On the Ontology of Events in Demographies of Organizations

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2004

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abstract:
Demographies of organizations apply demographic methods to study change in populations of organizations. There are (at least) five relatively independent demographies of organizations. All of these have to deal with the same conceptual and theoretical problems that are mainly the result of the biological analogies on which they are based. All of these demographies lack a clear and consistent conceptual framework. Such a framework could not only help solve these conceptual problems, but would also improve the possibility of knowledge exchange between the different fields. Ontology is – among others – the scientific field that specifies such conceptual frameworks. Besides introducing and explaining this type of ontology, this paper proposes an ontology of events in the demographies of organizations. Eight basic types of vital events can be distinguished and are defined by means of symbolic logic and set theory: founding, termination, split-off, take-over, split-up, merger, essential change, and population transfer. All other types of events are either supertypes or are non-vital events. Non-vital events can be transformed into population transfer events. All demographies of organizations share these events, this ontology.

keywords:
ontology, taxonomy, events, demography, organizations, firms, households

INTRODUCTION

Over the last three decades, demographic methods and concepts have been increasingly applied to institutional rather than biological entities. Concepts and methods once developed and utilized to describe and analyze changes in human populations are now also used to analyze changes in populations of organizations. Moreover, this development has taken place in not just one single scientific field, but – relatively independently – in at least five. Four of these deal with organizations such as firms, associations and unions. The fifth studies households and families, which can be regarded as organizations as well (*e.g.* Khalil 1995).

These five different *demographies of organizations* not only originated in different scientific fields, but also in different geographical locations:

1) the *demography of organizations* in American economic and organizational sociology (Hannan & Freeman 1977; 1989; Carroll & Hannan 2000);
2) the *démographie des enterprises* in French economic and business history (AFHE 1983; Jobert & Chevailler 1986; Jobert & Moss 1990; Jequier 1995);
3) the *demography of firms* in European (originally mainly Dutch) business statistics (Willeboordse 1986; Struijs & Willeboordse 1990; Kloek 1994);
4) the *demography of firms* in Dutch economic geography (van Wissen & Gordijn 1992; van Dijk & Pellenbarg (eds.) 1999b; van Wissen 2002);
5) the *demography of households and families* in (human) demography (Glick 1959; Wargon 1974; Burch 1979; Bongaarts, Burch & Wachter (eds.) 1987).

What all of these approached have in common is that they – to a certain extent – are based on biological analogies. They all apply tools, concepts and/or theories based on biological entities to institutional entities. However, 'a firm is a socioeconomic organization, to which biological laws do not apply' (van Wissen 1997, p. 222).

The same is true for any other type of organization. With respect to organizational ecology, Young wrote that:

> definitions are vague and difficult or else entirely lacking. (…) One must conclude that the concepts of biological ecology do not lend themselves readily to organizations. (…) These concepts have to be stretched beyond recognition to fit organizational phenomena. (Young 1988, p. 21)

Consequently, in all of these fields similar methodological and conceptual problems arose (*e.g.* Carroll & Hannan 2000; Jequier 1995; Willeboordse 1986;

van Dijk & Pellenbarg 1999a; Bongaarts 1983). Most of these problems seem to be effects of the application of biological concepts and are, therefore, of a conceptual nature. For example, in human demography, there are only two ways of entering a population: birth and immigration. Similarly, there are also only two possible exits: death and emigration. However, firms, households and other organizations can be newly founded, split of a pre-existing organization, result from a merger, etc. Hence, there is no single, uniform equivalent of birth in institutional populations. Neither is there a single, uniform equivalent of death.

If the concepts of 'birth' and 'death' cannot be applied to firms or other organizations, the corresponding demographic rates , 'birth rates' and 'death rates', cannot be measured. Therefore, the demographies of organizations need other concepts, other events and other measures (rates). However, thus far it seems that most demographies of organizations still lack a coherent conceptual framework (*e.g.* Bongaarts 1983; Willeboordse 1986; van Wissen 2002).

The field that studies and specifies conceptual frameworks is *ontology* (or at least a specific form thereof). '*An* ontology is an explicit *specification of a conceptualization*' (Gruber 1993, p. 200 – my italics). Ontologies specify the basic building blocks of theories, but also the categories of measurement. While epistemology provides the foundations for theory *testing*, ontology provides the foundations for theory *building* and for *measurement*. Ontologies, however, may serve further purposes. Shared ontologies allow communication and knowledge exchange between scientific disciplines or theories, and a shared ontology of demographic events (and entities) is a requirement for the use of computers and the internet in the education of demographies (Devedžić & Devedžić 2002).

To facilitate (improved) communication between the different demographies of organizations an ontology is needed that specifies the basic conceptual framework (or part thereof) of all of these without enforcing the theoretical insights of any one of them. Hence, while the ontology specifies the building blocks of theory, these building blocks have to be *theoretically neutral* themselves. Moreover, the building blocks have to be usable in theory building *and* as units of measurements (or have to be easily adaptable to these purposes).

The goal of this paper is to specify part of this shared conceptual framework of the demographies of firms. This part is the *ontology of events*. Such an ontology specifies all possible events in a theoretically neutral (or at least as neutral as possible) fashion. Before this ontology is specified, the following two sections more extensively explain the nature and problems of the demographies of organizations and the merits and methods of ontology and the related tool of conceptual analysis in social science.

DEMOGRAPHIES OF ORGANIZATIONS

Demographies of organizations apply demographic methods to the study of organizations and organizational behavior. The central feature of these approaches is their focus on the level of the population rather than on the individual organization. Within the set of demographies of organizations, the demography of households and families holds a special position. It studies a very specific subject that is not studied in any of the other demographies. The other four all deal with more or less the same subjects: firms, associations, unions and the like.

Demographies of organizations have been developed in different fields and with different labels. Of course some of these labels, such as the 'demography of households and families', point at very specific subjects, but the following are all labels for demographies of more or less the same subjects: 'demography of organizations' (Hannan & Freeman 1989); 'demography of enterprises' (AFHE 1983; Kloek 1994); 'corporate demography' (Carroll & Hannan 2000); 'demography of corporations and industries' (Carroll & Hannan 2000); 'industrial demography' (van Wissen 2000); 'economic demography' (van Dijk & Pellenbarg 2000; van Wissen 2000); 'demography of firms' (Willeboordse 1986; van Dijk & Pellenbarg (eds.) 1999b); 'firm demography' (van Dijk & Pellenbarg 2000); 'demography of the firm' (van Wissen 2000); and finally, the awful 'firmography' (van Dijk & Pellenbarg 2000).

The modern demography of organizations was probably introduced by Stinchcombe (1965) as the study of (mainly) 'births' and 'deaths' of organizations, although he later used the term to refer to the human demography of the people in an organization (which is now often labeled 'organizational demography') (Stinchcombe, McDill & Walker 1968). The demography of households and families, however, is at least a decade older (*e.g.* Glick 1959) and Carroll and Hannan (2000, ch. 3) describe some earlier forms of what they call 'corporate demography'.

Hannan and Freeman (1977; 1989) incorporated the demography of organizations into *organizational ecology*, a theory and field within organizational and economic sociology that applies ecological concepts and theories to populations of organizations. While organizational ecology is very rich in theory, most other demographies of organizations are extremely poor in this respect. The *demography of firms* or *enterprises* in business statistics, (Dutch) economic geography and (French) economic history is mostly (but not exclusively) limited to the *description* of population change. While organizational ecology is a theory of organizational behavior based on a biological (*i.e.* ecological) analogy, these demographies of firms are primarily strategies for empirical research. Of course, a demography of firms may be used as a strategy to test the theories of organizational ecology and organizational ecology may influence actual research questions in the demography of firms, but these connections only reinforce the distinction between theory and research strategy (or instrument). However, to make such a 'division of labor' or any other knowledge exchange between these different fields possible, a shared ontology is needed.

As a research strategy, a demography of firms may be useful in economic and organizational sociology (*i.e.* organizational ecology), but also in economic geography and economics itself. A demography of firms is a two-step strategy of (1) calculating measures of population change and (2) trying to explain these by or use these as an explanation for other phenomena. For example, numerous studies have been published on the relation between 'firm birth' and employment growth (*e.g.* Birch 1979; Reynolds 1987; Barnes & Haskel 2002; van Stel & Storey 2002). Some of these studies find positive correlations while others find no relationship at all. Interestingly, Heshmati (2001) showed that the effects found in empirical studies on the relationships between growth, size and age of firms are dependent mainly on the research methods *and definitions* chosen (see also Brons 2005). Rightly, Willeboordse (1986) claimed that a meaningful demography of firms demands clear definitions of the concept of the firm and the events (or 'changes' as he calls them) firms may experience.

Of the different demographies of organizations, the *demography of households and families* was probably the first to explicitly discuss its conceptual foundations. In the 1980s the methodological debate in this field focused on the question whether its analyses should be based on households or families, or the individuals within those households or families. Some demographers (*e.g.* Glick, 1959; Burch, 1979; Murphy, 1996) insisted that family demography should use the family as its basic unit of analysis. But others argued that 'demography is not well equipped to study households or any other group of persons which forms a unit either biologically, socially, or economically and which therefore should be treated as a unit. The unit of analysis in demography has traditionally been the individual' (Willekens 1988, p.87) and that 'families and households are slippery little devils; they can divide and merge, and there is no way to tell when one family ceases and the next begins' (Ruggles 1990, p. 23).

Rather than discussing the ontological foundations of the field, most family demographers chose to adopt another perspective. Households and families were regarded as properties of single individual members: the heads of households (*e.g.* Brass 1983; Willekens 1988; Keilman & Keyfitz 1988). This solution (if it is one) was not only defended as an escape from insurmountable methodological problems but also with the argument that it ultimately is the individual which should be of interest (*e.g.* Ruggles 1987; Keilman 1988). This latter argument, however, does not make much sense since it is households the field is interested in, not heads of households. Nevertheless, the approach chosen does work in the demography of households and families. Theoretically it is of course incorrect to replace households by heads of households (with the households as their properties) in the analysis, but in practice there is little difference. The same approach, however, would not work in the demography of firms. An approach that regards a multinational corporation (or even most smaller firms) as a property of its CEO is obviously absurd. (Moreover, such an approach would probably not be acceptable to more theoretically informed branches of the demographies of organizations such as organizational ecology.)

The main task of the demographies of organizations is to study vital *rates* of organizational events (*e.g.* Hannan & Freeman 1989). Rates are the most basic tools or measurements of demography. A rate is the number of entities that experienced a certain event in a certain period, divided by the total population that could have experienced that event in that period (*e.g.* Palmore & Gardner 1983). In other words: a rate is events (or occurrences) divided by population at risk. However, in demographies of organizations, there are a large number of ill-defined events with very unclear and sometimes extremely heterogeneous populations at risk. This seriously hampers measurement of the corresponding rates in demographies of organizations.

Organizational 'birth' may serve as an example. As events in human demography and demography of organizations are not completely identical, it is not clear at all what 'firm birth' means exactly and how to measure a 'birth rate' of firms. The choice at which point something is considered to be a new firm and, hence, it is 'born' is not an inconsequential one (Hannan & Freeman 1989;

Baldwin *et al.* 2002). The later the demarcation point of birth in the founding process of new firms, the lower the resulting 'birth rate' (and the higher the 'life expectancy'). Secondly, it is not immediately clear which types of entry should be considered a 'firm birth' and how to classify the other types of entry events. And thirdly, the problem is further complicated by the fact that new firms may have both institutional and human founders. This fuelled a discussion on whether the population at risk in birth rates of firms should be defined as the total labor supply (*labor market approach*) or as the pre-existing population of firms (*organizational approach*) (*e.g.* Keeble *et al.* 1993; van Dijk & Pellenbarg 1999a; van Wissen 2000).

These theoretical problems may have serious empirical repercussions, which is illustrated easily by comparing the 'birth rates' measured by the two approaches mentioned above for 531 (of 572) Dutch municipalities in 1997 (the 41 missing cases are mostly very small rural municipalities) (data sources: CBS/VKK 1999; CBS 2001). The two measurements prove to be dramatically dissimilar. In fact, the (Pearson) correlation between the two 'birth rates' is as low as 0.262.

An obvious solution to this problem is to discard the biological analogy, to discard the concept of 'birth' and to replace is by a set of appropriate concepts describing the possible entry events in demographies of organizations. The ontology of events specified in this paper offers such a set of concepts (and their definitions) and similarly specifies exit and other events. Before we turn to the ontology of events, it might be useful to more extensively explain the use of ontology and conceptual analysis in social science first.

ONTOLOGY AND CONCEPTUAL ANALYSIS

Like all human behavior, science is a linguistic effort. Without language there would be no science. Language provides the building blocks for science. Concepts and grammar (semantics and syntax) are the bricks and mortar of language. Sometimes, however, these bricks seem to be made out of jelly. Conceptual analysis is the elucidation of vague, but often very common, concepts. Famous early predecessors of conceptual analysis, Socrates and Plato, for example, discussed (mainly) ethical concepts, such as 'goodness', in an attempt to find objective descriptions or definitions of these concepts. (For an extensive review of the history of and literature on conceptual analysis see Brons 2005, ch. 2.)

Conceptual clarity is necessary to enable reasonable communication within (social) science: ‘A good word is like a good tree whose root is firm, (…) it gives its fruit at every season’ (Quran 14:24). The ‘bad trees’, on the other hand, are the all too ambiguous concepts that cause misunderstanding and ambiguity in science and philosophy. Wittgenstein argued, for example, that (a lot of) philosophical problems originate from erroneous use of language: ‘Denn die philosophischen Probleme entstehen, wenn die Sprache feiert’ (For philosophical problems arise when language goes on holiday.) (Wittgenstein 1971 [1953], § 38). The same is (to a large extent) true in (social) science (*e.g.* Winch 1958; Koepsell 1999; Brons 2005).

Although ontology is traditionally regarded as part of metaphysics and dealing with ‘existence', it is also the philosophical and scientific field that deals with conceptual frameworks, rather than single, isolated concepts as in conceptual analysis. Nevertheless, there are strong links between ontology, even in this ‘modern’ sense, and traditional metaphysics. Metaphysics is often interpreted as the study or philosophical theory of what is beyond nature and experience, of some more fundamental structure of reality. Although the term ‘metaphysics’ became deeply embedded in philosophical terminology, it, however, hardly has a fixed meaning. Bunge (1977), for example, distinguishes ten different interpretations, while he suggests himself that ‘metaphysics is *general cosmology or general science*: it is the science concerned with the whole of reality’ (p. 5). All scientific effort is ultimately grounded in some metaphysical theory (*e.g.* Russel 1948; Lakatos 1969; Harvey 1969). Metaphysics as the study of this ‘ultimate reality’, however, is not what concerns us here. What does concern us is the fact that ‘*metaphysics can dig up, clarify, and systematize* some basic concepts and principles occurring in the course of scientific research and even in scientific theories’ (Bunge 1977, p. 23).

In the early 18th century Wolff proposed to divide metaphysics in four parts one of which was ontology, which he defined as the study or theory of being or existence. Traditionally, this philosophical or *existential ontology* was the study asking ‘What things exist?’ In recent decades, however, the concept of ‘ontology’ was associated with new fields and new questions.

1) The key question in ontology in artificial intelligence and knowledge representation is: ‘What things should we represent?’ This is the field of *representational ontology* (*e.g.* Uschold *et al*. 1997).
2) According to Koepsell (1999) ‘many real world problems do result from unclear ontologies’ and the goal of *applied ontology* is to remedy this ‘by

careful study of the categories of the social world' (p. 220). Applied ontology is often intended to specify the conceptual framework or language of a specific scientific field (*e.g.* Smith & Mark 1999). In practice, representational ontology and applied ontology are closely related, the main difference being that representational ontology is normative, while applied ontology is descriptive.

3) Applied ontology is (also) closely related to *scientific ontology*, although there are some differences. Scientific ontology is more explicitly philosophical and more similar to traditional existential ontology than applied ontology. 'The analysis we expect from scientific ontology concerns, in particular but not exclusively, the ontological categories and hypotheses that occur, either in a heuristic or in a constitutive capacity, in scientific research' (Bunge 1977, p. 10).
4) *Social ontology* studies what ultimately makes up social reality (*e.g.* Searle; 1995; Weissman 2000). As such it seems to be a special type of existential ontology. However, social ontology could also be interpreted as the ontology of the social sciences. Hence, like scientific ontology, social ontology is a mix of existential ontology and applied ontology.
5) *Formal ontology*, finally, is the study of formal categories such as parts and wholes, introduced by Husserl (1900-1) (*e.g.* Smith & Künne (eds.) 1982; Smith & Mulligan 1983; Smith 1996). Formal ontology has to be distinguished from formalization in ontology, which is increasingly applied in all of these fields.

Besides these fields that are explicitly labeled 'ontology' there is another that has a similar goal, but with a much more pragmatic perspective. *Statistical classification* is the study and definition of the basic units of measurement in some (social) system. In practice statistical classification is nearly identical to applied ontology, although it generally prefers measurability to theoretical correctness. As will be shown below, most of the research on the ontology of the demographies of organizations is actually statistical classification.

The concept of 'ontology' does not only refer to scientific or philosophical fields or theories but also to what these fields study. *An* ontology is defined by Gruber (1993) as a 'specification of a conceptualisation' (p. 200). Similarly, Uschold and Gruninger (1996) think of an ontology as 'an explicit account of a shared understanding in a given subject area' (p. 93). An ontology is a specified set of concepts, a conceptual structure or framework, a language. An ontology of a scientific field or theory specifies the building blocks of that field or theory, the basic 'things' (objects, events, properties, etc.), that constitute its (theoretical) universe. Hence, an ontology of the demographies of organizations provides a complete specification of the conceptual framework of the field.

Ontologies are structured sets of definitions and like definitions they should be *non-creative* (Leśniewski 1931; Suppes 1957). Ontologies are not intended to give new 'information' but to (better) structure what is already – although often implicitly and unconsciously – known. *A 'good' ontology is a systematic representation of the obvious*.

This does not mean that ontological research is unnecessary. Firstly, ontology structures what was unstructured before. Without conceptual analysis, concepts are like shapeless chunks of clay. Conceptual analysis transforms these into bricks. Ontology adds structure, it builds a wall out of the bricks, a wall that should be strong enough to support theoretical and empirical research. Secondly, without ontology no data collection is possible. Concepts and ontologies structure experience and observation: 'Abstract concepts are but as flowers gathered, they are only moments dipped out from the stream of time, snap-shots taken, as by a kineotoscopic camera, at a life that in its original coming is continuous' (James 1909, p. 235). Thirdly, ontologies are necessary for (inter-theoretical) communication. Without a shared conceptual framework, a shared set of basic definitions, in one word: a shared ontology, no knowledge exchange, no synthetic theories, no division of labor (see above) is possible.

There is no standard methodology in any of the above mentioned types of ontology (*e.g.* Uschold & Grunninger 1996; Rosenberg 1997 – statistical classification even seems to be completely devoid of explicit methodology) and neither is there in conceptual analysis, but that does not mean that anything goes. (The most influential methodologies of conceptual analysis are probably those forwarded by Sartori (1984) and Wilson (1963) (see also Brons 2005, ch. 2), but these are of limited relevance in ontology building.)

The most basic rule in ontology is 'Ockham's razor': *Entia non sunt multiplicanda praeter necessitatem* (entities should not be multiplicated more than necessary). (Although attributed to the 14th century philosopher Ockham, it has not been found in this form in any of his works.) Ockham's razor is the methodological rule in ontology that one should not assume more entities than necessary and that one should prefer the ontology that contains the smallest number of categories or types of entities:

> Our acceptance of an ontology is, I think, similar in principle to our acceptance of a scientific theory, say a system of physics: we adopt, at least insofar as we are reasonable, the simplest conceptual scheme into which the disordered fragments of raw experience can be fitted and arranged. (Quine 1948, pp. 35-36)

Bunge (1977) proposed ten rules for scientific ontology, which are also relevant in applied ontology. However, Bunge's rules seem to be a bit obvious. His most important (most relevant) rules are: (1) formalize everything (in logical, set-theoretical or other mathematical notation); (2) avoid words with an ambiguous meaning; (3) be rigorous and exact; (4) use objective terms only; (5) be systematic; (6) test for coherence but also for compatibility and contiguity with contemporary science. The most important of Bunge's rules may be the first: formalization. Most of the others will apply automatically in formal analyses. Much earlier Russell asserted that 'wherever possible, logical constructions are to be substituted for inferred entities' (1914, p. 115).

Formalization, however, has its limits (we'll come back to that later) and there are other ways to be 'rigorous, exact and systematic'. The most widespread method in applied ontology is probably the application of *taxonomic* structures (*e.g.* Jones & Paton 1999; Welty & Guarino 2001). Taxonomies are tree-shaped figures characterized by *genus* - *species* relations between the objects on different levels. Of all two objects connected by a line, the object on the higher level is the *genus* or supertype and the object on the lower level is the *species* or subtype. This implies, that anything that is true for the species, must be true for the genus; or – in other words – the set of objects that satisfy the conditions of the genus must contain the (sub-) set of objects that satisfy the conditions of the species. In traditional taxonomies (in biology, for example) objects are a species of one and only one genus. This, however, is not necessarily the case in ontology (*e.g.* Sowa 1995; Uschold & Grunninger 1996; Jones & Paton 1999). There may be more lines connecting an object on one level to the objects on a higher level. For example, actors in social systems generally have more than one role: a seller is usually also a buyer.

Gruber (1995) suggested a number of further rules or guidelines for ontologies that are intended for knowledge sharing. Most important (least overlapping with the above) are *extensibility*, *minimal ontological commitment* and *minimal encoding bias*. According to the extensibility guideline ontologies should be extendible for new (although related) applications. The minimal ontological commitment guideline suggests that 'an ontology should make as few claims as possible about the world being modelled, allowing the parties committed to the ontology freedom to specialise and instantiate the ontology as needed' (Uschold & Grunninger 1996, p. 105 – above this was labeled 'theoretical neutrality'). The minimal encoding bias guideline points out that ontologies should not depend on the (formal) language chosen.

The possibly most important (an possibly also the most obvious) methodological rule in both ontology and conceptual analysis can be derived from Quine's (1968) principle of *ontological relativity*:

> What makes ontological questions meaningless when taken absolutely is not universality, but circularity. A question of the form 'What is an F?' can be answered only by recourse to a further term: 'An F is a G'. The answer makes only relative sense: sense relative to an uncritical acceptance of 'G'. (p. 204)

Hence in ontological research and/or conceptual analysis more ambiguous terms or concepts have to be defined in less ambiguous or preferably even unambiguous terms.

As mentioned above, formalization may be a useful tool in ontology building and conceptual analysis. Applicable formal methods have been developed in early 20th century philosophy and are still being developed in sub-fields of artificial intelligence and computer science, such as knowledge engineering and conceptual modeling. The most important tools are variants or adaptations of *symbolic logic*, especially first-order logic (FOL), and *set-theory* (which is basically FOL plus the $\in$-symbol). Mathematical concepts, for example, were analyzed logically by Frege (1884) and Whitehead and Russell (1910-3). More recently, symbolic logic has been applied in conceptual analysis in formal ontology (see above) (*e.g.* Smith 1996).

Alternative formal languages that can be applied in conceptual analysis and ontology include *conceptual graphs* (Sowa 1984; 1992) and *description logic* (*e.g.* Brachman & Levesque 1984; Donini *et al.* 1991). Conceptual graphs were originally intended to elucidate conceptual structures, sets of interrelated concepts, but can also be used in conceptual analysis. The purpose of conceptual graphs 'is to express meaning in a form that is logically precise, humanly readable, and computationally tractable' (Sowa 1992, p. 3).

Since most of these techniques may be translated into first-order logic and set-theory (on the relationship between conceptual graphs and first-order logic see *e.g.* Wermelinger 1995; Amati & Ounis 2000), and these latter formal languages are most widespread, it seems most practical to use these as a standard. In some cases this standard may have to be extended, however. The formal definition of some concepts needs higher order logics or indexing that is not standard in first-order logic. In first-order logic and set-theory there is a number of possible basic structures for definitions of the objects in an ontology (or a single concept in conceptual analysis). The most basic is:

$$\forall x\ [\ A(x) \leftrightarrow B(x)\ ] \qquad \text{(def. 1)}$$

(for all x, x is an A if and only if it is a B), which defines A as any 'object' to which condition B applies. Condition B is generally a set of conditions $B_1(x) \wedge B_2(x)$ etc. Hence the basic symbols in formal definitions are the universal quantifier $\forall$, and the connectives $\wedge$ (and, conjunction) and $\leftrightarrow$ (if and only if, iff, biconditional).

In taxonomic structures the set of conditions B in definition 1 is composed of the two subsets that apply to the species only and those that apply to the genus (and therefore also to the species). Hence, if a genus G is defined by its property (or set thereof) B_G:

$$\forall x\ [\ G(x) \leftrightarrow B_G(x)\ ] \qquad \text{(def. 2a)}$$

then its species S1 is/are defined by the properties of the genus B_G plus the specific properties of this/these species $B_{S1:}$

$$\forall x\ [\ S1(x) \leftrightarrow B_G(x) \wedge B_{S1}(x)\ ]\ . \qquad \text{(def. 2b)}$$

The species S1, however, may be a genus itself to species S2 further 'downwards' in the taxonomy:

$$\forall x\ [\ S2(x) \leftrightarrow B_G(x) \wedge B_{S1}(x) \wedge B_{S2}(x)\ ]\ , \qquad \text{(def. 2c)}$$

in which B_G *and* B_{S1} are the properties that define the genus and B_{S2} is what is specific for the species. For every object on a lower level in the taxonomy, the properties of the object on the higher level it is connected to (*i.e.* is a species of) are a subset of its properties and some more specific properties (to define the species) are added.

Not all concepts can be defined as in definition 1 or 2. Many concepts in social science refer to sets of objects rather than to individuals:

$$A =_{def} \{ x \mid B(x) \} \qquad \text{(def. 3)}$$

(A is the set of all x-s that are B-s). An example of such a definition is this formal definition of the concept of 'culture' (Anderson & Moore 1963; Brownstein 1995):

$$\text{'culture'} =_{def} \{ \alpha \mid \exists x,y \Diamond [x \textit{ learns } \alpha \textit{ from } y \wedge x \neq y] \} \qquad \text{(def. 4)}$$

('culture' is the set of α-s for which there are an x and a y (that are not the same thing) such that it is possible that x learns α from y).

A further class of 'objects' that are generally not easily defined as in definition 1 or 2 are events. Events (in general) are usually defined as changes in (physical) objects (*e.g.* Lombard 1986). Hence an event could be defined as:

$$\forall x,t,t' [\exists e [A(e,x,t,t')] \leftrightarrow \exists B [\neg (B(x)_t \leftrightarrow B(x)_{t'})]] \qquad \text{(def. 5)}$$

(for all objects x and points in time t and t' there is an e and e is an event of type A (happening to x in period t to t') iff there is some property B such that x was a B at either t or t', but not at both). In other words: there is an A-event if there is a change in condition B of x. Or alternatively: an A-event is a change in condition B of an x. Note that in definition 5 we have left first order logic, which does not allow quantification over properties (B).

As mentioned, all formalization has its limits. Although formalization may help in systematically structuring an ontology and especially in formalizing taxonomic structures, in conceptual analysis its use is limited because of Quine's ontological relativity (see above). The utility of formalization in conceptual analysis is dependent on the reducibility of the concepts, which are to be analyzed, to more basic concepts, which are already defined or are even part of the structure of the formal language itself. It is, for example, rather unclear what the advantage is of definition 4 in comparison to a similar ordinary language statement. As an analytical tool, therefore, formalization is most useful in the analysis of concepts, which are reducible to formal categories such as sets and set membership, as is the case in, for example, part - whole relationships in formal ontology (*e.g.* Smith 1996).

If such a reduction is not possible, formalization is less likely to be as powerful a tool (in conceptual analysis) as one might wish. The problem is that formal languages are rather poor *meta-languages* (languages used to describe concepts in the object-language), while Tarski (1935) proved that to analyze a concept satisfactorily (in his case: 'truth') the meta-language must be substantially richer in expressive power than the object-language. This implies that a full conceptual analysis of most social scientific concepts is virtually impossible, since there is no expressively 'richer' language available than the ordinary language these concepts are from, while, on the other hand, ordinary language often lacks the rigor needed for sharp description and definition. While this may limit the usefulness of formalization in the analysis of isolated concepts (as in conceptual analysis), it does, however, not affect ontology. Indeed, formalization does not necessarily result in better definitions, but it does generally more explicitly and more rigorously structure conceptual systems (by formally specifying taxonomic relationships, for example).

AN ONTOLOGY OF DEMOGRAPHIC EVENTS

A top-level ontology of demography distinguishes *events* and *objects*. Basically, demography counts events ('births', 'deaths', etc.) and objects (people, firms, organizations) that (may) experience these events. These are the essential building blocks of the demographic universe. However, both events and objects have *properties*, which determine whether events and/or objects should be counted in a specific measurement. Event rates are always related to a specific period, hence the point in time at which an event came to pass is of prime importance to calculate such a measure. Likewise, migration rates demand knowledge about the place of an object; and industry specific research, such as in organizational ecology, demands knowledge about the industry of an object (firm). All (these) properties are (or can be) treated as classes. Periods are temporal classes, regions are spatial classes and an industry is a class of similar activities. Temporal classes (periods) are used to group events; spatial and industrial classes (regions and industries) delimit (sub-) populations and, therefore, spatial and industrial boundary crossings are demographic events.

Most of the ontological research in the demographies of organizations was done by statisticians and refers to the objects. Obvious examples are the *International Standard Industrial Classification of all Economic Activities* (ISIC

Rev. 3 – UN 1990) and the *Statistical Classification of Economic Activities in the European Community* (NACE – EC 1990; 2002). Recently Eurostat and among others the British and Dutch statistical agencies have been working on a revision of NACE, which resulted in the CLAMOUR project and a new model (*e.g.* van der Hoeven *et al*. 2001). All of these ontologies of objects distinguish 'things' like legal units, institutional units, kind-of-activity units, local units, local kind-of-activity units, etc. Besides these statistical approaches to the ontology of organizational objects, some ontologies have been build for enterprise modeling in computer science and/or related fields (*e.g.* Uschold *et al*. 1997).

Within the field of statistical classification, an ontology of the *events* in the demographies of organizations was proposed by Struijs and Willeboordse (1988; 1990; 1995), who attempted to formally define these events as relations between the number of firms before and after the event accounting for preservation of identity. For example, a 'birth' is a 0:1 relation in which preservation of identity is inapplicable; a split-off is a 1:n relation with preservation of identity; a merger is a n:1 without preservation of identity; etc.

There are, however, two important objections to Struijs and Willeboordse's ontology. Firstly, events were defined above as changes in objects. Similarly, demographic events are changes in demographic objects. However, demographic events are also *population changes*. Pressat (1979) defines an event as a fact that both concerns an individual *and* directly influences the structure and development of (one or more) populations. Hence, demographic events conceptually link individual change to population change. The fact that demographic events change both individuals and populations is essential in demography's population perspective. Demography studies population change, not individual change (as such) and, hence, definitions of demographic events should link individual change to population change. The classification of Struijs and Willeboordse, however, describes events as changes in objects only and makes no reference to population(s) whatsoever. Consequently, events that imply a population transfer (such as migration) do not fit in their system.

Secondly, Struijs and Willeboordse's ontology may be insufficiently rigorous and systematic. For example, the different events are simply listed and no taxonomic structure (or any other structure) is (explicitly) revealed. To build a stronger foundation for the demographies of organizations and to improve knowledge (and data) exchange between its different branches, a more rigorous and more explicitly structured ontology of events is needed. An ontology, moreover, that is explicitly based on demography's population perspective.

In mathematics, populations are (special kinds of) sets (*e.g.* James & James 1992) and some demographers seem to adopt a similar notion. In the original French edition of his dictionary of demography, Pressat (1979) defines a population as an ‘ensemble d’individus coexistant à un moment donné et délimité selon des critères variés d’appartenance' (p. 155). Interestingly, ‘ensemble' and ‘appartenance' are (a.o.) the French terms for ‘set’ and ‘set membership’ respectively. Hence Pressat's definition of ‘population’ may be translated as ‘a set of individuals which coexist at a given moment, bounded by criteria depending on their set membership.’ However, the corresponding definition in the English edition of his dictionary (Pressat 1985) does not include any reference to sets.

If populations can be (formally) interpreted as sets, demographic events can be defined formally as changes in set membership. However, to do so, the notions of ‘population’ and ‘changes in set membership’ need some further elucidation. The set P_A is the population of all individual organizations of type A (definition 6). (The concept of ‘type' should not be interpreted in its logical sense here, neither does it refer to the notion of ‘form’ (or anything similar) as in Pólos, Hannan & Carroll (2002). ‘Type A’ here simply means ‘any predicate or set of predicates, labeled ‘A’’.)

$$P_A = \{ x \mid A(x) \wedge \mathit{individual}(x) \} \qquad \text{(def. 6)}$$

(the population P_A is the set of all x-s that are A-s and that are individuals). Note that definition 6 implies that $\forall A[\exists P_A]$ and that, hence, the concept of ‘population’ does not necessarily refer here to populations in a (organizational) ecological sense, but in a abstract demographic or logico-mathematical sense.

Individuality is defined by Guarino and Welty (2000) as a combination of identifiability and unity. As members of P_A are already identified – by definition – as A-type entities, individuality can – in this case – be equated to unity. Here, unity may be defined as not being a part or division (predicated ‘PT') of another, similar, entity. Hence definition 6 can be rewritten as:

$$P_A = \{ x \mid A(x) \wedge \neg\exists y \, [A(y) \wedge PT(x,y)] \} \qquad \text{(def. 7)}$$

(the population P_A is the set of all x-s that are A-s and for which there are no y-s that are also A-s on of which x is a part), in which the part or division of the two-place predicate PT(x,y) could possibly be rewritten as $x \subset y$ if organizations are defined as sets of roles (or tasks or routines, etc.), but that is a subject for another paper.

As mentioned, an event is a change in an object. Hence, in the case of the demography of firms, for example, an event may be defined as a change in the properties or characteristics of a firm. This could be formalized by stating that there is an event if and only if $(\Phi x)_t \neq (\Phi x)_{t'}$ in which the set of properties of a firm x is symbolized by Φx (Φ from Greek φυσις, meaning nature or constitution (of a thing)). Defining an event as a *state transition* (in this way) implies that there has been no event if an object (organization) changes and changes back in a period t to t' (in which t and t' are two points in time such that $t \neq t'$). Although this is theoretically incorrect, it is standard practice in demography since data availability is usually limited to fixed points in time (generally with a one-year interval). However, this implies that the definition is practically correct only if t and t' are defined as the points in time at which data was collection and t' is defined as the first data collection time-point after t.

In demography, events are aggregated into *rates*. Demographic rates are defined as the number of occurrences divided by the exposure (of the population at risk). As a consequence of the state transition definition of events, the number of events of a certain type equals the number of objects for which the conditions at t and t' in the definition hold. However, there are some exceptions to this rule in cases where more than one object originates from or ends in one event (compare the birth of twins in human demography). The population at risk, on the other hand, is the number of objects for which the condition at t holds and the condition at t' was possible. Hence the rate for event F can be defined – with noted exceptions – as:

$$rate_{\mathrm{F}} = \frac{\left| \{ \mathrm{x} \mid condition\ (\mathrm{F,t,x}) \wedge condition\ (\mathrm{F,t',x}) \} \right|}{\left| \{ \mathrm{x} \mid condition\ (\mathrm{F,t,x}) \wedge \Diamond condition\ (\mathrm{F,t',x}) \} \right|} \qquad \text{(def. 8)}$$

(the F-rate is the cardinal number of the set of all x-s to which condition F applied at both t and t' divided by the cardinal number of the set of all x-s to which condition F applied at t and could possibly have applied at t'). By means of definition 8 any definition of an event that specifies the conditions at t and t' (and nothing else) can be easily transformed into a definition of its corresponding rate.

The most basic distinction in types of demographic events is that between vital and non-vital events. Vital events are usually defined as a special class of events causing (some kind of) population change (*e.g.* Pressat 1979). This definition is rather ambiguous, because almost any (demographic) event causes some kind of change to the exact size or structure of a population. A more precise definition may be obtained by recognizing that vital events (predicated 'V') are essentially changes in population (set) membership:

$$\forall x,t,t' \ [\ \exists^1 e\ [\ V(e,x,P_A,t,t')\ ] \leftrightarrow \neg\ (\ (x \in P_A)_t \leftrightarrow (x \in P_A)_{t'}\ )\ ] \qquad \text{(def. 9)}$$

(for all x, t and t', there is one and only one ($\exists^1$) vital (V) event e (happening to x in population P_A in period t to t') iff x was a member of P_A at either t or t', but not at both). Hence in any vital event at either t or t' but not at both x is not a member of P_A ($x \notin P_A$). The subtypes of vital events (the lower levels in the taxonomy) then are specific forms of $x \notin P_A$. (Since specific forms of $x \in P_A$ – if these exist – do not affect the size of P_A, these are not relevant in vital events.) One of these specific forms of $x \notin P_A$ is related to the part or division relationship in definitions 7. These parts or divisions of organizations cannot be ignored in demographies of organizations. Non-individual parts or divisions of organizations (predicated 'NIP'; definition 8) play a crucial role in several events.

$$\forall x,y,\ [\ NIP(x,y,P_A) \leftrightarrow (\ x \notin P_A \wedge y \in P_A \wedge PT(x,y)\ )\ ] \qquad \text{(def. 10)}$$

(for all x and y, x is a non-individual part of y which is a member of population P_A iff x is not a member of P_A and y is and x is a part or division of y). Besides 'NIP', there are two other ways for an organization of not being an element of P_A: non-existence (predicated 'NEX'; definition 12) or membership of a complementary population P_B:

$$\forall x\ [\ x \notin P_A \leftrightarrow (\ \exists y\ [\ NIP(x,y,P_A)\ ] \vee NEX(x) \vee \exists P_B\ [\ x \in P_B \wedge P_B \cap P_A = \varnothing\ ]\ )\ ] \qquad \text{(def. 11)}$$

(for all x, x is not a member of population P_A iff their is an y, x is an non-individual part of, or x does not exist, or there is a population P_B that does not overlap with P_A and of which x is a member).

$$\forall x\ [\ NEX(x) \leftrightarrow \neg \exists P_A\ [\ x \in P_A \vee \exists y\ [\ NIP(x,y,P_A)\ ]\ ]\ ] \qquad \text{(def. 12)}$$

(for all x, x does not exist if there is no population P_A, x is a member of, or in which there is a member y, x is a non-individual part of).

The subtypes of vital events can be shown by means of a cross-tab based on the four different conditions for x, specified in the definitions above: membership ($x \in P_A$), non-individuality ($\exists y[NIP(x,y,P_A)]$), non-existence ($NEX(x)$), and membership of a complementary population ($\exists P_B[x \in P_B \wedge P_B \cap P_A = \varnothing]$).

table 1: *a cross-tab of the existential conditions of x at t and t'*

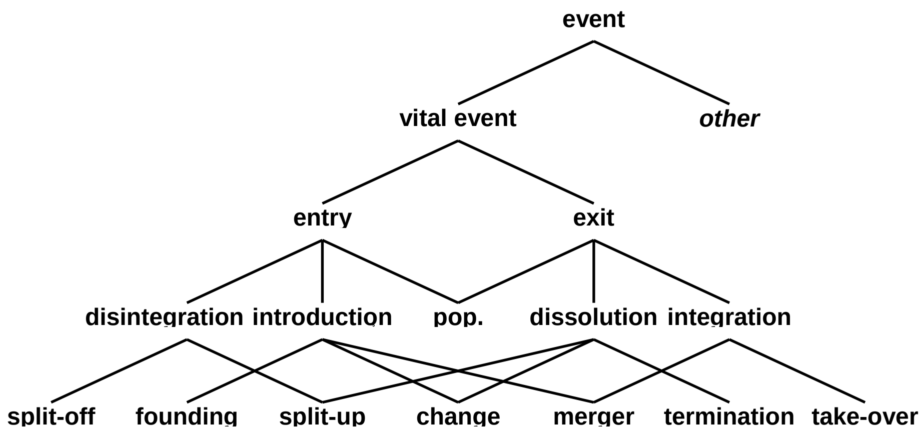
		t'			
		$x \in P_A$	$\exists y[NIP(x,y,P_A)]$	$NEX(x)$	$\exists P_B[x \in P_B \wedge P_B \cap P_A = \varnothing]$
t	$x \in P_A$	*no event*	exit by integration *	termination	emigration
	$\exists y[NIP(x,y,P_A)]$	entry by disintegration **	*no event*	*non-vital event*	*non-vital event*
	$NEX(x)$	new founding (in P_A)	*non-vital event*	*no event*	new founding (in P_B)
	$\exists P_B[x \in P_B \wedge P_B \cap P_A = \varnothing]$	immigration	*non-vital event*	termination	*no event*

Notes: * take-over or merger; ** split-off or up.

Besides the seven vital events in table 1 (take-over, merger, termination, population transfer (migration), split-off, split-up, new founding), there is an eighth: (essential) change, which reflects the fact that organizations (contrary to biological entities) may change that much that it is better to speak of a new entity. All of the events in table and essential change are defined in this paper.

The vital events mentioned are part of the taxonomic structure presented in figure 1. Some events combine entry and exit. Moreover, all events that do no imply a strict beginning or end of an organization (*e.g.* migration vs. new founding) may involve more than one population, which somewhat complicates the classification (and definition) of events. To avoid this complication the next two sections define all types of possible vital events in a *single population* with the restriction that population transfer is impossible. This restriction will be relaxed in the section on *population transfer* and *non-vital events*.

figure 1: *a taxonomy of demographic events*



pop.transf. = population transfer. Events are described and defined in following sections.

ENTRY AND EXIT

Preston *et al*. (2001) claim that 'no matter how a population is defined, there are only two ways of entering it: being born into it; or migrating to it' (p. 2). This may be true in demographies of biological entities, but in the case of organizations, entry is a bit more complicated as will be shown here. Entry (predicated 'E'), in general, is the event in which an object was not a member of a population at the beginning of the measurement period and was a member at the end of this period:

$$\forall x,t,t' \; [\; \exists^1 e \; [\; E(e,x,P_A,t,t') \;] \leftrightarrow (\; (x \notin P_A)_t \wedge (x \in P_A)_{t'} \;) \;] \qquad \text{(def. 13)}$$

(for all x, t and t', there is one and only one entry (E) event e (happening to x in population P_A in period t to t') iff x was not a member of P_A at t but was at t').

According to definition 11 there are three ways of not being a member of P_A (the condition for t in definition 13): non-individuality (NIP), non-existence (NEX) and membership of another (non-overlapping) population. The exclusion of the possibility of population transfer in this section, however, limits the possibilities to two: *disintegration* and *introduction* (the third option will be dealt with in the section on population transfer). The essential difference between organizational introduction and entry by disintegration (such as split-off or split-up) is that the object in question in the case of introduction (predicated 'EI'; definition 14) did not exist at all at t, while it did exist – albeit only as a part or division (of a member of P_A) – in the case of entry by disintegration (predicated 'ED'; definition 15).

$$\forall x,t,t' \, [\, \exists^1 e \, [\, EI(e,x,P_A,t,t') \,] \leftrightarrow (\, NEX(x)_t \wedge (x \in P_A)_{t'} \,) \,] \qquad \text{(def. 14)}$$

(for all x, t and t', there is one and only one entry by introduction (EI) event e (happening to x in population P_A in period t to t') iff x did not exist at t but was a member of P_A at t').

$$\forall x,t,t' \, [\, \exists^1 e \, [\, ED(e,x,P_A,t,t') \,] \leftrightarrow (\, (\, \exists y \, [\, NIP(x,y,P_A)] \,)_t \wedge (x \in P_A)_{t'} \,) \,] \text{(def. 15)}$$

(for all x, t and t', there is one and only one entry by disintegration (ED) event e (happening to x in population P_A in period t to t') iff there was a y that was a member of P_A and of which x was a non-individual part at t and x was a member of P_A at t').

As shown in figure 1 above, both introduction and entry by disintegration can be further subdivided in a number of events. Introduction events include new founding, merger and (essential) change. Entry by disintegration may occur by split-off or split-up. Merger, (essential) change and split-up, however, are combination events, which also comprise exit events. These are dealt with in the following section on *combination events*, while new founding and split-off are defined in this section.

New founding is the event of a completely new firm establishment. Hence, contrary to the other introduction events, no other (organizational!) objects and/or events are involved in new founding. Founding (predicated 'EIF'), therefore, is defined as an introduction event involving just one object and just one event:

$$\forall x,t,t' \, [\, \exists^1 e \, [\, EIF(e,x,P_A,t,t') \,] \leftrightarrow (\, NEX(x)_t \wedge (x \in P_A)_{t'} \wedge \neg \exists e',y \, [\, V(e',x,P_A,t,t') \wedge V(e',y,P_A,t,t') \,] \,) \,] \qquad \text{(def. 16)}$$

(for all x, t and t', there is one and only one founding (EIF) event e (happening to x in population P_A in period t to t') iff x did not exist at t but was a member of P_A at t' and there was no other event e' and no y such that this other event was a vital event happening to both x and y in the same period t to t').

The only pure entry by disintegration event is split-off. In a *split-off*, the object in question first exists as a part or division of another entity and then becomes an independent object (firm). In entry by split-off (predicated ‘EDS’), two firms are involved (the ‘parent' and the ‘child’) and both are members of P_A at t':

$$\forall x,t,t' \; [\; \exists^1 e \; [\; EDS(e,x,P_A,t,t') \;] \leftrightarrow \exists y \; [\; NIP(x,y,P_A)_t \wedge (x \in P_A \wedge y \in P_A)_{t'} \;] \;] \qquad \text{(def. 17)}$$

(for all x, t and t', there is one and only one entry by split-off (EDS) event e (happening to x in population P_A in period t to t') iff there was a y that was a member of P_A and of which x was a non-individual part at t and both x and y were members of P_A at t').

Exit events (predicated ‘X’; definition 18) are basically the reverse of entry events (definition 13). Definitions for exit events are obtained by replacing the conditions for t and t' in the definitions for entry events.

$$\forall x,t,t' \; [\; \exists^1 e \; [\; X(e,x,P_A,t,t') \;] \leftrightarrow (\; (x \in P_A)_t \wedge (x \notin P_A)_{t'} \;) \;] \qquad \text{(def. 18)}$$

(for all x, t and t', there is one and only one exit (X) event e (happening to x in population P_A in period t to t') iff x was a member of P_A at t but was not at t').

The *dissolution* event (predicated ‘XD’; definition 19) is the reverse of introduction (definition 14). *Integration* (predicated ‘XI’; definition 20) is the reverse of disintegration (definition 15). *Termination* (predicated ‘XDT'; definition 21) is the reverse of new founding (definition 16). And finally, *Take-over* (predicated ‘XIT'; definition 22) is the reverse of split-off (definition 17).

$$\forall x,t,t' \; [\; \exists^1 e \; [\; XD(e,x,P_A,t,t') \;] \leftrightarrow (\; (x \in P_A)_t \wedge NEX(x)_{t'} \;) \;] \qquad \text{(def. 19)}$$

(for all x, t and t', there is one and only one exit by dissolution (XD) event e (happening to x in population P_A in period t to t') iff x was a member of P_A at t but did not exist at t').

$$\forall x,t,t' \; [\; \exists^1 e \; [\; XI(e,x,P_A,t,t') \;] \leftrightarrow (\; (x \in P_A)_t \wedge (\; \exists y \; [\; NIP(x,y,P_A)] \;)_{t'} \;) \;] \qquad \text{(def. 20)}$$

(for all x, t and t', there is one and only one exit by integration (XI) event e (happening to x in population P_A in period t to t') iff x was a member of P_A at t and there was a y that was a member of P_A and of which x was a non-individual part at t').

$$\forall x,t,t' \; [\; \exists^1 e \; [\; XDT(e,x,P_A,t,t') \;] \leftrightarrow (\; (x \in P_A)_t \wedge NEX(x)_{t'} \wedge \neg\exists^1 e' \; \exists y \; [\; V(e',x,P_A,t,t') \wedge V(e',y,P_A,t,t') \;] \;) \;] \quad \text{(def. 21)}$$

(for all x, t and t', there is one and only one termination (XDT) event e (happening to x in population P_A in period t to t') iff x was a member of P_A at at t, but did not exist at t' and there was no other event e' and no y such that this other event was a vital event happening to both x and y in the same period t to t').

$$\forall x,t,t' \; [\; \exists^1 e \; [\; XIT(e,x,PA,t,t') \;] \leftrightarrow \exists y \; [\; (x \in P_A \wedge y \in P_A)_t \wedge NIP(x,y,P_A)_{t'} \;] \;] \quad \text{(def. 22)}$$

(for all x, t and t', there is one and only one exit by take-over (XIT) event e (happening to x in population P_A in period t to t') iff there was a y such that both x and y were members of P_A at t and that y was a member of P_A and x was a non-individual part of y at t').

COMBINATION EVENTS

Combination events combine exit and entry in a single event. Figure 1 presented four types of combination events: *split-up*, *merger*, (*essential*) *change* and *population transfer*. The first of these two are relatively similar to split-off and take-over respectively. The third is a little bit more problematic. The fourth implies multiple populations and will, therefore, be dealt with in the following section.

In merger and split-up at least three objects (firms, organizations, etc.) are involved. In the case of a split-up, two of these (the new firms) experience entry (by disintegration) and the third (the original firm) experiences exit (by dissolution). In the case of merger it is the other way around. Definitions 23 and 24 define split-up and merger respectively. In the case of definition 23, x splits up into the set Z; and in the case of definition 24, the members of Z merge into x. Definitions 23 and 24 introduce four new predicates: ‘CES’: entry by split-up; ‘CXS’: exit by split-up; ‘CEM’: entry by merger; and ‘CXM’: exit by merger.

$$\forall x,Z,t,t' \; [\; |Z|>1 \rightarrow \forall z \; [\; z \in Z \rightarrow \exists^1 e \; [\; CES(e,z,PA,t,t') \wedge CXS(e,x,P_A,t,t') \;] \leftrightarrow (\; NIP(z,x,P_A)_t \wedge (\; z \in P_A \wedge NEX(x) \;)_{t'} \;) \;] \;] \quad \text{(def. 23)}$$

(for all x, Z, t and t', if Z has more than one members (|Z|>1), then for all of these members z there is one and only one event e that is an entry by split-up (CES) happening to all z (in population P_A in period t to t') and an exit by split-up (CXS) happening to x (in population P_A in period t to t') iff all z were non-individual parts of x (which was a member of P_A) at t and all z were members of P_A while x did not exists at t').

$$\forall x,Z,t,t' \; [\; |Z|>1 \rightarrow \forall z \; [\; z \in Z \rightarrow \exists^1 e \; [\; CEM(e,x,PA,t,t') \wedge CXM(e,z,P_A,t,t') \;] \leftrightarrow (\; z \in P_A \wedge NEX(x)\;)_t \wedge NIP(z,x,P_A)_{t'} \;]\;] \quad \text{(def. 24)}$$

(for all x, Z, t and t', if Z has more than one members (|Z|>1), then for all of these members z there is one and only one event e that is an entry by merger (CEM) happening to x (in population P_A in period t to t') and an exit by merger (CXS) happening to all z (in population P_A in period t to t') iff all z were members of P_A while x did not exists at t and
all z were non-individual parts of x (which was a member of P_A) at t').

Essential change is the only vital event that does not affect population size. Nevertheless, since it can be regarded as a combination of exit and entry, it is vital according to definition 13. It is the event of an object changing (itself) that much that it becomes a new object. Remember that events in general are defined as changes in the set of the characteristics of objects Φx. The question now is, in what cases the change in Φx is so substantial, that the old object (organization) no longer exists and a new one is 'born'. This is the problem of identity over time, which has been discussed by numerous philosophers (for an overview see Noonan (ed.) 1993; Sider 2000). However, the demographies of organizations are in need of a more practical approach.

The easiest solution is based on Leibniz' (1953 [1686]) principle of the *identity of indiscernibles*. According to this principle, two objects are the same if and only if they share all their properties. This is called 'strong identity'.

$$\forall x,y,t,t' \; [\; (x)_t = (y)_{t'} \leftrightarrow (\Phi x)_t = (\Phi y)_{t'} \;] \quad \text{(def. 25)}$$

(for all x, y, t and t', x at t and y at t' are identical (one and the same object) iff the sets of properties of x at t and y at t' coincide). This easy way out, however, causes a serious problem: it prohibits any change. In other words: according to proposition 1 any change in the characteristics of an organization will result in its dissolution and the introduction of a new organization, which would rather drastically distort introduction and dissolution rates of organizations. The fact is, of course, that firms, for example, do change and that we still recognize them as the same firms. In the introduction of her famous *The theory of the growth of the firm* (1959) Edith Penrose wrote:

> In practice the name of a firm may change, its managing personnel and its owners may change, the products it produces may change, its geographical location may change, its legal form may change, and still in the ordinary course of events we would consider it to be the same firm and could write the story of its 'life'. (pp. 22)

A more or less contrary position was defended by, for example, Triffin (1956), who argued that any change in the production function of a firm, however small, will result in a new firm, with new profit opportunities of its own.

As *strong identity* (symbolized by =) proves to be too 'strong', we need to define identity over time as some form of *weak identity* (symbolized by $=_w$). An obvious solution is to propose, that organizational identity is dependent on a subset of Φ containing the essential properties or characteristics only: Φ_E:

$$\forall x,y,t,t' \, [\, (x)_t =_w (y)_{t'} \leftrightarrow (\Phi_E x)_t = (\Phi_E y)_{t'} \,] \qquad \text{(def. 26)}$$

(for all x, y, t and t', x at t and y at t' are weakly identical (one and the same object) iff the sets of essential properties of x at t and y at t' coincide). However, this implies that we should define a single property or set of properties Φ_E, which has to stay the same to guarantee identity over time. This might be impossible or extremely difficult at least. A more appropriate alternative is available in an application of Wittgenstein's (1971 [1953]) notion of *family resemblances*. He developed this idea trying to explain the meaning of the concept of 'game'. According to Wittgenstein 'der Begriff 'Spiel' ist ein Begriff mit verschommenen Rändern' (the concept of 'game' is a concept with blurred edges) (§ 71). Such a concept can only be explained by referring to a set of properties of games in general and claiming that each specific game has at least some properties, which are elements of the before mentioned set of properties of games in general.

Applying the concept of family resemblance to a definition of identity over time based on sets of properties involves comparing the similarities and differences of x_t and $y_{t'}$. In definition 27, x (existing at t) and y (existing at t') are one and the same object to the extent of i, in which i is the sum of the weights w of the intersection of Φx and Φy divided by the sum of the weights w of the union of Φx and Φy, in which w is the weight that is assigned to each type of property ('type of property' here refers to a class of properties like 'address' rather than to a particular member of this class, a specific address of an actual organization):

$$\forall x,y,t,t' \left[\exists i \left[(x)_t \approx^i (y)_{t'} \;\wedge\; i = \frac{\sum_{\varphi \in (\Phi x_t \cap \Phi y_{t'})} w_\varphi}{\sum_{\varphi \in (\Phi x_t \cup \Phi y_{t'})} w_\varphi} \right] \right] \qquad \text{(def. 27)}$$

in which $\forall w_\varphi$ [$0 < w_\varphi < 1$] and $\exists w_\varphi$ [$w_\varphi > 0$] .

Definition 25 results in *fuzzy identity* over time in which the extent of fuzzy identity is determined by i. The larger i, the 'stronger' the identity over time. The values (for i) of 0 and 1 (whether in a crisp or in a fuzzy version) mean absolutely no identity and complete (strong) identity, respectively.

The fuzzy identity of definition 27 can be converted into a crisp event by introducing a *threshold*. Theoretically, such a threshold would be incorrect of course, because every possible cut-off point is disputable, but in practice definition 27 is used in combination with a threshold in, for example, the Provincial Employment Register of the Dutch province of Groningen (PWR Groningen) for the identity over time of local establishments of firms. In this data set three (types of) properties (name, address, and activity) are assigned the weight (w) 1 and all other (types of) properties have weight (w) 0. The threshold is fixed at two-thirds, which means that, to stay the same local establishment, only one of three properties can change in one year.

Based on definition 27 the combination event of essential change can be defined as two objects having identity over time below the threshold (definition 28). (Two new predicates are introduced in definition 28: 'CEC': entry by (essential) change and 'CXC': exit by (essential) change.)

$$\forall x,y,t,t' \; [\; \exists^1 e \; [\; CEC(e,y,P_A,t,t') \wedge CXC(e,x,PA,t,t') \;] \leftrightarrow$$
$$(\; x_t \approx^i y_{t'} \wedge i < \mathit{threshold} \;) \wedge (x \in P_A \wedge NEX(y) \;)_t \wedge$$
$$(\; NEX(x) \wedge y \in P_A \;)_{t'}] \qquad \text{(def. 28)}$$

(for all x, y, t and t', there is one and only one event e that is an entry by essential change (CEC) happening to x (in population P_A in period t to t') and an exit by essential change (CXC) happening to x (in population P_A in period t to t') iff x at t and y at t' are weakly identical (one and the same object) to the extent i and i is smaller than the threshold and x is a member of P_A while y does not exist at t and y is a member of P_A while x does not exist at t').

Definition 27 in combination with a threshold can be used in a similar fashion to distinguish split-off from split-up and take-over from merger. In split-off and take-over, one of the participant objects (organizations) persists, has (fuzzy / weak) identity over time (i≥*threshold*). In split-up and merger all identity over time (i) is below the threshold.

POPULATION TRANSFER AND NON-VITAL EVENTS

Population transfer is the event of a single object leaving one population and entering another. An obvious example of this event is migration in which a single object leaves one regionally bounded population and enters another regionally bounded population. However, population transfer can also be combined with all types of vital events involving existence (either P_A membership or being a part or division of a P_A member, NIP) of objects at both t and t'. For example, the event of merger (definition 24) may involve population transfer if one of the initial objects z that merge into x is from another population. It is possible to define all possible combinations of vital events distinguished in figure 1 with population transfer, but this would introduce a number of rather obscure events recognized by hardly anyone. Moreover, in practice, this type of combinations does rarely (if ever) occur as a single event. Hence, in the case of this type of combination events, it would be advisable to treat these as two (or even more) separate events.

Populations and sub-populations are not necessarily bounded by regions (alone). Any property may function as a (sub-) population forming class. Populations may be bounded or subdivided by size classes, industries, profitability classes, or any other way. This implies that any non-vital event can be transformed into a vital event by introducing a further classification. In all of these cases an exit out of one population and an entry into another is a population transfer event.

The population transfer event is defined as a P_B membership at t and a P_A membership at t', providing that P_A and P_B are non-overlapping populations.

Definition 29 introduces two new predicates: ‘TE': entry by population transfer and ‘TX’: exit by population transfer.

$$\forall x,t,t' \,[\, \exists^1 e \,[\, TE(e,x,P_A,t,t') \wedge TX(e,x,P_B,t,t') \,] \leftrightarrow (P_A \cap P_B = \varnothing \wedge (x \in P_B)_t \wedge (x \in P_A)_{t'}) \,] \qquad \text{(def. 29)}$$

(for all x, t and t', there is one and only one event e that is an entry by migration (TE) in population P_A (happening to x in period t to t') and an exit by migration (TE) in population P_B (happening to x in period t to t') iff P_A and P_B do not overlap and x is a member of P_B at t and a member of P_A at t').

Non-vital events are all events that do not directly affect population membership and do not involve existential change (see def. 13). This includes organizational growth, but it also includes the (usually) rather irrelevant event of the replacement of a single employee. *Discrete* non-vital events may be counted and treated as ordinary demographic events. *Continuous* (non-discrete) events, such as growth and aging, are sometimes countable, but this usually does not capture the essence of the event. It is, for example, not very useful to count the number of firms that have grown and calculate a ‘growth rate' out of this without taking the extent of each individual’s growth into account.

Continuous events (like growth) cannot be measured with standard demographic tools. However, as was mentioned above, any non-vital event may be transformed into a vital event by operationalizing the changing characteristic as a (sub-) population forming class. For example, growth is a typical example of a non-vital event. However, it is a vital event if the population the organization belongs to is co-defined as a size class and if the organization in question grows from one size class to another. This would result in an exit from the original population and an entry into the new population. Hence, by introducing further classifications or adding characteristics to the definition of a (number of) population (-s) non-vital events may be transformed into population transfer events (definition 29). However, this would result in some information loss.

Whether an event is a vital event may depend on the type of object used for demographic analysis (and, hence, the type of demography). Partial relocation, for example, the event of a firm establishing a new division in another region, would not be a vital event in a demography of firms (although it could be perceived as a fuzzy population transfer involving decreased membership in one population and increased membership in a second population, in which case it would be a ‘fuzzy vital event'). In a demography of local establishments, however, it could be a vital event, possibly even two: the founding of the new establishment and its relocation.

In human demography important non-vital events include marriage, divorce, adoption, aging, etc. Except for aging, these have no counterparts in demographies of organizations. Although this is sometimes suggested, marriage is not at all similar to merger. Merger is the integration of a number of demographic objects (firms) into a single new object (firm). Marriage will not result in the creation of a new single object (person). A better analogy to marriage would be some kind of contract between two organizations.

An important type of non-vital events in both human demography and demographies of organizations is causing an event to be experienced by another object (person or organization) or producing an event. This includes, for example, murder, but far more importantly, it also includes giving birth. In practice, birth rates are often measured as ‘giving birth rates’. In human demography, the number of births is divided by the number of fertile women to measure a birth rate. Strictly speaking, this is incorrect. Although the event of birth implies the event of giving birth and the other way around, these events do not have the same population at risk. In calculating a birth rate as the number of births divided by the number of fertile women, two different events are mixed up: the population of fertile women is not the population at risk of experiencing birth but of experiencing giving birth. In fact – dependent on the definition of t and t' – there is either no population at risk of experiencing birth, as those experiencing birth did not previously exist, or the population at risk is the population of fetuses. Hence, it is either impossible or not very useful to measure a birth rate.

While confusing birth rates and ‘giving birth’ rates does not cause any serious problems in human demography (only twins cause a small distortion), it does in demographies of organizations as was shown above. Probably, the event most similar to birth is the introduction event (definition 14). Three subtypes of introduction were distinguished in figure 1, similarly, three types of causing introduction can be distinguished: (1) causing founding, (2) causing entry by (essential) change, and (3) causing entry by merger. Further types of causing entry are (4) causing entry by split-off and (5) causing entry by split-up. Events 2 to 5 have similar populations at risk: subsets of the population of organizations. As completely new (and independent) firms (or other types of organizations) are rarely (if ever) founded by existing firms, the event of causing founding has a very different population at risk: the number of people that may found a firm (or other type of organization). Hence, a rate of causing founding does not belong to the demography of firms, but to a demography of entrepreneurs.

The confusion of birth rates and causing birth rates lead to the debate between proponents of the before mentioned labor market approach and organizational approach in measuring ‘birth rates’ of firms. It turns out both approaches are wrong. Strictly speaking, it is impossible to measure a birth rate due to the fact that there is no population at risk. Measuring a ‘causing birth rate' instead is also impossible, because this ‘supertype' event includes a number of different events with very different populations at risk.

(Note that in practice, rates or similar measures are often used to calculate population change. In calculations like these, rates for the different entry events are the plusses and rates for the different exit events are the minuses. Of course, to make this kind of calculations possible, denominators in the rates have to be the same. The focus on population change suggests to use the existing population size at t as the denominator in these measures. In some cases, such as new founding, this will, however, not result in a rate in the formal sense of the word but in some kind of proportion.)

DISCUSSION

In the section on ontology and conceptual analysis above, a number of methodological rules and requirements for ontology building were suggested. These included: formalization, taxonomy, extensibility, minimal ontological commitment, and minimal encoding bias. The ontology specified in this paper is explicitly formal and taxonomic. The possibility of reducing the relevant concepts to set-theoretical categories (sets and changes in set-membership) more or less solved the problem of ontological relativity and made formalization, moreover, relatively easy. The other three rules mentioned here are related (to each other). Minimal ontological commitment, like Ockham’s razor, requires definitions with a minimum number of variables. Five types of definitional variables were used in the definitions in this paper: the entities (x, y, etc.) to which the event (e) (or events) happened, the population (P_A) (or populations) bounded by some property A (note that populations and properties are *not logical* variables) that entity is (or was) part of, and two points in time (t and t'). None of these can be missed. All definitions are written in relatively basic set-theoretical and logical notation, limiting encoding bias, and can be easily translated into other (formal / symbolic) languages, which allows extensibility. The main limit to extensibility is that the definitions proposed here are ‘practically’ rather than ‘theoretically’ correct because of the definition of t and t' as two consecutive points of measurement. Redefining t and t' and adding $\neg\exists e'[V(e',x,P_A,t,t')]$ would make most definitions theoretically correct. (The main exception is definition 28 of existential change, which can never be a theoretically correct *crisp* event. Note that in case of founding (def. 16) and termination (def. 21), $\neg\exists e'[V(e',x,P_A,t,t')]$ is already part of the definition.) However, redefining t and t' such that these are not two consecutive points of measurement would make the definitions empirical useless.

Although demographies of organizations have to deal with a higher level of complexity and a greater number of (possible) events than human demography, the actual number of different events does not seem to be as large as Carroll and Hannan (2000) may have feared. Only eight basic types of vital events have been distinguished. These are founding, termination, split-off, take-over, split-up, merger, essential change, and population transfer. All of these have been formally defined above. As population transfer is dependent on the population classification chosen, there are as many subtypes of population transfer as there are possible classifications: infinite. However, logically these are all the same type of event. Moreover, population transfer may (seem to) occur in combination with most of the other types of events. All other types of events are either supertypes and should be specified as the exact type of event intended or are non-vital events. Non-vital events can be transformed into vital events by imposing a classification based on the changing characteristic and treating the event as a population transfer event.

The ontology presented in this paper is only a partial ontology. As mentioned, a top-level ontology of the demographies of organizations distinguishes events and objects. The ontology of events specified here may solve some theoretical problems, such as the birth-rate debate (see the preceding section), but to solve many of the ambiguities in these fields, an ontology of objects is needed as well. Moreover, objects and events are not unrelated. Whether an object experienced an event is partly dependent on the definition (delimitation) of that object (see above). The most fundamental problem in such an ontology of objects is that of individuality. This is the question whether organizations are discrete individuals (*e.g.* Khalil 1997). If they are not, counting them does not make sense and the demographies of organizations (including organizational ecology) would be built on quicksand. If they are, the boundaries of and between organizations (and the parts or divisions thereof) need analysis and definition. In conclusion and paraphrasing Bunge (1977, p. 23): *ontology can help solve pseudo-questions that* *arise in science and originate in misconceptions; ontology can dig up, clarify, and systematize basic concepts and principles occurring in the course of scientific research*.

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APPENDIX

list of predicates

predicate *abbreviation*	*short description*	***definition***
CEC(e,x,P_A,t,t')	entry by (essential) change	28
CEM(e,x,P_A,t,t')	entry by merger	24
CES(e,x,P_A,t,t')	entry by split-up	23
CXC(e,x,P_A,t,t')	exit by (essential) change	28
CXM(e,x,P_A,t,t')	exit by merger	24
CXS(e,x,P_A,t,t')	exit by split-up	23
E(e,x,P_A,t,t')	entry event	13
ED(e,x,P_A,t,t')	disintegration event	15
EDS(e,x,P_A,t,t')	split-off event	17
EI(e,x,P_A,t,t')	introduction event	14
EIF(e,x,P_A,t,t')	(new) founding event	16
individual(x)	individuality	n.d.
NEX(x)	non-existence	10
NIP(x,y,P_A)	non-individual part of element of P_A	8
PT(x,y)	part of / division of	n.d.
TE(e,x,P_A,t,t')	entry by population transfer	29
TX(e,x,P_A,t,t')	exit by population transfer	29
V(e,x,P_A,t,t')	vital event	12
X(e,x,P_A,t,t')	exit event	18
XD(e,x,P_A,t,t')	dissolution event	19
XDT(e,x,P_A,t,t')	termination event	21
XI(e,x,P_A,t,t')	integration event	20
XIT(e,x,P_A,t,t')	take-over event	22

n.d. = not formally defined (in this paper)