SIMFIRMS
Simulating the spatial demography of firms
With an application in the Netherlands

Leo van Wissen

Faculty of Spatial Sciences
University of Groningen
PO Box 11650
NL-9700 AV Groningen
Email: l.j.g.van.wissen@frw.rug.nl

Draft version, May 2000

1. Introduction

In recent years the interest in the demography of the firm has increased substantially. There are two main reasons for this development. First, there is a renewed interest in entrepreneurship and new firms as agents of innovation and economic change, not only in small business economics, but also in other fields, such as organizational sociology, economic geography and demography. Second, increasingly data on the demography of individual firms become available for analysis. Compared to human demography the availability and quality of these data are limited, but progress is being made. The present paper fits in this trend. The focus of this paper is on a prototype spatial simulation model of the demography of firms. Here, demographic events are defined as firm formation, firm closure, firm relocation and firm growth/decline. This model, called SIMFIRMS, was developed in the Netherlands, in the nineties at the Netherlands Interdisciplinary Demographic Institute NIDI. The study was commissioned by the Netherlandsd Spatial Planning Office in order to explore the potentials of this approach as a planning instrument. In the Netherlands, the spatial planning process is based on a set of spatial and regional simulation models, covering various sectors of society such as population, the housing market, labour supply, transportation, or land use. However, similar planning instruments for the regional economic sector are underdeveloped. For historical reasons spatial planning in the Netherlands has always been strongly focused on the housing market and transportation, whereas the economic sector was relatively neglected. This is caused in part by the relative autonomous position of economic actors: the government can only play a facilitating role for economic development, and planners tend to concentrate on processes over which they have more control. Another reason for this underdeveloped position of the economic sector in spatial planning is the dominant position of macro-economic models, such as those used by the Netherlands Bureau for Economic Policy Analysis (CPB), which is the basis for economic policy in the Netherlands. The spatial or regional dimension is not considered important in these types of models.

Existing models for regional economic analyis are regional input-output models and shift-and-share models. Although these models are certainly useful in their own right, they are essentially macro level and static models. A model based on the demography of the firm as a regional economic modelling device has the potential advantage of being micro or behaviourally oriented: it focuses on events and processes at the level of the individual firm, and at the same time the consequences are aggregated and evaluated at the level of the population. For spatial planning a behavioural focus on the economic sector is of great advantage, because it can only play a facilitating role in economic development. Therefore, a model is needed that links these facilitating conditions to economic behaviour of entrepreneurs and firms. Through its focus on processes the demography of the firm is also *dynamic*: by its very nature demography is the scientific study of *changes* in the size and composition of a population. Input-output models and shift-and-share models are essentially equilibrium models that reflect the sectoral and regional economic structure, but not the dynamic change in the structure.

Thus, due to its micro and dynamic orientation the demography of the firm is potentially a promising tool for spatial planning. Nevertheless, its practical usefulness still hase to be tested. In the SIMFIRMS project a first step in this direction was taken. The main goal was:

to develop and implement a regional demographic model of the firm, that simulates the birth, death, migration and growth/decline processes of firms, and through which the developments in the size and composition of the population of firms at the regional level can be projected, as well as the number of employed persons

For spatial planning, the regional distribution of employment is equally important as that of firms. By including the size dimension in the demography of firms, an estimate of the employment consequences of firm demography can be made. However, in the present paper we will deal only with the firm demographic aspects of the model, especially firm formation and firm closure. We concentrate thereby on the structure of the model, as well as on some results. In another paper (Van Wissen, 2000), more information can be found on parameter estimation. In the next section, a number of problems of simulating the demography of the firm are discussed. Section three presents the structure of the model, and section four focuses the key concept of *carrying capacity*. In section five a number of model results are presented. The paper ends with a discussion and evaluation of the results.

2. Issues in modelling the demography of firms

Since modelling the demography of the firm is a new field, there are many new problems that need to be solved. Of course, there are the traditional problems with data, and these need to be solved urgently. Fortunately, longitudinal information at the individual firm level is becoming more and more available, altough there is no comparison with population registers of persons. One of the complicating factors is the definition problem: what is the basic unit of analysis or modelling? There is a legal, economic and a locational (physical) answer to this question, and these answers are not necessarily consistent with each other. For instance, a legally defined enterprise may contain one or more economically defined firms. A firm in the economic meaning is organised around one production process. A firm in turn may be composed of one or more plants or business establishments. This 'fuzziness' of definition has also consequences for the demographic events. What exactly is a firm formation? Is change of ownership a continuation of an existing firm or the closure and subsequent startup of a new firm? Many of these problems are yet to be solved, both conceptually and empirically. Here we merely note that in a spatial modelling framework the business establishment (BE) is a relatively straightforward choice as the basic unit for modelling, and this is indeed used in SIMFIRMS.

There are at least three other issues in demographic modelling of firms that should be mentioned here, and that arise in the translation of traditional demographic concepts to the field of firms or BE's. The first is the concept of firm formation, which is the economic equivalent of birth. Other than in human populations the population at risk of birth (starting a new firm) is not easily defined in the population of firms. Therefore, the definition and calculation of a birth rate is problematic. Some researchers define it as the number of firm formations per 1000 existing firms, others define it relative to the working population. These alternative views (implicitly) reflect different views of the process of firm formation: either as a decision in the individual working career to become an entrepreneur, or as an organizational decision to start a new activity or branch. In SIMFIRMS both processes are taken into account, which means that there are two birth processes. In the first birth process the working population is the population at risk, and a birth rate is defined that is different across age categories, sex, and levels of education of the working population. In the second birth process the exisiting population of firms is the population at risk, and the birth rate varies over the economic sectors and size classes. Unfortunately we still do not know much about these birth processes. In SIMFIRMS the symplifying assumption is made that birth rates vary across economic activities but not across size categories. Moreover, new foundings belong to the same economic activity as the parent firm.

A second issue in applying demographic methods to the population of firms is the limited role of age as a determining variable for vital events. A fertility-age curve does not exist in the demography of the firm, and the relation between age and relocation of firms is much weaker than in human demography. Only in firm survival a clear age pattern may be observed, at least in the first 10 to 15 years of existence (Ekamper, 1996). But even this relationship may be questioned. If size of the firm is taken into account the relationship becomes much weaker or vanishes (Carroll and Hannan, 2000). The observation about the limited rol of demographic variables may also be restated by saying that non-demographic variables play a dominant role in determining demographic events of firms. The literature on these alternative determinants is varied. Economists stress the role of the market (Geroski, 1991 DB; Geroski and Schwalbach, 1991 DB; Mason and McNally, 1997 DB), the skills of the entrepreneur (Bates, 1990; Davidsson, 1991 DB; Roper, 1998), technology and innovation (Doms and Dunne, 1995 DB), and the role of the business cycle or the economic environment in general (Caves, 1998 DB; Kirchhoff, 1994 DB; Almus and Nerlinger, 1999 DB; Audretsch and Mahmood, 1995 DB; Mata, 1996 DB). Economic geographers often take a more empirical point of departure and study the role of the regional environment in firm dynamics (McDermott and Taylor, 1982 DB; Hayter and Watts, 1983 DB; Hamilton and Linge, 1997 DB). Another line of research is formed by organizational sociologists. They focus on the organizational structure of the firm (Shane, 1996) or on the role of new cohorts of firms as agents of economic change (Carroll and Hannan, 2000), thereby stressing the importance of such concepts as carrying capacity (Hannan and Freeman, 1989 DB), structural inertia (Hannan and Freeman, 1984 DB), legitimation and density dependence (Hannan, 1989 DB, Hannan and Carroll, 1992 DB; Hannan et al., 1991 DB), and resource partitioning (Carroll, 1985) Although there are links between these approaches (Boone and Van Witteloostuijn, 1995 DB), they remain largely different. Faced with this variety of approaches, the question remains which factors to include in a simulation model of firm dynamics. Starting point for the development of SIMFIRMS was the notion that firms operate in an economic environment of the market, where individual events and decisions are taken within a macro environment of interindustry linkages and consumer demand. Moreover, firms operate in a *spatial* environment. The resulting simulation model is built around the two key concepts of *carrying capacity* and *spatial demand field*. These will be explained in section four. First, the overall structure of the model is presented in section three.

A third issue in modelling the demography of the firm is the definition of the state space and the primary events. Demographic processes are not distributed homogeneously over the population, but vary systematically with age, economic activity and size of the firm. Therefore, these variables are used to define the state space of the projection model (the set of all possible distinct configurations of all primary characteristics of the firm). In a regional model the regional dimension is added to the state space. Size is also important to deal with the *paradox of firm demography*: the category of firms that matters most in terms of employment and production matters least in number. For instance, the 5 per cent largest firms in the Netherlands employ about 35 per cent of all workers. It is no coincidence that an important application of the demography of the firm is the analysis of labour demand.

Therefore, size is a primary variable in the demography of the firm. As a consequence, changes in size are primary events in a firm-demographic model. There is no equivalent of this event in human demography. An event is a move from one state to another, and this also includes the vital events firm formation and closure, changes in economic activity and migration.

3. The structure of SIMFIRMS

The structure of SIMFIRMS resembles to a substantial degree a demographic multiregional cohort component projection model, in which the population is classified by age and region. Each year the population ages one year and a new cohort is born and added to the population, whereas older cohorts gradually die out and are subtracted from the population. The regional population also changes due to selective in- and outmigration processes. Thus, the model includes the vital events firm formation and firm closure, as well as internal in- and outmigration. International migration is not taken into account, since in quantitative terms this component is not important. But there are also differences with a standard cohort component projection model. The inclusion of size in the state space necessitates the use of micro simulation as the appropriate tool for projections. SIMFIRMS is a microsimulation model, with one important exception: the firm formation component is modelled partly as a macro simulation module, in which firm formation rates are applied to two different populations, which correspond to the two distinct birth processes discussed above: (1) workers by age, sex and education, and (2) firms by economic activity. Following this birth event, micro simulation is applied to each new-born unit in order to establish the initial size of the firm and its location. Another consequence of including size in the definition of the state space is that changes in the size of the firm should be modelled as well in a growth/decline function.

The structure of the program is presented in figure 1. At the start of each projection period, which runs from time t to t+1, a list of firms is read. This list contains a sample of size N=50,000 of all business establishments in the Netherlands, corresponding to a sample of approximately 9 per cent. Aggregation of this list gives the number of units for each economic sector s and region i at time t, and this information is needed in order to calculate the level of the carrying capacity for each sector s and location i. The carrying capacity is an important variable that drives the probability of demographic events, to be explained below. The demographic events are driven by individual characteristics of the business establishment (BE), such as age and size, by the carrying capacity, and (optionally) by macro-economic indicators in the form of constraints on the growth of the total number of firms, in the period from t to t+1. Finally a number of relevant regional-specific indicators, such as the amount of floor space that may be allocated to industrial or commercial usage, are important as well.

The constraints on the growth of the number of firms can be imposed optionally and are derived from a sector-specific macro-economic production function, that predicts the net change in the number of BE's in the Netherlands.

Technically, each BE unit in the list is read sequentially, and for each event a probability function is applied. Each function, with only a few exceptions to be discussed below, predicts the outcome of a stochastic process: the occurrence or not of an event: firm closure, migration, or change in size. These functions have the general form:

$$\text{Prob } (X=x) \propto f\,(\text{age, economic activity, size, region, Market, } \varepsilon) \qquad (1)$$

where f (.) is an appropriate function. The first four arguments of the function are the primary variables of the system and their inclusion implies that all rates are heterogeneous between states and homogeneous within states. The variable Market is a key variable in the model. We will explain how it is defined below. The stochastic component ε is included in the micro simulation in a monte carlo process. The survival model as well as the growth/decline model are specific forms of this equation (1). In particular, the survival model for an individual firm of economic sector e in region r has the form:

$$\text{Surv}(t,t+1) = \exp(A_i + C_s + ß_1\,\text{age} + ß_2\,\text{size} + ?\,\text{Market}^{SURV}(i,s,t)) \,/\, [1 + \exp(A_i + C_s + ß_1\,\text{age} + ß_2\,\text{size} + ?\,\text{Market}^{SURV}(i,s,t))] \qquad (2)$$

where A_i and C_s are region- and sector-specific dummies, the ß's and ?coefficients to be estimated and Market^{SURV} a suitable function of the Market variable. In the macro simulation part of the firm formation module ε is zero.

There are two firm formation equations; as discussed above there is one equation for births out of the working population and one for births out of the population of firms. The first birth equation has the form:

$$B^W(i,s,t) = \mu^w\,(i,s|\text{age,sex,educ},t)\; W(\text{age,sex,educ},t)\; \text{Market}^{BIRTH}(i,s,t) \qquad (3)$$

where $B^{w}(i,s,t)$ is the number of births out of the working population by economic activity s, region i in time period t; $\mu^{w}(i,s|age,sex,educ,t)$ is the birth rate for firms of activity s in region i, out of the working population segmented by age, sex and education at time t. W(s,sex,educ,t) is the average size of the working population segmented by age, sex and ducation in time period t, and $Market^{BIRTH}(i,s,t)$ is a variable to be explained in detail in the next section.

The second birth equation has the form:

$$B^{F}(i,s,t) = \mu^{F}(s|r,i,g,t)\ F(r,i,g,t)\ Market^{BIRTH}(i,s,t) \qquad (4)$$

where B^{F} is the number of firm formations out of the population of firms in category (i,s) at time t, $\mu^{F}(s|r,i,g,t)$ is the birth rate out of the population of firms of economic activity r, region i, size g in time period t, and F is the average size of the population of type (r,i,g) in time period t. In SIMFIRMS $\mu^{F}(s|r,i,g,t)$ is simplified to $\mu^{F}(i,s,t)$: a birth into another activity is not possible, and the parent population is not broken down by size g.

In the case of migration, the first process determines whether the firm moves or not. A second, conditional function determines the new location of the firm, using a spatial interaction model of the form:

$$Prob(j|i,s,t) \propto f\ (Dist(j,i), Market^{MIG}(j,s,t), Z(j,t)) \qquad (5)$$

where Prob(j|i,s,t) is the conditional probability of choosing new region j given that it has chosen to leave region i; Dist(j,i) is a measure of distance between both regions, $Market^{MIG}(j,s,t)$ is an indicator to be explained below, and Z(j,t) is a set of regional-specific exogenous variables.

Details of the specification and estimation of the parameters of these function are presented elsewhere (Van Wissen, 2000; Van Wissen and Ekamper, 2000). In the next section the Market variable is discussed in more detail.

After the processing of all events for one unit, the characteristics of the BE are updated: the unit may have died as a result of the Monte Carlo outcome of the closure function, or it may have changed in size or changed its location. The updated record is written to the list. After all BE's have been processed sequentially in this manner, the newborn BE's are added to the list.

The number of newborn firms is known for each (i,s) submarket, and again using Monte Carlo techniques, the characteristics of the new unit are determined stochastically: in particular its size. This concludes the simulation loop for year t, and the model proceeds to year t+1. The output of the model is the longitudinal list of units, which may be accessed by a tabulation program, to process all types of output cross-classifications of all variables.

Figure 1 Structure of SIMFIRMS

4. The Market variable and carrying capacity

In the Market variable economic, geographical and sociological notions are combined in one indicator. The central notion was proposed by organizational ecologists (Hannan and Freeman, 1989) as a logistic growth function:

$$\dot{X} = g(K-X)X \qquad \textbf{(6)}$$

The growth of the population is driven by the difference between the carrying capacity K and the actual size of the population X. In the earlier publications of the organizational ecologists carrying capacity was not specified explicity, but the growth function was transformed into a second order polynomial (Hannan and Freeman, 1989). The maximum of this function could be interpreted as the carrying capacity. This approach has a number of major drawbacks however. The maximum is extremely sensitive to small changes in the parameters, and the derivation of the size of the carrying capacity is merely a curve fitting exercise. The concept itself remains a black box. In the approach developed in SIMFIRMS the carrying capacity is modelled explicitly. Here, carrying capacity is defined as *the maximum demand for goods that can be exerted in the local market*. This demand is exerted by three sectors in the economy, viz. (1) consumers, (2) other firms through intermediate demands, and (3) the export sector. Consumers and other firms are located in space and they buy goods and services from firms also located in space. *Where* they exactly buy these goods is unknown, but a probability function may be defined over space that gives for each consumer or firm in location i the probability that the good is bought from a firm located in j. This probability field is called the *spatial demand field* for that good, and is defined in two dimensions. Some goods and services have a probability field with very small radius, such as grocery products. The demand field of some other goods and services may be completely flat: there is no distance decay. This is for instance the case in E-commerce markets. If we add up all these spatial demand fields from both consumers and firms, we arrive at an aggregate demand field over space for each type of good or service. We interpret this aggregate demand field as the carrying capacity for that good at that location. It results from the spatial distribution of consumers and other firms in the near and more distant environment, to which goods may be supplied. Note that this aggregate demand field results from the domestic demand sectors. The additional demand exerted by exports is added to this aggregate demand field and need not be uniform across space. Comparing carrying capacity K(i,s) with actual supply X(i,s) for good s at location i determines the propensity of firms of activity s to expand or contract at i:

$$\frac{\partial X(i,s)}{\partial V(i,s)} > 0 \qquad \textbf{(7)}$$

Here, V(i,s) = K(i,s) – X(i,s). Equation (7) defines S sectoral submarkets in I spatial units. These submarkets are not mutually independent, but interact in space and between sectors. First the *sectoral interactions* may be defined by using the simplest of all multi-sectoral equilibrium models: the *input-output* model. This model includes producers, consumers, exports, imports and other sectors of the economy in a set of interrelated linear equations. Disregarding the spatial dimension for the moment, total demand for goods of sector s may be decomposed into intermediate demand, exerted by other producers who need the product s as input into their production process, and consumer demand. For the moment we disregard the other final demand category export. The demand equation for each sector s is given by

$$D(s) = \sum_{r=1}^{S} a_{sr} X(r) + c_s B \qquad \textbf{(8)}$$

where a_{sr} are the technical coefficients that describe the amount of input of good s for production of one unit of output of r; X(r) is the produced amount of good r, c_s is the per capita consumption of good s and B is the size of the population. Equation (8) is an elementary input-output equation without investments and exports, that specifies the interrelations among producers and between producers and consumers in the national economy. Note that here final consumption is explicitly related to the size of the population B using the consumption coefficients c_e. The parameters of these demand equations of the input-output model may be derived from the national input-output table and the national accounts. So, equation (8) gives the level of market demand at the national level, which is the equilibrium demand level based on total production of all economic sectors s, X(r), and final consumption c_s B.

The spatial demand field captures the spatial interaction dimension of the model. A spatial demand field defined at location i is a probability density function that gives, for every location i (i=1,..,I) in the neighbourhood of j, the probability that the good *s*, that is required at location j as either an intermediate input by a producer or as final input by a consumer, is produced at location i. This probability p(i|j,s) is not uniform over all production locations i, but decreases with distance between i and j. In other words, the form of the demand field is in general not flat but a dome with its top in the centre located at the demand origin j and decreasing with increasing distance from the centre. In addition, since the good is produced somewhere, it holds that $\sum_i p(i|j,s)=1$, for all j. A function that is often used for modelling probability functions is the logit function. Used as a spatial interaction function with only argument distance it has the following form:

$$p(i|j,s) = \frac{\exp(-ß_s T_{ij})}{\sum_m \exp(-ß_s T_{mj})} \tag{9}$$

where T_{ij} is the distance between locations i and j, and $ß_s$ is a distance deterrence parameter which is specific to the good *s* being demanded. If instead of the linear distance the log of the distance is used, the exponent in both nominator and denominator is replaced by $T_{ij}^{-ß}$ .A high value of ß indicates a strong distance decay effect and a steep slope of the spatial demand field, implying that with increasing distance it soon becomes highly unlikely that the required good s at location j is produced in i. A small value of ß indicates a small distance decay effect and thus a relatively flat spatial demand field. With very small values of ß it is still likely that even at larger distances between i and j goods demanded by producers and consumers at j are produced in i. A value of 0 implies a perfectly flat spatial demand field and the absence of any distance effect. A good s demanded in j may be purchased anywhere with equal probability. It should be clear that ß is specific for every economic good s, since the form of the demand field varies with the character of the good. The spatial demand field of grocery products is very small (high ß), whereas the demand for specialised services is often exerted at the national or even international market (ß is very small or zero). Note that this system, just like the input-output model, is demand-driven. Firms require inputs, and look around for suppliers to meet their demand. Where, in which locations they look around for producers is specified by the demand field; how much is demanded in j is determined by the number and sectoral structure of firms and consumers in j. The total level of production of good s in i required by consumers and firms located in j is given by D(i,j,s) = D(j,s) p(i|j,s). Thus, D(i,j,s) is the flow of goods s produced at location i and demanded by consumers and firms in j.

Summing up demand over all locations j we arrive at the total demand for goods s that is directed to producers in zone i:

$$D(i,s) = \sum_{j=1}^{I} D(j,s)p(i|j,s) \tag{10}$$

The variable D(i,s) is the crucial element for our purposes. It is a measure of the total required production level for good s in location i, given the spatial distribution of producers and consumers around i and the shape of the demand fields. It is, in other words, the carrying capacity of goods s at location i: D(i,s) = K(i,s). By comparing K(i,s) with the actual level of production X(i,s) the likely direction of local economic development of sector s located in i may be derived. The direction and size of growth can be modelled in terms of a logistic growth path as follows:

$$dX(i,s) \,\%\, ?\, ?_s (K(i,s) \& X(i,s)) X(i,s) \qquad \textbf{(11)}$$

This equation, which is essentially similar to equation (2), states that growth in the unit time interval of sector s at location i, dX(i,s), is proportional to the intrinsic growth rate $?_s$ of sector s, multiplied by the overall speed of adjustment of the process ?, and the difference between carrying capacity K(i,s) and production X(i,s).

Summarising so far, the advantages of this definition of spatial carrying capacity for economic demography are the following:

- The spatial input-output representation is consistent with the national input-output table.
- If the national input-output table represents an equilibrium situation, then the spatial input-output model gives for each location i the local disequilibrium in demand and supply for each sector. Since the system is consistent with the national input-output table, excess demand in some locations will be mediated by excess supply in other locations
- Intersectoral linkages as well as spatial interaction linkages between sectors are included in the model
- The model presents a link between spatial economic disequilibrium on the one hand and macro-economic indicators of the national economy on the other
- The information concerning K(i,s) and X(i,s) is of interest in itself, since it describes the spatial distribution of demand and supply, as well as local market disequilibrium for each economic sector
- In addition K and X are instrumental in driving the local spatial economic development for each sector, as hypothesized in equation (11).

Equation (11) is a deterministic difference equation defined at the meso level of spatial-sectoral subsectors of the economy. However, the equation may also be given a microinterpretation. The growth rate of sector s at location i may be viewed as an underlying latent variable that determines the growth potential of individual firms of sector s in location i. Individual firms are the agents of economic growth through new firm formation, firm closures, relocations and firm growth.

Equation (11) is a specific example of a system of logistic growth equations for interacting populations (Wilson and Kirby, 1981, p. 54-5). The system may be formulated in matrix terms as a dynamic difference equation. In matrix terms the system has the following form:

$$\mathbf{dx} = \mathrm{Diag}(\mathbf{x})\,\mathbf{T}\,[\mathbf{k}-\mathbf{x}] \qquad \textbf{(12)}$$

Where **dx** is a (R×1) (where R=S×I) stacked growth vector of subvectors $\mathbf{dx}^{1},..,\mathbf{dx}^{I}$, denoting the growth in the unit time interval from t to t+1, of each of the s sectors in region i, Diag(**x**) a (R×R) diagonal matrix with elements **x,** and **T** a (R×R) diagonal matrix with diagonal elements equal to $?_{is}$, the sector-specific intrinsic growth rate (note that $?_{is} = ?_{s}$, since intrinsic speed of change is not related to location). The elements of the (R×1) vector of the carrying capacity **k** are calculated as:

$$\mathbf{k} = \mathbf{Gx}+\mathbf{Cb}+\mathbf{e} \qquad \textbf{(13)}$$

where **G** is a R×R matrix with elements $?_{rr'} = ?_{(i,s),(i',s')} = (a_{ss'}\, p(i'|i,s))$, the product of both intersectoral and spatial interactions between all subsectors (i,s). The form of the spatial interaction function is given in (9). These elements may be interpreted as spatial discounted technical coefficients of the input-output table. **C** is a R × R diagonal matrix of per capita consumption coefficients with elements $c_r = c_{i,s}$. Note that $c_{is} = c_s$, since consumption is not dependent on spatial location. **b** is the population vector with elements $b_r = b_{is}$. (note that, as above, $b_{is} = b_i$). **Cb** is the final consumption component of the carrying capacity, whereas **Gx** is the intermediate demand component. The R×1 vector **e** is the vector of (exogenously given) exports.

Coupled logistic equation systems of the form (12) have been studied extensively, both from a geographical point of view (Wilson and Kirby, 1981), in organizational ecology (Tuma and Hannan, 1984), and within demography (Keyfitz, 1977). Although each equation is linear, the resulting behaviour of the system is intrinsically nonlinear and not always stable. A complete treatment of all properties of this system will not be given here. General accounts are provided in the above references. In SIMFIRMS the vector **dx** is a key (although not the only) driving force behind demographic processes of firms, and is present in the demographic functions presented in section 3 as the Market variable. The exact specification depends on the function. The general relationship is a follows:

dX(i,s) > 0 ? ? Birth(i,s) / ? Market(i,s) > 0, ? Death(i,s) / ? Market(i,s) < 0,
? Inmig(i,s) / ? Market(i,s) > 0, ? Outmig(i,s) / ? Market(i,s) < 0,
? Growth(i,s) / ? Market(i,s) > 0 **(14)**

and:

dX(i,s) < 0 ? ? Birth(i,s) / ? Market(i,s) < 0, ? Death(i,s) / ? Market(i,s) > 0,
? Inmig(i,s) / ? Market(i,s) < 0, ? Outmig(i,s) / ? Market(i,s) > 0,
? Growth(i,s) / ? Market(i,s) < 0 **(15)**

5. Implementation in SIMFIRMS

The framework of the carrying capacity variable was implemented in SIMFIRMS. The necessary input in order to calculate eqs. (12) –(13) is:

- The spatial distribution of production over space and economic sectors: X(i,s); X may be measured in terms of gross output, employment, or another suitable indicator. In SIMFIRMS it is measured in terms of employment.
- The spatial distribution of the population **b**
- The matrix of technical coefficients **A** of the input-output model as well as the consumption coefficients **C**
- The vector of exports **e**
- The sectoral-specific spatial deterrence parameters $ß_s$. .These were estimated from observed data on sectoral-regional growth and the spatial configuration of production (i.e. by substituting eq. (13) in (12), and using observed values of the vectors **dx** and **x** the $ß_s$ were estimated using non-linear least squares optimization**;** see Van Wissen and Ekamper (2000)**)** Using the matrix **A** and the $ß_s$ the matrix **G** can then be calculated**.**
- The sectoral-specific growth rates in the matrix **T** had to be estimated for each demographic process separately, since the speed of each demographic process is different. We therefore transformed equation (12) into the form: Market(i,s) = (K(i,s) – X(i,s)) × X(i,s), and this variable was used as a regressor in a series of statistical models at the individual firm level using longitudinal data to estimate the sectoral growth coefficient $?_s$ for this particular demographic function.jointly with the age, size and other coefficients. The general forms of these functions were described in section 3.

6. Some results

The coefficients of SIMFIRMS were estimated from longitudinal data on firms in the Netherlands in for the years 1986, 1990 and 1991. These longitudinal data come from LISA, a register of firm plants, used, originally for social security legislation, and more recently for many economic and spatial planning purposes (Kemper et al., 1996). For the estimations, a 2 per cent sample was taken (N ˜10,000). For the simulations, a base year micro population was sampled (N=50.000) referring to the 1st of May of the year 1991. In this section we present a number of simulation results at the national and regional level for the period 1991-1998 and compare it, whenever possible, with observed data.

National results

Here we focus on total birth and death events in the Netherlands. Figure 2 presents the simulated and observed birth rate in the Netherlands in the period 1991-1998. Figure 3 presents similar results on deaths. The simulated results are compared to two different 'observed' figures, pertaining to the two most important registers: the firm register by Statistics Netherlands (SN) and the business unit register by the Chambers of Commerce (CoC). The overall level for both births and deaths is too high: about a factor 2 for births, and a factor 2 to 3 for deaths, depending on the source of observation. The death rate jumps from an initial level close to the CoC value in 1991 to a very high level in 1992 and thereafter. The reason for this large difference in birth rates is the different basis for the estimation of the birth and death functions: they are based on 1986-1991 data from the so-called LISA business unit register, which reported far more births than either SN or CoC in this period. The death intensity in LISA is close to that in the CoC register. However, since the net growth rate (births minus deaths) is far too high compared to reality, the model 'adjusts' the death rate through the effect of the carrying capacity: the growth in the number of firms in the first simulation year 1991 is very high, as a result of which the level of the carrying capacity is exceeded in many spatial submarkets ((i,s) combinations), which in turn leads to increasing death rates in these submarkets. The result in terms of the net increase in the number of firms is shown in figure 4. Although there is no close fit between the simulated net increase by SIMFIRMS and the observed net change by SN, the level of magnitude is about the same, and the U-shaped curve as observed by SN is also visible in the simulated pattern by the program, although the exact timing is not the same. So, the carrying capacity effect leads to a negative feedback between birth and death processes.

Figures 2, 3 and 4 about here

Regional results

At the regional level we can only compare the simulated net change in the number of firms with observed change by SN. Figure 5 shows for each of the 43 regions at the so-called Corop level in the Netherlands the results of two computer simulations: one unconstrained simulation, and one simulation with constraints on the net change in the number of firms (as explained in section 3). The constraints are sector-specific and derived from a macro-economic production function using observed exogenous information (van Wissen and Ekamper, 2000). Observed data pertain to the period 1994-1997 (indexed values, 1994=100). Results for the unconstrained simulation are generally somewhat better, although model fit for the *net change* in the number of firms is rather low (R^2 of indexed change around 0.10 for the unconstrained case, and 0.06 for the constrained case).

7. Conclusions

Clearly the model does not reproduce observed change very well, both at the national and the regional level. A number of factors account for this discrepancy. First, the different data registers do no correspond very well with each other. The model parameters are based on the LISA register of business establishments, and both the stock and the flow characteristics of this register are different from either CoC or SN registers. These differences are the result of both measurement error, differences in definitions, etc.. Second, there are a number of drawbacks in the specification of the functions driving the birth and death processes, especially the Market variable, which is based on the carrying capacity concept. In the carrying capacity variable many feedback relations are incorporated: spatial as well as sectoral. The model behaviour suggests that these interactions may be too strong. The proper empirical estimation of the relevant parameters of the carrying capacity variable requires a lot of further attention. Thirdly, at the regional level the demographic behaviour of a small number of large firms dominate the outcomes of the smaller regions. The likelihood of closure or new formation of a large firm is very small, but through the growth/decline function, modelling change in size of the unit, may have a large impact at the regional level. This function works well within the size range of 1 to 25 –since this is the dominant size category of firms- but for larger firms changes is size are less well predicted by this function; at the same time simulated growth or decline is much larger in magnitude for larger firms than for smaller, and this also applies to simulation errors.

Combining these data and specification problems one might wonder if the effort of simulating the demography of firms is worth the trouble at all, but this conclusion would be too pessimistic. On the one hand, it is clear there is only a weak correspondence between observed and model outcomes, both at the national and the regional level. The operational stage of the model SIMFIRMS is therefore still many steps away. On the other hand, the model serves as a powerful heuristic device in thinking and structuring demographic modelling of firms. In doing so, we have chosen to include the regional dimension as well, and to base the simulations on real world data, instead of simulations on synthetic data. These decisions have multiplied the number of problems to be encountered, and in future work simpler submodels should be used in order to solve specific problems. However, in our view, demography should always be based on empirical observations, and applied to real world problems, and empirical estimation and implementation of the model are essential stages of the process. The experience gained with designing and implementing SIMFIRMS proved to be very useful as a pedagogic device to that end. It has revealed many research questions that need to be addressed, both at the national level and the regional level. Answering these questions need not necessarily leed to SIMFIRMS 2 with better predictions, but will undoubtedly lead to better insight into the demographic processes shaping the population of firms.

References

Almus, M. and E.A. Nerlinger (1999) Growth of new-technology based firms: which factors matter? In: *Small Business Economics*, vol. 11, no. 2, pp. 141-152

Audretsch, D.B. and N. Mahmood (1995) New firm survival: new results using a hazard function, in: *Review of Economics and Statistics*, vol. 73, no. 3, pp. 441-450

Bates, T. (1990) Entrepreneur human capital inputs and small business longevity, in: *Review of Economics and Statistics*, vol. 72, no. 4, pp. 551-559

Boone, C. and A.van Witteloostuijn, (1995) Industrial organization and organizational ecology: the potentials of cross-fertilization, in: *Organizational Studies*, vol. 16, pp. 265-298

Carroll, G.R. (1985) Concentration and specialization: Dynamics of niche width in populations of organizations, in: *American Journal of Sociology*, vol. 90, pp. 1262-1288

Carroll, G.R. and M.T. Hannan, (2000) *The Demography of Corporations and Industries*, Princeton: Princeton Univ. Press

Caves, R.E. (1998) Industrial Organization and New Findings on the Turnover and Mobility of Firms, in: *Journal of Economic Literature*, vol. 36, no. 4, pp. 1947-1984

Davidsson, P. (1991) Continued entrepreneurship: ability, need and opportunity as determinants of small firm growth, in: *Journal of Business Venturing,* vol. 6 no. 6, pp. 405-429

Doms, M., T. Dunne, and M.J. Robers (1995) The role of technology use in the survival and growth of manufacturing plants, in*: International Journal of Industrial Organization,* vol. 13, no. 4, pp. 523-545

Ekamper, P. (1996) Opheffing van bedrijfsvestigingen: Een sterftetafelbenadering (Dissolution of firms: a life table approach), in: *Planning, Methodiek en Toepassing*, no. 48, pp. 12-21

Geroski, P.A. (1991) *Market Dynamics and Entry*, Oxford, Blackwell

Geroski, P.A. and J. Schwalbach, (1991) *Entry and Market Contestability*, Oxford, Blackwell

Hamilton, F.E.I. and G.J.R.Linge (1997) *Spatial Analysis, Industry and the Industrial Environment*, Chichester, Wiley

Hannan, M.T. (1989) Age dependence in the mortality of national labour unions: comoparisons of parametric models, in: *Journal of Mathematical Sociology,* vol. 15, no. 1, pp. 1-30

Hannan, M.T. and G.R. Carroll (1992) *Dynamics of Organizational Populations: Density, Legitimation and Competition*, New York, Oxford Univ. Press

Hannan, M.T. and J. Freeman (1984) Structural inertia and organizational change, in: *American Sociological Review*, vol. 49, pp. 149-164

Hannan, M.T. and J. Freeman (1989) *Organizational Ecology*, Cambridge, M.A., Harvard Univ. Press

Hannan, M.T. D. Barron, and G.R. Carroll, (1991) On the interpretations of density dependence in rates of organizational mortality, in: *American Sociological Review*, vol. 56, pp. 410-415

Hayter, R. and H.D. Watts (1983) The geography of enterprise: a reappraisal, in: *Progress in Human Geography,* vol. 2, no. 4, pp. 157-182

Kemper, J. , W. Kloek and L. van Wissen (1996) Databronnen voor economische demografie (Datasources for economic demography), in: *Planning, Methodiek en Toepassing*, no. 48, pp. 42-48

Keyfitz (1977) *Introduction to the Mathematics of Population, with revisions*. Addison Wesley, Reading, Mass.etc.

Kirchhoff, B.A. (1994*) Entrepreneurship and dynamic capitalism: the economics ofbusiness firm formation*, Westport, Praeger

Mason, C.M. and K.N. McNally, (1997) Market change, distribution, and new firm formation and growth: The case of real-ale breweries in the UK, in: *Environment and Planning A*, vol. 29, no. 3, pp. 405-418

Mata, J. (1996) Small firm births and macroeconomic fluctuations, in: *Review of Industrial Organization*, vol. 11., no. 2, pp. 173-182

McDermott, P.J. and M.J. Taylor (1982) *Industrial Organization and Location*, Cambridge, Cambridge Univ. Press

Roper S. (1998) Entrepreneurial characteristics, strategic choice and small business performance, in: *Small Business Economics*, vol. 11,no. 1, pp. 11-24

Shane, S.A. (1996) Hybrid Organizational Arrangements and Their Implications for Firm Growth and Survival: A Study of New Franchisors, in: *Academy of Management Journal*, vol 39, no. 1, pp. 216-234

Tuma, N.B. and M.T.Hannan (1984) Social Dynamics, models and methods, San Diego, Academic Press

Van Wissen, L. van (2000) A micro-simulation model of firms. Applications of concepts of the demography of the firm, in: *Journal of the Regional Science Association (forthcoming)*

Van Wissen, L. and P. Ekamper (2000) SIMFIRMS: A spatial demographic simulation model of firms

Wilson, A.G. and M. J. Kirby (1980) Mathematics for geographers and planners, Oxford, Clarendon Press

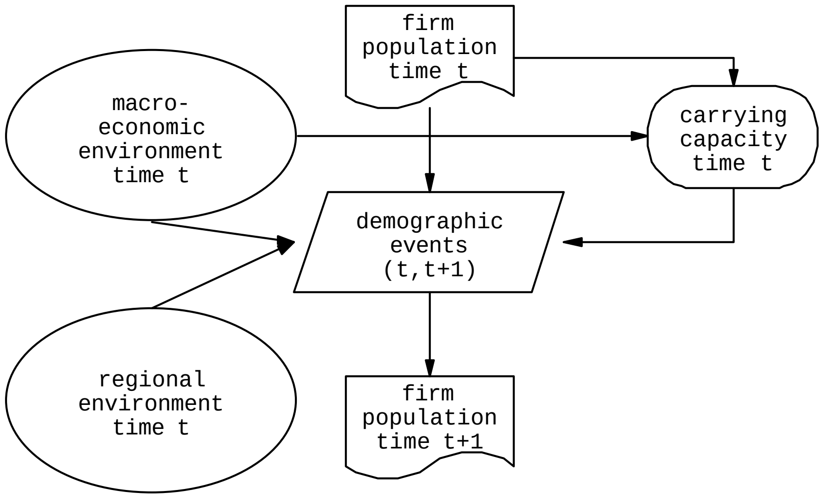


Figure 1 General Structure of SIMFIRMS

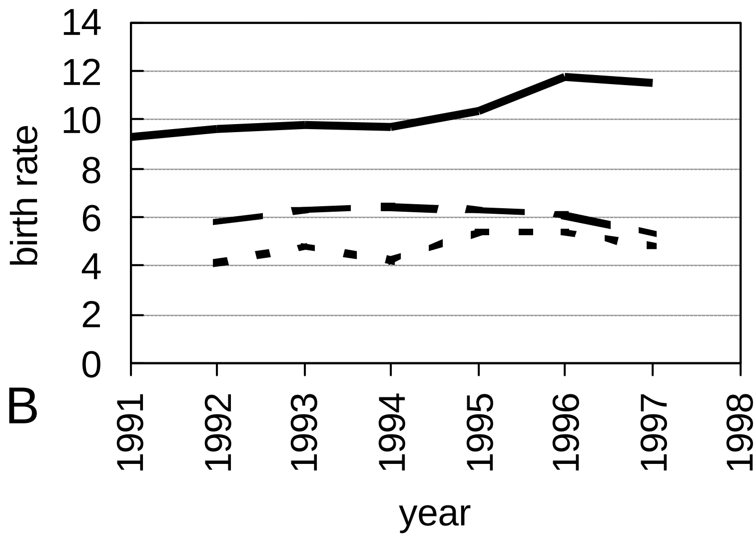


Figure 2 Birth rate observed and simulated

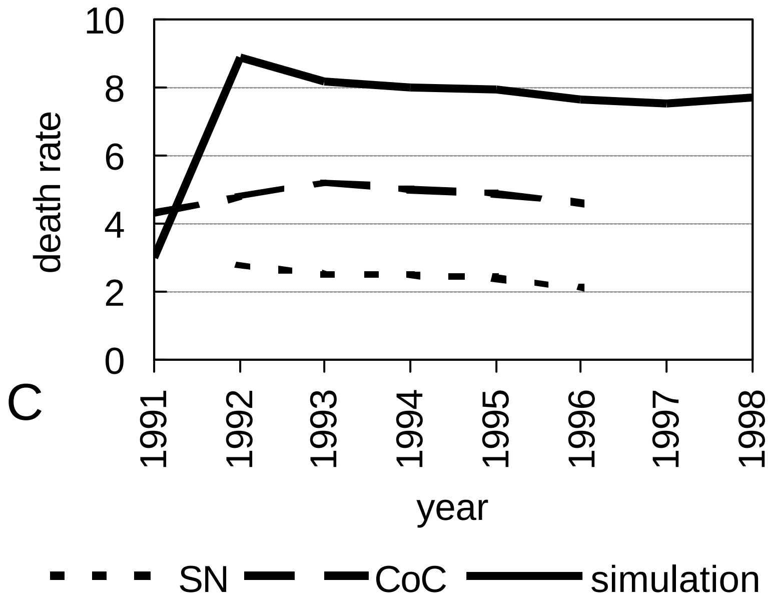


Figure 3 Death rate: observed and simulated

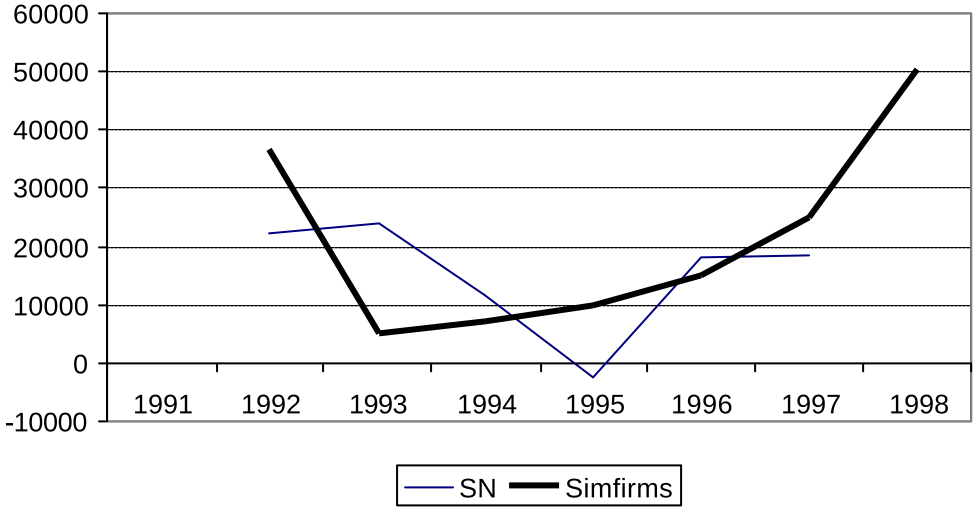
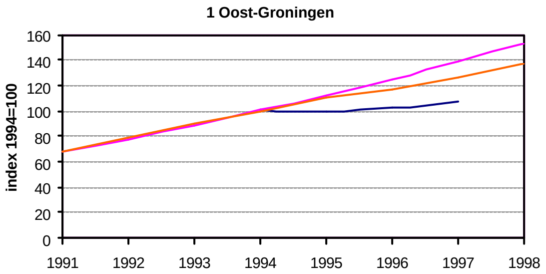
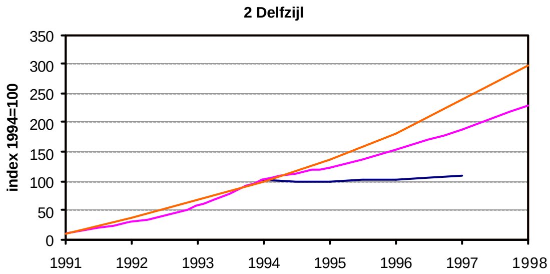


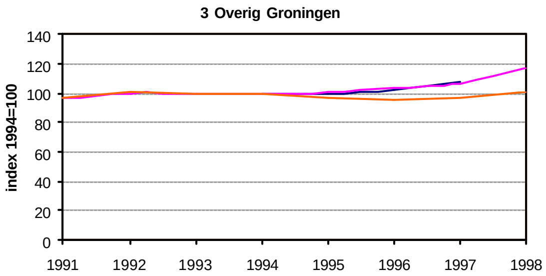
Figure 4 Observed and simulated net change in the number of firms in the Netherlands 1991-1998

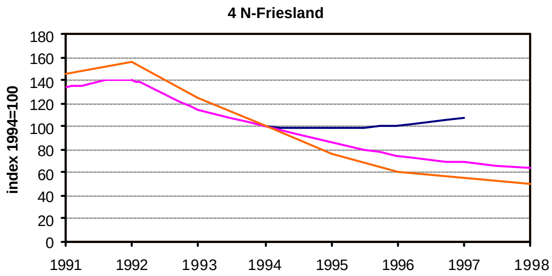
Next pages:

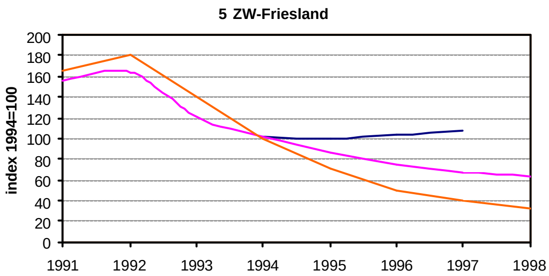
Figure 5 (following pages 1-43) Regional development in number of firms 1991-1998 (indexed values: 1994=100)

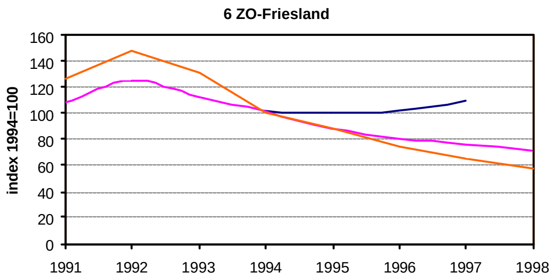

1 Oost-Groningen
index 1994=100
0 20 40 60 80 100 120 140 160
1991 1992 1993 1994 1995 1996 1997 1998

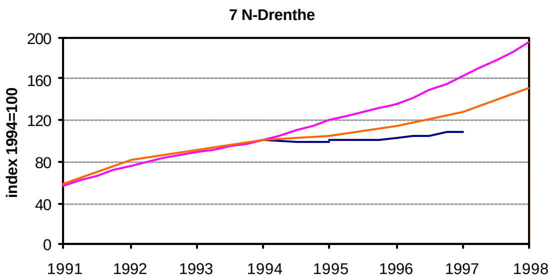

2 Delfzijl
index 1994=100
0 50 100 150 200 250 300 350
1991 1992 1993 1994 1995 1996 1997 1998

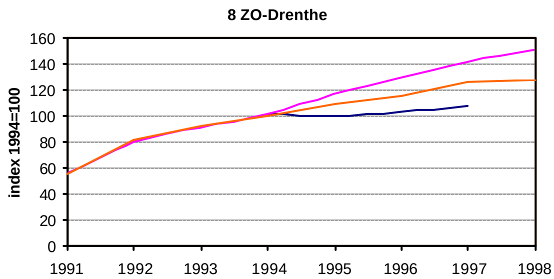

3 Overig Groningen
index 1994=100
0 20 40 60 80 100 120 140
1991 1992 1993 1994 1995 1996 1997 1998

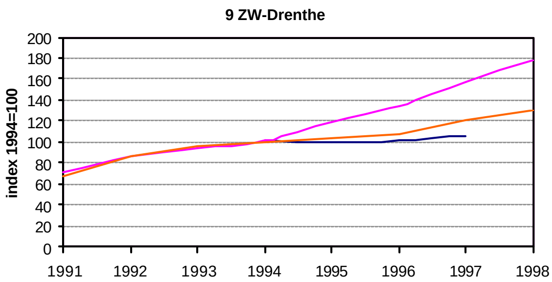

4 N-Friesland
index 1994=100
0 20 40 60 80 100 120 140 160 180
1991 1992 1993 1994 1995 1996 1997 1998

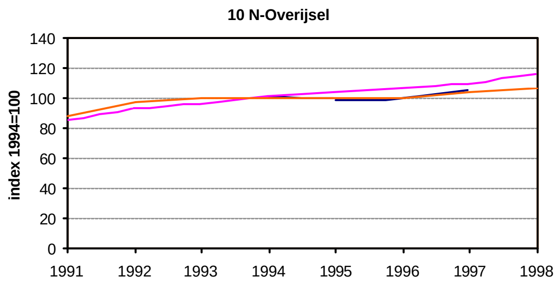

5 ZW-Friesland
index 1994=100
0 20 40 60 80 100 120 140 160 180 200
1991 1992 1993 1994 1995 1996 1997 1998


6 ZO-Friesland
index 1994=100
0 20 40 60 80 100 120 140 160
1991 1992 1993 1994 1995 1996 1997 1998

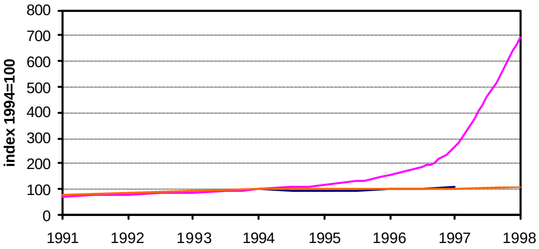

7 N-Drenthe
index 1994=100
0 40 80 120 160 200
1991 1992 1993 1994 1995 1996 1997 1998


8 ZO-Drenthe
index 1994=100
0 20 40 60 80 100 120 140 160
1991 1992 1993 1994 1995 1996 1997 1998

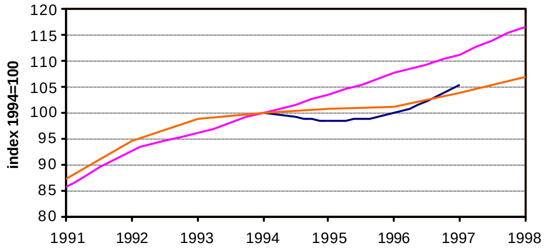

9 ZW-Drenthe
index 1994=100
0 20 40 60 80 100 120 140 160 180 200
1991 1992 1993 1994 1995 1996 1997 1998


10 N-Overijsel
index 1994=100
0 20 40 60 80 100 120 140
1991 1992 1993 1994 1995 1996 1997 1998

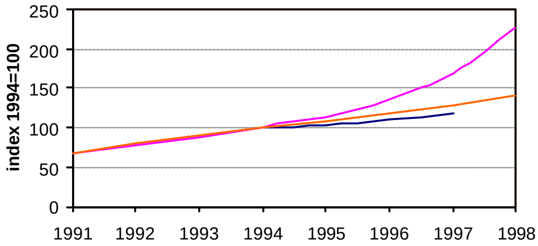
11 ZW-Overijsel



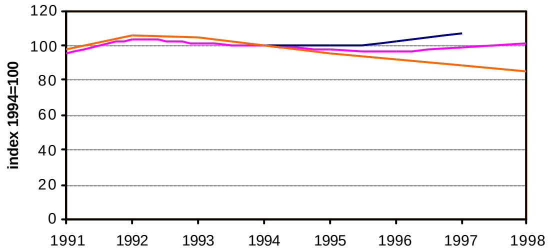
12 Twente



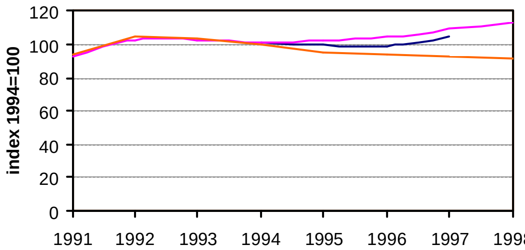
13 Flevoland



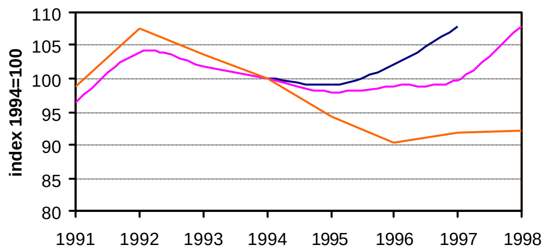
14 Veluwe



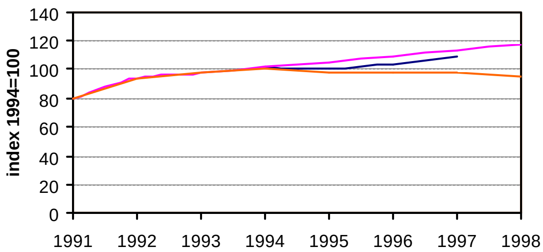
15 Achterhoek



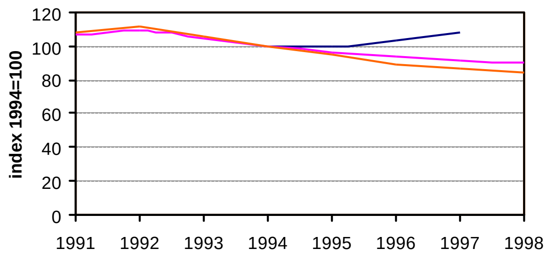
16 Arnhem/Nijmegen



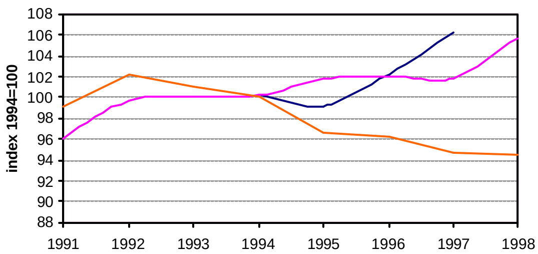
17 ZW-Gelderland



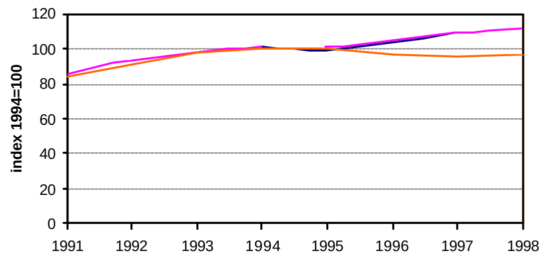
18 Utrecht

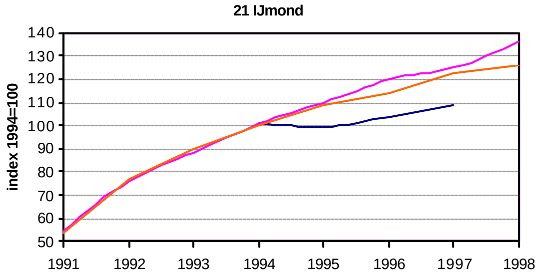


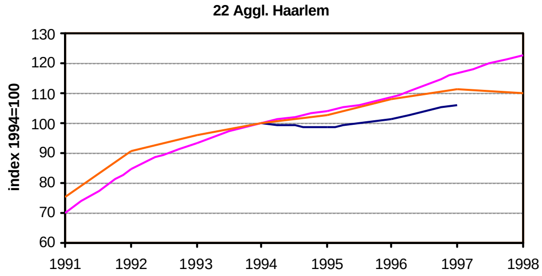
19 Kop v. N-Holland

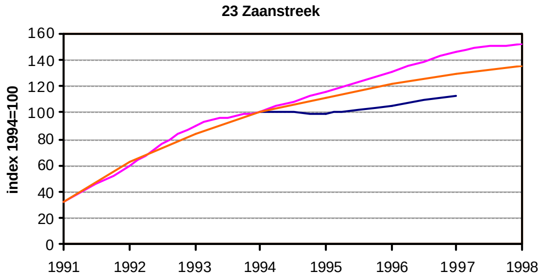


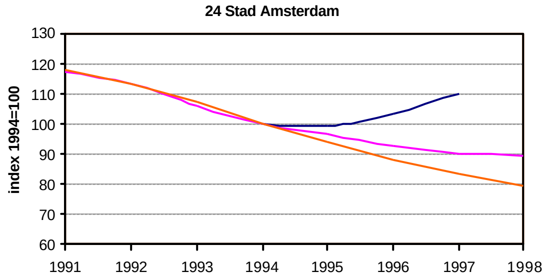
20 Alkmaar

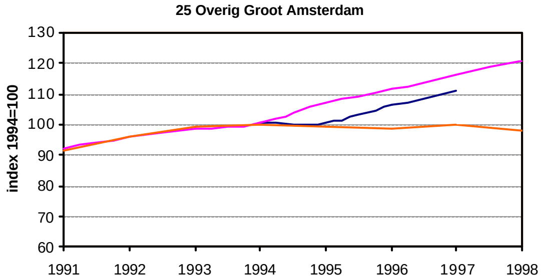


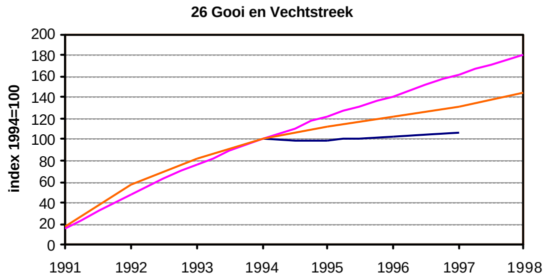

21 IJmond
index 1994=100
140 130 120 110 100 90 80 70 60 50
1991 1992 1993 1994 1995 1996 1997 1998

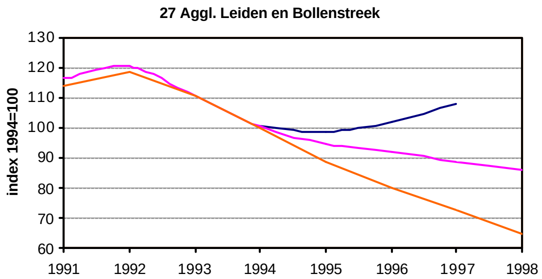

22 Aggl. Haarlem
index 1994=100
130 120 110 100 90 80 70 60
1991 1992 1993 1994 1995 1996 1997 1998

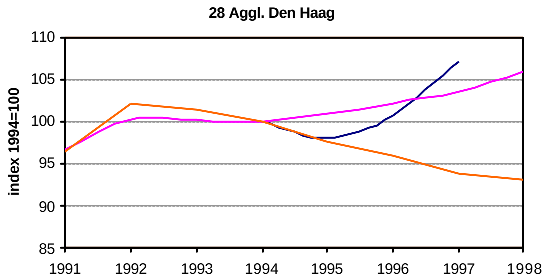

23 Zaanstreek
index 1994=100
160 140 120 100 80 60 40 20 0
1991 1992 1993 1994 1995 1996 1997 1998

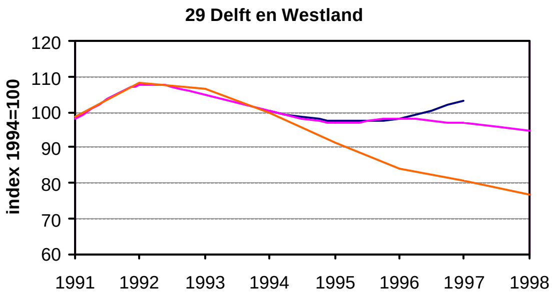

24 Stad Amsterdam
index 1994=100
130 120 110 100 90 80 70 60
1991 1992 1993 1994 1995 1996 1997 1998

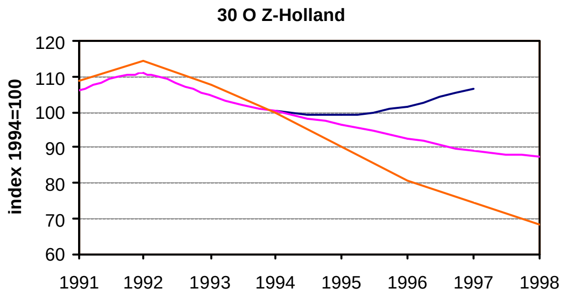

25 Overig Groot Amsterdam
index 1994=100
130 120 110 100 90 80 70 60
1991 1992 1993 1994 1995 1996 1997 1998

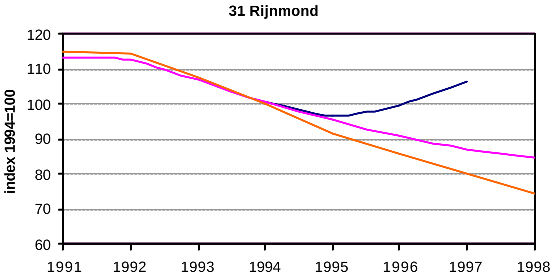

26 Gooi en Vechtstreek
index 1994=100
200 180 160 140 120 100 80 60 40 20 0
1991 1992 1993 1994 1995 1996 1997 1998

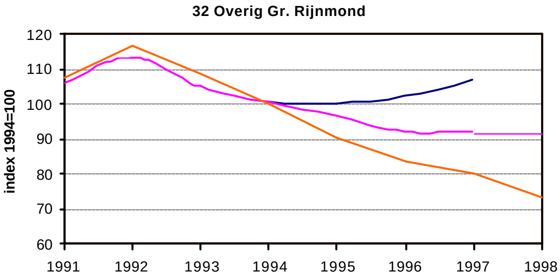

27 Aggl. Leiden en Bollenstreek
index 1994=100
130 120 110 100 90 80 70 60
1991 1992 1993 1994 1995 1996 1997 1998

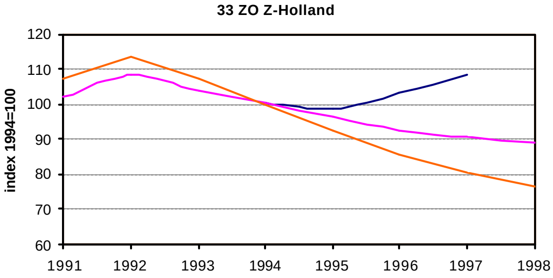

28 Aggl. Den Haag
index 1994=100
110 105 100 95 90 85
1991 1992 1993 1994 1995 1996 1997 1998

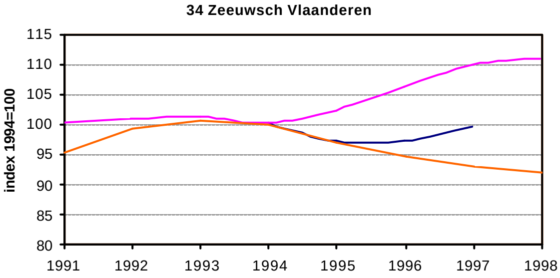

29 Delft en Westland
index 1994=100
120 110 100 90 80 70 60
1991 1992 1993 1994 1995 1996 1997 1998

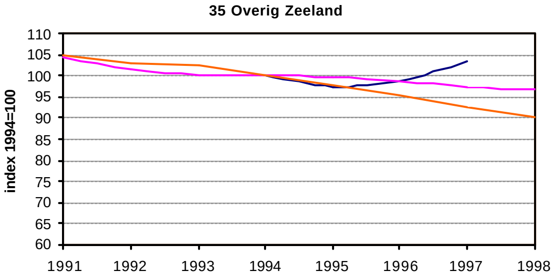

30 O Z-Holland
index 1994=100
120 110 100 90 80 70 60
1991 1992 1993 1994 1995 1996 1997 1998

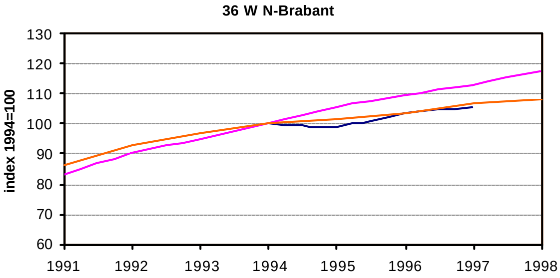

31 Rijnmond
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998

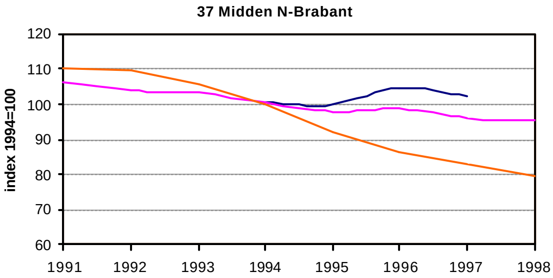

32 Overig Gr. Rijnmond
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998

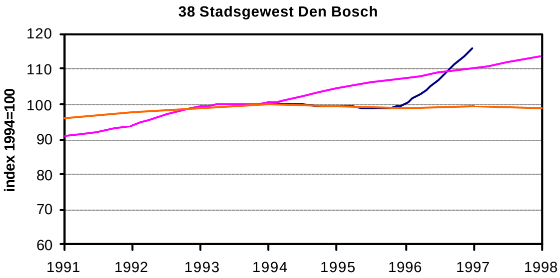

33 ZO Z-Holland
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998

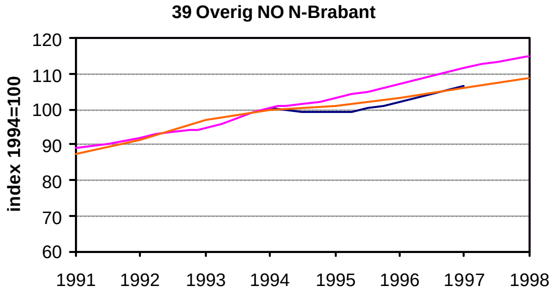

34 Zeeuwsch Vlaanderen
index 1994=100
115
110
105
100
95
90
85
80
1991 1992 1993 1994 1995 1996 1997 1998

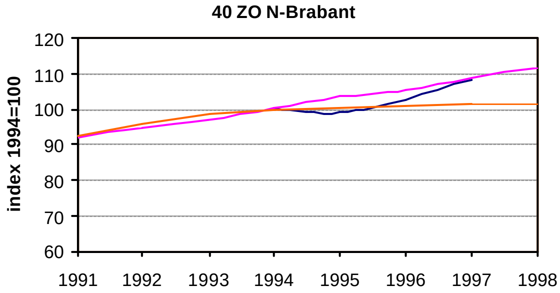

35 Overig Zeeland
index 1994=100
110
105
100
95
90
85
80
75
70
65
60
1991 1992 1993 1994 1995 1996 1997 1998

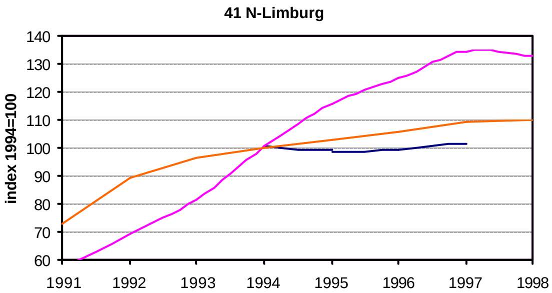

36 W N-Brabant
index 1994=100
130
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998

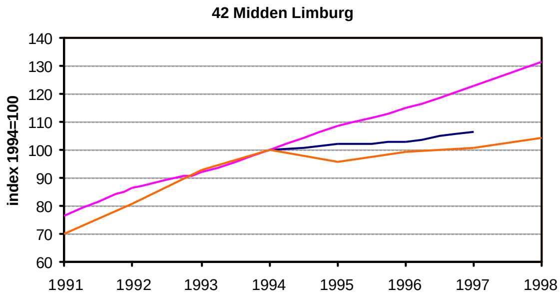

37 Midden N-Brabant
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998

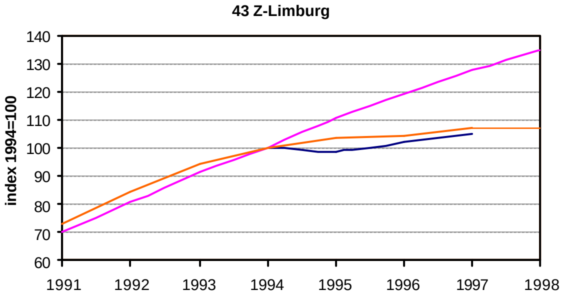

38 Stadsgewest Den Bosch
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998


39 Overig NO N-Brabant
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998


40 ZO N-Brabant
index 1994=100
120
110
100
90
80
70
60
1991 1992 1993 1994 1995 1996 1997 1998


41 N-Limburg
index 1994=100
140
130
120
110
100
90
80
70
60
1991
1992
1993
1994
1995
1996
1997
1998


42 Midden Limburg
index 1994=100
140
130
120
110
100
90
80
70
60
1991
1992
1993
1994
1995
1996
1997
1998


43 Z-Limburg
index 1994=100
140
130
120
110
100
90
80
70
60
1991
1992
1993
1994
1995
1996
1997
1998