Economic-demographic effects of immigration: Results from a dynamic, spatial microsimulation model.

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Abstract: Sweden has a fairly liberal immigration policy compared to many other developed countries and the foreign-born now constitute approximately 11% of the population. However, in recent years, this policy has been re-examined as the ability of the country to absorb large streams of immigrants, particularly refugees, has been called into question. This paper examines the economic and demographic consequences of immigration using a dynamic, spatial microsimulation model called SVERIGE (*System for Visualizing Environmental and Regional Influences Governing the Environment*). The empirical section presents the results of simulations that vary three key characteristics of immigration: (1) the magnitude of the immigration stream, (2) the ethnic origin of the immigrants, and (3) the settlement characteristics of the immigrants. Outcome variables examined include immigration, emigration, births, population, migration, labor force participation, and average earnings. Results show that a large increase of immigration can be accommodated by a host country with modest economic-demographic effects and the characteristics of immigrants, including initial settlement choice, have a recognizable influence on outcomes.

Keywords: Immigration, Sweden, spatial modelling, microsimulation

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1.0 Introduction

Growing economic disparities between the industrialized West and underdeveloped countries and decreased costs of transportation have caused a spurt in immigration over the past few decades. Countries such as Canada, the U.S., Sweden, and Switzerland with more liberal immigration regimes have seen foreign-born populations expand into the double digits as a percentage of their total populations (OECD 2001 and author's calculations for Sweden). With this growth, however, have come calls from some quarters that countries re-examine their abilities to absorb large streams of immigrants (Briggs 1996).

Immigration affects host countries in a variety of ways—socioeconomically, demographically, spatially and culturally (Briggs 1996; Greenwood 1994; Simon 1989). These effects have been studied exhaustively through the past few decades using a variety of qualitative and quantitative approaches. However, most of these studies address historical conditions and patterns, while many of the questions being raised are of a "what if" nature. Simulation, which can be used to examine the consequences of alternative immigration policies, is potentially one of the most useful tools for answering such questions but unfortunately is rarely used. The absence of large-scale economic-demographic models with detailed economic-population linkages has meant that few immigration policy handles are available for the social scientist to reliably simulate immigration.

One simulation method with the potential to shed considerable light on the effects of different immigration processes on recipient countries is microsimulation. Microsimulation was introduced over four decades ago 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, 1996, 1998; 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 1997a; 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 been made to examine spatial processes (Ballas and Clarke 1999; Caldwell, et al. 1998; Clarke 1996; Vencatasawmy et al. 1999)

The spatial dynamic microsimulation model (called *SVERIGE* or *System for Visualising Economic and Regional Influences Governing the Environment*) built at the Spatial Modelling Centre in Kiruna, Sweden, is one such model. It is the first national-level spatial microsimulation model available and permits analysts to study the spatial consequences of various national, regional, and local-level public policies. 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 several immigration policies in the Swedish context. The paper is divided into four 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 explains how immigration is treated within the SVERIGE microsimulation model. The fourth section describes current Swedish immigration trends and issues and outlines the policy simulations that will be conducted. The fifth section presents empirical results and their implications. The paper ends with a summary and conclusion.

2.0 Microsimulation models background

2.1 Advantages and disadvantages of microsimulation modeling.

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. 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 1999). 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, 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 1999) 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 economists and regional scientists have been relatively slow to embrace the method. Orcutt introduced the method forty 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 most industrialized countries and a handful of sub-national models exist as well (Oskamp 1995, Clarke 1996; Ballas and Clarke 1999). Table 2.1 lists some of the microsimulation models cited in this paper.

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-III 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 questions (Citro and Hanushek 1991a; Klevmarken 1997). Microsimulation models are regarded as 'black boxes' by many (Williamson 1999), although this is a criticism that could be leveled at any complex model. Some researchers criticize microsimulation as a data-intensive endeavor that is too disconnected from microeconomic theoretical foundations (Klevmarken 1997). Nelissen (1994) argues that microsimulation models do not usually yet incorporate "third-order" effects (i.e., induced changes in economic output because of markets—e.g., export-base, input-output multiplier effects), but Isard et al. (1998) describes multiple ways in which this can be done (more about this later). Moreover, 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). Some 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).

2.2 Features of microsimulation models

Constructing a microsimulation model involves several steps (see Harding 2000 and Ballas and Clarke 1999 for additional details). First, the specific model type must be selected. Second, the microdata set must be comprised. Third, transitions from one state to another (using contingency tables, conditional probabilities, or duration models) must be estimated. Third, the simulation must be generated (based on outcomes obtained via Monte Carlo simulation). Fourth, the output must be organized, and (5) the results must be validated and documented. The way in which each of these steps are addressed depends on several important features of the microsimulation method selected. These features are divided below into the following categories: (1) Dynamic versus static, (2) longitudinal versus cross-section, (3) closed versus open population, (4) data sources, (5) behavioral equations representation, (6) modular sequence and timing, (7) micro-macro linkages, (8) alignment, (9) validation, and (10) policy simulation.

Most microsimulation models are what are called *static* models. They simulate individual behavior over a relatively short period of time, generally have less endogeneity than their *dynamic* model counterparts, and are less expensive to construct. Static models simulations often involve modifying rules for government programs (e.g., tax rates and deductions, social security payments and eligibility thresholds) and examining their distributional impacts. Recursive effects on demographic and economic variables are rather limited; instead certain cross-sectional features are updated via 'static aging' techniques. Dynamic models are more elaborate—microunits are 'dynamically' aged according to a life-cycle behavioral model. Each year individuals are born, become educated, leave home, obtain employment, cohabit and marry, have children, sometimes divorce, and die. Whenever one of these demographic events occurs in a given period, it affects the likelihood of subsequent events happening. Change occurs intermittently and with consequences for future development rather than in one fell swoop as is the case with static models.

Dynamic models themselves come in basically two varieties: *cohort/longitudinal* and *cross-sectional* models. Cohort/longitudinal models simulate a single age cohort of individuals over time, whereas cross-sectional models simulate an entire cross-section of the population (i.e., different ages) over time (Harding 1993). Cohort models are simpler and less expensive to construct than cross-sectional models because there is less role for linkages among individuals (e.g., characteristics of spouses) to influence subsequent development, but the downside of this conceptual simplicity is less realism and fewer applications.

Cohort/longitudinal models are inherently *closed* models. That is to say, the individuals that are simulated come from the original sample. Cross-sectional models may be either open or closed. If the individuals in a sample change through processes other than birth and death, the model is *open* (Wolf 1997). Ways in which openness can occur are immigration, emigration, and the creation of simulated persons for cohabitation/marriage.

Microsimulation models differ in the quality of input data used for creating initial microdata samples and estimating transition behavioral relationships. The 1991 NASD Panel Study on MSM and future prospects for MSM identified data quality as one of the primary inhibitors to greater scholarly acceptance of microsimulation (Citro and Hanushek 1991a). Ideally, both samples and behavioral relationships would be created with comprehensive survey data and/or administrative records available for the entire study *population*.[1] Such data are rarely available. Instead, researchers are frequently faced with the task of imputing the characteristics of samples from assorted artificially linked databases (i.e., creating *synthetic* populations) or employing techniques that create *hybridized* samples that contain both survey and synthetic components (Wolf 1997). Moreover, it often becomes necessary to impute behavioral relationships using a variety of microdata samples and/or to impute transition probabilities on the basis of chain probability formulas that employ joint probabilities computed from different data sources. The statistical hazards of using event transitions computed using such techniques are described further in Klevmarken (1997, 21-22).

Equations and parameters used for determining event transitions are represented in a variety of ways. These include the following methods: (1) tables, (2) regression equations, (3) probability distributions, (4) transition probabilities, (5) decision trees, (6) ‘institutional rules’, and (7) ‘random assignment/statistical matching schemes (Nelissen 1994, 91-93; Klevmarken 1997). Klevmarken (1997) identifies parameterization of behavioral responses in microsimulation models as a weakness of current practice and shows how they might be better anchored in theory and good econometric practice. Many models are constituted largely or entirely of event transitions determined by transition probabilities and/or lookup tables (e.g., MOSART,TOPSIM, NEDYMAS), and the atheoretical nature of such models are recognized by their builders (Fredriksen 1998; Clarke and Holm 1987).

A growing number of models utilize regression equations (e.g., SVERIGE, DYNAMOD2, MICROHUS). Different regression approaches can be found in practice, including (1) logit/probit models, (2) count models, (3) regression equations with continuous dependent variables, (4) log dependent variables, (5) duration/survival models, and (6) error components (panel data) models (O’ Donoghue 2000; Klevmarken 1997). Klevmarken (1997) points out that transition relationships built with regression equations are subject to certain pitfalls because (1) the behavioral relationship can quickly become outdated and (2) the behavioral relationship must not only produce valid aggregate results but realistic individual development paths. For instance, normal behavioral changes over time and changes induced by new public policies can alter the parameter values in an equation, especially for longer-term simulation. Because dynamic time variance in parameters occurs, he recommends that panel data regression techniques be utilized when possible with longitudinal data. Also, since equations built without ‘memory’ can result in individual time paths that are unstable, it is recommended that lagged relationships are used (Klevmarken 1997, 9).

Other event assignment schemes are also available. Statistical matching routines are most often used in determining cohabitation partners and/or ‘cloning’ households or individuals characteristics from an existing pool to augment the immigrant population. Institutional modules represent the quantitative and logical rules by which governments award social welfare payments and/or tax individuals. Changing parameters for these decision rules is often an important part of policy simulation. Finally, methods utilizing artificial intelligence techniques such as Neural Networks have been recommended, although there are currently no operational models available that incorporate them (Holm et al. 1996).

Transition relationships are used in tandem with randomization to determine whether or not a particular outcome occurs. The occurrence of an event is determined by *Monte Carlo* simulation. For instance, each microunit is exposed to a possibility that a certain event will occur based on a simple probability. This probability is estimated from tables or by an estimated regression equation. The latter is a function of variables derived from 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. Two rationales are given for introducing a stochastic component in microsimulation. First, there is a lack of knowledge about conditions of model, specification, model form, etc, and second, socioeconomic events have a certain random character that is difficult to simplify by solely deterministic processes (Holm et al. 1996). Simulation results are often quite sensitive to the manner in which the Monte Carlo simulation is conducted; for instance the distributional properties of the random variable and the randomization seed. Variance reduction techniques are recommended to improve confidence that simulation results are not simply the result of the randomization method selected.

At the end of each event, microunit attributes are updated. As some modules occur before others, the attributes used in estimating the transition probabilities have different time subscripts. Both the modular timing and sequence must be determined and have some bearing on microsimulation results. Three timing methods have been suggested in the literature: (1) *time driven*, (2) *event driven*, and (3) *random order*. Time-driven models implement modules in a pre-determined sequence for periods of time. Event-driven models implement modules conditional on the outcome of other modules. Changes in events determined by one module affect the implementation of other modules. Random order methods implement modules in a random sequence. Among time-driven models, a choice must be made between the unit of time: the choices are continuous-time and discrete-time (monthly, annual, or longer) time periods. Continuous-time models determine the length or timing of specific events (e.g., marriage) using survival/duration models. Discrete models re-compute event probabilities for each discrete time period.[2] Most current models are discrete-time models (e.g., SVERIGE, CORSIM, MOSART, and DYNAMOD2) that use annual discrete time (although DYNAMOD2 uses some modules with monthly time). The order in which modules are implemented varies from model to model. For instance, NEDYMAS simulates the demographic modules first, education next, and income last, but other models stagger demographic, labor-market and other modules. A new generation of models (e.g., MICROHUS) is being built that introduces continuous-time features. Continuous time is used to increase computational speed, smooth individual transitional paths, and introduce more realistic behavioral properties.

Although microanalytic simulation models focus on the dynamics of individual behavior, a handful of models has introduced macroeconomic features in order to improve aggregate forecasting performance, more realistically represent market processes which influence individual behavior, and more completely explore the “microeconomic basis of aggregate behavior” (Anderson 1990). Galler (1997a) points out that a severe limitation of current microsimulation models is the lack of “feedback that result from interactions on the markets.” Three fundamental ways of introducing *micro-macro linkages* exist, including: (1) using output data from a macro model for input data in a micro model, (2) using aggregated microdata from a micro model as input data for a macro model, and (3) bilateral linkages from micro model to macro model and vice-versa. Numerous models make use of technique (1) as explained below but only a few (e.g., Zedlewski 1990) try to introduce dual feedback. There has been much discussion (Harding 2000; Isard et al. 1998; Caldwell 1983) about how micro models might make better use of macroeconomic linkages.

A procedure called *alignment* is one way in which macroeconomic feedback can be imposed on microsimulation aggregate results. Basically, it involves adjusting individual simulation results by a inflation/deflation factor necessary to achieve aggregate results which correspond to historical or forecasted results. Alignment results in new individual outcomes, adjusted totals, and adjusted flows. Most current microsimulation models make use of the technique to some extent (e.g., MOSART, DYNAMOD2, CORSIM, and NEDYMAS). In addition to making up for unexplained system effects (O’Donoghue 2000; Swan 2000), the technique is justified as a way of rectifying other module defects such as mis-specified behavioral equations and data limitations/errors (O’Donoghue 2000).

Although alignment tells developers about the aggregate performance of the model, finding out whether results are accurate for policy simulation and forecasting purposes in a more comprehensive manner is the task of *validation*. According to the National Research Council (Citro and Hanushek 1991b, 3), validation is often “a largely neglected activity” in model building efforts. The amount of time spent in building, programming, and debugging models often leaves little time for properly documenting and validating the models, although some researchers have gone to great lengths (Fredriksen 1998; Nelissen 1994) to demonstrate the accuracy of their models. Potential sources of model error are numerous, including: (1) model specification, (2) "changes in underlying assumptions," (3) "changes in covariates," (4) "errors in the initial population," (5) "errors in the estimation of parameters," (6) choice of randomization pattern, and (7) "programming errors" (Fredriksen 1998, 41). To this list could be added errors in choices made in the various stages of the modeling process that are described above.

Validation techniques examine model output in systematic ways to reveal deficiencies/errors in the model itself. Caldwell and Morrison (2000), Andreeason and Texmon (1997), and Klevmarken (1997) suggest several methods. One method is to compare aggregate or mean model output over time with official historical data derived from administrative records and/or survey results. A related method is to compare various cohort aggregates (e.g., age, gender) for specified points in time with official data. If other trustworthy models of the economy exist, one might also compare model forecasts to the forecasts of these other models. Furthermore, the distributional characteristics as well as central tendencies/sums of time series and cross-sections might be compared. Caldwell and Morrison (2000) further recommend a technique called "collateral validation." Basically, results are scrutinized for processes that are heavily dependent on multiple modules working interactively. A third technique is to examine whether the life courses (or 'biographies') of selected individuals are realistic. Erratic changes in economic-demographic outcomes are at odds with the smooth transitions that one observes in real life. A corrective remedy to such event 'jumpiness' is to introduce memory or lags into transition equations. A fourth validation technique is to tweak the parameters or assumptions of the model and examine its sensitivity. A model that is excessively sensitive to minor parameter changes is suspect. A final technique is to examine the variance of simulation results by conducting repeated experiments with the same model but alternative random seeds. The ideal model has low variance. But, the method also provides a tool for validating model results in a variety of situations. By using repeated sampling methods and non-parametric (bootstrapping/jackknifing) statistical methods, simulation results can be assessed for their statistical significance, which can be useful in assessing whether an impact is due to randomization error or actual policy impact.

The final stage of microsimulation model building is using the model in an real-life policy application. The ways in which the model can be utilized for *policy simulation* depends on the "policy handles" and variety of modules built into the model. A model with only economic and demographic modules will be fairly limited for the purposes of investigating social insurance and tax issues, but useful in making demographic forecasts. There are basically three ways of conducting "what if" type experiments (Caldwell et al. 1998). The first is to change the parameters of the microsimulation model behavioral equations for the variable of interest, while holding all other variables constant. The second is to modify the characteristics of the initial population in a way to produce a population that has the desired alternative characteristics. The third is to introduce alternative values into the alignment mechanism.

3.0 SVERIGE microsimulation model

3.1 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, et al. 1998, Caldwell 1997), 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 (see table 3.1 for a summary of its features). 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. Figure 3.1 illustrates this modular structure and the sequence in which modules are implemented.

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. SVERIGE not only makes life-cycle transitions dependent on a spatial context but also models individual spatial transitions such as internal migration. In the terminology of object-oriented programming geographical "objects" such as neighborhoods and labor markets have attributes that influence the behavior of "objects" such as individuals, households, and homes (see figure 3.2 and appendix A. for a full listing of objects and their attributes). As a result, the model is capable of generating a variety of geographically detailed reports that may interest regional scientists and policymakers.

SVERIGE behavioral equations/transition matrices are computed with samples taken from a comprehensive longitudinal database of Swedish households and employers. The samples used to estimate each equation behavioral equation were drawn from basically the same database. Therefore, SVERIGE is less affected by data reliability and measurement error problems (Klevmarken 1997; Citro and Hanushek 1991a) than competing international models that use non-survey data and artificial data generation techniques.

3.2 Model structure

SVERIGE 1.0 contains 10 modules. Each module consists of a series of discrete or continuous variable equations, transition matrices, or rules that determine the occurrence of specific events in a person's life. When individual events occur, personal attributes are updated. In this version of SVERIGE, all the events occur at yearly intervals.

In SVERIGE there are three ways in which personal attributes can be changed. In the fertility module, for example, when a mother gives birth, the attribute "Gavebirth" is then updated. This resultant change is affected by an individual's present attributes. Changes in attributes can also be triggered by interactions with others. For example, if two persons are chosen to cohabit then the attribute "location" of the woman is changed to that of the man. Finally, attributes such as "earnings" are influenced to a large degree by their previous values. These mechanisms are summarized in figure 3.3.

The model currently implements these modules in the following order: fertility, education, employment and earnings, marriage, divorce, leaving home, migration, mortality. The equations, counters, and pointers used in the model are summarized in table 3.2 and Appendix A. They are further briefly described in the subheadings that appear below. A more complete explanation of these models may be found in Vencatasawmy, et al (1999). Technical documentation written from a computer programmer's perspective is available in Softcenter AB (2000).

3.2.1 Mortality module

The mortality module terminates lives in the model. Two sets of mortality equations are used: individuals under the age of twenty-five are estimated as an exponential time trend from historical mortality rates grouped into twelve age/sex groups; individuals twenty-five years of age and older are estimated using logistic equations with variables (see equation (2) in table 3.2) found important in epidemiological studies. If a person reaches 127 years, his/her life is automatically terminated.

In addition to removing individuals from the simulation, death directly triggers both personal and household changes. For instance, when a death occurs, the marital status of the surviving spouse changes from “married” or “sambo” to “widow.” In addition, if the deceased is a single or parents die, then the under-aged children (less than sixteen years) are assigned to an orphan queue and allocated to a family in the same labor market region at the end of the year. Children older than fifteen years old automatically become a heads of household and leave home.

3.2.2 Fertility module

The primary role of the fertility module is to create new lives for simulation in the microsimulation model. Upon birth, each infant is assigned a sex based on a fixed probability of 0.5134 of being a male. Only women between the ages of fifteen and forty-four years are at risk of giving birth. Equations are estimated for two groups, married and unmarried women. The group “unmarried” includes singles, sambos (common law marriages), widows, and divorcees. All births produce a single baby. Fertility behaviors in SVERIGE are influenced directly by individual and household attributes such as employment, marital status, age, family earnings, and education (see equation (1) in table 3.2).

3.2.3 Education

The Swedish education system contains six levels. Compulsory school is called Grundskola and consists of nine years of basic preparation. Ninety percent of the students advance to the next stage, Gymnasium. This level offers vocational and college preparatory programs and typically takes three years to complete. After Gymnasium comes college (called Högskola) for around twenty-five percent of Swedish gymnasium students. An undergraduate term at Högskola lasts three years. Graduate or professional school follows college or university. There is also an adult education program called Komvux.

SVERIGE uses a series of logistic regression equations to determine completion of Grundskola[3], completion of Gymnasium, entry to Komvux, persistence through Komvux, entry to Högskola, persistence through Högskola, entry to graduate school and persistence through graduate school. 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.

Much research has been done on the influence of different factors on educational achievement. Family attributes appear to play a dominant role and the educational levels of mothers have greater effects than those of the fathers (Rephann Forthcoming). Other important indicators are family income and parental marital status. Equations (9)-(11) show the variables used in the module.

3.2.4 Employment and earnings

The aim of this module is to estimate the amount of time employed for each individual between the ages of sixteen and sixty-five and his/her wage rate. The module consists currently of four sub-modules, a logistic regression equation determines the likelihood that a given individual is employed at all during the year. For those who are simulated as being employed, the next two sub-modules determine the amount of weeks worked utilizing a logistic regression equation to determine full-time workers and a transition matrix to determine the number of weeks worked by part-time workers. The final module estimates the average relative wage rate (the ratio of wage rate to average wage rate) for each employed individual. Annual earnings are computed as the product of weeks worked and wage rate. The variables in these modules are summarized in equations (12)-(14).

3.2.5 Cohabitation and marriage

The marriage module creates sambo relationships for selected unmarried individuals over the age fifteen and Christian marriage partners for sambo couples. The module consists of three sub-modules. The first sub-module (sambo decision) determines whether a person is eligible for sambo or not (i.e., who will enter the sambo market). The second sub-module (cohabitation compatibility) computes an index of compatibility for pairs of eligible singles based on their attributes (including geographical location) and matches pairs on the basis of the compatibility index using a heuristic matching algorithm. The final sub-module (marriage decision) determines whether cohabiting individuals will get married or continue cohabiting. A list of the variables used in these modules is provided in equations (3)-(5).

Cohabitation and marriage may require several adjustments in personal and household attributes, including change in marital status (from “single,” “widowed,” or “divorced,” to “cohabiting” or “married), adjustment of household earnings for two-income households, and aggregation of children. Moreover, cohabitation triggers the movement of female partners to the male partner’s home.

3.2.6 Leaving home

The leaving home module determines whether a person will leave the parental home to start a new household. They are eligible to leave home, beginning with the age of 16. If someone has still not left home by the age of 30 then he/she is forced to do so. The variables used in this module are shown in equation (8).

3.2.7 Divorce/dehabitation

The divorce module dissolves sambo and marital relationships. Seven logistic equations are used corresponding to groups based on age of female spouse, presence of children, and immigration status. These groupings were based on empirical studies with the marriage sub-module. The variables used in this module are illustrated in equation (6).

Divorce results in persons being assigned new marital statuses (from “married” to “divorced” or from “sambo” to “single”) and makes them eligible for remarriage. Also, it triggers a number of other microsimulation events, including movement of the former husband out of the marital dwelling, re-allocation of minor children to each new household, and de-coupling of household earnings. Currently, minor children are assigned to the female partner.[4]

3.2.8 Immigration

Because the number of immigrants that enter the country every year fluctuates due to internal and external economic and political factors, it is very difficult to design a model that will capture changes in the magnitude and settlement patterns of immigrants. As a result this module[5] relies entirely on hard coded probabilities and external data. The module is used to create new lives that are derived from outside of Sweden.

Immigrants are clustered into ten groups based on their geographical and cultural origins. Given an initial stock of immigrants, look-up tables of historical probabilities are used to assign the age, sex and marital status of the head of the household. Given these three characteristics, a comparable individual from a pool of immigrants is chosen to clone this new immigrant family. The economic and family characteristics of this clone are thus assigned to the new immigrant household head. The labor market region where the immigrant will settle is then estimated using a transition matrix based on immigrant settlement characteristics for the different immigrant groups. The family is then placed into a queue of families looking for residential locations (100 meter square land tracts). They are assigned a particular location in the migration module, which is discussed below.

3.2.9 Emigration

This module determines who will leave Sweden as emigrants. Statistics Sweden defines an emigrant as anyone who intends to settle abroad for at least one year. This same definition was used here. This module only distinguishes emigrants from non-emigrants. It does not attempt to model the country of destination. Logistic equations for four groups were used, based on age and marital status. The variables used in the module are listed in equation (17).

3.2.10 Internal migration

The internal migration module makes the microsimulation a fully interregional model that links events in one region with occurrences in another. This migration module tracks the movement of households and individuals to an accuracy of 100 meters. Movement can be either inter-regional or intra-regional. Sweden can be divided into 108 labor market regions where commuting between labor markets is minimized while commuting within labor market region is maximized (Finansdepartementet 1994). A move is called intra-regional when it happens within a labor market and is called inter-regional when it happens between labor markets. In the current version of SVERIGE, emphasis has been given to inter-regional migration. Intra-migration is modeled by heuristic rules.

More than 80% of the change in population size and composition on the community level is related to migration. Therefore, for the microsimulation model to be effective, the real life regional and local migration patterns should be modeled accurately. The design of this module is based on the structure set out by Holm and Malmberg (1997) and Vencatasawmy and Swan (1998). The inter-regional migration decision is divided into three stages: Decision to move, choosing a labor market, and choosing a 100-meter square. The reasons for such assumptions reside in the way people make choices and for modeling reasons. In discriminating between movers and non-movers in the first stage, both personal and regional attributes are used. In the second stage only regional attributes are used and in the third stage an attraction measure based on personal characteristics is used. In intra-regional migration, the first two steps are ignored.

Logistic regressions were estimated for the first stage using variables depicted in equation (18) of table 3.1. The second stage is estimated using a conditional logit model also known as the McFadden's conditional Logit model. When the data consists of choice specific attributes instead of individual-specific characteristics, this is a more appropriate model than the Multinomial logit model. The model is otherwise essentially the same as the multinomial logit (Maddala, 1983). Although this model requires "the independence of irrelevant alternatives" which is violated in such studies (Fotheringham, 1991), this model was chosen for its qualities. There is one equation for each origin as according to Fortheringham (1991) who found a link between the parameter values and the origins in similar studies. In the third stage squares are allocated to people based on a similarity index. The variables used to determine the similarity index are: average family size for the residents living on the squares, average earnings for the residents on the squares, average education level of the square inhabitants and average age of inhabitants.

3.2.10 Other Modules

New Modules and Processes

Very few microsimulation models have introduced space in a meaningful way. The only truly interregional microsimulation model is TOPSIM, an immediate predecessor to SVERIGE. Williamson (1999, 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). Yet, because microsimulation models are driven by demographic changes and interregional population change is dominated by migration, it is critical that migration flows be accurately represented in such models. The difficulty of accurately modeling regional movements makes migration the weakest link in interregional modeling efforts (Holm et al. 1996).

Future versions of SVERIGE may include four additional modules: housing, property values, transportation, and environmental pollution. A property value module, currently under development, could determine property values (Rephann 1998; Åström and Vencatasawmy 2000). The transportation module would determine commuting distances to employment. An environmental module would compute levels of airborne emissions, solid waste, and water pollution. Modeling the housing sector is important, in part, because of its effects on population development (e.g., household formation and structure, migration). Fransson (1997, 2000) and Oskamp (1995, 1997) outline ways that such a module might be fashioned. The housing module should determine housing tenure choices and match households with rental and owner-occupied units. Also, the existing housing stock should be modified through depreciation, renovation, and new construction. The module should represent housing demand and housing supply and introduce a market clearing mechanism that reconciles demand and supply. It has the potential of replacing the local mobility sub-module presently used in the internal migration module for identifying local location choices.

Missing Modules and Processes

SVERIGE is basically an economic-demographic model and lacks some features that would make it more useful for policy analysis. Dynamic microsimulation models are most useful in researching intergenerational issues and their impact on public finances, but SVERIGE entirely lacks a public sector. Ideally, it would model the circumstances under which individuals and households draw resources from the public sector and determine the extent to which they generate public revenue. Among the programs that have been modeled (because their awards or costs are determined by rules based on individual characteristics) are (1) pension systems (Andreassen and Texmon 1997), (2) social welfare (income maintenance), (3) unemployment insurance, (4) disability/workman's compensation (Nelissen 1994; Andreassen and Texmon 1997), (5) childcare, (6) housing for institutionalized populations (Nelissen 1994; Andreassen and Texmon 1997), and (6) conscription (Nelissen 1994).

Currently, SVERIGE models earnings, but the addition of modules representing these alternative income sources would allow other income measures, such as personal income and disposable personal income to be created. More importantly, they would allow one to investigate the effect of changing rules governing the costs and awards of program participation. Pension modules are age and income-driven. They work by deducting contributions from income based on income level and awarding payments on the basis of retirement age and contributions made to the system or approximations thereof. Welfare and unemployment payments are determined by income status and number of dependents, while unemployment payments are dictated by employment status and income in employment. Disability/workman's compensation comes into play when an individual becomes disabled; disability (and rehabilitation) must be formally modeled before it can be used to adjust income status.

Attempts have been made also to represent additional private income sources other than earnings. Keister and Caldwell (2000) describes the construction of a wealth module for CORSIM. The paper details how the wealth sectors covered, how the individual equations were estimated, and how alignment data was constructed. Klevmarken (1998) contains a wealth module that contains assets like real estate, financial assets, and consumer durables and liabilities like mortgages and loans. An inheritance module distributes wealth between generations and between spouses. A childcare module allocates children to childcare centers. Finally, the model contains an income and taxes module to compute labor income, transfer payments, and taxes.

3.3 Construction of Initial Population.

This paper relies on a testing version of SVERIGE (v. 1.0) that utilized a small sample of 6,510 individuals. The individuals were drawn from a longitudinal database that contained information on all Swedish residents using a proportional sampling methodology. Current versions allow an intermediate sized sample (403,075 individuals) and the entire population of Sweden to be used. The advantages of the former is speed of processing while the latter minimizes errors introduced by sampling and allows more exhaustive small area analysis. Unlike 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.

4.0 Economic and demographic effects of immigration

A fairly voluminous literature examines the economic and demographic consequences of immigration. Some research centers on the regional characteristics and regional consequences of different types of immigration flows (Greenwood 1994; Isserman 1993). Also macroeconomic economic-demographic models have been used to examine the effects of different types of immigration streams (Isserman 1993). The advantages of a microanalytic approach have already been discussed but in the context of modeling immigration flows, it might be useful to elaborate further on the pluses and minuses.

Representing immigrant characteristics.

Most macroeconomic models allow the total flows into a country or region to be changed but the strength of microanalytic models is that one can vary both the volume of the flows and the specific characteristics of the immigrants upon arrival. This feature of the model is a definite plus because a body of literature shows that the arrival characteristics of immigrants (e.g., location of settlement, age, educational levels) can have an effect on economic-demographic development and changing immigration law can have a very definite effect on the arrival characteristics of immigrations.

Currently, immigrants to Sweden differ in many ways from natives. They are younger, more likely to be male, and are geographically more concentrated in urban areas and southern Sweden. However, immigration policy, European Union labor market conditions, and national economic performance can have a profound influence on the characteristics of these inflows. SVERIGE allows one to change the features of immigrant flows such as settlement location, age, and ethnicity.

Representing differences in economic and demographic behavior

Numerous studies show that immigrant economic and demographic behavior is initially quite different from natives (e.g., earnings, employment, fertility, mortality, migration). However, with length of stay, these differences tend to lessen (Rephann and Vencataswamy 2000; Fischer et al. 1998). Macroeconomic models assume that immigrants and natives are the same in their economic and demographic behavior. Although “adaptive behavior” is not built into the current version of SVERIGE, there are several modules that incorporate differences in immigrant and native behavior. These include the marriage/partner selection, divorce, education, and employment modules.

Representing labor market adjustments

One of the most serious deficiencies of the model is the limited way that it represents labor markets. However, as has already been pointed out, this limitation is a common pitfall of microsimulation models (Galler 1997a, Anderson 1990, 191) and is a common source of model error. In most economic-demographic models, the sequence of labor market adjustments to immigration is something as follows. An influx of immigrants causes an exogenous increase in labor supply. This labor supply increase results in lower equilibrium wages. Lower equilibrium wages (i.e., lower capital-labor ratio) induce capital inflows. Capital inflows increase labor demand. In addition, the consumer expenditures of immigrants and capital brought by immigrants will increase labor demand. These labor demand increases results in higher equilibrium wages. The absolute (or overall) changes in wages (up or down) depend on the relative size in demand and/or supply shifts.

The sequence of changes brought about as a result of immigration in SVERIGE is much different because SVERIGE supports just labor supply. Labor demand is basically inert. The sequence of labor market adjustments is as follows. An influx of immigrants causes an exogenous increase in labor supply. Whether or not these individuals are unemployed or have low wages depends on their individual attributes. For instance, younger and less educated individuals command lower wages because of lower productivity and are less likely to be employed. If an area has a proportionally large number of these individuals, it has a correspondingly higher unemployment rate. This regional unemployment rate (which is included in the employment and wage equations) is associated with lower wages and serves to decrease inmigration and increase outmigration. A lower regional unemployment rate has the opposite effects. Thus, regional labor demand doesn't matter. If a region is burdened with individuals who don't work, regional wages will be depressed until the period of time when residents (1) acquire enough additional characteristics (age, education, etc.) to improve their employment propensities or (2) migrate to other regions.

Although the SVERIGE labor market adjustments only crudely and partially mimic market adjustments, it must be reemphasized that microsimulation models are not chosen because of the elegant way that they represent arbitrage mechanisms. Their strengths lie elsewhere. However, other options exist to better represent these important model components. Fredriksen (1998) (p. 25) describes three (3) ways in which micro/macro link may be forged: (1) "inclusion of both persons, firms, and other institutions in one microsimulation model," (2) "iterative (recursive) simulation of a microsimulation model and a macroeconomic model, or (3) "constraining the projections against labor demand from a macroeconomic model" (i.e., alignment).

In the first method, a business sector populated by individual labor hiring enterprises fills employment vacancies with employees who are part of a queue of workers searching for jobs. The labor market module would determine which workers are assigned to particular firms on the basis of skill matches and a wage adjustment mechanism. Unfortunately, no current microsimulation model incorporates such an elaborate specification. The closest attempt to incorporate labor demand is Nelissen (1994, 1993, 1991) which does it via distributional assumptions about job offers. A simulated labor hours supply decision is compared to simulated labor hours demanded and a wage rate for each individual and an optimal job is selected. Once this 'optimal' job is determined, transitions from this initial state are determined by decision rules. For instance, determining transition from the state of being employed, a hard-coded probability based on the national unemployment rate is used (in times of increasing cyclical unemployment, the likelihood of becoming unemployed increases).

In the second method, other models (e.g., Computable General Equilibrium, Econometric models) with strong labor market specifications interact with the microsimulation model (see Anderson

1990 and Isard et al. 1998). Anderson describes micro-macro linkages that flow from micro to macro, macro to micro, and models in which information flows both ways.

In the third and most common method, microsimulation model output is adjusted (or ‘aligned’) so that it conforms to historical or forecasted aggregate values. For instance, average earnings will be lowered or raised to the extent that they are above or below historical averages and these equilibrium historical adjustment factors are imposed on individuals in the sample (individual earnings are adjusted upward and downward). The argument is sometimes made that, since historical figures reflect the free interplay of labor supply and demand, when microsimulation results are constrained by these historical values, they too will reflect the influence of these market competing market forces (Swan 2000). Alignment serves as a fudge factor to rectify deeply embedded errors introduced by various model flaws (O’Donaghue 2000).

5.0 Data and policy scenarios

Foreign-born residents made up approximately eleven percent of the Swedish population in 1995. This level has been reached after a surge in immigration during the post-war years (see figure 5.1) that has become increasingly diverse in recent years (see figure 5.2). Swedish immigration law has undergone three distinct phases that have affected both the volume and diversity of newcomers. After the Second World War, Sweden witnessed an influx of workers from other European countries who were recruited to fill vacant industrial slots followed in 1954 by an agreement among the Nordic countries to create a common labor market that resulted in increased Nordic immigration. During the 1960s, because of tightening labor market conditions in northern Europe, workers were recruited from farther afield, primarily from southern Europe but also from nearby Finland. In 1967, however, Sweden introduced a more restrictive immigration law and labor recruitment from abroad was severely curtailed. Afterwards, an increasing number of immigrants were refugees from war-torn or repressive countries in Asia, Africa, Latin America and the Balkans.

The changing volume and origins of the immigrant stream have ramifications for regional economic and demographic development in Sweden for several reasons. First, immigrant settlement patterns are somewhat different from those of native Swedes (Borgegård et al. 1996; Borgegård and Håkansson 1998). For example, although Stockholm County is the home of 20% of Swedish residents it is the settlement choice of 32% of Swedish immigrants (see Figure 5.3). Second, immigrant demographic and socioeconomic characteristics differ from natives. Sixty percent of immigrants are male and immigrants are much younger than the average Swede. Third, immigrant socioeconomic differences persist for some time after entry. For example, internal migration patterns, following arrival in Sweden, differ from native Swedes (Rephann and Vencatasawmy 2000; Andersson 1996).

The results reported here illustrate nine simulations (see table 5.1) using differing assumptions about the magnitude, ethnic composition, socio-economic/demographic characteristics, and spatial distribution of immigration to Sweden. The first simulation (***BASE***) provides baseline numbers. It maintains 1998 Swedish immigration levels and characteristics into the future. The second simulation (***IMM1***) tests the effect of a large influx of immigrants—the immigrant inflow is increased from the present level of about .7% to about 5% of the population with the same immigrant characteristics. The third (***IMM2***) simulation tests for the effect of an immigrant group that tends to be younger and has lower average levels of human capital than natives. The simulation is of the same magnitude as ***IMM1*** except that all of the immigrants are of African origin (Ethiopia, Eritrea, Somalia, Djibouti, Sudan, North Africa and middle east, Other Africa) and have African immigrant economic demographic and spatial settlement characteristics. The seventh simulation (***IMM7***) tests the effect of an immigrant group that is similar in many respects to natives--residents originating from other Nordic countries (Denmark, Finland, Iceland, and Norway). The fourth (***IMM3***), fifth (***IMM4***), and sixth (***IMM5***) simulations test the effect of varying regional settlement characteristics. ***IMM3*** tests the effect of concentrating immigrants in a densely populated urban area (Stockholm Labor Market Area). ***IMM4*** concentrates them in a sparsely populated rural area in Northern Sweden (Kiruna Labor Market Area). ***IMM5*** distributes the refugees in the exact same proportions as current residents in a test of the effect of an "All of Sweden Strategy".[6] The seventh (***IMM6***) and ninth (***IMM8***) simulations test the effects of restrictive immigration policies. ***IMM6*** tests the effect of prohibiting immigration to Sweden.

6.0 Results

SVERIGE is capable of generating output for a variety of attributes aggregated into different levels for different time periods.[7] However, the preliminary results reported here are aggregates and/or means for selected economic and demographic characteristics simulated for 30 years (1985-2015). These variables include: (1) immigation, (2) emigration, (3) birth rate, (4) migration rate, (5) population, (6) Average family Income, and (7) Labor Force Participation Rate/Unemployment rate. Results reported include actual variable outcomes, variable impacts (experimental values minus baseline values), and cumulative impacts (cumulative experimental values minus baseline values). No alignment is used in generating the microsimulation results reported here.

Figure 6.1 shows the magnitude of immigration created under each simulation. Whereas current immigration levels are about 60,000 people or .7% of the population, an influx equal to five percent of the population translates into approximately 400,000 new residents. IMM1-IMM5 and IMM7 show a huge influx in 1998, followed by typical immigration streams for the remainder of the period. IMM6 curtails immigration for the entire period 1998-2015 and IMM8 stops it for one year--1998.

One noteworthy side-effect of an influx of immigrants is increased emigration (see figure 6.2). Immigrants are more likely to emigrate than natives and this tendency manifests itself in an increased outmigration of residents 3-4 years after the influx. Differences are also evident for the various immigration streams. Nordic immigration stimulates the most emigration while African immigration the least. This finding may be explained by the fact that economic migrants from nearby countries often have both more incentives and fewer barriers to return migration. The initial settlement characteristics may also play a small role in emigration choices. Of the four settlement patterns, the "All of Sweden" pattern prompts the highest magnitude of out-migration. Since emigration choice is associated with previous internal movements, an increased likelihood of migration caused by non-optimal initial settlement choices would increase the risk of subsequent emigration too.

Figure 6.3 shows that initial spatial settlement patterns are related to post-immigration internal moves. The "All of Sweden" policy, Kiruna concentration, and Stockholm patterns induce a greater rate of migration than baseline or regular immigration settlement patterns. Furthermore, African immigration causes more internal migration than Nordic immigration, a product of the greater propensity for African immigrants to move and a lower average age. Curtailing immigration has the effect of reducing migration rates because natives are less likely to move than immigrants (Rephann and Vencatasawmy 2000).

Not surprisingly, increased immigration stimulates births while curtailed immigration has the opposite effect (see figure 6.4). Among the various immigration streams, however, the Nordic one has the lowest birth impact and the current mixed ethnic stream the most. This result is easily explained by the fact that groups with relatively higher fertility rates (e.g., Asian, Middle East) are part of the latter while Nordic born immigrants have the lowest fertility rates. Spatial settlement patterns may also be important. The Kiruna and "All of Sweden" settlement patterns correspond to lower numbers of births than other settlement patters. Although the exact channels by which this result is achieved are difficult to identify in complex models such as this one, one might speculate that increased migration reduces the propensity to marry and cohabitate, which in turn reduces the probability to have children.

Figure 6.5 shows the effect of births, deaths, immigration, and emigration. Both no immigration scenarios have a detrimental effect on population growth. The permanent immigration moratorium

(IMM6) leads to the loss of nearly 10% of the population, while the one-year suspension results in a net loss of fewer than 100,000. The next lowest population result is obtained for the Nordic immigration influx. Based on previous discussion, this result can be seen as resulting from lower Nordic birth rates and the much greater propensity to emigrate. The other immigration simulations are clustered near the top of the graph, with approximately 500,000 more residents.

The two final indicators, average earnings (see figure 6.6) and labor force participation (see figure 6.7) represent the labor market effects of immigration. Both no and low immigration scenarios have the biggest positive impact on average family earnings and labor force participation rates. This result likely stems from the way the labor supply modules are constructed. In particular, an aging workforce is a more experienced workforce that earns more. Therefore, the average earnings of a more aged (but still within the working age years) workforce is greater than the average earnings of a younger workforce. A similar explanation can be offered for the labor force participation findings. This partly explains also why the Nordic immigration simulation results in higher average earnings—Nordic immigrants are older than the average immigrant and also are more likely to return migrate.

6.0 Summary and conclusions.

Immigration can have profound effects on host countries. The issue has been studied in a variety of ways using theoretical and ex-post empirical approaches. The use of large-scale forecasting and simulation models to study immigration policy, however, is much less common. This paper uses such a model: a dynamic, spatial microsimulation of Sweden (called *SVERIGE* or *System for Visualizing Economic and Regional Influences Governing the Environment)* to illustrate how a microsimulation model can be used to investigate the effects of alternative immigration policies. The paper examines the effects of three policy choices: (1) the size of the immigration stream, (2) the countries of origin, and (3) the initial settlement pattern of immigrants. All three variables are the subject of contemporary immigration policy and debate.

The paper shows that a microsimulation model has certain modeling advantages of more common macro models such as econometric and CGE models, including the ability to vary the characteristics of immigrant cohorts in multiple ways. In addition, SVERIGE has some advantages over microsimulation models being used elsewhere. It is based on complete survey data for the entire nation and on behavioral equations that are rooted in social science theory. Moreover, in contrast to other models, it introduces spatial explanatory variables as driving forces of individual choices. On the downside, the weak specification of markets and arbitrage mechanisms means that labor market outcomes in particular must be interpreted with caution.

The results obtained here show that a large increase of immigration can be accommodated by a host country with minimal impacts on the population or economy. The effect of a one-time jump in immigration is to boost the population to a higher level, but the resumption of ordinary immigration streams returns population to slow growth. An increase in immigration is followed by a corresponding increase in births, migration rates, and emigration. The latter serves to dampen the net impact of a large immigration stream. Labor market outcomes are also relatively modest. This result, however, is the product of the incomplete specification of SVERIGE's labor market module. The module is supply driven and assumes that workers supply their labor and are compensated largely on the basis of their own personal characteristics rather than features of labor demand.

The characteristics of immigrants, including their initial settlement characteristics has some bearing on their eventual impacts. For instance, African immigrants were less likely to emigrate than Nordic immigrants and to be younger, thereby magnifying their demographic and economic effects. Settlement characteristics are also important. Immigrants that are dispersed or concentrated in patterns that vary from a 'laissez-faire' pattern are more likely to migrate internally following immigration.

The work reported here leaves room for two major extensions that would improve the quality of output interpretation. First, although the differences in the magnitude of outcomes for different simulations were regarded as being significant, it was not possible to validate the impacts statistically. The possibility exists that the impacts are merely the result of using a particular common random seed to generate the simulations. However, by running the same simulations with multiple random seeds and examining the variance of the results (Holm et al. 1996) in the manner of bootstrapping, one might statistically test the impact of different simulation scenarios on economic-demographic variables. Second, because a relatively small sample was used in the simulations here, regional or small area outcomes could not be generated. However, with the completion of an initial starting population representing the entire population of Sweden, it is now possible to illustrate such effects and to examine various other cohorts in a more detailed fashion.

Appendix A. Objects and attribute definitions.

Two types of attributes are listed: “static” (normally “one-ended” attributes like age, sex and income) and relational attributes (like mother or family). The relational attributes connect object instances. Mother is an attribute of a person object, which points at another instance of the same object type. Family is another attribute of an individual, which is a pointer to an instance of another object type: household. Relational attributes are implemented with the help of pointers or references. Their main advantage is that they give access not only to the object but also to all its attributes. For example, the mother’s education could easily be retrieved and used as one determinant of the daughter’s education, employment and income.

The following convention regarding time notation is used. Current year is denoted by *t*, but that time index is often omitted. The year before the current year is denoted by *t-1* and next year is denoted *t+1*. The new values for the attributes are calculated for the current year.

The person object contains the following properties/attributes:

Label	Type	Values	Comment
ID	Longint		Identifier
Sex	Boolean	Male, Female	
Bornregion	Byte	0-100	Country group, county in Sweden
Year	Date	1900-2100	
Age	Byte	0-120	
YearsinSweden	Byte	0-120	
Educlevel	Byte	0-7	
Educsector	Integer	SUN 3-digit	Educational discipline
Ineducation	Boolean	Yes/no	Enrolled in school or university
Working	Boolean	Yes/no	Employed
Wkworked	Integer	0-52	Weeks employed
Unemployed	Integer	0-52	Weeks unemployed
Outoflabour	Integer	0-52	Weeks out of labour force
Timeoutoflab	Integer	0-50	Years not at all in labour force
Workplace	Workplace	Pointer	Pointer to workplace
Earnings	Integer	100 SEK	Annual earnings from employment
Father	Person	Pointer	Pointer to father or adopted father
Mother	Person	Pointer	Pointer to mother of adopted mother
Partner	Person	Pointer	Pointer to partner/wife/husband
Child	Person	Pointer	Pointer to child
Yearssplit	Byte	0-100	Years since split or divorce
Yearswidow	Byte	0-100	Years since partner died
Yearscohab	Byte	0-100	Cohabitation + married
Maritalstatus	Byte	0,1,2,3,4	0=single, 1=cohab, 2=married, 3=widowed, 4=divorced
Bornyear	Boolean	Yes/no	
Diedyear	Boolean	Yes/no	
Gavebirth	Boolean	Yes/no	
Emigrateyear	Boolean	Yes/no	
Leavehome	Boolean	Yes/no	
Timeindwelling	Byte	0-	Months since move to present dwelling
Numbermoves	Integer	0-	Number of previous moves
Location	Land	Pointer	Pointer to land (redundant)
Household	Household	Pointer	Pointer to household

The household object contains the following properties/attributes:

Label	**Type**	**Values**	**Comment**
ID	Longint		Identifier
Year	Date	1900-2100	
Adults	Byte	1-	Number of adults in household
Children	Byte	1-	Number of children in household
Tenants	Byte	1-	Number of non-family members in household
Earnings	Integer	100 SEK	Annual earnings from employment
Dispinc	Integer	100 SEK	Disposable income for household
Dispincperind	Integer	100 SEK	Disposable income/person for household
Region	LA-region	1-108	Labour market region (redundant)
Dwelling	Home	Pointer	Pointer to home
Family	Boolean	Yes/No	

The home object contains the following properties/attributes:

Label	**Type**	**Values**	**Comment**
ID	Longint		Identifier
Year	Date	1900-2100	
Owner	Byte		Category of owner
Housetype	Byte		Type of housing, age of house
Housesize	Integer	m2	Size of living area
Lastincome	Integer		Disposal income of last tenants family
Lastfamsize	Byte		No. of persons in last tenants family
Occupied(t)	Boolean	Yes/no	If no, the dwelling "slot" is vacant
Occupied(t-1)	Boolean	Yes/no	
Zone	Neighbourhood	Pointer	Pointer to Neighbourhood (redundant)
Location	Land	Pointer	Pointer to land square

The land object contains the following properties/attributes:

Label	**Type**	**Values**	**Comment**
Year	Date	1900-2100	
Source	Byte	O,1,2,3	0=empty,1=houses,2=workplaces,3=1+2
x-coordinate	Longint		
y-coordinate	Longint		
Distance	Integer	Km	Distance to Labour Market (LA) region centre
Parish	Integer		
Commune	Integer		
County	Integer		
Zone	Neighbourhood	Pointer	Pointer to Neighbourhood
Labour Market	LA-region	Pointer	Pointer to Labour Market (LA) region
Pollution	Integer		Pollution levels
Landuse	Byte		Crude land use estimate
Propertyvalue	integer	100 SEK/m2	Total estimated value of land unit
Landvalue	Integer	100 SEK/m2	Estimated land rent

The workplace object contains the following properties/attributes:

Label	Type	Values	Comment
ID			Identifier
Year	Date	1900-2100	
Sector	Byte		Institutional sector
Branch	Integer		Standard industrial classification
Employment	Integer	0-	Number of employed at workplace
Income	Longint	100 SEK	Total salary for employed
Bluecollar	Integer	0-	Number of employed blue collar (0-3)
Bluevac	Integer	0-	No. of vacancies for educ level 0-3
Whitevac	Integer	0-	No. of vacancies for educ level 4-7
Labour Market	LA-region	Pointer	Pointer to LA-region (redundant)
Location	Land	Pointer	Pointer to land square (static only 1994)

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

Label	Type	Values	Comment
ID	Byte		LA-region number
Year	Date	1900-2100	
Population	Longint		Total population number
Employed	Longint		Total employed number
Unemployed	Longint		Total unemployed number
Whitecollar	Longint		Total number of residents edlevel 4-7
Vacancies	Longint		Total number of vacancies
Earnings	Integer		Total earnings
Area	Integer	km2	Total land area

The Neighborhood object contains the following properties/attributes:

Label	Type	Values	Comment
ID	Byte		Neighborhood zone number
Year	Date	1900-2100	
Population	Integer		Total population number
Employed	Integer		Total employed number
Unemployed	Integer		Total unemployed number
Vacancies	Integer		Total number of vacancies
Primary school	Boolean	Yes/no	
Vacant slots	Integer		Number of vacant slots,

ENDNOTES

[1] A whole population has obvious output advantages as well: A national model can preserve 'relations' (Holm et al. 1996).

[2] Galler (1997b) compares discrete-time versus continuous-time (hazard function) approaches to specifying behavioral equations in an MSM. The author concludes that a discrete-time approach is preferred in the discrete periods are relatively small.

[3] A more elaborate educational module can be found in Nelissen (1994). NEDYMAS uses a pass probability for each elementary grade while SVERIGE waits until final elementary year to determine passage. Unlike SVERIGE, several possible options are possible in elementary education—one can "fail" and enter "special education," be compelled to repeat a grade level, or "drop" out. Alternatively, especially successful students can skip a grade. Also, educational re-entry is allowed (like SVERIGE) and educational curricula are modeled. High school and college level students may change their curricula and jump from vocational to general education programs.

[4] Nelissen (1994) allows minor children to be assigned to male partner in 5-20% of the cases.

[5] Some microsimulation modules have additional immigration module features. NEDYMAS (Nelissen (1994, 1993, 1991)) permits family reunification. DYNAMOD2 models immigrants and refugees and various other categories of immigrants (including family, skilled, New Zealand labor area) (Walker 2000). It also permits considerable flexibility in specifying immigrant characteristics (and multiple characteristics can be changed).

[6] One approach (known in Sweden as the "Whole of Sweden Strategy") is to disperse immigrants in a manner similar to native distribution patterns (Rooth 1998). Such policies are adopted for a variety of reasons, including: (1) to better utilize limited housing and infrastructure for the care of immigrants, (2) to decrease the cost of maintaining immigrants, (3) to lessen native resistance to refugees and dilute their visibility by spatially dispersing them, (4) to encourage their spatial assimilation, and (5) to disperse their labor market effects and possibly relieve regional labor shortages in peripheral areas.

[7] Possible output is cumulative totals based on following attributes: PID, Family ID, Relation, Sex, Born region, Age, Years in Sweden, Education level, Education sector, In education, In education previous year, Working, Working previous year, Unemployed, Unemployed previous year, Out of labor force, Years out of labor force, Marital status, Years in current marital status, Years in current dwelling, Absolute monthly earnings, LA Region, East Coordinates, North Coordinates, Alive, Working full time, Estimated weeks working, Got new earnings, Unemployment rate: LA region Unemployment rate: Sweden, Age of mother when born, Family earnings, North center, East center, North centre previous year, East centre previous year, Distance to region center, Kids or not, Number of children, Kids 0-2 years, Kids 3-6 years, Kids 0-17 years, Kids in previous relations, Spouse's PID, Years in school, Years in gymnasium, Years in Komvux, Years in University, Years in Graduate School, Number of moves, Spouse immigrated this year, Left home this year, Moved this year, Migrated this year, Sambo this year, Parent this year, Died this year, Immigrated this year, Emigrated this year, Married this year, Widowed this year, Divorced this year Current year, Not born in Sweden

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Table 2.1 Microsimulation Models

Acronym	***Model Name (Country)***	***Sources***
CORSIM	Cornell Microsimulation Model (US)	Caldwell (1996, 1997) Caldwell et al. (1998)
DYNACAD	Canadian Dynamic Microsimulation Model (CANADA)	Morrison (2000)
DYNAMOD2	Dynamic Microsimulation Model (AUSTRALIA)	King et al. (1999) Walker (2000)
FAMSIM	Family Simulation Model (AUSTRIA)	Lutz (1997), Spielauer (2000)
LOCSIM	Local Simulation (NETHERLANDS)	Oskamp (1995)
MICROHUS	Household Microsimulation Model (SWEDEN)	Klevmarken (1996, 1998)
MOSART	Microsimulation of Schooling, Labor Supply and Pensions (NORWAY)	Andreassen et al. (1996) Fredriksen (1998) Andreassen and Texmon (2000)
NEDYMAS	Netherlands Dynamic Microanalytic Simulation Model (NETHERLANDS)	Nelissen (1991, 1993, 1994 1996, 1998)
SIMLEEDS	Leeds Microsimulation Model (UK)	Ballas and Clarke (1999)
SVERIGE	System for Visualizing Regional Influences Governing the Environment (SWEDEN)	Vencatasawmy et al. (1999)
TOPSIM	Total Population Simulation Model (SWEDEN)	Holm et al. (1996)

Figure 3.1 Modules of SVERIGE Model

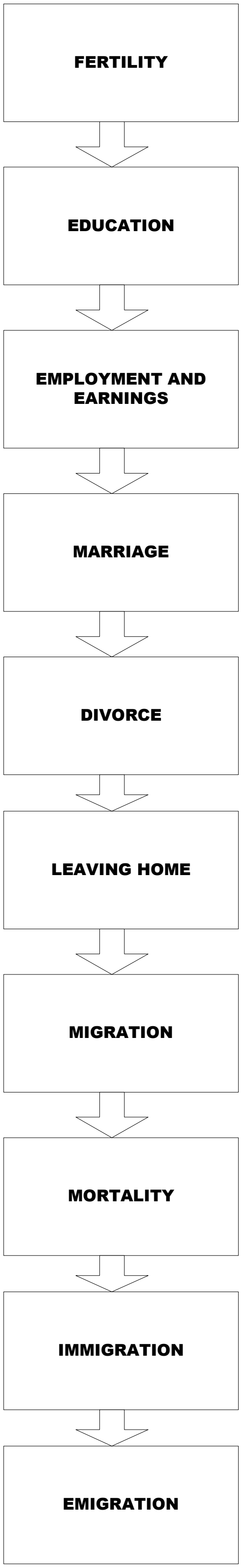

Table 3.1. Features of SVERIGE

Features	***SVERIGE***	***Alternatives***
Micro-units	Individuals, households, geographical units	Houses, employers
Dynamic or static	Dynamic	Static
Cross-section or longitudinal	Cross-section	longitudinal
Open vs. Closed	Open	Closed
Discrete time vs. continuous	Discrete time (years)	Discrete time (months), Continuous
Modular sequence	Time-driven	Event driven
Modular timing	Discrete (annual)	Discrete (shorter periods) Continuous
Types of Modules	Demographic, labor and Income, spatial	Social insurance, tax wealth
Sample Size	Population, sample	Sample
Data sources	Linked administrative, Census records	Surveys, synthetic data, imputations
Behavioral Equations.	Transition matrix, Discrete, multinomial, Continuous	Survival function
Alignment	Yes (user option)	No
Micro-macro linkages	None	Linkage with CGE, Econometric, I/O Models
Validation	Limited	Extensive
Policy applications	Limited	Extensive

Figure 3.2 Relations between objects and attributes

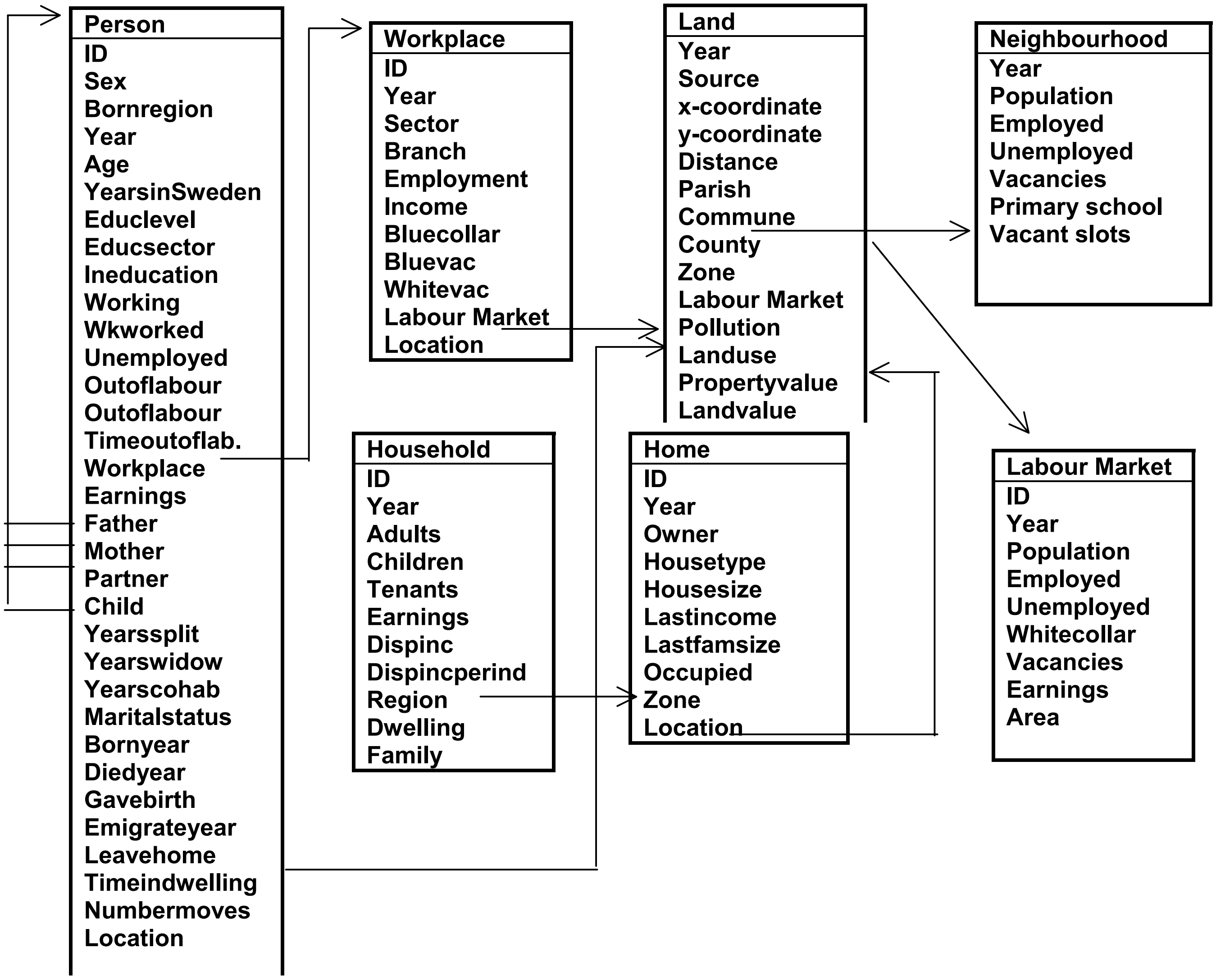

Figure 3.3 Pathways for updating object attributes

New attribute value ← event ← old attribute value, same person, same attribute
old attribute value, same person, other attributes
old attribute value, other person, same attribute
old attribute value, other persons, other attribute
other events
attributes of other objects
aggregates (of object attributes)

Table 3.2 Determinants of person attributes in SVERIGE

(1) Gavebirth – (age, maritalstatus, earnings(family), educlevel, working), sex of new birth is random draw
(2) Diedyear – (age, maritalstatus, earnings(family), educlevel, sex, working)
(3) Cohabit - (age, children, earnings, educlevel, maritalstatus, sex, working)
(4) Married- (age(female partner), age(youngest child), children, children(female partner)(t-yearscohab), maritalstatus, earnings(household), educlevel, (earnings(female partner)-earnings(male partner)), (edlevel(female partner)-edlevel(male partner)), (age(female partner)-age(male partner)), bornregion(female partner), bornregion(male partner))
(5) Partner – pointer to partner, mating algorithm(sex, age, educlevel, bornregion)
(6) Divorced- (age(female partner), age(child), children, children(female partner)(t-yearscohab), earnings(household), educlevel, maritalstatus, bornregion(female partner), bornregion(male partner))
(7) Widowed- spouse diedyear
(8) LeaveHome- (age, earnings, educlevel(mother), educlevel(father), sex)
(9) Ineducation- (age, earnings(family), educlevel(mother), educlevel(father), maritalstatus, working, bornregion, ineducation(t-1), sex, location)
(10) Educlevel- (educlevel(t-1), ineducation)
(11) Educsector - exogenous
(12) Working- (age(t-1), age(youngest child), children, civilstatus, educlevel, sex, working(t-1), ineducation(t-1), bornregion, yearsinSweden, location)
(13) Wkworked- (age(t-1), age(youngest child), children, civilstatus, 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), Emigrateyear)
(17) Emigrateyear-(sex, maritalstatus, yearsinSweden, numbermoves, bornregion, working, educlevel, location)
(18) Location- (age, age(oldest child), age(youngest child), children, sex, educlevel, yearsinSweden, bornregion, working, earnings(family), timeindwelling, numbermoves, location).
(19) Age – Age(t-1)
(20) Mother- Natural mother or adoption
(21) Father- Natural father

Table 5.1 Description of simulations.

BASE	Baseline simulation with normal immigration flows.
IMM1	5% All immigrants, same spatial distribution, same econ-demo characteristics.
IMM2	5% African refugees, same spatial distribution, same econ-demo characteristics.
IMM3	5% African refugees, Stockholm concentration, same econ-demo characteristics.
IMM4	5% African refugees, Kiruna concentration, same econ-demo characteristics.
IMM5	5% African refugees, evenly distributed, same econ-demo characteristics.
IMM6	No immigration, 1998-2015.
IMM7	5% Nordic immigrants, same distribution as rest of population, same econ-demo characteristics.
IMM8	No immigration, 1998 only.

Figure 5.1 Immigration percentage of population, 1875-2000

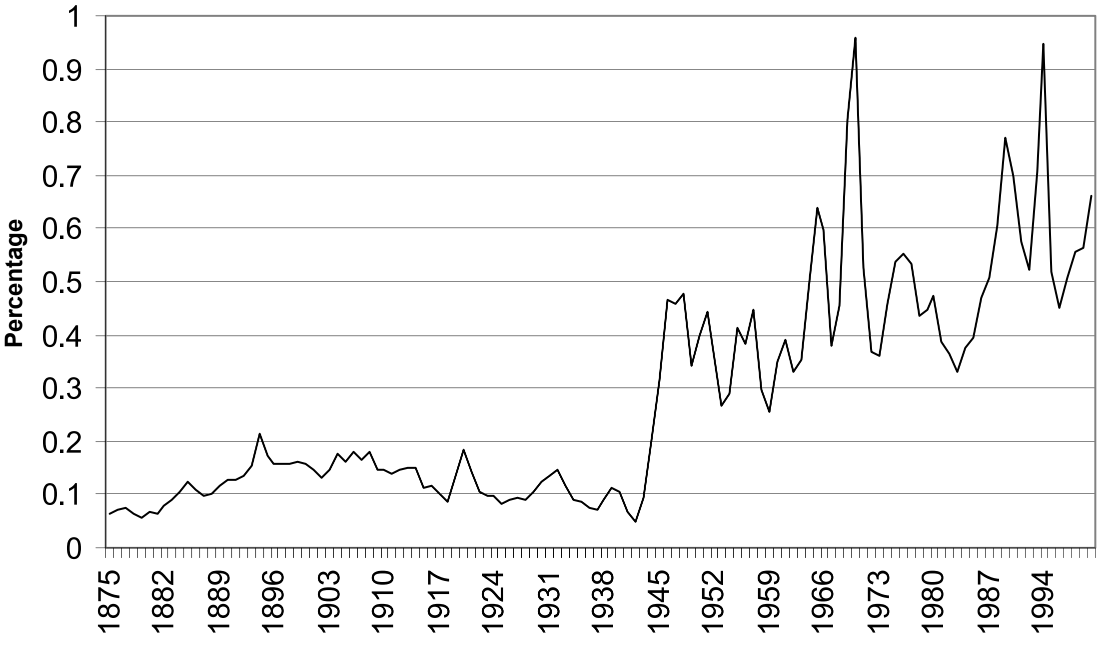

Figure 5.2 Immigration by Origin

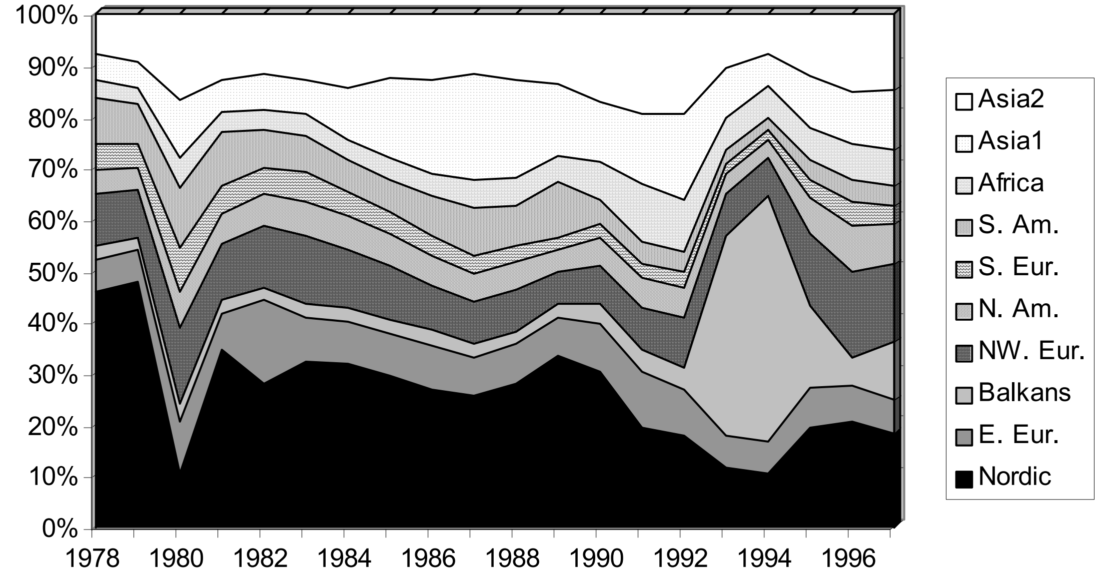

Figure 5.3 Percentage of Immigrants who Settle in Stockholm

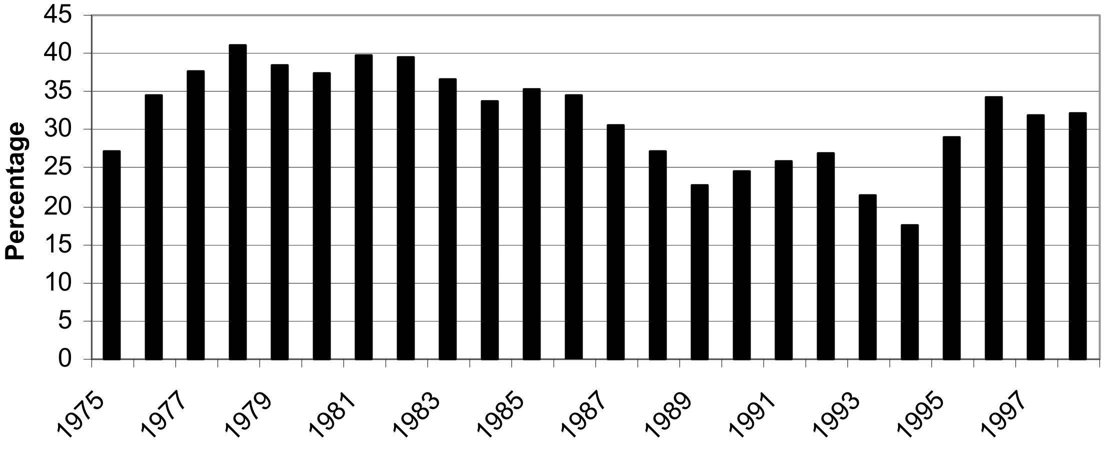

Figure 6.1 Immigration

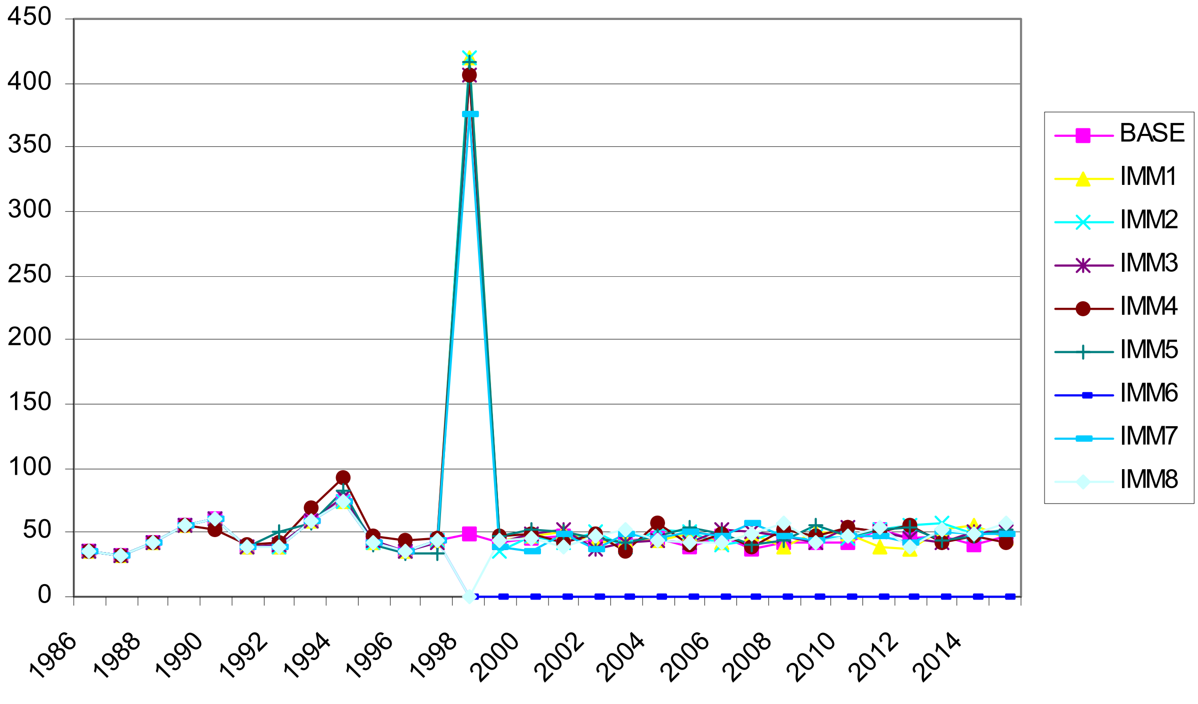

Figure 6.2 Cumulative Emigration Impacts

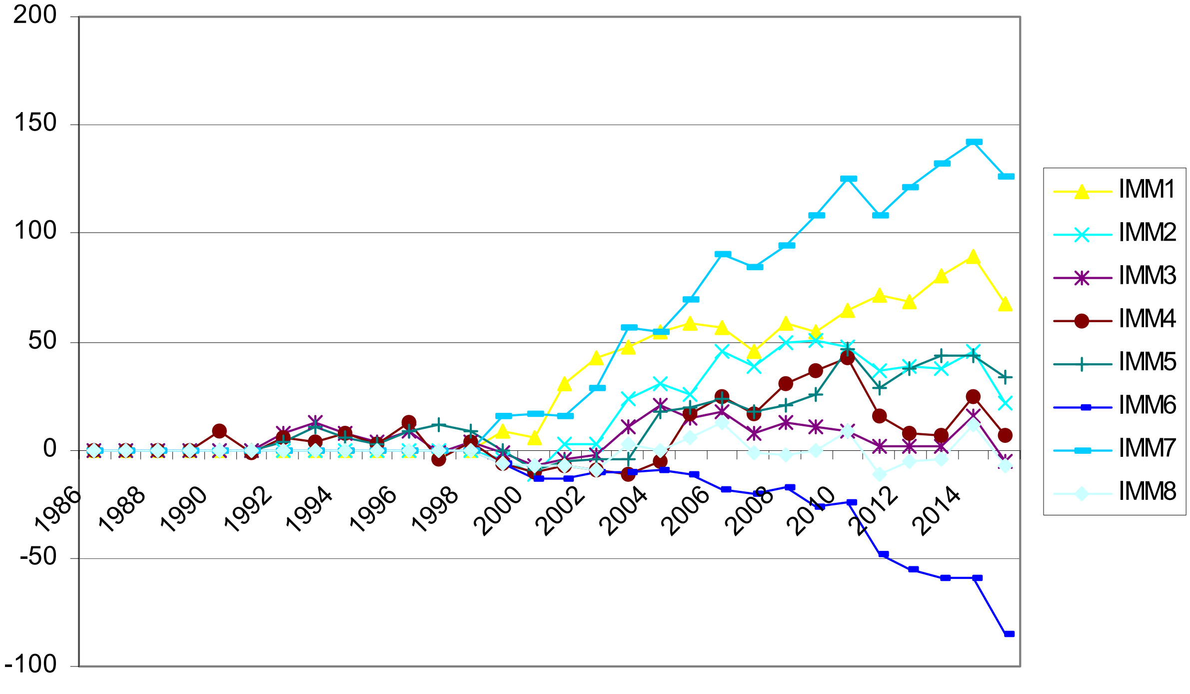

Figure 6.3 Migration Rate Impact

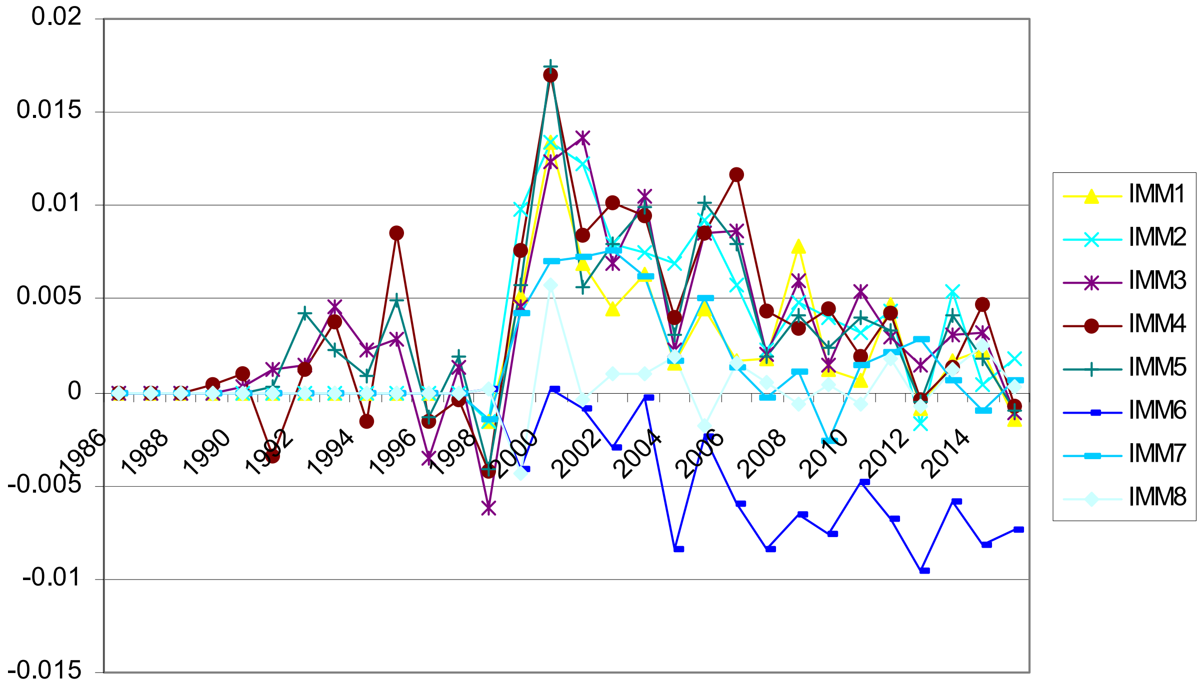

Figure 6.4 Cumulative Birth Impact

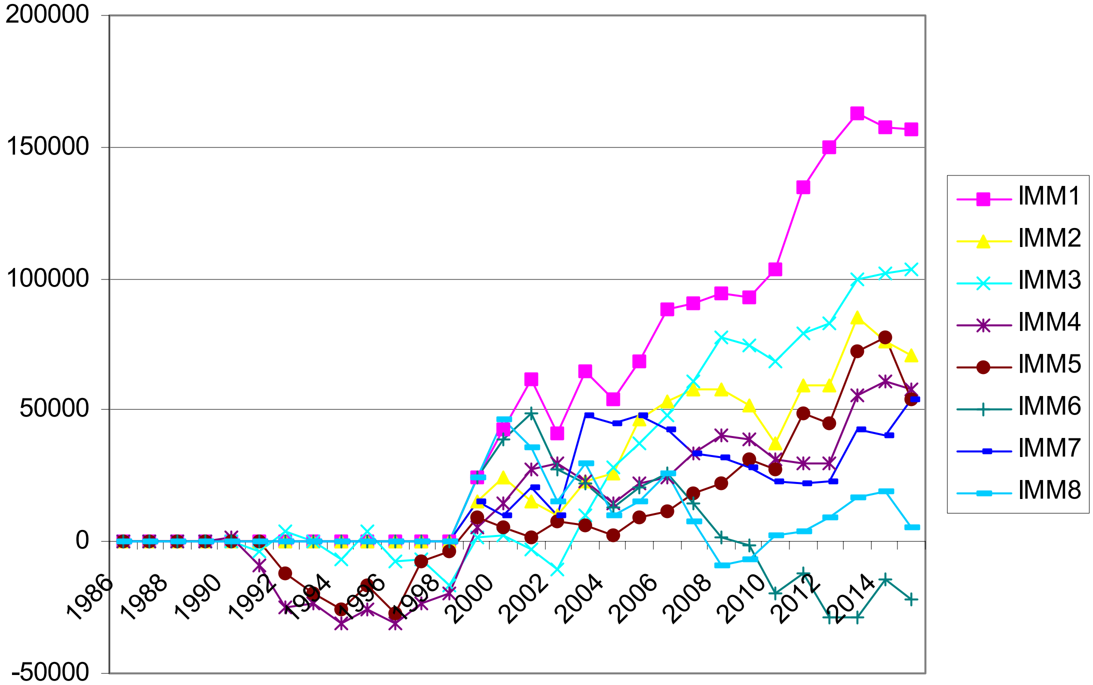

Figure 6.5 Population

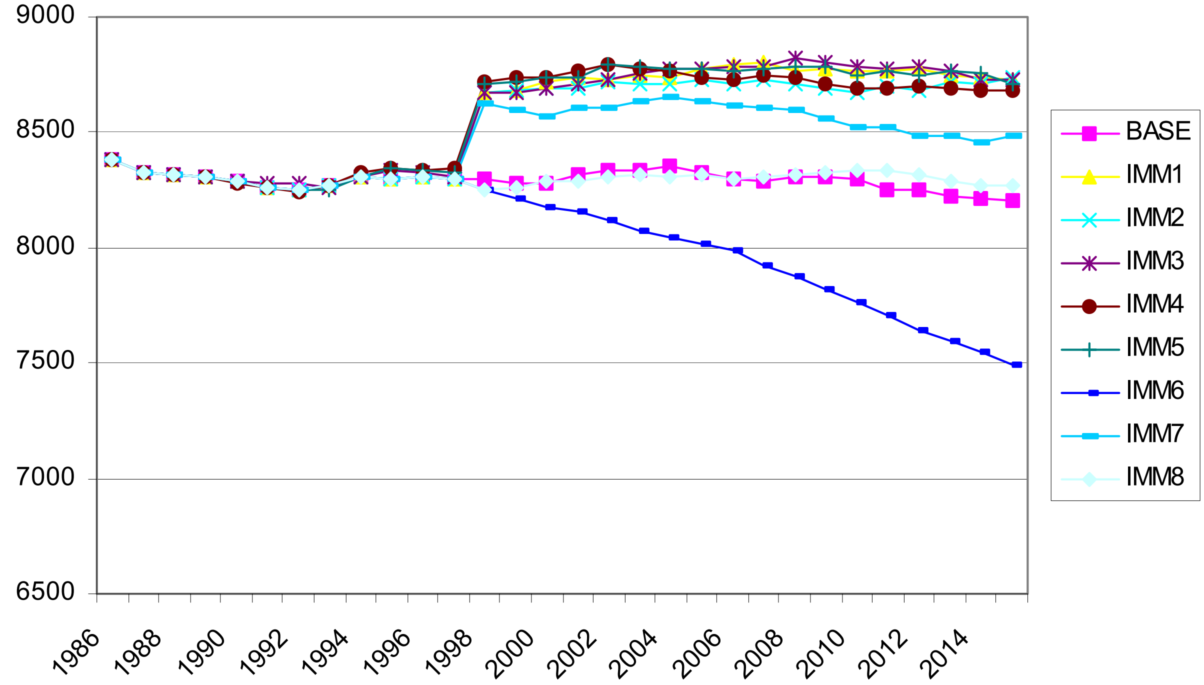

Figure 6.6 Average Earnings Impact

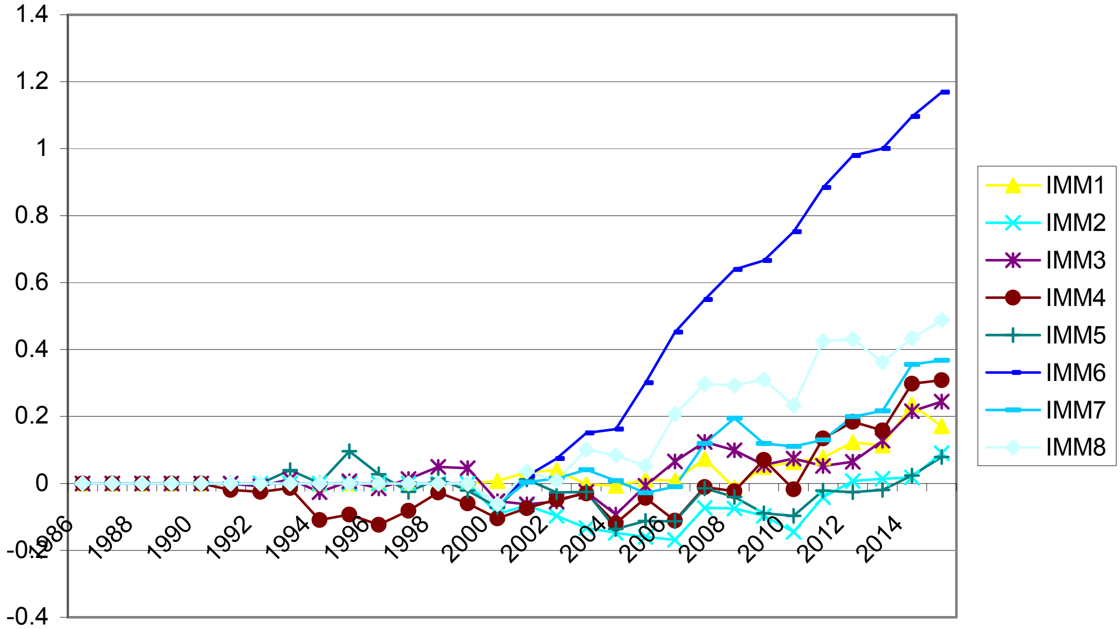

Figure 6.7 Labor Force Participation Impact