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Lucian-Liviu Albu and Tiberiu Diaconescu

5. May 2009

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Lucian Liviu Albu

Diaconescu Tiberiu

(Institute for Economic Forecasting, Bucharest)

Abstract

Starting from existing literature and recent years studies, several modeling schemes have been developed, which may prove useful to substantiate strategies aimed at achieving a demographic and economic balance between generations. This way, we can obtain simulations from a country or group of countries (European Union, for example) on long and very long term, and then quantify the impact of demographic aging on macroeconomic aggregates, taking into consideration, as a rule, that models are standard macroeconomic models generally balanced on short and medium term, when the population appears as exogenous variable.

Keywords: demographic aging, long-term simulations, loop cybernetics, demoeconomic model, overlapping generation model

JEL: C01, C13, C15, J11

* Paper presented at the 16th International Economic Conference – IECS: "Industrial revolutions, from the globalization and post-globalization perspective", Sibiu, Romania, May 7-8, 2009.

Increased life expectancy and consequently the average age of general population are the two results of accelerated economic growth in the modern period. Developing science and technology in recent times, the contribution of technical progress, education and health system led to an increase in the rate of income per capita unprecedented in history. Among the unavoidable consequences, there was the increasing weight of elders in total population, in other words The Aging Phenomenon.

Starting from existing literature and, from recent year's studies within The Research Project, we developed several modeling layouts that may prove useful to substantiate the strategies aimed at achieving an economic and demographic balance between generations.

Fundamental cybernetics loop underlying the demoeconomics modern models, which further allows for demographic variables to become endogenous, refers on the one hand to the fact that increase per capita income leads to an increased life expectancy and average age for general population. This is the same with demographic aging, hence it can become an inhibitor to economic growth itself in the future. In this area of interest lays our work, namely: the estimation of basic parameters for the demoeconomics models and the simulation of future trajectory of income per capita and other macroeconomic variables which might fall under the impact of the aging phenomenon.

As shown in previous studies within the project, currently, both globally and by groups of countries, there is an increasingly emphasized aging phenomenon. This is due, especially in economically developed countries, to reduction of female fertility and to an improved health system. Therefore, nowadays, in most economic advanced countries we register a weight reduction for newborn children, while extending life expectancy. Poverty and social exclusion are generally regarded as the biggest obstacles that one must overcome to ensure a decent living for the elderly. Typically, only those who achieve decent revenues and contribute to pension funds, since early stages of life, will be able to avoid poverty in the period in which they leave employment.

As a general worldwide trend, after 1975 the rate of dependency on young people (the number of people aged 0-14 years, compared to that of persons aged 15-64 years) has decreased rapidly. In the same time, the rate of dependency on the elderly (number of persons aged 65 years and over reported to the number of persons aged 15-64 years) increased (though at a slower rate than that of the change in the rate of dependency on young people). Overall, the total dependency rate (resulting from the composition of the two indicators) has registered in a downward trend. In the future, we estimate further decrease in the rate of dependency on young people in parallel with an increased rate of dependency on the elderly. Calculations show that through extrapolation is likely that the two rates become equal before the year 2100 (smoothing is expected to manifest for values between 30-35% of young people and adults, i.e. people aged 15-65 years). For comparison, between six and eight decade of the last century the rate of dependency on young people was over 60% (a maximum over 65% recorded during 1965-1970), and the rate of dependency on elderly was placed under 10%.

Numerous studies, both theoretical and based on available empirical data, show that on long-term there is a significant correlation between demographic variables and level of economic development. These correlations are also widely used in the so-called chained generations' models. The main correlation resulting from the simple analysis of statistical data is that between life expectancy of general population and their economic development. Thus, it has been proven that as a general long-term trend, when GDP per capita increases due to better living, the average lifespan of the population and life expectancy increase, too. The relationship between GDP and life expectancy may be analysed also converse. Namely, along with increased quality of life and life expectancy, we get an increase of the active life on population; thus resulting an increase in the productive capacity of all nations and therefore of GDP per capita. If we take into account the European Union (EU-27), in 2003 and 2006, the above-mentioned correlation is presented in graphical form in Figure 1 (EU countries are designated by ***i***, in an ascending order on the abscissa by GDP per capita in euros in 2006, starting with Bulgaria - which has the lowest level -, all they way to Luxembourg - with the highest level; and on the ordinate axis we have life expectancy in EU countries, expressed in years, denoted by ***v***).

One factor with significant impact on the relationship of demographic development - economic growth is denoted by rate or fertility index (expressed by the number of children borned from one woman during her fertile life). General worldwide historical trend has a declining fertility rate related to the increase in the level of economic development. In EU, however, empirical evidence for recent periods of time (2003 and 2006) seem to refute this hypothesis, as seen from the graphical representation in Figure 2 of the correlation between GDP per capita and fertility rates (where on the OY axis is the fertility rate **-** ***f***, and on the abscissa countries within EU - denoted by ***i*** - ordered ascending by GDP per capita in euros in 2006). On the other hand, if we take the infant mortality rate (calculated as a ratio between the number of dead children for every 1,000 children borned alive), unlike that of fertility, the hypothesis of inverse correlation relative to the level of economic development is true for recent periods (years 2003 and 2006), both globally and for the European Union, as is suggested by the graphical representation in Figure 3 (where infant mortality is denoted by ***m0*** on the ordinate axis, and on the abscissa countries within the EU, denoted by ***i*** ordered ascending by GDP per capita in euros in 2006).

According to recent records, in 2003 and 2006, all countries from the European Union register a series of significant correlation between demographic indicators; which may constitute an important milestone for all projections of demoeconomic development in the future. Thus, within the geographical boundaries of the European Union through empirical observations, there is a direct logistic-type correlation between life expectancy - ***v***, and fertility - ***f*** (Figure 4), and an inverse hyperbolic one between life expectancy and infant mortality, m0 (Figure 5). In addition, another inverse hyperbolic-type relationship seems capable of satisfactory estimation of the correlation between fertility and infant mortality (Figure 6).

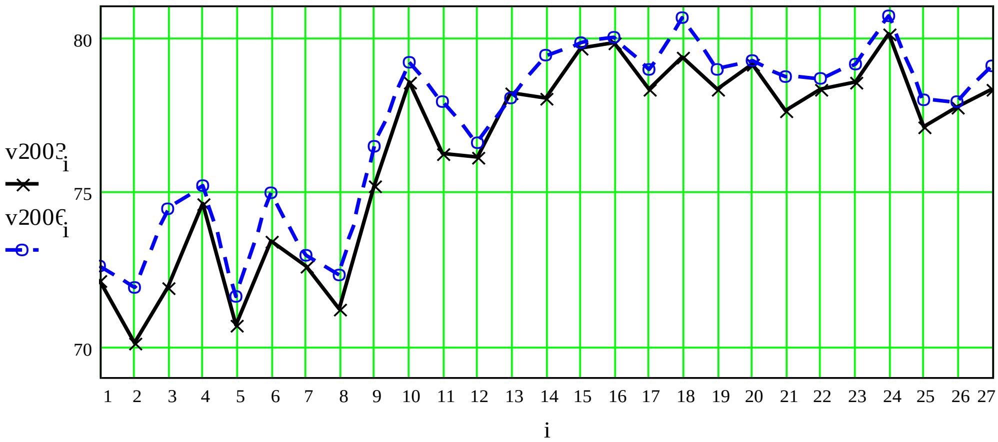

Figure 1.

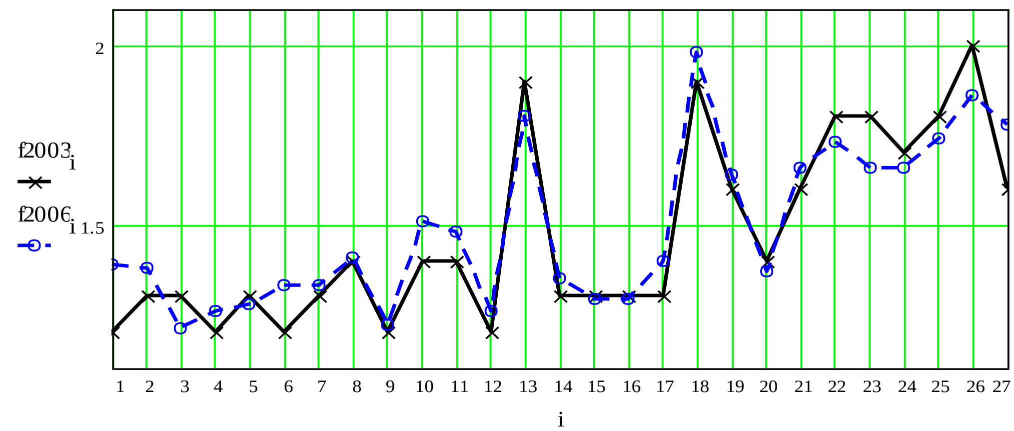

Figure 2.

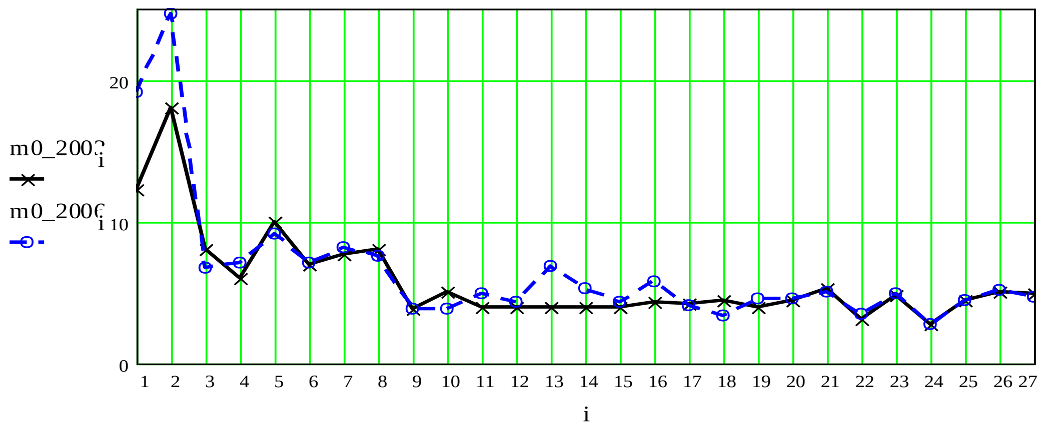

Figure 3.

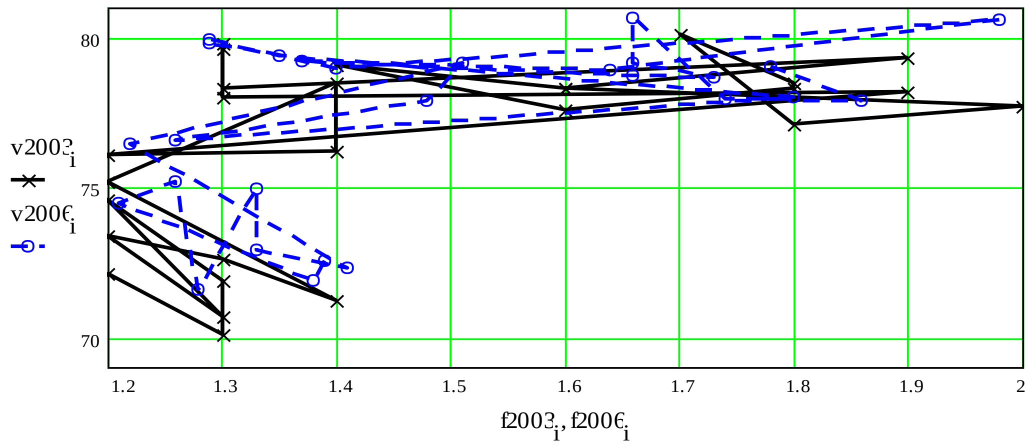

Figure 4.

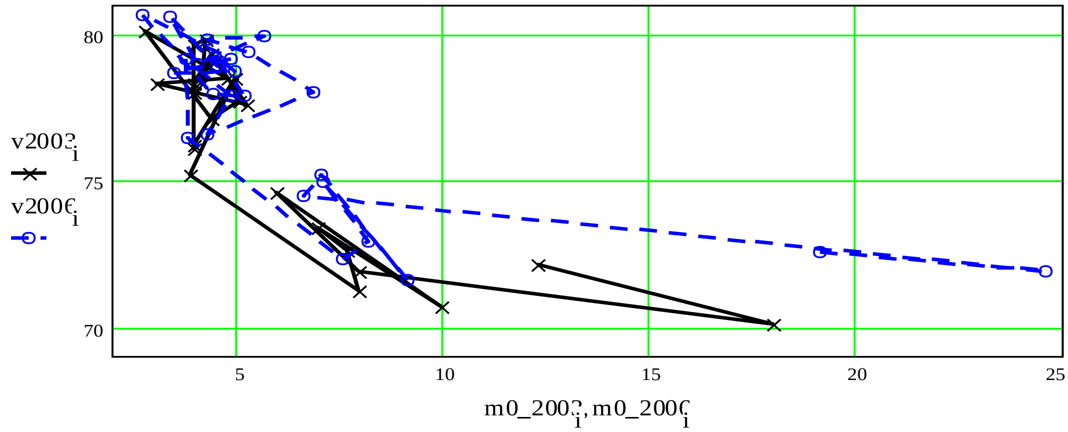

Figure 5.

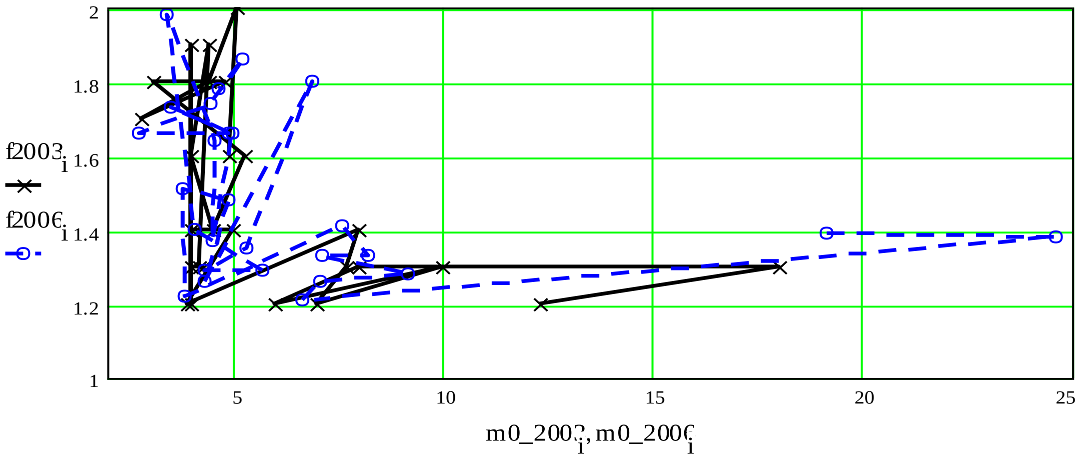

Figure 6.

In reality, the relations between demographic variables and macroeconomic ones are more complex than in the case of separate correlations between two variables. In order to study further complex correlation, a first step might be the representation of dynamics in a tridimensional space. In the case of European Union, examples of such 3D images along with the so-called "geodesic maps" (or "contour plot") attached to them, for 2003 and 2006, are presented in Annex 1. A more refined analysis can be made from this, which in return may facilitate the development of appropriate quantitative models for the geographical location of the European Union, the extraction of significant conclusions for future trends, and substantiation of a coherent set of policy measures in the field. As an example, we present some useful elements, derived from the analysis of spatial representations for the year 2006.

Based on the spatial representation of the correlation among life expectancy, female fertility and GDP per capita (***v-f-y***), we can see the highest rates of GDP per capita (the area marked on the "geodesic" map with intense red, bounded by the contour line 40, representing thousands of euro per capita) corresponding, in 2006, to a life expectancy ranging between approximately 78-81 years and with a female fertility placed approximately in the range 1,65-1,95 (see Annex 1). On the other hand, the lowest GDP per capita in the EU (the area marked by intense blue color, bounded by the contour line of 10 thousand euro per capita) corresponded in the same year, with a life expectancy below 76 years and a fertility below 1.45.

The representation in Annex 2 presents the spatial correlation of GDP per capita, female fertility and life expectancy, which is just another view on the relationship between the same three variables as in Annex 1, produced by the rotation axes of coordinates. Based on the "geodesic" map for 2006 one can observe, as an example, that a life expectancy of over 79 years (areas marked with red) usually corresponds to a level of GDP per capita of over 15 thousand euro. However, it can be concluded that, in most cases, the level of GDP per capita instead of fertility has a strong influence upon life expectancy (observation based on the fact that, mostly for values of GDP per capita below 30 thousand euro, there are some vertical colored bands almost parallel).

Representation of spatial correlation GDP per capita - infant mortality - life expectancy, in Annex 3, allows a more refined interpretation of it. Thus, one can observe, for the year 2006, for example, as a rule, for values of GDP per capita over 15 thousand-euro and child mortality by more than 6 thousand live births, that the level of child mortality instead of GDP per capita influences life expectancy stronger (a conclusion drawn based on the fact that in the above mentioned area there are some horizontal colored bands almost parallel). Based on graphics in Annex 4, which show spatial correlation among demographic variables: Infant mortality - Female Fertility - Life expectancy; one can find that, in 2006, for example, life expectancy decreased (the transition from the red to the blue) if infant mortality will increase and/or fertility decrease. Conversely, life expectancy will increase (transition from the blue to the red) if infant mortality will decrease and/or fertility increase.

In the economic literature, starting from the classical model of Ramsey (which implies the existence of a representative consumer with an infinite lifespan and that makes decisions on the optimal consumption-saving ratio), there has been developed in recent decades a class of models that attempt to capture the correlation between changes in age structure of the population or between the so-called aging demographic, and economic growth. Nowadays, they are known as models of overlapping generations. Subsequently, we propose some simple modeling schemes that may prove useful in future efforts to study correlations between demographic variables and economic development, and in addition achievement of possible forecasts on the impact of aging population phenomenon related to growth, based on statistical data currently available.

Yaari (1965) has identified the two major complications that may occur in a model that takes into account the uncertainty of lifespan (note that in the standard Ramsey model there is no uncertainty on the lifetime). First, the assumption of expected utility must be used, thus the whole life expectancy utility becomes the objective. Secondly, the restriction of non-negativity regarding the agent’s property at the time of his death is similarly stochastic since it depends also on the random moment of death. Based on Yaari’s model one can reach the following conclusion: the survival uncertainty makes households to settle for the future more difficult, i.e. the subjective rate of time preference in the event of uncertainty upon lifetime is greater than in a classical case. If there is a positive probability that a person might not live long enough for it to enjoy a certain future consumption, then it tends to treat more difficult the time preference). Without further details of his theoretical developments in the case of a single consumer, we will mention however that Yaari has suggested that we should use a special type of life insurance based on the so-called insurance policies (also known as actuarial notes or bonds) used by insurance companies. Referring strictly to the consumer choice issue and taking into account Yaari's analysis, the consumer will always hold its funds in the form of financial insurance policies, that is he or she will ensure against the possible loss of life.

The results of Yaari's approach remained unused until Blanchard (1985) who transformed the central elements of his own continuous-time model for chained generations, which subsequently became one of the key models in the modern macroeconomic theory. Blanchard had significantly simplified Yaari's model assuming that, the probability density function for death of a consumer is exponential. Rather than assume a probability of instantaneous age-dependent death (as in the case of Yaari's model), Blanchard assumed that the rate of hazard is constant and independent with the consumer's age. Such an approach had several advantages. The first is that it leads to optimal consumption rules that can be easily aggregated for households. Thus, there is a possibility to maintain a high level of aggregation in the model, although the consumers' population is heterogeneous through age relation. Secondly, the remaining life expectancy for each agent is equal to $1/\beta$ (where $\beta(\tau)$ is the so-called hazard rate or instantaneous probability of death at τ moment), and, if $\beta=0$ is fixed, Blanchard's model coincides with the Ramsey 's agent representative model. Such extended model, called Blanchard-Yaari, is a time-conitous model of chained generations, which, due to its flexibility has been widely used as a central model in a series of applications of macroeconomic theory. The key element that distinguishes the Blanchard-Yaari model from the Ramsey's one is that the former makes distinction between agents according to their date of birth, while the latter involves only a single representative agent. By incorporating advanced modeling tools, Yaari-Blanchard model can be solved and analysed at macroeconomic level although individual households are heterogeneous. Its flexibility allowed an expansion of the model in various directions. One of these extensions considers endogenous labor supply, which plays a central role for a number of economic theories (such as that of the real business cycle). Such extensions of the model allowed the study of significant issues regarding the dynamics of the economic system under the impact of economic policy measures. Among the extended Blanchard-Yaari's model applications, we therefore state: the study of dependence on age based productivity, the economies' dynamic in an open economy model, the impact on growth of investments or wage dynamic, the estimation of financial assets and human capital, etc.

The main consequence of the time-continuous Blanchard-Yaari's model, whose basic assumption is perpetuate youth, lies in that a finite lifetime horizon can be properly analyzed. Instead, the model failed to prove itself suitable in the case of consumption aspects related to an evaluation attempt over the life cycle. Of course, in the standard Blanchard model, the age of one household affects the level and substance of its assets (first issue), but not its inclination towards consumption outside the limit imposed by the sum of held assets (an aspect related to the life cycle). In the absence of a testamentary reason and with a finite life, it is expected that an elder agent to have a penchant for consumption more than a young agent, primarily because the former agent has a shorter planning horizon of life (or a higher risk of death) than the latter. A simplest model, which captures both finite horizon and the lifecycle of the household, was designed by Diamond (1965), from a preliminary study of Samuelson (1958). The model, known today as the Diamond-Samuelson, is one with discrete time: and, for more than four decades, it has become the core for many areas in economic sciences. This model, in its standard form, includes the block of households and the block of companies, and even more, some restrictions over the market equilibrium.

In the Diamond-Samuelson model, one can consider that individual agents live two periods. In the first period (youth), they work, and in the second (old), they are withdrawn from employment. Since agents will want to consume in both periods of life, they will save during youth and then will stop saving in the old age period. During the first period, the agent offers an inelastic labor for which he receives a salary, which further on is spent on consumption and saving. During the second period, the agent no longer works, but receives income from interest on its savings. The initial fond plus interest is spent for consumption in old age. Therefore, the household is subject to two budget identities, as with the period of youth and then old age. Without further detailed equations for Diamond-Samuelson model, we mention that it allows a specific approach in the context of chained generations, for some significant problems at macroeconomic level, such as: the behavior of households and firms, the equilibrium market conditions, the dynamics and stability of the economic system restrictions, the trajectory of effectiveness, the mechanism of operation in the pension system (as is the standard one, Pay-as-you-go or PAYG), the equivalence between PAYG and funding of government debt through deficit, the relationship between PAYG type pensions and the endogenous retirement, the welfare effects, the macroeconomic effects of the aging phenomenon. Subsequently, the Diamond-Samuelson model was developed and its main extensions were targeting human capital assessment and its mechanism of formation, the explaining of the relationship human capital - education, estimating the impact of public investment, the quantifying parameters of the so-called golden rule of accumulation and the impact of intergenerational relationships upon the dynamics of the economic system, etc

Generations chained models are used in particular for their valences at a theoretical level. In many cases, they demonstrate the complexity of economic agents' behavior and economic system in general. When some of the basic parameters of the models overcome certain thresholds, the systems can move successively from stable regimes of behavior to some cyclical and even chaotic ones. In addition, besides the reported problems, chained generations models, mainly with theoretical values, are usually applied in hard cases for developing forecasts and/or substantiating the macroeconomic policies. Therefore, economists use in parallel, for analysis and forecasting, a series of simple theoretical models, which can facilitate the quantification and simulation of economic processes and mechanisms. To this regard, one can devise a scheme by which modeling could try to quantify the link between the aging phenomenon of population and the basic factors of economic growth, i.e. labor and capital, starting from the simplified form of the general structure of the population:

$$P = P_I + P_{II} + P_{III} \tag{1}$$

where P represents total population, P_I – young population, with ages below 15 years, P_{II} – adult population, with ages between 15-64 years, and finally P_{III} – old population, 65 years and above. Also, in relation with adult population, without explanation for unemployment and considering that $P_{II} = L$, potential labor force, the employment rate, μ, can be written:

$$\mu = Lo / L \tag{2}$$

where Lo is employed population, i.e. one that ensures the achievement of GDP, Y.
The implications of changing the age structure of population and particularly the aging phenomenon, which can be measured through increase in the share of elderly population, P_{III}, per total, one can still include in a production function, Y, one factor, Y(L) or two factors, Y(L,K), usually a Cobb-Douglas type.

It is already an axiom that increasing life expectancy and low fertility women are among the main causes that generate the phenomenon of aging, which in turn leads to long-term decrease in the total population. Today, in all developed countries there is an accentuated phenomenon of aging. In many developed countries in Europe already there is a natural decrease of total population (in spite of the infant mortality reached very low values). Only net immigration makes total population still not fall to steep. According to specialized international bodies, in the next three decades, it is very likely that all this geographic area will be affected with aging (due to the fact that it provides further immigration, it is likely that declining population in some way is lagged).

In order to apply various models to quantify the impact of demographic aging on the economy dynamic and for attempting various forecasts for Romania it would be useful to estimate present correlations related to the geographical area of European Union. Using the latest data available, we estimate some econometric correlations where demographic variables are involved, as follows.

In the last few years, in the case of EU, there is a significant direct linear correlation between the level of economic development, ***y***, on the one hand, and life expectancy, ***v***, female fertility, ***f***, and infant mortality, ***m0***, on the other hand, expressed by the regression equation having the following form:

$$y(v, f) = a0 + a1*v + a2*f + a3*m0 + u \qquad (3)$$

where a0, a1, a2 and a3 are estimated coefficients, u - residue. Synthetically, the results of estimation for 2006 are: a0=-169.4906315; a1=+1.886628779; a2=+32.3015554; a3=-0.3307476105. Using figure 7, we represent the real data series for GDP per capita, y (continuous line) and its estimations, y_E (dashed line), on the abscissa we have all 27 countries from EU (ascending ordered by GDP per capita expressed in euros in 2006). In the same figure, we also have the minimum values curve, y_L, and the maximum values one y_U, which bounds the range of the statistical confidence level (the two dashed lines).

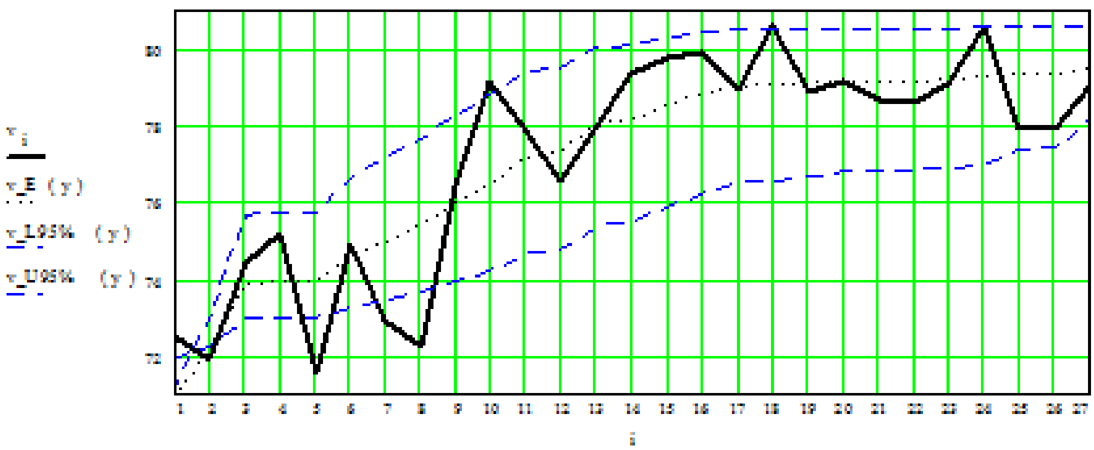

Figure 7.

Studying individually the relationships between the level of development and the life expectancy (y-v), between the level of development and fertility rate (y-f), and finally between the level of development and infant mortality (y-m0), we can see the existence of some direct significant correlations. However, they are of logistic type (for the first two demographic variables), and hyperbolic type (for the last considered variable). Among the regression equations, which describes best the correlation of inverse relationship we have selected the following ones:

$$v(y) = \{b0 / [1 + b1*e^{(-b2*y)}]\} + u \quad (4)$$

$$f(y) = \{c0 / [1 + c1*e^{(-c2*y)}]\} + u \quad (5)$$

$$m0(y) = d0 + (d1 / y) + u \quad (6)$$

where b0, b1, b2, c0, c1, c2, d0 and d1 represents estimated coefficients for each equation, e is the natural logarithm basis, and u represents the residue for all three. Synthetically, the results of estimations for 2006 are: b0=+79.49903726; b1=+0.1792495991; b2=+0.1229746193; c0=+1.962115342; c1=+0.6290018541; c2=+0.03422126024; d0=+1.849366498; d1=+56.47572196. Using figure 8, we represent a series of actual data compared to life expectancy, ***v*** (continuous line) and its estimations, ***v_E*** (dotted line), on the horizontal axe **i** is the same as in Figure 7. Also for minimum and maximum curves ***y_L*** and ***y_U***.Using Figure 9, we represented versus actual data series for fertility, f (continuous line) and its estimations f_E (dotted line), on the horizontal axe **i** is the same as in Figure 7. Also for minimum and maximum curves f_L and f_U. Using Figure 10, we show versus actual data series for infant mortality, m0 (continuous line) and its estimation m0_E (dotted line), on the horizontal axe **i** is the same as in figure 7. Also for minimum and maximum curves m0_L and m0_U.

To achieve plausible forecasts regarding the correlation's dynamic between demographic variables and economical ones, and as a consequnce for proper foundation for both measures of economic policy and the impact on population, there is certain need, along with the use of information and results analysis at an worldwide and european level, for constructing some regression functions specific to each country. On short and medium term, the correlations and estimate the parameters of the regression functions can even deviate significantly from long-term trends, which reflect the laws of economic and demographic. However, on long and very long term, the trajectories of national or regional level, will converge towards their demonstration. In this sense, the consideration of such information and studies, provided by specialized international bodies, becomes a priority, especialy when the final policies and strategies on short and medium term are drawn. For example, we present a set with this type of information in Annex 5, which may constitute the basic assumptions for the forecast models.

Regarding the forecasting studies on the impact of changes for demographic variables and the phenomenon of aging population, upon economic growth, one can also prove the models and theoretical trajectory of such variables. For example, for the above mentioned three demographic variables, the long-term trajectories (or theoretical trajectories) can be calculated depending on the future development of GDP per capita based on regression equations presented. The graphics of the three theoretical trajectory (dotted lines) depending on the level of economic development are presented in Figures 11-13 (the significance of symbols is the same as in Figures 8-10, with the difference that the abscissa axis, instead of ***i***, representing the 27 EU countries grouped on an ascending level of GDP per capita, we will have the actual level, expressed in thousand euros per capita in 2006). The theoretical trajectories estimated by available data for 2006 for EU countries, shows the convergence on long-term (was considered because the "arrow development" implies growth in the future GDP per capita) to certain constant values of the three basic demographic variables: a) life expectancy converges on long term towards a maximum represented by asymptote b0=79.50 years; b) women fertility converges on long term towards a maximum represented by asymptote c0=1.96 births per woman; c) infantile mortality converges on long term towards a minimum represented by asymptote d0=1.85 deaths for 1000 borned alive.

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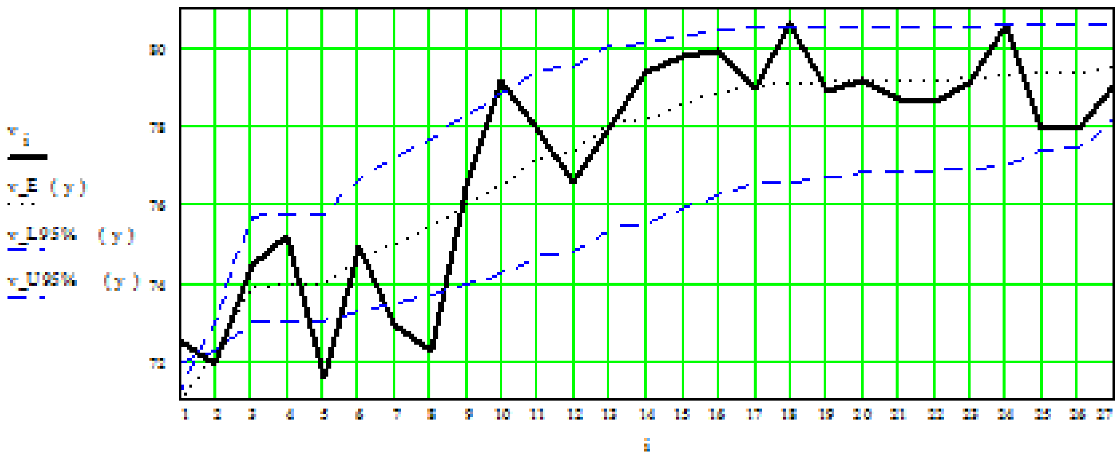

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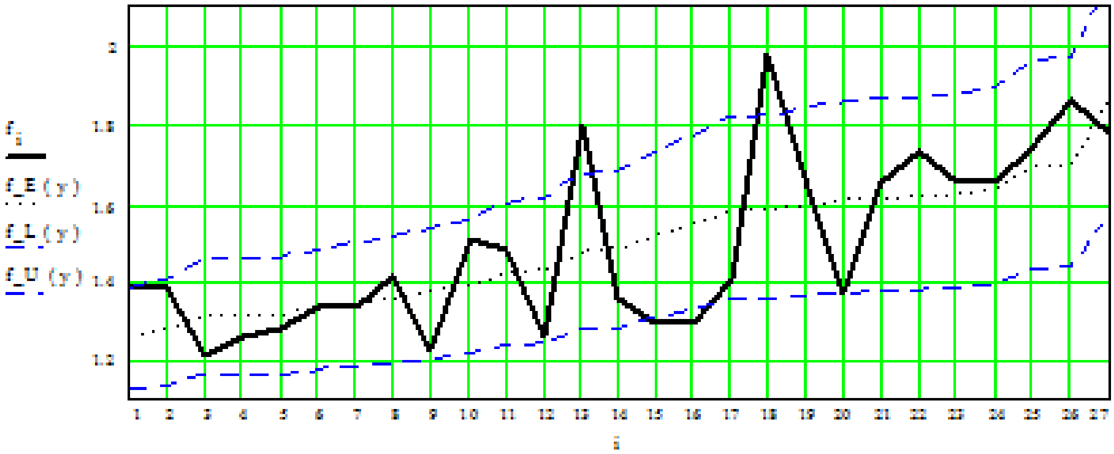
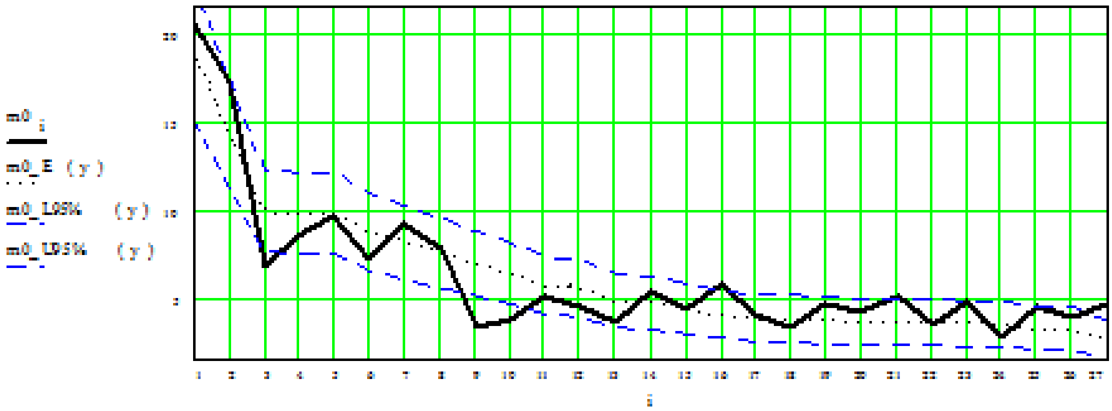


Figure 9.



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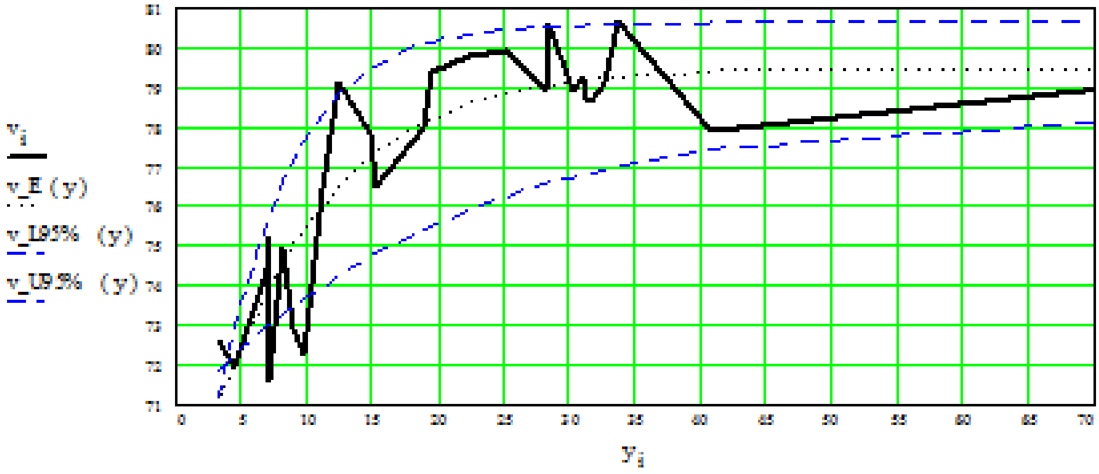

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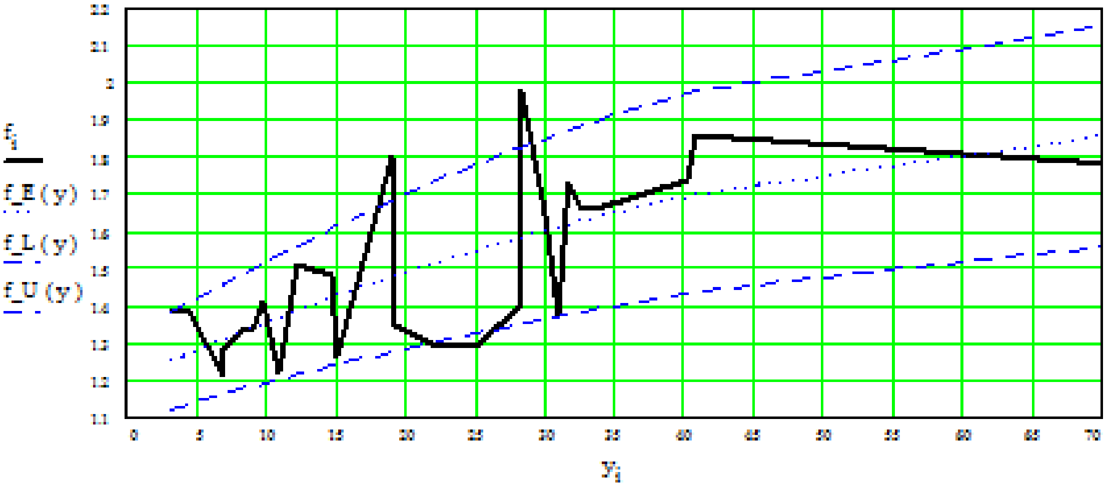

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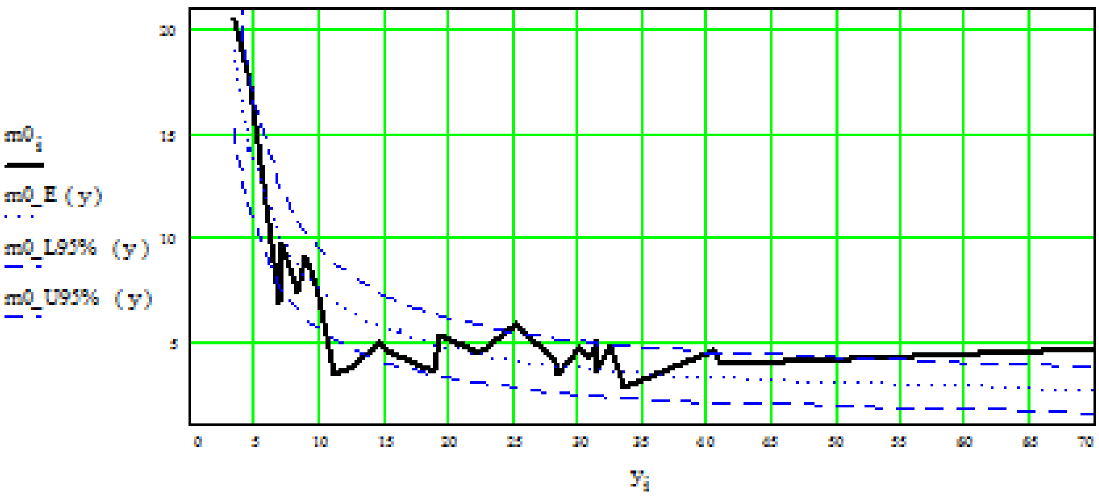

Figure 13.

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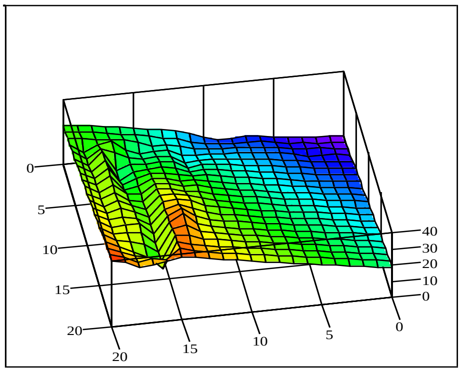
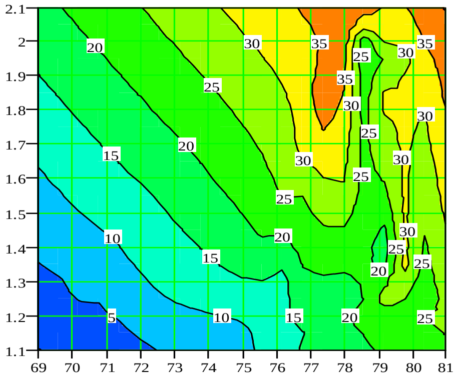
Correlation: Life expectancy – Female fertility – GDP per capita



v2003, f2003, y2003

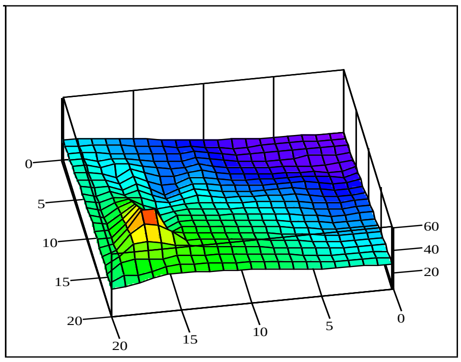


v2003, f2003, y2003

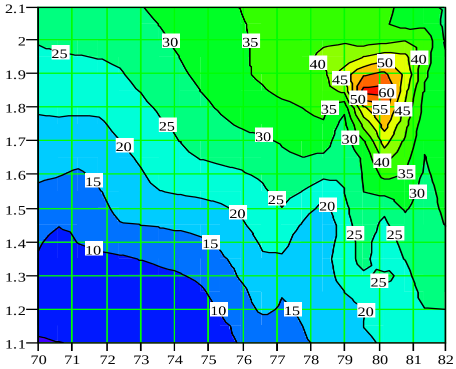
mir(v2003) = 70.1 max(v2003) = 80.1

mir(f2003) = 1.2 max(f2003) = 2

mir(y2003) = 2.551 max(y2003) = 59.152



v2006, f2006, y2006



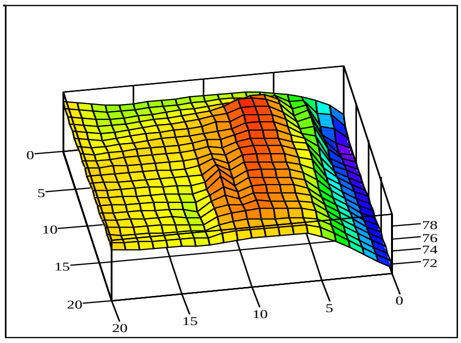
v2006, f2006, y2006

mir(v2006) = 71.6 max(v2006) = 80.63

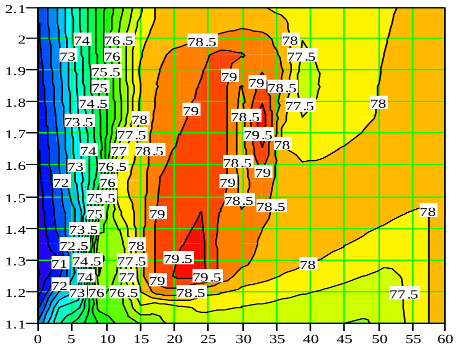
mir(f2006) = 1.21 max(f2006) = 1.98

mir(y2006) = 3.3 max(y2006) = 71.6

Correlation: GDP per capita – Female fertility – Life expectancy

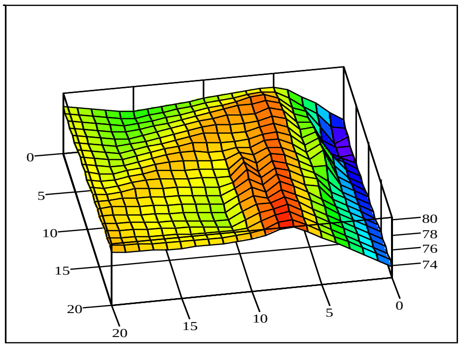


y2003, f2003, v2003

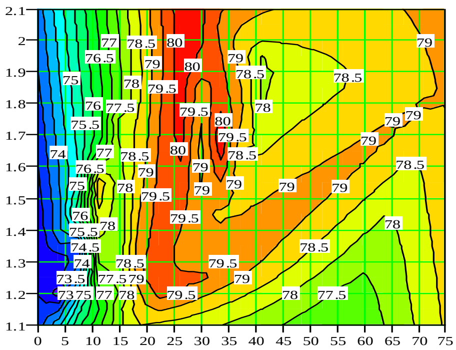


y2003, f2003, v2003

mir(y2003) = 2.551 max(y2003) = 59.152
mir(f2003) = 1.2 max(f2003) = 2
mir(v2003) = 70.1 max(v2003) = 80.1



y2006, f2006, v2006

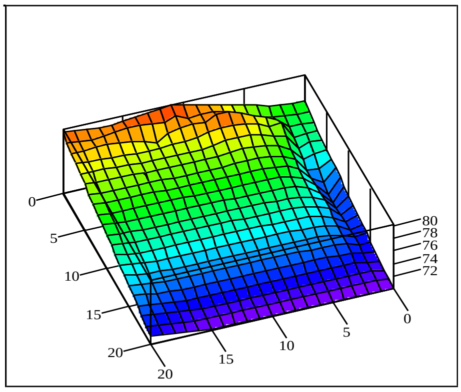


y2006, f2006, v2006

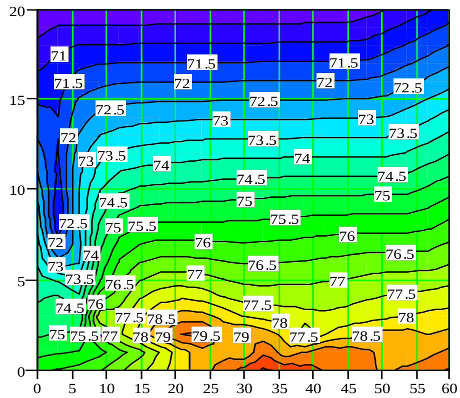
mir(y2006) = 3.3 max(y2006) = 71.6
mir(f2006) = 1.21 max(f2006) = 1.98
mir(v2006) = 71.6 max(v2006) = 80.63

Annex 3

Correlation: GDP per capita – Infantile Mortality – Life expectancy



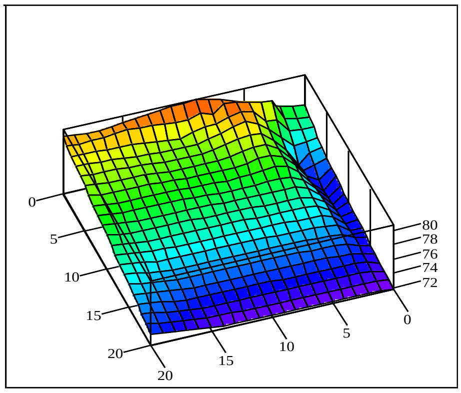
y2003, m0_2003, v2003



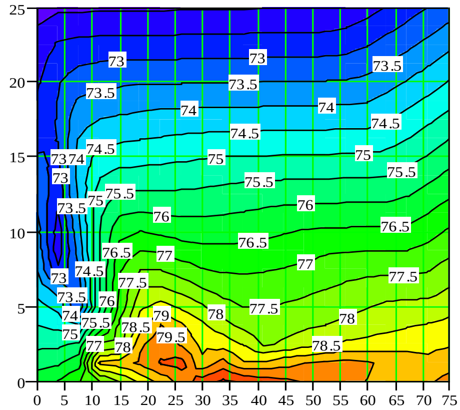
y2003, m0_2003, v2003

mir(y2003) = 2.551
mir(m0_2003) = 2.8
mir(v2003) = 70.1

max(y2003) = 59.152
max(m0_2003) = 18
max(v2003) = 80.1



y2006, m0_2006, v2006

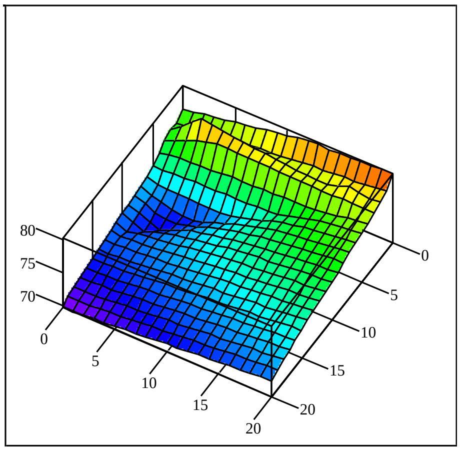


y2006, m0_2006, v2006

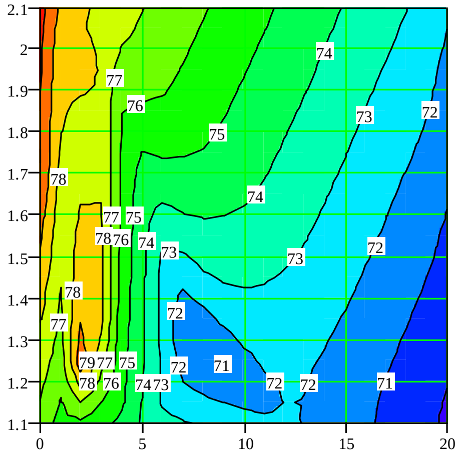
mir(y2006) = 3.3
mir(m0_2006) = 2.76
mir(v2006) = 71.6

max(y2006) = 71.6
max(m0_2006) = 24.6
max(v2006) = 80.63

Correlation: Infantile mortality – Female fertility – Life expectancy

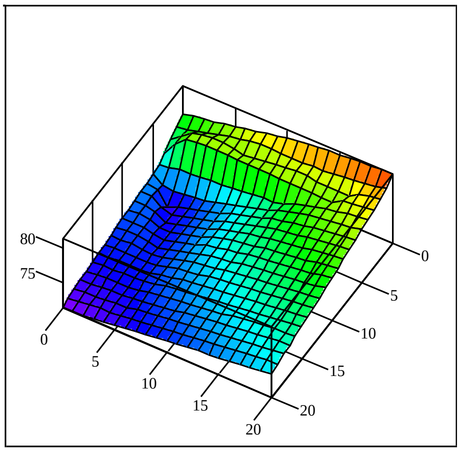


m0_2003, f2003, v2003

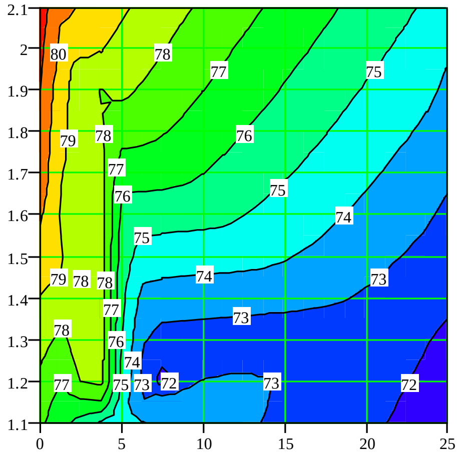


m0_2003, f2003, v2003

mir(m0_2003) = 2.8	max(m0_2003) = 18
mir(f2003) = 1.2	max(f2003) = 2
mir(v2003) = 70.1	max(v2003) = 80.1



m0_2006, f2006, v2006



m0_2006, f2006, v2006

mir(m0_2006) = 2.76	max(m0_2006) = 24.6
mir(f2006) = 1.21	max(f2006) = 1.98
mir(v2006) = 71.6	max(v2006) = 80.63