A DEMOECONOMETRIC MODEL OF POLAND AND ITS APPLICATION TO COUNTERFACTUAL SIMULATIONS

Zbigniew Pawlowski
Instytut Ekonometrii
Akademia Ekonomiczna
Katowice

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FOREWORD

Roughly 1.6 billion people, 40 percent of the world's population, live in urban areas today. At the beginning of the last century, the urban population of the world totaled only 25 million. According to recent United Nations estimates, about 3.1 billion people, almost twice today's urban population, will be living in urban areas by the year 2000.

Scholars and policy makers often disagree when it comes to evaluating the desirability of current rapid rates of urban growth in many parts of the globe. Some see this trend as fostering national processes of socioeconomic development, particularly in the poorer and rapidly urbanizing countries of the Third World; whereas others believe the consequences to be largely undesirable and argue that such urban growth should be slowed down.

As part of a search for convincing evidence for or against rapid rates of urban growth, the Human Settlements and Services Area initiated in 1977 a research project to study the process of structural transformation in nations evolving from rural–agrarian to urban–industrial societies. Data from several countries selected as case studies are being collected, and the research is focusing on spatial population growth and economic development, and on their resource and service demands.

This report focuses on the Polish Case Study. Professor Pawlowski, from the Academy of Economics in Katowice, Poland, presents an econometric model using a number of economic, technological, and demographic variables in order to explain the past growth of the Polish economy. The model has been developed in order to show the existing interrelations of economic and demographic phenomena. From the results obtained, two simulation scenarios have been designed representing extreme situations in Polish economic history during the period 1960–1976: namely, moderate economic growth and fast economic growth plus an increase in the standard of living.

A list of papers in the Population, Resources, and Growth Series appears at the end of this report.

Andrei Rogers
Chairman
Human Settlements
and Services Area

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CONTENTS

1 INTRODUCTION

1.1 THE GENERAL AIM OF THE RESEARCH

The aim of the research described in this report is to understand the quantitative behavior of the growth of the Polish economy and to discover to what extent this growth is interrelated with demographic phenomena, especially migration from rural to urban areas.

The research has led to the construction of an econometric model explaining the variations of a number of key economic and demographic variables pertaining to Poland during the sixties and seventies. As will be seen later in this report, there is indeed a strong interdependence between demographic factors, particularly the population totals and their distribution among rural and urban areas, and economic factors.*

Once the model had been built and estimated, its equations were used to obtain the reduced form, which in turn made it possible to perform some counterfactual simulations and forecasts. The counterfactual scenarios were designed to show the impact that a change in the economic situation would have on demographic phenomena. Our experiments show that different economic policies can affect many of the demographic variables introduced into the model, in significantly different ways.

Since the model discussed in this report takes into account both economic and demographic factors and is basically of the econometric type from the point of view of its construction and estimation, it is referred to as the DemoEconometric Model of Poland (DEMP-1).

* The reciprocal impact of demographic variables and the state and dynamics of the Polish economy will be more fully reflected by a second version of the model, whose construction is now largely complete.

1.2 SOME CHARACTERISTIC FEATURES OF THE POLISH NATIONAL ECONOMY

Although we do not propose to give a detailed exposition of all the characteristic features of the Polish economy, it seems worthwhile to stress some basic points. It is hoped that this will help the reader to follow the rationale used in building the model, i.e., to understand the definitions of the variables and the reasons for including them in specific equations of the model.

The following 13 points are worth bearing in mind:

1. Poland is a country with a centrally planned national economy. This means that economic growth and many social phenomena are regulated by appropriate long-, medium-, and short-term plans, while market mechanisms play a small role or are totally excluded.
2. The industrial sector exhibits a steady, high rate of growth (an average annual rate of 8% for 1960–1970, and 12% for 1970–1978) and is almost totally composed of state and cooperative units.
3. The agricultural sector is predominantly private (about 85% of arable land is owned by peasants who operate private farms), is composed of rather small private farms (average area less than 7 hectares), and uses family labor.
4. The whole agricultural sector – both socialized and private – is heavily dependent on weather conditions. Inadequate rainfall, or rainfall concentrated in the wrong period of the year, can cause the yield of crops to be as much as 20% lower than under normal conditions. Moreover, it should be noted that the frequency of occurrence of years with adverse weather conditions is high (for instance, 8 such years out of the last 20).
5. The service sector is considered as unproductive, i.e., as adding nothing to the volume of national income, thus implying that it is subordinate to the industrial and agricultural sectors.
6. Prices of consumer, intermediate, and investment goods are to a large extent determined by the appropriate state authorities. Since there is virtually no market mechanism, prices are not necessarily equilibrium prices, and it may take some time before a price change occurs which puts demand and supply into equilibrium.
7. During the whole post-war period, Poland has been experiencing not only a situation of full employment but also a shortage of manpower in the socialized sectors. Total employment figures have been steadily rising.
8. The industrial sector, especially, has been drawing the labor force away from the agricultural and household sectors.
9. There has been a steady outflow of people – especially the young – from rural to urban areas. The reasons for these migrations are not so

much wage differentials (in fact during some periods the average income of farmers has been higher than the average wage in industry) but are connected more with seeking new ways of life, shorter working hours, and access to better services, culture, and education. The limit to out-migrations from rural to urban areas is set by the existing shortage of housing facilities in the urban areas.

10. Because of this limit to out-migrations there exists in Poland a special group, the peasant-workers. These are people who own and work on private farms, and simultaneously take full-time jobs in state firms, especially in industry, construction, or transportation. The peasant-workers provide a mainly unskilled or semiskilled labor force for these sectors.
11. The standard of living has been steadily increasing in real terms over the period studied.
12. Directly after 1945 and up to the late fifties, Poland experienced a high rate of population growth due to a high birth rate and a decreasing death rate. Since the early sixties the rate of population growth has significantly declined, primarily because of a decrease in birth rate, not only in urban but also in rural areas.
13. In the post-war period, a visible process of urbanization, especially in middle-sized towns, has occurred as a result of migrations and general population growth. In 1950 the number of towns in Poland with a population greater than 100,000 was 16, whereas now there are more than 30 such towns.

1.3 THE HISTORY OF ECONOMETRIC MACROMODELING IN POLAND

Before presenting DEMP-1 it seems worthwhile to devote a few lines to the history of econometric modeling of the Polish economy. This history goes back as far as 1964, when Pawlowski *et al.* (1964) published a paper presenting a small, six-equation model describing the existing interrelations between employment, investments, national income, foreign trade, and standard of living (as represented by the wage rate).* Four years later the same group of authors published a book (Pawlowski *et al.* 1968) in which they described a new and larger model. The new model contained 17 endogenous variables. The types of economic phenomena were roughly the same as those dealt with in the earlier model, except that the employment, investment, and national-income variables were disaggregated into two types, namely, the agricultural and nonagricultural productive sectors.**

*It is fair to say that the first attempt in Poland to use econometric methods for macroanalysis was that of Pajestka (1961), who tried to fit a Cobb–Douglas–Tinbergen production function to Polish data on national income, employment, and fixed productive assets. It is doubtful, however, if such an approach can be labeled as econometric modeling for the national economy.

**It is interesting to add that four years ago an analysis of the predictive power of that model was made by Artwig (1976) who found, surprisingly enough, that for some of the variables the model still provided fairly good predictions.

While the contributions in the field of macromodeling made during the sixties could be considered mainly as academic experiments, in the seventies models designed for the practical purpose of application in national planning began to appear. In this respect, mention should be made of the work of Kanton (1975) and, especially, that of Maciejewski and Zajchowski (1974) and Maciejewski (1976). A research group at the State Planning Commission built a couple of econometric models which were then used in practice, either for short-term prediction or for evaluation of expected effects induced by different envisaged variants of a medium-term economic plan. The econometric macromodels used by planners in the seventies contained more than 50 variables, and were thus much larger than those of the sixties. Maciejewski's models included as endogenous variables employment, man-hour inputs of labor, sectoral outputs (on the basis of classical econometrics, and not the input–output approach), national-income formation, production fixed assets, foreign trade, balance of payments, income flows, and consumer demand.

Finally, a large econometric model of the Polish economy is being built by Welfe and his team at the University of Lodz. Since the complete model has not yet been published it is difficult to say much about its character. From some of the papers published to date, which present different aspects of the model (see for instance Welfe and Debski 1976), it can be inferred that this model will assume a much higher degree of disaggregation and that it will combine the classical econometric approach with input–output analysis.

None of the models mentioned, however, have made provision for demographic variables. Consequently no analysis of the existing intercorrelations between the sphere of economics and that of demography has been made. To our knowledge, DEMP-1 is the first Polish econometric macromodel to approach this problem.

2 THE ENDOGENOUS VARIABLES

2.1 THE REALM OF THE MODEL

The extent to which DEMP-1 covers the realm of economic and demographic phenomena in Poland rests on two assumptions. First, the model must contain endogenous variables that reflect the process of economic growth of the country and make it possible to study the impact of the economic factors on the demographic factors and *vice versa*. Second, the whole model must be quantifiable (i.e., its parameters must be given numerical values stemming from the statistical estimation of the model) and the estimation must be based on officially published data (in this case data from the Statistical Yearbooks and other publications of the Polish Central Statistical Office).

While the first assumption makes it possible to ignore some phenomena which – although of an economic or demographic nature – are not crucial for the main area of analysis, the second assumption is a more stringent one. As happens in many countries, the system of Polish official statistical data is not wholly consistent with the real needs of econometric modeling and, therefore, data may not be available for some important variables. This precludes the introduction into the model of some of the variables which otherwise should be accounted for.

The various economic and demographic phenomena whose behavior and time variation have been accounted for and analyzed in the framework of the model, i.e., those that represent the endogenous sphere of the model, can be summarized by means of the following blocks of endogenous variables:

1. Employment variables
2. Investment variables
3. National income variables
4. Consumption variables
5. Demographic variables

As can be seen from this list, DEMP-1 does not consider a number of economic phenomena that are usually accounted for in quantitative macromechanism models. First, one should note that the model does not make provision for foreign trade; second, the model does not deal with price formation; and third, there are no financial-flow variables in the model. Thus, the model represents the "real-term" approach and provides no facilities for analysis of any eventual impact on the economy of changing price structures or inflationary trends.

There are three main reasons for this limitation of DEMP-1. The first is the desire to keep the size of the model (as measured by the number of its endogenous variables) within reasonable limits. The second is the problem of gaps in the data (especially for foreign trade). Finally, and perhaps most important, the reason for keeping strictly to the real-term approach is that, in a system of centrally planned economies with no (or almost no) market mechanism, prices do not usually follow a well-defined pattern or even exhibit a stochastic regularity. This is because administrative decisions determine the majority of prices.

While discussing the "real-term" approach it must be noted that DEMP-1 makes one exception to the rule of leaving out price variables. Among the endogenous variables of the model there is one variable that is defined as the consumer price index. Since the level of many individual prices largely determines the level of the standard of living, it was thought advisable to include the equation for this variable in the model. We should note, however, that this equation is only meaningful when the regularity of consumer price formation in the past is considered. Since the majority of prices are state-determined, the correlations observed in the past have no meaning for the future and, therefore, the consumer price index equation has no predictive meaning. In other words, there is nothing to guarantee that future price decisions will be based on considerations similar to those used in the past.*

2.2 THE LEVEL OF DISAGGREGATION

Although DEMP-1 is a highly aggregative model, it nevertheless makes provision for the partitioning of its endogenous variables. There are three main types of disaggregation used in the model; one refers to sectoral composition, another to territorial distribution of inhabitants of the country, and the third to the division of investment data into exogenous and endogenous components.

The sectoral disaggregation leads us to distinguish three separate sectors:

1. Nonagricultural – Sector I
2. Agricultural – Sector II
3. Services (non-productive sector of national economy) – Sector III

*This is a problem which we shall treat more fully in a later section. When modeling a national economy with centrally directed planning, one finds that some endogenous variables are, to a large extent, influenced by administrative decisions, and hence the corresponding model equations are not autonomous in the sense of providing reasonable insight into the future behavior of the given endogenous variable.

This classification follows the material-product concept used in planning and in the collection of statistics in the socialist countries. Thus, the first sector includes industry, construction, transportation, and some other minor components, while the third sector embraces such activities as administration, health services, education, culture, and personal services.

The second type of disaggregation used in the model applies to all demographic and employment variables and considers the rural and urban populations separately.

The model also makes provision for a third, rather special type of disaggregation. This applies to the investment variables which, besides being split according to the sectoral criterion, are also presented as the sum of their endogenous and exogenous parts, each part being statistically measured. This third type of disaggregation stems from a long-standing difficulty which has been present ever since the first attempts at the modeling of centrally planned economies. In some of the models constructed to date, investment has been treated as an endogenous variable, and in some other models as an exogenous variable. While the argument for the first approach is that, to a large extent, the present level of investment is determined by the past level and that, therefore, it is interesting to find out what is the relevant relationship, one cannot discount lightly the argument for the second approach: namely that, in a planned economy, investment is a major decision variable. Since there is much truth in both arguments, a method was found to split total investment data into two components, one representing the endogenous part and one the exogenous part of investment level; this method will be discussed in detail in Chapter 5.

2.3 THE LIST OF ENDOGENOUS VARIABLES OF DEMP-1

We now present the complete list of endogenous variables of the model, together with the corresponding symbol for each variable. These symbols will be used consistently throughout the report.

- Y_1 – national income (computed according to the material-product concept) from Sector I, in billion zlotys, constant prices
- Y_2 – employment (i.e. number of persons employed) in Sector I (excluding peasant-workers), in millions
- Y_3 – employment of peasant-workers in Sector I, in millions
- Y_4 – employment in Sector II, in both private and socialized farms, including estimated part-time work on private farms by family members, in millions
- Y_5 – urban population, in millions on January 1st of each year
- Y_6 – rural population, in millions on January 1st of each year
- Y_7 – total employment in Sector I ($Y_7 \equiv Y_2 + Y_3$), in millions
- Y_8 – national income from Sector II, in billion zlotys, constant prices
- Y_9 – employment in Sector III, in millions

Y_{10} – total employment ($Y_{10} \equiv Y_2 + Y_3 + Y_4 + Y_9$), in millions
Y_{11} – endogenous investment in Sector I, in billion zlotys, constant prices
Y_{12} – endogenous investment in Sector II, in billion zlotys, constant prices
Y_{13} – endogenous investment in Sector III, in billion zlotys, constant prices
Y_{14} – total investment in Sector I, in billion zlotys, constant prices
Y_{15} – total investment in Sector II, in billion zlotys, constant prices
Y_{16} – total investment in Sector III, in billion zlotys, constant prices
Y_{17} – total investment in the whole national economy ($Y_{17} \equiv Y_{14} + Y_{15} + Y_{16}$)
Y_{18} – total national income ($Y_{18} \equiv Y_1 + Y_8$), in billion zlotys, constant prices
Y_{19} – labor productivity in Sector I, in thousand zlotys value-added output per person, constant prices
Y_{20} – labor productivity in Sector II, in thousand zlotys value-added output per person, constant prices
Y_{21} – average labor productivity in Sectors I and II, in thousand zlotys value-added output per person, constant prices
Y_{22} – consumption out of private funds, in billion zlotys, constant prices*
Y_{23} – overall index of consumer prices
Y_{24} – urban birth rate, per 1000 inhabitants
Y_{25} – rural birth rate, per 1000 inhabitants
Y_{26} – urban death rate, per 1000 inhabitants
Y_{27} – rural death rate, per 1000 inhabitants
Y_{28} – net urban in-migration rate, per 1000 inhabitants**

In addition, when considering the reduced form of the model and simulations based upon it, it is useful to introduce yet another auxiliary endogenous variable Y_{29}, the net rural out-migration rate. Variables Y_{28} and Y_{29} have the same numerators while the denominators are different: in the case of Y_{28} the denominator is the urban population total while for Y_{29} the denominator is the rural population total.

Whenever a variable is expressed in constant prices the price system of 1971 has been used. Furthermore, all the endogenous variables which refer to employment levels or indicate demographic rates are measured as yearly averages.

DEMP-1 has altogether 28 endogenous variables. Of these, 9 variables (namely $Y_2, Y_3, Y_4, Y_7, Y_9, Y_{10}, Y_{19}, Y_{20}, Y_{21}$) belong to the employment block, 7 variables form the investment block ($Y_{11}, Y_{12}, Y_{13}, Y_{14}, Y_{15}, Y_{16}, Y_{17}$), 3 variables express national income (Y_1, Y_8, and Y_{18}), 2 variables refer to the

*That is, consumption financed by private financial funds resting in the hands of the population. Variable Y_{22} thus does not include the so-called "social consumption", which is financed directly by the state (education, health care, etc.).

**This is net in-migration in the sense of a surplus of people moving from rural to urban areas over those who move from towns to the countryside.

standard of living (Y_{22} and Y_{23}), and, finally, 7 variables belong to the demographic block. Since 4 variables (Y_7, Y_{10}, Y_{18}, and Y_{21}) are definition totals or averages of other endogenous variables, this eventually reduces the size of the model to 24 autonomous endogenous variables. Thus, the model is of a moderate size.

3 THE EXPLANATORY VARIABLES OF THE MODEL

3.1 THE CHOICE OF EXPLANATORY VARIABLES

Having explained the endogenous variables of the model, something must now be said about the way the structural equations* for these variables were constructed. The approach adopted was to include in a single equation all the explanatory variables that – in the light of existing economic theory – influence the corresponding endogenous variable. Although logically sound, this approach usually yielded too few explanatory variables for an adequate fit of the model to the statistical data used for its estimation.

In order to improve the fit, the following procedure was adopted. For every endogenous variable whose variation was inadequately explained by the variables suggested by economic theory, a tentative list of possible alternative explanatory variables was compiled, the "candidates" in this list being chosen either on the basis of common sense and as working hypotheses or on the grounds of observed high correlation (in absolute value) with the endogenous variable concerned. To illustrate the next stages in the procedure, we will consider in detail the treatment of the list of additional explanatory variables for the national income from Sector I, Y_1.

Let $\{X_i\}$ denote the set of candidates collected to serve as additional explanatory variables for the national income (Y_1). The $\{X_i\}$ variables are chosen by a procedure, first described by Pawlowski (1973), which assumes that the following conditions must be obeyed:

1. All the variables suggested by economic theory must be included as explanatory variables in the equation explaining the behavior of variable Y_1.
2. The equation must provide an adequate fit with the statistical data; therefore if the variables referred to under condition 1 do not give such

*The terminology first introduced by Koopmans (1950) is used throughout this report.

a fit, additional variables from $\{X_i\}$ must be used to ensure the required degree of fit.

3. The explanatory variables which will finally be included in the equation must be as independent of one another as possible.
4. The number of explanatory variables included in the equation must be small. This leads to the conclusion that, from all the possible subsets of explanatory variables from $\{X_i\}$, together with the variables suggested by economic theory, a subset of explanatory variables will be finally adopted which – besides obeying conditions 2 and 3 –contains the minimum number of elements.

With reference to condition 2, let us note that the requirement of adequate fit will usually be a constraint on the coefficient of multiple correlation or on the value of the standard error of the equation. Condition 3, on the other hand, requires all the explanatory variables to be as independent as possible. These requirements are present for two reasons: to avoid multicollinearity and to maximize the amount of information provided by the explanatory variables.* Together with condition 4, condition 3 leads us to consider correlation matrices, e.g. P_j, whose elements consist of correlation coefficients of two types of variables. The first type are variables belonging to a chosen subset of the set $\{X_i\}$, and the second type are explanatory variables suggested by economic theory.

Since the condition of least correlation among the explanatory variables is equivalent to maximizing the determinant of the corresponding matrix of correlation coefficients, it is immediately found that this algorithm leads to the choice of a vector of explanatory variables, e.g. j_0, that satisfies the relation

$$|P_{j_0}| = \max_{\{X_i\}} |P_j| \tag{3.1}$$

To conclude our remarks on the method of choosing the explanatory variables, it should be noted that condition 4, which requires that the number of such variables should be minimized, is especially important when the statistical sample-size is small. This is due to the fact that when statistical data are scarce and the number of explanatory variables (and parameters to be estimated) is large, the standard errors of estimation of these parameters will usually be high, thus endangering the correctness of any inference made from the model.

The approach described in this section applies to all the stochastic equations of the model except when the variables suggested by economic theory provide a sufficiently good fit; this is, however, seldom the case. It should also be noted that, for a number of equations, the set $\{X_i\}$ of possible additional explanatory variables contains only one or two elements, mainly due to the lack of relevant statistical data.

*The impacts of two highly correlated variables are almost parallel, and therefore give little additional information about the mechanism of formation of the dependent variable in the equation.

3.2 THE MAIN TYPES OF EXPLANATORY VARIABLE IN THE MODEL

The explanatory variables appearing in different stochastic equations of the model belong to six distinct groups:

1. Lagged endogenous variables
2. Quantitative, purely exogenous variables
3. Quantitative decision variables
4. Dummy variables of purely exogenous character
5. Dummy variables intricately connected with planning processes
6. Other nonlagged endogenous variables of the model

The lagged endogenous variables are mostly investment variables, and they are extensively used because the investment cycles in the Polish economy are rather long; hence, the effects of investment outlays are delayed. The maximum time-lag used in the model is three years, and this applies to investment in Sector I, i.e., in nonagricultural productive activity. As can be seen from the list of all the predetermined variables of the model (Section 3.4), DEMP-1 also makes use of other lagged endogenous variables, with lags of one or two years.

The group of quantitative, purely exogenous variables has only four members, namely the unit variable, the time variable, the square-of-time variable, and the balance of payments. On the other hand, there are many variables in the third group: the quantitative decision variables. Without enumerating all of them here we shall focus our attention on some which are of special interest. Those of primary importance are the variables representing the level of exogenous investment, either in Sector I or in Sector II. As will be seen later, in the section discussing the results of the estimation of the model, these two "classical" decision variables exert their influence on a number of phenomena, of both an economic and a demographic nature.

Another decision variable of interest is the construction of flats in urban areas.* Such flats are constructed either directly by the state or through cooperatives, and the finance for such activities comes finally from the national budget. This variable was found to have some impact both on the birth rate and on employment levels. New flats in urban areas attract people who have been working only on their private farms and who have decided to take jobs in Sector I, hoping eventually to move permanently to the towns.

DEMP-1 makes extensive use of dummy variables. Since, however, the reasons for introducing such variables are to a large extent connected with the economic system of the country, some of them need to be carefully explained. For this reason we will examine the problem of dummy variables in more detail in the next section.

*As may be easily seen, this variable, if expressed in monetary terms, would represent a part of total investment outlay in Sector III. To avoid the cumbersome problem of price changes in residential construction the variable in question is measured in the model in a quantitative way – in units of 10^3 rooms.

3.3 THE PROBLEM OF DUMMY VARIABLES

The system of centralized economic planning presupposes direct state intervention in economic processes in order to achieve long-term and short-term economic and social policy targets. This means that not all the economic variables are autonomous, in the sense of being free to vary according to regular patterns established in the past. On the contrary, since deviations from planned trajectories occur, the economic system is subject to various interventions, which consist not only of changes of decision variables but also of restrictions or limitations (or encouragements) of particular activities. The consequences of these interventions are that the economic processes (variables) thus affected do not follow a regular pattern over time but instead exhibit some discontinuities.

The easiest and best parameter-saving approach in such a case is to introduce into the model an appropriately defined dummy variable.* During the period 1960–1976 which is covered by the model there occurred various such discontinuities in the growth pattern, so DEMP-1 makes use of a number of appropriate dummy variables.

Two of these variables call for special attention. The first one, X_{22}, is a variable which assumes the value 1 for the years 1971–1976, and zero for all earlier years. The reason for introducing this variable (which, as can be seen from the results of the estimation of the model, proved to be very important) is that in 1971 and subsequent years a special economic and social policy was pursued in Poland. This policy was markedly different from the one followed during the sixties, and consisted, broadly speaking, of fast economic growth coupled with a substantial rise in the standard of living of the population. This new policy not only generated higher investment outlays and a higher consumption level – which could be dealt with in the model by assuming appropriate changes in such variables – but also caused a number of other effects of a more quantitative character (greater efficiency of management, better work motivation, new consumption patterns, attaching new value to family life, etc.). To account summarily for all these changes and discontinuities in the former pattern of economic (and also demographic) processes, it was thought best to introduce into the model a special dummy variable. As will be seen later, the variable X_{22} affects a major part of the endogenous variables of the model. For the sake of easy reference, X_{22} will henceforward be referred to as the "fast economic growth" variable.

Another interesting dummy variable of a similar type is X_{21}, which is the heavy investment variable. For a number of years, heavy investment was pursued as the underlying economic policy. This in turn caused several repercussions that are important enough to be taken into account when modeling the economy; hence the use of X_{21}. This variable is equal to 1 for the years when especially heavy investment outlays were made and equal to 0 for all other

*Dummy variables can also be used if it is thought that policy shifts affect the coefficients of the explanatory variables. See, for instance, Pawlowski (1977).

years. (Note that $X_{22} = 1$ for years when there was both heavy investment and a fast rise in the standard of living, whereas only the first condition is necessary for $X_{21} = 1$.)

The reader must be warned, however, that equations containing such dummy variables as X_{21} or X_{22}, while adequately explaining the past, have only a restricted predictive power. The coefficient of the dummy variable expresses the size of the impact of qualitative factors which are concealed by the dummy variable, but there is nothing to guarantee that similar policy measures will have the same result in the future. Therefore an equation of the model can only be considered as "safe" for predictive purposes if the user predicts that the future will be such that the dummy variables can be set equal to zero.

Finally, let us note that DEMP-1 also has two dummy variables of a purely exogenous character. These are connected with the fact that Polish agriculture is highly sensitive to adverse weather conditions, i.e., to droughts or to heavy rainfalls occurring in the wrong season. Since such bad weather conditions may cause the yield of crops to be as much as 20% lower than their expected level and since low agricultural production usually has far-reaching repercussions, it was thought necessary to introduce appropriate dummies; these later proved to be significant.

3.4 THE LIST OF PREDETERMINED VARIABLES

We now present the complete list of the predetermined variables of the model together with their corresponding symbols.

X_1 – fixed assets in agriculture, in billion zlotys, constant prices
X_2 – real wage index in socialized nonagricultural sectors
X_3 – use of artificial fertilizers in agriculture (100 kg/ha)
X_4 – difference between X_2 and the index of real per capita income in private agriculture
X_5 – exogenous investment in Sector I, in billion zlotys, constant prices
X_6 – exogenous investment in Sector II, in billion zlotys, constant prices
X_7 – exogenous investment in Sector III, in billion zlotys, constant prices
X_8 – flats constructed in urban areas, in units of 10^3 rooms
X_9 – balance of foreign trade (exports – imports), current zlotys
X_{10} – unit variable
X_{11} – time variable, assuming the value 1 for 1960, the value 2 for 1961, etc.
X_{12} – square-of-time variable
X_{13} – variable Y_1 lagged one year
X_{14} – variable Y_{14} lagged two years
X_{15} – variable Y_{14} lagged three years
X_{16} – variable Y_{15} lagged one year
X_{17} – variable Y_{15} lagged two years

X_{18} – variable Y_{19} lagged one year

X_{19} – weather dummy variable, assuming the value 1 for years when agricultural yields suffered greatly from exceptionally dry or wet weather, and equal to zero for other years

X_{20} – bad agricultural output dummy variable, assuming the value 1 for years when $Y_{8,t} < Y_{8,t-1}$, and equal to zero for other years

X_{21} – heavy investment dummy variable, assuming the value 1 for years when the policy of especially heavy productive investment was pursued, and equal to zero for other years

X_{22} – fast economic growth dummy variable, assuming the value 1 for the period 1971–1976, and equal to zero for other years

X_{23} – demographic echo dummy variable, assuming the value 1 for years when large generations, born during the post-World War II baby boom, came to maturity and started reproducing; for other years this variable is equal to zero

X_{24} – variable Y_5 lagged one year

X_{25} – variable Y_6 lagged one year

As can be seen, this list contains 25 predetermined variables. Eight of them are lagged endogenous, four are of a purely exogenous character, eight are exogenous to the model but are, at the same time, decision variables, and five are dummy variables.

In Section 5.2, where the method of splitting total investment into its endogenous and exogenous components is presented, some additional predetermined variables will be used. However, since these variables only appear in that section, they are not listed here among the predetermined variables in use for the whole model.

4 THE SAMPLE PERIOD AND THE STATISTICAL DATA

One of the basic assumptions made at the start of this research was that the model would be based on the data which are officially published by the Central Statistical Office of Poland in its Statistical Yearbooks of Poland.

The time-series data used for the estimation of the model cover the period 1960–1976; when the research leading to DEMP-1 started in 1978, statistical data for 1977 and 1978 were not yet available. Although the length of this period is not excessive and a sample of 17 observations is not large, it was thought better to keep to such a restricted sample than to extend it by using the data pertaining to the fifties. The first five or six years of the decade 1950–1959 were still part of the period of post-war reconstruction. The economic and demographic structural parameters at that time may have had substantially different values from the present ones, not only for technological reasons but also due to the significantly different system of economic management that then existed. The last years of the fifties were perhaps not so strikingly different from the present, but, for a number of variables, data were either missing or were compiled on the basis of totally different systems of classification, thus making it necessary to exclude them on comparability grounds. In some cases it was necessary to rework even the data for the period 1960–1976, to ensure either a consistent classification system or a uniform price system.

In the pages which follow, Figures 1–13 illustrate some characteristic features of a number of the model variables, most of which are endogenous in character. In order to show their variation more clearly, all the variables have been expressed as indexes, based on a 1960 index level of 100. Moreover, particular figures usually show indexes of two or three variables which are either logically related or are otherwise of interest for simultaneous analysis.

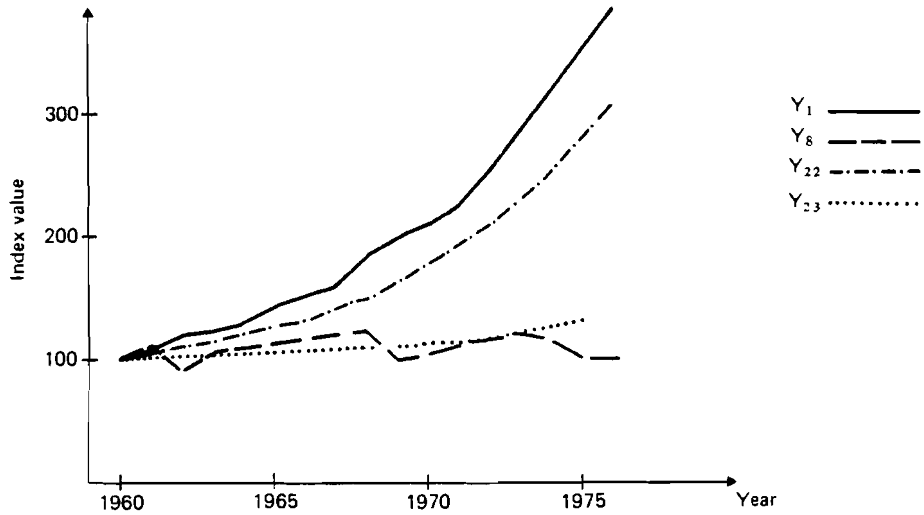

FIGURE 1 National income and consumption variables.

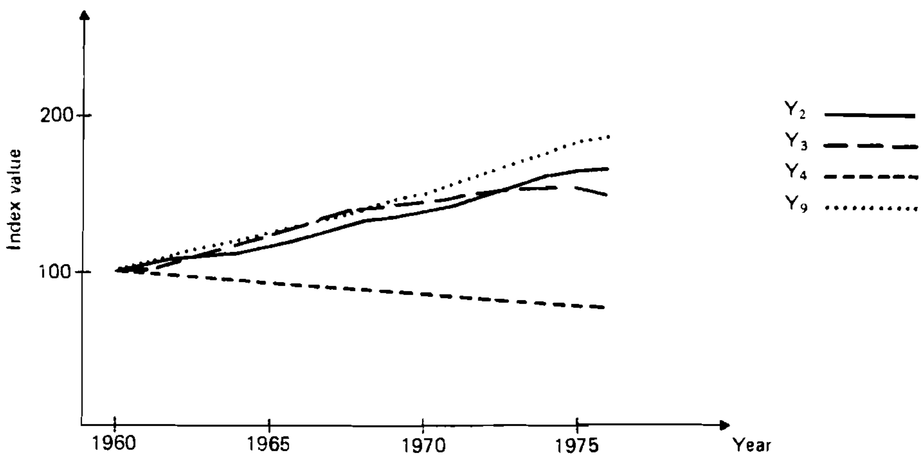

FIGURE 2 Employment variables.

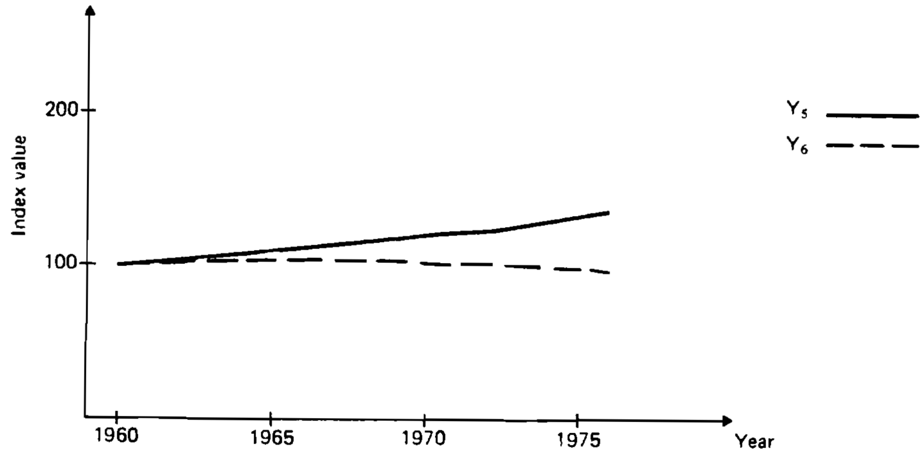

FIGURE 3 Population variables.

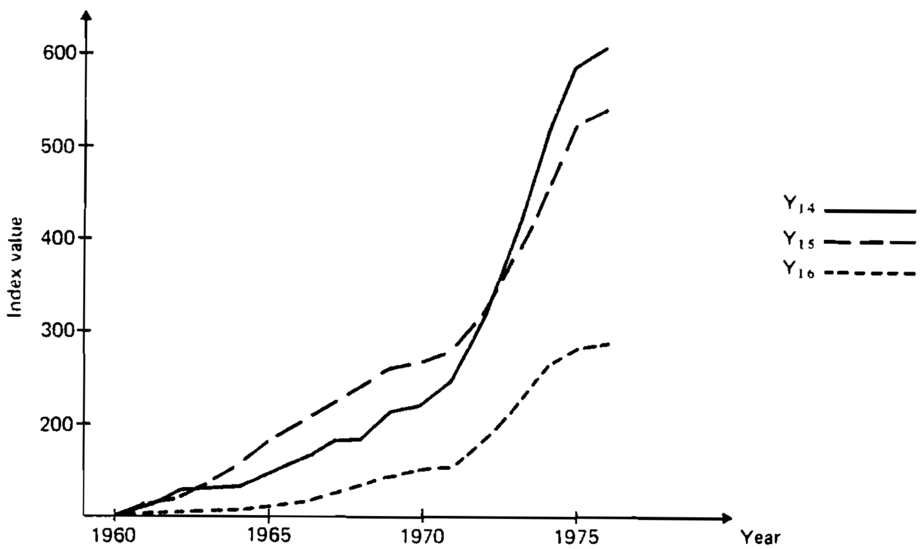

FIGURE 4 Total investment variables.

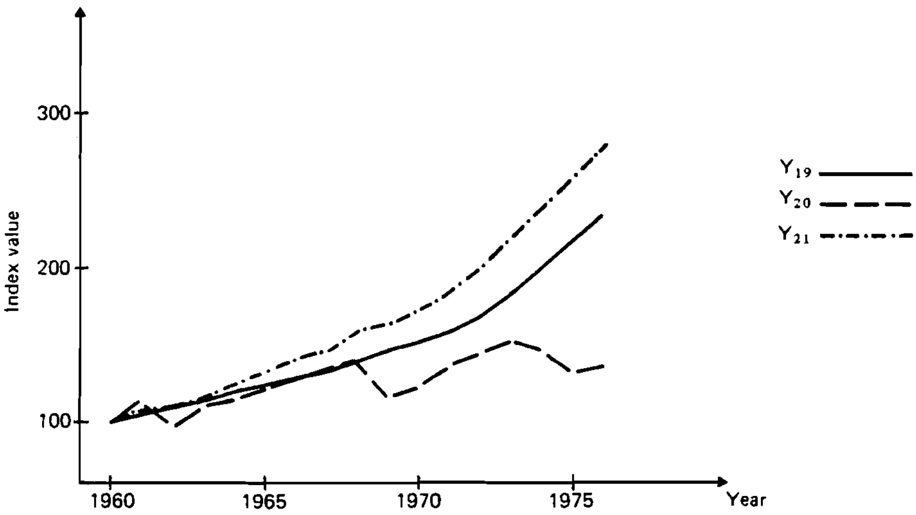

FIGURE 5 Labor productivity variables.

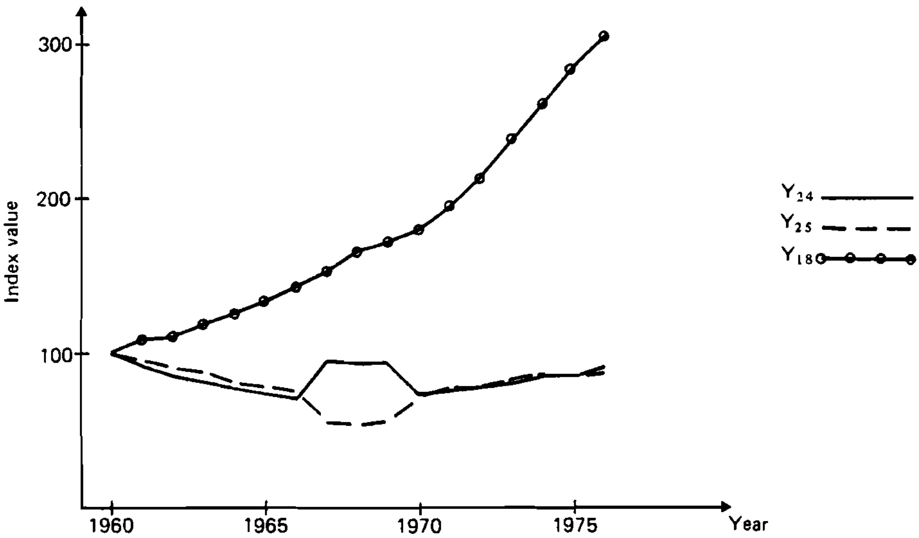

FIGURE 6 Birth rate variables and total national income.

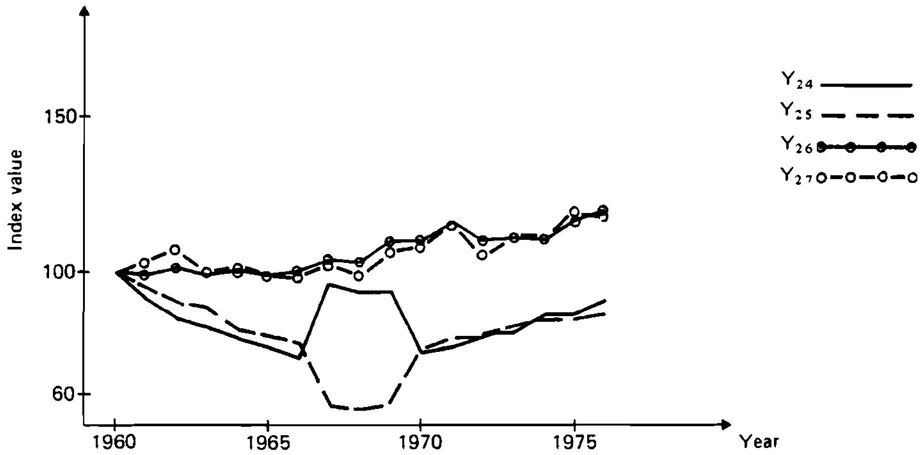

FIGURE 7 Birth rate and death rate variables.

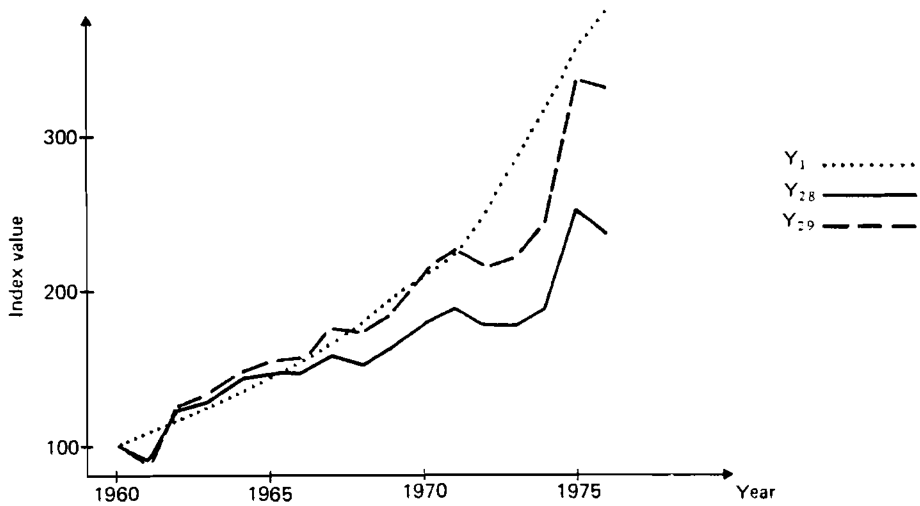

FIGURE 8 National income from Sector I and rates of rural out-migration and urban in-migration.

FIGURE 9 Endogenous and exogenous investment in nonagricultural productive sectors.

FIGURE 10 Endogenous and exogenous investment in agriculture.

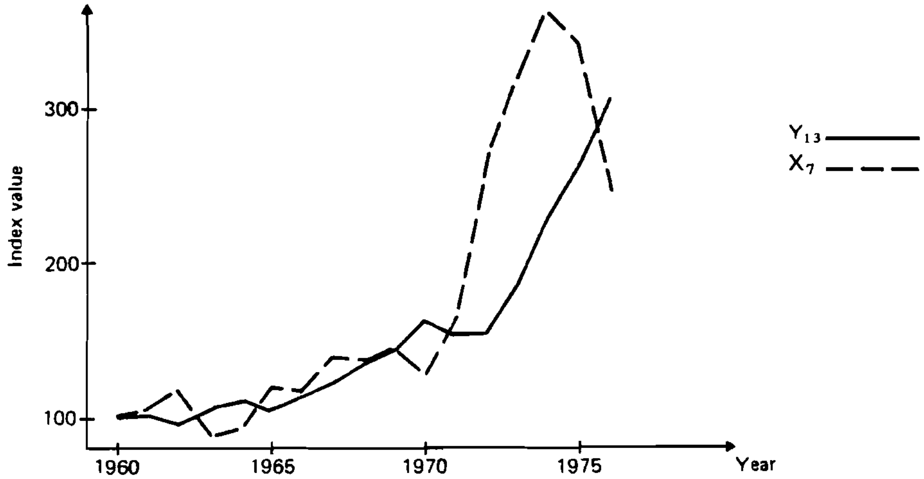

FIGURE 11 Endogenous and exogenous investment in services.

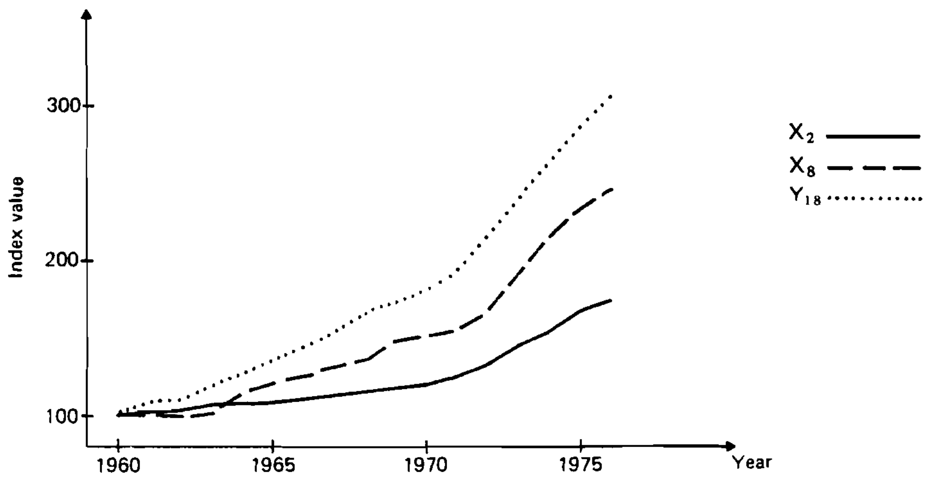

FIGURE 12 Real wages, construction of flats, and national income.

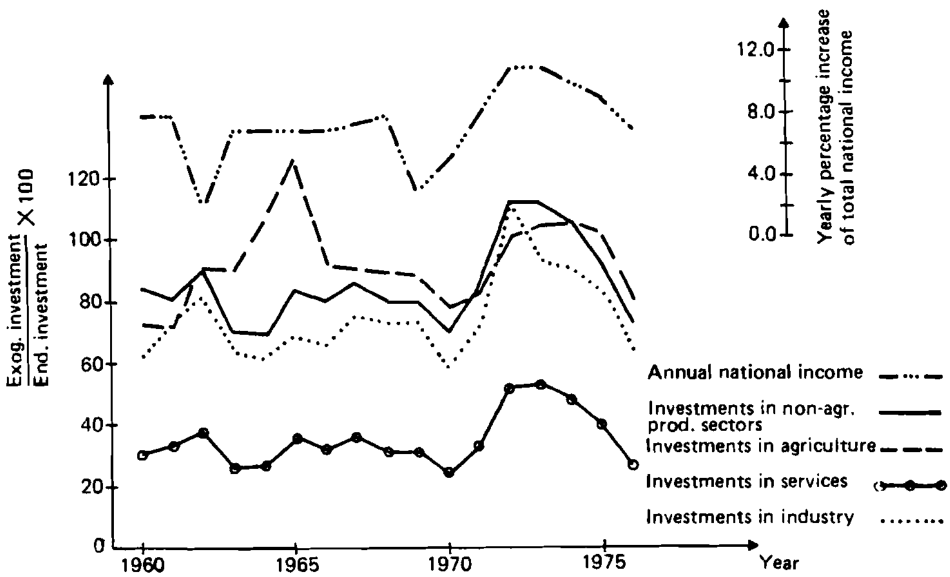

FIGURE 13 Percentage ratio of sectoral exogenous investment to sectoral endogenous investment.

5 ENDOGENOUS AND EXOGENOUS INVESTMENT

5.1 THE PROBLEM

When the various disaggregations used in the model were discussed in Section 2.2, it was pointed out that the sectoral total investment variables were split into two components: endogenous and exogenous investment.

The rationale underlying such an approach is twofold. First, one must take into account the fact that, in every country with a centrally planned economy, investment is one of the key decision variables. Every year, large financial outlays are made by the state to finance investment. The level and the distribution of these outlays depend on the economic policy which, in turn, is assumed to achieve optimal targets stemming from long-range economic and social policies and not from current needs. On the other hand, not all investment outlays are exogenous. Some are influenced by previous investment outlays. Since the average length of the investment cycle is significantly longer than one year, investment activities started in the past are not all finished before the beginning of the current year. This means that if such investments are not being discontinued (which would usually involve some serious loss) they must still be financed. Thus we arrive at the concept of the endogenous part of total investment as that which is induced by previous investment outlays:

$$\text{Total investment} = \text{endogenous investment} + \text{exogenous investment} \qquad (5.1)$$

The statistical data published by official authorities, however, make no such distinction and always refer to the total investment. A method, therefore, had to be found to perform the disaggregation shown in Eq. (5.1), and our solution to this problem is presented in the next section.

5.2 THE METHOD OF ESTIMATING THE ENDOGENOUS INVESTMENT

From the discussion above, the model for determining the endogenous part of investment in year t should have the following general form:

$$J_{\text{end},t} = f(J_{\text{total},t-1}, J_{\text{total},t-2}, \ldots, J_{\text{total},t-c}) \tag{5.2}$$

where $J_{\text{end},t}$ denotes endogenous investment in year t, $J_{\text{total},t-i}$ denotes total investment i years prior to year t, and c is a positive integer such that investment cycles of length greater than c occur extremely infrequently. The practical difficulties connected with this model are not negligible. The integer c is usually not known and, even if it were, the number of variables on the right-hand side of Eq. (5.2) would normally be so large that a problem would still exist. For this reason it was necessary to look for other models which, although simpler, would still provide a good approximation for the estimation of endogenous investment.

After experimenting with the data, a more simple one-year-lag model was found. This simpler model assumes that there is a relation between total investment shares in national income during two consecutive years and that, eventually, such shares also depend on an exogenous variable. Such a model can be written as

$$\frac{J_{\text{total},t}}{Y_{18,t}} = \alpha_1 \left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} \right) + \alpha_2 X_t + \alpha_3 \tag{5.3}$$

where Y_{18} denotes total national income (see Section 2.3), X stands for the auxiliary exogenous variable, and $\alpha_1, \alpha_2, \alpha_3$ are constant parameters. Once the model has been estimated, i.e., once the numerical estimates a_1, a_2, a_3 of α_i parameters are known, the endogenous part of the investment in year t can be computed as

$$J_{\text{end},t} = \alpha_1 J_{\text{total},t-1} \left(\frac{Y_{18,t}}{Y_{18,t-1}} \right) \tag{5.4}$$

After the endogenous investment has been estimated, one can then deduce the level of exogenous investment from the total investment, by using Eq. (5.1).

5.3 ESTIMATION OF INVESTMENT RELATIONS

Total investment figures were divided into their endogenous and exogenous parts for all three sectors studied. Furthermore, and just for curiosity's sake, the same experiment was performed with the statistical data referring to total investment allocated in industry (note that industry is a subsector of Sector I in DEMP-1). The results of the estimation of the model shown in Eq. (5.3) for these four cases were as follows:

For Sector I:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.229 = 0.6063\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.222\right) + 0.0435(X_{22} - 0.294) \tag{5.5}$$

where X_{22} is the fast economic growth dummy variable defined in Section 3.3.

For Sector II:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.045 = 0.5758\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.0434\right) + 0.001174\, X'_{11} \tag{5.6}$$

where X'_{11} is a time variable defined in a slightly different way from that in Section 3.4: X'_{11} is equal to –7.5 in 1961, –6.5 in 1962, etc., and finally $X'_{11} = +7.5$ in 1976.

For Sector III:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.236 = 0.3272\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.226\right) + 0.0042(X_{26} - 0.3125) \tag{5.7}$$

where X_{26} is a dummy variable assuming the value 1 in the years 1970–1976 and equal to zero for other years; thus X_{26} differs from X_{22} in only one respect, namely that for 1970 $X_{26} = 1$ while $X_{22} = 0$. Variable X_{26} reflects a shift in economic policy connected with encouraging increased employment in Sector III.

For the industrial sector alone:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.143 = 0.6371\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.137\right) + 0.0338(X_{22} - 0.3125) \tag{5.8}$$

where, again, X_{22} is the fast economic growth dummy variable.

Under the assumption that the rate of growth of national income is approximately constant over a period of time, one can easily use Eq. (5.4) to estimate the average length of the sectoral investment cycle. For instance, if we put $Y_{18,t}/Y_{18,t-1}$ numerically equal to 1.06, we can rewrite Eq. (5.4) as

$$J_{\text{end},t} = 1.06 \cdot a_1 \cdot J_{\text{total},t-1} \tag{5.9}$$

where a_1 stands for the estimate of α_1. By using the geometric series sum formula and substituting the value of a_1 from Eqs. (5.5)–(5.8), we find that the average length of investment cycle in Sector I is almost 2.75 years, in Sector II it is 2.6 years, in Sector III it is as great as 8.1 years, and in the industrial sector taken separately it is 3.1 years.

6 THE ESTIMATION OF THE MODEL

6.1 THE STRUCTURAL FORM OF THE MODEL

Before going into details of the estimation results for all the equations of DEMP-1, it seems advisable to describe first the general shape of the model. The equations presented below correspond to the subsets of explanatory variables which were thought most appropriate in view of the procedure adopted when building the equations (see Section 3.1).

The model is predominantly linear, with only two exceptions: the variables Y_5 and Y_6. The fact that the majority of the equations are linear does not stem from a personal belief that the various interrelations are in fact linear, but rather it is a necessary result of the small size of the statistical sample (time-series data referring to only 17 yearly observations). When presenting the structural form, the symbol L is used for a linear relation, whereas the non-linear relations have been explicitly written down. The symbol ξ denotes the random component of each stochastic equation. As usual, ξ has been assumed to be a random variable with zero expectation and finite variance for every such equation.

If straightforward identities are excluded, the model contains 15 equations to be estimated. Of these, 7 are interdependent linear equations, and 8 are either linear recursive or are such that the endogenous variable explained by the equation depends only on the predetermined variables.

$$Y_1 = L(Y_7, X_{10}, X_{13}, X_{14}, X_{15}, X_{22}, \xi)$$
$$Y_2 = L(Y_1, Y_5, X_{10}, X_{11}, \xi)$$
$$Y_3 = L(Y_1, Y_{14}, X_2, X_8, X_{10}, \xi)$$
$$Y_4 = L(Y_6, Y_{15}, X_{10}, X_{22}, \xi)$$
$$Y_5 \equiv (1 + \frac{Y_{24} - Y_{26} + Y_{28}}{1000})X_{24}$$
$$Y_6 \equiv (1 + \frac{Y_{25} - Y_{27} - Y_{29}}{1000})X_{25}$$

$$
\begin{aligned}
Y_7 &\equiv Y_2 + Y_3 \\
Y_8 &= L(X_1, X_3, X_{10}, X_{19}, X_{22}, \xi) \\
Y_9 &= L(Y_1, Y_5, Y_{22}, X_{10}, \xi) \\
Y_{10} &\equiv Y_2 + Y_3 + Y_4 + Y_9 \\
Y_{14} &\equiv Y_{11} + X_5 \\
Y_{15} &\equiv Y_{12} + X_6 \\
Y_{16} &\equiv Y_{13} + X_7 \\
Y_{17} &\equiv Y_{14} + Y_{15} + Y_{16} \\
Y_{18} &\equiv Y_1 + Y_8 \\
Y_{19} &= L(X_{10}, X_{13}, X_{18}, \xi) \\
Y_{20} &= L(X_{10}, X_{16}, X_{17}, X_{19}, \xi) \\
Y_{21} &\equiv \alpha(t) Y_{19} + [1 - \alpha(t)] Y_{20} \\
Y_{22} &= L(Y_8, Y_{20}, Y_{23}, X_{10}, X_{20}, X_{22}, \xi) \\
Y_{23} &= L(Y_8, Y_{10}, X_9, X_{10}, \xi) \\
Y_{24} &= L(Y_{22}, X_{10}, X_{22}, X_{23}, \xi) \\
Y_{25} &= L(Y_{22}, X_{10}, X_{22}, \xi) \\
Y_{26} &= L(Y_1, X_{10}, X_{11}, X_{12}, \xi) \\
Y_{27} &= L(Y_8, X_{10}, X_{11}, X_{12}, \xi) \\
Y_{28} &= L(Y_{14}, X_4, X_{10}, X_{21}, \xi)
\end{aligned}
$$

The equations for the variables Y_{11}, Y_{12}, and Y_{13} do not appear here since these variables (sectoral endogenous investments) have been dealt with using the method described in Sections 5.2 and 5.3. It should also be noted that the variable Y_{21} is defined by means of an identity which assumes the form of a weighted average with the weights changing over a period of time. This is because Y_{21} represents the average level of labor productivity, and this level depends on the relative (variable over a period of time) shares of Sector I and Sector II.

6.2 THE METHODS OF ESTIMATION OF STRUCTURAL EQUATIONS

Because of the system of interrelations among the nonlagged endogenous variables dictated by the structural form of the model, two different methods of parameter estimation had to be used. For the recursive equations and for the equations with only predetermined endogenous variables, the ordinary least-squares method was used. As can be seen from the shape of the structural equations presented in Section 6.1, this procedure was appropriate for variables $Y_8, Y_{19}, Y_{20}, Y_{22}, Y_{24}, Y_{25}$, and Y_{28}.

All the remaining nonlagged endogenous variables form the interdependent part of the model, so that use of the ordinary least-squares method would yield biased estimates. It was therefore decided to use the double-least-squares method instead (see, for example, Theil 1961).

However, one further remark must be made in this context. Since the 17-observation sample size is smaller than the total number of predetermined variables appearing in the model, the moment matrix $X_K' X_K$ of these predetermined variables would be singular, and consequently, it would not be possible to obtain estimates of the parameters of the interdependent structural relations.

For this reason the size of the matrix $X_K' X_K$ was reduced with respect to the number of predetermined variables. This resulted in the use of a submatrix in order to express the explanatory endogenous nonlagged variables as a function of the model's predetermined variables. This submatrix, denoted for example by $\hat{X}_K' \hat{X}_K$, was obtained as follows:

1. All the lagged endogenous variables were omitted from $X_K' X_K$.
2. Submatrix $\hat{X}_K' \hat{X}_K$ was assumed to be a 10×10 matrix composed of exogenous variables that had a large variance and had little correlation with each other.*

Besides calculating the values of the parameter estimates by both methods of estimation, two goodness-of-fit parameters were computed. The first one was the standard error of the equation – denoted by s – and the second was the so-called coefficient of random variation, defined as the percentage ratio of s to the observed arithmetic mean value of the variable whose variations were explained by the equation in question. This coefficient of random variation will be denoted by C.

Standard errors of estimation of structural parameters were also computed, and these are given in Section 6.3, as values in parentheses under the corresponding parameter estimates. These standard errors, however, are of only limited informative value since they were computed by using the classical formulas which assume a lack of autocorrelation between the random components. In fact, for almost half of the estimated equations the value of the Durbin–Watson statistic was found to be less than 2.0, a fact which suggests the existence of positive first-order autocorrelation of ξ_t.

6.3 THE RESULTS OF THE ESTIMATION

In this section we present the results of the estimation of the stochastic structural equations of the model, for each equation in turn. For the sake of simplicity, the symbol representing the random component has been omitted from each equation. These results are as follows:

$$\begin{aligned} Y_1 = {} & \underset{(102.6)}{-61.097} + \underset{(22.2)}{9.274Y_7} + \underset{(0.29)}{1.147X_{13}} + \underset{(0.74)}{0.516X_{14}} - \underset{(0.51)}{1.217X_{15}} \\ & + \underset{(12.4)}{21.496X_{22}} \end{aligned} \tag{6.1}$$

*The choice of 10 as the number of exogenous variables forming the submatrix $\hat{X}_K' \hat{X}_K$ was somewhat arbitrary. On the other hand, with the total number of such variables in the model being almost twice as large (17), this restriction leads to the construction of a submatrix $\hat{X}_K' \hat{X}_K$ which is numerically well-behaved, i.e., nonsingular.

$$Y_2 = \underset{(4.5)}{13.287} + \underset{(0.007)}{0.0024Y_1} + \underset{(0.33)}{0.557Y_5} + \underset{(0.07)}{0.326X_{11}} \tag{6.2}$$

$$Y_3 = \underset{(0.62)}{1.024} + \underset{(0.0005)}{0.0013Y_1} + \underset{(0.0013)}{0.0015Y_{14}} - \underset{(0.007)}{0.0092X_2} + \underset{(0.0066)}{0.0005X_8} \tag{6.3}$$

$$Y_4 = \underset{(4.4)}{27.080} - \underset{(0.28)}{0.974Y_6} - \underset{(0.005)}{0.044Y_{15}} - \underset{(0.20)}{0.538X_{22}} \tag{6.4}$$

$$Y_8 = \underset{(18.5)}{140.826} + \underset{(0.006)}{0.076X_1} + \underset{(0.13)}{0.391X_3} - \underset{(3.9)}{21.224X_{19}} - \underset{(6.8)}{12.473X_{22}} \tag{6.5}$$

$$Y_9 = \underset{(0.43)}{-1.694} + \underset{(0.0007)}{0.00045Y_1} + \underset{(0.03)}{0.209Y_5} + \underset{(0.0009)}{0.00051Y_{22}} \tag{6.6}$$

$$Y_{19} = \underset{(8.5)}{26.492} + \underset{(0.02)}{0.079X_{13}} - \underset{(0.33)}{0.115X_{18}} \tag{6.7}$$

$$Y_{20} = \underset{(0.48)}{10.079} - \underset{(0.13)}{0.088X_{16}} + \underset{(0.12)}{0.220X_{17}} - \underset{(0.51)}{1.914X_{19}} \tag{6.8}$$

$$Y_{22} = \underset{(491.3)}{-1711.2} + \underset{(0.04)}{0.076Y_8} - \underset{(36.4)}{13.084Y_{20}} + \underset{(4.8)}{24.253Y_{23}} - \underset{(2.4)}{7.125X_{20}}$$

$$+ \underset{(29.4)}{112.314X_{22}} \tag{6.9}$$

$$Y_{23} = \underset{(14.3)}{-30.493} - \underset{(0.04)}{0.070Y_8} + \underset{(0.8)}{6.431Y_{10}} - \underset{(0.2)}{0.235X_9} \tag{6.10}$$

$$Y_{24} = \underset{(1.7)}{16.266} + \underset{(0.00004)}{0.00019Y_{22}} + \underset{(0.8)}{0.042X_{22}} + \underset{(1.1)}{2.446X_{23}} \tag{6.11}$$

$$Y_{25} = \underset{(3.3)}{24.339} - \underset{(0.08)}{0.0122Y_{22}} + \underset{(3.2)}{5.407X_{22}} \tag{6.12}$$

$$Y_{26} = \underset{(0.7)}{8.287} - \underset{(0.002)}{0.0041Y_1} - \underset{(0.004)}{0.0053X_{11}} + \underset{(0.007)}{0.0175X_{12}} \tag{6.13}$$

$$Y_{27} = \underset{(0.9)}{10.244} - \underset{(0.008)}{0.018Y_8} - \underset{(0.007)}{0.0132X_{11}} + \underset{(0.003)}{0.0058X_{12}} \tag{6.14}$$

$$Y_{28} = \underset{(0.6)}{5.587} + \underset{(0.005)}{0.020Y_{14}} + \underset{(0.003)}{0.006X_4} - \underset{(0.72)}{0.139X_{21}} \tag{6.15}$$

TABLE 1 Parameters of goodness-of-fit.

Endogenous variable	Parameters of fit s	$C(\%)$	Endogenous variable	Parameters of fit s	$C(\%)$
Y_1	10.92[a]	1.7	Y_{22}	24.27[a]	4.5
Y_2	0.13[b]	2.3	Y_{23}	1.67[c]	1.7
Y_3	0.03[b]	4.5	Y_{24}	1.56[d]	9.3
Y_4	0.20[b]	2.0	Y_{25}	2.08[d]	10.5
Y_8	5.69[a]	4.4	Y_{26}	0.18[d]	2.3
Y_9	0.04[b]	2.0	Y_{27}	0.28[d]	3.3
Y_{19}	0.82[e]	1.2	Y_{28}	1.11[d]	12.0
Y_{20}	0.83[e]	6.5			

[a]Billions of zlotys, 1971.
[b]Millions of persons.
[c]Index points, based on 1960 value = 100.
[d]Persons per 1000 inhabitants.
[e]Thousands of zlotys per person.

The parameters s and C, which summarize the goodness-of-fit of the estimated equations, are presented in Table 1.

6.4 SOME COMMENTS ON THE ESTIMATION RESULTS

Although the estimated structural equations themselves provide the most precise information about the quantitative relations which exist between the variables representing economic and demographic phenomena in Poland, it seems, nevertheless, worthwhile and necessary to comment further upon some of them.

As shown by Eq. (6.1), which explains the variations of Y_1, national income stemming from Sector I is strongly dependent on labor inputs and on lagged investments in that sector. The negative sign of the coefficient of X_{15} (the variable representing investments lagged three years) can probably be explained by frequent shifts of economic policy on the intensity of investments and the rate of growth of output. Also of interest is the positive coefficient of the fast economic growth dummy variable X_{22}. Its relatively high value shows that the new economic and social policy pursued in the years 1971–1976 produced visible results and helped to speed up economic growth in the area of nonagricultural productive activity. To conclude our comments on the Y_1 equation, it should be noted that, since X_{13} denotes Y_1 lagged one year and since the coefficient of X_{13} is very near to 1.0, Eq. (6.1) can explain *changes* in nonagricultural national income rather than its absolute value.

In Eq. (6.2), which explains the behavior of Y_2, all the estimated coefficients have the correct signs. There is obviously a positive feed-back from the level of production (represented here by Y_1) to employment and, in fact, the corresponding coefficient is positive. The positive coefficient of Y_5 can be interpreted as reflecting the policy of full employment pursued in Poland. This policy is found to influence about 55% of the urban population increase to take up employment in Sector I; the remaining 45% are either employed in Sector III or are not formally employed (e.g., students, married women with children). Out-migration from the towns to rural areas is negligible. Finally, it should be noted that the equation for Y_2 contains also a time trend which has been introduced because, over the period studied, the work participation coefficient of women has been steadily increasing.

The equation explaining Y_3, Eq. (6.3), is interesting because it illustrates the specifically Polish phenomenon of peasant-workers. The inflow of such people to Sector I is found to depend positively on three factors. As evidenced by the estimated equation, the number of peasant-workers is regulated not only by the level of economic activity in Sector I but more particularly by the level of investment in this sector.* The third factor to affect the number of peasant-workers is the level of housing construction in urban areas. This can be explained by the fact that many peasants start working in nonagricultural firms, having in mind the future possibility of leaving their farms, and emigrating to urban areas (this applies especially to young people). Obviously, the fact that housing construction is more intensive increases the chances that potential migrants will be able to obtain urban housing, and therefore encourages them to take such steps. Less obvious is the interpretation of the negative sign connected with variable X_2. Perhaps this arises because the periods of fast growth in wage-rates have coincided with the periods when private farming enjoyed prosperity and its outlook for the future was also bright. These good prospects for private farming may have been a factor reducing the willingness to emigrate to urban areas.

Variable Y_4 was defined as employment in agriculture. As can be seen from Eq. (6.4), the level of employment in this sector is influenced by the amount of investment in the sector and by the general level of economic activity. The establishment of the new policy of fast and intensive economic growth at the beginning of 1971 created many new jobs, particularly in the industrial and building sectors. Owing to the lower birth rate, the size of new generations in towns has always been noticeably smaller than in rural areas, and, since there were no reserves in manpower in urban areas (except for the natural reserves due to new generations reaching maturity), the additional workers for Sector I had to be found in rural areas. The negative coefficient of variable Y_6 provides an insight into the autonomous mechanism of emigration to the towns. With improved investment policies, agriculture now does not need as many people to work in the fields and raise cattle as it did in previous years.

The next stochastic equation to be estimated, Eq. (6.5), is that for variable Y_8, which represents national income generated in Sector II. As may be expected, such income depends positively on fixed assets and on the amount of fertilizer used. On the other hand, Y_8 depends negatively on X_{19} and X_{22}. The first of

*It should be noted that a large proportion of the peasant-workers are hired by construction firms for which they provide the unskilled labor force, still very much in demand.

these variables is a dummy, taking the value 1 in the years of unfavorable weather conditions, so it is no surprise that its coefficient is negative. The second, X_{22}, is the fast economic growth dummy variable and therefore one should expect its coefficient to be positive. Unfortunately, however, this dummy variable only proved to be significant as far as Sector I is concerned. For half of the years, when $X_{22} = 1$, the variable X_{19} also assumed the value 1, which means that while the policy of fast growth was pursued, adverse weather conditions for agriculture were very often present. Hence the relevant coefficient proved to be negative.*

As may be seen from Eq. (6.6), the variable Y_9, i.e., employment in services, depends on Y_1, Y_5, and Y_{22}. The first of these variables has a positive coefficient, and this is justified by the fact that economic planners consider services as a sector subordinate to industrial and related activities. This means that services are supposed to expand in relation to the overall level of nonagricultural activity. The coefficient of Y_5 shows that about 20% of the urban population increase is used as an addition to the labor force in Sector III. Finally, the positive coefficient of Y_{22} reflects the situation arising when an increase in the private consumption fund is coupled with an increase in that part of Sector III that provides direct services to individuals.

The equation explaining Y_{19}, Eq. (6.7), is of a simple, autoregressive character. Labor productivity in Sector I is seen to depend on its previous level, but since the corresponding coefficient is negative, one infers that this productivity tends to oscillate when all other factors remain constant. The other explanatory variable is X_{13}, which is really a proxy for one-year lagged investments in Sector I. The positive and statistically significant coefficient of X_{13} shows that such investment plays an active role and causes labor productivity to increase.

The level of labor productivity in agriculture is also found to be dependent on investment [Eq. (6.8)]. Attention should be paid, however, to the negative sign of the coefficient of X_{19} which is the bad weather dummy variable. In fact, the impact of adverse weather conditions – as we have already mentioned in Section 1.2 – is very serious.

The equation reflecting the mechanism of Y_{22}, Eq. (6.9), is of interest. We find that the level of private consumption is very sensitive to the agricultural production level, i.e., to the level of the domestic food supply. The large and positive coefficient of X_{22} reflects the fact that 1971–1976 was a period when much was done to increase private consumption. On the other hand, it is more difficult to explain the positive dependence of Y_{22} on the level of consumer prices. However, one is tempted to advance the opinion that the results of the estimation reflect a specific phenomenon. The substantial increase in the population's income, which occurred during a period when the supply of consumer

*This, by the way, is a good example of what has already been pointed out, namely that equations with dummies specific to central planning are seldom of a predictive character. In fact, there is no reason to suppose that a future policy of fast economic growth in Sector I would result in the level of national income derived from agriculture declining.

goods did not increase enough to satisfy demand, was coupled with price increases. Because of a strong desire to increase their levels of consumption, the consumers spent more (in real terms) even when the level of prices rose.

The level of consumer prices Y_{23} [described by Eq. (6.10)] depends on agricultural production, on the balance of foreign trade, and on variable Y_{10}. In the first two cases the coefficients are negative as expected. An improved home supply of food provides no stimulus for price increases and a better foreign trade situation means that price increases to cut consumption are not necessary. A more detailed explanation is needed with respect to Y_{10}, i.e., total employment. This variable can be considered as a proxy for the total amount of income earned by the population, which – in the existing situation of limited supply of consumer goods – is an important price-inflating factor. Thus, the whole equation for variable Y_{23} can be thought of as reflecting the mechanism used for equilibrating the purchasing power of the population with the supply of consumer goods, with food always being the most important item of private consumption.

Eqs. (6.11)–(6.15), that pertain to variables Y_{24}–Y_{28}, explain the observed variations of the demographic variables of DEMP-1. It is fair to say that, although these variables do show some degree of dependence on economic factors, one might have hoped that they would show a stronger dependence and thus a lower level of random variation.

It is interesting to note that the birth rates in urban and rural areas react in different ways to a rise in private consumption. While in towns an increase in private consumption is found to stimulate births, the opposite effect occurs in rural areas where a better standard of living means less babies. Both Y_{24} and Y_{25} depend positively on the variable X_{22}. This can be explained by the fact that the new economic and social policy started in 1971 has had, among other targets, the aim of attaching more value to family life and larger families.

The equations pertaining to urban and rural death rates (variables Y_{26} and Y_{27}), Eqs. (6.13) and (6.14), show these rates to depend negatively on economic growth (variables Y_1 and Y_8, respectively). This seems logical since better economic conditions induce better living conditions and more sophisticated health care. It should not be overlooked, however, that in both equations there is a quadratic trend and the coefficient of variable X_{12}, i.e., of the square-of-time variable, is positive. This means that, in spite of the favorable influence of economic growth on death rates, there is a tendency for these rates to increase in the future. This long-term upward trend may be due to at least two factors. One is the aging of the population, causing the proportion of old people (for whom the probabilities of death are obviously higher) to increase with time. The second may be connected with air pollution and other industrial side effects.

The last stochastic equation of the model, Eq. (6.15), pertains to migrations from rural to urban areas (involving variable Y_{28}). Here again, the coefficients connected with the explanatory variables have the correct signs. Migration is found to be positively correlated with the level of investments in Sector I:

it has already been pointed out that increasing the level of investments creates an incentive for migration, both because in-migrants from rural areas find many jobs in the building sector and because investments mean new, larger-scale non-agricultural productive activity. The migration variable is also found to depend positively on the urban–rural wage differential (variable X_4). This, it should be pointed out, is in strong contrast to the behavior of peasant-workers, whose decisions to take a second job do not depend on wage considerations. Perhaps the reason is that while peasant-workers can still count on the income derived from their farms, emigrants from rural areas must rely solely on the monetary income derived from their work in the towns. Finally, variable Y_{27} is found to depend negatively on variable X_{21}, i.e., on the heavy investment dummy variable. This is quite understandable. In past years when heavy investment outlays in productive sectors (and especially in Sector I) were made, the construction of housing facilities was noticeably slowed down and this – by cutting down the supply of potential new accommodation – induced a decrease in the level of migration.

7 THE REDUCED FORM OF THE MODEL

7.1 THE LIMITED REDUCED FORM

Once the estimation of the structural form has been performed it becomes possible to find the reduced form of the model. From the application point of view this latter form is even more important, since it makes possible a number of different inferences, such as straightforward prediction,* multiplier analysis, or counterfactual simulation.

Solving the set of equations (6.1)–(6.15), together with the relevant identities concerning the nonlagged endogenous variables, gives us the reduced form of the linear part of the model. If, for the time being, we also omit from our considerations the investment variables,** we obtain the limited reduced form of DEMP-1. The matrix of the coefficients of this limited reduced form is presented in Appendix A.

Since the numerical values of the parameters can be directly seen – as presented in Appendix A – there is no need to discuss them further. The qualitative side of the limited-reduced-form problem is much more interesting, namely, the information concerning the predetermined variables that enter into the different equations of the reduced form. Such information is provided by Table 2, in which the rows correspond to the various nonlagged endogenous variables while the columns indicate the predetermined variables. Whenever the coefficient of the reduced-form equation is different from zero, the symbol + appears at the intersection of the appropriate row and column. If, however, the coefficient is equal to zero then the symbol 0 appears in Table 2. Thus, the number of +

*A distinction is made here between the two types of econometric inference about the future, namely prediction, which consists of inference from a causal-type model, and forecasting, based on any noncausal model (trend, autoregressive, adaptive, etc.).

**Because the investment variables form a special block of the model, which is very different from the remaining equations in terms of the method of splitting total investments and the form of investment equations, which take the form of definition identities (see Section 6.1).

TABLE 2 Zero and non-zero coefficients of the limited reduced form.

Endogenous variable	Predetermined variables of DEMP-1																					
	X_1	X_2	X_3	X_4	X_5	X_6	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
Y_1	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_2	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_3	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_4	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Y_7	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_8	+	0	+	0	0	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	+	0
Y_9	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_{10}	0	+	0	0	+	+	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_{18}	+	+	+	0	+	0	+	0	+	+	0	+	+	+	0	0	0	+	0	0	+	0
Y_{19}	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	+	0	0	0	0	0
Y_{20}	0	0	0	0	0	0	0	0	+	0	0	0	0	0	+	+	0	+	0	0	0	0
Y_{22}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	0	0	0	+	0	0	+	0
Y_{23}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	0	0	0	+	0	0	+	0
Y_{24}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	0	+	0	+	+	0	+	+
Y_{25}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	+	+	0	+	+	0	+	0
Y_{26}	0	+	0	0	0	0	+	0	+	+	+	+	+	+	+	0	0	+	0	0	+	0
Y_{27}	+	0	+	0	0	0	0	0	+	+	+	0	0	0	0	0	0	+	0	0	+	0
Y_{28}	0	0	0	0	+	0	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	0

symbols in a row indicates the total number of predetermined variables influencing the endogenous variable, and the location of the + symbols shows which ones these variables are. On the other hand, the 0 symbols indicate that a predetermined variable has no impact on the endogenous variable.*

A closer look at Table 2 reveals that there are three blocks of endogenous variables that are dependent upon similar predetermined variables. These blocks are: (Y_{22}, Y_{24}, Y_{25}), $(Y_1, Y_2, Y_3, Y_7, Y_9, Y_{10}, Y_{18}, Y_{26})$, and (Y_8, Y_{27}); other endogenous variables exhibit specific individual patterns. It should be noted that the variables forming the first block depend on the largest number of predetermined variables, and that Y_4 depends on the smallest number (2) of them.

Perhaps it is even more interesting to note those particular predetermined variables which most often have an impact on the endogenous variables of the model. In doing this we shall, however, exclude from our considerations the unit variable, since it obviously must appear in all linear equations.

There are 8 predetermined variables which appear to have an impact on a large number of endogenous variables. These are variables $X_2, X_5, X_8, X_{11}, X_{13}, X_{14}, X_{15}$, and X_{22}. Checking their definitions we find that three of them, namely X_{13}, X_{14}, and X_{15}, are lagged endogenous variables, three are exogenous decision variables (X_2, X_5, and X_8), one is the fast economic growth dummy variable X_{22}, and the last is the time variable X_{11}. This particular pattern of the most often-recurring predetermined variables has important and far-reaching implications. We should note that the three exogenous decision variables are very crucial since they refer to wage level, to construction of flats, and to exogenous investment in Sector I. This inference is further strengthened by the widespread influence of variable X_{22}, which summarizes the effects of the 1971–1976 shift in economic policy, aimed at fast economic growth coupled with a rise in the standard of living.

On the other hand, one must not overlook the importance of the time element, which manifests itself in two ways. First, it acts directly through the variable X_{11} which – as may be seen from Table 2 – influences quite a number of endogenous variables. Second, time enters the economic mechanism by means of lagged endogenous variables. As has been pointed out earlier, three such variables, namely X_{13}, X_{14}, and X_{15}, appear frequently as influencing factors. While X_{13} has a lag of one year, X_{14} is lagged two years, and X_{15} incorporates the even longer lag of three years. When one notes that, in the reduced form, other lagged variables, namely X_{16}, X_{17}, and X_{18}, also appear (though not often) and that one of them has a two-year lag, then it becomes apparent that time is a factor that really plays a major role in the quantitative mechanism of the Polish economy.

The existence of lags, and especially of the long ones, implies that it is quite likely that the results of economic decisions undertaken by appropriate

*Had the structural form of the model been fully interdependent, the nonlagged endogenous variables would be dependent on all the predetermined variables. In fact this is not so because some of the structural form equations are of the recursive or simple form; in the latter case, the endogenous variable is dependent on only some of the predetermined variables.

planning and other institutions will not always be felt immediately but will rather be spread over a period of time, sometimes with quite substantial delays.

As can be seen from Table 2, more than half of the endogenous variables of the model are subject to such time-delayed impacts. This applies to variables $Y_1, Y_2, Y_3, Y_7, Y_9, Y_{10}, Y_{18}, Y_{22}, Y_{25}$, and Y_{26}, all of which depend on the lagged variables X_{13}, X_{14}, and X_{15}, and on the time variable X_{11}. Variable Y_{20} also shows a time-delayed response to stimuli since it depends (among other factors) on variables X_{16} and X_{17}, which are investments in Sector II with lags of one and two years, respectively.

7.2 THE EXTENDED REDUCED FORM

This section will be devoted to a brief exposition of how one could find the reduced form for all the endogenous variables of DEMP-1. This would involve adding to Table 2 (or to a generalized version of Table 2, presenting not only the symbols 0 and + but also numerical values of the coefficients) an appropriate number of rows corresponding to the variables omitted thus far. These variables are $Y_5, Y_6, Y_{11}, Y_{12}, Y_{13}, Y_{14}, Y_{15}, Y_{16}, Y_{17}$, and Y_{21}. The additional rows of the table must be constructed according to the specific way in which an endogenous variable enters the model and the structural form of the model.

Let us consider first the variables Y_5 and Y_6. In Section 6.1, where the structural form was described, the equations for these two variables were written as

$$Y_5 = \left(1 + \frac{Y_{24} - Y_{26} + Y_{28}}{1000}\right) X_{24} \tag{7.1}$$

and

$$Y_6 = \left(1 + \frac{Y_{25} - Y_{27} - Y_{29}}{1000}\right) X_{25} \tag{7.2}$$

If we now substitute for $Y_{24} - Y_{29}$ their limited-reduced-form expressions (see Appendix A) we obtain the reduced-form expressions for Y_5 and Y_6, respectively. Let us note in this context that, because of the non-linearity of Eqs. (7.1) and (7.2) due to the multiplication of the terms in parentheses by X_{24} and X_{25}, the reduced-form coefficients will not be constant but will vary in time. The reduced-form coefficients for the variables Y_5 and Y_6 are given in Appendix B.

Next we turn our attention to the variable Y_{21}, defined as the average labor productivity in Sectors I and II. This may be expressed as

$$Y_{21} \equiv \alpha(t) \cdot Y_{19} + [1 - \alpha(t)] Y_{20} \tag{7.3}$$

where

$$\alpha(t) = \frac{Y_2 + Y_3}{Y_2 + Y_3 + Y_4} \tag{7.4}$$

TABLE 3 Values of $\alpha(t)$ coefficients.

Year	$\alpha(t)$	Year	$\alpha(t)$	Year	$\alpha(t)$
1960	0.38	1966	0.45	1972	0.53
1961	0.39	1967	0.46	1973	0.54
1962	0.40	1968	0.48	1974	0.56
1963	0.41	1969	0.49	1975	0.56
1964	0.42	1970	0.50	1976	0.57
1965	0.44	1971	0.51		

Hence, in order to derive the reduced-form coefficients for the equation pertaining to Y_{21}, one must find (from Appendix A) the reduced-form coefficients for Y_{19} and Y_{20}, and then weight them with $\alpha(t)$ and $1 - \alpha(t)$, respectively. Table 3 gives the values of $\alpha(t)$ for all years within the period 1960–1976, and it can be seen that $\alpha(t)$ is not constant over time. Hence, the reduced-form coefficients for Y_{21} will also vary with time in correspondence with the changing share of employment in Sector I.

Finally, one could also envisage the construction of the reduced-form equations for the investment variables. It was shown in Chapter 5 that the investment structural equations are essentially used for splitting total sectoral investments into their endogenous and exogenous parts, and that, in fact, they do not enter the proper structural form of the model. In spite of this, an approximation to the reduced-form relations for either total or endogenous investment variables can be found.

As was shown in Section 5.2, the endogenous part of investment was computed by means of the following formula

$$J_{\text{end},t} = \alpha_1 J_{\text{total},t-1} \cdot \frac{Y_{18,t}}{Y_{18,t-1}} \tag{7.5}$$

Taking into account the fact that total investment equals endogenous plus exogenous investment, Eq. (7.5) can be written as

$$J_{\text{end},t} = \alpha_1 (J_{\text{end},t-1} + J_{\text{exog},t-1}) \cdot \frac{Y_{18,t}}{Y_{18,t-1}} \tag{7.6}$$

Now $J_{\text{end},t-1}$, $J_{\text{exog},t-1}$, and $Y_{18,t-1}$ are all predetermined variables and, as such, they should enter the reduced-form equation. The variable $Y_{18,t}$ is, by definition, equal to $Y_{1,t} + Y_{8,t}$. The reduced-form coefficients for these variables are known and can be found in Appendix A. By summing the coefficients of each predetermined variable one can easily obtain the reduced form for $Y_{18,t}$. This completes the task since all the variables appearing on the right-hand side of Eq. (7.6) will be of predetermined character, thus providing the reduced-form equation for the sectoral endogenous investment variable. Note that because of the nonlinearity of Eq. (7.6) the coefficients of the reduced form will not be constant in time, but will vary depending on the variations of $J_{\mathrm{end},t-1}$ and $J_{\mathrm{exog},t-1}$.

To conclude this section it should be noted that the solutions presented here are of an approximate character. This is because the approach adopted made no provision for the feed-back effects between Y_5, Y_6, and the endogenous investment variables on the other endogenous variables of the model. For this reason we have used the term "extended reduced form" in the title of this section, thus implying that the resulting coefficients do not reflect the full impact of the predetermined variables, i.e., the impact corresponding to the situation when all the interrelations and feed-backs have been accounted for.

In classical linear models, when all the equations have been consistently estimated, the reduced form obtained by the standard formula* obviously reflects the full impact of the predetermined variables of the model.

7.3 THE RANGE OF POSSIBLE PRACTICAL USES OF THE MODEL

Once its reduced form has been obtained, the model is ready for practical applications. Since the main objective of the research which lead to the construction of DEMP-1 was to analyze the existing interrelations between economic and demographic factors in Poland, our analysis of the model's results must provide answers to the following questions:

1. Do economic factors have any impact on demographic variables, and if so, of what kind and intensity?
2. Are demographic factors important to economic growth?

The solutions to these problems can be obtained in a number of different ways. So far, the author has concentrated mostly on counterfactual simulation procedures. If the counterfactual simulations are performed over a sufficiently long period of time and the underlying scenarios are carefully chosen in order to make them differ significantly from each other with respect to the decision variables, the results usually prove to be fruitful. These results give a clear insight into the mechanism of existing interrelations and the role of the different decision variables.

Counterfactual simulation, however, is not the only possible method of inference. Much information can also be derived from analyzing single coefficients of the reduced-form equations, since such coefficients are direct multipliers, expressing the expected change in the endogenous variable given an assumed change in a particular predetermined variable.

*That is, by computing matrix P, defined as $P = B^{-1} \cdot C$, where B is the matrix of coefficients of nonlagged endogenous variables and C is the matrix of coefficients of predetermined variables.

It should be pointed out, moreover, that DEMP-1 can also be used for straightforward predictions of the future behavior of its endogenous variables. So far, however, the author's research in the applications of the model has concentrated on the counterfactual simulation procedures; these procedures and the resulting inferences will be presented in the next section.

8 COUNTERFACTUAL SIMULATION OF THE MODEL

8.1 THE SCENARIOS

The model in its present form is constructed to show primarily the existing interrelations of economic factors and their impact on such demographic phenomena as demographic coefficients and population totals for urban and rural areas. The counterfactual scenarios are designed to show the results of the impact of different economic policies on economic growth and on demography. Starting with two or more sets of basically different initial assumptions about the economic policy, and looking at the results obtained from the counterfactual simulation, it is possible to judge whether the demographic phenomena are really conditioned by economic factors and, if so, in which direction and to what extent.

For the purpose of such an analysis two different simulation scenarios have been designed, and these are referred to as Scenario A and Scenario B. In agreement with what was said earlier about the necessary divergence of scenarios, the two scenarios decided upon represent two extreme situations in the history of the Polish economy during the years 1960–1976.* Scenario A reflects the hypothetical assumption that, during the entire period, the economy was growing at the same moderate rate as it actually was during the sixties. On the other hand, Scenario B assumes that, from 1960 onward, Poland experienced a steady, high rate of economic growth similar to that observed in the years 1971–1976, and that this high rate of growth was coupled with a significant rise in the standard of living of the population.

In order to design such scenarios the values of the predetermined variables of the model had to be set at levels corresponding to the basic assumptions made for the two situations. Table 4 contains the values assumed for Scenario A while Table 5 refers to the levels of predetermined variables corresponding to

*Since DEMP-1 has been built using time-series data referring to the period 1960–1976, it seems logical that any counterfactual simulation based on it should refer to the same period.

TABLE 4 Values of predetermined variables assumed for Scenario A.[a]

Variable	Year 1971	1972	1973	1974	1975	1976
X_1	565	580	595	610	625	640
X_2	122	124	126	128	130	132
X_3	133	142	151	160	169	178
X_4	0	0	0	0	0	0
X_5	68	71	74	77	80	83
X_6	17	18	19	20	21	22
X_8	650	670	690	710	730	750
X_9	−0.2	0	0	0	0	0
X_{10}	1	1	1	1	1	1
X_{11}	12	13	14	15	16	17
X_{12}	144	169	196	225	256	289
X_{13}	650	685	730	770	810	860
X_{14}	130	137	144	151	158	165
X_{15}	120	130	137	144	151	158
X_{16}	38.5	41.0	43.5	46.0	48.5	50.1
X_{17}	36.2	38.5	41.0	43.5	46.0	48.5
X_{19}	0	0	0	0	0	0
X_{20}	0	0	0	1	1	1
X_{21}	0	0	0	0	0	0
X_{22}	0	0	0	0	0	0
X_{23}	0	0	0	0	0	0

[a]For the years 1960–1970, the values assumed for Scenario A are the same as the observed data reported in Table 6.

Scenario B. Assuming that Scenario B represents not only a much faster economic growth but also a higher standard of living, the data pertaining to the two scenarios differ, not only with respect to variables inducing economic growth (such as investments), but also with respect to variables connected with the standard of living (wages, housing construction). For easier comparison with the *real* behavior of predetermined variables over the period studied, Table 6 presents the relevant observed statistical data.

The counterfactual simulations performed were of the deterministic type, i.e., the random components of the stochastic equations of the model were all put equal to zero. The choice of the deterministic variant was made entirely by considering the computing time and facilities available. It must be remembered, however, that stochastic simulation yields much more valuable information, since it provides not only the expected values of endogenous variables but also gives insight into the distribution of individual observations. Moreover – when there is a strong autocorrelation between the random components present – the stochastic variant of simulation gives information about the behavior of

TABLE 5 Values of predetermined variables assumed for Scenario B.

Variable	Year 1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
X_1	385	415	445	475	505	535	565	595	625	655	685	715	745	775	805	835	865
X_2	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180
X_3	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228
X_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_5	28	32	37	43	50	57	65	75	85	99	114	131	153	176	202	233	268
X_6	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37
X_8	414	474	534	600	660	720	880	840	900	960	1020	1080	1140	1200	1260	1320	1380
X_9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{10}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X_{11}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
X_{12}	1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256	289
X_{13}	300	330	363	400	440	484	532	585	644	710	781	860	944	1038	1142	1256	1380
X_{14}	50	60	64	72	80	90	100	110	125	150	176	210	270	335	400	470	550
X_{15}	45	50	60	64	72	80	90	100	110	125	150	176	210	270	335	400	470
X_{16}	12	13	14	16	20	25	29	32	27	50	53	58	60	65	70	76	82
X_{17}	10	12	13	14	16	20	25	29	32	37	50	53	58	60	65	70	76
X_{19}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{20}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{21}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X_{22}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X_{23}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 6 Observed values of predetermined variables (for selected years).

Variable	Year 1960	1962	1964	1966	1968	1970	1972	1974	1976
X_1	385	401	421	451	491	539	588	671	791
X_2	100.0	103.0	107.7	111.3	115.5	119.5	134.4	155.7	175.5
X_3	36.5	44.1	49.1	66.4	93.4	123.6	149.1	173.6	193.3
X_4	0	8	1	−10	−14	7	−14	13	30
X_5	28.2	36.2	32.7	43.2	52.9	55.0	101.0	157.0	152.6
X_6	5.7	7.8	10.9	13.0	15.3	15.9	21.7	30.8	32.5
X_8	414.8	411.1	475.2	517.1	569.5	630.0	697.5	895.4	1009.4
X_9	−0.7	−1.0	0.1	−0.9	0.0	−0.2	−1.5	−7.2	−9.5
X_{10}	1	1	1	1	1	1	1	1	1
X_{11}	1	3	5	7	9	11	13	15	17
X_{12}	1	9	25	49	81	121	169	225	289
X_{13}	297.8	335.0	384.9	449.8	518.5	619.2	704.0	885.5	1116.3
X_{14}	48.3	60.6	76.5	80.1	97.1	119.4	133.9	191.3	306.2
X_{15}	43.4	57.5	66.4	78.8	88.9	109.6	130.2	148.7	246.0
X_{16}	12.0	15.0	17.9	24.7	29.9	35.5	37.8	51.0	70.1
X_{17}	10.0	13.5	16.5	21.2	27.2	32.5	36.2	43.5	60.2
X_{18}	43.0	45.9	49.3	54.6	57.6	64.5	69.7	80.5	96.2
X_{19}	0	1	0	0	0	1	0	1	1
X_{20}	0	1	0	0	0	0	0	0	1
X_{21}	1	0	0	0	1	0	1	1	1
X_{22}	0	0	0	0	0	0	1	1	1
X_{23}	0	0	0	0	1	0	0	0	0

individual growth paths. This is especially important when there is a possibility of some paths of an endogenous variable going astray, i.e., in the direction opposite to that shown by the expected values of the given variable.* Notwithstanding these advantages, it has only been possible, to date, to run the deterministic variant of the counterfactual simulation, because of the lack of an efficient computer.

8.2 THE ANALYSIS OF COUNTERFACTUAL SIMULATION RESULTS

Using the two scenarios described in Section 8.1, counterfactual simulation was performed with respect to all the endogenous variables of the model and for all the years of the period 1960–1976. However, to keep this report reasonably brief, we shall restrict ourselves to discussing the results which refer to national income, employment, and demographic variables.

*The frequency of occurrence of such stray paths of growth provides information about the possibility that random causes will completely disturb the pattern of behavior of an endogenous variable and make it significantly diverge from what might be "reasonably" expected.

The counterfactual simulations performed on the basis of Scenarios A and B provided, for every endogenous variable considered, two sets of "theoretical" values, each set being composed of 17 consecutive figures, one for each year in the period 1960–1976. The first set represents the expected values of the particular endogenous variable if Scenario A were true, and the second set gives the corresponding figures on the basis of the assumptions of Scenario B.

Tables 7–11 present the results of the counterfactual simulations of variables $Y_1, Y_8, Y_{18}, Y_2, Y_3, Y_4, Y_9, Y_{24}, Y_{25}, Y_{26}, Y_{27}, Y_{28}, Y_5$, and Y_6. For the sake of clarity, simulation results have been grouped so that each table contains the results pertaining to similar types of variables (national income, employment, etc.). Also, to avoid presenting too many data, which would obscure the general trends of the results, only those data referring to even-numbered years have been included in the tables.

When both sectoral and total national income are considered (see Table 7) we find that the pattern of growth corresponding to Scenario B leads to substantially higher figures (in constant prices!) than in the case of Scenario A. This is not surprising, though, since the basic difference between the two scenarios lies mainly in the assumption that the stimuli of economic growth are much stronger for Scenario B. The nontrivial observation, however, is that in 1976 the total national income figure is about 43 percent higher for Scenario B than for Scenario A. The obvious inference to be drawn is that if the policy of fast economic growth had been started as early as 1960 and pursued in all the subsequent years, the country's economic potential would now be significantly improved. Another striking conclusion that can be drawn from the data in Table 7 is that, even under the growth-pattern assumptions of Scenario B, we do not observe a substantial rise in the agricultural sector, which is lagging well behind the other productive sector.

When analyzing the results of counterfactual simulations applied to employment variables, we notice for both scenarios that the level of employment of full-time, one-job workers and employees in Sector I (variable Y_2) increases very substantially – and at almost the same rate for both scenarios. A slightly different pattern is seen with respect to the peasant-workers, who also increase in number; however, the magnitude of this increase is different for each simulation. While under Scenario A the expected number of peasant-workers (variable Y_3) in 1976 is almost 2.5 times greater than in 1960, under Scenario B the corresponding factor is only 2.2. Whatever its magnitude, the appearance of this difference is not surprising. Scenario B leads to a larger overall employment in Sector I than does Scenario A (the figures being 14.1 and 13.1 millions, respectively) and also to a more intensive construction of flats in urban areas. Thus, new workers attracted to Sector I from Sector II would –under Scenario B – not only easily find new jobs but could also, and in larger numbers, move permanently to the towns to settle because adequate accommodation would be available.

TABLE 7 Counterfactual simulation of national income.

		Year								
Variable	Scenario	1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_1	A	307	346	409	478	562	674	741	838	940
Y_1	B	331	400	491	594	721	866	1039	1192	1390
Y_8	A	126	107	128	133	140	127	153	136	141
Y_8	B	113	118	123	128	133	138	142	147	152
Y_{18}	A	433	453	537	611	702	801	894	974	1081
Y_{18}	B	444	518	614	722	854	1004	1181	1339	1542

TABLE 8 Counterfactual simulation of productive employment.

		Year								
Variable	Scenario	1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_2	A	5.1	5.9	6.7	7.5	8.4	9.3	10.1	11.0	11.9
Y_2	B	5.2	6.0	6.9	7.8	8.7	9.7	10.8	11.8	12.8
Y_3	A	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.2
Y_3	B	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3
Y_4	A	10.8	10.7	10.6	10.5	10.4	10.2	9.8	9.7	9.6
Y_4	B	10.3	10.1	10.0	9.8	9.6	9.4	9.3	9.1	8.9
Total	A	16.4	17.2	18.0	18.7	19.6	20.4	20.9	21.8	22.7
Total	B	16.1	16.7	17.6	18.4	19.2	20.1	21.2	22.1	23.0

TABLE 9 Counterfactual simulation of employment in services.

		Year								
Variable	Scenario	1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_9	A	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9
Y_9	B	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.2

TABLE 10 Counterfactual simulation of demographic coefficients.

Variable	Scenario	Year 1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_{24}	A	16.2	16.3	16.4	16.6	18.6	16.8	17.0	17.0	17.0
Y_{24}	B	16.6	16.6	16.6	16.7	18.7	16.8	16.9	16.9	17.0
Y_{25}	A	37.3	35.1	32.7	30.3	27.8	25.4	23.0	20.5	17.0
Y_{25}	B	24.9	22.4	20.5	20.0	19.5	18.8	18.0	15.0	13.0
Y_{26}	A	7.2	7.1	7.0	7.0	7.2	7.7	7.8	8.4	9.0
Y_{26}	B	6.6	6.4	6.3	6.0	6.3	6.4	6.5	6.8	7.2
Y_{27}	A	8.3	8.1	8.0	8.0	7.9	8.0	8.2	8.8	9.1
Y_{27}	B	8.1	8.1	8.0	8.0	8.1	8.2	8.3	8.5	8.7
Y_{28}	A	6.0	6.2	6.4	6.7	6.7	6.9	7.0	7.0	7.1
Y_{28}	B	6.0	6.2	6.4	6.7	7.1	7.7	8.4	9.5	10.7

TABLE 11 Counterfactual simulation of urban and rural population totals.

		Year								
Variable	Scenario	1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_5	A	14.2	14.8	15.2	15.8	16.5	17.0	17.5	18.1	18.6
Y_5	B	14.0	14.4	14.9	15.4	16.0	16.6	17.2	17.9	18.6
Y_6	A	15.8	16.5	17.2	17.8	18.2	18.6	18.8	18.9	18.8
Y_6	B	15.4	15.6	15.8	15.9	15.8	15.7	15.7	15.7	15.6
Total population	A	30.0	31.3	32.4	33.6	34.7	35.6	36.3	37.0	37.4
Total population	B	29.4	30.0	30.7	31.3	31.9	32.3	32.9	33.6	34.2

As far as agricultural employment is concerned, both scenarios show a decrease in the number of persons working in Sector II. In the case of Scenario B this decrease is slightly more pronounced (1.4 instead of 1.2 million persons). This is due to the fact that Scenario B induces a stronger "drain" of labor force away from agriculture, both because of the demand for new workers in Sector I and because of the high investment outlays in agriculture, thus making such an exodus to urban areas possible without a corresponding loss of agricultural output.

A counterfactual simulation was also run for the variable Y_9, i.e., employment in the service sector. Here we find that employment would rise faster under Scenario B than under Scenario A, and this difference in employment levels is especially visible in the seventies. However, it is somewhat surprising to note that the historically observed data for 1975 and 1976 are in fact even higher than the results for Scenario B, not to mention those for Scenario A. This is perhaps due to government decisions taken in the mid-seventies that aimed to expand small trades and the crafts, which provide direct services to the population. These government decisions were not accounted for explicitly in the model.

When viewing the results of counterfactual simulations performed for the demographic coefficients represented by the variables $Y_{24}-Y_{28}$, it can be seen that one of these variables, Y_{24} (urban birth rate), is practically unaffected by the different assumptions underlying the two scenarios. In both cases, the urban birth rate shows a very slow upward trend which, however, is less evident during the last years of the simulation period.

All the other demographic coefficients considered show different trends, depending on whether Scenario A or Scenario B is applied. These differences, however, seem to be of a quantitative and not a qualitative character, because the general characteristics of their variation are the same for both scenarios.

In contrast to the behavior of the urban birth rate, the rural birth rate visibly decreases in time, the speed of this decrease being faster for Scenario B. This is because the birth rate in rural areas depends inversely on consumption, which is steadily rising throughout the simulation period.

An interesting conclusion can be derived from the figures pertaining to death rates. The urban and rural death rates are lower for Scenario B, which is probably due to the fact that having a higher national income makes it possible to spend more money on health care. A still more interesting feature of these death rates is that, after a temporary decline, they start rising again, the minimum level occurring in the late sixties. The present version of the model does not permit us to ascertain the real cause of such a variation pattern, but we may speculate that the effect is due either to the aging of Poland's population or to the worsening of natural environmental conditions.

Finally, some points are worth noting with respect to the variable Y_{28}, defined as the urban net in-migration rate. Under both scenarios this rate increases, but there is a marked difference in the patterns of growth. If a moderate growth of the national economy is assumed, the simulated values of the urban in-migration rate rise, but this trend slows down remarkably in the later years of the period studied. On the other hand, for Scenario B the variable Y_{28} exhibits a much faster and steadier upward trend, even in the last years of the simulation period. This is not surprising, since among other factors, Scenario B assumes intensive construction of flats in urban areas, so that people who wish to move to towns find not only job possibilities but also suitable accommodation.

To conclude this overview of the counterfactual simulation results, Table 11 shows urban, rural, and total population levels computed on the basis of each scenario. The general pattern of urban population growth is the same, as regards its upward trend, and the computed population figures tend to coincide for the two scenarios in the last years of the simulation period.

In spite of out-migration, the rural population is found to be growing until 1970. From then on its level stabilizes. This is due to the declining birth rate and to the rising death rate. Possibly, if the simulation had also been performed for later years, one might observe a substantial decline in the rural population figures.

To provide a better overview of the results of the counterfactual simulations performed, the behavior of each variable under Scenarios A and B is shown in Figures 14–21, which follow. In each figure, the continuous line refers to Scenario A and the broken line to Scenario B.

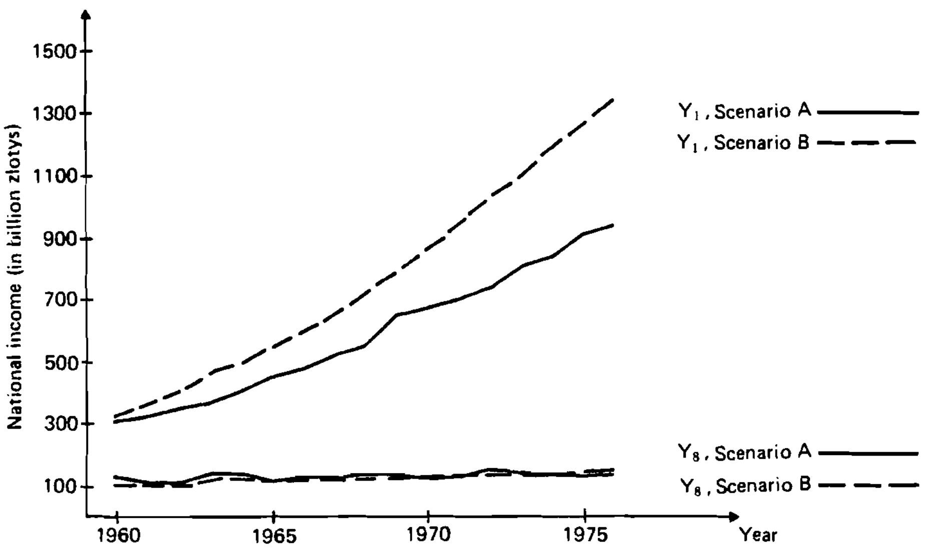

FIGURE 14 National income (sectoral), counterfactual simulation.

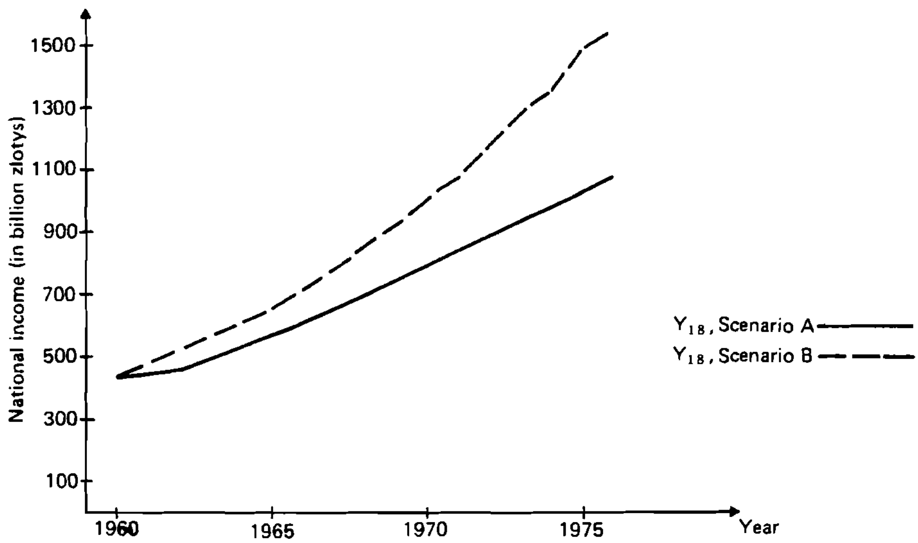

FIGURE 15 Total national income, counterfactual simulation.

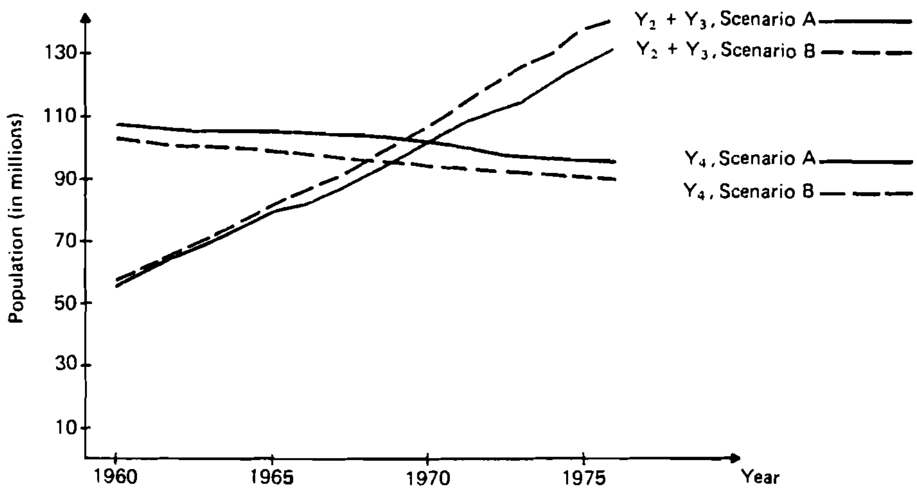

FIGURE 16 Productive employment in Sector I and Sector II, counterfactual simulation.

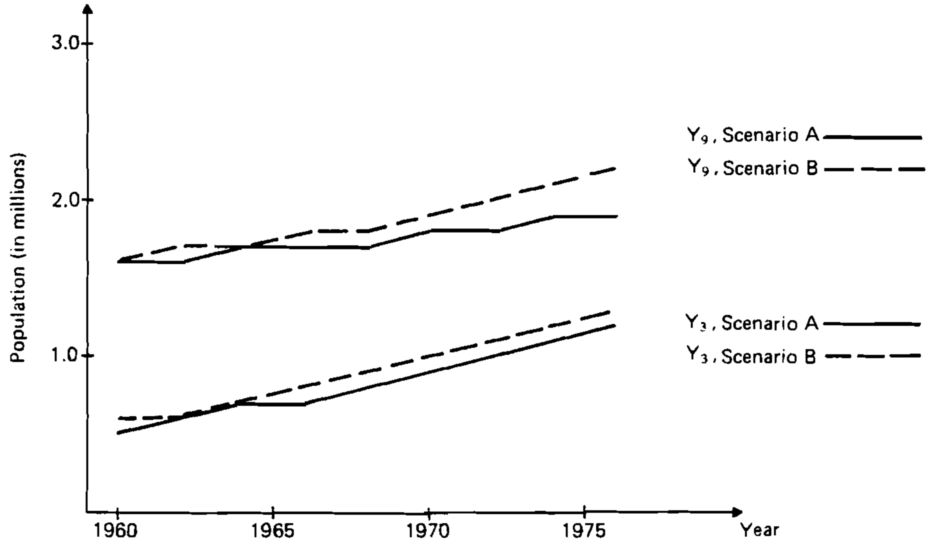

FIGURE 17 Employment in services and employment of peasant-workers, counterfactual simulation.

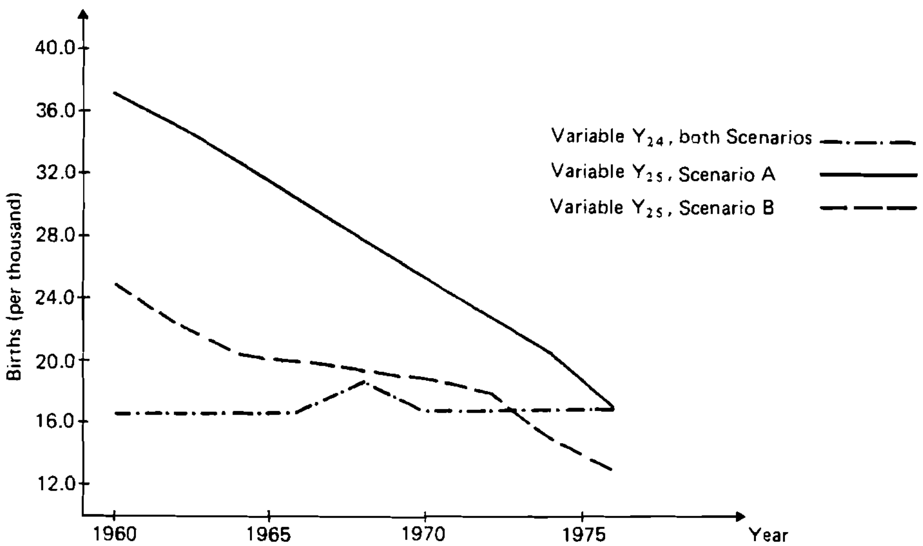

FIGURE 18 Urban and rural birth rates, counterfactual simulation.

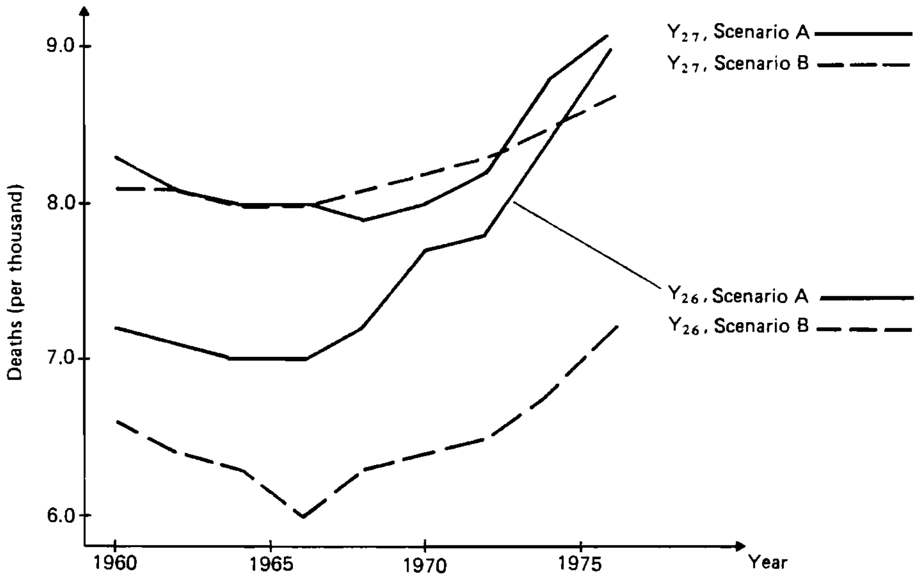

FIGURE 19 Urban and rural death rates, counterfactual simulation.

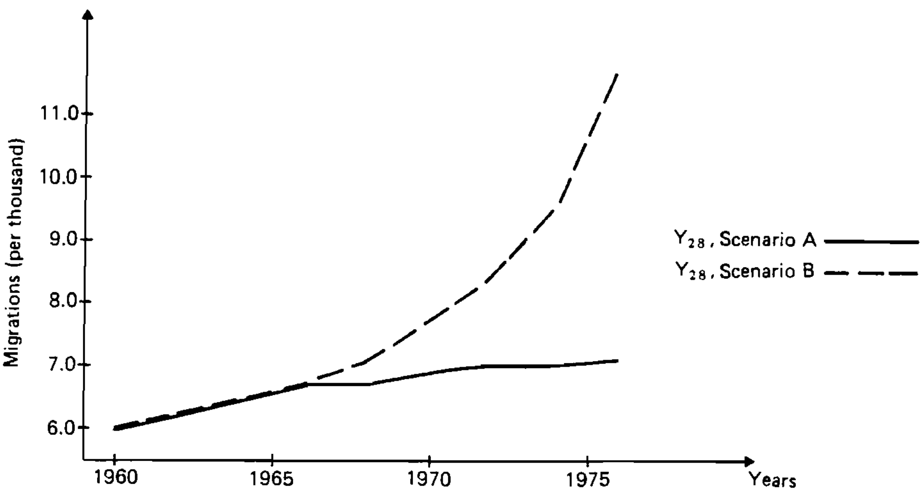

FIGURE 20 Net migration rate to urban areas, counterfactual simulation.

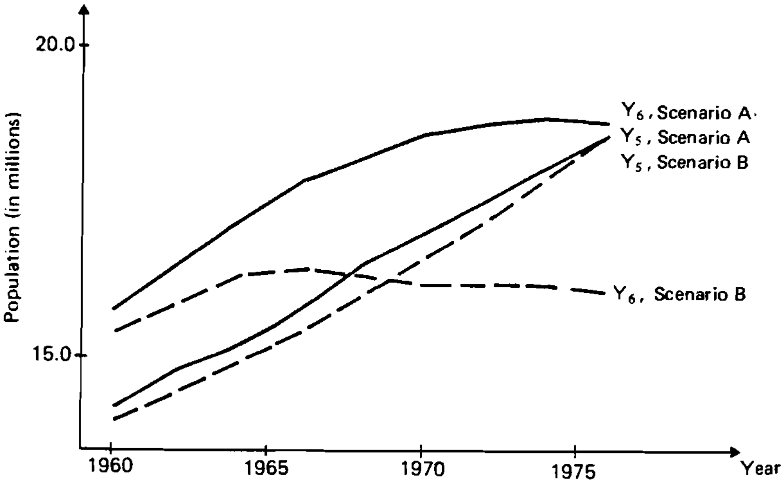

FIGURE 21 Urban and rural population, counterfactual simulation.

8.3 CONCLUDING REMARKS

DEMP-1, as presented and discussed in this report, may contain a number of shortcomings and approximations which preclude its practical application to large-scale and long-term analyses. In fact, a new version of the model (DEMP-2) is almost finished, and, from the results of the estimation of its structural relations, it seems that this newer version of the model provides more insight into the realm of quantitative interrelations between economic and demographic phenomena.

However, some important conclusions can already be drawn using the DEMP-1 version of the model. These conclusions may be summarized as follows:

1. In the light of our experience to date, it can be stated that it *is* possible to build demoeconometric models of countries that have a central economic planning system.
2. While some of the equations of such models may have a different interpretational and operational (predictive) meaning as compared to models of market economies, they nevertheless provide a basis for drawing inferences about the mechanism of economic growth and the mechanism of demographic behavior.
3. The demographic variables of Poland show a degree of dependence on economic factors which, although not excessively high, can be observed, especially when reference periods longer than 10 years are used for comparison.
4. Migration from rural to urban areas is not only influenced by such purely economic factors as income differentials, but also depends to a

large extent on social policy, particularly the intensity of housing construction in urban areas.

5. Because of the full employment policy consistently pursued during the whole post-war period, employment figures have been steadily rising in Poland. A further rise in the labor force may be constrained because of insufficient growth in the working-age population. Thus, the demographic factor may initiate a brake on economic growth, unless this growth is coupled with an adequate labor–capital substitution, and, consequently, higher labor productivity.

REFERENCES

Artwig, E. (1976) Próba badania stabilności modelu ekonometrycznego (An Attempt at Analysis of the Stability of an Econometric Model). Przeglad Statystyczny 3:311–319.

Kanton, M. (1975) Modele ekonometryczne w planowaniu centralnym (Econometric Models in Central Planning). Warsaw: Panstwowe Wydawnictwo Ekonomiczne (PWE).

Koopmans, T.C., ed. (1950) Statistical Inference in Dynamic Economic Models. New York: Cowles Foundation Monograph No. 10.

Maciejewski, W. (1976) Zastosowanie ekonometrycznych modeli rozwoju gospodarki narodowej (Applications of Econometric Models of the National Economy). Warsaw: Panstwowe Wydawnictwo Ekonomiczne (PWE).

Maciejewski, W., and J. Zajchowski (1974) Ogolna koncepcja ekonometrycznego modelu gospodarki Polski KP-2 (General Concept of the KP-2 Econometric Model of Poland). Gospodarka Planowa, No. 10.

Pajestka, J. (1961) Zatrudnienie i inwestycje a wzrost gospodarczy (Employment, Investments, and Economic Growth). Warsaw: Panstwowe Wydawnictwo Ekonomiczne (PWE).

Pawlowski, Z. (1973) Prognozy ekonometryczne (Econometric Predictions). Warsaw: Panstwowe Wydawnictwo Naukowe (PWN).

Pawlowski, Z. (1977) On the use of dummy variables in econometric model building, with special reference to centrally planned economies. In: Models for Regional Planning and Policy-making, edited by A. Straszak and B. Wagle. Proceedings of the joint IBM–IIASA Conference, Vienna, September.

Pawlowski, Z., A. Barczak, B. Ciepielewska, and T. Jakubczyk (1964) Proba budowy prostych ekonometrycznych rownan wzrostu na przykladzie gospodarki Polski (An Attempt at Building Simple Econometric Growth Equations: a Polish Example). Ekonomistra, No.3.

Pawlowski, Z., A. Barczak, B. Ciepielewska, and T. Jakubczyk (1968) Model ekonometryczny gospodarki Polski Ludowej (An Econometric Model of the Polish Economy). Warsaw: Panstwowe Wydawnictwo Naukowe (PWN).

Theil, H. (1961) Economic Policy and Forecasts. Amsterdam: North-Holland.

Welfe, W., and W. Debski (1976) Wlasnosci modelu gospodarki narodowej Polski W-1 (Properties of the W-1 Model of the Polish National Economy). Prace Instytutu Ekonometrii i Statystyki Uniwersytetu Lodzkiego, Series D, No. 10.

APPENDIXES

APPENDIX A Matrix of limited-reduced-form coefficients (elements multiplied by – 1).

Variable	Column 1	Column 2	Column 3
Y_1	+0.000000000 / 0	+0.883525104 / – 1	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.212046025 / – 3	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.931485326 / – 2	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	+0.952690429 / – 2	+0.000000000 / 0
Y_8	+0.755000000 / – 1	+0.000000000 / 0	–0.391000000 / 0
Y_9	+0.000000000 / 0	+0.441762552 / – 4	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.957108054 / – 2	+0.000000000 / 0
Y_{18}	+0.755000000 / – 1	+0.883525104 / – 1	–0.391000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	–0.121544630 / 0	+0.149279295 / + 1	+0.629456296 / 0
Y_{23}	–0.524725000 / – 2	+0.615516190 / – 1	+0.271745000 / – 1
Y_{24}	–0.243089260 / – 4	+0.298558590 / – 3	+0.125891259 / – 3
Y_{25}	+0.148234449 / – 2	–0.182120740 / – 1	–0.767936681 / – 2
Y_{26}	+0.000000000 / 0	–0.362245293 / – 3	+0.000000000 / 0
Y_{27}	–0.139675000 / – 2	+0.000000000 / 0	+0.723350000 / – 2
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 4	Column 5	Column 6
Y_1	+0.000000000 / 0	+0.144053006 / – 1	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.345727214 / – 4	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.151872689 / – 2	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.436000000 / – 1
Y_7	+0.000000000 / 0	+0.155329961 / – 2	+0.000000000 / 0
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	+0.720265030 / – 5	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.156050226 / – 2	+0.436000000 / – 1
Y_{18}	+0.000000000 / 0	+0.144053006 / – 1	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	+0.000000000 / 0	+0.243390155 / 0	+0.680025336 / + 1
Y_{23}	+0.000000000 / 0	+0.100355901 / – 1	+0.280391600 / 0
Y_{24}	+0.000000000 / 0	+0.486780310 / – 1	+0.136005067 / – 2
Y_{25}	+0.000000000 / 0	–0.296935989 / – 2	–0.829630910 / – 1
Y_{26}	+0.000000000 / 0	–0.590617325 / – 4	+0.000000000 / 0
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	–0.610000000 / – 2	–0.195000000 / – 1	+0.000000000 / 0

Variable	Column 7	Column 8	Column 9
Y_1	+0.000000000 / 0	−0.480176687 / − 2	+0.000000000 / 0
Y_2	+0.000000000 / 0	−0.115242405 / − 4	+0.000000000 / 0
Y_3	+0.000000000 / 0	−0.506242297 / − 5	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	−0.517766537 / − 3	+0.000000000 / 0
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	−0.240088343 / − 5	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	−0.520167421 / − 3	+0.000000000 / 0
Y_{18}	+0.000000000 / 0	−0.480176687 / − 2	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	+0.000000000 / 0	−0.811300516 / − 1	+0.570130977 / + 1
Y_{23}	+0.000000000 / 0	−0.334519668 / − 2	+0.235100000 / 0
Y_{24}	+0.000000000 / 0	−0.162260103 / − 4	+0.114036195 / − 2
Y_{25}	+0.000000000 / 0	+0.989786630 / − 3	−0.695620792 / − 1
Y_{26}	+0.000000000 / 0	+0.196872447 / − 4	+0.000000000 / 0
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 10	Column 11	Column 12
Y_1	−0.741731123 / + 2	−0.312691058 / + 1	+0.000000000 / 0
Y_2	−0.134653155 / + 2	−0.333104585 / 0	+0.000000000 / 0
Y_3	−0.112062505 / + 1	−0.406498376 / − 2	+0.000000000 / 0
Y_4	−0.270799000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_7	−0.145859405 / + 2	−0.337169569 / 0	+0.000000000 / 0
Y_8	−0.140825200 / + 3	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.165631344 / + 1	−0.156345529 / − 2	+0.000000000 / 0
Y_{10}	−0.670093271 / + 2	−0.602333024 / 0	+0.000000000 / 0
Y_{18}	−0.214998312 / + 3	−0.312691058 / + 1	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	−0.100788000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.764212957 / + 4	−0.939453480 / + 2	+0.000000000 / 0
Y_{23}	−0.390657131 / + 3	−0.387360368 / + 1	+0.000000000 / 0
Y_{24}	−0.162140259 / + 2	−0.187890696 / − 1	+0.000000000 / 0
Y_{25}	+0.344946808 / + 2	+0.114613325 / + 1	+0.000000000 / 0
Y_{26}	−0.799249024 / + 1	+0.181203334 / − 1	−0.175000000 / − 1
Y_{27}	−0.763863380 / + 1	+0.132000000 / − 1	−0.580000000 / − 2
Y_{28}	−0.558740000 / + 1	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 13	Column 14	Column 15
Y_1	−0.118754933 / + 1	−0.534438620 / 0	+0.125982954 / + 1
Y_2	−0.285011839 / − 2	−0.128265269 / − 2	+0.302359089 / − 2
Y_3	−0.154381413 / − 2	−0.694770206 / − 3	+0.163777840 / − 2
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	−0.439393252 / − 2	−0.197742289 / − 2	+0.466136929 / − 2
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	−0.593774665 / − 3	−0.267219310 / − 3	+0.629914769 / − 3
Y_{10}	−0.498770719 / − 2	−0.224464220 / − 2	+0.529128406 / − 2
Y_{18}	−0.118754933 / + 1	−0.534438620 / 0	+0.125982954 / + 1
Y_{19}	−0.791000000 / − 1	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.777928269 / 0	−0.350024855 / 0	+0.825276886 / 0
Y_{23}	−0.329759449 / − 1	−0.144352940 / − 1	+0.340232478 / − 1
Y_{24}	−0.153585654 / − 3	−0.700189710 / − 4	+0.165055377 / − 3
Y_{25}	−0.949072489 / − 2	+0.427115723 / − 2	−0.100683780 / − 1
Y_{26}	+0.486895225 / − 2	+0.219119834 / − 2	−0.516530111 / − 2
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 16	Column 17	Column 18
Y_1	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{18}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.115200000 / 0
Y_{20}	+0.878000000 / − 1	−0.219800000 / 0	+0.000000000 / 0
Y_{22}	−0.114874886 / + 1	+0.287579726 / + 0	+0.000000000 / 0
Y_{23}	+0.000000000 / 0	+0.000000000 / 1	+0.000000000 / 0
Y_{24}	+0.229749772 / − 3	+0.575159452 / − 3	+0.000000000 / 0
Y_{25}	+0.140147361 / − 1	−0.350847266 / − 1	+0.000000000 / 0
Y_{26}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 19	Column 20	Column 21
Y_1	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_8	+0.212235000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{18}	+0.212235000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.191350000 / + 1	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.592025799 / + 2	+0.712540000 / + 1	+0.000000000 / 0
Y_{23}	−0.147503325 / + 1	+0.000000000 / 0	+0.000000000 / 0
Y_{24}	−0.118405160 / − 1	+0.142508000 / − 2	+0.000000000 / 0
Y_{25}	+0.722271475 / 0	−0.869298800 / − 1	+0.000000000 / 0
Y_{26}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{27}	−0.392634750 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.138500000 / 0

Variable	Column 22	Column 23
Y_1	−0.222595083 / + 2	+0.000000000 / 0
Y_2	−0.534228200 / − 1	+0.000000000 / 0
Y_3	−0.289373608 / − 1	+0.000000000 / 0
Y_4	+0.537600000 / 0	+0.000000000 / 0
Y_7	−0.823601808 / − 1	+0.000000000 / 0
Y_8	+0.124726000 / + 2	+0.000000000 / 0
Y_9	−0.111297542 / − 1	+0.000000000 / 0
Y_{10}	+0.444110065 / 0	+0.000000000 / 0
Y_{18}	−0.978690832 / + 1	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.631255197 / + 2	+0.000000000 / 0
Y_{23}	+0.198922613 / + 1	+0.000000000 / 0
Y_{24}	+0.290748961 / − 1	−0.244550000 / + 1
Y_{25}	−0.463646866 / + 1	+0.000000000 / 0
Y_{26}	+0.912639841 / − 1	+0.000000000 / 0
Y_{27}	−0.230743100 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0

APPENDIX B Reduced-form coefficients[a] for equations of Y_5 and Y_6.

Endogenous variable	Predetermined variables appearing in the reduced-form equation									
	X_1	X_2	X_3	X_4	X_5	X_6	X_8	X_9	X_{11}	X_{12}
Y_5	−0.000024	0.000063	0.000126	0.006100	0.019510	−0.001360	0.000040	−0.001140	0.000663	0.017500
	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
	−0.004715	−0.002121	0.004998	0.000230	−0.000575	0.011841	−0.001425	−0.138500	−0.120339	2.445000
	X_1	X_2	X_3	X_4	X_5	X_6	X_8	X_9	X_{11}	X_{12}
Y_6	−0.002085	0.018210	0.000446	−0.000085	0.033469	0.082963	−0.000990	0.069562	1.159333	0.005800
	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
	0.009491	−0.004272	0.010068	−0.014015	0.035065	−0.329636	0.086929	−0.027000	4.867211	

[a] Note that the coefficients in the table which refer to Y_5 must be multiplied by the correct value of variable X_{24} for the year in question; similarly, the coefficients referring to Y_6 must be multiplied by the appropriate value of X_{25}.

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1. Nathan Keyfitz, *Understanding World Models.* RM-77-18. Laxenburg, Austria: International Institute for Applied Systems Analysis. Published in *Sociological Methodology 1978* edited by K.F. Schuessler, pp. 1–19. San Francisco: Jossey-Bass Publishers.
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THE AUTHOR

Zbigniew Pawlowski is Professor of Econometrics at the Institute of Econometrics, Academy of Economics, Katowice, Poland. He has been active in the field of econometric modeling for a number of years and has paid special attention to the modeling of centrally planned economies; his many publications include works on the use of dummy variables in econometric modeling, the building of econometric growth equations, and other important problems encountered when modeling national economies. Professor Pawlowski has participated in the work of several research areas during his frequent visits to IIASA.