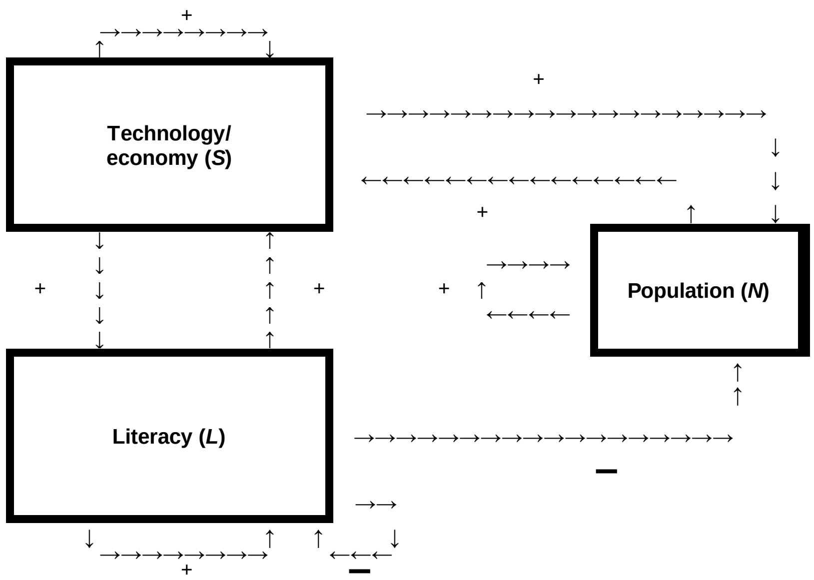
*Introduction to Social Macrodynamics. Compact Macromodels of the World System Growth* by Andrey Korotayev , Artemy Malkov, and Daria Khaltourina. Moscow: Editorial URSS, 2006. Pp. 81–86.

Chapter 5

# A Special Extended Macromodel of World Economic, Cultural, and Demographic Growth

In this model we make the following additional assumptions: (1) a literate population makes more technological innovations than an illiterate one. Consequently, literacy growth leads to acceleration of technological development. (2) In the Modern era the level of the World System's economic development is determined first of all by the level of development of human capital, which, we believe, can be roughly estimated by the world literacy level. These assumptions in conjunction with the assumptions of the models presented above suggest the following functional scheme of relationships between modeled subsystems (see Diagram 5.1):

**Diagram 5.1.** Functional Scheme of Relationships between Model Subsystems



The relationships between these three subsystems are modeled using the following set of differential equations:

$$\frac{dN}{dt} = aSN(1-L),$$

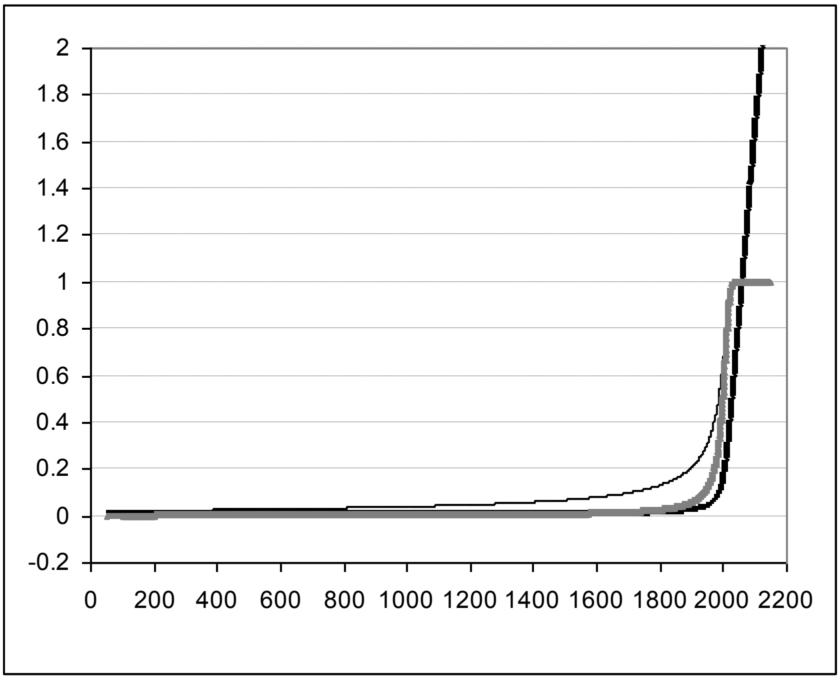
$$\frac{dS}{dt} = bLN,$$

$$\frac{dL}{dt} = cSL(1-L),$$

where $L$ is the proportion of the literate population and $a$, $b$, and $c$ are constants.

This model generates dynamics shown in Diagram 5.2:

**Diagram 5.2.** Dynamics Generated by the Model

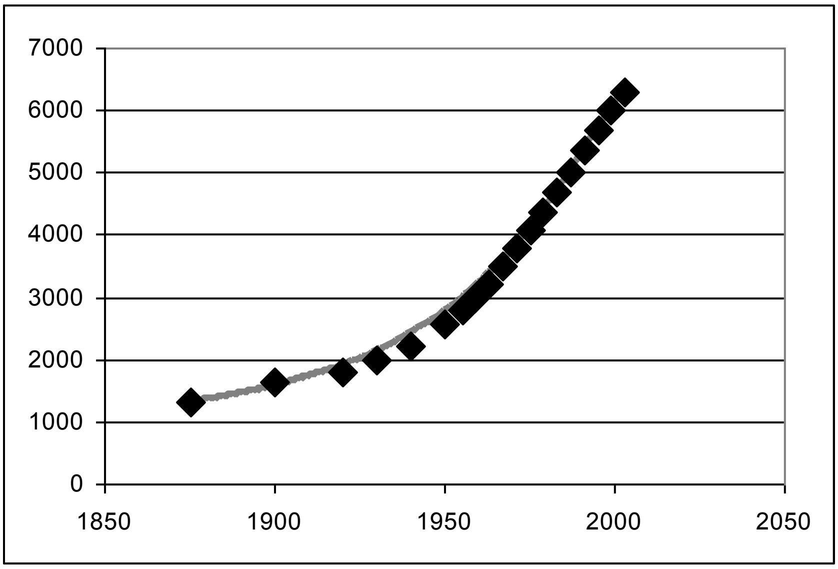



NOTE: *thick grey curve* – the world population counted as proportion from its size at stabilization level; *thin black curve* – literacy; *thick black curve* – level of the World System techno-economic development ($S$) counted as proportion from its level at world population stabilization point.

With such a compact model we are able to reproduce rather well both the hyperbolic growth of world population before 1962/3, and the subsequent increasing slow down of world population growth rates.

With our three-equation model we start the simulation in 1875 and do annual iterations with difference equations derived from the differential ones. We choose the following values of the constants and initial conditions: $N$ = 1325 million; $K$ = 1; $L$ = 0.22[1]; $a$ = 0.008 (this corresponds to the initial annual population growth rate and equals the average annual population growth rate in 1875–1900 CE according to Kremer's estimations [1993]); $b$ = 0.00005; $c$ = 0.007. The outcome of the simulation, presented in Diagram 5.3 indicates that irrespective of all its simplicity the model is actually capable of replicating quite reasonably the population estimates of Kremer (1993), US Bureau of the Census (2005) and other sources (Thomlinson 1975; Durand 1977; McEvedy and Jones 1978: 342–51; Biraben 1980; Haub 1995: 5; UN Population Division 2005; World Bank 2005) in most of their characteristics and in terms of the important turning points:

**Diagram 5.3.** Predicted and Observed Dynamics of World Population Growth, in millions

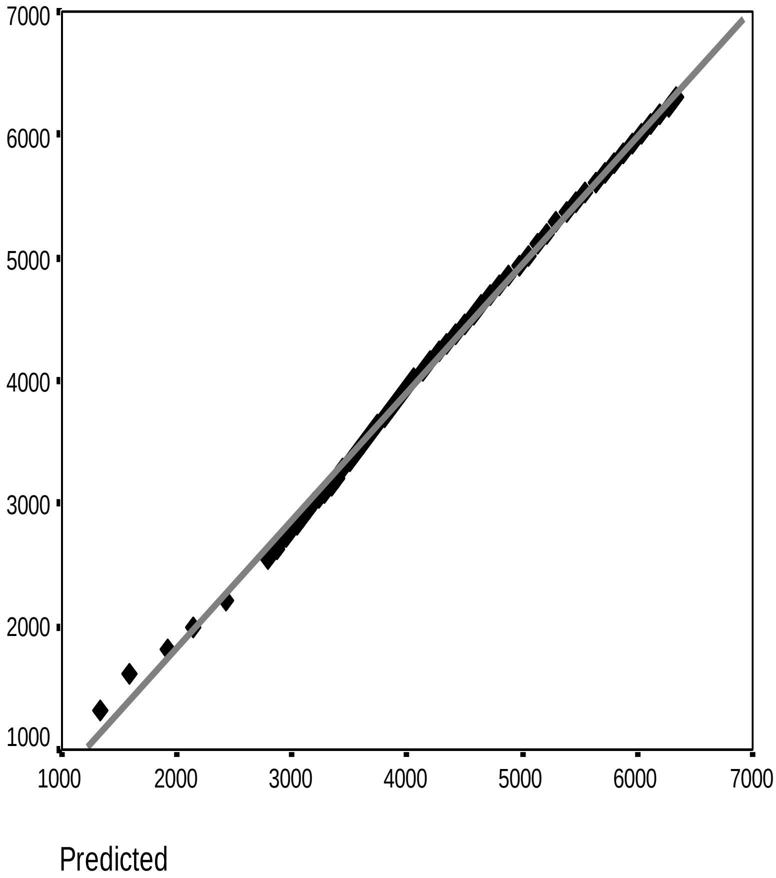



NOTE: The solid grey curve has been generated by the model; black markers correspond to the estimates of world population by Kremer (1993) for pre-1950 period, and the US Bureau of Census world population data for 1950–2003.

[1] Based on Meliantsev's (1996, 2003, 2004a, 2004b) estimates.

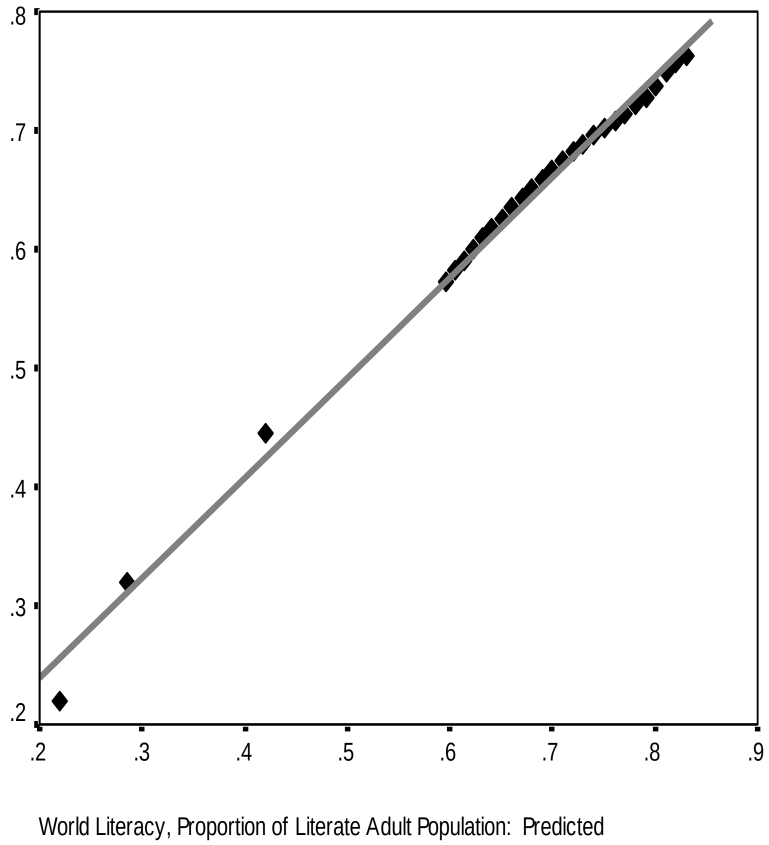
The correlation between the predicted and observed values for this simulation looks as follows: $R = 0.9989$, $R^2 = 0.9978$, $p << 0.0001$ (Diagram 5.4):

**Diagram 5.4.** World Population: Correlation between Predicted and Observed Values




The correlation between predicted and observed values of world literacy also turns out to be rather high (see Diagram 5.5):

**Diagram 5.5.** World Literacy, Proportion of Literate Adult Population: Correlation between Predicted and Observed Values




$R = 0.997$, $R^2 = 0.994$, $p << 0.0001$

This dynamics has exact parallels in the real world – the world population growth rates increased most rapidly when the world literacy was approaching 50% (as both in the model and in reality, the stretch between 30% and 70% was passed within just a few decades compared with millennia during which the first 10% were passed), they achieved their highest levels when the world literacy rate was around 50%, and started decreasing with a progressively amplifying speed almost immediately after it grew over 50% (cp. Kremer 1993: 683; US Census Bureau 2005; World Bank 2005).[2]

Of course, the special macromodel has a much narrower applicability than the general ones. For example, it does not work at all for the preliterate period of human history, as, according to the special macromodel, zero literacy would correspond to a zero rate of techno-economic and demographic growth, whereas this does not match the reality at all. On the other hand, the special macromodel describe rather well the modernization period, which appears to reflect the fact that the development of human capital became the most important factor of economic development (see, e.g.: Meliantsev 1996; Dobrynin, Dyatlov, and Kurganskij 1999; Denison 1962; Schultz 1963; Scholing and Timmermann 1988; Lucas 1988 etc.). Note that, as we shall see below (see Chapter 7), the literacy level could serve as a rather sensitive indicator of the overall level of human capital development. Note also that we have at our disposal some data suggesting that the growth of literacy could serve in itself as a powerful factor of economic development; this will be discussed in the next chapter.

[2] Thus, it turns out that the sets of 2–3 differential equations specified above account for up to 99.78 per cent of all the variation in demographic, economic, and cultural macrodynamics of the world in the last 2,000–25,000 years. In fact, in some sense the second part of our *Introduction to Social Macrodynamics* (*Secular Cycles and Millennial Trends*) will be concerned with the remaining 0.22–0.34% (As was indicated above, the simulation with compact macromodel 1 started in 500 BCE [and run till 1962 CE] already gave a correlation with observed data as high as 0.9983 [$R^2$ = 0.9966], whereas in the second part of our *Introduction* we will be dealing mainly with the last two millennia of the world history). As we will see, to account for the remaining fraction of the variation is much more difficult, and we will only be able to start this process. What is more, the models will become more and more bulky, less and less elegant. However, in many senses this remaining fraction of variation is much more interesting than 99.66–99.78% of it, as without accounting for it we shall never be able to make any specific, concrete and exact predictions.