1\right)$ may be interpreted as long-run elasticities[15]. They are equivalent in the absence of interregional commuting. Deviations from the equilibrium relationships (2.4) are corrected by changes of population and employment in model (2.3), provided that $\alpha_1, \beta_1 < 1$. When the level of population in a region is large relative to weighted employment, population growth in the first equation will be small ceteris paribus. In the second equation, when the level of employment in a region is large relative to weighted population, employment growth will be small ceteris paribus.

The *economic* intuition behind this *statistical* relationship is straightforward. When population in a region is large with respect to realised labour demand, *participation* here is low compared to its equilibrium value. Competition for jobs on the regional labour market can be expected to depress net incoming migration and thus population growth. When employment in a region is large with respect to potential labour supply, participation here is high with respect to its equilibrium. Competition for workers can be expected to depress employment growth. We thus interpret the system of equations (2.3) as a model that describes adjustment of regional labour supply and demand towards labour market equilibrium.

It makes sense to assume long-run elasticities of unity in the conditions (2.4), as otherwise equilibrium participation would depend on the levels of population and employment[16]. Moreover, this translates into a very plausible concept of equilibrium in a fixed effects model, as we will see in section 2.3. Imposing the long-run unit elasticity conditions $\alpha_1 + \alpha_2 + \alpha_3 = 1$ and $\beta_1 + \beta_2 + \beta_3 = 1$ on model (2.3) yields:

[14] Levels should be included if variables are expected to affect the long-run relationship between regional population and employment.
[15] In a linear model they can be interpreted as an equilibrium participation rate and its inverse.
[16] This would have the unlikely implication that the equilibrium ratio of employment to population were different in large and small regions, and therefore dependent on the shape of regions.

$$\Delta pop_{i,t} = \alpha_2 \Delta \overline{emp}_{i,t} - (1-\alpha_1)\left(pop_{i,t-1} - \overline{emp}_{i,t-1}\right) + \mu X_{i,t} + u_{i,t},$$

$$\Delta emp_{i,t} = \beta_2 \Delta \overline{pop}_{i,t} - (1-\beta_1)\left(emp_{i,t-1} - \overline{pop}_{i,t-1}\right) + \nu Y_{i,t} + v_{i,t}. \quad (2.5)$$

Population and employment *density* may be included in the set of explanatory variables. Note that in a fixed effects version of model (2.3) that does not impose a long-run elasticity of unity, the effects of these density variables would not be identified[17].

2.2 Encompassing a specification based on lagged adjustment dynamics

The derived models (2.3) and (2.5) can be compared to the dynamic specifications commonly used in the literature such as Steinnes and Fisher (1974), Carlino and Mills (1987) and Boarnet (1994a, b). These papers and subsequent studies have usually started by imposing an equilibrium relation and then assumed *lagged adjustment dynamics*. This signifies that population and employment adjust towards equilibrium, where the adjustment rate is based on the difference between the actual and equilibrium values of population and employment respectively, hence ignoring short-run effects[18].

Appendix 2 demonstrates that the lagged adjustment specification is nested in the models derived here. To be precise, in our notation, such a dynamic specification can be obtained by imposing the restrictions $\alpha_3 + \beta_1\alpha_2 = 0$ and $\beta_3 + \alpha_1\beta_2 = 0$ on model (2.3). A lagged adjustment specification of model (2.5) can be obtained by combining these restrictions with the long-run unit elasticity conditions. Imposing the resulting restrictions $(1-\alpha_1) - \alpha_2(1-\beta_1) = 0$ and $(1-\beta_1) - \beta_2(1-\alpha_1) = 0$ on this model yields:

$$\Delta pop_{i,t} = \frac{1-\alpha_1}{1-\beta_1}\left[\Delta \overline{emp}_{i,t} - (1-\beta_1)\left(pop_{i,t-1} - \overline{emp}_{i,t-1}\right)\right] + \mu X_{i,t} + u_{i,t},$$

$$\Delta emp_{i,t} = \frac{1-\beta_1}{1-\alpha_1}\left[\Delta \overline{pop}_{i,t} - (1-\alpha_1)\left(emp_{i,t-1} - \overline{pop}_{i,t-1}\right)\right] + \nu Y_{i,t} + v_{i,t}. \quad (2.6)$$

[17] Hence, one of the advantages of this assumption is that one can distinguish between population density and population effects, and similarly between employment density and employment effects within a time series context.

[18] Although this assumption may be justifiable when the time lag between observations is large, it seems less plausible a priori for yearly data.

2.3 Fixed effects and the equilibrium relationship

When the exogenous variables $X_{i,t}$ and $Y_{i,t}$ include region and time dummies, model (2.5) can be considered a *fixed effects* model[19]. Greenwood et al. (1991) interpret fixed effects in a migration equation as a measure for regional amenities, such as climate or proximity to the coast. In the employment growth equation, the region dummies may measure comparative advantages, such as regional resources or access to (international) markets. Similarly, the time dummies take up national trends in population and employment growth, such as decreasing fertility or business cycle effects respectively. The important point here is that all region and time specific heterogeneity that affects population and employment growth is controlled for, so that the risk of omitted variable biases is strongly reduced.

A consequence of including fixed effects in the model is that all other variables are identified up to region and time-specific constants. For example, since the area of a region is time-invariant, using population and employment levels in a log linear model is equivalent to entering population and employment *densities*[20]. Regional labour market equilibria are therefore also determined up to region and time-specific constants. Under the unit elasticity assumption, they take the following form:

$$\frac{POP_{i,t}}{EMP_{i,t}} = P_i Q_t \qquad \text{and} \qquad \frac{EMP_{i,t}}{POP_{i,t}} = R_i S_t . \qquad (2.7)$$

These conditions signify that a regional labour market is in equilibrium when *participation* equals the national rate (Q_t and S_t), up to a regional time-invariant deviation (P_i and R_i)[21].

2.4 Decomposition of population growth

It seems a plausible assumption that natural population increase, being the result of birth and death processes, does not respond to regional labour market developments. The

[19] Econometrically, the model is then specified as a two-way error components model (Baltagi, 2001).
[20] Some studies (e.g. Carlino and Mills, 1987) estimate the interaction of regional population and employment *densities*, instead of levels.
[21] Note that this equilibrium concept is equivalent to the relative probability of employment in a region, proposed by Treyz et al. (1993).

population-employment interaction can therefore be modelled more accurately by decomposing population growth into *endogenous* net migration and *exogenous* natural population increase[22]. Formally, the following identity holds:

$$\Delta POP_{i,t} = NIM_{i,t} + NFM_{i,t} + NPI_{i,t}, \tag{2.8}$$

where $NIM_{i,t}$ is net interregional or internal migration (incoming minus outgoing), $NFM_{i,t}$ is net foreign migration and $NPI_{i,t}$ denotes natural population increase[23]. The following approximation can be applied:

$$\Delta pop_{i,t} \approx \frac{\Delta POP_{i,t}}{POP_{i,t-t}} = \frac{NIM_{i,t}}{POP_{i,t-t}} + \frac{NFM_{i,t}}{POP_{i,t-t}} + \frac{NPI_{i,t}}{POP_{i,t-t}}. \tag{2.9}$$

We substitute equation (2.9) into the first equation of (2.5). Further, we include $NPI_{i,t}/POP_{i,t-1}$ and $NFM_{i,t}/POP_{i,t-1}$ in the explanatory variables $X_{i,t}$ and restrict their coefficients to one. Subtracting these natural population increase and foreign migration rates from the left and right-hand side of the population growth equation then yields a model for net internal migration:

$$NIM_{i,t} / POP_{i,t-1} = \alpha_2 \Delta \overline{emp}_{i,t} - (1-\alpha_1)\left(pop_{i,t-1} - \overline{emp}_{i,t-1}\right) + \mu' X'_{i,t} + u_{i,t}. \tag{2.10}$$

3. Net migration and employment growth in The Netherlands

The regional labour market model derived previously will be estimated on 1973 – 2000 time series for forty regions in the Netherlands[24]. Whereas estimation results will be

[22] In addition, natural population increase can be used as an instrument for population growth in the employment growth equation, thus improving identification of the model.

[23] Since we consider population aged between 15 and 65, migration and natural increase should refer to people in the same age group.

[24] All demographic information stems from municipal administrations, which are aggregated to the COROP level. Most data come from Statistics Netherlands (regional accounts), except information on the regional housing stock, which was provided by ABF Research. Employment is observed in man-years and not in persons, but this is unlikely to affect the results. In addition, we lack information on the number of self-employed (roughly 10% of the labour force). The results are unaffected by this omission to the extent that the spatial distribution of the share of self-employed does not change over time, because of the inclusion of fixed effects.

presented in the next section, we discuss here explanatory variables for net migration and employment growth that are relevant in the Dutch context.

3.1 Net migration

Housing markets are believed to be among the main determinants of migration in The Netherlands (cf. Bartels and Liaw, 1987, Nijkamp and Rietveld, 1981). We measure the response of migration to housing market developments through two variables. Growth of the housing stock $\Delta hou_{i,t}$ is included, where $HOU_{i,t}$ denotes the number of housing units. Analogous to the dynamic specification of the labour market model, we also include a deviation from equilibrium on regional housing markets. Assuming a long-run elasticity of unity between population and housing supply, this deviation is measured by the variable $\left(pop_{i,t-1} - hou_{i,t-1}\right)$. Bearing in mind that in a fixed effects model, all variables are identified up to region and time-specific constants, regional housing markets are considered to be in equilibrium when:

$$\frac{POP_{i,t}}{HOU_{i,t}} = T_i U_t \,. \tag{3.1}$$

This condition signifies that a regional housing market is in equilibrium when housing occupation equals the national rate U_t, up to a regional time-invariant deviation T_i.

Assuming that the elasticity of labour supply to demand is equal to one in the long run, we can identify the effect of population density $pop_{i,t-1}$ on net migration. A negative impact of this variable may be related to a preference for spacious dwellings or congestion externalities associated with living in a densely populated area.

The impact of regional labour markets on migration is incorporated by the variables employment growth $\Delta\overline{emp}_{i,t}$ and deviation from equilibrium $\left(pop_{i,t-1} - \overline{emp}_{i,t-1}\right)$. In addition we include $PRO_{i,t}$, the ratio of regional added value to employment, as a measure for labour productivity. Wages reflect productivity in a competitive labour market, so that this variable may measure the response of migration to regional wage differentials.

In section 2.4 the net migration model was obtained from a population growth equation by including $NPI_{i,t}/POP_{i,t-1}$ as a explanatory variable, and restricting its coefficient to one. We enter the same variable in the migration equation, which is statistically equivalent to relaxing the unit coefficient restriction. A negative sign can be expected because migrants compete with the new local population on housing and labour markets, and a part of these people will move to another region themselves[25].

Including these explanatory variables into the migration equation (2.10) yields the following specification:

$$\begin{aligned} NIM_{i,t}/POP_{i,t-1} = {} & A_i + B_t + \varphi_1 \Delta\overline{emp}_{i,t} + \varphi_2\left(pop_{i,t-1} - \overline{emp}_{i,t-1}\right) + \varphi_3 \Delta hou_{i,t} \\ & + \varphi_4\left(pop_{i,t-1} - hou_{i,t-1}\right) + \varphi_5 pop_{i,t-1} + \varphi_6 \overline{pro}_{i,t-1} + \varphi_7 NPI_{i,t}/POP_{i,t-1} + u_{i,t} \end{aligned} . \qquad (3.2)$$

This equation has been reparametrised for simplicity. Region and time dummies are denoted A_i and B_t. Productivity, relating to regional employment, is multiplied by the matrix W^1, and its lagged value is used in order to avoid endogeneity problems.

3.2 Regional employment growth

We include $CHI_{i,t}$, the ratio of the number of children aged under 15 to the number of persons aged between 25 and 45, the (young) parents, as an explanatory variable in the employment growth equation of model (2.5). A high ratio may affect *participation* negatively because children need care, reducing labour supply. Because this variable affects equilibrium participation, we use the level instead of growth of the ratio of children. The other supply side factors in this equation are growth of potential labour supply $\Delta\overline{pop}_{i,t}$ and deviation from equilibrium $\left(emp_{i,t-1} - \overline{pop}_{i,t-1}\right)$[26].

Demand side factors included in the employment growth equation are the share $SHA_{i,t}$, accessibility $ACC_{i,t}$ and regional productivity $PRO_{i,t}$. The share is defined as the regional

[25] Net foreign migration may be included in the model similarly. However, this variable may be determined simultaneously with net interregional migration, yielding biased coefficients. Omission does not seem to be problematic, because foreign migration has been numerically small compared to interregional migration during our period of observation.

[26] Employment growth depends on both labour demand and supply side factors, because employment equals *realised* labour demand.

employment growth that would be expected on the basis of national developments and the lagged industry composition of a region[27]. The intuition behind this variable is appealing. To the extent that regions produce for other regions or abroad (export), developments in (inter)national demand may affect regional employment. If demand shifts upwards for an industry that is heavily represented in some region, employment here should increase[28].

Although access to labour markets is controlled for by means of the labour supply variables, access to other input and output markets may be an important factor to employment growth as well. The following accessibility measure is common in the literature (cf. Rietveld and Bruinsma, 1998)[29]:

$$ACC_{i,t} = \sum_j \frac{EMP_{j,t}}{d_{ij}}. \qquad (3.3)$$

The effect of regional productivity is ambiguous. Interpreting it as a measure for regional wages, like in the migration equation, one would expect a negative impact on employment growth. Alternatively, a larger regional productivity may be the result of *agglomeration economies*, through pooled labour markets or knowledge spillovers for example (Fujita and Thisse, 2002). These economies of agglomeration may be expected to attract firms and employment.

We can identify employment density $emp_{i,t-1}$ as an additional measure of agglomeration economies, provided that the long-run elasticity of labour demand to supply equals one. The effect may also be negative due to land prices or diseconomies of agglomeration such as congestion.

Including these explanatory variables in the employment growth equation of model (2.5) yields the following specification:

[27] We operationalize this concept by introducing a *dynamic share* (Barff and Knight III, 1988) in the model.

[28] However, Borts and Stein (1964) have already pointed out a potential fallacy in this argument. The larger the share of employment of an industry in some region, the smaller is its growth potential here, unless labour supply is infinitely elastic. Therefore, in a supply dominated labour market this variable may proof of little value in explaining employment growth.

$$\Delta emp_{i,t} = C_i + D_t + \psi_1 \Delta \overline{pop}_{i,t} + \psi_2 \left(emp_{i,t-1} - \overline{pop}_{i,t-1} \right) + \psi_3 \overline{chi}_{i,t-1} + \psi_4 sha_{i,t} + \psi_5 acc_{i,t-1} + \psi_6 pro_{i,t-1} + \psi_7 emp_{i,t-1} + v_{i,t} \quad (3.4)$$

Again, the equation has been reparametrised for simplicity. Region and time dummies are denoted C_i and D_t. Affecting labour supply, the variable $CHI_{i,t}$ is multiplied by the same matrix W^2 as regional population, since participation in one region may affect employment in another. We use lagged values of $CHI_{i,t}$, $ACC_{i,t}$ and $PRO_{i,t}$ in order to avoid endogeneity problems.

4. Estimation of the regional labour market model

Given the elementary importance of identification in analysing simultaneous equations models, we start this section with a discussion of that issue. Results for the net migration and employment growth equations are presented in subsections 4.2 and 4.3 respectively, both for the model with and without region-specific fixed effects. We then test the lagged adjustment restriction, followed by a sensitivity analysis in 4.5.

4.1 Identification

When formulating the simultaneous model (3.2) and (3.4) we have implicitly made a number of *exclusion restrictions*, some variables in our model enter only one equation. Such exclusion restrictions are necessary to identify the model, since a variable that enters one equation can be used as an instrument for the endogenous variable in the other equation. The exclusion restrictions for equation (3.2) are that $\overline{CHI}_{i,t}$, $SHA_{i,t}$ and $ACC_{i,t}$ affect net internal migration only through employment growth (labour demand) but not directly[30]. The restrictions for equation (3.4) are that $\Delta hou_{i,t}$, $\left(pop_{i,t-1} - hou_{i,t-1} \right)$

[29] We enter the level and not growth of accessibility, because this variable would be endogenous in the employment growth equation.

[30] The variable $\overline{POP}_{i,t}$ and $\overline{EMP}_{i,t}$ are computed using weight matrices derived from a commuting model (see section 2 and Appendix 1). In order to obtain consistent estimates, we apply the same weight matrices to the external instruments in the first-stage regressions. This assumes that the exclusion restrictions we make should also hold for weighted instruments (cf. Boarnet 1994a, b).

and $NPI_{i,t}/POP_{i,t-1}$ affect employment growth only through population growth (labour supply)[31].

Housing markets may respond to changes in regional population and labour market developments, so the estimator for $\Delta hou_{i,t}$ may suffer from a simultaneity bias. We deal with this by means of two additional instrumental variables, which are excluded from both the net migration and employment growth equations. Given that a demand for housing is exercised when young people leave their parents, it may be expected that housing demand (and therefore supply) is large in a region where the population is relatively young. We measure this effect by $YOU_{i,t}$, the proportion of people aged between 15 and 35 to people aged between 35 and 65, and by the growth rate of this variable[32].

The exclusion restrictions we make in order to identify the simultaneous model may appear to be dubious. For example, one might expect demographic variables to affect net migration, and employment growth might respond differently to migration and natural population increase. We acknowledge potential problems in some exclusion restrictions made, but because of *overidentifying restrictions* we are able to validate them by means of statistical tests.

The estimation strategy we adopt is to estimate the model using two stages least squares (TSLS)[33]. We test for exogeneity by means of a Hausman test, and assume exogeneity when it is not rejected. More efficient estimates are then obtained in a second round of estimation, the results of which are presented in the remainder of this paper.

[31] Lagged levels of population, employment and housing stock are predetermined, so that OLS estimates would normally be unbiased. However, in the case of a dynamic fixed-effects panel data model, this procedure formally yields biased coefficients (Wooldridge, 2002). Because our time series is sufficiently long (about thirty years), we can ignore this bias and treat lagged levels as exogenous variables.

[32] In order to avoid endogeneity, we computed growth of this variable on the basis of natural population increase.

[33] We weight by the time average of regional population and employment. The covariance matrix estimator is robust to regional heteroskedasticity and autocorrelation of arbitrary form within the regional time series, see Wooldridge (2002).

4.2 Net interregional migration

We have estimated the migration equation (3.2), and Hausman tests were performed. Exogeneity was rejected for $\Delta hou_{i,t}$ but not for $\Delta\overline{emp}_{i,t}$. An overidentifying restrictions test did not reject our exclusion restrictions[34]. Consequently, the first specification in Table 4.1 shows estimation results for model (3.2) where only the former variable is instrumented. The table also presents a second specification that excludes regional fixed effects.

Net migration $NIM_{i,t}/POP_{i,t-1}$	I	II
growth housing stock $\Delta hou_{i,t}$	0.764 *** *I* *0.190*	1.199 *** *I* *0.055*
housing market equilibrium $\left(pop_{i,t-1} - hou_{i,t-1}\right)$	-0.040 * *0.021*	-0.049 *** *0.013*
growth realised labour demand $\Delta\overline{emp}_{i,t}$	0.029 * *0.015*	0.053 ** *0.025*
labour market equilibrium $\left(pop_{i,t-1} - \overline{emp}_{i,t-1}\right)$	-0.000 *0.013*	0.000 *0.001*
productivity $\overline{pro}_{i,t-1}$	0.011 * *0.007*	-0.000 *0.001*
population density $pop_{i,t-1}$	-0.032 ** *0.015*	-0.001 *0.001*
natural population increase $NPI_{i,t}/POP_{i,t-1}$	-0.061 *0.069*	0.001 *0.157*
regional dummies A_i (40)	yes	no
time dummies B_t (27)	yes	yes
R^2	0.900	0.795
R^2 of model with dummies included only	0.589	0.021

Table 4.1: net migration (equation 3.2)[35]

In the first specification, it appears that housing markets dominate net interregional migration. For $\Delta hou_{i,t}$ a unit elasticity is not rejected, which would imply that a one percent increase of the number of houses in a region leads to a population increase through net internal migration of one percent. Further, it appears that a deviation from regional housing market equilibrium (see condition (3.1)) is decreased through

[34] In order to perform Hausman tests for exogeneity, residuals of the first stage regression where included in an OLS estimation of model (3.2). The *t* statistics for the housing growth residual and the employment growth residual were *-1.94* and *-0.12* respectively, so that exogeneity was rejected at the *10%* level for the first variable, but it was not for the second. The instruments used were $chi_{i,t-1}$, $acc_{i,t-1}$ and lagged level and growth of $YOU_{i,t}$. With two overidentifying restrictions, the χ^2 statistic was *1.94*, so that the exclusion restrictions were not rejected at the *10%* level.

[35] Robust standard errors are in italic style, *, ** and *** indicate significance at 10%, 5% and 1% level respectively and a coefficient marked with *I* indicates that the associated variable is instrumented.

migration by about four percent yearly. These findings reflect the housing market tightness in The Netherlands over our period of observation, which is probably related to restrictive spatial policy[36].

The impact of regional labour markets on internal migration seems to be substantially smaller. An increase in employment is accommodated by migration for about three percent, so participation and commuting account for the rest of regional employment changes[37]. There is no evidence of migration responding to disequilibrium on regional labour markets (condition (2.7)), although higher regional productivity per worker does appear to have a small positive effect. This is surprising as nominal wage differentials in The Netherlands are small[38].

The significantly negative effect of population density on net migration may reflect congestion externalities or an increased preference for space. This latter development is arguably related to the phenomenon of suburbanisation or *urban sprawl*, the emergence of large residential areas within acceptable commuting distance of city or employment centres (Anas et al., 1998). Although the effect of natural population increase has the expected negative sign, it does not appear statistically significant.

In order to illustrate the role of the regional fixed effects, Table 4.1 presents a second specification that omits these dummies. Again we have performed Hausman tests on a first estimation, and only $\Delta hou_{i,t}$ turned out to be endogenous. The effect of this variable is now even larger, and the response to disequilibrium on housing markets appears to be stronger as well. However, productivity and population density are insignificant. This highlights the importance of properly accounting for regional heterogeneity, although the conclusion remains that housing markets rather than labour markets dominate internal migration.

[36] Through zoning and other tools, both the national and local governments have been heavily involved in regional supply of houses (Rouwendal and Rietveld, 1988, Rietveld and Wagtendonk, 2003).
[37] This finding is consistent with Broersma and Van Dijk (2002), who find that employment shocks are mainly accommodated through participation in the short run.
[38] Regulation of labour markets in the Netherlands is strong. About 80 percent of the employees' wages are bargained at the national level, so that firms cannot easily adjust their wages to regional labour market conditions. Accordingly, Van Dijk et al. (1998) did not find a significant nominal wage return to migration using microdata. Given our lack of direct information on regional wages, we must therefore be careful with the interpretation of this result.

The model accounts for ninety percent of variation in net domestic migration. Leaving out the regional dummies reduces this percentage with about ten percent, whereas a model consisting of regional and time dummies explains only sixty percent of the variance. The large explanatory power of the net migration model may be interpreted as additional evidence of the dominance of regional housing markets.

4.3 Employment growth

Similar to the migration equation, we have estimated the employment growth equation (3.4) and performed a Hausman test. Exogeneity was not rejected for $\Delta\overline{pop}_{i,t}$, and an overidentifying restrictions test did not reject our exclusion restrictions[39]. Therefore, the first specification in Table 4.2 shows estimation results for model (3.4) using OLS.

Employment growth $\Delta emp_{i,t}$	I	II
growth potential labour supply $\Delta\overline{pop}_{i,t}$	0.306 *0.191*	0.383 *I* *0.302*
labour market equilibrium $\left(emp_{i,t-1} - \overline{pop}_{i,t-1}\right)$	-0.091 *** *0.024*	0.001 *0.002*
ratio of children $\overline{chi}_{i,t-1}$	-0.095 ** *0.035*	-0.029 * *0.017*
share $sha_{i,t}$	0.178 *0.313*	0.532 *** *0.194*
accessibility $acc_{i,t-1}$	0.156 *0.130*	0.022 ** *0.008*
productivity $pro_{i,t-1}$	0.027 * *0.015*	0.007 *0.007*
employment density $emp_{i,t-1}$	-0.045 *** *0.013*	-0.011 *** *0.003*
regional dummies C_i (40)	yes	no
time dummies D_t (27)	yes	yes
R^2	0.526	0.445
R^2 of model with dummies included only	0.461	0.364

Table 4.2: employment growth (equation 3.4)

It appears that variables relating to labour supply have a strong impact on employment growth. The coefficient for growth of potential labour supply is positive, but not statistically significant. However, we do find a significant and large effect of deviations

[39] The *t* statistics for the population growth residual was *0.83*, so that exogeneity was not rejected at the *10%* level. The instruments used were $NPI_{i,t}/POP_{i,t-1}$, $you_{i,t-1}$ and $(pop_{i,t-1} - hou_{i,t-1})$. With two overidentifying restrictions, the χ^2 statistic was *0.43*, so that the exclusion restrictions were not rejected at the *10%* level.

from regional labour market equilibrium. It turns out that through employment growth, these deviations are reduced yearly by almost ten percent. Further, the equilibrium participation is low in regions where the ratio of children to people aged between 25 and 45 is relatively large.

In contrast, variables relating to labour demand hardly affect employment growth. Jointly, $SHA_{i,t}$, $ACC_{i,t}$ and $PRO_{i,t}$ are not statistically significant at the *5%* level. Only regional productivity appears to have a marginal impact. Its positive sign may indicate existence of agglomeration economies. However, the stronger and significantly negative effect of employment density gives and opposite signal, a larger spatial concentration of employment appears to be a push rather than a pull factor.

The second specification in Table 4.2 omits regional fixed effects. Now, exogeneity of $\Delta\overline{pop}_{i,t}$ is rejected, so we estimate its impact by means of instrumental variables. The overidentifying restrictions test again does not reject our exclusion restrictions. The results differ strongly from the first specification. Labour supply effects appear to be largely absent, notably there is no equilibrium correction on labour markets. In contrast, the share dominates regional employment growth. This large difference must be explained by unobserved regional heterogeneity. Apparently there have been time invariant regional factors positively correlated with the share, which have lead to employment growth[40].

The share of the employment growth variance explained by this model is about half, not much more than a model consisting of only dummies would. Apparently, regional employment growth is more difficult to explain than net domestic migration.

4.4 Testing for lagged adjustment dynamics

The dynamics of our model under the assumption of lagged adjustment are described in the equations (2.6). Applying the associated restrictions to the equations (3.2) and (3.4) yields $\varphi_2 - \varphi_1\psi_2 = 0$ and $\psi_2 - \psi_1\varphi_2 = 0$. These joint cross-equation parameter restrictions are tested with a standard Wald test, and rejected at the one percent level of

[40] Indeed the industry mix has been particularly favourable in the densely populated Randstad area, where fixed effects were positive as well. The unobserved heterogeneity may be related for example to international accessibility or the average level of education of the labour force.

significance ($\chi^2(2) = 14.8$, $p = 0.001$)[41]. We conclude that the assumption of lagged adjustment dynamics is not valid for our data.

4.5 Sensitivity for spatial and temporal heterogeneity

In order to verify robustness of our econometric results, we have performed two sensitivity analyses. First we have investigated whether there was spatial heterogeneity by distinguishing core and periphery of The Netherlands, and second we have checked for temporal heterogeneity by distinguishing ups and downs in the business cycle[42]. We specified dummy variables for periphery and downswing periods. The model was then extended with interaction effects of either dummy and all explanatory variables (except the region and time dummies). A significant interaction effect indicates that the effect of the associated explanatory variable differs over space or time.

Indeed, some significant interaction effects were found[43]. There is some evidence that labour markets are more demand driven in peripheral regions and that migration is more receptive to regional labour market conditions during downswings of the business cycle. However, the conclusions that migration is mainly driven by housing markets and equilibrium correction on regional labour markets occurs through employment growth appear robust to spatial and temporal heterogeneity.

5. Conclusions

Our empirical investigation into the interaction of regional population and employment provides evidence that in The Netherlands, regional labour markets are equilibrated through employment growth. Labour demand appears to affect interregional migration only slightly in the short run. This contrasts the popular view that regional labour supply adjusts to demand, which is implicit in many theories on regional economic growth. Moreover, we find little evidence that typical demand side factors such as accessibility and the industry mix contribute to regional employment growth. This justifies the claim that regional labour markets are supply dominated.

[41] We apply a Wald test using the robustly estimated covariance matrix.
[42] The core was defined as all regions in the Randstad and an intermediate zone. A period was considered to be a downswing in the business cycle when employment growth was lower than average employment growth over our period of observation.
[43] The results of this analysis are available upon request.

Housing markets are the most important determinant of net interregional migration by far, the short-run elasticity of growth of the housing stock approaching unity. Furthermore, migration appears to equilibrate regional housing markets. We relate these results to the housing market tightness over our period of observation, especially in the more densely populated west of the country, which may be due to restrictive policy.

The explicit distinction of short-run effects and equilibrium adjustment has furthered our understanding of regional labour and housing market processes. The derived simultaneous error correction model that allowed for this distinction encompasses lagged adjustment dynamics, such as applied by Steinnes and Fisher (1974), Carlino and Mills (1987), Boarnet (1994a, b) and many subsequent papers. Not only does such a specification ignore the meaningful difference between short and long-run effects, but also it imposes a restriction on the dynamic process that may not hold. For our data, the lagged adjustment dynamics assumption was statistically rejected.

Exploiting the time series structure of our data, we controlled for unobserved regional and temporal heterogeneity by means of fixed effects. This strongly reduces the risk of omitted variables biases. The exclusion restrictions made in order to identify the simultaneous model were validated by means of overidentifying restrictions tests. Therefore, the coefficient estimates appear to be reliable.

Given the geographical scale and structure of overlapping urban areas, our analysis may partly be interpreted in the context of *urban sprawl*. With increased welfare and improved infrastructure population has shifted from the cities to more spacious dwellings in surrounding residential areas[44]. We demonstrate a negative impact of population density on migration. The even larger impact of employment density on employment growth reflects a general finding that the density gradient is larger for employment than for population, but has been falling faster (Anas et al., 1998, and Mieszkowski and Mills, 1993). This evidence provides further support for the notion that employment has followed population rather than reversely.

[44] For example, population in the largest cities of Amsterdam, Rotterdam and The Hague has decreased.

Appendix 1: Accounting for interregional commuting

In the regional labour market model derived in section 2 we use *weighted* regional population $\overline{POP}_{i,t}$ and employment $\overline{EMP}_{i,t}$, in order to account for interregional commuting. To this aim we use *spatial weight matrices* W^1 and W^2, which are applied to regional employment and population in the first and second equation of system (2.1) respectively.

We compute $\overline{EMP}_{i,t} = \sum_j w_{ij}^1 EMP_{j,t}$, where w_{ij}^1 may be interpreted as the probability that someone working in region *j* lives in region *i*. Multiplying this probability by employment in region *j* we get the expected number of people working in *j* that live in region *i*, and summing over employment regions yields the expected working labour force in region *i*. This is interpreted as the weighted realised labour demand in this region.

Similarly, we compute $\overline{POP}_{i,t} = \sum_j w_{ij}^2 POP_{j,t}$, where w_{ij}^2 may be interpreted as the probability that someone living in region *j* would work in region *i*. Multiplying this probability by population in region *j* we get the *expected* number of people living in region *j* that potentially work in region *i* (the probability is also applied to people that do not participate). The sum over population regions yields weighted potential labour supply.

The probabilities w_{ij}^1 and w_{ij}^2 can be estimated given information on the relationship between interregional commuting flows and distance between regions, employing a doubly-constrained spatial interaction model **(**Fotheringham and O'Kelly, 1989**)**. The model takes the following form:

$$COM_{ij,t} = WLF_{i,t} EMP_{j,t} A_{i,t} B_{j,t} F\left(d_{ij}\right). \qquad \text{(A.1)}$$

In this model, the number of commuters $COM_{ij,t}$ increases proportionally to the working labour force $WLF_{i,t}$ in the region of residence and employment in the region of

work, but decreases in distance through the distance decay function $F(d_{ij})$, where $F'(d_{ij}) < 0$. The balancing factors $A_{i,t}$ and $B_{j,t}$ account for two sets of identities, which are that outgoing flows sum to regional working labour force, and incoming flows sum to regional employment. We assume the following functional form for the distance decay function $F(d_{ij})$:

$$F(d_{ij}) = \exp(\alpha_i D_i^1 + \beta_i D_i^2 + \gamma_i d_{ij}). \qquad \text{(A.2)}$$

So, it is assumed that the number of commuters between two regions decreases exponentially with distance. The dummy variable D_i^1 corrects for commuting within regions and the dummy variable D_i^2 measures border effects. We allow all variables to have a region specific effect, in order to deal with regional heterogeneity, so the coefficients are region specific[45].

The parameters α_i, β_i and γ_i have been estimated on 1992 – 2000 commuting data from the Dutch Labour Force Survey. Distance between two regions is measured by the average number of car kilometres travelled by commuters, because the largest share of interregional commuters travels by car. See Vermeulen (2003) for details.

In order to avoid endogeneity in model (2.3), it is not appropriate to use explanatory variables in the spatial weight matrices. The probabilities w_{ij}^1 and w_{ij}^2 are therefore assumed to be a function of the distance between regions only. Using the estimated distance decay function, they take the following form:

$$w_{ij}^1 = \frac{F(d_{ij})}{\sum_i F(d_{ij})}, \qquad w_{ij}^2 = \frac{F(d_{ji})}{\sum_i F(d_{ji})}. \qquad \text{(A.3)}$$

[45] In order to check for robustness to specification of the weight matrices, we have imposed in an alternative specification that seventy percent of the working labour force works in the residential region. Estimation results in section 4 were not significantly affected.

Note that $\sum_i w_{ij}^1 = 1$ and $\sum_i w_{ij}^2 = 1$, so that these weights can indeed be interpreted as probabilities[46].

Appendix 2: A test for lagged adjustment dynamics

We will show here that the model (2.3) encompasses lagged adjustment dynamics. The derivation of the lagged adjustment model presented here is based on Boarnet (1994a, b). The distinction between his linear and our log-linear specification is ignored for ease of exposition. Point of departure in his model is an equilibrium relation between regional population, employment and regional characteristics:

$$POP^*_{i,t} = \gamma \overline{EMP^*}_{i,t} + \mu' X_{i,t} + u_{i,t},$$
$$EMP^*_{i,t} = \delta \overline{POP^*}_{i,t} + \nu' Y_{i,t} + v_{i,t}, \qquad \text{(A.4)}$$

where * denotes equilibrium values. Regional population and employment adjust towards these equilibrium values in the following way:

$$\Delta POP_{i,t} = \lambda_{POP}\left(POP^*_{i,t} - POP_{i,t-1}\right),$$
$$\Delta EMP_{i,t} = \lambda_{EMP}\left(EMP^*_{i,t} - EMP_{i,t-1}\right). \qquad \text{(A.5)}$$

It is further assumed that the same adjustment dynamics apply to the spatially weighted variables $\overline{POP}_{i,t}$ and $\overline{EMP}_{i,t}$, so that the following estimable model is obtained:

$$\Delta POP_{i,t} = \lambda_{POP}\left(\gamma \overline{EMP}_{i,t-1} + \frac{\gamma}{\lambda_{EMP}} \Delta \overline{EMP}_{i,t} + \mu' X_{i,t} - POP_{i,t-1}\right) + u'_{i,t}, \qquad \text{(A.6)}$$

[46] However, the matrices W^1 and W^2 differ from the spatial weight matrices that are common in spatial econometric applications **(**Anselin, 1988**)** in two perspectives. Firstly, numbers on the diagonal are smaller than one, because diagonal flows have been included in the commuting model. Secondly, computing the required probabilities amounts to column normalisation, instead of the usual procedure of row normalisation.

$$\Delta EMP_{i,t} = \lambda_{EMP}\left(\delta \overline{POP}_{i,t-1} + \frac{\delta}{\lambda_{POP}} \Delta \overline{POP}_{i,t} + \nu' Y_{i,t} - EMP_{i,t-1} \right) + \nu'_{i,t} .$$

Now we rewrite the model as a simultaneous error correction model:

$$\Delta POP_{i,t} = \gamma \frac{\lambda_{POP}}{\lambda_{EMP}} \Delta \overline{EMP}_{i,t} - \lambda_{POP}\left(POP_{i,t-1} - \gamma \overline{EMP}_{i,t-1} \right) + \lambda_{POP} \mu' X_{i,t} + u'_{i,t} ,$$

$$\Delta EMP_{i,t} = \delta \frac{\lambda_{EMP}}{\lambda_{POP}} \Delta \overline{POP}_{i,t} - \lambda_{EMP}\left(EMP_{i,t-1} - \delta \overline{POP}_{i,t-1} \right) + \lambda_{EMP} \nu' Y_{i,t} + \nu'_{i,t} . \quad \text{(A.7)}$$

Note that this simultaneous model is nested in the simultaneous error correction model (2.3) derived in section 2. The following reparametrisation has to be applied to model (2.3) to obtain (A.7):

$$\alpha_1 = 1 - \lambda_{POP} \qquad \beta_1 = 1 - \lambda_{EMP}$$

$$\alpha_2 = \gamma \lambda_{POP} / \lambda_{EMP} \qquad \beta_2 = \delta \lambda_{EMP} / \lambda_{POP}$$

$$\alpha_3 = \gamma (\lambda_{EMP} - 1) \lambda_{POP} / \lambda_{EMP} \qquad \beta_3 = \delta (\lambda_{POP} - 1) \lambda_{EMP} / \lambda_{POP}$$

$$\mu = \lambda_{POP} \mu' \qquad \nu = \lambda_{EMP} \nu'$$

From this reparametrisation we can derive two restrictions: $\alpha_3 + \beta_1 \alpha_2 = 0$ and $\beta_3 + \alpha_1 \beta_2 = 0$. These restrictions can be tested as two joint cross-equation parameter restrictions by means of a standard Wald test.

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