THE IIASA HEALTH CARE ALLOCATION MODEL DRAM: CALIBRATION USING DATA FROM POLAND

M. Bojańczyk

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

FOREWORD

The principal aim of health care research at IIASA has been to develop a family of submodels of national health care systems for use by health service planners. The modeling work is proceeding along the lines proposed in the Institute's current Research Plan. It involves the construction of linked submodels dealing with population, disease prevalence, resource need, resource allocation, and resource supply.

This paper analyzes in-patient hospital care in Poland, using DRAM (Disaggregated Resource Allocation Model). For the study, parameters for eight treatment categories, one mode of care, and three health care resources were identified and empirical results were obtained using 1969 and 1970 data. Predictions of resource allocations for general medicine, general surgery, and obstetrics and gynaecology have also been presented.

Related publications in the Health Care Systems Task are listed at the end of this report.

Andrei Rogers
Chairman
Human Settlements
and Services Area

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ABSTRACT

This paper presents a further application of DRAM, which was developed at IIASA to help health care planners in analyzing and evaluating resource allocation decisions.

This time an effort has been made to calibrate DRAM for in-patient hospital care in Poland. The parameterization procedures have been performed for eight patient categories (child surgery, general medicine, general surgery, obstetrics and gynaecology, ophthalmology, otorhinolaryngology, traumatic and orthopaedic surgery, and paediatrics) and three resource types (hospital beds, hospital doctors, and hospital nurses). The data set consists of 22 administrative regions in 1969.

The ability with which the submodels were able to reproduce the actual allocations varied from one treatment category to another. (Six submodels were used: 3 one-resource, 2 two-resource, and 1 three-resource submodels.) Thus following the critical analysis in section 4.11, the three patient categories (general medicine, general surgery, and obstetrics and gynaecology) that appeared to reproduce the allocation patterns most successfully were chosen.

The reevaluated DRAM for reduced number of categories and for two resources -- hospital beds and hospital doctors -- was then used to predict resource allocations in some regions.

CONTENTS

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1. INTRODUCTION

DRAM (Disaggregated Resource Allocation Model) has been developed by the Health Care Systems Task at IIASA (Gibbs 1978; Hughes 1978a,b,c; Aspden 1980) to help planners in allocating resources for health care systems (HCS). With this model one can analyze the consequences of a certain mix of resource allocation for the provision of health care services. The model is currently being tested by groups in several countries, and some results from this work are now available for comparison. In general, these results indicate the broad applicability of the model to different sectors of the HCS (acute care or care for the chronically ill and elderly), and to countries (such as Canada, Czechoslovakia, and the UK) with substantially different philosophies of health care provision.

Based on the procedures set out in Aspden and Rusnak (1980) and Aspden (1980), this paper begins with a brief description of DRAM and is followed by a section presenting basic information on in-patient hospital care in Poland, the choice of treatment categories, and definitions of the DRAM variables used in this Polish case study. Information on the DRAM parameter estimation process and how it is applied to several proposed models is then given. The paper ends by showing how DRAM could be used to investigate some chosen planning issues for Polish in-patient hospital care.

The growing interest of the Ministry of Health Care and Welfare in the application of modern systems analysis to health care system management has encouraged the author to initiate these studies, and it is hoped that the research will continue.

2. A HEALTH CARE RESOURCE ALLOCATION MODEL: DRAM

Health services cannot be administered in a rigid, centralized way. In every country, it is the doctors who ultimately determine the use of health care resources (e.g., hospital beds, doctors, nurses) available to them. The specific question underlying DRAM is: If the decision maker provides a certain mix of resources, how will the health care system allocate them?

There are two assumptions about the behavior of the health care system in DRAM. First it is assumed that there is never sufficient supply of resources to meet all the potential (or ideal) demands for them (Feldstein 1967; Rousseau 1977).

For changing resource availabilities, the model simulates the balance chosen by the many agents in the system (doctors, nurses) in terms of treatment categories, alternative combinations (modes) of care within the same treatment category, and quantity and quality of care. The second behavioral assumption in DRAM is that the health care system behaves as if it were maximizing a certain preference (or utility) function, which increases with the number of patients treated and the resources received by each. The parameters of this utility function can be inferred from past allocations thus enabling health care planners to investigate the consequences of different allocations of resources.

There are J treatment categories ($j \in \bar{J} = \{1,2,...,J\}$), K treatment modes ($k \in \bar{K} = \{1,2,...,K\}$) and L resource types ($l \in \bar{L} = \{1,2,...,L\}$).* The definitions of the variables used in DRAM are as follows:

x_{jk} = numbers of individuals in the j-th patient category who receive resources in the k-th mode of care (per head of population per year)

X_{jk} = the ideal number of individuals in the j-th patient category who should receive resources in the k-th mode of care (per head of population per year) assuming no constraint on resource availability

y_{jkl} = supply of resource type l received by each individual in the j-th patient category in the k-th mode of care

Y_{jkl} = the ideal levels of supply of resource type l for each individual in the j-th patient category in the k-th mode of care assuming no constraint on resource availability**

R_l = the availability of resource type l (per head of population per year)

C_l = marginal cost of resource type l when all demands are satisfied

The utility function (Z) used in DRAM depicts the many agents who control the allocation of health care resources as trying to attain ideal levels of service (X) and supply (Y). However, their desire to increase the actual levels of service (x) and supply (y) decreases as these levels get higher. The costs of different resources are introduced in such a way that the marginal increases in Z, when ideal levels

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*In the paper J=8, K=1, L=1,2,or 3 depending on the DRAM type, i.e., for a one-resource model, L=1, for a two-resource model, L=2, and finally for a three-resource model, L=3.

**In the sequel, x,y are used to denote $\{x_{jk}\},\{y_{jkl}\}$ respectively, with a like notation for similarly subscripted variables.

are achieved ($x=X$, $y=Y$), equal the marginal resource costs.

Beyond these levels, extra resources are only useful as assets and not for treating patients. The utility function (Z) is a weighted sum of monotonically increasing, concave power functions. These functions assume consistency in the aggregate behavior of the health care system. These considerations can be expressed in the following mathematical form:

$$Z(x,y) = \sum_j \sum_k g_{jk}(x_{jk}) + \sum_j \sum_k \sum_l x_{jk}\, h_{jkl}(y_{jkl}) \qquad (1)$$

subject to

$$\sum_j \sum_k x_{jk}\, y_{jkl} = R_l \qquad \forall_l$$

where

1) $$g_{jk}(x) = \frac{\sum_l C_l X_{jk} Y_{jkl}}{\alpha_j} \left[1 - \left(\frac{x}{X_{jk}}\right)^{-\alpha_j}\right]$$

2) $$h_{jkl}(y) = \frac{C_l\, Y_{jkl}}{\beta_{jkl}} \left[1 - \left(\frac{y}{Y_{jkl}}\right)^{-\beta_{jkl}}\right]$$

3) α_j (> 0) is a parameter measuring the relative importance of treating the ideal number of individuals X_{jk} (higher values indicate greater importance)

4) β_{jkl} (> 0) is a parameter measuring the relative importance of achieving the ideal level Y_{jkl} (again, higher values indicate greater importance)

Hughes (1978c) has shown that the solution of the optimization problem formulated in equation (1) is as follows

$$\hat{y}_{jkl} = Y_{jkl}(\lambda_l)^{\frac{-1}{\beta_{jkl}+1}} \qquad (2)$$

$$\hat{x}_{jk} = X_{jk}(\mu_{jk})^{\frac{-1}{\alpha_j+1}} \qquad (3)$$

where μ_{jk} is a weighted sum

$$\mu_{jk} = \frac{\sum_l C_l \, Y_{jkl} \, \nu_{jkl}}{\sum_l C_l \, Y_{jkl}}$$

of the terms

$$\nu_{jkl} = \left[\left(\beta_{jkl} + 1\right) \lambda_l^{\frac{\beta_{jkl}}{\beta_{jkl}+1}} - 1\right] \beta_{jkl}$$

and where λ_l are the solutions of the following set of equations

$$0 = -R_l + \sum_j \sum_k X_{jk} \, Y_{jkl}(\lambda_l)^{\frac{-1}{\beta_{jkl}+1}} (\mu_{jk})^{\frac{-1}{\alpha_j+1}} \qquad \forall_l$$

The algorithm for determining the solutions (equations 2 and 3) has been developed by Hughes and Wierzbicki (1980). This algorithm has been programed, and requires no specialized software. Experience has shown that the computer program is easily transferred from computer to computer.

3. AN APPLICATION OF DRAM TO IN-PATIENT HOSPITAL CARE IN POLAND

3.1. Introduction

In this section some basic figures and management characteristics of the Polish health care system's in-patient hospital care activity are presented. The aim is to parameterize DRAM for in-patient hospital care data and to use the estimated parameter set to investigate the consequences of the changing mix of health care resource allocation on the health services supply level. (Out-patient care will be briefly discussed in section 4.3.)

Data for 1969* is used for the DRAM parameterization and the results are tested with 1970 data. (These years were chosen because of the consistency of the data.) Eight treatment categories are chosen and some measures for the different resource types are proposed.

3.2. In-Patient Hospital Care in Poland

In 1969 Poland was divided for administrative purposes into 22 regions. There were 19 so-called voivodships and five large-city districts, among them Warsaw -- the capital of Poland. Medical in-patient and out-patient care units were mostly managed by local regional decision centers; however total expenditures for the health care system were defined

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*In 1973 the reorganization of the Polish health care system resulted in the integration of in-patient and out-patient care services. After this time, data sets for in-patient and out-patient care were difficult to obtain because of changes in the administrative structure of regions in Poland (49 regions instead of the former 17) in 1975. Therefore the model calibration has been performed for the time period when data were to be collected in a consistent way.

every year by the parliamentary budget and then allocated among regions in a fairly rigid way by the Ministry of Health Care and Welfare. The Ministry, according to the existing regulations, is supposed to control all the aspects of health care services delivery, but a continuous process of decision decentralization, e.g., passing some controls to local governing and planning bodies, is under way.

Each region serves a population of about 1,500,000 on the average and covers about 14,200 square kilometers (or 18,300 sq. kilometers if the town districts are excluded). The five large-city districts have some slightly unusual features. Usually they are the seats of the biggest teaching hospitals. Also they provide standard services as well as some rare and sophisticated ones. These are usually expensive, however, and require special facilities and a highly qualified medical staff.*

3.3. The Choice of Treatment Categories

Following Aspden and Rusnak (1980) and Aspden (1980), the "treatment specialities" approach has been adopted, because it relates well to the available data for Polish in-patient hospital care, and it allows for comparisons with previous research. Moreover,in Poland as in Czechoslovakia and the UK, most measures of hospital resources are for treatment specialities. Because a consistent set of data for provided services and corresponding resources is a prerequisite of the DRAM parameterization process, the treatment specialty approach is appropriate for Polish in-patient hospital care description.

*Future research should consider the "catchment population versus resident population" problem to adjust better supply and service variables for this special subset of regions and to avoid bias in estimation (Mayhew 1981).

For this analysis, only the general hospitals of the Ministry of Health Care and Welfare, which are financed by regional budgets, are considered. In Poland there exist independent health care systems of the army and the Ministry for Transportation as well, but they are financed independently by the corresponding ministries and provide the services only for minor parts of the population. The analysis also does not include the majority of hospitals providing services in rare specialities, which are normally financed from the central budget. Basically, at the time of analysis there were 33 treatment specialities (hospitals wards) defined in the statistics of Polish hospitals. Of course, not all of them existed in each hospital or even in every region. The range varied from about 30 treatment specialities in Warsaw to some 15 in rural regions.

One should recall here two important requirements of the DRAM parameterization process:

(a) The parameter estimation process will be carried out on cross-sectional regional data, which implies the adoption of the same utility function Z(x,y) (equation 1) for different points in time and space.

(b) In the DRAM formulation the resource levels are treated as continuous variables.

From (a) it follows that for each chosen treatment category the area has to be self sufficient, thus excluding the narrower regional specialities from the analysis. Assumption (b) implies that the basic unit of each resource should be small compared with the total amount of resources allocated to a treatment category and that the variables used in DRAM should have reasonably comparable magnitudes. Hence treatment categories should not be too small.

Having considered the above assumptions and indications, the following set of treatment categories was chosen:

Child surgery
General medicine
General surgery
Obstetrics and Gynaecology
Ophthalmology
Otorhinolaryngology
Traumatic and Orthopaedic Surgery
Paediatrics

This is almost the same set of treatment categories that was selected by Aspden and Rusnak (1980) for Czechoslovakia and Aspden (1980) for the South West Health Region in the UK -- the only change being the introduction of child surgery. The above eight treatment categories accounted for more than 70 percent of the total number of patients in hospitals in 1969 [see Rocznik Statystyczny Ochrony Zdrowia 1974 (1975)].

Data on the numbers of patients and on the supply levels of resources for each treatment category were taken from statistical yearbooks of the Main Statistical Office, Roczniki Statystyczne 1969, 1970 (1970, 1971); Yearbooks of the Ministry of Health Care and Welfare (Biuletyny Statystyczne Ochrony Zdrowia 1969, 1970 (1970, 1971); and some were received from the Information and Medical Statistics Unit of the Ministry of Health Care and Welfare, Warsaw, Poland.

3.4. The Resource Measures for Hospital Beds, Hospital Doctors, and Hospital Nurses

Aspden and Rusnak (1980) and Aspden (1980) have chosen two fundamental types of resources used in in-patient hospital care: hospital beds and hospital doctors. They appear to be probably the most important health care resources for this type of care. But the question arises whether one should not analyze the impact of other resources, such as hospital nurses, operating theaters, and technical supporting personnel on the performance of hospitals. The role of the nurses was felt to be important enough to be included in this analysis. Moreover, it is worth mentioning that, despite the many common features and similarities, which can be analyzed with the help of DRAM, in health care management structures and planning processes, separate, thorough studies seem to be unavoidable.

DRAM provides a broad framework that allows for a wide range of subsystems to be analyzed: for example, health care delivery (single diseases, Gibbs 1978), treatment categories (Aspden 1970), in-patient care (Hughes 1978a), and out-patient care (Hughes and Wierzbicki 1980). Therefore certain step by step techniques must be introduced before an analysis can begin. Health care managers and medical doctors must be consulted, and a preliminary analysis (e.g., regression analysis -- see section 4.2) of input data must be complete, defining the modes of care, resource types, and treatment categories that reflect the peculiarities of the given health care system under consideration.

A first step is to decide how the resource types chosen for the DRAM parameterization, i.e., hospital beds, hospital doctors, and hospital nurses, are to be measured. There are two possible resource measures for hospital beds (R_l; l=1, beds):

(a) available beds (or beds-days, one bed-year = 365 bed-days) per 1000 population in a particular area

(b) "used" bed-days per 1000 population in this area (The ratio of the total number of days that patients spend in hospital wards to the resident population.)

The adoption of any of these measures determines the supply variable (y_{jkl}; l=1, beds):

(a) available bed-days per patient

and

(b) average length of stay

It has been argued in Aspden and Rusnak (1980) and repeated in Aspden (1980) that the first resource measure has the advantage over the second, more usual measure of occupied bed-days per patient by eliminating the separate estimation of occupancy rates (or equivalently, bed turnover intervals). In Appendix A some regression analysis results supporting this hypothesis have been briefly presented.

There are several possible measures of hospital doctors that have been presented, e.g., in Aspden (1980). In this study "the number of hospital doctors of all grades belonging to the specialities which treat a particular treatment category"* (Aspden 1980, p.10) was adopted as the measure because it was the only one for which data were available. (The unit of measurement was taken to be doctor days per 1000 population, one doctor year = 300 doctor days.) This was also the measure used in Aspden and Rusnak (1980).

The same approach was applied to hospital nurses, i.e., the number of nurses (including assistant nurses) affiliated with the hospital wards who were working with particular treatment categories, was taken as the measure of hospital nurses (nurse days per 1000 population, one nurse year = 300 nurse days).

Data on the levels for bed, doctor, and nurse supply for the eight patient categories under consideration for each region were received from the Information and Medical Statistics Unit of the Ministry of Health Care and Welfare. The totals for eight treatment categories, resident population, and area served for each region are given in Table 1.

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*For example, if the treatment category is child surgery, the measure would be the number of doctors within the child surgery specialty.

Table 1. Resource availabilities for the eight treatment categories — Poland 1969.

Region	Available bed-days per 1000 population	Available doctor-days per 1000 population	Available nurse days per 1000 population	Resident population in thousands	Area served in km^2
Warszawa [a]	2092	241	433	1288	450
Kraków [a]	2136	268	448	577	230
Łódź [a]	1763	205	330	753	210
Poznań [a]	1739	217	368	462	220
Wrocław [a]	1795	219	346	517	230
Białostockie	1247	108	243	1191	23200
Bygdoskie	1118	80	187	1915	20900
Gdańskie	1319	119	243	1461	11000
Katowickie	1800	143	312	3646	9500
Kieleckie	928	75	175	1910	19500
Koszalińskie	1547	93	244	790	18100
Krakowskie	916	61	167	2200	15400
Lubelskie	1094	85	191	1956	24900
Łódzkie	1116	76	192	1690	17100
Olsztyńskie	1428	115	257	985	21100
Opolskie	1749	143	261	1016	9600
Poznańskie	1114	93	187	2188	26800
Rzeszowskie	1088	71	207	1763	18600
Szczecińskie	1298	124	262	896	12800
Warszawskie	907	67	149	2560	29400
Wrocławskie	1829	122	275	1994	18900
Zielonogórskie	1525	169	225	883	14600

[a] Large towns constituting independent regions for administrative purposes.
Set R_A = regions 1 ÷ 11, set R_B = regions 12 ÷ 22.

4. PARAMETER ESTIMATION FOR DRAM: IN-PATIENT DATA FOR POLAND

4.1. Introduction

The parameterization of DRAM will be performed for several models beginning with simple one-resource models and ending with a three-resource model for in-patient hospital care. The family of models considered is presented in Table 2 and contains two models, AD and ADN, analyzed for the out-patient care mode of treatment (ambulatory care). In section 4.2 the preliminary regression analysis results for in-patient hospital care data will be presented, followed by some remarks on the parameter estimation for DRAM of Polish out-patient care data in section 4.3. Sections 4.4 to 4.10 present the DRAM parameterization process for models 1 to 10, respectively.

Estimates for the following three groups of parameters are required for the DRAM parameterization process:

(1) The ideal levels X,Y at which a patient would be admitted and receive resources, if there were no constraints on resource availability

(2) The power parameters α, β, which reflect the relative importance of achieving the ideal levels X and Y (for instance, if an α is relatively high then it is relatively more important to treat the corresponding X)

(3) The relative costs, C, of the different resources, in this case hospital beds, hospital doctors, and hospital nurses

In what follows the parameter set $\{X,Y,\alpha,\beta\}$ will be estimated from actual allocations of resources. The cost parameters, C, will be determined exogenously (see section 4.7). In estimating the parameter set $\{X,Y,\alpha,\beta\}$ the approach of Hughes (1978c) will be followed. This is described briefly in Appendix B. The approach assumes that each region for each year provides an independent data point; i.e., the same utility function Z(x,y) holds across time and space. Some justification for this has been given in Aspden (1980).

Table 2. Presentation of DRAM models under consideration.

Model	Treatment modes	Resources types	Treatment categories	Presented in:
B	In-patient hospital care	Beds	set TA	section 4.4
D	In-patient hospital care	Doctors	set TA	section 4.5
N	In-patient hospital care	Nurses	set TA	section 4.6
BD	In-patient hospital care	Beds Doctors	set TA	section 4.8
BDN	In-patient hospital care	Beds Doctors Nurses	set TA	section 4.10
AD	out-patient ambulatory care	Doctors	set TB	section 4.3
ADN	out-patient ambulatory care	Doctors Nurses	set TB	section 4.3

Set TA:
- Child Surgery
- General Medicine
- General Surgery
- Obstetrics and Gynaecology
- Ophthalmology
- Otorhinolaryngology
- Traumatic and Orthopaedic Surgery
- Paediatrics

Set TB:
- General Medicine
- Paediatrics
- Obstetrics and Gynaecology
- Ophthalmology
- Otorhinolaryngology
- General Surgery
- Dermatology
- Phtysiatry

but one has to be careful with this assumption. When studying each particular case it would be advisable to decide whether not to split the heterogeneous data set into some fairly precisely defined (homogeneous) subsets.

In the present study the parameter estimation process was carried out in six stages. Models were calibrated for bed supply, doctor supply, and nurse supply separately (Models B, D, N). Then two-resource models, for beds and doctors (Model BD) and for doctors and nurses (Model DN) were calibrated. In the end, the most complicated three-resource model BDN (beds, doctors, and nurses) was presented.

Before moving on to the parameter estimation process, it is necessary to extend the notation of section 2. The model parameters are estimated from 22 data points; they are split into two data point sets: R_A — regions 1 ÷ 11 and R_B — regions 12 ÷ 22 (see Table 1). The actual data for data point $i (i \varepsilon [1,22])$ will be represented as $x_j(i)$, $y_{jl}(i)$ with the mode subscript k removed since there is only one mode. (The short analysis of ambulatory care treatment mode was carried out in section 4.3.) Thus the amount of resource type l used at data point i is

$$\sum_j x_j(i) y_{jl}(i) = R_l(i)$$

Further, let $\hat{x}_j(i)$ and $\hat{y}_{jl}$ be the predicted levels, using DRAM with a particular parameter set (X, Y, α, β) and resource availabilities at data point i. The following measures of goodness-of-fit can then be defined

$$SS\hat{x}_j = \sum_j \left(\frac{x_j(i) - \hat{x}_j(i)}{w_j} \right)^2$$

$$SS\hat{y}_{jl} = \sum_i \left(\frac{y_{jl}(i) - \hat{y}_{jl}(i)}{v_j} \right)^2$$

where w_j is the weighted average of $x_j(i)$, and v_{jl} is a weighted average of $y_{jl}(i)$. As an indication of the goodness-of-fit of DRAM, it is useful to make the following comparisons

$$S\hat{S}x_j \text{ with } SS\bar{x}_j = \sum_i \left(\frac{x_j(i) - w_j}{w_j} \right)^2 \qquad \forall_j$$

$$S\hat{S}y_{jl} \text{ with } SS\bar{y}_{jl} = \sum_i \left(\frac{y_{jl}(i) - v_{jl}}{v_{jl}} \right)^2 \qquad \forall_j, \forall_l$$

To facilitate further comparative analysis the following measures for individual treatment categories have been introduced and calculated:

-- for cover (the number of persons per 1000 population who receive care) $x_j(i)$

$$gfx_j = \frac{S\hat{S}x_j}{SS\bar{x}_j} \qquad \forall_{j \in \bar{J}}$$

-- for supply levels $y_{yl}(i)$

$$gfy_{jl} = \frac{S\hat{S}y_{jl}}{SS\bar{y}_{jl}} \qquad \forall_{j \in \bar{J}} \forall_l$$

-- for the chosen model

$$tgf_j = \frac{S\hat{S}x_j + \sum_l S\hat{S}y_{jl}}{SS\bar{x}_j + {}_l\, SS\bar{x}_{jl}} \qquad \forall_{j \in \bar{J}}$$

For the chosen model and certain group $\bar{J}$ of treatment categories ($\bar{J}' \subset \bar{J}$) the following ratio will be calculated

$$tgf(\bar{J}') = \frac{\sum_{j \in \bar{J}'} \left\{ SS\hat{x}_j + \sum_l SS\hat{y}_{jl} \right\}}{\sum_{j \in \bar{J}'} \left\{ SS\bar{x}_j + \sum_l SS\bar{y}_{jl} \right\}}$$

4.2. Preliminary Regression Analysis of the Data for In-Patient Hospital Care

Before carrying out the estimation procedure presented in the previous section, it is useful to examine the results of simple linear regression analyses performed for each treatment category and resource type independently. Of course one should first examine the cover, the number of hospitalized people and the bed supply for each treatment category against the total hospital bed supply for all eight categories as well as for hospital doctors and nurses.

The one-resource version of DRAM assumes that for each patient category, the cover and supply levels per patient should monotonically increase as total resource supply increases. Therefore the following linear regression models have been analyzed:

$$\underline{K}_l = \underline{A}_l + \underline{B}_l \times \underline{M}_l + \underline{E}_l \qquad \forall_l$$

where

$$\underline{K}_l = \begin{bmatrix} x_1 & y_{11} \\ \cdot & \\ \cdot & \\ \cdot & \\ x_J & y_{Jl} \end{bmatrix} \qquad \underline{E}_l = \begin{bmatrix} E_{11} & E_{21} \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ E_{J1} & E_{Jl} \end{bmatrix}$$

$$A_1 = \begin{bmatrix} A_{11} & A_{21} \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ A_{J1} & A_{J1} \end{bmatrix} \qquad B_1 = \begin{bmatrix} B_{11} & B_{21} \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ A_{J1} & B_{J1} \end{bmatrix}$$

$$M_1 = \begin{bmatrix} R_1 \\ R_1 \end{bmatrix}$$

$\underline{K}_1$ is the matrix of cover and type 1 resource supply

$\underline{A}_1$ and $\underline{B}_1$ are the matrices of constants and slope coefficients of regression, respectively.

$\underline{M}_1$ is a matrix of total availability of type 1 resource

$\underline{E}_1$ represents uncorrelated errors with normal distribution

The regressions have been carried out for 22 data points, hence the variables x_j, y_{j1}, R_1 are vectors with 22 elements.

In Tables 3a - 3c the regression models for all three resource types have been presented as well as the regression coefficients with corresponding standard errors and r^2 coefficients. The cover and supply resources for treatment category j are as follows:

x_j = cover: numbers of individuals per 1000 population receiving some health care service

y_{j1} = bed supply: supply of bed-days received by each individual

y_{j2} = doctor supply: supply of doctor-days received by each individual

y_{j3} = nurse supply: supply of nurse-days received by each individual

The total resource availability measures are:

R_1 = total available bed-days per 1000 population for eight treatment categories

R_2 = total available doctor-days per 1000 population for eight treatment categories

Table 3. Regression analysis results.

Table 3a. Resource type-beds.

Treatment category	Cover[a]			Supply		
	constant (standard error)	slope (standard error)	r^2	constant (standard error)	slope (standard error)	r^2
Surgery	-1.612	0.003	0.402	11.634	0.004	0.169
	(1.041)	(0.001)	M[b]	(2.940)	(0.002)	M
General medicine	7.130	0.009	0.509	11.365	0.005	0.553
	(2.901)	(0.002)	G	(1.559)	(0.001)	G
General surgery	14.990	0.004	0.188	6.923	0.007	0.651
	(2.844)	(0.002)	M	(1.606)	(0.001)	G
Obstetrics and gynaecology	11.815	0.015	0.426	7.298	0.001	0.200
	(5.654)	(0.004)	M	(0.789)	(0.001)	M
Ophthalmology	-1.118	0.002	0.476	15.989	0.004	0.078
	(0.788)	(0.001)	M	(4.635)	(0.003)	B
Otorhinolaryngology	-1.273	0.004	0.559	13.892	0.001	0.015
	(1.097)	(0.001)	G	(2.922)	(0.002)	B
Traumatic and ortho-paedic surgery	-1.856	0.003	0.429	10.730	0.009	0.234
	(1.299)	(0.001)	M	(5.224)	(0.004)	M
Paediatrics	9.049	0.001	0.007	11.624	0.006	0.439
	(2.362)	(0.002)	B	(2.403)	(0.002)	M

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] Categorization of regression model: $B = r^2 \leq 0.100$

$M = 0.100 < r^2 < 0.500$

$G = 0.500 \leq r^2$

Table 3b. Resource type — hospital doctors.

Treatment category	Cover			Supply		
	Constant (Standard error)	Slope (Standard error)	r^2	Constant (Standard error)	Slope (Standard error)	r^2
Child surgery	-0.369	0.019	0.551	0.885	0.007	0.329
	(0.545)	(0.004)	G	(0.343)	(0.002)	M
General medicine	15.863	0.031	0.158	0.353	0.010	0.867
	(2.293)	(0.016)	M	(0.126)	(0.001)	G
General surgery	19.537	0.010	0.031	0.028	0.011	0.889
	(1.876)	(0.013)	B	(0.129)	(0.001)	G
Obstetrics and Gynaecology	20.254	0.096	0.477	0.444	0.002	0.637
	(3.260)	(0.023)	M	(0.050)	(0.000)	G
Ophthalmology	0.026	0.016	0.623	1.103	0.010	0.505
	(0.404)	(0.003)	G	(0.317)	(0.002)	G
Otorhinolaryngology	1.358	0.021	0.450	0.619	0.009	0.389
	(0.740)	(0.005)	M	(0.354)	(0.002)	M
Traumatic and orthopaedic surgery	0.939	0.016	0.242	1.300	0.009	0.030
	(0.904)	(0.006)	M	(1.609)	(0.011)	B
Paediatrics	10.993	-0.008 [a]	0.036	0.083	0.016	0.536
	(1.405)	(0.010)	B	(0.483)	(0.003)	M

[a] A negative value of the slope coefficient is contrary to the basic DRAM assumption that if resources increase more patients will receive care.

Table 3c. Resource type — hospital nurses.

Treatment category	Cover: Constant (Standard error)	Cover: Slope (Standard error)	Cover: r^2		Supply: Constant (Standard error)	Supply: Slope (Standard error)	Supply: r^2	
Child surgery	-1.554	0.014	0.565		1.589	0.010	0.707	
	(0.749)	(0.003)		G	(0.402)	(0.001)		G
General medicine	12.460	0.029	0.250		1.184	0.007	0.703	
	(3.020)	(0.011)		M	(0.295)	(0.001)		G
General surgery	18.117	0.031	0.06[illegible]		0.286	0.010	0.752	
	(2.577)	(0.009)		B	(0.341)	(0.001)		G
Obstetrics and gynaecology	14.932	0.069	0.448		1.480	-0.000	0.030	
	(4.671)	(0.017)		M	(0.165)	(0.001)		B
Ophthalmology	-1.167	0.013	0.711		2.418	0.005	0.145	
	(0.493)	(0.002)		G	(0.738)	(0.003)		M
Otorhinolaryngology	-0.288	0.017	0.540		2.019	0.003	0.102	
	(0.945)	(0.003)		G	(0.560)	(0.002)		M
Traumatic and orthopaedic surgery	-0.816	0.015	0.384		2.302	0.010	0.036	
	(1.136)	(0.004)		M	(3.294)	(0.012)		M
Paediatrics	11.273	-0.005	0.026		1.016	0.016	0.660	
	(1.971)	(0.007)		B	(0.695)	(0.003)		G

R_3 = total available nurse-days per 1000 population for eight treatment categories

In Table 3 certain crude categorizations of regression models are introduced based on regression values:

set B refers to a bad or very bad regression - $r^2 \leq 0.100$
set M refers to a weak regression - $0.100 < r^2 < 0.500$
set G refers to a good regression - $0.500 \leq r^2$

This table will serve as a reference point for DRAM parameterization, especially for one-resource models (B, D, and N), although one should not expect significantly better results of DRAM (i.e., small values for goodness-of-fit) for these treatment categories where there is a bad or no regressional relationship (set B).

4.3. Remarks on the Parameter Estimation for DRAM for Polish Out-Patient Care Data

The following treatment categories (in the ambulatory care treatment mode), for which consistent data were available, have been chosen:

General medicine Paediatrics Obstetrics and gynaecology	Basic care
Ophthalmology Otorhinolaryngology General surgery Dermatology Phtysiatry	Specialized care

The services provided by ambulatory care units have been measured in number of consultations per head of population. Doctors and nurses working in out-patient care units* were

*Only ambulatory care facilities in towns were considered. They provided, however, all the specialized services for the total resident population (including inhabitants of rural areas).

taken as the most important resources -- the measurement units being, respectively, doctor-days and nurse-days. The preliminary regression analysis of the type proposed in section 4.2 indicates that there is really no relationship between total available nurse-days and service or supply levels. The situation for doctor-days is slightly more encouraging but examination of Table 4, where the regression analysis results are presented, leaves no doubts that this model formulation does not fit the DRAM framework.

In particular the regressions of doctor supply on total available doctor-days in each treatment category appear to be of an extremely low explanatory value. On the contrary, regressions for cover, i.e., number of consultations, are very good.

The DRAM parameterization process carried out for the above-mentioned treatment categories and resource types (firstly, a one-resource model for doctors -- Model AD -- and then a two-resource model for doctors and nurses -- Model ADN) supported the hypothesis, resulting from regression analyses, that both models had very poor goodness-of-fit characteristics. Therefore this paper is limited to the in-patient hospital care mode of treatment.

4.4. Parameter Estimation for DRAM with One Resource: Hospital Beds

The parameters of the model were estimated using the procedure described in Appendix B. These estimations are examined in the next new sections, which usually begin with a table of DRAM parameter estimates and are followed by graphs,* giving the cover and supply levels per patient (observed and predicted), plotted against total resource availability per 1000 population for each of the 22 data points. Only four treatment categories are presented on each graph for clarity. The actual data points

*There are no graphs for two- and three-resource models.

Table 4. Regression analysis for out-patient care: resource type — doctors

Treatment category	Cover[a] constant (standard error)	Cover[a] slope (standard error)	r^2	Supply constant (standard error)	Supply slope (standard error)	r^2
General medicine	-0.008	0.008	0.888	43.622	0.034	0.105
	(0.075)	(0.001)		(2.588)	(0.022)	
Paediatrics	0.044	0.005	0.892	42.136	0.051	0.173
	(0.043)	(0.000)		(2.893)	(0.025)	
Obstetrics and gynaecology	0.043	0.001	0.878	49.722	0.049	0.141
	(0.013)	(0.000)		(3.120)	(0.027)	
Ophthalmology	0.007	0.001	0.806	50.652	-0.047[b]	0.092
	(0.015)	(0.000)		(3.820)	(0.033)	
Otorhinolaryngology	0.014	0.001	0.860	49.116	-0.039[b]	0.061
	(0.011)	(0.000)		(4.005)	(0.034)	
General surgery	0.092	0.001	0.499	23.126	0.046	0.202
	(0.034	(0.000)		(2.373)	(0.020)	
Dermatology	0.012	0.001	0.803	53.916	-0.069[b]	0.117
	(0.011)	(0.000)		(4.973)	(0.043)	
Phtysiatry	0.050	0.001	0.379	66.825	0.039	0.012
	(0.017)	(0.000)		(9.153)	(0.079)	

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] A negative value of the slope coefficient is contrary to the basic DRAM assumption that if resources increase more patients will recieve care.

are denoted by numbers; the values obtained from the models (one-resource type models) are denoted by a circle around the treatment category. The key for in-patient hospital care treatment categories remains the same throughout the paper but it will be repeated here for convenience:

1) Child surgery
2) General medicine
3) General surgery
4) Obstetrics and gynaecology
5) Ophthalmology
6) Otorhinolaryngology
7) Traumatic and orthopaedic surgery
8) Paediatrics

The crosses, seen on some of the graphs, denote places where more than one data point from adjacent treatment categories have the same values. The tables giving DRAM parameter estimates contain:

-- The parameters for the cover (X,α) with corresponding measures of goodness-of-fit ($SS\hat{x}_j$, $SS\bar{x}_j$, gfx_j; $\forall_{j\in\bar{J}}$ — see section 4.1)
-- The parameters for the supply levels (Y,β) with corresponding measures of goodness-of-fit ($SS\hat{y}_{jl}$, $SS\bar{y}_{jl}$, gfy_{jl}; $\forall_{j\in\bar{J}}$, $\forall_l$ — see section 4.1) followed by the aggregated measures of goodness-of-fit tgf_j $(\forall_{j\in\bar{J}})$ and terminated by the ranking matrix (goodness-of-fit measures are ordered by increasing values)

In addition the values of $tgf(\bar{J})$ and $tgf(\bar{J}')$* are presented -- according to the definitions of section 4.1. The first parameter estimation deals with hospital beds. Table 5 gives the DRAM estimates for Polish in-patient hospital care using a one-resource model. Figures 1 and 2 illustrate the hospitalization rates and supply levels per patient plotted against the total bed-days available per 1000 population in Poland.

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*Subset $\bar{J}'=\{2,3,4\}$ was chosen because, as seen in section 4.11, these treatment categories were used for prediction purposes.

Table 5. **One-resource (hospital beds) DRAM parameter estimates for Polish in-patient hospital care.**

Treatment category	Cover[a]					Supply levels: beds					tgf_J[b]	Ranking for:		
	X_j	α_J	$SS\hat{x}_J$	$SS\bar{x}_J$	gfx_J	Y_{J1}	β_{J1}	$SS\hat{y}_{J1}$	$SS\bar{y}_{J1}$	gfy_{J1}		r_{gfx_J}	$r_{gfy_{J1}}$	r_{tgf_J}
Child surgery	4.1	3.39	9.519	11.696	0.814	21.0	9.59	0.826	0.966	0.856	0.817	5	4	4
General medicine	32.5	3.51	0.589	1.211	0.487	22.6	12.50	0.248	0.428	0.581	0.511	3	1	2
General surgery	26.5	6.27	0.783	0.638	1.227	19.3	13.94	0.484	0.768	0.630	0.901	7	2	5
Obstetrics and gynaecology	46.0	5.02	0.851	1.441	0.299	10.0	15.32	0.246	0.269	0.913	0.466	1	5	1
Ophthalmology	6.5	1.00	3.892	7.285	0.534	22.5	213.14	1.370	1.371	1.000	0.608	4	6	3
Otorhinolaryngology	14.1	0.29	2.067	4.601	0.449	43.6	1.00	3.700	1.018	3.636	1.026	2	8	6
Traumatic and Orthopaedic surgery	19.1	0.001	8.543	9.111	0.938	58.1	1.00	2.752	1.849	1.489	1.030	6	7	7
Paediatrics	14.1	4.37	1.891	1.606	1.177	22.7	19.28	0.526	0.665	0.791	1.064	8	3	8

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J}) = 0.8518$

$tgf(\bar{J}') = 0.6358$

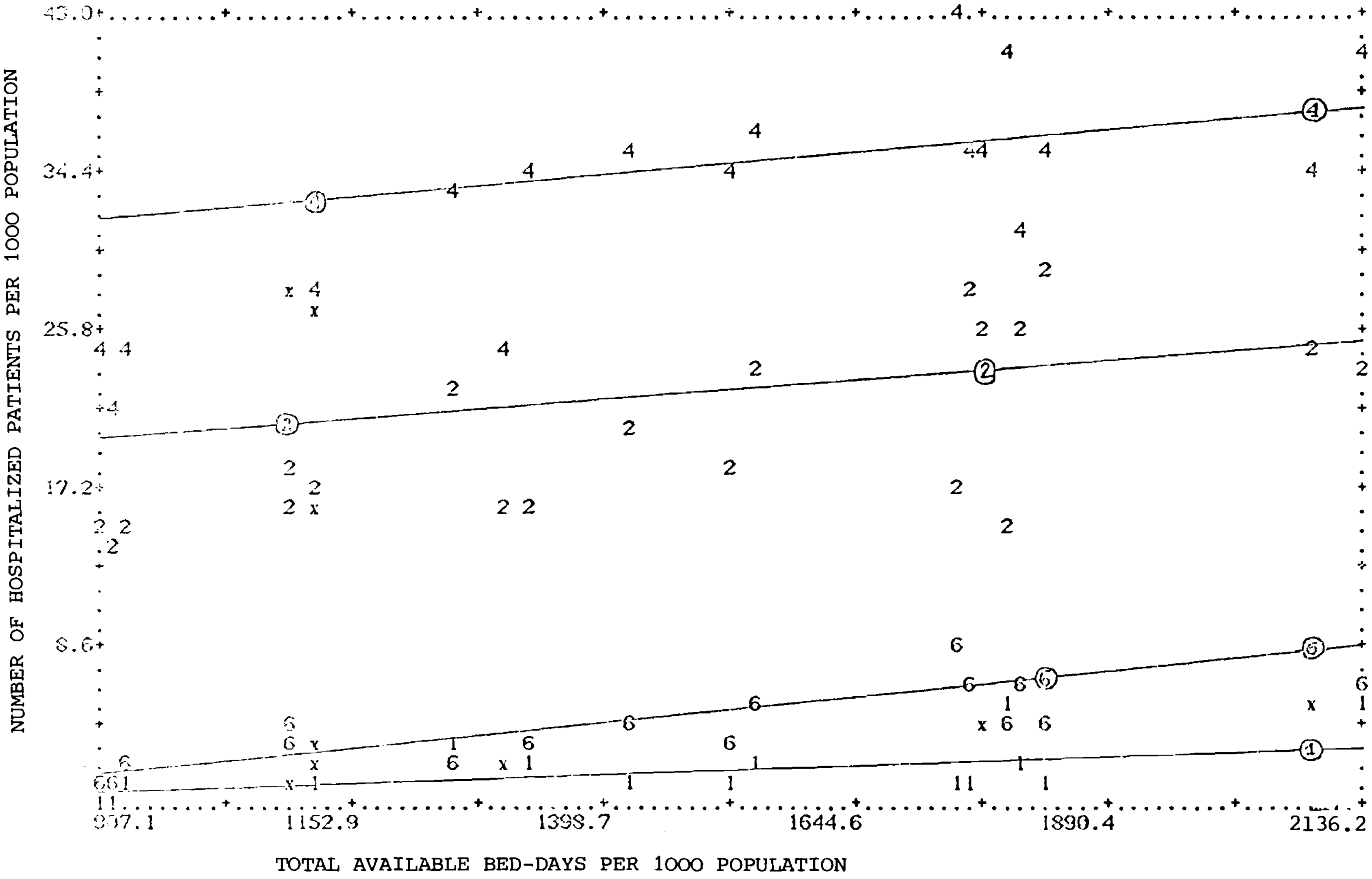

Figure 1a. Hospitalization rates for treatment categories 1,2,4, and 6 plotted against total available bed-days: observed and predicted.

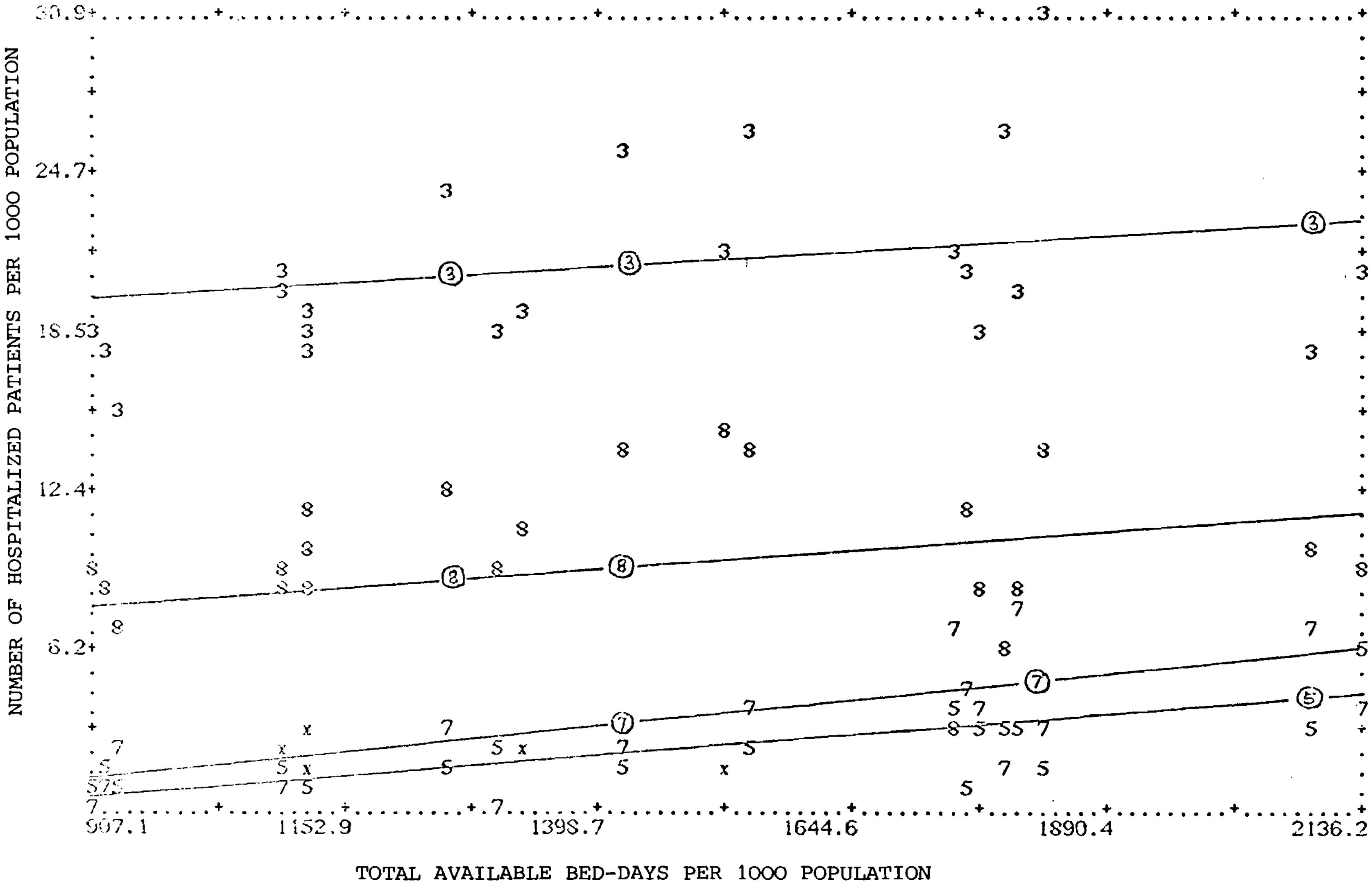

Figure 1b. Hospitalization rates for treatment categories 3,5,7, and 8; observed and predicted.

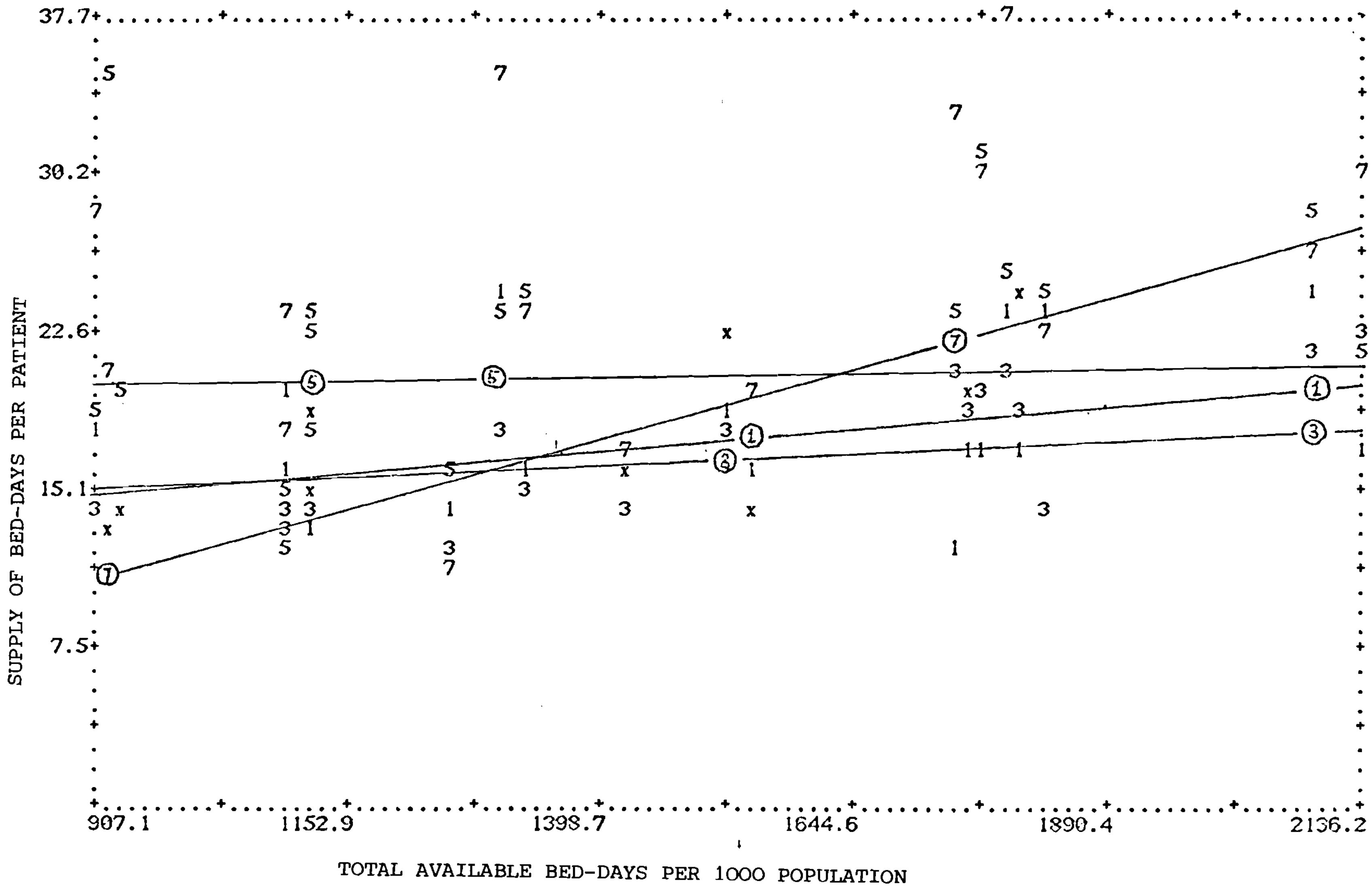

Figure 2a. Supply levels for treatment categories 1,3,5, and 7 plotted against total available bed-days: observed and predicted.

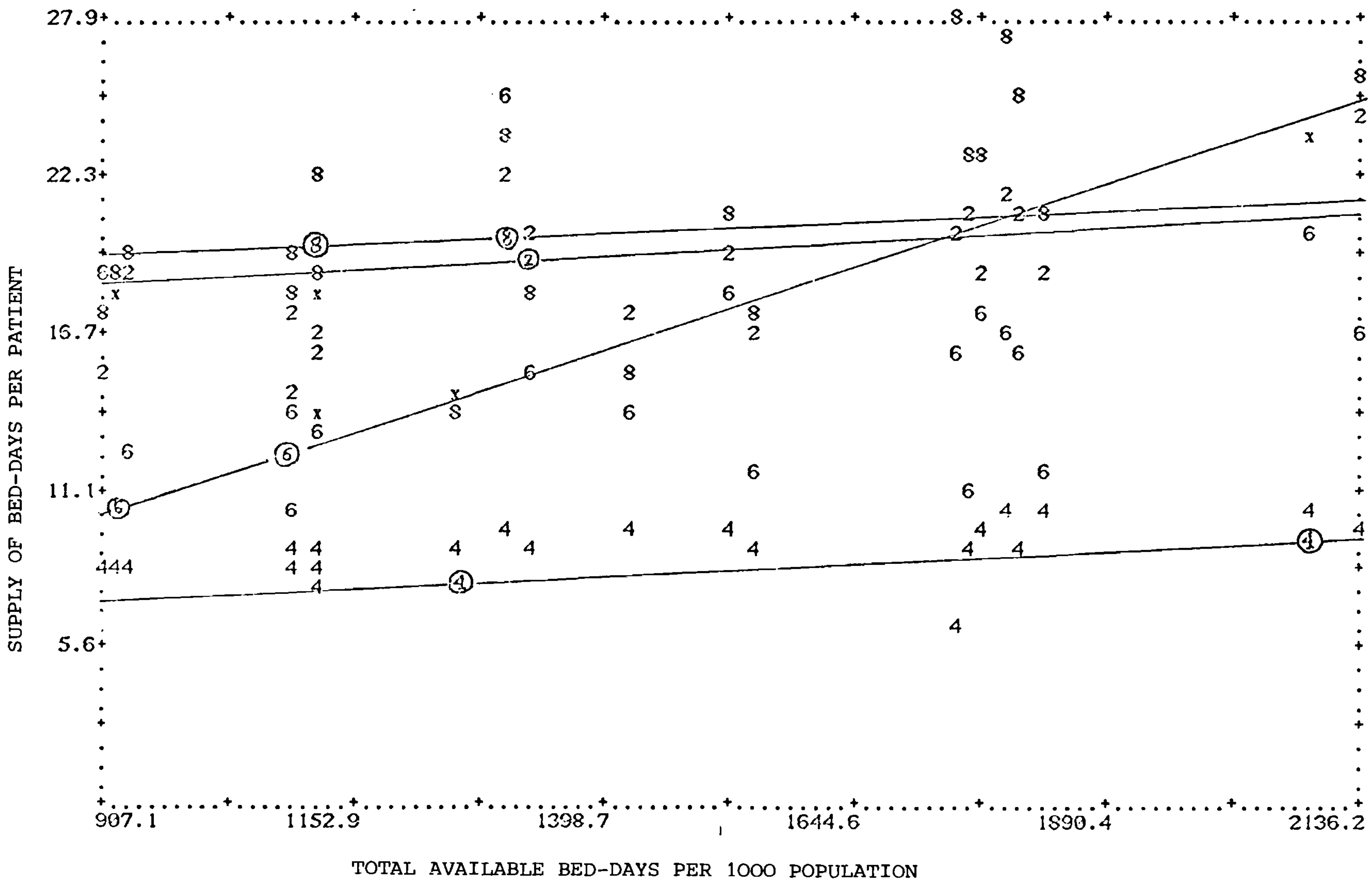

Figure 2b. Supply levels for treatment categories 2,4,6, and 8: observed and predicted.

4.5. Parameter Estimation for DRAM with One Resource: Hospital Doctors

The parameter estimates for hospital doctors are given in Table 6. Figures 3 and 4 give the hospitalization rates and supply levels per patient, both actual and from the model (using the parameters in Table 6) plotted against total available doctor-days per 1000 population for each of the 22 data points.

4.6. Parameter Estimation for DRAM with One Resource: Hospital Nurses

The parameter estimates for hospital nurses are given in Table 7. Figures 5 and 6 give the hospitalization rates and supply levels per patient, both actual and from the model (using the parameters in Table 7) plotted against total nurse-days per 1000 population for each of the 22 data points.

4.7. Cost Ratio Estimation for Two- and Three-Resource Models

To calculate the parameters for DRAM with more than one resource, it is necessary to estimate the ratio of the marginal costs of these resources (C_l in section 2) when all needs for health care are met. The calculation of this ratio will be performed using average costs. It is assumed that the aggregate cost function of many hospital units -- characterized usually by non-linear cost functions -- could be approximated by average cost (Hughes and Wierzbicki 1980).

Following the approach by Aspden (1980), the average total cost per patient in general hospitals in Poland in 1971* is:

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*The average costs do not vary much; thus the available data from 1971 have been taken as a crude estimate of cost ratio for 1969 and 1970.

Table 6. One-resource (hospital doctors) DRAM parameter estimates for Polish in-patient hospital care.

Treatment category	Cover[a]					Supply levels: doctors					tgf_J[b]	Ranking for:		
	X_J	α_J	$SS\hat{x}_J$	$SS\bar{x}_J$	gfx_J	Y_{J2}	β_{J2}	$SS\hat{y}_{J2}$	$SS\bar{y}_{J2}$	gfy_{J2}		gfx_J	gfy_{J2}	tgf_J
Child surgery	8.1	0.59	6.128	11.696	0.524	4.4	1.52	3.064	3.887	0.788	0.590	3	6	5
General medicine	36.5	2.64	1.221	1.211	1.009	3.4	2.33	0.652	3.326	0.196	0.413	5	1	2
General surgery	27.5	5.78	0.765	0.638	1.198	2.6	3.47	2.034	5.039	0.404	0.493	6	3	4
Obstetrics and gynaecology	52.7	3.58	0.269	0.720	0.373	1.1	4.68	0.392	1.053	0.372	0.373	1	2	1
Ophthalmology	6.3	1.00	3.080	7.285	0.423	4.9	2.30	1.343	2.698	0.498	0.443	2	5	3
Otorhinolaryngology	13.6	0.98	3.177	4.601	0.690	2.4	5.44	3.866	5.041	0.767	0.730	4	7	6
Traumatic and orthopaedic surgery	12.5	0.82	12.103	9.111	1.328	3.9	1.69	3.361	5.007	0.671	1.095	7	6	8
Paediatrics	18.2	2.50	3.052	1.606	1.900	3.2	3.73	1.797	3.835	0.468	0.891	8	4	7

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J}) = 0.6936$
$tgf(\bar{J'}) = 0.4487$

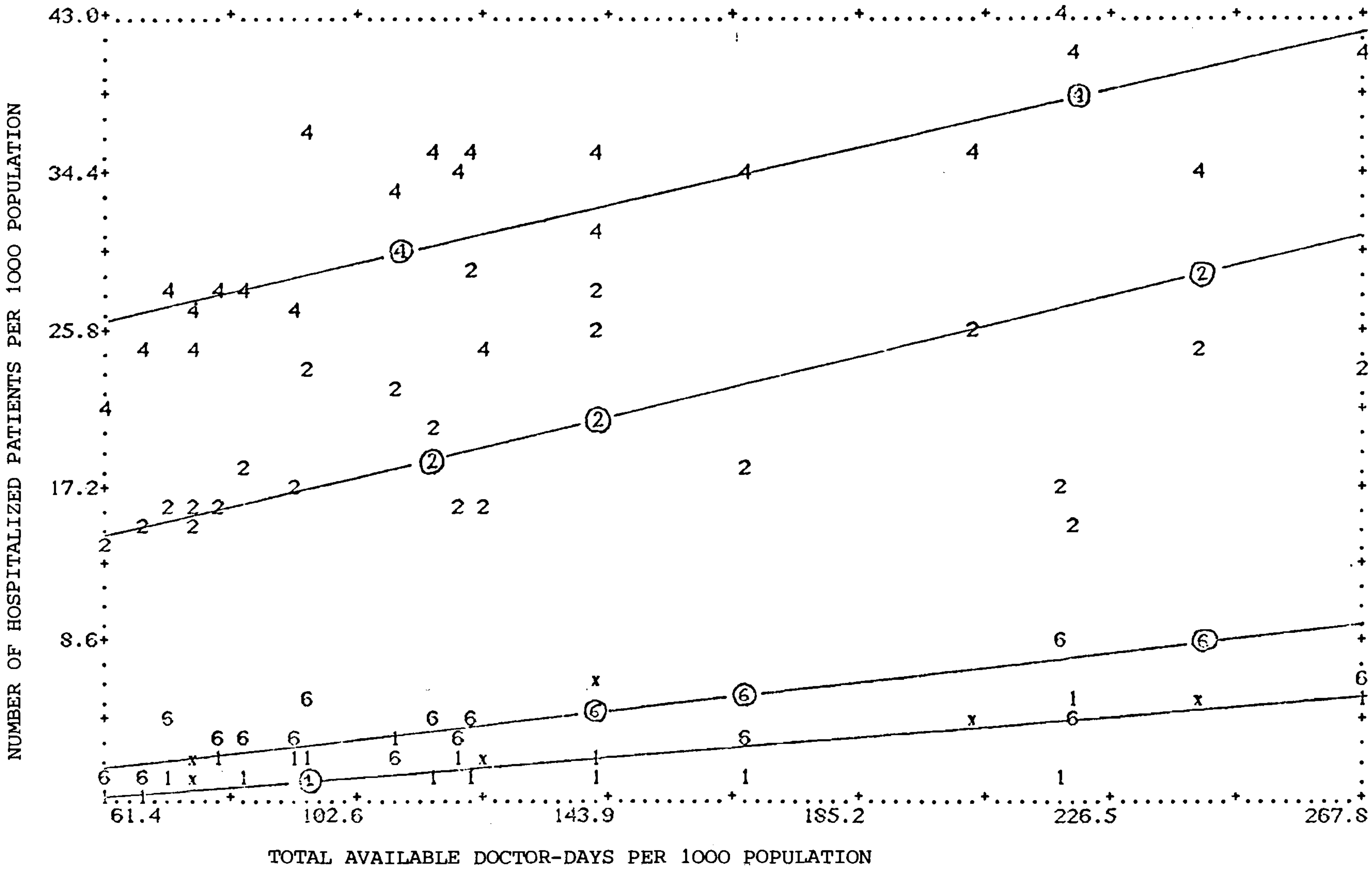

Figure 3a. Hospitalization rates for treatment categories 1,2,4, and 6 plotted against total available doctor-days: observed and predicted.

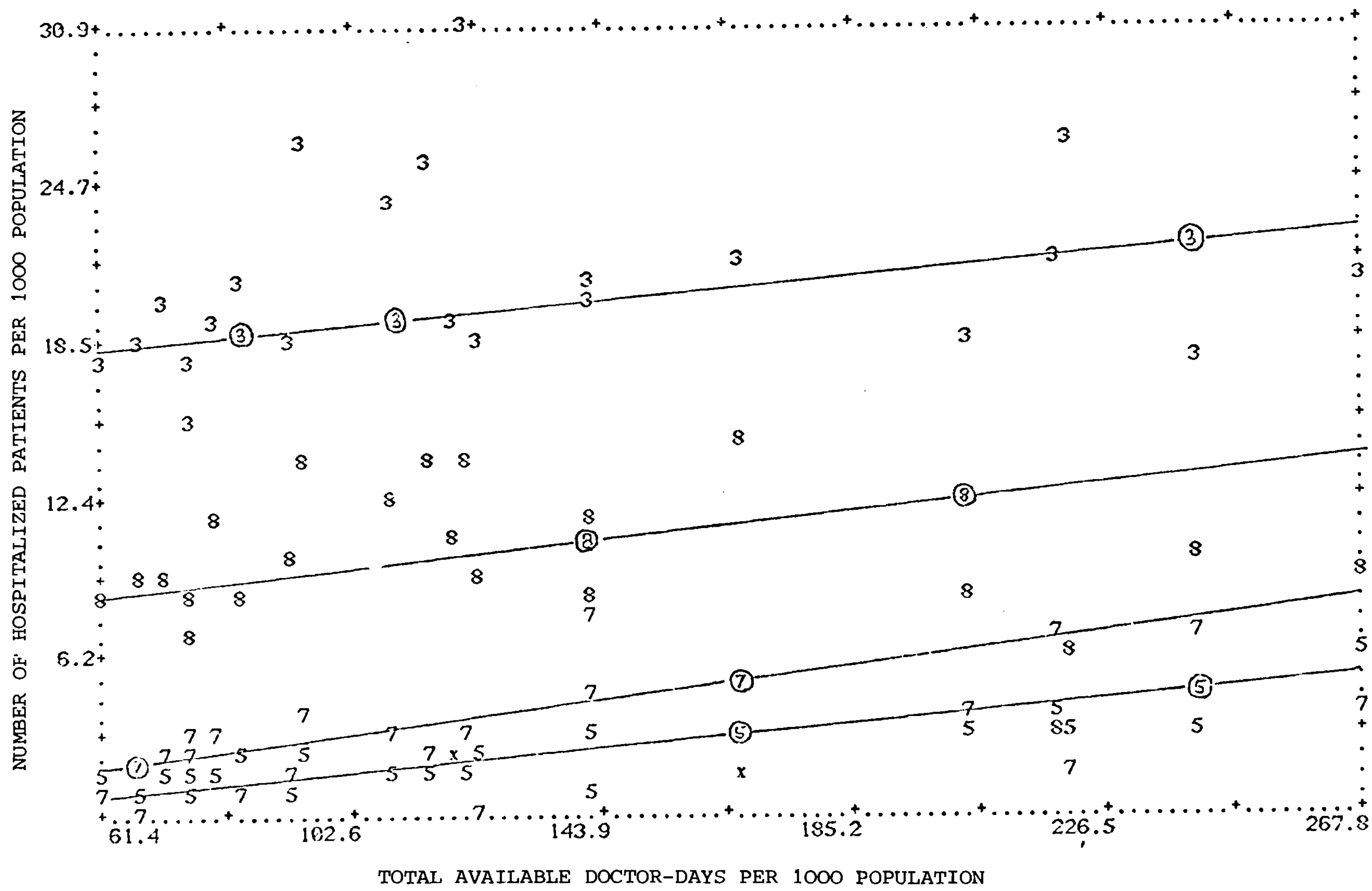

Figure 3b. Hospitalization rates for treatment categories 3,5,7, and 8; observed and predicted.

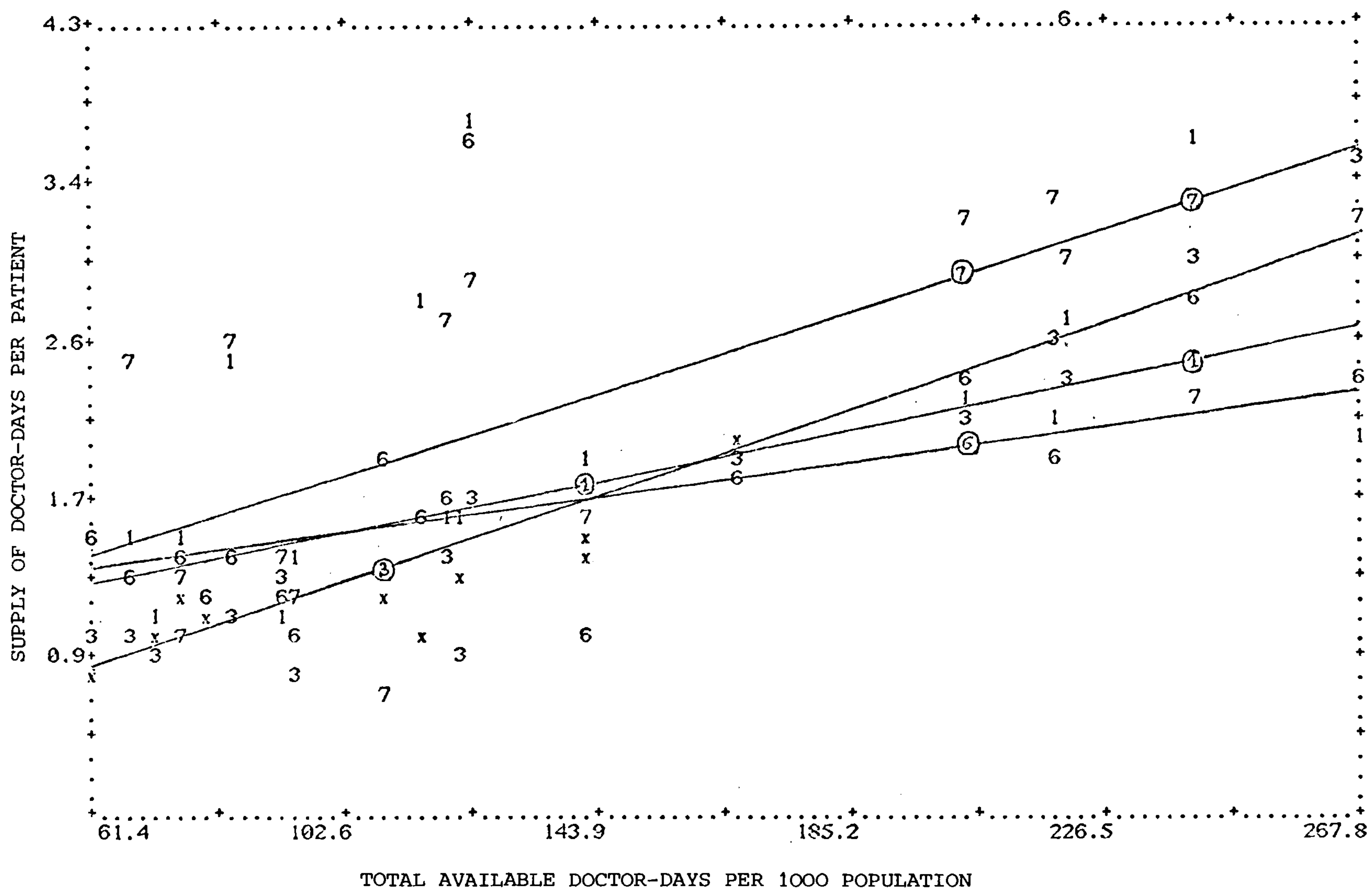

Figure 4a. Supply levels for treatment categories 1,3,6, and 7: observed and predicted.

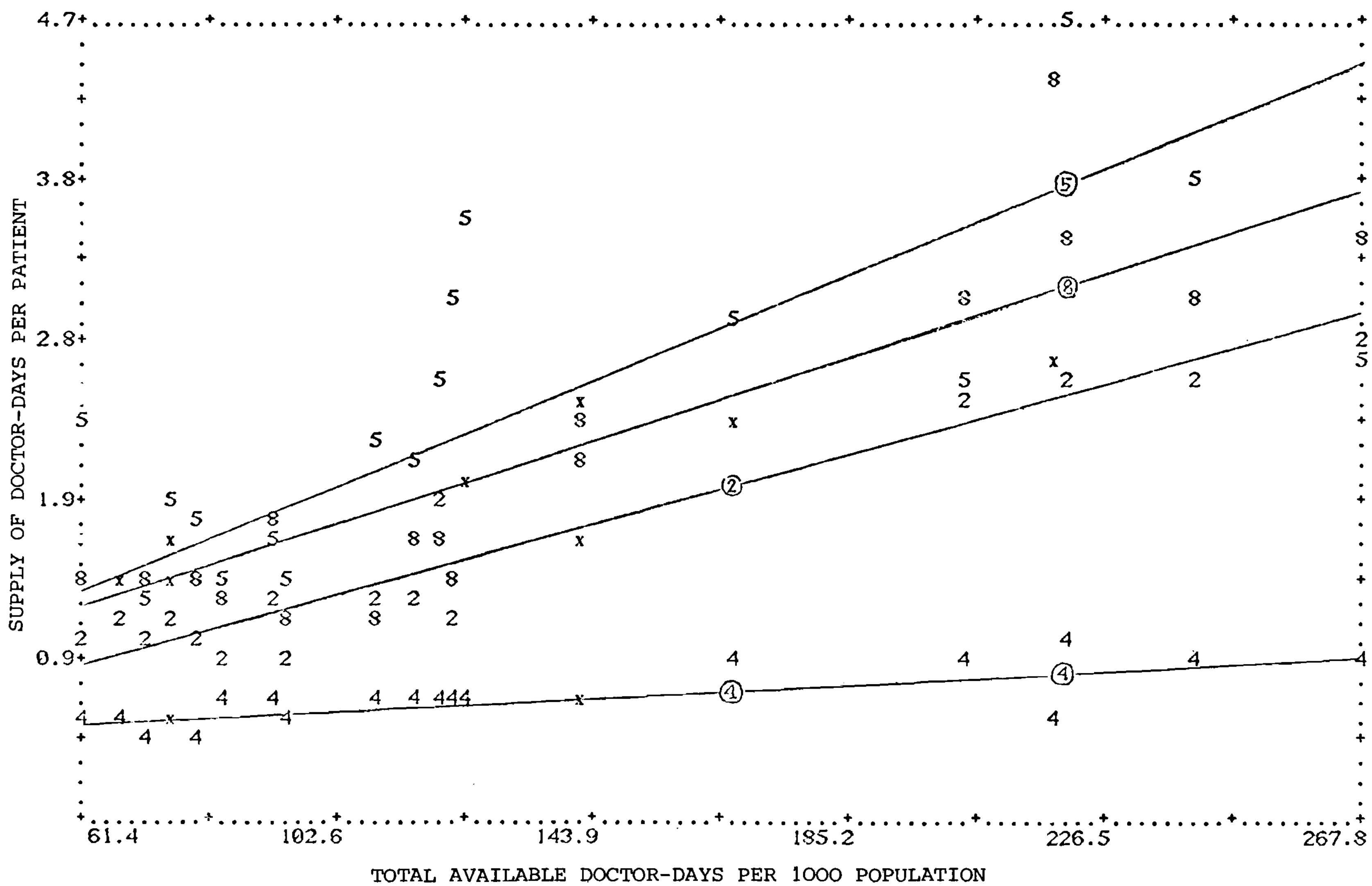

Figure 4b. Supply levels for treatment categories 2,4,5, and 8; observed and predicted.

Table 7. One-resource (hospital nurses) DRAM parameter estimates for Polish in-patient hospital care.

Treatment category	Cover[a]					Supply levels: nurses					tgf_j[b]	Ranking for:		
	X_j	α_j	$ss\hat{x}_j$	$ss\bar{x}_j$	gfx_j	Y_{j3}	β_{j3}	$ss\hat{y}_{j3}$	$ss\bar{y}_{j3}$	gf_{j3}		gfx_j	gfy_{j3}	tgf_j
Child surgery	6.7	1.65	5.925	11.696	0.507	5.6	9.55	0.599	1.201	0.499	0.506	2	1	1
General medicine	36.0	3.74	1.016	1.211	0.840	3.9	12.35	0.697	1.188	0.587	0.714	4	2	2
General surgery	28.9	6.41	0.848	0.638	1.329	3.0	39.67	2.211	2.326	0.950	1.032	7	5	5
Obstetrics and gynaecology	47.0	5.99	0.269	0.720	0.373	1.0	9.43	0.711	0.496	1.434	0.805	1.7	7	3
Ophthalmology	2.6	40.42	7.185	7.285	0.986	5.4	8.04	1.620	1.819	0.891	0.967	5	4	4
Otorhinolaryngology	23.2	0.114	3.468	4.601	0.754	11.3	1.00	5.645	1.727	3.269	1.440	3	8	8
Traumatic and orthopaedic surgery	17.1	0.72	9.777	9.111	1.073	6.0	4.42	2.477	2.688	0.921	1.038	6	6	6
Paediatrics	15.6	4.48	2.650	1.606	1.650	6.0	21.98	1.685	2.115	0.796	1.165	8	3	7

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J}) = 0.9277$

$tgf(\bar{J}') = 0.8743$

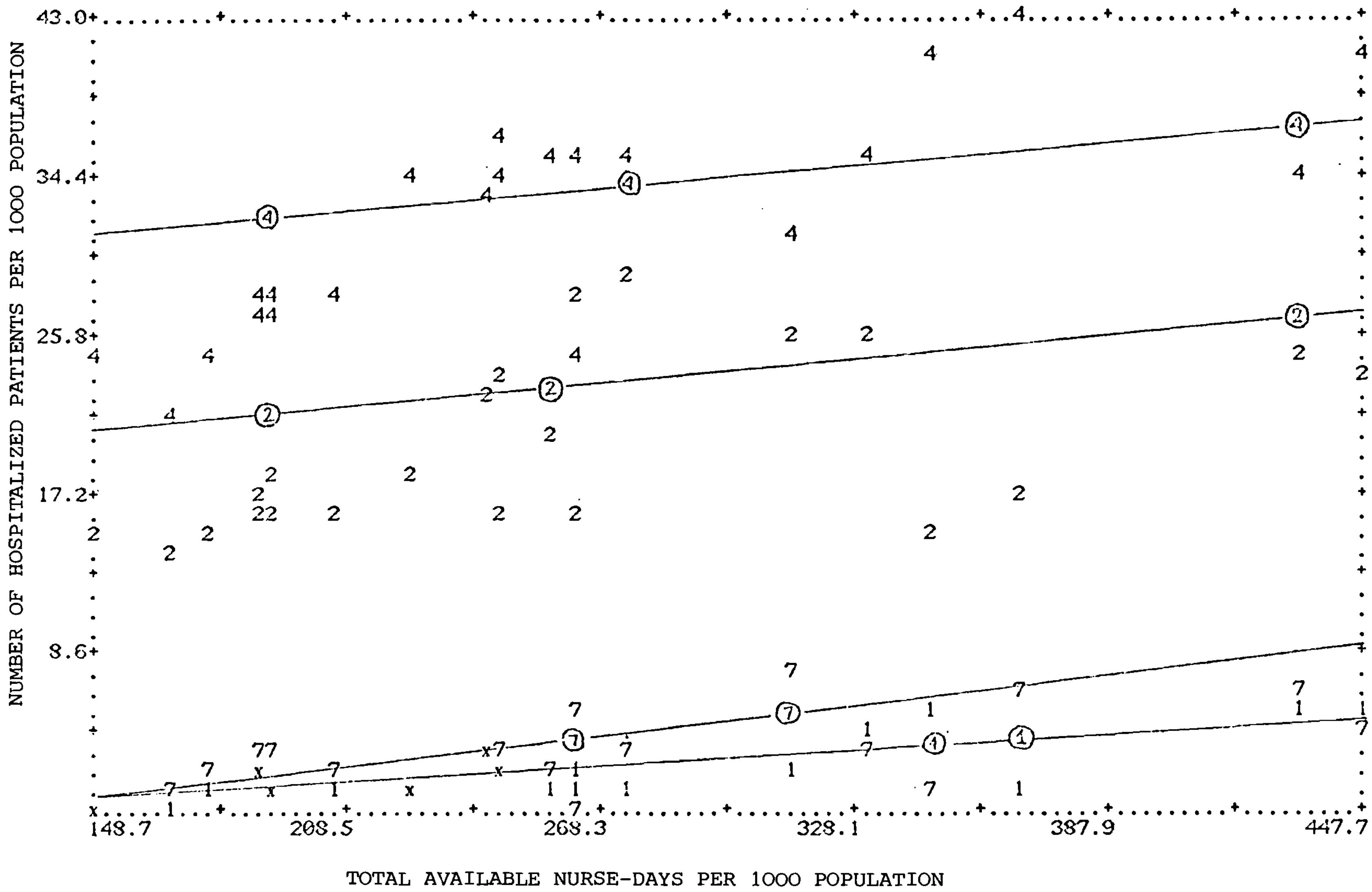

Figure 5a. Hospitalization rates for treatment categories 1,2,4, and 7 plotted against total available nurse-days: observed and predicted.

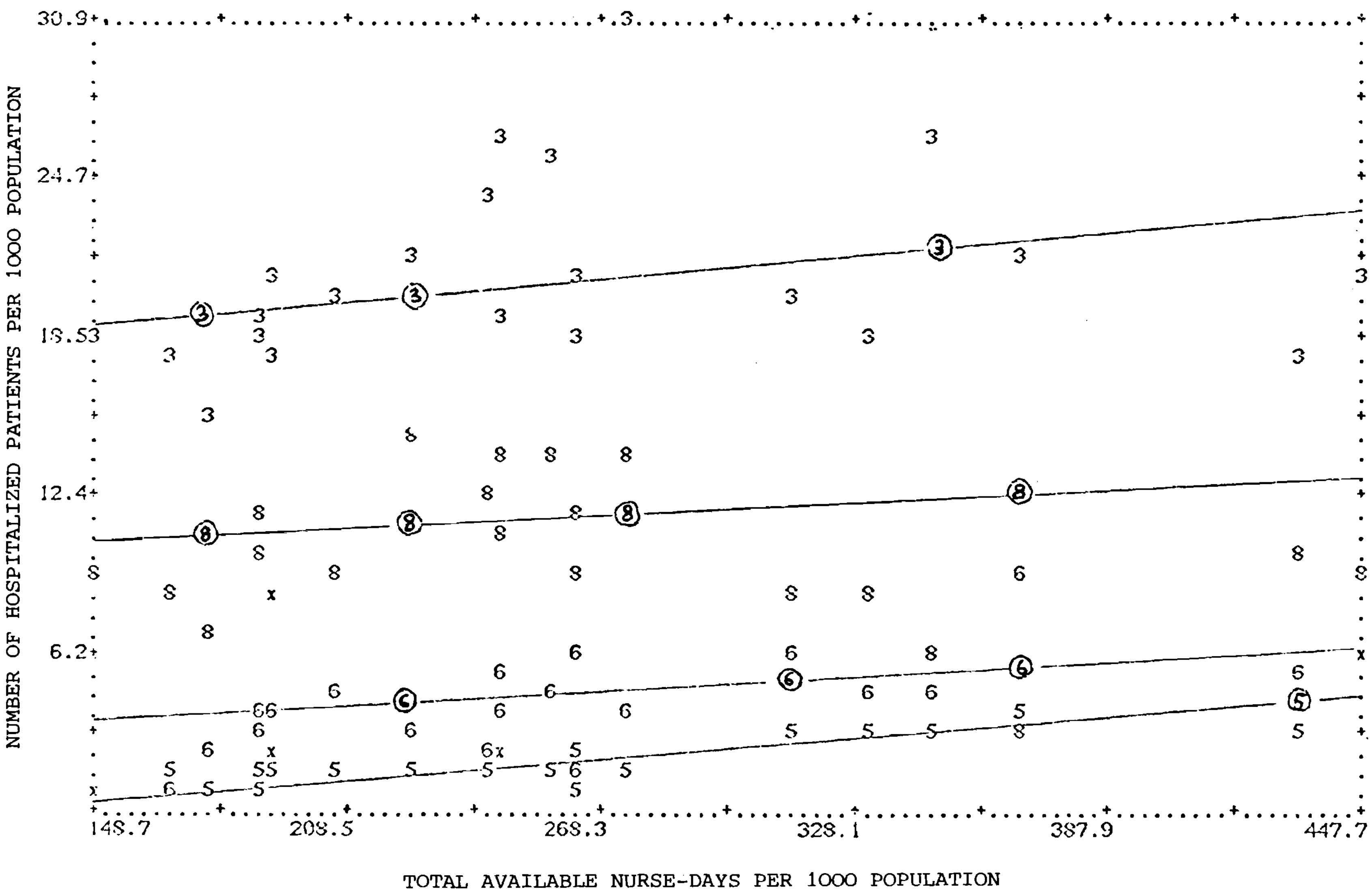

Figure 5b. Hospitalization rates for treatment categories 3,5,6, and 8: observed and predicted.

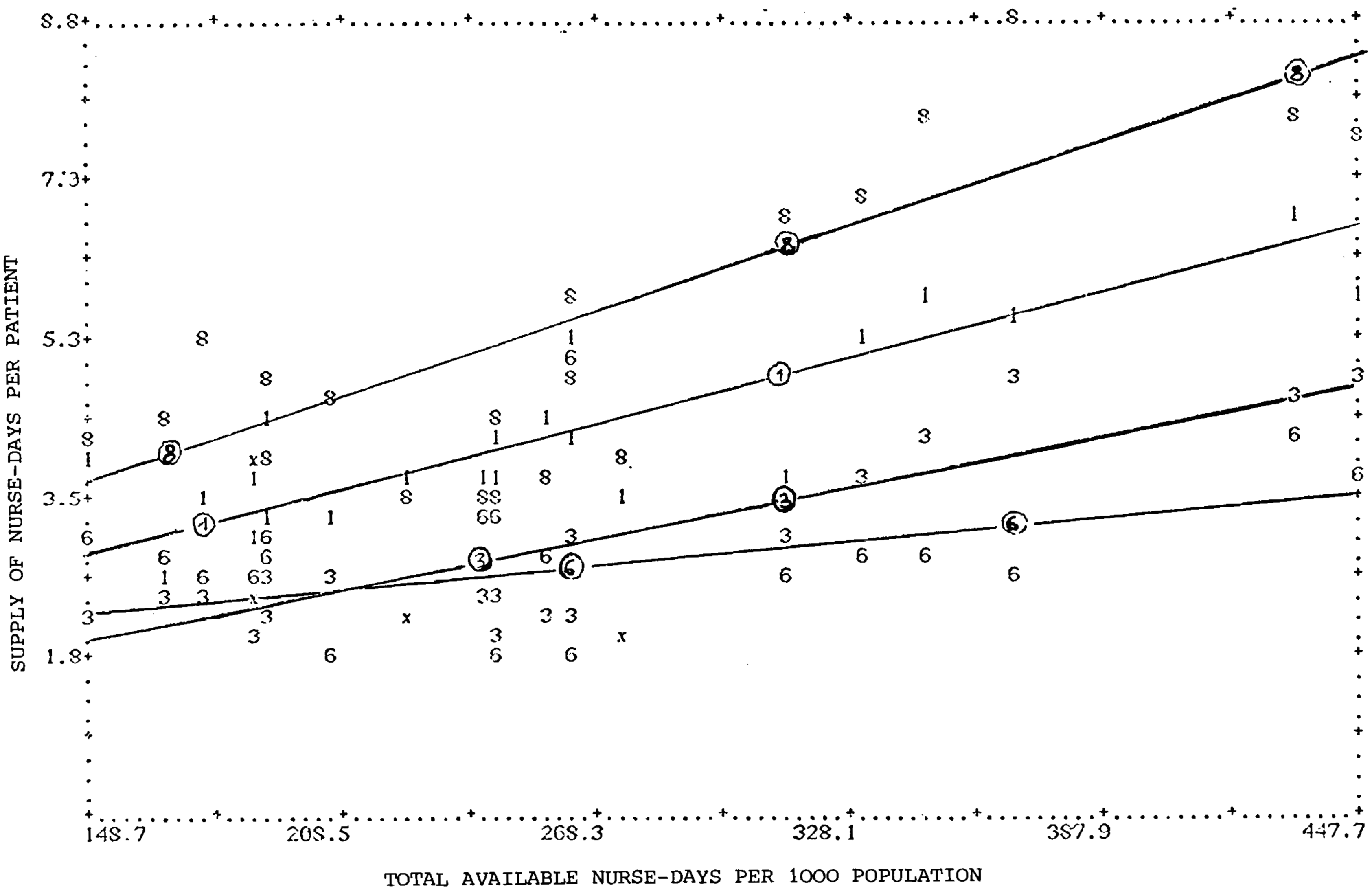

Figure 6a. Supply levels of treatment categories 1,3,6, and 8: observed and predicted.

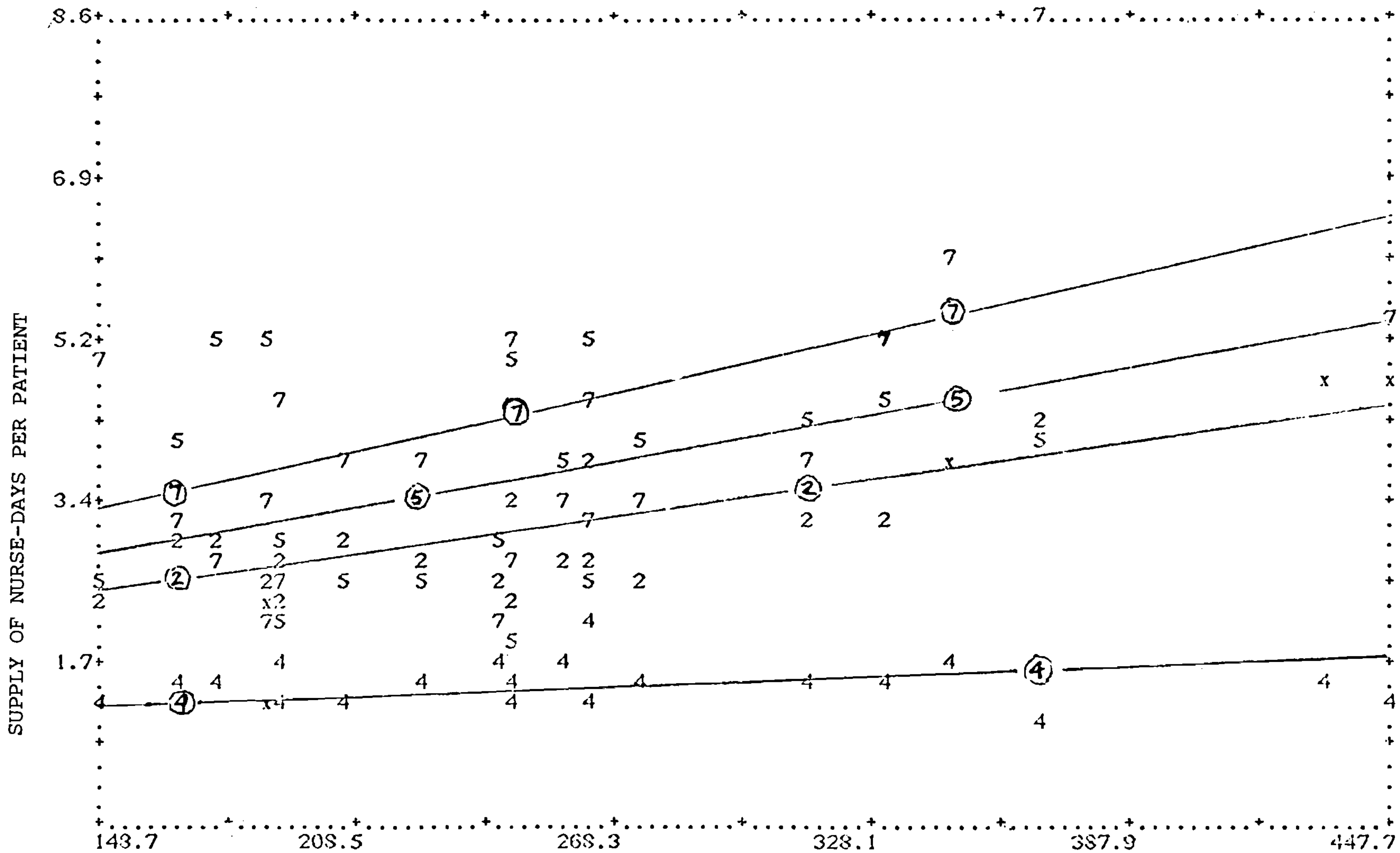

Figure 6b. Supply levels of treatment categories 2,4,5, and 7: observed and predicted.

	zloties	
Medical and nursing staff	1291.0	(K_d+K_N)
Medical supplies	406.0	(K_S)
Catering	288.0	(K_C)
General services (administration, domestic, estate management, etc.)	488.0	(K_G)
	2433.0	(TOT)

From the analysis of supply data, there is on average 17 bed-days ($\overline{bd}$), 2.5 doctor-days ($\overline{dd}$), and 3.5 nurse-days ($\overline{nd}$) per patient for all eight patient categories under consideration.

If one denotes the unit cost of resources, i.e., the costs of bed-day, doctor-day, and nurse-day by cbd, cdd cnd, respectively, then

$$Kd = cdd\ (\overline{dd})$$
$$Kn = cnd\ (\overline{nd})$$

and assigning all the other costs to beds

$$TOT - (K_d+K_n) = cbd\ (\overline{bd})$$

From the analysis of average monthly salaries of medical and nursing staff it follows that

$$cdd : cnd \simeq 5 : 3$$

Hence it can be calculated that

$$\frac{cdd}{cbd} = \frac{K_d}{TOT - (K_d+K_n)} \frac{\overline{bd}}{\overline{dd}} \left(\simeq 4.2\right)$$

For the remainder of the paper it is assumed that $C_1:C_2:C_3=$

$$C_1:C_2:C_3 = cbd:cdd:cnd = 1:5:3$$

This ratio was used in the DRAM parameter estimation procedures for two- and three-resource models. A detailed cost analysis may be worthwhile; however, it requires more financial data to be collected and analyzed in close collaboration of health care budget planners.

4.8. Parameter Estimation for DRAM with Two Resources: Hospital Beds and Hospital Doctors

Using the estimates of the bed-doctor cost ratio derived in the previous section, the parameters for the two-resource version of DRAM (Model BD) were estimated and are given in Table 8. A comparison of the gfx_j and gfy_{jl} $(l \in \{1,2\})$ ratios, between the two-resource model (Model BD) and the two one-resource models (B and D) is given in Table 9.

4.9. Parameter Estimation for DRAM with Two Resources: Hospital Doctors and Hospital Nurses

Using the above-mentioned estimates of the doctor/nurse cost ratio, the parameters for another two-resource version of DRAM (Model DN) were estimated. The results are given in Table 10. A comparison of the gfx_j and gfy_{jl} $(l \in \{2,3\})$ ratios, between the two-resource model DN and the two one-resource models D and N is given in Table 11.

4.10. Parameter Estimation for DRAM with Three Resources: Hospital Beds, Hospital Doctors, and Hospital Nurses

Finally the model with all three resources under consideration -- beds, doctors, and nurses -- was parameterized. The parameter estimates for model BDN are given in Table 12. The usual comparison of the gfx_j and gfy_{jl} $(l \in \{1,2,3\})$ ratios, between the three-resource model BDN and the three one-resource models B, D, and N is given in Table 13.

4.11. Conclusions

Several models have been analyzed for Polish in-patient hospital care. Some comparisons of the models' results with actual values have been carried out in sections 4.8-4.10 (see

Table 8. Two-resource (hospital beds and hospital doctors) DRAM parameter estimates for Polish in-patient hospital care.

Treatment category	Cover[a]					Supply levels: beds				
	X_j	α_j	$SS\hat{x}_j$	SSx_j	gfx_j	Y_{j1}	β_{j1}	$SS\hat{y}_{j1}$	$SS\bar{y}_{j1}$	gfy_{j1}
Child surgery	4.0	2.93	8.929	11.696	0.763	19.7	11.81	0.845	0.966	0.875
General medicine	31.4	3.31	0.757	1.211	0.626	21.5	18.11	0.318	0.428	0.744
General surgery	25.9	6.02	0.663	0.638	1.039	18.3	18.33	0.574	0.768	0.748
Obstetrics and gynaecology	44.8	4.81	0.214	0.720	0.298	9.6	18.22	0.251	0.269	0.932
Ophtalmology	5.8	1.00	3.311	7.285	0.454	22.4	241.60	1.373	1.371	1.002
Otorhinolaryngology	12.7	0.13	2.246	4.601	0.488	82.9	0.001	14.929	1.018	14.669
Traumatic and orthopaedic surgery	17.6	0.01	10.326	9.111	1.133	46.9	1.00	3.886	1.849	2.102
Paediatrics	13.9	3.97	2.094	1.606	1.303	21.9	23.37	0.572	0.665	0.861

Treatment Category	Supply levels: doctors					tgf_j[b]	ranking for:			
	Y_{j2}	β_{j2}	$SS\hat{y}_{j2}$	$SS\bar{y}_{j2}$	gfy_{j2}		gfx_j	gfy_{j1}	gfy_{j2}	tgf_j
Child surgery	4.3	1.38	3.135	3.887	0.807	0.780	5	4	8	6
General medicine	3.6	1.94	0.268	3.326	0.080	0.270	4	1	1	1
General surgery	2.8	2.51	1.331	5.039	0.264	0.399	6	2	2	2
Obstetrics and gynaecology	1.1	4.21	0.354	1.053	0.337	0.401	1	5	3	3
Ophtalmology	4.4	2.64	1.294	2.698	0.480	0.526	2	6	5	4
Otorhinolaryngology	2.8	3.31	3.176	5.041	0.630	1.909	3	8	7	8
Traumatic and orthopaedic surgery	5.6	0.85	2.971	5.007	0.593	1.076	7	7	6	7
Paediatrics	3.3	3.30	1.354	3.835	0.353	0.658	8	3	4	5

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J}) = 0.8797$

$tgf(\bar{J}') = 0.3517$

Table 9. Comparison of gfx_j and gfy_{j1} between BD and models B and D.

Treatment category	Two one-resource models			Two-resource model BD		
	$Min\{gfx_j\}$ from Tables 5 and 6	gfy_{j1} from Table 5	gfy_{j2} from Table 6	gfx_j from Table 8	gfy_{j1} from Table 8	gfy_{j2} from Table 8
Child surgery	0.524	0.856	0.788	0.763	0.875	0.807
General medicine	0.487	0.581	0.196	0.626	0.744	0.080
General surgery	1.198	0.680	0.404	1.039	0.748	0.264
Obstetrics and gynaecology	0.299	0.913	0.372	0.298	0.932	0.337
Ophtalmology	0.423	1.000	0.498	0.454	1.002	0.480
Otorhinolaryngology	0.449	3.636	0.767	0.488	14.669	0.630
Traumatic and orthopaedic surgery	0.938	1.489	0.671	1.133	2.102	0.593
Paediatrics	1.177	0.791	0.468	1.303	0.861	0.353

Table 10. Two-resource (hospital doctors and hospital nurses) DRAM parameter estimates for Polish in-patient hospital care.

Treatment category	Cover[a]					Supply levels: doctors				
	x_j	α_j	$SS\hat{x}_j$	$SS\bar{x}_j$	gfx_j	Y_{j2}	β_{j2}	$SS\hat{y}_{j2}$	$SS\bar{y}_{j2}$	gfy_{j2}
Child surgery	9.0	0.85	5.659	11.696	0.484	3.1	2.90	3.021	3.887	0.777
General medicine	40.3	2.53	1.174	1.211	0.970	3.0	3.18	0.523	3.326	0.157
General surgery	31.0	4.56	0.856	0.638	1.357	2.4	4.03	1.985	5.039	0.394
Obstetrics and gynaecology	56.4	3.40	0.772	1.441	0.408	1.0	5.95	0.322	1.053	0.306
Ophtalmology	7.4	1.00	2.331	7.285	0.320	3.7	4.28	1.400	2.698	0.519
Otorhinolaryngology	15.0	0.61	2.363	4.601	0.514	2.1	8.40	4.073	5.041	0.808
Traumatic and orthopaedic surgery	21.2	0.41	13.152	9.111	1.444	3.2	2.53	3.000	5.007	0.599
Paediatrics	17.9	3.00	2.786	1.606	1.735	2.9	4.93	1.745	3.835	0.455

Treatment category	Supply levels: nurses					tgf_j[b]	Ranking for:			
	Y_{j3}	β_{j3}	$SS\hat{y}_{j3}$	$SS\bar{y}_{j3}$	gfy_{j3}		gfx_j	gfy_{j2}	gfy_{j3}	tgf_j
Child surgery	5.0	16.49	0.904	1.201	0.752	0.571	3	7	2	3
General medicine	4.0	10.64	0.758	1.188	0.638	0.429	5	1	1	1
General surgery	3.0	48.35	2.158	2.326	0.928	0.626	6	3	5	5
Obstetrics and gynaecology	1.8	9.37	0.706	0.496	1.424	0.583	2	2	7	4
Ophtalmology	5.0	9.33	1.681	1.819	0.924	0.458	1	5	4	2
Otorhinolaryngelogy	10.7	1.09	4.014	1.727	2.324	0.919	4	8	8	7
Traumatic and orthopaedic surgery	5.2	5.69	2.830	2.688	1.075	1.132	7	6	6	8
Paediatrics	6.2	14.39	1.666	2.115	0.788	0.820	8	4	3	6

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J}) = 0.7403$

$tgf(\bar{J}') = 0.5492$

Table 11. Comparison of gfx_j and gfy_{j1} between model DN and models D and N.

Treatment category	Two individual resource models			Two-resource model DN		
	Min $\{gfx_j\}$ from Tables 6 and 7	gfy_{j2} from Table 6	gfy_{j3} from Table 7	gfx_j from Table 10	gfy_{j2} from Table 10	gfy_{j3} from Table 10
Child surgery	0.507	0.788	0.499	0.484	0.777	0.752
General medicine	0.840	0.196	0.587	0.970	0.175	0.638
General surgery	1.193	0.404	0.950	1.357	0.394	0.928
Obstetrics and gynaecology	0.373	0.372	1.434	0.408	0.306	1.424
Ophtalmology	0.423	0.498	0.891	0.320	0.519	0.924
Otorhinolaryngology	0.690	0.767	3.269	0.514	0.808	2.324
Traumatic and orthopaedic surgery	1.073	0.671	0.921	1.444	0.599	1.071
Paediatrics	1.650	0.468	0.796	1.735	0.455	0.788

Table 12. Three-resource (hospital beds, hospital doctors, and hospital nurses) DRAM parameter estimates for Polish in-patient hospital care.

Treatment category	Cover[a]					Supply levels: beds				
	X_j	α_j	$SS\hat{x}_j$	$SS\bar{x}_j$	gfx_j	Y_{j1}	β_{j1}	$SS\hat{y}_{j1}$	$SS\bar{y}_{j1}$	gfy_{j1}
Child surgery	4.6	2.39	7.798	11.695	0.667	18.7	17.95	0.852	0.966	0.882
General medicine	31.1	3.79	0.803	1.211	0.663	20.6	23.50	0.324	0.428	0.757
General surgery	26.0	6.57	0.634	0.638	1.072	17.8	26.15	0.592	0.768	0.771
Obstetrics and gynaecology	44.4	5.36	0.235	0.720	0.327	9.3	27.09	0.244	0.269	0.907
Ophtalmology	6.1	1.00	2.216	7.285	0.386	22.4	194.60	1.371	1.371	1.001
Otorhinolaryngology	15.3	0.15	2.493	4.601	0.542	70.5	0.001	22.896	1.018	22.497
Traumatic and orthopaedic surgery	19.7	0.02	10.244	9.111	1.124	43.2	1.00	4.993	1.849	2.701
Paediatrics	14.4	4.06	2.251	1.606	1.402	21.3	23.65	0.594	0.665	0.894

Treatment category	Supply levels: doctors					Supply levels: nurses					tgf_j[b]	ranking for:				
	Y_{j2}	β_{j2}	$SS\hat{y}_{j2}$	$SS\bar{y}_{j2}$	gfy_{j2}	Y_{j3}	β_{j3}	$SS\hat{y}_{j3}$	$SS\bar{y}_{j3}$	gfy_{j3}		gfx_j	gfy_{j1}	gfy_{j2}	gfy_{j3}	tgf_j
Child surgery	4.0	1.65	3.112	3.887	0.801	5.8	8.17	0.663	1,201	0.552	0.700	5	3	8	2	6
General medicine	3.5	2.15	0.277	3.326	0.083	4.9	4.81	0.410	1.188	0.345	0.295	4	1	1	1	1
General surgery	2.8	2.74	1.359	5.039	0.270	3.7	9.45	1.537	2.326	0.661	0.475	6	2	2	4	2
Obstetrics and gynaecology	1.1	4.53	0.323	1.053	0.307	2.3	4.34	0.931	0.496	1.877	0.683	1	5	3	8	5
Ophtalmology	4.2	3.02	1.300	2.693	0.482	6.4	4.08	1.521	1.819	0.836	0.532	2	6	5	5	3
Otorhinolaryngology	2.6	3.90	3.549	5.041	0.686	3.9	5.66	1.527	1.727	0.884	2.452	3	8	7	6	8
Traumatic and orthopaedic surgery	5.1	1.06	2.923	5.007	0.584	12.5	0.97	2.920	2.688	1.086	11.030	7	7	6	7	7
Paediatrics	3.3	3.59	1.327	3.835	0.346	7.2	6.94	1.236	2.115	0.584	0.658	8	4	4	3	4

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J}) = 0.9586$

$tgf(\bar{J}') = 0.4420$

Table 13. Comparison of gfx_j and gfy_{j1} between model BDN and models B, D, and N.

Treatment category	Three one-resource models				Three-resource model BDN			
	Min $\{gfx_j\}$ from Tables 5,6,7	gfy_{j1} from Table 5	gfy_{j2} from Table 6	gfy_{j3} from Table 7	gfx_j from Table 12	gfy_{j1} from Table 12	gfy_{j2} from Table 12	gfy_{j3} from Table 12
Child surgery	0.507	0.856	0.788	0.499	0.677	0.882	0.801	0.552
General medicine	0.487	0.581	0.196	0.587	0.663	0.257	0.083	0.345
General Surgery	1.198	0.630	0.404	0.950	1.072	0.771	0.270	0.661
Obstetrics and gynaecology	0.299	0.913	0.372	1.434	0.327	0.907	0.307	1.877
Ophtalmology	0.423	1.000	0.498	0.891	0.386	1.001	0.482	0.836
Otorhinolaryngology	0.449	3.636	0.767	3.269	0.542	22.497	0.686	0.884
Traumatic and orthopaedic surgery	0.938	1.489	0.671	0.921	1.124	2.701	0.584	1.086
Paediatrics	1.177	0.791	0.468	0.796	1.402	0.894	0.346	0.584

Tables 9, 11, and 13). In Table 14 the important parts of the ranking matrices, i.e., the aggregate goodness-of-fit index tgf_j (from the Tables 5, 6, 7, 8, 10 and 12) have been put together to allow the choice of the model type and the treatment categories for which the DRAM parameterization appears to give the best account of the actual results.

In the group of one-resource models the doctor resource model D provides the best description, having the lowest tgf_j values in almost all treatment categories. Both two-resource models are practically of the same explanatory power: the overall goodness-of-fit index is slightly better for the DN model, but the BD model seems better for treatment categories that have been chosen for prediction purposes. The three-resource BDN model reproduces the actual allocations of resources for all the categories slightly less accurately than the two-resource models, except for the particular subset of treatment categories 2-5, which reproduce as well as in the two-resource models.

From the analysis of the goodness-of-fit indexes in Table 14, one can see that all the models give quite satisfactory results particularly for the treatment categories 2-5: general medicine, general surgery, obstetrics and gynaecology, and ophthalmology. On the other hand the results for otorhinolaryngology, traumatic and orthopaedic surgery, and paediatrics show that for these categories the present formulation of DRAM is not applicable. It is interesting to note that Aspden (1980) received a similar ranking of the treatment categories.

In order to use DRAM as an aid in predicting, it is necessary to repeat the DRAM parameterization procedure but this time only for chosen treatment categories: general medicine, general surgery, obstetrics and gynaecology.

Table 14. Comparison of the ranking sequences and the tgf_j values for all the models considered within the in-patient hospital care treatment mode.

Number	Treatment category	One-resource models						Two-resource models				Three-resource model	
		B from Table 5		D from Table 6		N from Table 7		BD from Table 8		DN from Table 10		BDN from Table 12	
1	Child surgery	4	III[a]	5	II	1	II	6	II	3	II	6	II
2	General medicine	2	II	2	I	2	II	1	I	1	I	1	I
3	General surgery	5	III	4	I	5	IV	2	I	5	II	2	I
4	Obstetrics and gynaecology	1	I	1	I	3	III	3	I	4	II	5	II
5	Ophtalmology	3	II	3	I	4	III	4	II	2	I	3	II
6	Otorhinolaryngology	6	IV	6	II	8	IV	8	V	7	III	8	V
7	Traumatic and orthopaedic surgery	7	IV	8	IV	6	IV	7	IV	8	IV	7	IV
8	Paediatrics	8	IV	7	III	7	IV	5	II	6	III	4	II

[a] Class I refers to a tgf_j of ≤ 0.5, class II to a tgf_j of 0.5-0.8, class III to 0.8-1.0, class IV to 1.0-1.5, and class V to a tgf_j of > 1.5.

5. ILLUSTRATIVE EXAMPLES OF THE USE OF THE TWO-RESOURCE DRAM FOR POLISH IN-PATIENT HOSPITAL CARE

5.1. Predicting the Allocation of Health Care Resources in Chosen Regions

From the analysis carried out in section 4.11 it was found that the DRAM parameterization procedure had to be performed again for a two-resource BD model for three treatment categories:

-- general medicine (j = 2)

-- general surgery (j = 3)

-- obstetrics and gynaecology (j = 4)

The criterion of choice was quite obvious; the first three treatment categories resulting from the ranking introduced in section 4.11 were acceptable for predicting resource allocation by using DRAM.

Thus the parameter set estimated from past resource allocations (in year 1969, see Appendix C) were used to predict resource allocations in 1970. The comparisons of actual allocations and those predicted by the model for chosen regions* are presented in Table 15. The best results were obtained for the doctor-days supply, which correspond with the preliminary regression analysis of section 4.2 (see Table 3b).

The results for cover predictions are worse and the arguments from section 4.2 could be repeated here as well (compare Table 3a and Table 3b; see also Table C1 in Appendix C).

5.2. Predicting the Allocation of Health Care Resources on the National Level

The same parameter set that was presented in section 5.1 (estimated from past allocations of resources in 1969 using the cross-sectional method) was used to predict resource

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*Regions representing different levels of resource availabilities were chosen (compare Table 1 in section 3,4).

Table 15. Allocation of resources in selected regions in 1970: actual and predicted.

Region	Treatment category	Cover[a] x_j	$\hat{x}_j$	Resource supply: beds y_{j1}	$\hat{y}_{j1}$	Resource supply: doctors y_{j2}	$\hat{y}_{j2}$
Łódź Town	2	23.727	24.447	20.794	19.763	2.688	2.488
	3	17.724	22.220	20.539	16.984	2.377	2.021
	4	36.123	36.334	9.176	9.037	0.916	0.915
Kieleckie	2	15.477	14.304	17.453	17.242	1.560	1.466
	3	15.668	15.908	13.603	15.297	1.105	1.294
	4	24.251	24.615	8.334	7.938	0.688	0.674
Opolskie	2	25.890	24.107	21.240	20.340	1.566	1.538
	3	20.094	22.04	17.100	17.363	1.270	1.347
	4	35.431	36.235	8.920	9.288	0.728	0.693
Poznańskie	2	16.970	16.672	18.161	18.180	1.194	1.285
	3	18.794	17.506	14.706	15.931	1.166	1.158
	4	27.794	27.531	8.176	8.348	0.601	0.624
Warszarskie	2	15.396	14.824	16.050	17.529	1.170	1.269
	3	18.012	16.267	14.167	15.491	1.080	1.146
	4	25.300	25.257	8.425	8.063	0.618	0.620
Zielenogórskie	2	18.797	21.910	18.646	19.175	2.512	2.392
	3	21.345	20.754	17.100	16.595	1.974	1.955
	4	37.401	33.534	9.085	8.782	0.900	0.895

[a]Cover refers to the number of persons per 1000 population who receive care.

allocations on the national level for the three earlier chosen treatment categories: general medicine, general surgery, and obstetrics and gynaecology (Table 16).

The results are quite satisfactory for both the cover and the resource supplies. They are better than the regional predictions, which might be due to the significantly higher level of aggregation. (Different patterns of behavior are smoothed over the space.)

6. CONCLUSIONS

The aim of this paper was to analyze the planning applicability of DRAM for Polish in-patient hospital care. The DRAM parameters were estimated for a model with eight patient categories (child surgery, general medicine, general surgery, obstetrics and gynaecology, ophthalmology, otorhinolaryngology, traumatic and orthopaedic surgery, and paediatrics) and three resource types (hospital beds, hospital doctors, and hospital nurses) from 1969 data for 22 regions (17 voivodships and 5 large-city districts of Poland). Several one-resource, two-resource, and three-resource models were tested.

From the analyses and comparisons of the models, the following conclusions are drawn:

- The most important resources in Poland appear to be beds and doctors.
- Of beds and doctors, doctors seem to have the greater explanatory power.
- The assumption of the uniqueness of the utility function for different regions does not appear to be sound in several cases.
- It would be advisable to split input data into subgroups of regions with more homogeneous patterns of resource allocations.
- The use of the model has to be limited only to those treatment category allocations that can

Table 16. Allocation of resources in Poland in 1970: actual and predicted.

Resource availabilities in 1970

R_1 = 976 bed-days R_2 = 81 doctor-days

Treatment category		Cover[a]		Beds supply		Doctors supply	
		x_j	$\hat{x}_j$	y_{j1}	$\hat{y}_{j1}$	y_{j2}	$\hat{y}_{j2}$
General medicine	j=2	19.91	20.02	18.94	18.99	1.57	1.62
General surgery	j=3	20.38	19.62	15.86	16.47	1.38	1.44
Obstetrics and gynaecology	j=4	31.34	31.30	8.78	8.70	0.69	0.65

[a] Cover refers to the number of persons per 1000 population who receive care.

be satisfactorily reproduced.

-- Preliminary research has to be carried out for choosing appropriate treatment categories.

-- Further research on out-patient care is required, while discussions with health care planners on health care resource utilization patterns are necessary to propose more comprehensive measures of resources.

The three treatment category model predictions, which have been made using DRAM, are for illustrative purposes only. A closer collaboration with health planners at the Ministry of Health Care and Welfare, however, is hoped to bring improved DRAM versions that will be capable of predicting resource allocations in a real planning context, using more disaggregated categories, more resource types, and more modes of treatment.

The specific character of the regions seems to play an important role in the assumption of the universality of the utility function over space. The diversity of allocation patterns is reflected in Mayhew (1980, 1981) by the inclusion of the spatial dimension demand factors, accessibility costs and certain other refinements that address regional heterogeneity. Similar studies should be carried out in Poland.

APPENDIX A: AVERAGE LENGTH OF STAY VERSUS AVAILABLE BED-DAYS PER PATIENT AS THE MEASURES OF BED SUPPLY

In section 3.4, the possible measures for the resource type -- hospital beds, hospital doctors, and hospital nurses -- were presented and analyzed. With regard to hospital beds, two measures were considered: available bed-days per patient and average length of stay.

In Table A1 the results of a regression analysis for both measures dependent on total available bed-days (per 1000 population for all eight treatment categories) are presented.

The r^2 coefficients for available bed-days per patient are significantly better than those for average length of stay. Moreover the similar regression analysis performed for bed turnover intervals suggests that they are rather unrelated to bed-days availability. These two features may support the appropriateness of the choice of the available bed-days per patient as the hospital bed supply measure.

Table A1. Comparison between the measures of hospital bed supply.

Treatment category	Available bed-days per patient against total available bed-days[a]			Average length of stay against total available bed-days			Bed turnover interval against total available bed-days		
	Constant (standard error)	Slope (standard error)	r^2	Constant (standard error)	Slope (standard error)	r^2	Constant (standard error)	Slope (standard error)	r^2
Child surgery	11.634 (2.940)	0.004 (0.002)	0.169	10.925 (1.722)	0.002 (0.001)	0.087	0.709 (2.902)	0.002 (0.002)	0.070
General medicine	11.365 (1.559)	0.005 (0.001)	0.553	11.126 (1.429)	0.004 (0.001)	0.470	0.239 (0.740)	0.001 (0.000)	0.216
General surgery	6.923 (1.606)	0.007 (0.001)	0.651	7.596 (1.504)	0.004 (0.001)	0.483	-0.673 (0.603)	0.002 (0.000)	0.600
Obstetrics and gynaecology	7.298 (0.789)	0.001 (0.001)	0.200	6.395 (0.583)	0.001 (0.000)	0.164	0.902 (0.446)	0.000 (0.000)	0.087
Ophtalmology	15.989 (4.635)	0.004 (0.003)	0.078	14.066 (3.690)	0.003 (0.002)	0.054	1.923 (2.225)	0.001 (0.002)	0.041
Otorhinolaryngology	13.892 (2.922)	0.001 (0.002)	0.015	9.105 (2.147)	0.002 (0.001)	0.120	4.787 (1.587)	-0.001 (0.001)	0.069
Traumatic and orthopaedic surgery	10.730 (5.224)	0.003 (0.004)	0.234	12.697 (5.133)	0.005 (0.003)	0.095	-1.697 (2.005)	0.004 (0.001)	0.271
Paediatrics	11.624 (2.403)	0.006 (0.002)	0.439	8.239 (2.319)	0.006 (0.002)	0.398	3.385 (1.418)	0.001 (0.001)	0.028

[a] From Table 3a.

APPENDIX B: PARAMETER ESTIMATION FOR DRAM

In the paper, to estimate the DRAM parameters (X,Y,α,β) for in-patient Polish care, the approach of Hughes (1978c) was followed.

The estimation was carried out based on the data for 22 administrative regions in Poland. As it was mentioned before (see section 2), it is assumed that the same utility function $Z(x,y)$ is applicable both to Poland and also to each of the individual regions.

The available data points are split into two equal groups (11 regions in each group). Initial estimates of (α,β) are provided, and the (X,Y) are estimated using the first data set (say R_A as from Table 1, section 3.4). Given these estimates of (X,Y) new (α,β) are then estimated from the second data set (R_B of Table 1). Given these new (α,β) further (X,Y) are then estimated using the data set and so on until successive estimates of (X,Y,α,β) only changed by a small amount.

The complete parameter estimation process is given in Figure A1. The linkage mechanisms (determination of Lagrange multipliers λ_l associated with each resource constraint -- Equation 4 section 2, and determination of θ_l, i.e., the ratio of type l resource at ideal levels to current usage at particular data points) are described in detail in Aspden (1980) or Hughes and Wierzbicki (1980).

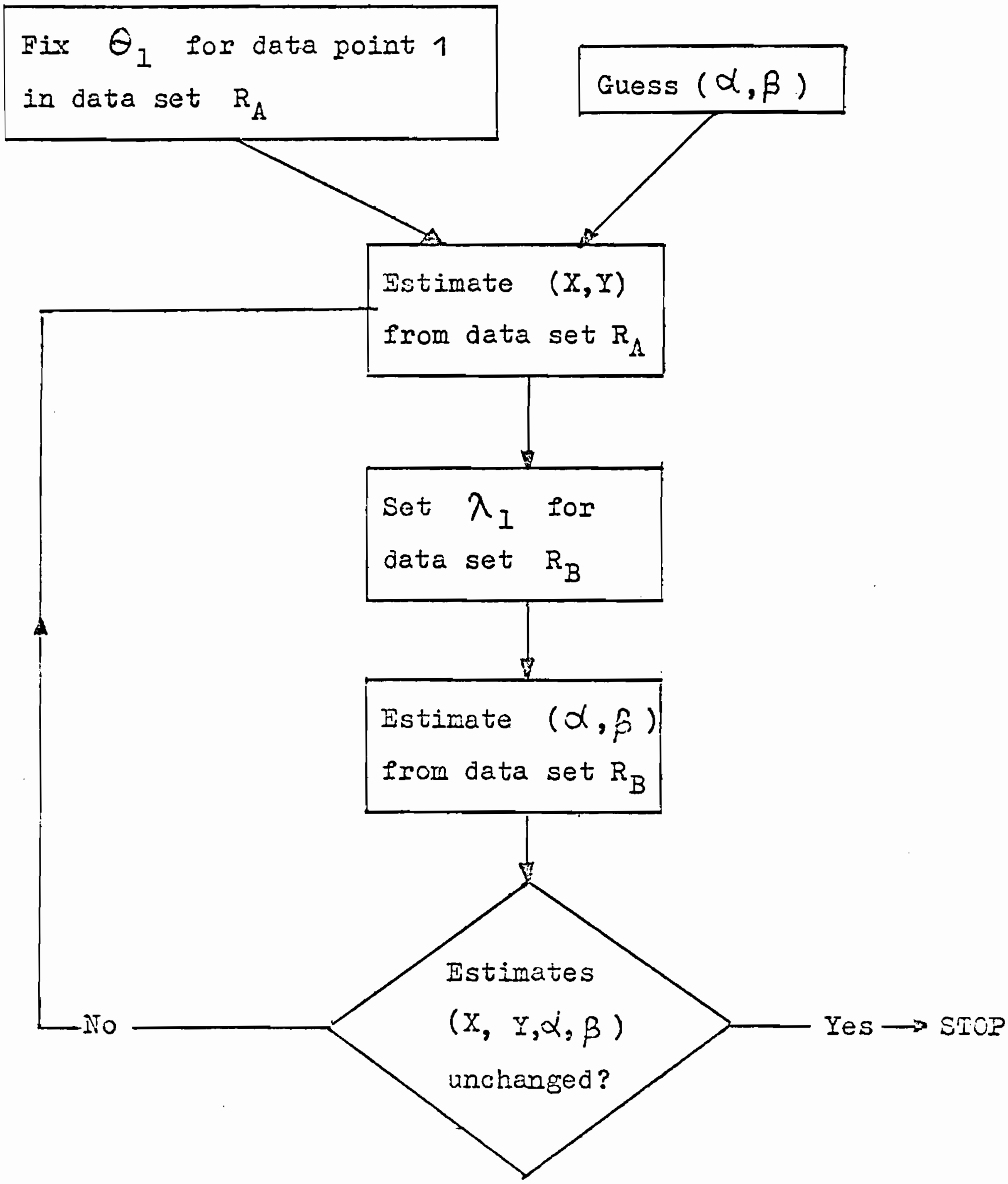

Figure B1. The parameter estimation process.

APPENDIX C: PARAMETER ESTIMATION FOR DRAM WITH TWO RESOURCES — HOSPITAL BEDS AND HOSPITAL DOCTORS: THE THREE TREATMENT CATEGORY CASE

In Table C1 the DRAM parameters derived from 1969 and 1970 data (22 points, two resource types: beds and doctors; three treatment categores: general medicine, general surgery, obstetrics and gynaecology) are presented. The structure of this table is similar to Table 8, for example, with the only difference being that the values resulting from the prediction mode (actual values for 1970 and predicted values using two sets of parameters: from 1969 data and from 1970 data).

Two parameter sets do not differ substantially one from the other, and therefore they have the same predictive ability.

Table C1. Two-resource (hospital beds and hospital doctors) DRAM parameter estimates for Polish in-patient hospital care: three treatment categories.

	Treatment category		Cover[a]					Supply levels: beds				
			x_j	α_j	$ss\hat{x}_j$	$ss\bar{x}_j$	gfx_j	Y_{j1}	β_{j1}	$ss\hat{y}_{j1}$	$ss\bar{y}_{j1}$	gfy_{j1}
1969 parameters	General medicine	2	48.90	0.622	0.770	1.123	0.686	24.30	6.331	0.330	0.494	0.668
	General surgery	3	34.10	1.687	0.633	0.704	0.900	19.90	8.561	0.676	0.848	0.798
	Obstetrics and gynaecology	4	61.00	1.285	0.332	0.711	0.466	11.00	6.709	0.368	0.500	0.736
1970 parameters	General medicine	2	44.50	0.711	0.712	1.123	0.634	25.40	4.965	0.402	0.494	0.814
	General surgery	3	32.80	1.700	0.670	0.704	0.952	20.10	8.185	0.674	0.848	0.795
	Obstetrics and gynaecology	4	59.90	1.282	0.314	0.711	0.441	12.10	3.872	0.365	0.500	0.730

	Treatment category		Supply levels: doctors					tgf_j[b]	ranking for:			
			Y_{j2}	β_{j2}	$ss\hat{y}_{j2}$	$ss\bar{y}_{j2}$	gfy_{j2}		gfx_j	gfy_{j1}	gfy_{j2}	tgf_j
1969 parameters	General medicine	2	2.90	0.958	0.338	2.965	0.114	0.314	2	1	1	1
	General surgery	3	2.30	1.322	1.623	4.430	0.366	0.490	3	3	3	3
	Obstetrics and gynaecology	4	1.00	2.381	0.333	0.996	0.334	0.468	1	2	2	2
1970 parameters	General medicine	2	3.00	0.999	0.299	2.965	0.101	0.308	2	3	1	1
	General surgery	3	2.30	1.845	1.626	4.430	0.367	0.496	3	2	3	2
	Obstetrics and gynaecology	4	1.00	2.711	0.318	0.996	0.320	0.520	1	1	2	3

[a] Cover refers to the number of persons per 1000 population who receive care.

[b] $tgf(\bar{J})=0.4230$ (1969)
$tgf(\bar{J}')=0.4213$ (1970)

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