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A micro-simulation model of firms: Applications of concepts of the demography of the firm

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Abstract. Recently, there is an increasing demand in spatial planning for models based on the demographic concepts of birth and death of firms. This article describes the structure of a spatial demographic simulation model of firms, and its application within The Netherlands. The model structure is essentially of the familiar demographic cohort component type, where an initial cohort of firms ages in a number of discrete steps, and where in each step additions and subtractions to and from the population are modelled using birth, death and migration components. Apart from the central processes of birth, death and migration, the type of economic activity and firm size are highly important for understanding firm behaviour over time. The article describes the transition functions for each of the demographic components and for firm growth. In addition, some empirical results are presented of a number of model simulations in The Netherlands. The results were partly validated using observed economic demographic data. It is concluded that a substantial amount of work remains to be done in this new field. The model presented here has direct implications for the research agenda of the study of the demography of the firm.

JEL classification: R11, R15, R30

Key words: Demography of the firm, regional economic growth, micro-simulation, firm formation, firm dissolution

1 Introduction

Demography of the firm, economic demography, or industrial demography, as it is alternatively called, is traditionally concerned with the description of (usually annual) changes in the population of firms. More recently, explanatory analyses and models of elements of demographic behaviour have been introduced by researchers from various disciplines. The field is certainly multi disciplinary, with major contributions by geographers, regional economists, sociologists and demographers (Gordijn and Van Wissen 1992). Although there are no areas covered exclusively by one discipline, it seems that geographers have a special interest in migration (Kemper and Pellenbarg 1993, 1995, 1997) and regional economists favour studies in firm formation (Reynolds et al. 1994). Traditionally, firm survival has received attention from demographers (Ekamper 1996) and sociologists (Baum and Singh 1994; Brüderl and Schüssler 1990; Hannan et al. 1988a,b), but since the seminal work of Wever (1983) it is known in economic geography and related fields as well. Model specification and estimation in economic demography received for the first time attention by Hannan and Freeman (1989), and more generally it is a central issue in organizational ecology (Hannan and Carroll 1992; Carroll and Hannan 2000). Until now, no attempt has been made to use economic demography in a projection context.

The need for a projection model based on the concept of the demography of the firm arose within the Department of Spatial Planning of The Netherlands. The Department needed a scenario instrument for regional economic growth, based on a set of behavioural rules of the agents of economic growth, i.e., firms. Spatial policy making aimed at influencing regional economic growth is essentially focused at creating favourable growth conditions and defining spatial, environmental and other constraints for economic actors. Existing regional economic tools such as regional input-output analysis or shift and share analysis are essentially macro-tools and lack an explicit behavioural mechanism to simulate and evaluate spatial economic policies. These more traditional tools describe and predict an equilibrium situation of the economic structure, but do not give insight into the processes that lead to these equilibria. In practice, the evolution of the system is often as interesting and important for planning purposes as the static equilibrium structure. Demography of the firm is rooted in a view of the economy as being driven by the behaviour of individual actors, which may be more appropriate in understanding various economic processes than the traditional macro level.

In this article a first attempt at specifying and implementing an economic demographic simulation model will be made. More specifically, the article describes the structure of a spatial model of economic demography, that simulates the developments in size of the population of firms, as well as its composition and spatial distribution (more precisely: business establishments) over time. The model is applied empirically in The Netherlands. From a sample taken from a micro register of business establishments in The Netherlands, reflecting the population on the 1st of May 1991, a simulation was made until the year 1998. The results were partly compared to actual demographic trends of firms in The Netherlands, that are available until 1996. The results of this empirical exercise are mainly interesting from a methodological point of view. In fact, in all likelihood it will be too much asked to expect accurate projections from any micro-economical model of economic growth. Even existing large scale macroeconomic models, in use in many countries for making economic projections, are only reasonably accurate in the short run, and produce mid- and longer term projections with a high degree of uncertainty. Nevertheless, they are very useful for understanding consequences of current developments, even when we are sure that the future will be different. The same expectations hold for the usefulness of results of an economic-demographic projection model. The results may increase understanding of current trends in the economy, and highlight a number of consequences of current developments at the firm level for the national and regional economy.

This first attempt at a simulation approach for economic demography is only a start, and in good research tradition, it raises more questions than it can answer. One of its prime results is therefore a research agenda. This research agenda, which will be discussed in the final section, includes both theoretical, methodological and empirical issues.

2 Defining the problem

The basic unit in economic demography may be the enterprise, the firm or the local business plant. Juridical ownership relations are defined at the enterprise level. These are often complex legal structures, as a result of historical reasons, fiscal and other financial and institutional reasons. These relationships are not necessarily structured along the lines of physical production processes. The production process is the basis of the definition of the firm (Willeboordse 1986). In one enterprise one or more firms may operate. In turn, one firm may exist of one ore more local business establishments or plants: a physical structure, a building or lot where work activities take place as part of a production process. For the present application, having a spatial dimension, the level of the local business establishment was chosen.

In economic demography, the primary attributes of the firm are economic activity, age and size of the firm. If applied in a spatial setting, as is the case here, then geographical location is added to this list. In principle we are dealing with a four-dimensional state space of the system. As a consequence, the number of different categories for each attribute is usually quite large, and therefore the number of different states a firm may occupy is usually large as well. On the basis of these characteristics of the economic-demographic system, the choice for micro-simulation in favour of macro-simulation is obvious (Van Imhoff and Post 1998; Hooimeijer and Oskamp 1999).

The evolution of a firm over time is described by the successive states that the firm is in during its lifetime, as well as the sojourn time in each state. A state of the system is defined with reference to a unique combination of attributes of the primary variables. For instance, a state might be defined as: industrial activity, age 10 years, size 5 persons, in region Amsterdam. The different states of the system define the events to be included in the model. Similar to humans, a firm is born, passes through a number of stages in the life cycle in the process of aging, and dies eventually. However, there are substantial definitional problems for the process of firm birth (formation) and death (closure) (Kemper et al. 1996;

Willeboordse 1986). Another event is change in economic activity. These events are not uncommon, especially for young firms, seeking a niche in the market. Firm growth is highly associated with the stage in the life cycle. There are a number of candidates for measuring actual firm size and firm growth, such as the number of employed persons, or total production, or value added. The actual choice depends on the problem definition and data availability. A change in firm size is an event and endogenous in the model. Finally, changes in geographical location (firm relocations) are events to be included in the model.

In Sect. 4, more details will be given of the definition of the states of the system, while Sect. 5 presents the analytical structure of the model components. The model is basically a demographic cohort component model. This term reflects the fact that the dynamic evolution of the population is the result of the occurrence of events (the components of cohort change) to members of the population. The components are birth, death, firm growth and migration. In a cohort component model a cohort is born in a certain time period and ages over time. The total population is the sum of all cohorts and the evolution of the population is the result of the sequence of new cohorts being added to the population and the gradual dying off of older cohorts. This evolutionary process is modelled in a micro-simulation context. In the next section this will be clarified.

3 Micro-simulation in economic demographic models

The essence of any micro-simulation computer programme in discrete time is as follows (see also Galler 1995; Hooimeijer and Oskamp 1999; Van Imhoff and Post 1998):

1. read a record from a list with information about the attributes of one element of the sample at time t;
2. apply the set of microscopic probabilistic functions to this element, where the attributes of the unit are covariates of the functions;
3. use Monte Carlo simulation to determine the outcome of these probabilistic functions for this member;
4. update the attributes of this member in the record to represent the attributes of the member at time $t+1$, and add or replace it in the list; and
5. continue with the next member of the sample (go back to step number 1).

Of course, much more complex structures are possible, but they are variations based on this basic scheme. The micro-simulation computer program for economic demography SIMFIRMS, described in this article, closely resembles this basic structure, with one exception (the macro simulation module for births), which will be clarified below.

Applying micro-simulation in an economic-demographic context has not been attempted before. Therefore, a number of problems were encountered for which the literature did not have a clear-cut answer. These problems are the result of the different nature of the demographic and economic processes that govern the behaviour of the micro units. In human demography, biological factors are important determinants of demographic change. Aging and mortality, as well as the ability for reproductive behaviour are to a large extent biologically determined. Other – sociological, economic and cultural – factors are important as well but their influence is limited to variations in behaviour within each biological stage of life. Therefore, age and sex are the key demographic variables in population demography. In contrast, the nature of demographic change of economic units is completely determined by economic and socio-cultural factors. There are two direct consequences of this non-biological nature of the process. First, the notion of reproductive behaviour of firms (fertility or firm formation) is not so easily defined. Consequently, the question arises how to simulate this process of firm formation. The second problem is how to incorporate the economic driving factors of firm behaviour in a model of economic demography.

3.1 Simulation of firm formation

Unlike human fertility, firm fertility is not a straightforward concept. The process of the birth of a new firm is complex. In the literature two approaches may be observed. The first approach relates the number of births to the existing population of firms, which leads to the concept of the firm birth rate. This approach assumes that it is the firm that is at risk of giving birth to a new firm, for instance by splitting off, starting a new branch or establishment, and so on. Of course this is a correct description of many new firm formations: they were created by a positive decision of one or more firms. However, this approach ignores the process of new firm creation by individuals, either as employees in a firm, school-leavers or unemployed. Creating your own firm is one way of becoming employed (Beesley and Hamilton 1994). In a micro study using retrospective information of workers in the 1985 labour market survey in The Netherlands (Ekamper and Van Wissen 2000) an “educated guess” was made of the number and characteristics of new firm formations based on decisions of individuals. Important attributes of the workers turned out to be age, sex and schooling, and these attributes interacted with the attributes of the new firm, in particular economic sector, and size. This small scale study should be replicated with better and more recent data in order to gain more understanding of the process.

In the former approach, the population of firms is the population at risk, in the latter approach it is the labour supply. Both types of births should be taken into account. The following birth equation was therefore specified:

$$B = c[d\mathbf{a}'\mathbf{l} + (1 - d)\mathbf{e}'\mathbf{z}] \tag{1}$$

where B is the number of births, c is a scaling parameter to specify the overall birth level, and d a constant specifying the relative weight of births from the labour force in the total number of births. $\mathbf{l}$ is a vector containing the distribution of the labour force by relevant characteristics (age, sex, schooling), and $\mathbf{a}$ is a vector of equal length containing category-specific birth factors (age, sex, schooling). Similarly, $\mathbf{z}$ is a vector of firms by primary characteristics (size, age, economic activity) and $\mathbf{e}$ a vector of equal length containing category specific firm birth factors. In the model, as will be described in more detail in Sect. 5, births B are segmented according to the primary state attributes economic sector, size and location. Birth equation (1) was used in the simulation model. However, it is very inefficient to use micro-simulation in this context, and therefore, the birth module was specified in the program partly as a macro- simulation component. In Sect. 5 the specification of this equation is described.

3.2 The concept of carrying capacity

One of the largest differences between human demography and economic demography is that growth and decline of firms are governed to a large extent by the market. If the economy thrives, more firms will probably be born, existing firms will tend to grow and less firms will close down. In a declining economy the reverse tends to happen. However, this process linking macro- and microlevel behaviour is complex. One could conjecture that the behaviour of an individual firm is determined by the macro level of the market, but at the same time the macrolevel is the outcome, or the aggregate, of the behaviour of many consumers and producers.

In order to assess the economic performance of the firm, one would need annual accounts. This is clearly not feasible, nor desirable in the demography of the firm. Instead, we are looking for simple indicators that describe the behaviour of the population over time. In micro-simulation this is a multi-level problem since we are looking for macro-level descriptors of the market forces that influence micro behaviour of the firm. There is a remote equivalent in the behaviour of biologic populations, which has been transferred to the behaviour of organizations in the field of organizational ecology. This is the concept of carrying capacity (Hannan and Freeman 1989; Hannan and Carroll 1992). Carrying capacity is a central concept in ecology and denotes the maximum size a population can attain under the conditions of the current environment. The carrying capacity K is one parameter in the logistic equation, often used to describe the growth path of biologic populations in a closed environment:

$$\Delta X(t) = aX(t) \cdot (K(t) - X(t)) \tag{2}$$

In this equation $X(t)$ is the size of the population at time t, $\Delta X(t)$ is the growth of the population in the unit time interval $(t, t+1)$ and a is the intrinsic growth rate of the population. The more $X(t)$ approaches the carrying capacity $K(t)$, the smaller the term $(K(t) - X(t))$ and the smaller the population growth. At $X(t) = K(t)$ population growth is zero, and if $X(t)$ is larger than $K(t)$ then growth is negative. The essence of the approach adopted here is that the carrying capacity $K(t)$ is defined as the market capacity or market demand, which may be time dependent, and that individual behaviour of the firm in terms of formation, growth and closure is partly determined by a factor $(K(t) - X(t))$, relating current market supply $X(t)$ to market capacity $K(t)$. If supply is smaller than current demand, production will increase; if current demand is smaller than supply, production will decrease. Note that prices are not taken into account here: it is assumed that all producers are price takers and market clearing is established through supply adjustment, and therefore it is not really an economic model. In reality, these processes are of course much more complex, but we are not interested in a complete economic model of the firm, but in defining macro rules for the behaviour of the population of firms. $X(t)$ is related to the size of the population of firms. If $K(t)$ could be found, then the statistic $K(t) - X(t)$ or any suitable function relating both variables is a covariate of the functions determining birth, growth and death of firms. We call $K(t) - X(t)$ or logarithmic transformations of it market pressure or market stress.

Market demand $K(t)$ is modelled in a multi-sectoral and spatial input-output framework that includes intermediate and final demand categories. This carrying capacity model is described in more detail in Van Wissen (1996, 1997), and Ekamper and Van Wissen (2000). It calculates the demand for good s exerted at location i, taking into account the inter-industry relations between economic sectors, as specified by the input-output table, and spatial relations between suppliers and producers, by means of distance functions. The outcome $K_{is}(t)$ can be compared to current level of production $X_{is}(t)$ and the (relative) difference between the two is used as a predictor of economic demographic behaviour at the micro-level.

Basically, the driving force in this model, market capacity K, is derived from an input-output model, where supply follows demand at a smaller rate of change. Indeed, the speed of adjustment is exactly what determines the intensity of the demographic events. Equally important, the speed of adjustment, as specified in the demographic processes, is also dependent on other characteristics of the firm, such as age. Therefore, the composition of the population of firms in terms of primary variables is an important factor determining economic growth processes.

In Sect. 5 the relationship between this "market pressure" variable in a carrying capacity form and demographic behaviour at the firm level is estimated in a statistical model. Before describing the individual demographic components, the overall model structure will be presented.

4 The overall model structure

The structure of the economic demographic model SIMFIRMS resembles that of a standard cohort component model. Events are birth, death, migration and growth of business establishments. The development over time of the population is the result of birth of new cohorts, the dying off of old cohorts, and the aging of existing cohorts over time. The population develops in discrete time and transitions take place between t and $t + 1$. A transition is a change of state from time t to time $t + 1$ which is different from an event. Multiple events may take place between both time points, but since the state of the firm, as defined by

Table 1. Definition of the primary state variables and events in SIMFIRMS

Primary attribute		Values	Definition	Events
Age		0,1,2,3,4,. . . years	Age at last birthday of the firm plant	Birth, aging, death
Economic activity	1	Agriculture and fishery	Based on 1974 NACE definition	None
	2	Energy and mining		
	3	Industry		
	4	Construction		
	5	Wholesale		
	6	Retail		
	7	Cafes, restaurants, hotels		
	8	Transportation and Communication		
	9	Banking, insurance		
	10	Other services		
	11	Public sector		
Size		1,2,3,4 . . . employed persons	Number of workers ($>$ 12 hours/week) in the firm plant	Changes in size
Geographical location*		1,. . .,40 regions	Corop regions: equivalent to nodal regions and the so-called NUTS 2 level, a standard regional classification used by the European Commission	Firm relocations between regions

* Formally the spatial level used in the model is the municipal level. However, this level is not used in the present empirical application

the primary state variables is only measured at discrete time intervals, only one change of category within each primary state variable may be observed in each time interval. If the time interval is sufficiently short (in this case one year), the difference between transition and event is small. However, some events are not independent, for instance birth and firm growth, or migration and growth. The sequence of multiple transitions within the model is therefore important (Galler 1995). There exist a number of ways to deal with this problem (Van Imhoff and Post 1998). However, at present we do not know enough of these interactions between events to justify an elaborate model framework that deals with these competing risks in an appropriate manner. Instead, SIMFIRMS uses a fixed sequence of events. Consequently, all probabilities are conditional probabilities, as determined by the order of events. Unfortunately, it was not always possible to estimate conditional probabilities from empirical data. The use of unconditional probabilities will result in some bias in the outcomes, although due to the length of the unit time interval – one year – this bias is likely to be small.

Table 2. Estimated coefficients of model for firm closure (equation (6)) using logistic regression

Variable	Interpretation	Coefficient value
$(K-X)/X$	Market stress	-0.003
$\ln(g)$	Log of firm size	-0.517^{*}
$\dot{g}$	Firm growth rate:	0.726^{**}
$\ln(a)$	Log of age	-0.107^{**}
Pseudo-R^2	0.47	

Significance: * = 0.95 level; ** = 0.99 level

4.1 System identification

In the current application of SIMFIRMS, the primary attributes and variable categories mentioned in Table 1 were used.

Aging includes the existential events of birth and death of the firm. In reality more complex existential events are possible, such as fusion, takeover, merger, splitting off, splitting up. However, these events are more important at the enterprise level, and not so much at the establishment level. Legal ownership of a firm plant may change, as the concern structure changes, but these events have often little effect on continuation of local production processes.

The 11 types of economic activities were chosen because they were the most appropriate categories from a spatial planning point of view, while taking into account the limited content of the database of firms at hand. Changes of economic activity were not taken into account, since no reliable information exists for this event. In the definition of the size of the firm no distinction is made between part-time and full-time workers, since the registration in the database was not consistent at this point.

4.2 SIMFIRMS model structure

SIMFIRMS is a computer model that simulates the annual changes in the size and composition in the population of business establishments in The Netherlands. SIMFIRMS runs through annual rounds of simulations whereby the population ages from time t to $t+1$. The structure of a one-year cycle of the model is as follows:

Table 3. Results of regression of size of firms at $t + 1$

Variable	Interpretation	Coefficient value
C	Constant	0.095**
$\ln(g(t))$	Logarithm of size at time t	0.89**
$(\ln(g(t)))^2$	Log of size squared	0.012**
$\ln(K/X)$	Log of mark pressure	0.001*
σ	Error variance	0.0200
R^2	Explained variance	0.91

Significance: * = 0.95 level;** = 0.99 level

A. Preparations for micro simulation:

1. Read the list of individual firms $n = 1, \ldots, N$ by primary state variables
2. Aggregate the individual firms to $X_{isga}(t)$: the number of firms in location i, of type s, size g, and age a at time t
3. Read relevant exogenous information for time t, such as regional labour supply indicators, other regional and/or time specific indicators
4. Determine carrying capacity $K_{is}(t)$ for each location i and economic sector s at time t

B. Micro simulation (for each unit in the list of firms sequentially by means of Monte Carlo simulation):

5. Simulate death of the firm *(firm closure)*, using the death function (see below)
6. If surviving: Simulate *growth* and *decline*, using the growth function (see below)
7. If surviving: Simulate *relocation* of the firm, conditional on individual historical growth path, using relocation functions (see below)

C. Mixed macro/micro-simulation:

8. Simulate total number of births *(firm formation)* from labour force and population of business firms B_{is}, by means of macro-simulation using the birth function. Next, determine the primary state variables size g and location i of each new-born unit by means of micro-simulation

D. Demographic accounting:

9. Aggregate total number of closures, migrations and size changes into state variables into $X_{isga}(t + 1)$. This is the starting population of the next cycle of the model.

The process is repeated, until the complete projection period is completed.

5 The individual components

In this section, the probabilistic functions of the four economic demographic components will be described in some detail: births, deaths, migration, and growth/decline.

5.1 Births

The startup of a new business establishment involves a sequence of decisions. The first decision is *existential:* to start or not to start a business unit. As discussed in Sect. 3, this decision may be either an individual decision of a person, or a firm decision to start a new unit. The second decision involves the economic sector of the firm. Equation (1), presented in Sect. 3, gives a simplified representation of the birth equation. In the economic demographic model macro-simulation is used to estimate the number of births by sector s and geographical location i:

$$B_{is} = c\mu i \left[d \sum_k a_{sk} l_{ki} + (1-d) \sum_r e_{sr} z_{ri} \right] \tag{3}$$

or, in matrix notation:

$$\mathbf{B} = c[d\mathbf{AL} + (1-d)\mathbf{EZ}]\mathbf{M} \tag{4}$$

where $\mathbf{B}$ is a $(S \times I)$ matrix of number of startups by sector $s\ (= 1, \ldots, S)$ and location $i\ (= 1, \ldots, I)$. $\mathbf{A}$ is a $(S \times K)$ matrix of sector-specific birth probabilities, for each defined group of labour supply by age, sex and education (summarized in a single index $k = 1, \ldots, K$), and $\mathbf{L}$ is a $(K \times I)$ matrix of the number of workers by category k in location i. Similarly, $\mathbf{E}$ is a $(S \times R)$ matrix of sector-specific birth rates, where the row index is related to the economic activity of the newborn firm, and the column index $r\ (= 1, \ldots, R)$ refers to the attributes of the “mother-firm”. These attributes are economic activity and size of the firm. Furthermore, $\mathbf{Z}$ is an $(R \times I)$ matrix of existing firms by economic sector and location. Finally, $\mathbf{M}$ is an $(I \times I)$ diagonal matrix with spatial multipliers, representing spatial variation in opportunities in starting a firm, in the form of the market pressure variable involving X_{is} and the carrying capacity K_{is}.

Underlying the birth equation (3) are a large number of assumptions that await further testing. For example, the link between the quality of the work force and startups of firms should be verified using more recent information. The assumption, that the economic activity of the “child unit” is equal to that of the “mother-firm” is obviously a gross simplification, and should be relaxed after more research becomes available. Indeed, the search for the appropriate form of equation (3) and the estimation of its parameters necessitates a series of studies into the structure of the firm birth process.

Joint estimation of all parameters in equation (3) or its matrix representation (4) is not possible. The information on births does not allow it, and moreover, even with all required information available, not all parameters will be identified. The values of the parameters were derived in a series of steps. First, as documented in Van Wissen and Ekamper (2000) the scalar weights c and d were estimated to be equal to 1.0 and 0.5 respectively, based on total firm births in the Netherlands in the period 1986–1990. Note that here they pertain to all regions and sectors simultaneously, an assumption that most likely will not hold if more detailed information becomes available. Second, the elements of matrix $\mathbf{A}$ and

E were determined from observed numbers of births related to the size of the labour force and the population of firms at the regional level respectively. Third, the total numbers of births at the regional level, observed in The Netherlands in the period 1986–1990 by economic sector as a percentage of the existing number of firms was regressed in a logistic regression form on the market stress variable $U_{is} = \ln(K_{is}/X_{is})$, as well as on a set of spatial dummy variables, to control for location-specific effects on birth rates, and a set of sector-specific dummies, to control for sector-specific effects on the birth rates. The outcome of this logistic regression model is a birth probability for region i and sector s, P_{is}^B which combines parameters μ_i in **M** and e_{sr} in **E** respectively. The dummies in the regression relating to the location and the economic sectors are not used in the simulation model, but their effect is incorporated in the matrices **A** and **E** in equation (4). They are included in the logistic regression in order to control for regional- and sectoral-specific effects that may otherwise bias the estimation of γ, the coefficient of the market stress variable U_{is}.

The logistic regression has the following form:

$$P_{is}^B(t) = \frac{1}{1 + \exp -[\alpha_s + \beta_i + \gamma \ln(K_{is}(t)/X_{is}(t)]} \tag{5}$$

where α_s and β_i are sectoral and spatial dummies respectively. Details of the estimation of this model may be found in Van Wissen and Ekamper (2000). The estimated coefficient γ for the market pressure variable is 0.11, and significant at the 0.99 level, which implies that the higher the market capacity K_{is} relative to current production size X_{is} for sector s at location i, the higher the birth probability. The R^2 value of this statistical model is 0.876. Therefore, the coefficient used for the market pressure variable in the simulation model is 0.11.

The third decision in the birth process concerns the *size* of the newborn unit. Note that the size distribution pertains to the size of the firm at time $t+1$, which is different from the size at birth. The size-distribution at time $t+1$ is a function of the size at birth, the probability of surviving until $t + 1$ and the growth path between the time of birth and $t + 1$. The distribution of size of newborn firms at time $t + 1$ is negative exponential and this function was used to determine in a micro-simulation step the size of the new firm. Different functions were estimated for firms born out of the working population and firms born out of "mother-firms", and separately for all economic sectors. Fig. 1 shows the form of the functions for retailing and industry.

Note that the distribution for startups of retailing firms out of the working population is discontinuous at size = 1. For a number of economic sectors the function is negative exponential only for sizes larger than 1. In these cases a special parameter is used for size = 1.

5.2 Firm closures

Firm closure is related to a number of attributes of the firm. First, the probability of surviving increases with age of the firm. This phenomenon is called

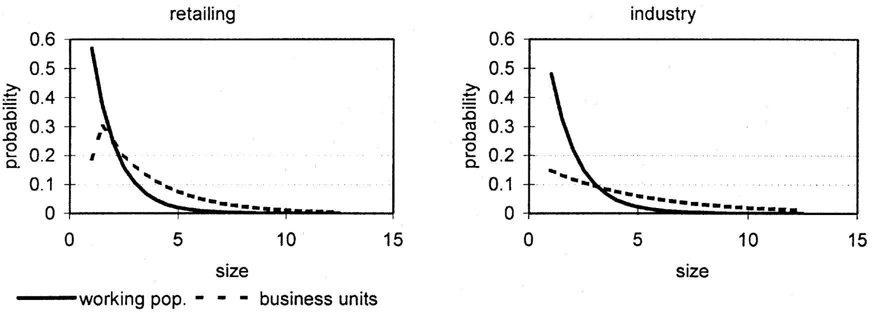

Fig. 1. Estimated size distributions for retailing and industry

the ‘liability of newness’ hypothesis (Stinchcombe 1968). This hypothesis has been questioned to some extent because some authors found that the death risk increases initially, and only decreases in a later stage of firm life (Brüderl and Schüssler 1990). This is called the ‘liability of adolescence’ hypothesis. Ekamper (1996), in constructing a life table for firms in The Netherlands, found evidence for the former, but not the latter hypothesis. In Ekamper’s analysis, age is a determining variable for firm closure in the first 10 to 15 years, but there is hardly any relationship after this age.

Firm size is a second determining variable. The ‘liability of size’ states that large firms have a smaller death risk than small firms. Closing a large firm is costly, and is prevented as much as possible.

A third important variable is the dynamic character of the firm: inert firms tend to live longer. Dynamic behaviour increases the probability of success, but also of failure. The older a firm gets, the more inert it is likely to become. There is a selection mechanism as well. The percentage of inert firms increases with age, since the dynamic ones have been closed already at younger ages.

Some economic sectors are more dynamic than others, and therefore the death rate varies over economic sectors. This variation is also caused by the production environment or “production milieu” of the firm (Lambooy 1972). This includes all the environmental conditions relevant for the economic production of the firm, such as the availability of infrastructure, accessibility to other firms with forward or backward linkages, the institutional setting in the local environment, or local taxation. Inter-industry linkages are covered by the concept of the spatially defined carrying capacity, but other conditions vary by location and economic sector.

These observations have led to the specification of a probability model of dying as follows:

$$P^D(t,t+1 \mid g,i,s,a) = \frac{1}{1+\exp\left\{-\left[\alpha_s+\beta_i+\gamma_s\left(\frac{K_{is}-X_{is}}{X_{is}}\right)+\theta_1\ln(g)+\theta_2\dot{g}+\theta_3\ln(a)\right]\right\}} \tag{6}$$

which is a logistic model. $P^D(t, t+1|g, i, s, a)$ is the probability of dying in the unit time interval for an establishment unit with size g, location i, economic sector s and age a, at time t. This probability depends on a set of sector-specific dummies α_s, a set of location-specific dummies β_i, the market stress variable $(K_{is} - X_{is})/X_{is}$, the logarithm size of the firm, g, the growth rate of the firm,$\dot{g}$, which is defined as $(g(t+1) - g(t))/(0.5 \times (g(t+1) + g(t)))$, and the logarithm of age a. The coefficients of this equation as well as of the equations of all other demographic components were estimated from a 10 per cent sample of all observed firm closures in the period 1990–1991 in The Netherlands (the so-called LISA register of firm units[1] lists the results of the estimation of this logistic regression model. For ease of presentation, we disregard the results for the sector- and regional dummies. More details can be found in Van Wissen and Ekamper (2000).

The results of the estimation show that in general the expectations are confirmed. The coefficient of the market stress variable is negative, as it should be, but insignificant. Moreover, the larger the firm, the smaller the death probability, and the higher the growth rate, which is linked to the dynamic character of the firm, the higher the death rate as well. Finally, the higher the age, the smaller the death rate. Despite the insignificance of the market stress variable in the estimation, all coefficients were included in the micro-simulation model.

5.3 Growth

With respect to growth of firms a number of hypotheses may be postulated. Gibrat's law states that relative growth is proportional to size. The validity of this assumption is questionable. Nelson and Winter (1982) state that growth depends on investments in research and development, which is more concentrated in larger firms. Thus, larger firms tend to grow more than proportional. Another hypothesis states that firms grow in the early stages of their life cycle, until they mature and reach a saturation level. The life cycle may also be viewed as a sequence of events, such as birth, relocation, merger. These life shocks of a firm may trigger new growth. Third, and not surprisingly, the market determines growth to a large extent.

[1] The LISA is an official register of business establishments, and in principle includes all addresses in the Netherlands where work is employed. The total number of units in the register is approximately 550,000. The register is longitudinal: every unit has a unique code. For each unit, the following attributes are collected annually, pertaining to the situation per the 1st of May: address of the unit, number of workers (males, females, part- and full-time), economic activity (four digit level), classification of events since last year (birth, death, migration). The data collection process is organized at the regional level, and therefore, there are regional differences in the classification of events due to regional differences in measurement. In the period 1986–1990 some regions are missing from the data and therefore the period 1990–1991 was used for the estimation of most of the parameters of the model. For estimation purposes a stratified sample with size $n = 10,000$ was taken from the register, with region and economic activity as stratification variables. For the starting population, a sample of size $n = 50,000$ was drawn which allows a reasonable high level of precision at the regional (the so-called 'Corop') level in combination with economic activities, but not at a finer level of detail.

Based on these considerations, the following growth equation was specified:

$$g(t+1|i,g,s) = \exp\left\{C + \alpha_s + \beta_1 \ln\ g(t) + \beta_2(\ln\ g(t))^2 + \gamma \ln \frac{K_{is}}{X_{is}} + \varepsilon\right\} \quad (7)$$

where $g(t+1|i,g,s)$ is the size of the firm at time $t+1$, given that it has attributes location i, size g and economic sector s at time t. C is a constant, and α_s a sector-specific dummy. The covariates include the size of the firm at time t, size squared, and the market pressure variable. ε is a firm-specific random term, which is normally distributed with mean 0 and variance σ. This random term is important in the micro-simulation model, as will be discussed shortly. Table 3 gives the results of the estimation, where, for ease of presentation, the sectoral dummies have been omitted. They can be found in Van Wissen and Ekamper (2000).

The size of the firm at $t+1$ depends on current size and current size squared. The coefficient of the current size is 0.89, whereas the coefficient of size squared is 0.12, which leads to a U-shaped curve. The combined effect implies that for small firms the growth expectation is slightly negative, and for larger firms (> 10 employees) the growth expectation is positive. This curve was fitted on a sample of firms with size between 1 and 25. For larger values than 25 extrapolation of the growth expectation results in too large values. Therefore, for firms larger than 25 employees the growth expectation based on current size is set to 5, which is slightly larger than the expected value at current size 25. Note that due to the other variables in the equation the growth expectation may be smaller or larger than this value. The effect of the market pressure variable $\ln(K/X)$ is positive, as it should. The coefficient is significant at the 0.95 level. The variable age turned out to be not significant, and was left out of the final equation. The same is true for recent growth in the past. The R^2 value of the function is 0.91, which looks quite high, but is mainly due to the inclusion of current size as an explaining variable for future size.

The growth equation cannot be used in a micro-simulation context without problems. To see this we divide the model into a structural part and a random part. According to equation (7) size at $t+1$ is equal to:

$$\mathrm{E}[\ln(g(t+1))] = C + \alpha_s + \beta_1 \ln g(t) + \beta_2(\ln g(t))^2 + \gamma \ln(K_{is}/X_{is}) + \varepsilon$$

or: (8)

$$\mathrm{E}[Y(t+1)] = \eta(t) + e$$

where $\eta(t)$ is the structural part and ε is a normally distributed random component. If we would use only the function $\eta(t)$ to determine the new firm size, the variance of the new firm size would reduce drastically, since $\mathrm{var}(\mathrm{E}(Y(t+1))) = \mathrm{Var}\,\eta(t) + \sigma^2$. If we use only the structural part, the variance of the new firm size would become smaller and smaller over time in the simulation and regress to the mean. In order to prevent this from happening, we need to introduce random variation in the simulation, by including the random part σ. This means that for every firm we need to take a random draw from a normal distribution with mean

0 and variance σ^2 and add this to the structural part. The simulated new firm size is:

$$\hat{g}(t+1) = \exp(\eta(t) + \varepsilon) \tag{9}$$

After simulation of ε the new firm size is determined, and rounded to the nearest integer.

5.4 Firm relocations

Firm relocation is a complex process that involves a number of steps. In firm relocations two types of factors are important: push and pull factors. Push factors cause a firm to re-evaluate its current location, which may result in the decision to move. Typical push factors are: changing market orientation, technological change, space requirements, location costs, accessibility problems, local policy, labour market mismatch. Once a moving decision has been taken, another location has to be found. Here, different locations are evaluated and ranked according to their attractiveness, or pull factors. Typical pull factors are to some extent the mirror of the push factors, but with a positive content: locational quality, better market orientation, higher accessibility, better labour market, more space, local policies, etc. Geographers have noted that in the life cycle of a firm a clear geographical pattern can be discerned. Typical locational behaviour for a firm in its life cycle is to be born in or near the centre of a large city, and, if the firm is successful and grows, to move to the suburbs or beyond. In The Netherlands and other countries this suburbanisation development can be found (Kemper and Pellenbarg 1997). In general, firm relocations are over short distances, and interregional moves are not common for a firm.

The two decision points in the relocation process are maintained in the micro-simulation model. In fact, following standard demographic migration theory and methodology, two steps may be distinguished. First, the decision to relocate or not (move/non-move). Second, and conditional upon the decision to move, the decision of the new region (as stated in Table 1, region is defined at the so-called Corop level). Unfortunately, due to data limitations in the LISA register of firm units, estimation of the second part of the model is not possible. Therefore, the coefficients of the destination choice model were estimated from macro data on observed flows between regions, as reported by the Chambers of Commerce (CoC).

This sequence of decisions is modelled in a sequential logit framework. The first decision, to move or not, is modelled using a binary logit form with outcome the probability of moving in the unit time interval for a firm located in i: $P_i^{M(1)}$, the second step of the choice of the destination region is modelled as a multinomial logit model with outcome the conditional probability of choosing destination region j for a firm located in i : $P_{j|i}^{M(2)}$. The joint decision whether to move and where to relocate is the product of these two probabilities:

$$P_{ij}^{M} = P_i^{M(1)} \times P_{j|i}^{M(2)}. \tag{10}$$

Table 4. Results of the estimation of the coefficients of the binary logit model for moving (Y=1) or not (Y=0)

Variable	Interpretations	Coefficient value
C	Constant	-3.410^{**}
ln (a)	Log of age	-0.245^{**}
$\dot{g}$	Firm growth rate:	0.749^{**}
ln (K_i/X_i)	Market stress variable	-0.004^{*}
Pseudo R^2		0.84

Significance: * = 0.95 level;** = 0.99 level

The binary choice model for moving or not depends on age, recent firm growth, the market stress variable, as well as sectoral and regional dummies. Table 4 gives the results of the estimation of the coefficients of the model, except for the regional and sectoral dummies

The results reveal that the probability of moving decreases with age. This is in line with the observation that inertia increases with age. Next, growth increases the probability of moving. Third, the estimated coefficient value of the market stress variable has the right sign (-), but is insignificant. The negative sign implies that the larger the market carrying capacity, the less likely the firm is to relocate.

The regional choice submodel $P_{j|i}^{M(2)}$ is a multinomial logit model involving distance and the market stress variable. Distance was included both linear and log-linear, to guarantee a close fit both at shorter and longer distances. In addition, an intra-regional dummy variable was introduced, to represent the attractiveness of intra-regional (market) versus inter-regional (market) moves. The specification of the model is:

$$p_{j|i}^{M(2)} = \frac{\exp Z_{ij}}{\sum_{k=1}^{I} \exp Z_{ik}} \tag{11}$$

where:

$$Z_{ij} = \alpha\delta_{ij} + \beta_1 D_{ij} + \beta_2 \ln D_{ij} + \gamma \left(\frac{K_i - X_i}{X_i} \right) \tag{12}$$

In equation (12) the sectoral index, present in the market pressure variable, has been omitted for ease of presentation. Table 5 present the results of the estimation.

When looking first at the coefficients of the distance variables, we note that both are negative, implying, as expected, that short distance moves are more likely than long distance moves. The effect of both distance variables over-estimates the probability of very short moves, and therefore the Cronecker delta, for intra-regional moves, is negative. Finally, the coefficient of the market stress variable is positive, as expected, but not significant. The positive sign indicates that a higher carrying capacity is more attractive to migrating firms. The non-significance implies that this result is likely caused by chance. The high Pseudo-R^2 is related to the observed regularity that most moves are intra-regional, and the model correctly replicates this.

Table 5. Results of the estimation of the coefficients of the multinominal logit model for regional choice

Variable	Interpretations	Coefficient value
$\delta_{ii'}$	Cronecker delta for intra-regional moves $\delta_{ii'} = 1$ if $i = i'$, else 0	-0.390^{**}
$D_{ii'}$	Straight line distance between region i and i'	-0.062^{**}
$\ln D_{ii'}$	Log of straight line distance between i and i'	-0.216^{**}
(K_i/X_1)	Market stress variable	-0.004^{*}
Pseudo R^2	Explained variance	0.34

Significance: * = 0.95 level;** = 0.99 level

6 An empirical application

In this section we present a number of results of the simulation model for the period 1991–1998. Despite the spatial character of the model we will concentrate here on some national outcomes of the model: the stock and flow of the population and the vital statistics. More results, including results of the growth module and spatial dimension, may be found in Van Wissen and Ekamper (2000).

There are serious measurement errors in the estimation of the number of firms and business establishments as well as events. Moreover, there are many different definitions of what exactly constitutes a firm or a business establishment, or an event. As a result, producing vital statistics about the population of firms and establishments is difficult; not only in estimating the size of the population, but also in measuring the right number of vital events (births, deaths, migration, growth and decline). For instance, in 1994 Statistics Netherlands (SN) estimated that there were 608 thousand firms in The Netherlands and 668 thousand business establishments. In 1996 the number of firms had grown to 626 thousand. The data register of the Association of Chambers of Commerce (CoC) estimated in 1996 a total of 906 thousand establishments, which is significant more than the estimate of SN and LISA. According to the LISA register, the number of establishments in 1991 was 550 thousand. Even when taking into account the four-year time difference and a high growth rate, the difference is too large. Likewise, the number of firm formations in 1996 was, according to SN 34 thousand. The CoC estimated a total of 48 thousand new business establishments. Comparable figures for the number of deaths in 1995, are 14 thousand according to SN and 42 thousand according to the CoC. In other words, we have a serious measurement problem (Kemper et al. 1996; EIM 1995). This problem is not easily resolved, although progress is being made in better definitions and measurement instruments. For the moment, we only look at the indexed growth of each register, and assume that they are reasonable indications of the real growth in the number of business establishments. Formally we should only look at the data from the CoC, because they pertain to the same units (business establishments) as the basic unit in this simulation. However, for comparison purposes, we have also included data on firms by SN.

6.1 Size of the population

Figure 2A presents both the observed number of firms, as registered by LSN in the period 1991–1997, as well as the number of business establishments by CoC. The dashed lines give the observed indexed trend of firms by SN and of business establishments by CoC. The solid line is the simulated trend. The observed growth in the number of business establishments, according to CoC is very high: on average 5.2% per annum. The trend in the number of firms observed by SN is much more modest but still high: a growth of 2.3% per annum.

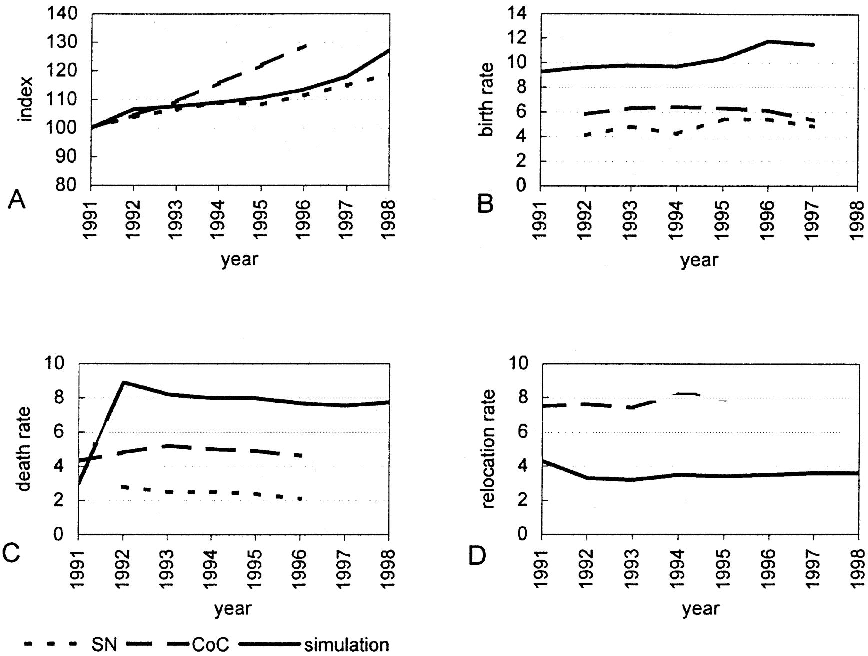

Fig. 2A–D.. Graphical overview of vital statistics of the population of firms/ business units in 1991–1998. **A** Observed number of firms (SN) and business units (CoC), and simulated trend; **B** Observed formation rate of firms (SN) and business units (CoC), and simulated trend in formation rate; **C** Observed closure rate of firms (SN) and business units (CoC, and simulated trend in closure rate; **D** Observed relocation rate of business establishments (CoC) and simulated trend in relocation rate

6.2 Births

The micro-simulation model predicts continuous and increasing growth in the number of firms after 1991. This is the result of birth and death processes. The time path of the birth rate can be observed in Fig. 2B. The two dashed lines are the observed firm formation rate (SN) and business establishment formation rate (CoC) respectively. The solid line is the outcome of the simulation model. The birth rate is about twice as high as the birth rate in the SN data and also significantly higher than in the CoC data register. These different levels are primarily caused by the differences between the three data registers LISA, SN and CoC, although SN and CoC converge in the course of the nineties. A second difference is the slightly downward trend observed by both SN and CoC after 1995, whereas the model simulation shows a slight upward trend until 1996, after which a small decrease occurs.

6.3 Deaths

Turning to deaths, it may be observed that there is a large difference between the death rate of firms by SN and that of business establishment closures by CoC in The Netherlands (Fig. 2C). Although the units are different and cannot be compared directly, it is highly unlikely that the observed difference is attributable to different definitions of the unit. Defining the event of death is not without problems either. A firm is an organization that changes its character over time. In order to distinguish between an existing firm changing character or a firm death (eventually followed by a firm birth) continuity rules have to be defined (see Willeboordse 1986 for an overview of the rules used by SN). Although these definitional issues are extremely important, we will not go into more detail here. In the model, a death is defined in an administrative sense as used in the LISA data register, which is not similar to SN, nor CoC.

The initial death rate (which is equal to the starting value observed in LISA) is close to the level observed by SN and CoC, but jumps in the second year to very high levels. This is clearly an initial values problem. The probability of dying for a unit depends, inter alia, on recent growth. In the first simulation year, recent growth is defined as the average growth in the period 1986–1990, which is, by definition, much less volatile than annual growth. After the second year, increased variation is introduced when the first simulated growth events are input in the death equation. After this initial year, the death rate decreases slightly. Observed death rates for firms (SN) or business establishments are much lower. Clearly, the death equation could be improved using more information on recent firm behaviour. It appears that the impact of recent growth, once measured correctly, should be re-estimated.

6.4 Migration

Firm relocations haven been reported regularly by Kemper and Pellenbarg for the Netherlands (1993, 1995, 1997) and Pellenbarg (1996). Their figures are based on the register of the Association of the Chambers of Commerce (CoC). In 1991 they counted 54 thousand firm unit relocations. The comparable number in the LISA database for the period May 1990-May 1991 is only 21 thousand. The quality of the LISA data register is clearly problematic in this case. For instance, the total number of reported outmigrations is 21 thousand, but the reported number of inmigrations, which should be equal to the number of outmigrations, is only half of this figure, namely 12 thousand. The parameters of the simulation model are based on the LISA data register, and it is therefore no surprise that the simulated number of firm relocations is far below the number observed in the CoC register (Fig. 2D). But not only the level, also the trend is different. According to the CoC data, as reported by Kemper and Pellenbarg, the migration rate increased between 1993 and 1994 from 7.4 to 8.2%. In the model results, a sharp downward shift occurs in the first simulation year, after which the migration rate increases slightly over the whole simulation period. The initial decrease is due to initial values problems, similar to that observed in the death rate. Here again the problem is to set the values of the variable recent growth. This variable was estimated as the annual average of the growth observed in four years. Extreme values are therefore levelled out and the effect of growth is therefore underestimated.

Overall, it can be said that the model suffers from serious initial values problems. In the first year in a number of components the model adjusts to a significantly different intensity due to wrong initial values of the determining functions. Once at a different level of intensity, the model behaves smoothly, and more or less parallel to observed trends.

7 Conclusions

Setting up and designing SIMFIRMS was and is to a large extent a pedagogic methodological exercise. One needs to take a holistic approach to the dynamic processes of change in the population of firms or business establishments. At the same time the specification of each of the sub-modules requires a microscopic view to each of the components. The combination of both approaches is not only interesting for improved model building, but interesting in its own right. A prime motivation of the project is to gain insight in the spatial development of the economic sector by looking at the individual actors in the economic process. The cohort-component model is in principle suited for this task, but there are many problems to be solved on the route. From a holistic point of view, the model results point at a number of interrelations between components that would be more difficult to see in isolation. Examples of these interrelations in the model were for instance the relationship between birth on the one hand and growth of existing firms on the other hand. In regions were births are limited due to, for instance a low value of the carrying capacity, substitution of economic growth takes place in existing firms instead of new firm formations. Or, in regions where most indicators are favourable, such as the level of the market stress, a highly educated labour supply, and ample commercial land, a synergetic effect occurs whereby regional economic growth is very high. These observations may lack quantitative precision when compared to reality, but may help to improve our thinking and understanding of the dynamic processes that govern the population of firms, and thus regional economic processes.

Nevertheless, it would be unrealistic to expect at this stage that simulations of this type will give reliable projections of the future of the population of firms.

Both data and theory need to be improved substantially before we arrive at more satisfactory results. SIMFIRMS was designed to explore the path in this direction and sketch possible future directions of research. Micro-models may give additional insight into the mechanisms of development, and to all sorts of more detailed questions. But one should be careful in interpreting the outcomes in strict quantitative terms. Maybe this will change in the future, with better models and data, but a lot of work needs to be done. Therefore, one of the most important outcomes of the model is a research agenda to fill in the gaps in our knowledge of the process.

This research agenda has a theoretical, methodological and empirical chapter. From a theoretical point of view, the model reveals our relative ignorance in a large number of economic demographic processes. In good demographic tradition, an interdisciplinary approach should be adopted to make progress (Dykstra and Van Wissen 1999). Theoretical insights may be gained by incorporating elements from organizational ecology, industrial organization and evolutionary economics. From a methodological point of view, the main issue is how to apply and adapt the apparatus and concepts of human demography in the field of economic demography. Clearly, the cohort-component method, which is at the heart of SIMFIRMS, should be the starting point, but the real challenge is how to develop new concepts that reflect the processes that drive each of the components. Age and sex, the bread-and-butter variables of demographers, do not bring us very far in this respect. Maybe this challenge is most appropriate for the process of firm birth, and its relations with the size and quality of the labour force and the stock of firms. Of course at the micro level much is known about the behaviour of new entrepreneurs (Beesley and Hamilton 1994; Van Praag 1996) and there are many studies linking regional characteristics to new firm formation (Storey 1982; Reynolds et al. 1994; Wever 1984). However, we think that the demographic framework of risk and exposure may reveal new insights into this process. This requires the proper definition of the population(s) at risk, as well as the definition and measurement of the risk.

Traditional demographic variables are simply not sufficient to get a hold on the dynamic behaviour of the population of firms. Of crucial importance in economic demographic modelling is to incorporate the concept of the market. Here, the concept of carrying capacity was used to this end. Carrying capacity is the driving force behind all demographic components. It is defined here as market capacity, or the maximum level of demand the market can exert. Although this term is very important in organizational ecology, its empirical basis is still weak, and the present application is no exception to that. Much work needs to be done to give it a firmer basis in this field, both at the theoretical level (for instance its relationship with prices, the ecological concept of ‘niche width’ (Freeman and Hannan 1983) and at the empirical level. Among other things, the functional form of the variable needs further study. Demographers are usually good at empirical work: measurement, precise description and careful empirical analysis are at the heart of the discipline. There is certainly a need for such an approach, as should be obvious from the large variation in observations reported in the empirical section of this article. Indeed, the data are of course always a problem. Surely, designing an operational simulation model at this stage is too early, if we are still lacking high quality data to base our parameter estimations on, and to use as base populations, or for validation. But data registers do not improve without reason. One has to ask the right questions to the data before additional investments are made to give the right answers. Only by asking analytical questions to the data, derived, for instance from problems we face in designing a simulation model, we may expect to have better quality data in the near future.

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