Microsimulation for local impact analysis: An application to plant shutdown

Terance J. Rephann*, Kalle Mäkilä**, and Einar Holm**

*Allegany College of Maryland

12401 Willowbrook Road, SE

Cumberland, MD 21502 USA

trephann@allegany.edu

**Spatial Modelling Centre

Box 389

S 981 28 Kiruna, Sweden

kma@smc.kiruna.se

Einar.Holm@geography.umu.se

Paper to be presented at the 50th Annual North American Meetings of the Regional Science Association International in Philadelphia, PA, on November 20-22, 2003

JEL Classification: R15 (Econometric and Input-Output Models; Other Models), C15 (Statistical Simulation Methods; Monte Carlo Methods)

Keywords: Plant closure, impact analysis, spatial modeling, microsimulation

Abstract: Microsimulation was introduced nearly fifty years ago but has experienced a revival in the social sciences recently. Its use in regional science, however, has been limited although it offers some advantages over common regional analytic methods. This paper describes a microsimulation model that can be used to analyze the impact of a regional economic event. The model incorporates spatial, social, and economic factors and allows outcomes to be aggregated at different geographical scales, for different cohorts, and for variables not ordinarily considered in impact analysis. The model is used to simulate the effects of a plant shutdown on workers.

Acknowledgements: The able work of members of the Spatial Modelling Centre SVERIGE development team made this paper possible. These members included Coomaren Vencatasawmy, Neil Swan, Eva Alfredsson, Magnus Åström, Johan Esko, Marianne Öhman, Johnny Siikavaara, Kerstin Holme, Mona Mattsson-Kauppi, Mirjana Boskovic, and Gunnel Mörtvik. This research was supported by funding from the European Community, European Regional Development Fund. The views expressed in the article are those of the authors alone

http://www.equotient.net

Published in *Journal of Regional Science* 45,1: 183-222.

1. INTRODUCTION

Regional scientists routinely use a variety of ex-ante methods to estimate the economic impacts of local economic events before they happen. These techniques include export base models, input-output models, econometric models, computable general equilibrium models, and mathematical programming models. However, Walter Isard in Isard, et al. (1998, p. 5) observes that microsimulation has been used very little in regional science despite its "great potential for adding depth to behavioral studies in attacking difficult urban-regional problems and formulating spatial interregional policies . . ."

Microsimulation was introduced nearly a half century by Orcutt (1957) and has experienced a revival in the social sciences over the past decade (Merz, 1991; Clarke, 1996; Isard et al., 1998; Williamson, 1999). It has been used in national-level population projection studies (Fredriksen, 1998), to investigate social security/pension contributions and benefits (Favreault and Caldwell, 2000; Nelissen, 1994; Andreassen, Fredriksen, and Ljones, 1996; Zedlewski, 1990), to examine the effect of various tax regimes on fiscal budgeting and inequality (Klevmarken and Olovsson, 1996), to analyze support networks and retirement care needs as the population ages (Williamson, 1996; Galler, 1997; Hancock, 2000), to examine educational and health issues (Caldwell, 1996; Harding, 2000), to study wealth distribution (Caldwell et al., 1998) and to assess housing policy (Oskamp, 1995). Recent microsimulation modeling efforts have also been made to examine spatial processes (Ballas and Clarke, 2001; Caldwell et al., 1998; Clarke, 1996; Holm et al., 2002).

The dynamic microsimulation model called *SVERIGE* (or *System for Visualizing Economic and Regional Influences Governing the Environment*) is a spatial model built at the Spatial Modelling Centre in Kiruna, Sweden. It is the first national-level spatial microsimulation model available and permits analysts to study the demographic, economic, and spatial consequences of various national, regional, and local-level public policies and phenomena, including the effects of a plant closure. Assisting the model building effort is a unique database comprising longitudinal socio-economic information on every resident of Sweden for the years 1985 to 1995. The locations of the individuals in this database are given in co-ordinates accurate to the level of 100 meters. It is, therefore, possible to estimate behavioral equations on various geographical scales and to describe complex dynamic spatial relationships.

This paper describes some of the key components of the model and simulates the effect of the hypothetical shutdown of a large employer, the Saab automobile plant in Trollhättan, Sweden. The paper is divided into six sections. The first section describes the main features of microsimulation models. The second section outlines the SVERIGE microsimulation model structure, components, and unique characteristics. The third section provides a short literature review of firm shutdown effects on localities. The fourth section describes the application. The fifth section presents empirical results of a plant shutdown. The paper ends with a summary and conclusion.

2. MICROSIMULATION MODELLING ADVANTAGES AND DISADVANTAGES

Microsimulation is a modeling technique that generates artificial data for the most elemental units in a system. In regional science, these elemental units are variously called individuals, households, employers, housing stock, and geographical areas. Instead of focusing on aggregate behavioral relationships as most methods in regional science (e.g., econometric, input-output, computable general equilibrium), these elemental units serve as the basic building blocks of the system and their behaviors must be modeled.

Microsimulation models have numerous advantages over the macroeconomic modeling that has dominated regional science. For instance, they allow the theoretical richness of microeconomic theory to be embedded into working models with fewer theoretical compromises and greater ease. In contrast to econometric models, microsimulation models "simulate the whole distribution of policy target variables, not only their mean values" which is especially advantageous when "economic relations are highly nonlinear, when tax laws and rules transfer programs introduce censoring and truncation, and when sub-populations differ in behavior" (Klevmarken, 1997, p. 2). Another advantage is that they permit microunit relations and nested hierarchical relationships to be driving forces in microunit growth and change (Clarke and Holm, 1987; Harding, 2000). These complicated relationships can be represented with modern object-oriented programming languages in a way that is elegant, simple, and computationally efficient (Ballas and Clark, 2001). Nelissen (1994) argues that microsimulation's benefits stem from their ability to incorporate the so-called 'second-order' (induced behavioral effects) effects in addition to the usual 'first-order' (direct effects due to policy change) effects. One ramification is that household processes (i.e., demographic processes) "are of greater importance to individual income development than socio-economic changes such as becoming unemployed" (Nelissen, 1994, p. 3).

One of the strongest selling points of microsimulation models is the type and quality of outputs generated: they can be used to look at both aggregate and disaggregate/distributional effects of population and economic change (Merz, 1991; Ballas and Clark, 2001) and to generate longitudinal microunit "biographies" that provide a better intuitive feel for the diverse outcomes of complex, non-linear economic-demographic processes. Because of their complexity and the variety of data elements that can be generated, perverse, unintended, or unexpected impacts of policies can be thoroughly investigated. Caldwell (1996) lists over 20 additional advantages of microsimulation; and Caldwell and Morrison (2000) provides even more.

Whatever the advantages of microsimulation, it is clear that regional scientists have been relatively slow to embrace the method. Orcutt introduced the method fifty years ago, but the main proponents have been in Europe, a few U.S. research institutes that focus on complex systems, and government agencies involved in taxation fiscal impact analysis and pension reform evaluation. National-level models now exist in many industrialized countries and a handful of sub-national models exist as well (Oskamp, 1995, Clarke, 1996; Ballas and Clarke, 2001).

Several reasons have been advanced for the slow acceptance of the method. The first set of reasons centers on the expense of development and upkeep. Traditionally, computer storage and computational speed were barriers to microsimulation model development, but with the advent and spread of Pentium generation microprocessors, these obstacles have disappeared (Holm et al., 1996). However, development costs are still important inhibitors. Most microsimulation models require an investment of several man-years to develop and additional man-years to maintain (Fredriksen, 1998; Williamson, 1999). The expense incurred in beyond the reach of most University-level research departments and requires substantial up-front investments.

Microsimulation has also been criticized because of modeling, data quality, and methodological issues (Citro and Hanushek, 1991; Klevmarken, 1997). Microsimulation models are regarded as 'black boxes' by some (Williamson, 1999), although this is a criticism that could be leveled at any complex model. Microsimulation models are sometimes criticized for being disconnected from microeconomic theoretical foundations (Klevmarken, 1997). Nelissen (1994) observes that microsimulation models do not yet incorporate "third-order" effects. These effects are basically the summative induced changes (or 'multiplier effects') in economic output caused by producer and consumer purchases that are captured by models favored by regional scientists such as export-base models, input-output models, social accounting matrices, and econometric models. Data quality can present a problem. The lack of high-quality, comprehensive, longitudinal socio-economic data has induced modelers to generate less reliable synthetic data for sampling and imputed data for building behavioral transitions. Model outputs are often not robust (Williamson, 1999), so that great care must be taken in inferring conclusive results and some models have shown no improvement over macroeconomic models in the aggregate (Holm et al., 1996). Many criticisms of microsimulation are indictments of the way in which microsimulation has been carried out rather than the method itself. For instance, models are criticized for being poorly validated (or difficult to validate), poorly documented, too slow, and encompassing too few real-life applications (Williamson, 1999; Fredriksen, 1998; Holm et al., 1996).

Many of these criticisms of implementation are not relevant to the microsimulation model described here because of extensive efforts made in assembling real microdata, creating software code for fast processing, validating the model, and documenting the model. Other modeling criticisms (such as the lack of 'third order' effects) are valid but cannot be currently accommodated within the model. However, Isard (1998) suggests some promising ways that current regional modeling techniques might be combined with microsimulation to rectify this particular shortcoming. In the next section, SVERIGE's history, basic structure, and operating characteristics are outlined to provide enough background for understanding the model architecture and the regional economic application, but a much more detailed description of the model, computer software, and validation process is available in the model documentation (Holm et al., 2002).

3. SVERIGE MICROSIMULATION MODEL

Model History and Unique Characteristics

SVERIGE is a dynamic spatial microsimulation model for Sweden based on households. It generates events for individuals through the interplay of deterministic models of individual behavior and a Monte Carlo simulation. The behaviors are functions of individual, household, and regional socio-economic characteristics, usually included as independent variables in logistic equations or simply as categories used to estimate transition matrices that describe the probability of moving from one state to another. The model is dynamic as the evolution and development of the individuals occurs in chronological order, with initial conditions being changed for subsequent periods by counters and simulation.

The model core is based upon CORSIM (Cornell Microsimulation Model) (Caldwell, 1996), which itself is a modification of Orcutt's DYNASIM (Dynamic Microsimulation Model), the first dynamic microsimulation model. SVERIGE differs in several important respects from CORSIM and DYNACAN. First, SVERIGE is a Swedish model and thus explains behavior in a different institutional context. Although it is based on the same social science as the others, differences in cultural and institutional peculiarities were too big to be ignored. Examples of such differences are the power relations between men and women, the degree of class equity, the elaborateness of social support mechanisms, and the diverse types of recognized family groupings (e.g., marriage versus cohabitation, referred to as "Sambo"). As these define the social context in which individual decisions are made and constrain the ways in which individuals interact, the equations used in SVERIGE are different but the life-cycle modular structure is the same as CORSIM.

Second, SVERIGE is a spatial model while CORSIM is not. In fact, SVERIGE is the first national-level interregional spatial microsimulation model. Although other microsimulation models with spatial inputs and outputs exist (Williamson, 1999), they focus on individual regions. The only truly interregional microsimulation model prior to SVERIGE is TOPSIM (Holm et al., 1996), an immediate predecessor to SVERIGE. Williamson (1999, p. 7) notes that this bias against geography occurs because "many problems are not perceived as having an inherently spatial dimension." However, space is a useful addition when: (1) it improves the accuracy of microsimulation models by introducing spatial and geographical variables as driving forces of change and (2) it allow results to be presented and interpreted with for space and regions. The availability of geocoded microdata and new techniques for blending geographical, population, and economic data make it likely that spatial models will become more common (Clarke, 1996).

The spatial features of SVERIGE come not only from making life-cycle transitions dependent on a spatial context but also modeling individual spatial transitions such as internal migration. In the terminology of object-oriented programming geographical "containers" such as neighborhoods and labor markets (which have no agenda of their own and whose values are derived from the spatial movements of the constituent persons and families) are dynamically updated based on the behavior of constituent "objects" such as individuals, households, and homes (see appendix A. for a full listing of objects and their attributes). As a result, the model is capable of generating geographically detailed reports for various scales that may interest regional scientists and policymakers.

SVERIGE's simulation population and estimated equations draw on a comprehensive longitudinal database that contained information on all Swedish residents called TOPSWING (TOtal Population of Sweden INdividual and Geographical database). Unlike CORSIM and most other microsimulation models, SVERIGE relies on actual data rather than synthetic populations for simulation runs and the entire population rather than samples that are potentially unrepresentative in some respects. SVERIGE behavioral equations/transition matrices were estimated with samples taken from this same comprehensive longitudinal database of Swedish households and employers. Therefore, the model probably has fewer data reliability and measurement error problems (Klevmarken, 1997; Citro and Hanushek, 1991) than competing international models that rely on non-survey data and artificial population generation techniques.

Computational time is also advantageous for SVERIGE. The current version of the model reported in this paper uses a "turbo" simulation engine. This super efficient engine is able to process one year of data from the entire population of Sweden (approximately nine million individuals) in less than two minutes on a 1 GHz machine with 1 Gb memory. This processing time is a big improvement over previous versions of the model.

Model Structure

SVERIGE contains 11 modules. A module is a function or a group of functions that forms a unit and simulates a certain life event or action. Modular functions are used in tandem with a Monte Carlo experiment to determine whether or not a particular event occurs. Each microunit is exposed to a possibility that a certain event will occur based on a simple probability. This probability is estimated from functions (e.g., single parameters, rules, or estimated regression equations) determined by theory. Thus each microunit at risk of an event is assigned a probability and a random risk. If the probability is greater than the risk, then the event occurs.

The probability function can be formally represented as follows:

(1) $P(e|i,t) = f_e(\mathbf{X}_{it}, \mathbf{X}_{jt}, \mathbf{X}_{rt})$
where:
i=individual
j=container (e.g., region)
r=other objects related to individual i (e.g., spouse, child)
t=time (period)
e=event (e.g., migrate, change job, divorce, die)
X=vector of individual, container, or object attribute values.

A random risk number (γ) is drawn from the interval [0,1]. If $P(e|I,t) \geq \gamma$ then the event occurs and the individual's attributes are updated.

The modules are used to change the status of the individual attributes during simulation and are in most cases executed in a strict time sequence every year for each individual. However, some events, such as moving from home and divorce, unconditionally trigger another event (e.g., residential move). Modules decreasing the number of individuals or families are executed first (mortality and emigration) and after that fertility. Thereby, all family structures are set before events that change attributes of existing individuals are simulated. Those modules are the following ones in order of execution: education, marriage, leaving home, divorce, migration, and employment and earnings. The last module is immigration. This modular order was decided for conceptual reasons but experimentation showed that some reordering of the sequence did not significantly influence model aggregates.

Model equations and their corresponding variables are represented in Table 1 and variable descriptions are found in Appendix A. Since the entire model consists of over one hundred equations and numerous additional parameters and rules, a complete description of these details is provided elsewhere (Holm, et al., 2002). However, each of the modules is described briefly here to convey the basic architecture of the model.

Aging. Every year the simulation starts with the aging module where all time related attributes such as age, years married, and years lived in Sweden are updated. Some changes of status are also performed here, for example adding individuals to the labor force when they are 16 years old as well as removing them when they reach the mandated retirement age of 65.

Mortality. The mortality module is used to terminate lives in the model. Since the model is dynamic, each individual is aged and characteristics such as education level, employment status, income, and marital status are modified during the life cycle. According to epidemiological studies, these attributes influence an individual's death risk. Apart from removing individuals from the simulation, events of death cause personal as well as household changes. For instance, when a death occurs, the civil status of the surviving spouse changes from married to widowed. If the deceased is the head of the family, then the spouse will become the new head.

Emigration. This module determines who will leave Sweden as emigrants. Once this event occurs, the lives are effectively removed from the microsimulation model. The decision to emigrate is influenced by age, gender, education level, previous immigration, and years since former immigration.

Fertility. The primary role of the fertility module is to create new domestically born individuals in the microsimulation model. Fertility behavior is influenced directly in the model by a number of individual and household attributes generated in the employment and earnings, education , and marriage modules (including age, family earnings, education, and civil status). The probability of having a baby is calculated every year for all females between 15 and 44 years inclusive. Upon birth, each infant is assigned a sex based on the outcome of a Monte Carlo experiment with a fixed probability of being a male.

Education. SVERIGE uses a series of logistic regression equations and transition probabilities to imitate the education progression of individuals (i.e., completion of elementary school, completion of high school, entry to adult education, persistence through adult education, entry to college/university, persistence through college/university, entry to graduate school and persistence through graduate school). There are basically three routines: (1) an entry routine, which selects individuals into education, assigns them a curriculum, and removes them from the workforce, (2) a persistence routine, which returns non-completers at different educational stages to the workforce, and (3) an educational sector assignment routine, which assigns educational sectors (i.e., engineering and technical fields, business and social sciences, allied health, education, and arts and humanities) on the basis of a simple matrix of transition probabilities. Only full-time students are modeled, but both traditional and adult students are eligible to participate. Their educational experience is cumulative. Internal counters keep track of educational credit awarded for various levels of education. If a student drops out of the education system at any stage, it is possible to come back and finish or start adult education or to re-enter college/university. Equations (9)-(11) show the variables used in the module.

Only full-time students are modeled, but both traditional and adult students are eligible to participate. At any time, students may be selected to discontinue education but they are eligible to rejoin education later on. Men usually start university one year later because of compulsory military service.

Cohabitation. The cohabitation module creates common-law or marriage partners for selected unmarried individuals over the age of fifteen. The module actually consists of three sub-modules that are handled separately. The first sub-module (cohabitation decision) determines whether a person is eligible for cohabitation or not based on logistic regression equations with variables outlined in Table 1. The second sub-module matches males and females into couples. All prospective partners are placed in a multi-dimensional matrix based on gender, age, education level, and income class. Depending on which cell they are placed, suitable pairs are formed in the matching process. The third sub-module (marriage decision) determines whether cohabiting couples will get married.

Leaving Home. The leaving home module determines whether or not a person should leave the parental home and start a new household. The probability of leaving home is computed for individuals between the ages of 14 and 30 years using a logistic regressions equation based on individual and family characteristics. Significant life events such as having a child, becoming a college student, or getting married are handled differently and result in removal from the parental household. The persons who qualified to leave home is given a probability and put in a queue. It is decided with random numbers whether the person will leave or not. If not, they will have to qualify again next year. If a person is still living with parents at the age of 30 years, he or she is automatically reassigned to his or her own new household but stays at the same co-ordinates.

Divorce. The divorce module dissolves common law and marital relationships. Divorce results in persons being assigned a new civil status (from married or cohabitation to divorce) and makes them eligible for re-marriage. A number of other microsimulation events like movement of one person out of the marital dwelling, re-allocation of minor children to one of the resulting new households, and decoupling of household earnings are the consequences of a divorce. Currently, minor children are assigned to one of the parents on the basis of a Monte Carlo experiment using a fixed transition probability and the parent that keeps the children will stay at the old dwelling. Variables that influence the probability of a divorce are: age and education of the female, family earning, whether the couple is married or not, children from previous relationships, if one of the couple is born outside of Sweden, and if the female earns more, is older, or has higher education compared to the male.

Migration. Movement of households can be inter-regional or intraregional. Intra-regional migrations are modeled by a number of simple rules for the life events of cohabiting, divorce, and leaving home (described previously). Interregional migration is performed between 108 labor market regions of Sweden. The estimation procedure is divided into three steps:

(1) *Decision to move*. Logistic regressions are used to estimate the probability of migration. The decision to move is determined for the head of the family and the spouse and children will simply be moved together with the head. The parameters what influence the probability of migration are: age, education, earning, employment, age of oldest and youngest child, how long the head of the family has stayed in the same dwelling, number of previous moves, national origin, number of years since immigration (set equal to year of age for natives), and the regional attributes of size of population, average earnings, and unemployment rate.

(2) *Choice of destination labor market*. The choice of labor market uses regional variables in a multinomial logit regression that generates different probability estimates for each origin-destination option. This probability is estimated using a conditional logit model also known as the McFadden’s conditional logit model.

(3) *Allocation to 100-meter square*. This sub-module is invoked for both regional and local movers. A compatibility index is calculated that compares migrants to the average economic-demographic characteristics of households residing

on candidate destination squares. Variables used in computing the compatibility index include earnings, education level, and family size. The migrant is assigned to the closest match.

Employment and Earnings. The primary aim of the employment and earnings module is to estimate the amount of time each individual between the ages of 16 and 65 years is employed during the year and his or her wage. The module consists of four sub-modules. Initially, an equation determines the likelihood that a given individual is or is not employed during the year. For those who are simulated as being employed, it is then decided if they will work full-time (465 weeks or more) or part-time. If the person is a part-timer it is decided, using a transition matrix, how many weeks he or she will work. Finally, the wages for full-timers and part-timers are calculated using different functions. The variables in these sub-modules are summarized in equations (12)-(14).

Immigration. The immigration module is used to create new individuals in the model that arrive from outside of Sweden. The immigrants are picked from an immigration pool that contains a historical set of 60,000 individuals. A constant transition matrix with age, gender, marital status, and origin is used to predict the demographic distribution of heads of immigrants. Another transition matrix is used to assign the household head to a labor market and the last part of the migration module is used to assign a 100 meter square. Given the characteristics of the head, a person or a family from this pool will be cloned and continue as individuals in the simulation program. These synthetic individuals become part of the resident population and will undergo additional simulation in subsequent years.

4. THE EFFECTS OF PLANT SHUTDOWN

The literature suggests that plant closures may have a variety of effects on regions and localities. These include: (1) effects on worker subsequent labor market experience, (2) effects on worker health and psychological well-being, (3) effects on worker families including marital stress, and (4) effects on communities hosting the plant.

Much of the focus on workers has been on the on their labor market experiences following the plant shutdown. After unemployment, several paths are possible, including: (1) reemployment in region, (2) continued unemployment, (3) dropping out of labor force due to retirement, (4) retraining-education for reemployment, (5) migration and reemployment, (6) dropping out of labor force due to illness or sickness, (7) self-employment, and (8) death (Gordus, et al., 1981; Tomaney, et al., 1999). Among the most important factors in assessing the economic costs of plant shutdowns are the duration of unemployment experienced by workers and their earnings once re-employed. While studies show that many workers find new employment within several months of a plant shutdown, the new job is frequently lower paid and more likely to be located in the service sector. The unemployment and earnings experience after displacement also differs by age, gender, race, education, job tenure, industry sector, geographical location (e.g., rural/urban), and the general strength of local/national labor markets (Gordus, et al., 1981; Perucci et al., 1987; Hamermesh, 1989; Maxwell, 1989; Leahy and Lin, 1992; Farber 1997; Tomaney, et al. 1999; Beneria and Santiago, 2001; Hamrick, 2001). Several attributes likely affect a workers' path of adaptive behavior, including "employment history/life skills", "prelayoff standard of living," "worker life stage," "family circumstances and income," and "attachment to place/community and rurality" (Carroll et al., 2000).

The impacts of plant closure extend beyond worker labor market experiences to self-esteem, mental health, and physical wellbeing. Periods of unemployment marked by lower social status and fewer resources for life and leisure may result in increased personal dissatisfaction, stress, and mental health problems (Castro and Romero, 1987; Gordus, et al., 1981; Grayson, 1985; Perrucci et al., 1987; Shields and Price, 2001). The loss of income and fringe benefits for medical care and nutrition or the aggravation of stress may also contribute to physical illness and if left untreated to morbidity (Westin, et al., 1988; Westin, et al., 1989; and Westin, 1990). Furthermore, the unemployment experience itself may exact a higher "psychological-psychosocial health cost" than what is embodied by income loss alone (Shields and Price, 2001). Families may be affected too. Worker families adapt to the post-employment experience in different ways, with the spouse taking more responsibility for supporting the household (Gordus, et al., 1981). But, unemployment can also trigger increased worker-spouse conflict (Broman, et al., 1990; Perrucci and Perrucci, 1997). These indirect effects of plant closure make up some of the so-called "social costs" of economic disruption. However, not all researchers agree that these social costs are significant (Leahy and Lin, 1992) because of an apparent resilience and adaptability of workers and their families to new circumstances and questions concerning the exact mechanisms by which displacement affects stress (Bartley, 1987).

Communities are affected by plant closures economically, demographically, and socially. Ballas and Clarke (2001) show that the geographical/neighborhood, income, and demographic effects are dispersed among neighborhood groups in a city and that multiplicative secondary and induced household effects can be expected. In addition to decreased local income and higher unemployment, increased out-migration and greater income inequality (Beneria and Santiago, 2001) may result. Some regions, however, may be better able to absorb labor from plant shutdowns. For instance, regions with a healthy, growing labor market can better absorb displaced workers. Moreover, more urbanized regions, with more diversified industrial structures offer better reemployment prospects and opportunities than rural areas (Hamrick 2001).

SVERIGE offers the ability to estimate the individual, family, and community/regional effects discussed here within a single model. The subsequent labor market experience of the worker is an important issue: the duration of unemployment, decision to remain in the labor force, decision to seek additional education or training, decision to move elsewhere to find work, are all choices that will be made and can be tracked within the model. The secondary effects of these experiences and decisions on the well-being of the worker and his/her family (i.e., the so-called "social costs" of unemployment) are also important. Periods of unemployment and income loss are associated with a number of events within the model such as less likelihood of cohabitation and marriage, greater likelihood of divorce, and higher mortality. Finally, the effects on workers, families, and neighbors can be aggregated into geographical units to observe the effects on indicators of community well-being such as average income, income distribution, unemployment, population, etc.

5. HYPOTHETICAL PLANT SHUTDOWN: THE SAAB AUTOMOBILE PLANT IN TROLLHÄTTAN

The shutdown application chosen for this paper is a branch plant for the Saab automobile company. This application was selected because of the ease of locating the plant in the micro database, the availability of relatively high employee earnings in the manufacturing sector, and the possibly of plant closing or significant firm worker displacement in the future because of highly competitive conditions in the automobile manufacturing sector.

Saab began in 1937 as Svenska Aeroplan Aktiebolaget (Swedish Airplane Company Limited, abbreviated SAAB) to provide bombers and fighters for the Swedish Air Force (Automotive Intelligence 2001). Automobile production began in 1949 at its Trollhättan plant, starting with 1,246 automobiles in 1949 and growing to a peak production of 134,112 in 1986. Saab expanded operations over the next several decades to include facilities at Gothenburg (Sales and Marketing, transmissions production), Nyköping (distribution), Södertälje (engine production), and Uusikaupunki, Finland (convertible production), although Trollhättan continues to serve as its largest production facility, product development hub, and corporate headquarters.

Saab occupies a niche in the mid-level luxury car market and competes with other smaller European carmakers such as BMW, Mercedes-Benz, and Volvo. However, this market has come under increasing worldwide competition from Japanese (Lexus, Infiniti, Acura), Korean, and American producers. Saab, itself, became an early example of international consolidation trends in the automobile industry when General Motors purchased a fifty percent share in the firm in 1990 with the aim of restoring the automaker's profitability. This share was increased to 100% in 2000. The company had failed to restore its profitability as recent as the late 1990s, losing approximately $200 million in each of the years 1997 and 1998 (Automotive Intelligence, 2001). To maintain a competitive position, Saab has slashed its employment dramatically over the past decade, from 17,000 to 11,500 in the mid 1990s (Dicken, 1998) to approximately 8,522 in 2001. Furthermore, it closed a production facility at Malmö in the early 1990s just three years after it was opened (Dicken, 1998, p. 351). With continued competitive pressures in the automobile industry, Saab's long-term viability remains a question mark.

To study the possible effects of a plant shutdown at Saab, the production and administrative facilities in Trollhättan were selected. Employees of the Trollhättan plant were identified by searching the TOPSWING database for employees of the motor vehicle manufacturing sector located in the Trollhättan municipality. This revealed approximately 8,400 individuals who worked for the same enterprise and enterprise branch and whose workplace coordinates were located at just four positions. The Saab workforce there is predominantly male (71%) and includes a large proportion of foreign-born (20%). Most of the foreign-born are derived from Nordic countries. The vast majority (89%) of Saab workers reside in the Trollhättan labor market region where the plant is located. However, an additional 8% live in the adjoining labor market (LA) regions of Gothenburg (5%) and Uddevalla (3%). The remaining ones live elsewhere in Sweden.

These approximately 8,400 workers will form the basis of the simulations here. Both baseline and experimental runs will be conducted, with the baseline forming the counterfactual and the experimental presenting the “what if” condition of total branch plant shutdown entailing the displacement of the entire Trollhättan plant workforce.

SVERIGE is able to generate output for a variety of attributes aggregated into different levels (e.g., individual, family, neighborhood block, municipality, region) for different time periods. However, the focus here is on the workers; therefore, results reported here are for the individuals directly affected by plant shutdown for a 22 year period, beginning in 1990 and ending in 2012. The Trollhättan plant shutdown occurs in 1991. Attributes examined include employment, earnings, education, mortality, divorce, marriage, migration, and emigration. These variables are selected in order to explore the simulated economic and social effects of plant shutdown. The “baseline” condition shows what would have occurred in the absence of plant shutdown, while “experimental” identifies the simulation corresponding to plant shutdown.

6. RESULTS

This section examines some economic, social, demographic, and community impacts of a plant shutdown. Figure 1 shows the employment experience of the 8,399 Saab employees following plant closure. Because the simulation runs occur on an annual basis, the employees are prevented from working during the year of plant closure (i.e., 1991). However, they recover rapidly following the layoff, with approximately seventy percent finding employment in the next year and eighty-seven percent within five years. This monotonic recovery pattern is similar to that identified in the literature (Aronson and McKersie, 1980; Grayson, 1985; Westin, 1990).

Re-employment results can be disaggregated in a variety of ways. When they are disaggregated by age, gender, education, and country of birth, the model adequately predicts disparities identified by empirical studies. Figure 2 shows that the immediate re-employment experiences of 50+ year olds is poor. Figure 3 indicates that men are more likely to be quickly re-employed than women, and that more educated and native workers have an easier time finding employment than others. These results reflect the employment equation parameter estimates which take into account the effect of these variables on search intensity, human capital, and employment demand.

Since employment status is an important variable in many of the microsimulation model’s economic, social and demographic equations, this relatively rapid employment convergence should produce more conservative estimates of the impact of plant shutdown on the other reported indicators. Figure 4 shows the effect of plant shutdown on average annual earnings. The pattern (Series 1) mirrors that of employment in the model because unemployed workers have no income. However, when the unemployed are subtracted from the denominator (Series 2), the pattern is still one of slow convergence because of the preponderance of re-employment that occurs below the initial wage level. The only peculiarity is an initial earnings “burst” that smoothes out over time. A normalized earnings graph (see Figure 5) shows experimental earnings as a percent of baseline earnings for the two differently calculated series. It shows that workers recover fifty-eight to eighty percent of their original pre-shutdown earnings after the first year. These series converge on ninety percent within two decades of closure.

Within the model, employment and income have secondary demographic and social effects that, in turn, affect the likelihood of subsequent demographic events. Figure 6 shows that the plant closure has the effect of increasing somewhat the number of workers who elect to undertake higher education. This outcome conforms to the literature on higher education (Rephann, 2002a), which indicates that enrollment fluctuates counter-cyclically. This ‘education’ effect is most pronounced one year after closure and drops off after that. This result is partially attributable to the parameters of the “Ineducation” equation (9) described in Table 1—this equation selects individuals to be included in higher education. The path of effect is primarily income level—lower income individuals (as measured by previous year income) have a greater tendency to select college than others, theoretically because of the lower opportunity costs and concomitant greater returns that accrue. One of the advantages of microsimulation is that that the composition of these results can be further explored for validation or prediction. Further decomposition of the simulation results for those choosing education reveals that they are predominantly younger and female.

Public policy discussions of the ‘social costs’ of plant shutdown often center on family and health effects. SVERIGE produces simulations for indicators of each of these effects. The ‘social costs’ are represented by family formation and dissolution, which some current socioeconomic research suggests exacts quantifiable private and community costs (Oswald, 1997; Boardman et al., 1997). Figure 7 shows that worker marriages are much less frequent in the plant shutdown scenario with 570 fewer workers cohabiting or being married in 1995. Although not examined in this paper (because the worker's spouse is not included in the study output), the lower cohabitation rate would be expected to affect births and family size. Figure 8 shows that the divorce/de-cohabitation impact increases substantially in the immediate aftermath of the plant shutdown.

The health costs of plant closure are represented by mortality. If the closure and subsequent life experience (which includes increased risk of being single as well as being unemployed) contributes to premature illness and death, additional private and public costs accrue. Figure 9 shows that the model simulates an increase in deaths as a result of plant closure. The cumulative death impact reaches 104 in 2000, nine years after the plant closure. The same effect is evident for worker spouses (see figure 10). This mortality impact diminishes in a desultory fashion thereafter as the entire cohort in both baseline and experimental simulations ages and expires (in both the baseline and experimental situations, everyone eventually dies resulting in a net zero long-term impact). The cumulative widowed impact becomes negative in later years because of the much lower number of matrimonial bonds formed in the post-impact experimental situation. These results are consistent with some of the epidemiological research that connects plant shutdowns with increased stress and economic deprivation that exacerbate worker morbidity.

The next figure shows the effect of plant shutdown on emigration. Since a large number of plant workers are foreign born, the unemployment experience triggers a small exodus of mainly foreign workers from the country (see figure 11). This result reflects, in part, an interaction between modular equations indicating that foreign-born workers are less likely to be re-employed at comparable earnings and unemployed, lower earning foreign-born workers have a higher propensity to return emigrate. This result is consistent with empirical studies of Swedish immigrant return migration (e.g.., Klinthäll 1998).

The final three figures show worker residential location impacts. The model simulates a net outmigration of workers from the affected region because of the push factors of unemployment and lower earnings. Figure 12 shows fewer workers residing in the Trollhättan municipality (where the vast majority of employees reside) during the immediate aftermath of the plant shutdown than they would have without the plant shutdown. However, this outmigration is partially reversed several years later. Figure 13 indicates why—the net migratory effect one year after the shutdown is most pronounced in labor market regions in close proximity to Trollhättan. Many of these workers return to Trollhättan in later years. The long-run effect on Trollhättan population (relative to the baseline) is fewer than one hundred workers, a relatively small magnitude compared to what one might expect for such a catastrophic event. After two decades, workers are somewhat more geographically dispersed as indicated by figure 14 than they would be if the plant had closed.

The somewhat limited migration experience reflects both expected outcomes and model peculiarities. First, the availability of extensive Swedish unemployment and health benefits during employment crises dampens outmigration relative to the U.S. experience (Swan 2000). Second, plant shutdown induces a relatively large number of 'early retirements.' These retirees are less likely to move than employed workers nearing retirement age. Third, the model assumes basically infinitely elastic regional labor demand with re-employment decisions affected by individual labor supply decisions. Re-employment within the region, therefore, occurs more rapidly than it would otherwise. Fourth, the model was calibrated with data reflecting mainly situational transitions rather than catastrophic events such as a plant shutdown and the parameters estimated for the microeconomic behavioral relations are less sensitive to an unemployment experience than might be expected.

In addition to aggregated results, the microsimulation model output data make it possible to explore the effect of events on individual life "trajectories," biographies, "life paths," or "destinies." Table 2 shows how a plant shutdown affects the key life transitions for each of three randomly chosen individuals from Trollhättan: ("Magnus") a 22 year old single male, ("Kirsten") a 28 year old single female, and ("Sven") a 50 year old male. The baseline situation is depicted by column A and experimental shutdown situation by Column B. In the baseline situation, Magnus begins to cohabit with his partner in 1992 and experiences a steady progression in income level throughout his career until the end of the simulation period in 2012. In the plant shutdown situation, his circumstances and life path changes, mostly for the worse. In 1991, he becomes unemployed and is re-employed in 1992 albeit at lower earnings. Although he begins to cohabit in 1992, marriage is delayed until one year later (1995). Magnus recovers from his initial earnings losses but his progress lags behind the baseline.

Life trajectories can change in often unpredictable ways. For instance, in the baseline situation, Kirsten is a frequent mover. She begins to cohabit in 1992, moves to Stockholm in 1993, moves again in 1996 (to Ostersund) and gets married. She moves once again in 2003 (Haparanda) and again in 2005 to Lycksele. Throughout the period, her earnings steadily improve. In the experimental case, she is unemployed in 1991 and re-employed in 1992, although at lower earnings. She gets married in 1992 and in 1993 enters education and receives the third year of a Högskolan degree. For about the next decade her earnings are fairly low and erratic. In 1997 she moves to Lysekil. She gets divorced in 2000 and becomes unemployed in 2001. In 2004 she moves again, this time to Goteborg. By the end of the period, however, she has re-gained significant ground and achieved the same earnings level as occurred in the baseline situation.

Sven's situation illustrates how the stress of cumulative misfortune can contribute to terrible consequences. Sven's earnings remain show a steady progression upward until he nears retirement in 2004. In 2005, the model automatically retires him and he lives for the remainder of the period (on non-earnings income). The twenty-two years are uneventful. The experimental case is much different: Sven is furloughed in 1991 and remains unemployed until 1993. That year he finds a job at a slightly higher level of pay but retains it for only a year. He finds his next job in 1995 at a somewhat lower level of pay. However, Sven dies prematurely in 2008 and his biography concludes.

These graphs and individual case studies indicate the potential ramifications of significant regional disruptions and the complex induced interactions that affect individual life paths. Although the explanatory equation for a particular event is key to understanding outcomes, in a systems model such as SVERIGE, it is difficult to pinpoint exactly the variable(s)/event(s) that are responsible for each outcome because of the sequence of events that constantly change an individual's attributes. However, one can surmise that the unemployment event has a large direct bearing on many of the indirect outcomes reported here. The unemployment experience affects nearly every equation in the model through employment status and annual earnings. These variables in turn affect the likelihood of cohabitation, divorce, migration, mortality, etc, which later affect the likelihood of employment, mortality, marriage, etc.

7. SUMMARY AND CONCLUSIONS

Microsimulation has much to offer regional scientists who want to understand the distributional, economic, demographic, and social impacts of regional policies and events. This paper demonstrates the applicability of a spatial, dynamic microsimulation model to the situation of a hypothetical large automotive plant shutdown. The model simulates a fairly resilient worker labor market response albeit at lower average earnings than before, a burst of new educational entries, decreased family formation, increased divorce, increased morbidity, and some population egress from the region. In addition, the model produces plausible cohort outcomes and lifetime biographies for individuals simulated in the model. Findings are consistent with the literature on plant shutdown and suggest that such a model may be used to conduct more detailed, comprehensive impact analysis than existing more aggregate regional methods such as input-output and econometric models permit.

Although building a model such as SVERIGE without the benefit of a comprehensive, longitudinal micro database may seem out of reach for most researchers, hybridized data techniques and microdata samples have been utilized successfully to generate artificial populations and behavioral equations for dynamic simulation (Clarke 1996). Therefore, the plant shutdown application described here can be replicated elsewhere using locally available data.

This paper represents one of several applications using the SVERIGE model—others include simulations of national immigration policy (Rephann, 2002b) and small area population change (Holm et al., 2002) used in earlier stages of model development. However, much work remains to be done in refining the existing model modules, adding more modules, and providing additional diagnostic capabilities. Validation is an ongoing process because of the complexity of the model. More modules will be added to provide behavioral explanations for other non-earning sources of income (e.g., transfers, retirement income, capital) and additional years (1996-2000) will be added to the longitudinal micro database. In addition, future versions of the model may the ability to vary the random seeds of a simulation make it possible to conduct non-parametric or bootstrapping of impact estimates and thereby to provide statistical confidence intervals for model output.

REFERENCES

Andreassen, Leif, Dennis Fredriksen, and Olav Ljones. 1996. "The Future Burden of Public Pension Benefits: A Microsimulation Study," in Ann Harding (ed.), *Microsimulation and Public Policy*. Amsterdam: Elsevier, pp. 329-357.

Aronson, Robert L. and Robert B. McKersie. 1980 "Economic Consequences of Plant Shutdowns in New York State," Ithaca, NY: New York State School of Industrial and Labor Relations, Cornell University.

Automotive Intelligence. 2001. "Saab Automobile AB, Trollhättan, Sweden," (http://www.autointel.com/nao_companies/general_motors/saab01.htm)

Ballas, D. and G. Clarke. 2001. "GIS and Microsimulation for Local Labour Market Analysis," *Computers, Environment and Urban Systems*, 24, 305-330.

Bartley, Mel. 1987. "Redundancy and Health," in Raymond M. Lee (ed.), *Redundancy, Layoffs and Plant Closures: Their Character, Causes, and Consequences*. London: Croon Helm, pp. 305-334.

Beneria, Lourdes and Luis E. Santiago. 2001. "The Impact of Industrial Relocation on Displaced Workers: A Case Study of Cortland, New York," *Economic Development Quarterly*, 15, 78-79.

Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David L. Weimer. 1997. "'Plug-in' Shadow Price Estimates for Policy Analysis," *Annals of Regional Science*, 31, 299-324.

Broman, C. L., V. L. Hamilton, and W. S. Hoffman. 1990. "Unemployment and its Effect on Families: Evidence from a Plant Closing Study," *American Journal of Community Psychology*, 18, 643-659.

Caldwell, Steven. 1996. "Health, Wealth, Pensions and Life Paths: The CORSIM Dynamic Microsimulation Model," in Ann Harding (ed.), *Microsimulation and Public Policy*. pp. 505-522.

Caldwell, S. B., G. P. Clarke, and L. A. Keister. 1998. "Modelling Regional Changes in US Household Income and Wealth: A Research Agenda," *Environment and Planning C: Government and Policy*, 16, 707-722.

Caldwell, Steven and Richard J. Morrison. 2000. "Validation of Longitudinal Dynamic Microsimulation Models: Experience with CORSIM and DYNACAN," in Lavinia Mitton, Holly Sutherland, and Melvyn Weeks (eds.), *Microsimulation Modelling for Policy Analysis: Challenges and Innovations*. Cambridge, UK: Cambridge University Press, pp. 200-225

Carroll, Matthew S., Keith A. Blatner, Frederick J. Alt, Ervin G. Schuster, Angela J. Findley. 2000. "Adaptation Strategies of Displaced Idaho Woods Workers: Results of a Longitudinal Panel Study," *Society and Natural Resources*, 13, 95-113.

Citro, Constance F. and Eric A. Hanushek, eds., 1991. *Improving Information for Social Policy Decisions: The Uses of Microsimulation Modeling – Volume 1, Review and Recommendations*. Washington, DC: National Academy Press.

Clarke, G. P., ed., 1996. *European Research in Regional Science 6. Microsimulation for Urban and Regional Policy Analysis*. London: Pion.

Clarke, Martin and Einar Holm. 1987. "Microsimulation Methods in Spatial Analysis and Planning," *Geografiska Annaler B,* 69, 145-164.

Dicken, Peter 1998. *Global Shift: Transforming the World Economy*. London: Paul Chapman Publishing Ltd.

Farber, Henry S. 1997. "The Changing Face of Job Loss in the United States, 1981-1995," *Brookings Papers on Economic Activity: Microeconomics*, 55-128.

Favreault, Melissa M. and Steven B. Caldwell. 2000. "Assessing Distributional Impacts of Social Security Using Dynamic Microsimulation," In A. Gupta and V. Kapur (eds.), *Microsimulation in Government Policy and Forecasting*. Amsterdam: Elsevier, pp. 395-426.

Fredriksen, Dennis. 1998. "Projections of Population, Education, Labour Supply and Public Pension Benefits. Analyses with the Dynamic Microsimulation Model MOSART," Oslo, Norway: Statistics Norway.

Galler, Heinz P. 1997. "Microsimulation: History and Applications," in Wolfgang Lutz (ed.), *FAMSIM-Austria: Feasibility Study for a Dynamic Microsimulation Model for Projections and the Evaluation of Family Policies based on the European Family and Fertility Survey*. Vienna: Austrian Institute for Family Studies, pp. 24-37.

Gordus, Jeane Prial, Paul Jarley, and Louis A. Ferman. 1981. *Plant Closings and Economic Dislocation.* Kalamazoo, Michigan: W. E. Upjohn Institute for Employment Research.

Grayson, J P. 1985. "The Closure of a Factory and its Impact on Health," *International Journal of Health Services: Planning, Administration, Evaluation*, 15, 69-93.

Hammermesh, Daniel S. 1989. “What do we Know about Worker Displacement in the U.S.?” *Industrial Relations*, 28, 51-59.

Hamrick, Karen S. 2001 “Displaced Workers: Difference in Nonmetro and Metro Experiences in the Mid 1990s,” *ERS Rural Development Research Report*, No. 92. Washington, DC: Economic Research Service-USDA.

Hancock, Ruth. 2000. “Charging for Care in Later Life: An Exercise in Dynamic Microsimulation,” in Lavinia Mitton, Holly Sutherland, and Melvyn Weeks (eds.), *Microsimulation Modelling for Policy Analysis: Challenges and Innovations*. Cambridge, UK: Cambridge University Press, pp. 226-237.

Harding, Ann. 2000. “Dynamic Microsimulation: Recent Trends and Future Prospects,” in A. Gupta and V. Kapur (eds.), *Microsimulation in Government Policy and Forecasting*. Amsterdam: Elsevier, pp. 297-312.

Holm, E., U Lingren, K Makila, G. Malmberg. 1996. “Simulating an Entire Nation,” in G. P. Clarke (ed.), *European Research in Regional Science 6. Microsimulation for Urban and Regional Policy Analysis*. London: Pion, pp. 164-186.

Holm, Einar, Kirsten Holme, Kalle Mäkilä, Mona Mattsson-Kauppi, and Gunnel Mörtvik. 2002. “The SVERIGE Spatial Microsimulation Model: Content, Validation, and Example Applications,” Kiruna, Sweden: Spatial Modelling Centre, (http://www.smc.kiruna.se/publications/PDF/SVERIGE.pdf).

Isard, Walter, Iwan Azis, Matthew Drennan, Ronald Miller, Sidney Saltzman, and Erik Thorbecke, eds., 1998. *Methods of Interregional and Regional Analysis*. Brookfield, Vermont: Ashgate.

Klevmarken, Anders and Paul Olovsson. 1996. “Direct and Behavioural Effects of Income Tax Changes—Simulations with the Swedish Model MICROHUS,” in Ann Harding (ed.), *Microsimulation and Public Policy*. Amsterdam: Elsevier, pp. 203-229.

Klevmarken, N. Anders. 1997. “Behavioral Modelling in Micro Simulation Models: A survey,” Uppsala, Sweden: Department of Economics, Uppsala University.

Klinthäll, Martin. 1998. “Patterns of Return Migration from Sweden: 1970-1993,” Paper presented at the TSER workshop on Labour Demand, Education, and the Dynamics of Social Exclusion in Lisbon, Portugal on October 29-November 1, 1998.

Leahy, Peter J. and Xiannuan Lin. 1992. “Plant Closings: A Comparison to Natural Disasters,” *American Journal of Economics and Sociology*, 51, 333-348.

Maxwell, Nan L. 1989. “Labor Market Effects from Involuntary Job Losses in Layoffs, Plant Closings,” *American Journal of Economics and Sociology*, 48, 129-141.

Merz, J. 1991. “Microsimulation: A Survey of Principles, Developments and Applications,” *International Journal of Forecasting*, 7, 77-104.

Nelissen, J. H. M. 1994. *Income Redistribution and Social Security*. London: Chapman and Hall.

Orcutt, G. 1957. “A New Type of Socio-economic System,” *Review of Economics and Statistics*, 58, 773-797.

Oskamp, Anton. 1995. “LocSim: A Microsimulation Approach to Household and Housing Market Modelling,” PDOD-Paper No. 29, Department of Planning and Demography, University of Amsterdam.

Oswald, Andrew. 1997. “Happiness and Economic Performance,” *Economic Journal*, 107, 1815-1831.

Perrucci, Carolyn C. and Robert Perrucci.1997. “Gender Differences in the Economic, Psychological and Social Effects of Plant Closings in an Expanding Economy,” *Social Science Journal*, 34, 217-233.

Perrucci, Carolyn C., Dena B. Targ, Robert Perrucci, and Harry R. Targ. 1987. “Plant Closing: A Comparison of Effects on Women and Men Workers,” in Raymond M. Lee (ed.) *Redundancy, Layoffs and Plant Closures: Their Character, Causes, and Consequences*. London: Croon Helm, pp. 181-207.

Rephann, Terance. 2002a. “The Importance of Geographical Attributes in the Decision to Attend College,” *Socio-Economic Planning Sciences*, 36, 291-307.

___ 2002b. “Economic-demographic Effects of Immigration: Results from a Dynamic, Spatial Microsimulation Model,” paper presented at the 41st Annual Meeting of the Southern Regional Science Association on April 11-13, 2002 in Arlington, VA.

Shields, Michael A. and Stephen Wheatley Price. 2001. “Exploring the Economic and Social Determinants of Psychological and Psychosocial Health,” Discussion Paper No. 396, Institute for the Study of Labor (IZA). Bonn, Germany.

Swan, Neil. 2000. “Unemployment Insurance and Labour Mobility: Analysis using a New Swedish

Microsimulation Model," in Lavinia Mitton, Holly Sutherland, and Melvyn Weeks (eds.), *Microsimulation Modelling for Policy Analysis: Challenges and Innovations*. Cambridge, UK: Cambridge University Press, pp. 251-268.

Tomaney, John, Andy Pike, and James Cornford. 1999. "Plant Closure and the Local Economy: The Case of Swan Hunter on Tyneside," *Regional Studies*, 33, 401-412.

Westin, S., Norum, D., and Schlesselman, J. J. 1988. "Medical Consequences of a Factory Closure: Illness and Disability in a Four-year Follow-up Study," *International Journal of Epidemiology*, 17, 153-161.

Westin, S., Schlesselman, J. J., and Korper, M. 1989. "Long-term Effects of a Factory Closure: Unemployment and Disability during Ten Years' Follow Up," *Journal of Clinical Epidemiology,* 42, 435-441.

Westin, S. 1990. "The Structure of a Factory Closure: Individual Responses to Job-loss and Unemployment in a 10-year Controlled Follow-up Study," *Social Science and Medicine*, 31, 1301-1311.

Williamson, P. 1996. "Community Care Policies for the Elderly, 1981 and 1991: A Microsimulation Approach," in G. P. Clarke (ed.), *European Research in Regional Science 6. Microsimulation for Urban and Regional Policy Analysis*. London: Pion, pp. 64-87.

Williamson, Paul. 1999. "Microsimulation: An Idea whose Time has come?" paper presented at the 39th European Congress of the European Regional Science Association in Dublin, Ireland, on August 23-27, 1999.

Zedlewski, Sheila R. 1990. "The Development of the Dynamic Simulation of Income Model (DYNASIM)," in Gordon H. Lewis and Richard C. Michel (ed.), *Microsimulation Techniques for Tax and Transfer Analysis*. Washington, DC: The Urban Institute Press, pp. 109-136.

TABLE 1: Determinants of Selected Person Attributes in SVERIGE

(1) Gavebirth – (age, maritalstatus, earnings(household), educlevel, working[t-1])
(2) Died – (age, maritalstatus, earnings(household), educlevel, sex, working[t-1])
(3) Cohabit - (age, children, earnings, educlevel, maritalstatus, sex, working[t-1])
(4) Married- (age, age(partner), age(youngest child), children, children(partner)[t-yearscohab], maritalstatus, earnings(household), educlevel, edlevel(partner), earnings, earnings(partner), bornregion, bornregion(partner))
(5) Partner – pointer to partner, mating algorithm(sex, age, educlevel, bornregion)
(6) Divorced- (age(youngest child), children, children(female partner)[t-yearscohab], earnings(household), educlevel, edlevel(partner), maritalstatus, bornregion, age, age(partner), bornregion(partner), working[t-1])
(7) Widowed- died(partner)
(8) LeaveHome- (age, earnings, educlevel(mother), educlevel(father), sex)
(9) Ineducation- (age, earnings(household), educlevel(mother), educlevel(father), maritalstatus, working[t-1], bornregion, ineducation[t-1], sex)
(10) Educlevel- (educlevel[t-1], ineducation)
(11) Educsector - exogenous
(12) Working- (age[t-1], age(youngest child), children, maritalstatus, educlevel, sex, working[t-1], ineducation[t-1], bornregion, yearsinSweden, unemployed(labor market), employed(labor market), distance)
(13) Wkworked- (age[t-1], age(youngest child), children, maritalstatus, educlevel, ineducation[t-1], working[t-1], yearsinSweden, bornregion, location)
(14) Earnings- (age[t-1], earnings[t-1], educlevel, ineducation, sex, location, wkworked)
(15) Bornregion- Exogenous for immigrants or parent's location for Swedes
(16) YearsinSweden- New immigrants or newly born = 0, (YearsSweden[t-1], Emigrate)
(17) Emigrate-(age, sex, maritalstatus, yearsinSweden, numbermoves, bornregion, working[t-1], educlevel, earnings, population(labor market))
(18) Move— (age, age(oldest child), age(youngest child), children, sex, educlevel, working[t-1], yearsinSweden, bornregion, working, earnings(household), timeindwelling, numbermoves, earnings(labor market), employed(labor market), unemployed(labor market), population(labor market))
(19) Age – Age[t-1]
(20) Mother- Natural mother or adoption
(21) Father- Natural father

TABLE 2: Individual Life Paths (Events)

	Magnus		*Kirsten*		*Sven*	
	Base	Shutdown	Base	Shutdown	Base	Shutdown
1990	E5	E5	E6	E6, ED5	E10	E10
1991		Unemp, E0		Unemp, E0	E11	Unemp, E0
1992	Cohabit, E6	Emp, Cohabit, E2	Cohabit	Emp, E5, Marry	E12	
1993	E7		Move (1)	Ined, ED6		Emp, E11
1994	Marry, E8				E13	Unemp, E0
1995	E9	Marry, E3	Move (88)		E14	Emp, E8
1996	E10					
1997	E11		Move (83), Marry E7	E4, Move (40)	E15	
1998	E12	E4		E3	E16	E9
1999	E13	E5	E8		E17	
2000	E14	E7		E2, Divorce		
2001	E15		E9	Unemp, E0		E8
2002	E17	E8	E10	Emp, E4	E16	E7
2003	E18		Move (106)		E16	E6
2004	E20	E9	E11	Move (39)	E15	E5
2005			E12		Pension, E0	Pension, E0
2006		E10	Move (95)	E5		
2007			E11		E6	
2008		E11		E7		Deceased
2009				E8		
2010		E12		E10		
2011				E11		
2012		E13	E12	E12		

Key

E0-E12—Earnings levels from category 1 to category 12. (1)=Stockholm
ED0-ED9—Educational levels from category 1 to category 9. (39)=Goteborg
Ined—Enrolled in school/college. (40)=Lysekil
Unemp—Begin unemployment event (83)=Solleftea
Emp—Begin employment (88)=Ostersund
Move – migration event (95)=Lycksele
Pension – Retirement event (106)=Haparanda
Marry—Get married event
Divorce—Get divorced event

FIGURE 1: Employment.

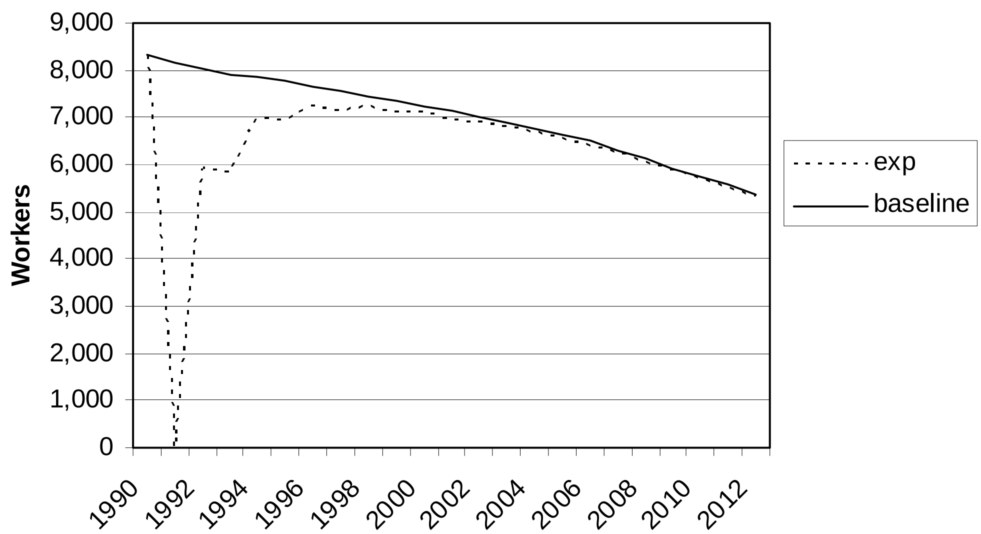


FIGURE 2: First Year Employment Recovery by Age.

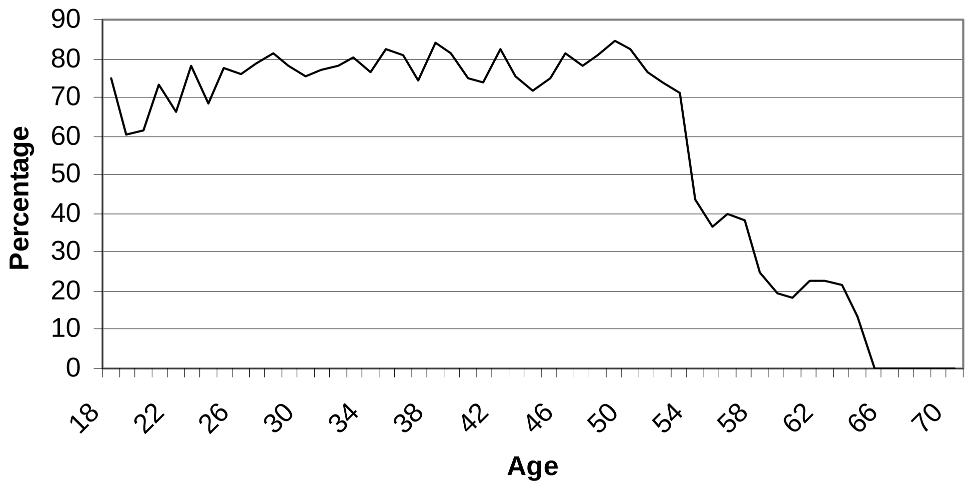


FIGURE 3: First Year Employment Recovery by Group.

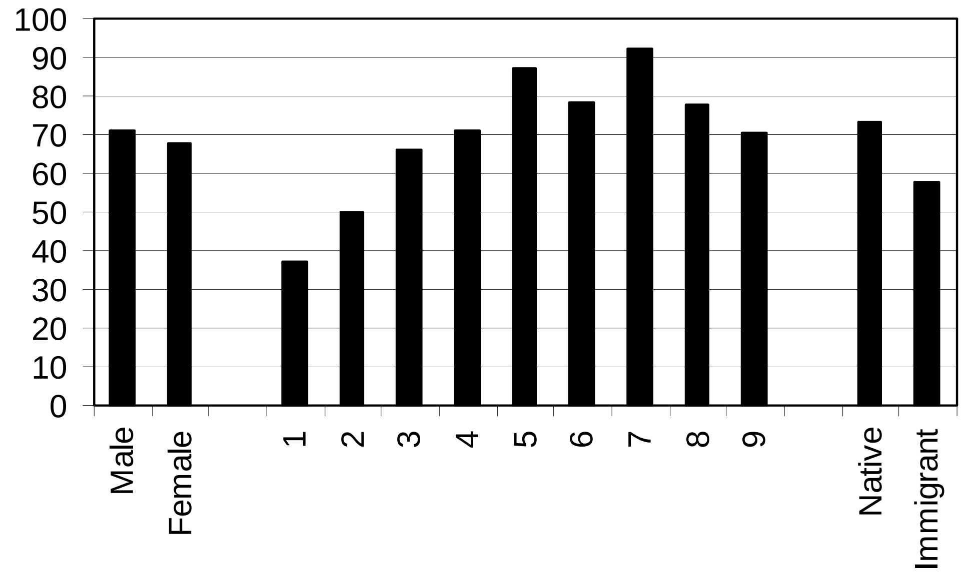


FIGURE 4: Earnings Impact.

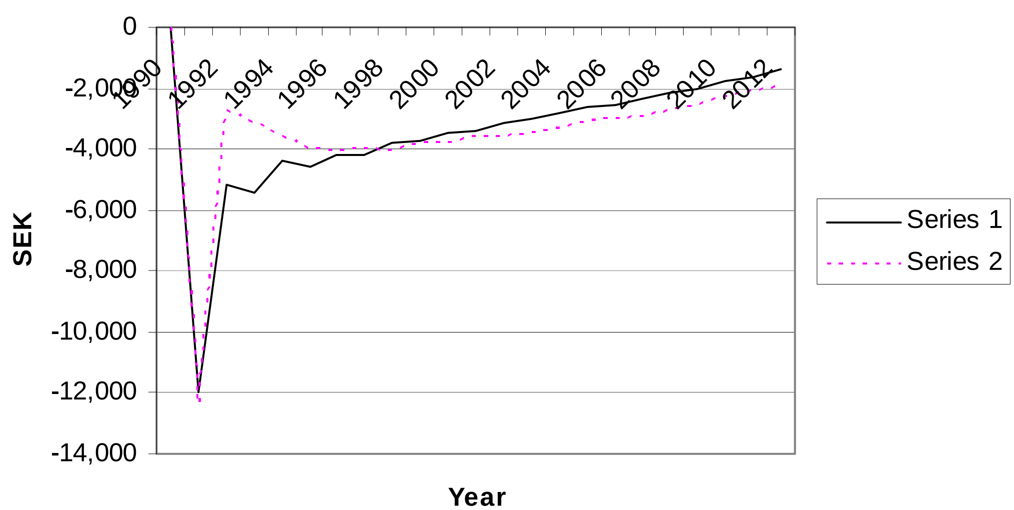


FIGURE 5: Normalized Earnings.

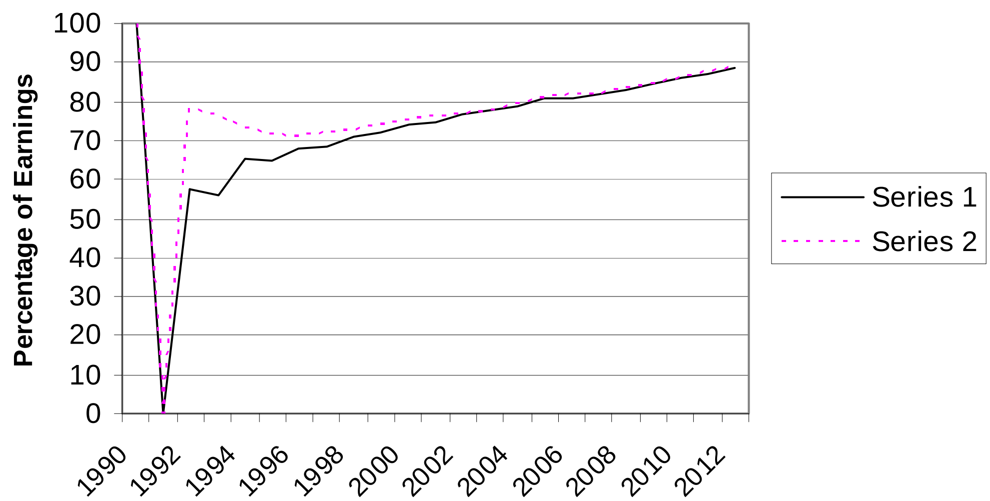
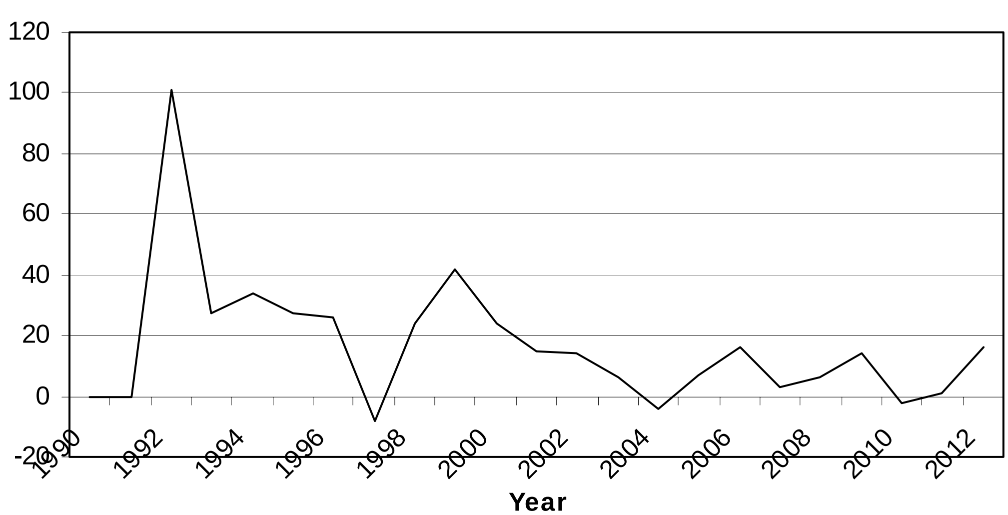


FIGURE 6: Education Impact.



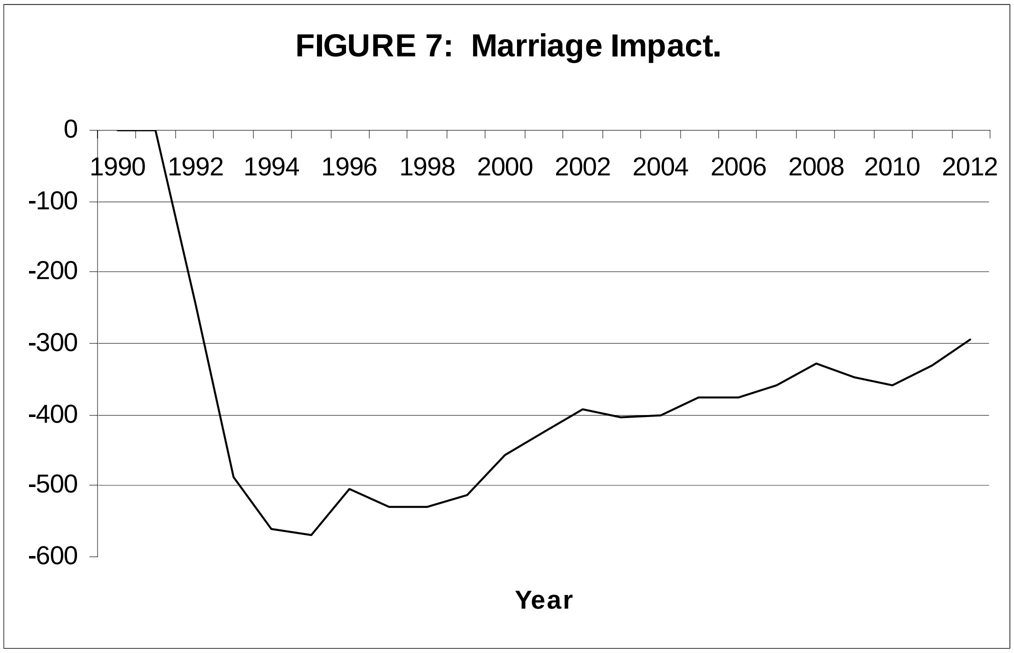


FIGURE 7: Marriage Impact.
0
-100
-200
-300
-400
-500
-600
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year

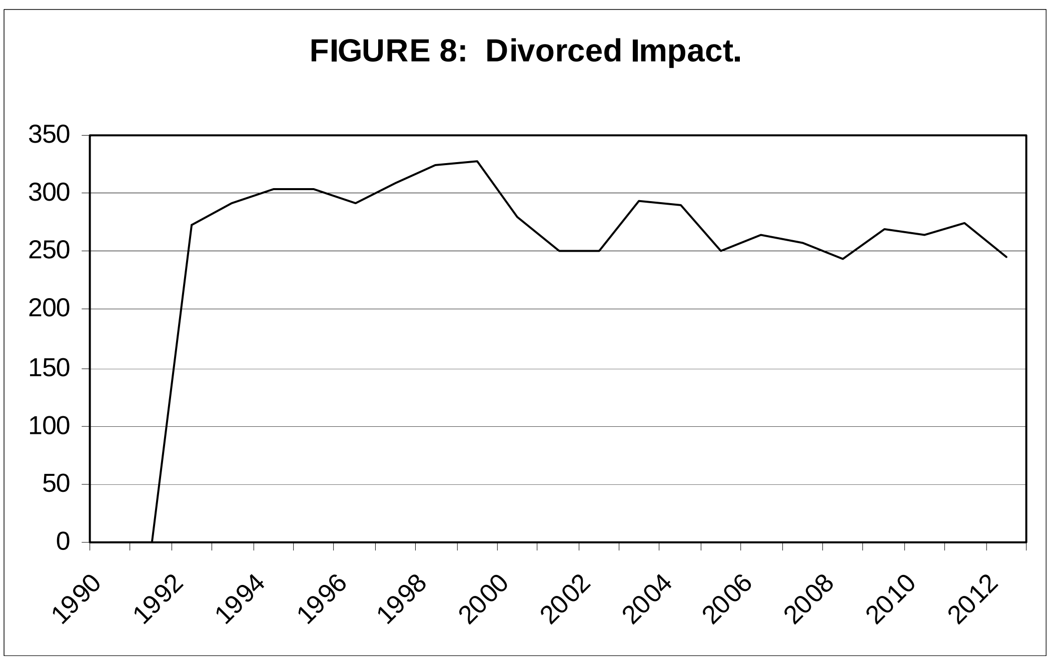


FIGURE 8: Divorced Impact.
350
300
250
200
150
100
50
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

FIGURE 9. Cumulative Mortality Impact.

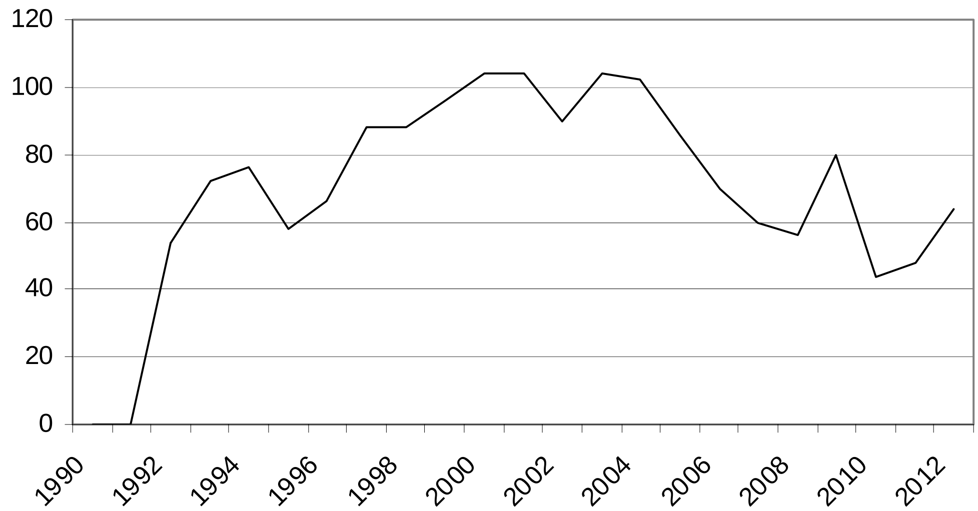


FIGURE 10. Cumulative Widowed Impact.

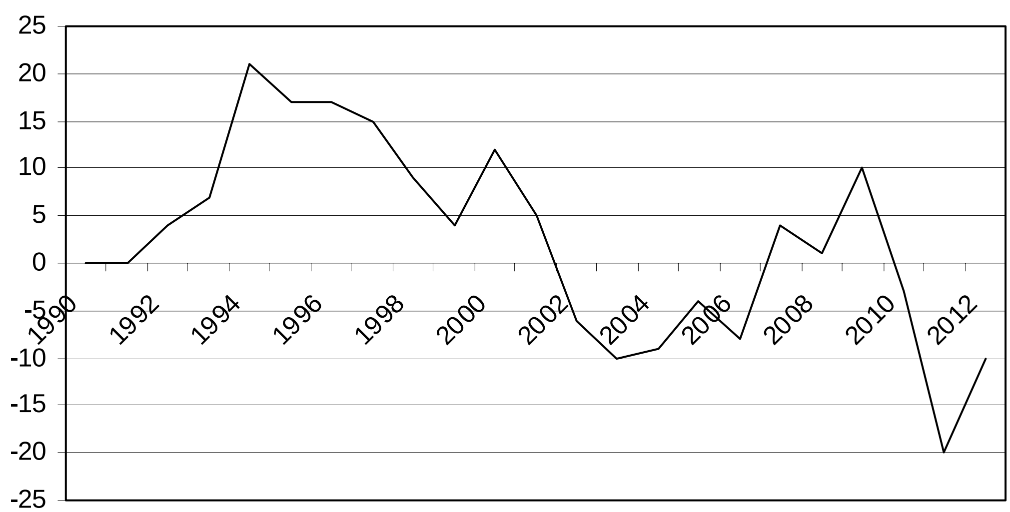


FIGURE 11: Cumulative Emigration Impact.

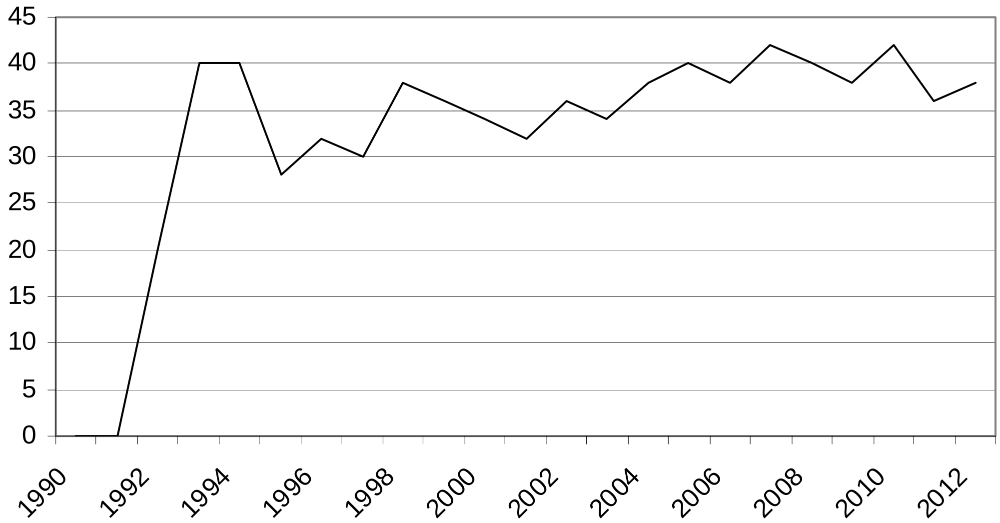
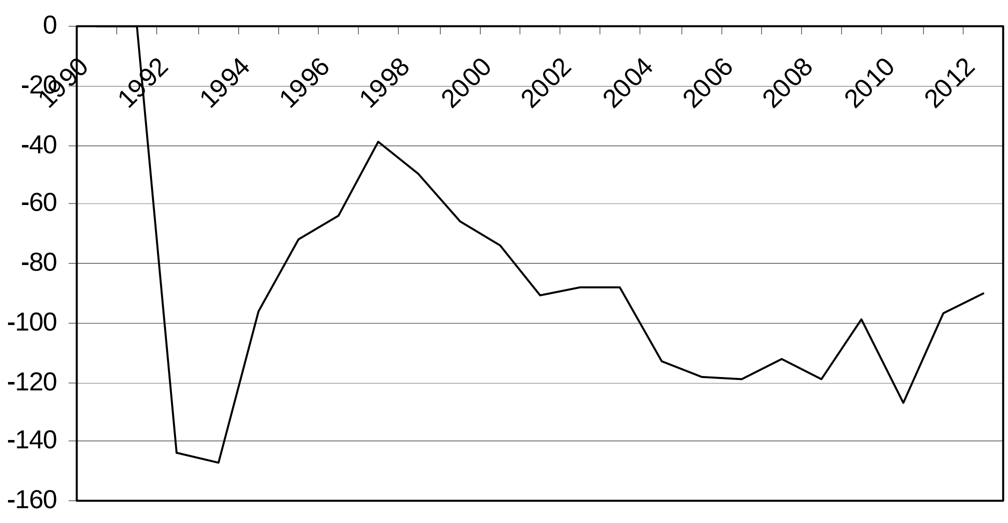


FIGURE 12: Trollhättan Residency.



APPENDIX A: Objects and Attribute Descriptions

The person object contains the following properties/attributes:

Label	**Description**
ID	Identifier
Age	Age in years
Born	Born
Bornregion	Country group, county in Sweden
Child	Pointer to child
Cohabit	Common law marriage
Died	Died
Earnings	Annual earnings from employment
Educlevel	Educational level (levels 1-7 reflect degree attainment)
Educsector	Educational discipline (technical, business, health, education, humanities)
Emigrate	Emigrated
Father	Pointer to father or adopted father
Gavebirth	Gave birth
Head	Pointer to household head
Household	Pointer to household
Ineducation	Enrolled in school or university
Leavehome	Leave home
Location	Pointer to land
Maritalstatus	Marital Status, (single, cohabitation, married, widowed, divorced)
Married	Married
Moved	Moved
Mother	Pointer to mother of adopted mother
Numbermoves	Number of previous moves
Outoflabor	Weeks out of labor force
Partner	Pointer to partner/wife/husband
Sex	Gender
Timeindwelling	Months since move to present dwelling
Unemployed	Weeks unemployed
Wkworked	Weeks employed
Working	Employed
Year	Year
Yearscohab	Years of cohabitation and/or marriage with partner
YearsinSweden	Years lived in Sweden

The household object contains the following properties/attributes:

Label	**Description**
ID	Identifier
Children	Number of children in household
Dwelling	Pointer to home
Earnings	Annual earnings from employment
Family	Family identifier
Year	Year

The Labor Market (LA) region contains the following properties/attributes:

Label	**Description**
ID	LA-region number
Earnings	Average earnings
Employed	Total employed number
Population	Total population number
Unemployed	Total unemployed number
x-coordinate	Longitudinal coordinate of population centroid
y-coordinate	Latitudinal coordinate of population centroid
Year	Year

The land square object contains the following properties/attributes:

Label	**Description**
Age	Average age of household head
Earnings	Average earnings
Educlevel	Average educational attainment of household head
Labor Market	Pointer to Labor Market (LA) region
Size	Average household size
x-coordinate	Longitudinal coordinate
y-coordinate	Latitudinal coordinate
Year	Year