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THE FUTURE OF THE STUDENT IN HIGHER EDUCATION: NUMBERS, FLOWS, COMPETITION AND PLANNING IN A GEOGRAPHICAL CONTEXT

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ABSTRACT

This paper tries to learn from the failures in the mid-1980s to forecast student numbers for the late 1980s adequately. The failure is one not of poor assumptions or inadequate data but rather of inadequate conceptualisation of a complex system. The paper attempts to rectify this inadequacy in a second section using diagrams and in a third section using some simple mathematics. Most decision makers in the Higher Education system have a good intuitive understanding of the way the system behaves and the mathematical models attempt to capture this understanding. Implementation of the models suggested would however need substantial resources and commitments by all Higher Education institutions. Reactions to these suggestions are invited.

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1. CONTEXT

In the public arena in 1991 two themes are current. The first is that the level of education and training of a population is crucial to its economic well-being in the 1990s and beyond. The second is that the resources (particularly finance) available for providing this education and training are limited and must be used with the very greatest efficiency. Will it be possible to achieve a higher level of education and training for the population in the 1990s given resource constraints, in particular, in the realm of higher education?

To answer this question requires a review of higher education developments in the 1980s, together with some prognostication of their continuation (or not) in the 1990s. In particular, we need to understand the factors affecting the entry of students into higher education and how these factors are likely to change in the future.

In order to plan for the provision of HE facilities, the Department of Education and Science (DES) carried out two sets of forecasts of demand for HE. The first (DES, 1983) was criticised by HE professionals and substantially revised in the following year (DES 1984a,b). However both forecasts suggested that the numbers of students in HE would not rise very much in the 1980s (from a base in the 1983-84 academic year) and would fall substantially in the 1990s as a consequence of the decline in the number of 17 to 19 year olds (reflecting low numbers of births in the 1972 to 1982 period). The higher numbers in the second DES forecasts derive mainly from assumptions about mature students. Following the DES forecasts, Rees (1986) carried out a similar exercise to establish whether trends in student numbers would vary by region of domicile of the student and by university cluster, employing data on the origins of university students provided in the University Central Council on Admissions (UCCA) statistics. His main conclusion was that student migration served to smooth out the regional variation in demand as seen from the point of view of universities. In particular, the less favourable position of northern regions in terms of potential local students was tempered by the ability of northern universities to recruit students from southern England.

Did these forecasts turn out to be correct in the 1980s? Table 1 reports the variant X and Y forecasts of DES (1984) for "young home initial entrants" (that is, students aged 17 to 20 entering an HE institution to study for a first degree or sub-degree) and compares them with the numbers reported in more recent DES Statistical Bulletins (DES 1988, 1991). Also included in the table are the estimated numbers of persons aged 18 at June 30 on the year of entry and the projected number of qualified leavers. Comments are made on the trends revealed in each numbered column in the table.

TABLE 1. *Numbers of persons aged 18, projected young home initial entrants and actual first year home full time students, aged under 21, 1980-89, Great Britain*

Year	Persons aged 18	Projected Qualified leavers	Projected Entrants Variant X	Projected Entrants Variant Y	Actual first year home full time students aged under 21
	(1)	(2)	(3)	(4)	(5)
1980	894	132.9	113.9	113.9	123.4
1981	911				130.2
1982	937				136.5
1983	945	151.1	134.1	122.9	135.4
1984	912	149.8	133.7	121.9	137.9
1985	901	149.8	134.5	121.8	136.8
1986	873	149.1	134.5	121.2	136.6
1987	868	147.7	133.2	120.1	138.5
1988	842	144.4	130.2	117.4	141.2
1989	852	145.8	131.5	118.6	157.8

Sources:

(1) 1980-86 from OPCS population estimates; 1987-89 from OPCS (1989).
(2) to (4) From DES (1984a). The 1980 figures are estimated. The 1983-89 figures are projections.
(5) From DES (1988) and DES (1991).

Persons aged 18

Although young persons enter higher education at ages 17, 18, 19 and 20, the majority (60 per cent) enter aged 18 and the numbers in adjacent cohorts are very similar. We can therefore use the numbers aged 18 to provide a measure of the fluctuation in the size of the main initial entry cohort. The numbers aged 18 rise to 1983, mirroring the rise in the number of births to 1964-5; and then fall steadily thereafter except in 1989 when there is a slight check.

Qualified leavers

To enter HE the student has to attain some minimum qualifications (passes in 2 A levels in England, Wales and Northern Ireland, and in 5 Highers in Scotland). Column (2) displays the Variant I projections (after 1983) in the number of qualified school leavers. The Qualified Leaving Index (total qualified leavers as a percentage of the average of the numbers aged 18 and 19) was assumed to rise from 15.0% in the 1980-1 academic year to 17.4% in 1989/90. This has turned out to be a conservative estimate with rates of 17 year olds staying on in school rising from 30% in 1985-6 to 37% in 1989-90 in England, for example. The QLI must have risen substantially more than DES assumed in 1984. The percentage of 18 year olds achieving qualified leaver status must have reached at least 20% by 1989/90.

Projected entrants

Columns (3) and (4) of Table 1 display two variants of the DES projections. Variant X uses the level of participation in 1981 of 18 year olds, while variant Y uses 1983 levels, when the supply of places was held severely in check by public expenditure restraints. The variant Y projections were clearly underestimates as the HE system was allowed to expand gently to 1986 and more rapidly from 1986.

Actual entrants

Column (5) in Table 1 reports DES statistics of the actual numbers of young entrants admitted to HE institutions. Already in 1980 there was a discrepancy of nearly 10,000 between the base year figures used in the DES projections and the reported figures in the DES Statistical Bulletin. The variant X and actual numbers remain close together between 1983 and 1986, but diverge thereafter, but particularly in the entry year of 1989. The divergence will have grown even more in 1990 and, in all probability, in 1991 (Bates 1991).

Critics (e.g. Diamond 1989) were quick to identify factors that they felt had been underplayed in the DES work. These included the more favourable trends in births (and later 17 to 20 year olds) in social classes I and II, from which the bulk of HE students are recruited, than in the other social classes and the increasing propensity for girls to stay on at school after 16, attain HE entry qualifications and apply for HE courses outside traditional spheres (such as teaching). These criticisms, however, were not crucial because both factors had been built into the second set of DES forecasts.

Critics (e.g. Association of University Teachers) merely made more optimistic assumptions about how far trends such as increased female participation in HE would go.

What was more crucial was the failure to recognise the distinction between demand for HE places (the number of qualified applicants to HE) and the supply of places in HE. In the 1979-86 period the numbers entering the University sector of HE were strictly controlled and limited by the University Grants Committee on behalf of the central government, although locally controlled polytechnics did increase the number of places for full time students in this period. Overall it was clear that the number of HE places offered fell short of the number of qualified school leavers (and others) wishing to enter HE. Therefore, when the strict quota controls on university places were relaxed progressively from 1987, the numbers of students entering began to rise.

Where the supply of places did not constrain the number of students such as in the polytechnics and colleges of education, particularly part-time courses, numbers expanded quite rapidly in the post 1984 period (Figure 1).

It was clear that the frameworks for forecasting the numbers of students entering HE were inadequate. Although DES 1984-5 and Rees (1986) were careful to talk about student demand, their forecasts reflected severe constraints consequent on restriction in the supply of places in HE institutions. Unless an adequate framework is developed, it will be easy to repeat the mistake of the mid-1980s and forecast on the basis of current supply/demand relationships for the rest of the 1990s.

In order to forecast student numbers more effectively, we need a model that represents adequately both the demographic and socioeconomic factors affecting student demand, the procedures that govern student entry to HE and the changing situation with respect to supply of HE places. This task of model building is attempted in the remainder of the paper, diagrammatically in section 2 and algebraically in section 3. In section 4 of the paper the data requirements and feasibility of the model are reviewed. The model is not implemented because it requires substantial resources to organise the assembly of data and more importantly it requires a client institution capable of unlocking the crucial databases access to which is denied the HE university academic working in his shrinking UFC funded research time.

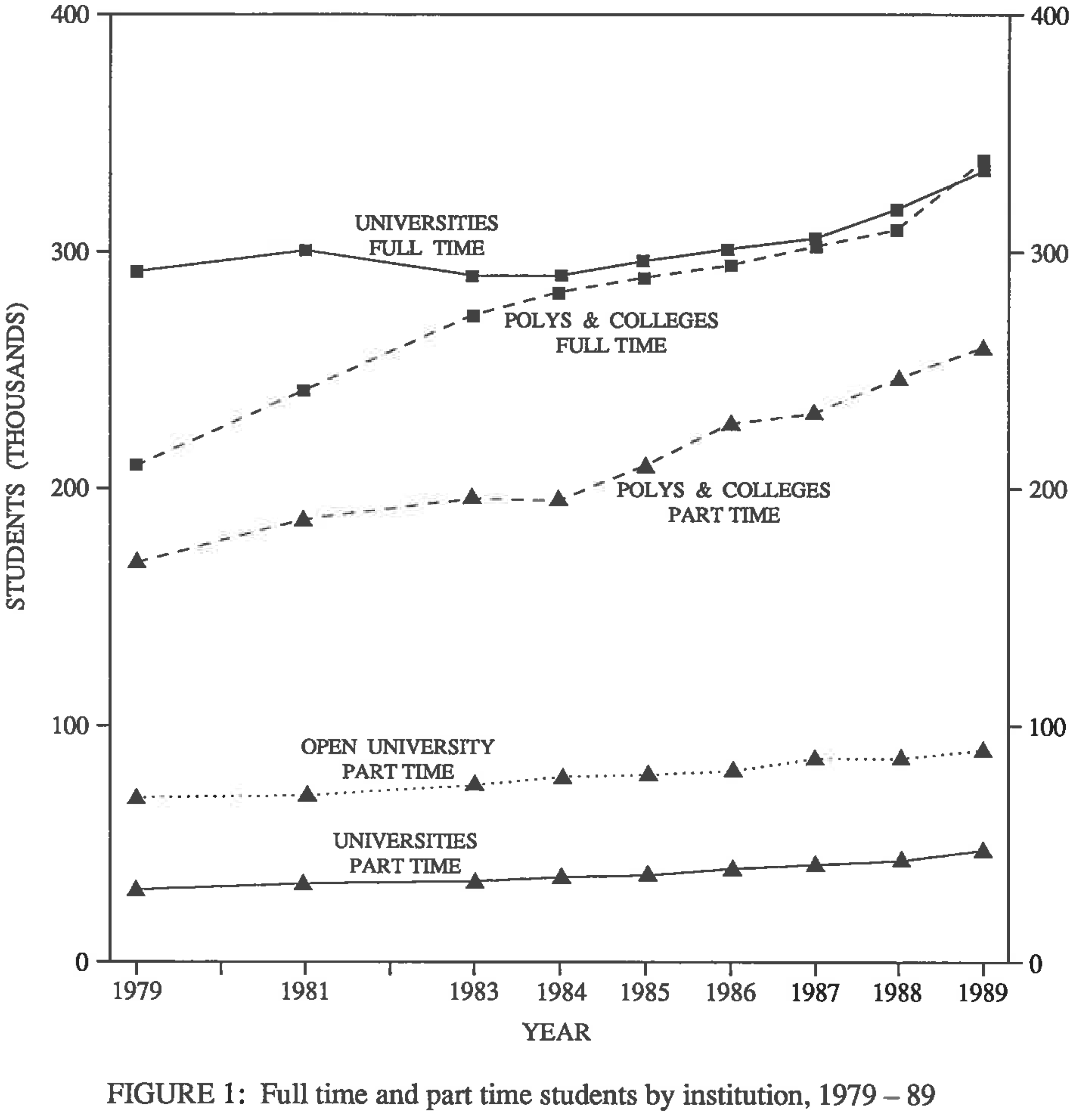

FIGURE 1: Full time and part time students by institution, 1979 – 89

2. A REVISED FRAMEWORK FOR FORECASTING STUDENT NUMBERS

2.1 *Stage 1: an aggregate model*

The system that we are studying can be represented (in Figure 2) as a sequence of stocks (boxes) connected by flows (arrows) and controlled (via valves) by processes. The system begins with a stock of persons born some 17 to 20 years ago in the country. The maximum size of the HE entry cohort is known well in advance of the year of entry.

The demographic process of mortality will slightly reduce the number in the cohort by age 18 and international migration may modify (up or down), but the reduction will only be 1 or 2% at most.

The survived 17 to 20 year olds will have proceeded through the various stages of schooling and a proportion of them will be successful at GCSEs or equivalents, and at A levels or Highers and attain qualifications needed for HE entry. The proportion of successive birth cohorts attaining ages 17 to 20 who attain qualified leaver status has been rising substantially in the past decade.

Only some of these go on to enter HE, becoming young initial entrants, through the admission process. The admission process has been designed to match the number of entrants to the number of places which HE funding provides. The mechanism by which this is achieved is through requiring that entrants gain higher than minimum grades for entry. On very popular courses (e.g. Law, Veterinary, Science, Medicine) the grades demanded may well be the maximum attainable (e.g. 3 A grades at A level). Grade requirements are adjusted from year to year to ensure quotas of places are filled as exactly as possible. Candidates unsuccessful in obtaining admission at their first choice institutions have further opportunities at second choices, and via alternative admission systems (UCCA or PCAS or direct entry or the clearing house systems).

2.2 *Stage 2: a model disaggregated by social class and gender*

The stage 1 model was widely regarded as too simple. The population could not be treated as one homogeneous entity but contained subgroups which behaved differently. Two types of subgroups were regarded as important. The population could be divided into males and females and into six social classes (Figure 3). The influence of these two classifications is somewhat different.

There are no significant differences in the trends of male and female births or in trends in mortality or international migration between birth and age 18. There are however significant differences in the rates of staying on in school to take post 16 qualifications and in applications to HE: these have risen much faster for female pupils who have, by the end of the 1980s,

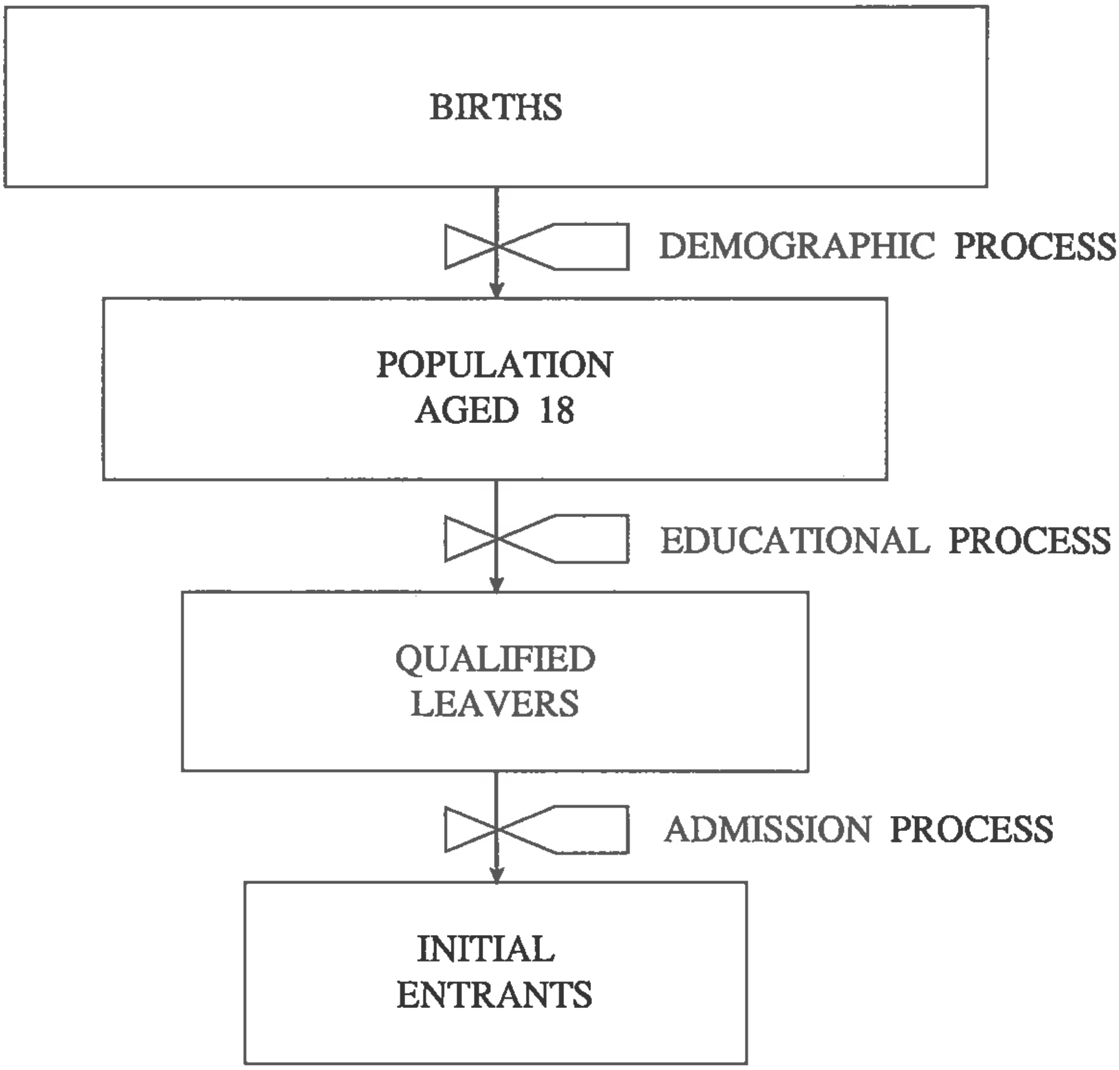

FIGURE 2: Student stocks and flows : 1. an aggregate model

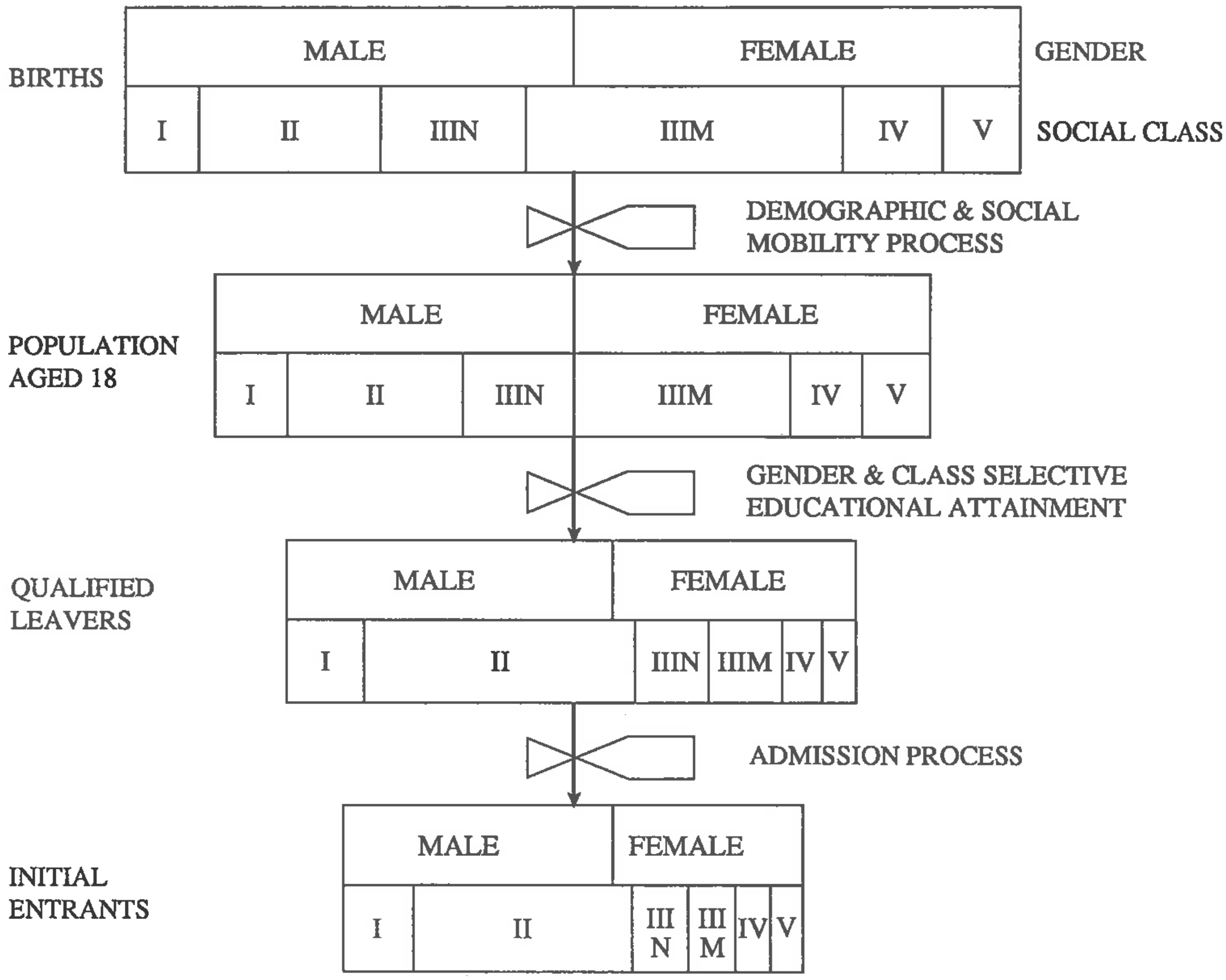

FIGURE 3: Student stocks and flows: 2. a model with class disaggregation

virtually caught up with their male counterparts. This trend is a product of the changing role and aspirations of women in contemporary Western society.

The influence of social class on the student stocks and flows is different. Here the observation is made that the numbers born to fathers in social classes I and II have increased while those born to fathers in social classes IIIN, IIIM and IV and II have declined over the 1960 to 1980 period (see Table 3.11 in DES 1984b). This is a product principally of a shift in the occupational distribution of fathers over the 1960s and 1970s rather than differential trends in fertility rates (births/populations at risk). There were also further shifts in the social composition between ages 0 and 18 as a result of net upward social mobility of lower class families (at least until the early 1980s).

Because of these trends in population disaggregated by social class and because of the link between social class and educational aspirations and achievement, more qualified leavers were produced than an aggregate analysis suggested.

Note that there is little selectivity by social class and gender given educational attainment during the admission process, as HE institutions admit students through grade performance only.

2.3 *Stage 3: a model disaggregated by gender, class, region and institution*

A third stage in model refinement was introduced by Rees (1986), that of regional disaggregation depicted in Figure 4. Trends in births in the regions do not differ greatly although fertility rates are higher in northern regions and in Northern Ireland. Inter-regional migration between birth and 18, however, reverses these differentials leading to more favourable trends in southern regions (Rees 1986, Figure 2). The social class composition of southern regions is more favourable for the production of qualified school leavers than northern regions (Rees 1986, Table 2), though both Northern Ireland and Scotland (for different reasons) produce proportionally more qualified school leavers (allowing for the differences in class composition) than does northern England.

The diagram shows that the definition of region changes in the last stock to that of HE institutions which are the controllers, to date, of the system. A vigorous migration process out of domicile regions occurs to HE institutions in other regions. Whereas HE institutions control the numbers admitted, the patterns of migration reflect student choice, information and certain educational and cultural discontinuities (Stillwell and Rees 1985). Qualified leavers also take up alternatives other than entry to HE, namely economic activity (work) or, more rarely, inactivity (through marriage). When job prospects for school leavers are poor, more choose to stay on to apply for entry to

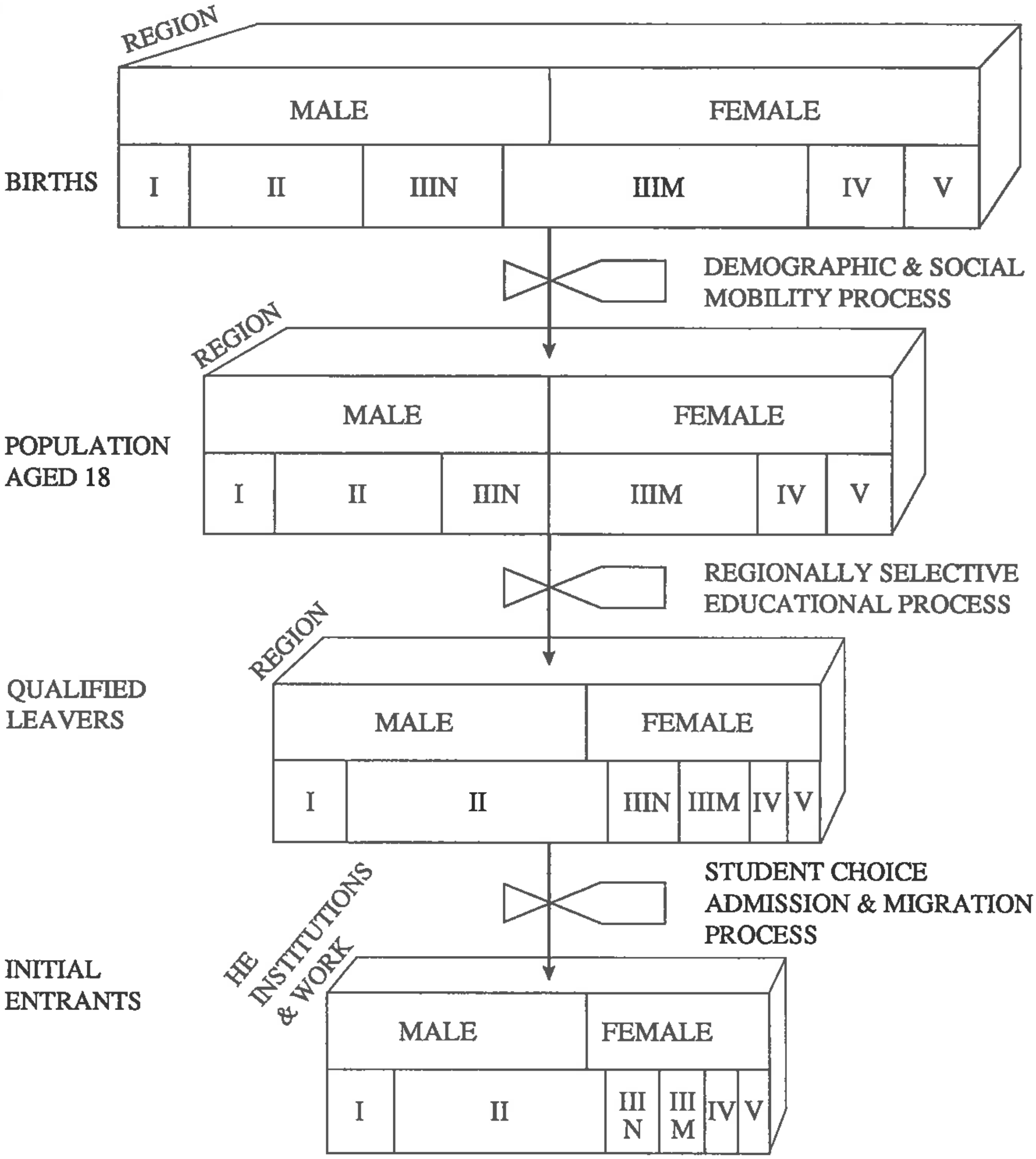

FIGURE 4: Student stocks and flows: 3. a model with gender, class, region and Institution disaggregation

HE. When job prospects are good more of the cohort able to enter the labour force choose to do so.

2.4 *Stage 4: a model disaggregated by region, institution, course and attainment*

The framework depicted in Figure 4, despite the three way disaggregation of stocks, fails to represent adequately what goes on in the HE admission process. Students select and enter particular courses on the basis of the qualifications gained at school.

Figure 5 shows the stages through which potential students to any course in an institution will go through before becoming, if successful, initial entrants. These stages will be familiar to most British readers. Perhaps the most interesting phase from the point of view of forecasting the initial entrants to an institution is the control labelled "admission rules". These rules are that admissions tutors must accept all candidates reaching their grade offer.

(1) If the number of acceptances exceeds the number of places on a course, the admissions tutor will raise the grade offer in the next admissions round.

(2) Conversely, the grade offer will be lowered if insufficient candidates achieve acceptable grades.

(3) Institutions attractive to students set high grade offers in order to attract the best qualified students, though they must be careful not to discourage applicants.

(4) Institutions unattractive to students set low grade offers and must enter the clearing house schemes if their quota of places is unfilled. In may ways the grade offer acts as the pricing mechanism for matching candidates and institutions of comparable quality, and for clearing the market (either by filling all places or satisfying all applicants).

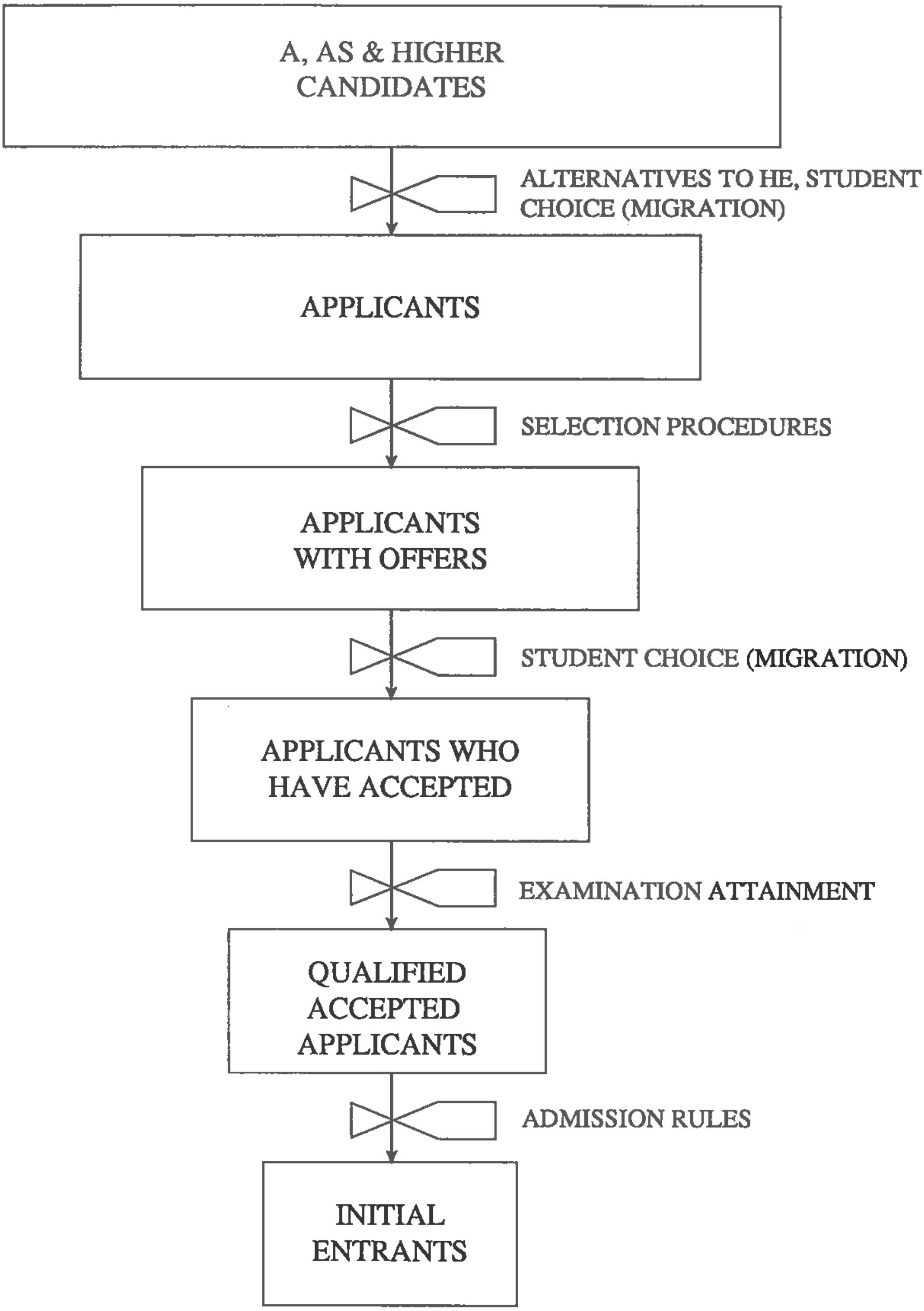

FIGURE 5: Student stocks and flows in the admission process

3. FORMAL MODELS FOR FORECASTING STUDENT NUMBERS

To develop formal models of student stocks and flows a set of algebraic variables and attached subscripts are used. The following upper case letters are employed to indicate the main stocks of people in the system:

B = births
P = population
Q = qualified school leavers
E = entrants to higher education.

These variables are broken down into subgroups by attaching various subscripts. The main ones used are:

a = age (single year)
g = gender
c = social class of origin (based on occupation)
d = current social class
i = region of birth
j = region of domicile
k = institution of higher education
x = course of study .

Also attached to the stock variables are time labels as post-scripts. Normally, these refer to the month of October in the year in which students are recorded as entering HE. For example,

$Q_{ag}(t)$ = qualified school leavers of age a and gender g at time t

Lower case letters are employed to represent probabilities of transition between one stock and the next. For example,

$s_a(t-a,t)$ = the probability of survival from birth to age a for time period t-a to t

3.1 *An aggregate model of student stocks and flows*

The model begins with the input of the numbers of births in successive years, $B(t-a)$, some a years prior to the current forecast year,

$B(t-a)$ for $t = 1, \ldots , nt$

where nt is the number of years the forecast is required for. If this exceeds 17 then a projection of the number of births is needed.

The population aged a in year t, $P_a(t)$, is derived as

$$P_a(t) = s_a(t-a,t)\ B(t-a) \qquad (1),$$

for all ages a at which persons enter HE, mainly at ages 17 to 20 but also beyond age 20. In practice, s_a is nearly one: current life tables indicate that 96% of the population survives to age

The age a population is then multiplied by the probability for year t that qualified leaver status is attained at age a, $q_a(t)$,

$$Q_a(t) = q_a(t)\ P_a(t) \qquad (2),$$

to yield the number of qualified leavers in year t of age a, $Q_a(t)$. The qualified leaver probability has been rising quite sharply at younger ages as more pupils stay on after 16, more of them take A levels, AS levels and Highers and as more pupils achieve pass grades in those exams.

The number of entrants to HE in year t aged a is then given by

$$E_a(t) = e_a(t)\ Q_a(t) \qquad (3)$$

where $e_a(t)$ is the probability that a qualified leaver will be admitted to an HE institution. Stated in this way the model appears to be demand driven. In practice, it is often the supply of places which has acted as the principal constraint.

Let $E_*(t)$ be the number of places for initial entrants to HE determined by the HE planning system. Equation (3) can be re-written as

$$E_a(t) = f_a\ E_*(t) \qquad (4)$$

where f_a is the fraction of entrants of age a

$$f_a(t) = Q_a(t)\ /\ Q_*(t) \qquad (5)$$

where $Q_*(t) = \Sigma_a\ Q_a(t)$. The probability of entry to an HE institution then becomes a function of the quota of places

$$e_a(t) = (f_a(t)\ E_*(t))\ /\ Q_a(t) \qquad (6)$$

and is not an independent variable. Equation (4) holds when

$$\Sigma_a\ Q_a(t) > E_*(t) \qquad (7)$$

and equation (3) holds when

$$\Sigma_a\ Q_a(t) < E_*(t) \qquad (8).$$

Crudely speaking, if inequality (7) holds, HE institutions choose entrants; if inequality (8) holds entrants choose HE institutions.

Note that the formal model derived here is more general that displayed in the corresponding diagram (Figure 2) because the formal model refers to any age a while the diagram, for convenience, depicts only the population aged 18. Initial entrants are both young (aged 17 to 20) and mature (aged 21 and over).

3.2 *A model of student stocks and flows with gender and class disaggregation*

Let us now disaggregate the first formal model by two population characteristics which affect the probability that pupils will attain qualified leaver status, namely gender and social class.

First, data on the numbers of births by social class and gender are needed some a years prior to the current forecast year:

$$B^c_g(t-a) \text{ for } t = 1, \ldots , nt$$

where c refers to the following social classes based on occupation

- I = professional occupations
- II = intermediate occupations, including most managerial and senior administrative occupations
- IIIN = skilled occupations - non-manual
- IIIM = skilled occupations - manual
- IV = partly skilled occupations
- V = unskilled occupations.

The number of persons aged a in a social class is a product of the number of births to families in that social class and the rate of social mobility between birth and age 18 of the family:

$$P^d_{ag}(t) = \Sigma_c \, m^{cd}(t-a,t) \, s_{ag}(t-a,t) \, B^c_g(t-a) \qquad (9)$$

where

$P^d_{ag}(t)$ = the population of age a and gender g at time t in social class d

$m^{cd}(t-a,t)$ = the probability that persons born into social class c move to social class d over the interval between birth and the current age

$s_{ag}(t-a,t)$ = the survival probability from birth to age a for time period t-a to t for persons of gender g.

DES (1984a, 1984b) give detailed consideration to the numbers born in the different social classes and to the rates of social mobility. There is some debate about whether subsequent variables in the model (such as attainment of qualified leaver status) should depend on social class of origin (c) or current social class (d), but this is probably not of crucial importance. Survival probabilities do vary between the genders and change slightly over time but again the differences and trends are not vital.

The next step in the model is to compute the numbers attaining qualified leaver status, disaggregated by social class and gender, $Q^d_{ag}(t)$,

$$Q^d_{ag}(t) = q^d_{ag}(t) \, P^d_{ag}(t) \qquad (10),$$

where $q^d_{ag}(t)$ is the probability that persons of gender g, social class d and age a attain qualified leaver status in year t. DES (1984b) reports on both the social class dependency of these probabilities and the trends by gender. It is probably useful to decompose the probabilities into the product of person probabilities and gender ratios

$$q^d_{af}(t) = q^d_{am}\ r_f(t) \tag{11}$$

where the subscript f refers to females and m to males and r_f is the ratio of the female rate (of attaining qualified leaver status) to the male rate. As female attainment rates have risen relative to male rates steadily in the 1970s and 1980s this ratios has converged to unity. The ratio of female to male first year full time students in HE in Great Britain has risen from 76% in 1979 to 89% in 1989. The dependency of the probabilities of attaining qualified leaver status on social class is acute: 50.5% of class I persons aged 18 became UCCA candidates in 1977-81 compared with only 4.2% of class IV and V pupils (DES 1984a).

The third process to be incorporated in the model is that of admission. Here we assume no dependence of entry probability on either gender or class so that the number of entrants classified by age a, gender g and social class d in year is given by

$$E^d_{ag}(t) = e_a(t)\ Q^d_{ag}(t) \tag{12}.$$

Again, the appropriate equation for determining the number of entrants if the supply of places is constrained is

$$E^d_{ag}(t) = f^d_{ag}(t)\ E_*(t) \tag{13}$$

assuming no quotas by age, gender or class apply, where $f^d_{ag}(t)$ is the fraction of qualified leavers in age a, gender g and class d defined as

$$f^d_{ag}(t) = Q^d_{ag}(t)\ /\ Q_*(t) \tag{14}.$$

Under supply constrained conditions the probability of entry is a function of the quota of places, as in the stage 1 model:

$$e^d_{ag}(t) = (f^d_{ag}(t)\ E_*(t))\ /\ Q^d_{ag}(t) \tag{15}.$$

3.3 *A model of student stocks and flows with disaggregation by gender, class, region and institution*

Further refinement of the model is needed if it is to function as a tool for the analysis of student entry at particular institutions at specific locations. HE institutions do recruit widely through the country but, to a greater or lesser extent, their students tend to come, other things being equal, from nearby (but not immediately adjacent) regions. Because regions vary in their propensity to generate students (because of differences in population size and composition by age and class and because of educational differences) the mix of markets will be different for each institution (see Rees 1986 for a more detailed exposition of this argument).

The first transition in the model can be represented, recognising birth region i and domicile region j, as

$$P^{dj}_{ag}t = \Sigma_c \; m^{cd}(t-a,t) \; \Sigma_i \; s^{ij}_{ag}(t-a,t) \; B^{ci}_{g}(t-a) \qquad (16)$$

where

$P^{dj}_{ag}(t)$ = the population of age a, gender g, class d resident in region j in year t

$m^{cd}(t-a,t)$ = the probability that persons born into social class c move to social class d over the interval between birth and the current age

$s^{ij}_{ag}(t-a,t)$ = the probability of survival from birth in region i to residence in region j at age a over time period t-a to t for persons in gender g

and

$B^{ci}_{g}(t-a)$ = births to families in class c in region i some a years before year t.

Here we assume that the rate of movement between social classes is independent of origin region of birth mainly because no data are available to refute the hypothesis. The survival probabilities are disaggregated by birth region and residence region and reflect inter-regional migration and could be generated from a standard multiregional life table (Willekens and Rogers 1978). Over 17 to 20 years there is a non-negligible degree of population redistribution between regions.

The second transition in the model concerns attainment of qualified leaver status which in this case is further disaggregated by domicile region at age a:

$$Q^{dj}_{ag}(t) = q^{dj}_{ag}(t) \; P^{dj}_{ag}(t) \qquad (17).$$

There is evidence to suggest that the probabilities of attaining qualified leaver status do vary substantially by region. Table 2

TABLE 2. *The ratio of UCCA entrants to the population aged 18 by domicile region*

Domicile region	University entrants as a % of the population aged 18	
	1981	1989
Northern Ireland	12.0	19.0
Scotland	5.6	12.8
Northern	6.9	7.9
Yorkshire & Humberside	7.1	8.0
North West	9.1	9.8
East Midlands	6.9	8.1
West Midlands	7.1	8.5
East Anglia	7.9	9.2
Rest of the South East	11.1	12.1
Greater London	8.3	11.7
South West	8.5	10.7
Wales	9.2	10.3

Notes:
1. Sources: UCCA 1982 and 1990 and author's calculations.
2. The percentages are not true probabilities because entrants enter at ages other then 18.
3. The Scotland figure in 1981 is low because a large number of students entered Scottish universities directly rather than through UCCA. A much higher proportion of entrants in 1989 came via UCCA.

extracts regional indicators from UCCA statistics for 1981 and 1989. Southern English regions exhibit higher ratios than Northern English, but both Scotland and particularly Northern Ireland generate proportionally more University entrants than either part of England.

The third transition in the regionally disaggregated model includes the process of student migration from domicile region to institution. The number of entrants to institution k of students of class d, age a and gender g in year t, $E^{dk}_{ag}(t)$, is given by

$$E^{dk}_{ag}(t) = e^{k}_{a}(t)\ \Sigma_j\ v^{jk}\ Q^{dj}_{ag}(t) \tag{18}$$

where

$e^{k}_{a}(t)$ = probability at age a of becoming an institution k entrant in year t

v^{jk} = probability that a region j entrant migrates to institution k in year t

$Q^{dj}_{ag}(t)$ = the number of qualified leavers of age a, gender g and class d in domicile region j in year t.

This equation makes a number of assumptions. Firstly, it assumes that the migration probabilities are independent of age, gender and class. UCCA statistics show that the gender differences in migration are negligible (Stillwell and Rees 1985, Tables 10 and 11 and Figures 5 and 6). Secondly, it assumes that entrance probabilities are independent of class, origin region and gender on the basis that tutors for admission are constrained from such discrimination by law. The age dependence, which is carried over from the second version of the model reflects the fact that at later ages parts of the cohort may have already been admitted to HE.

Equation (18) also assumes, as with earlier versions of the transition sub-model, that the system is demand led. If this is not the case (which is the historical experience), that is, that

$$\Sigma_j\ \Sigma_a\ \Sigma_g\ Q^{dj}_{ag}(t) > \Sigma_k\ E^{k}(t) \tag{19}$$

then equation (18) needs to be rewritten as

$$E^{dj}_{ag} = f^{dj}_{ag}(t)\ E^{k}(t) \tag{20}$$

where $f^{dj}_{ag}(t)$ is the fraction of institution k entrants admitted from class d, domicile region j, age a and gender g qualified leavers.

At this stage it is probably best to reformulate the problem as one of forecasting the flow of students from domicile region to institution. The techniques used in the modelling of spatial interactions (Wilson 1974) or migration (Stillwell and Congdon 1991) can be utilised. Two relevant models from the spatial interaction model (SIM) family are the production constrained SIM and the attraction constrained SIM. By production is meant the generation of qualified school leavers in domicile regions; by attraction is meant the admission of new entrants to HE institutions. If the number of qualified leavers exceeds the number of places available then it is appropriate to use an attraction constrained model. If the number of places exceeds the number of qualified leavers, then a production constrained model should be used. Up to this year it is clear that an attraction constrained model was needed but if the following trends were to be confirmed in the early 1990s then a production constrained model could become appropriate. The trends are:

(1) decline in the number of eighteen year olds (very certain);

(2) the completion of the rise in female participation in HE (highly likely);

(3) much lower growth in the size of classes I and II from the late 1970s (speculative);

(4) recovery from 1992 onwards in the job prospects of young labour force entrants (speculative); and

(5) substantial growth in institutional capacities as HE institutions are allowed more and more freedom to make their own decisions about the number of places to offer (speculative).

Before specifying the two SIMs let us try to simplify the variables involved. While it is necessary to use age, gender and social class disaggregations in the sub-models for qualified leavers, these characteristics should play no part in the admission process. It is necessary to retain domicile region because this affects the degree of competition faced by either institutions (in the production constrained SIM) or students (in the attraction constrained SIM). Therefore we can sum the number of qualified leavers over age, gender and class before entering them into the SIMs:

$$Q^j(t) = \Sigma_a \Sigma_g \Sigma_d Q^{dj}_{ag}(t) \qquad (21).$$

An attraction constrained SIM of student flows. This sub-model is appropriate when qualified leavers exceed the supply of places

$$\Sigma_j Q^j(t) > \Sigma_k E^k(t) \qquad (22).$$

The flow of students from domicile region j to institution k, $E^{jk}(t)$, is the variable to be predicted, though institutions are normally interested only in the sum over possible origins

$$E^k(t) = \Sigma_j E^{jk}(t) \qquad (23).$$

The flow of students is predicted by the following equation:

$$E^{jk} = B^k(t)\ Q^j(t)\ E^k(t)\ f(c^{jk}) \qquad (24)$$

where

$B^k(t)$ = a balancing factor for institution k that ensures that all places are filled in year t

$Q^j(t)$ = the number of qualified leavers in domicile region j in year t (seeking entry to HE)

$E^k(t)$ = the number of places for initial entrants at HE institution k in year t

c^{jk} = the cost of transfer between domicile region j and institution k

$f(c^{jk})$ = a function of the transfer cost e.g. the negative power function.

The balancing factor term is derived internally to the model through requiring that the flows to an institution exactly match the places available

$$\Sigma_j\ E^{jk}(t) = E^k(t) \qquad (25)$$

Substituting the RH side of equation (24) into the LH side of equation (25) we obtain

$$\Sigma_j\ B^k(t)\ Q^j(t)\ E^k(t)\ f(c^{jk}) = E^k \qquad (26)$$

and this can be rearranged to yield an expression for $B^k(t)$

$$B^k(t) = 1\ /\ \Sigma_j\ Q^j(t)\ f(c^{jk}) \qquad (27)$$

The model can now usefully be reexpressed to show the competitive forces at work

$$E^{jk}(t) = E^k(t)\ \{Q^j(t)\ f(c^{jk})\ /\ \Sigma_j\ Q^j(t)\ f(c^{jk})\} \qquad (28)$$

The term in curly brackets predicts the share of institution k's places that will be filled from domicile region j. It reflects the domicile region's competitive position. This share is determined by the region's share of qualified leavers discounted by the costs of interaction between the domicile region and institution. The interaction costs are related to travel cost between the student's home and HE institution. There are considerable differences between domicile regions in the friction of distance for potential students (see Stillwell and Rees 1985, section 4.3) and additional barriers exist between UK countries because of differences in educational systems (see Stillwell and Rees 1985, section 4.4). Note that under the attraction constrained model not all qualified leavers will enter HE in any one year though, of course, individuals may reapply for entry in later years at older ages. Potential students entering work rather than HE can be catered for by adding employment as one of the competing destinations.

Production constrained SIM of student flows. Here we assume that the total number of qualified leavers is exceeded by the number of places on offer. The model predicting the flow of students from domicile region to HE institution is as follows

$$E^{jk}(t) = A^j(t)\ Q^j(t)\ W^k(t)\ f(c^{jk}) \qquad (29)$$

where the new variables are defined as follows

$A^j(t)$ = a balancing factor for domicile region j that ensures that all qualified leavers are placed in HE institutions in year t

$W^k(t)$ = the attractiveness of institution k in year t.

The balancing factor term is derived internally through requiring the flows from a domicile region exactly match the qualified leavers in that region

$$\Sigma_k E^{jk}(t) = Q^j(t) \qquad (30).$$

Substituting the RH side of equation (29) into the LH side of equation (30) we obtain

$$\Sigma_k A^j(t)\ Q^j(t)\ W^k(t)\ f(c^{jk}) = Q^j(t) \qquad (31)$$

and this can be rearranged to yield an expression for $A^j(t)$

$$A^j(t) = 1 / \Sigma_k W^k(t)\ f(c^{jk}) \qquad (32).$$

The model can again be reorganised to show the competitive forces at work

$$E^{jk}(t) = Q^j(t)\ \{W^k(t)\ f(c^{jk}) / \Sigma_k W^k(t)\ f(c^{jk})\} \qquad (33).$$

The term in curly brackets predicts the competitive power of HE institution k in competing for region j's potential students. This competitive power is determined by the institution's attractiveness (a function of size, reputation, course quality and marketing) discounted by the costs of interaction between the domicile region and the institution. There are clearly great differences between the attractiveness of institutions but these depend on type of courses offered and attainment level of student, topics taken up in the next version of the model (section 3.5).

From this production constrained model, HE institutions will, of course, be interested in the sum of predicted inflows to their institution

$$E^k(t) = \Sigma_j E^{jk}(t) \qquad (34).$$

The alternative of work can be entered into this SIM quite easily by defining an additional institution, employment in domicile region and deriving a suitable attractiveness measure, $W^j(t)$, based on unemployment and vacancy levels.

3.4 *A model of student stocks and flows with disaggregation by region, institution, course and attainment*

For the model to be useful to individual institutions the student groups must be identified in terms of the courses applied to and the grades attained in entry examinations (A, AS or Higher).

Introducing courses and attainments into the model would very substantially increase the level of disaggregation of the population stocks. For example, the University Statistical Record (UFC 1990) publishes details of the number of undergraduates by 16 subject groupings and 112 individual subjects. Student attainment at A and AS levels is now recorded on a 30 point scale (counting grade A at A level as 10 points, grade B as 8 points down to grade E at 2 points, counting grade A at AS levels as 5 points down to grade E as 1 point).

It is therefore essential to drop as many background characteristics of the potential students as possible. Gender and social class, though they are important determinants of educational attainment and HE application, are not considerations at admission and so can be dropped. The numbers of potential students can be summed over age which again is not directly relevant at entry, so that the framework can focus on the key determinants of grade in relation to selected course.

The notation needs to be extended. Let x refer to a course of study at an HE institution and e to exam grade attained (on the 30 point scale used by admission tutors). The stock of qualified leavers is replaced by a sequence of stocks, depicted in Figure 5, that represent the stages potential students travel through before being admitted as initial entrants to HE. These stocks, all referring to year t, are as follows

(1) $QC^{jk}_{x}(t)$ = candidates, domiciled in region j, for course x in HE institution k

(2) $QO^{jk}_{x}(t)$ = candidates, domiciled in region j, for course x in HE institution k who have received an offer

(3) $QA^{jk}_{x}(t)$ = candidates, domiciled in region j, for course x in HE institution k who have accepted an offer

(4) $QA^{jk}_{ex}(t)$ = candidates, domiciled in region j, for course x in HE institution k who have accepted an offer and have obtained exam grade e

(5) $E^{k}_{x}(t)$ = initial entrants to course x in HE institution k.

These stocks must be predicted using a variety of techniques. We can use a production constrained SIM to model the destination selection process converting qualified school leavers into candidates for admission (in UCCA, PCAS or direct procedures):

$$Q^{jk}_{x}(t) = A^{i}_{x} \;\; Q^{j}_{x}(t) \; W^{k}_{x}(t) \;\; f(c^{jk}) \qquad (35)$$

where

$A^{j}_{x}(t)$ = the balancing factor for region j and course x

$Q^{j}_{x}(t)$ = the number of qualified leavers in domicile region j applying for course x in year t (up to five times the number of qualified leavers)

AS or Higher examinations, attain particular grade levels and if these equal or exceed the offer, are automatically admitted to their selected course:

$$E_x^k(t) = \Sigma_j \Sigma_{e>=emin(k,x)} gp_e^j QA^{jk}_x(t) \qquad (40)$$

where gp_e^j is the probability that accepted candidates from domicile region j achieve grade level e. These probabilities are assumed to vary by domicile region, though this would need to be confirmed.

However, this is not the end of the story. In the past, if $E_x^k(t)$ exceeded the quota of places planned by the HE institution, admission tutors were given a dressing down by their Registrar. In the last couple of years, the Registrar may have instead pinned a medal on the tutor's chest.

On the other hand if $E_x^k(t)$ falls short of the quota, the admission tutor quickly lowers the minimum grade level and accepts further candidates. If no acceptable candidates remain on the books, candidates are sought from cognate courses within the institution or the tutor requests candidates from the national pool for course x (such as that operated by UCCA, for example). Failure after all these measures to fill course quotas leads to serious reviews of admission practice and course attractiveness.

At the end of the admission process, when stocks and flows of initial entrants are disaggregated by course and institution, these can exist both empty places on courses and qualified candidates for courses who have failed to gain entry though it is rare that the courses coincide.

3.5 *Further improvements needed*

What the most detailed model fails to take into account are the costs to institutions of providing places, the revenue derived by institutions as a result of filling places, the costs to individual students of accepting places and the benefits perceived by students of taking up a place in HE. Adding such variables will, however, have to await reactions to the suggestions made to date.

$W_x^k(t)$ = the attractiveness of course x at institution k in year t

$f(c^{jk})$ = a function of the impedance costs of travel between region j and institution k (e.g. a negative power function of a weighted function of student rail and coach fares and petrol costs).

Impedance costs are assumed to be independent of course selected in this formulation but this may need modification for part time courses with their heavy commuting costs. The balancing factor, $A_x^j(t)$, is derived in the usual way by constraining predicted flows to the numbers of qualified leavers

$$\Sigma_k A_x^j Q_x^j(t) W_x^k(t) f(c^{jk}) = Q_x^j(t) \tag{36}$$

so that

$$A_x^j = 1 / \Sigma_k W_x^k(t) f(c^{jk}) \tag{37}$$

The attractiveness of courses could be measured by the number of places on offer (at the simplest level) modified by a quality indicator (measured perhaps by grade score demanded). The number of qualified leavers seeking to enter particular courses through studying trends in subject choice in previous years and at A, AS and Higher levels. It is at this first stage in the course and grade disaggregated model that spatial interaction factors play a part.

The next step in the admission process is for candidates to be made offers. Offers are made on the basis of the reading of applicants' records by admissions tutors supplemented by interview evidence for a proportion. In effect, the admission tutor makes a prediction of the candidate's future grade score and if this equals or exceeds the minimum level set for entry to the course, an offer is made. So candidates become candidates with offers at institution k through a process such as

$$QO_x^{jk}(t) = \Sigma_{e>=emin(k,x)}\, gp_{ex}(est)\, QC_x^{jk}(t) \tag{38}$$

where $gp_{ex}(est)$ is the proportion of course x candidates estimated by the admissions tutor to be capable of achieving grade level e. Only those with estimated grade levels above the minimum, emin(k,x) for course x at institution k receive offers. These proportions are assumed independent of domicile region j (or of demographic and socioeconomic attributes).

Candidates receiving offers then have to choose which to hold. This step can be represented thus:

$$QA_x^{jk}(t) = ap_x^k\, QO_x^{jk}(t) \tag{39}$$

where we have assumed ap_x^k, the probability of acceptance, is dependent on institution and course only, as candidates have made their locational choice earlier.

Candidates with offers which they have accepted then sit their A,

4. DATA REQUIREMENTS, FEASIBILITY AND POTENTIAL CLIENTS

The models described contain a very large number of detailed variables and a large number of assumptions (of dependence or independence of events on prior conditions) requiring testing. It would therefore need considerable resources to implement. But we must ask whether the data are, in principle, available, and, if so, under what conditions.

I believe that most of the data required by the model are held in either central databases (UCCA; PCAS; the USR; PCFS records) or in databases in individual institutions. However, not a lot of data are published for institutions. The UCCA statistics on student migration refer only to clusters of universities, for example, though detailed UCCA data for institutions are, of course, made available to the institutions themselves. For such a project to be feasible permission from all participating HE institutions would be required. Such permissions could only really be obtained through endorsement or promotion of the project by the Committee of Vice Chancellors and Principals and by the Committee of Director of Polytechnics and Colleges.

It would not be feasible for a single institution to procure such a model because the spatial interactions involved mean that the model must include the competition of all other institutions for students. The model would therefore have to be built for use by all or any HE institution or the Department of Education and Science in the same way as the Treasury Economic Model is provided in independent form to subscribers.

The paper began by showing that previous forecasting methods failed to capture the essentials of the system being studied. It was then demonstrated that a more disaggregated approach recognising the influence of supply considerations as well as demand factors was essential. This led to the specification of a model, the data requirements of which were formidable and meant that the model could not be implemented by an individual researcher. Further progress will depend on reactions to the suggestions presented in the paper.

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Abbreviations:
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OPCS= Office of Population Censuses and Surveys
UCCA= Universities Central Council on Admissions
UFC = Universities Funding Council

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