Economic growth with incomplete financial discipline

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We introduce soft budget constraint and stop-go policy into a stable two-sector AK macro-model. As the extended model does not have any fixed point, we use computer-simulation to examine the dynamic behaviour of the model. We show that depending on the starting position and the parameter values, the economy can follow a path leading to the collapse or moves oscillatory avoiding the downfall. Further on, we demonstrate that the partial shortage of financial discipline leads to wrong investment decisions which slow the process of capital accumulation. The macroeconomic path directed to the collapse can be reversed by strengthening the financial discipline, keeping down corruption, modification of preferences in investment policy or exogenous technological change.

Keywords: chaotic dynamics, simulation, bribe

1. Introduction

According to the consensus evolved through the last decades, the most important sources of the economic growth are the growth of population, investments to human and physical capital and technological development. The developed countries and Hungary are characterized by the decrease of population instead of growth, therefore in this paper we do not examine this factor, and the effect of technological development is placed in the third section. First of all, we focus on the investment processes.

In a pure market economy investment decisions are made by private companies, but in a typical mixed economy the role of the governmental investments is highly significant, especially in human and physical infrastructures. There are many examples like construction of motorways or underground lines and investments in higher education. These projects financed by public money strengthen the redistributive mechanisms opposite to the processes of the market economy.

However, corruption is a constant accompaniment of redistribution, furthermore, based on Mauro (1998), corruption distorts the structure of investments, because politician prefer to contribute those non-productive giant investment projects through which they can earn bigger amount of bribe easier. Thus governmental investments promote economic growth only partially. A significant part of financial investment resources penetrating back to a particular group of private households, and these resources are dissipating away from the economy.

In this paper, we add this so called treasury corruption introduced by Hámori (1998) to a simple two-sector dynamic macroeconomic model as Bessenyei (2001) did it formerly to Ramsey's model. Instead of applying those assumptions, herewith, we base on the two-sector AK model demonstrated by Jones (1976). Accordingly there are two separated producing sector in the economy. The first one manufactures productive goods and the second one makes consumer goods. The technology of these sectors is characterized by the following production functions:

$$Y_i(t) = A_i K_i(t),\ i = 1,2, \qquad (1)$$

where the sector's output is directly proportional with the amount of the applied capital, $K_i(t)$. Apart from technological progress, we assume A_i constant. The form of the production function suggests that we do not take into consideration the decreasing return of capital. This is not unrealistic because the decreasing return would be valid if we constrained the definition of capital only to physical capital. Since a significant part of the governmental investments targets developing of human capital, in our model we use the expression of capital in this broader way.

The only scantily available resource is physical and human capital which is assumed not malleable. That means if a capital good is installed in a sector, it is not able to be transferred to the other sector. Let $\mu(t)$ to sign the ratio of capital installed in the first sector which is able to be enhanced by the economic policy in power through governmental investments. Accordingly:

$$K_1(t) = \mu(t)I(t) - \delta_1 K_1(t) \tag{2}$$

and

$$K_1(t) = (1-\mu)I(t) - \delta_1 K_1(t) \tag{3}$$

where δ_1 is the rate of amortization of capital goods in the sector i, while $I(t)$ refers to the gross investment.

We assume that by paying bribe, companies can usually enforce their will efficiently. Therefore they produce such pseudo capital which has no marginal productivity and do not serve any sector to develop. This assumption is suggested by Acemoglu and Verdier (2000). They conclude that the most essential consequence of corruption is the dysfunctionality of central reallocation of resources. Since the uselessness of capital in the sector manufacturing consumption goods would became quickly obvious, they are installed in the first sector. To earn more bribe from giant projects, the government endeavor to increase the rate of investments in the first sector, thus $\mu'(t) > 0$ hence the first sector turns back to itself. The increase of the ration of unproductive investments leads to financial disorder first of last, which causes the fall of consumption. Following Kornai (1980), we assume that the decrease of consumption has a social limit of tolerance. If this limit is violated, the government turns up against the spontaneous processes mentioned above. This intervention is called half-monetary restriction by Soós (1986), which results $\mu'(t) \ll 0$. Accordingly the motion equation of $\mu(t)$ is the following:

$$\mu'(t) = \begin{cases} \gamma_1 \mu(t), & \text{if} \quad C > 1-d \\ \gamma_2 \mu(t) & \text{else} \end{cases} \tag{4}$$

where the parameters of the stop-go economic policy are $\gamma_1 < 0 < \gamma_2$. Consumption is normalized to unity, therefore $C(0) = 1$, d is the social limit of tolarence against the consumption decrease. On the other hand, the pseudo capital goods cannot be included in investments,

$$I(t) = \left(1-\mu(t)\right)^{\alpha} Y_1(t), \tag{5}$$

where α determines the ratio of pseudo capital goods compared to first sector's output. If $\alpha = 0$, then $I(t) = Y_1(t)$, and ratio of pseudo capital goods is zero. This equation emphasises that the more the governmental industrial policy prefers the first sector, that is the higher the $\mu(t)$ is, the higher the ratio of wrong investments in the output of the first sector.

Accordingly the growth rate of investment good manufacturing sector is:

$$\hat{Y}_1(t) = \mu(t)\left(1-\mu(t)\right)^{\alpha} A_1 - \delta_1 \tag{6}$$

Therefore the current value of $\mu(t)$ determines the growth rate of the first sector, and $d\hat{Y}_1(t)/d\mu(t) = \left(1-\mu(t)\right)^{\alpha}(1-\alpha\mu(t))$. Consequently if α is not too high, that is $\alpha < 1/\mu(t)$, the capital installed in the in the first sector results faster growth of this sector.

The growth of the consumption good manufacturing sector is not so obvious:

$$\hat{Y}_2(t) = \left(1-\mu(t)\right)^{1+\alpha}\frac{A_2}{z(t)} - \delta_2, \quad (7)$$

where the ratio of the two sectors' output is $z(t) = Y_2(t)/Y_1(t)$. Both the increase of $\mu(t)$ and $z(t)$ can decrease the growth rate of the second sector. It comes from the definition of $z(t)$ that $\ln z(t) = \ln Y_2(t) - \ln Y_1(t)$. If we differentiate both side by time, the growth rate of z is given by the difference of the growth rate of the two sectors. Accordingly, the equation of motion for $z(t)$ is the following:

$$z'(t) = (1-\mu(t))^{\alpha}\left[\left(1-\mu(t)\right)A_2 - \mu A_1 z(t)\right] - (\delta_2-\delta_1)z(t) \quad (8)$$

Bessenyei (2006) proved that the model introduced above can win another economic interpretation. The detailed economic explanation of the differential equation (4) and the algebraic derivation of the equation of motion (8) can also be found in this article. Our purpose is to examine the dynamics of the model as properly as it is possible.

2. Chaotic dynamics

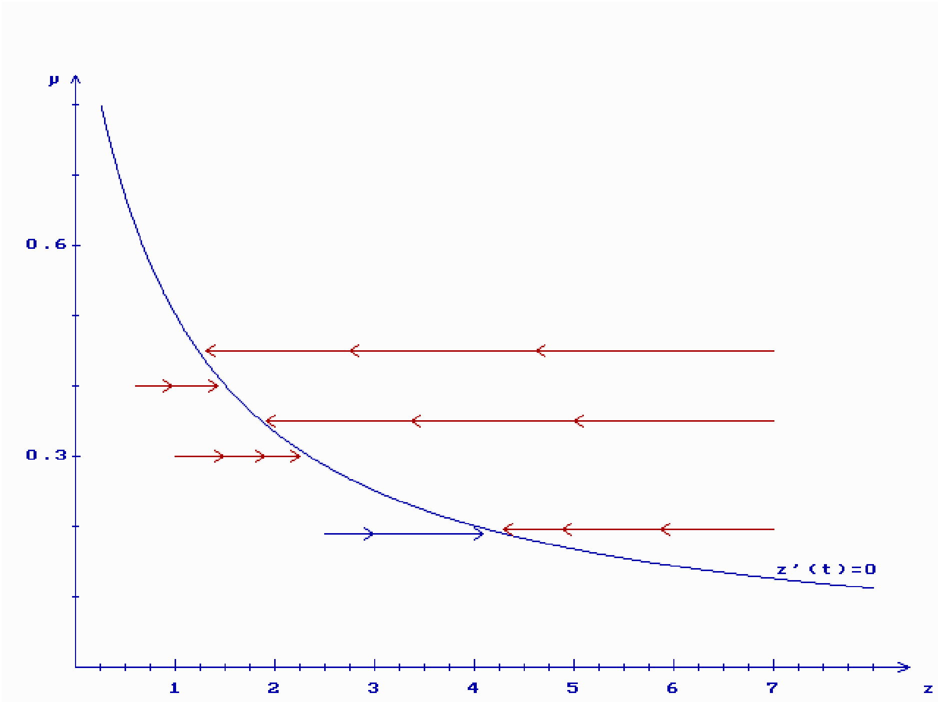
It is obvious that the dynamic system consisting of equation (4) and (8) has fixed point only if μ is zero, therefore the government do not follow the stop-go policy introduced above. In this case $\gamma_1 = \gamma_2 = 0$. Figure 1 shows that on one hand the fixed point is stable, on the other hand the higher the value of μ, the lower the value of z, therefore the higher the ratio of investments installed in the first sector, the lower the equilibrium ratio of consumption to investments.

The $z'(t) = 0$ curve in Figure 1 contains those values of endogenous variables which ensure the balanced economic growth, therefore the output of the two sectors increases in the same way and so $Y_2(t)/Y_1(t)$ is constant. However, equation (1) shows that if the government let the corporate will to increase μ, and later it needs to restrict this ease, and $\gamma_1 < 0 < \gamma_2$, then there is not any combination of endogenous variables which could satisfy $\mu'(t) = 0$.

Figure 1 was designed with parameter values in Table 1. The last two columns gives the initial situation of the two trajectories on the bottom.

Therefore if the government cannot avoid the stop-go policy introduced in the first section, then the dynamic system described by equation (4) and (8) has no fixed point. In this case the available mathematical methods of stability test can not be applied. With computer simulation, it is easy to prove that the behaviour of the system is chaotic. Shone (2002) presents more details on simulation of simple and complex dynamic systems with package of software like Mathematica or Maple, but it skips simulation of chaotic systems. Figure 2 (like the previous one) was designed with an own developed software, and represents in the $(z(t), \mu(t))$ phase plane that the model is very sensible to the initial value of $\mu(0)$. Since endogenous variables are constrained, the behaviour of the system is chaotic.

Figure 1: Stable equilibrium of the model



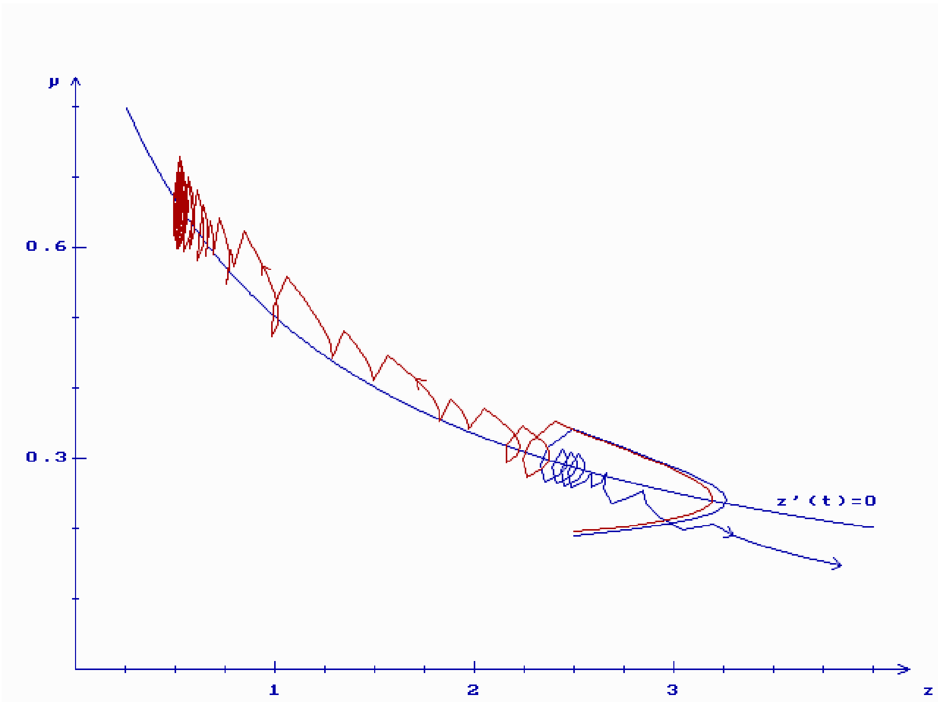
Source: own design

Table 1: Parameters and initial values of the two simulations

Trajectory	α	A_1	A_2	δ_1	δ_2	γ_1	γ_2	d	$z(0)$	$\mu(0)$
1	1,1	1	1	0,2	0,2	,04	,08	0,25	2,5	0 0,19
2	1,1	1	1	0,2	0,2	,04	,08	0,25	7	0 0,195

Source: own design

Figure 2: Sensibility to the initial position



Source: own design

Compared to the date in Table 1, the difference is only that both trajectories start from $z(t) = 0{,}25$. In the case of the Trajectory 1, the ratio of the manufactured capital installed in the first sector is so low that the values of the endogenous variables lead to economic collapse after serious fluctuation. The collapse is caused by the decreasing ratio of the capital installed in the first sector which leads to the decrease of investment based on the equation (6). Equation (7) results the fall of the output in the second sector because $z(t)$ increases limitless.

Trajectory 2 differs from the previous one only slightly in the initial point. The sector manufacturing investment goods has a half percent bigger share of investments, but this is sufficient to avoid the collapse. It is traceable in Figure 2 that the two trajectories move together for a while, but later they split up, and in the second case, the cyclic fluctuation of endogenous variables gets more or less stabilized. From theoretical point of view, it is an interesting question whether a limit cycle evolves, but practically it does not matter because so much time elapses to the stabilization of the fluctuations trough which the values of parameters must change. Our model is appropriate for medium-term forecast rather than on the long run.

3. Comparative dynamics

The simulation above shows the system's sensibility to the initial position expressively, but from the practical point of view it is very important to clarify what an effect a change in a value of a parameter has on a phase curve. The answer is especially interesting in the case of a trajectory directing to collapse. The question resembles to the problem of comparative statics where the modification effect of a parameter change on the equilibrium state is made clear. In our model there is not a fixed point that means equilibrium situation, therefore the comparison of equilibrium states is not possible. However, we have the opportunity to compare trajectories initiating from the same point with different parameters that is comparative dynamic analysis.

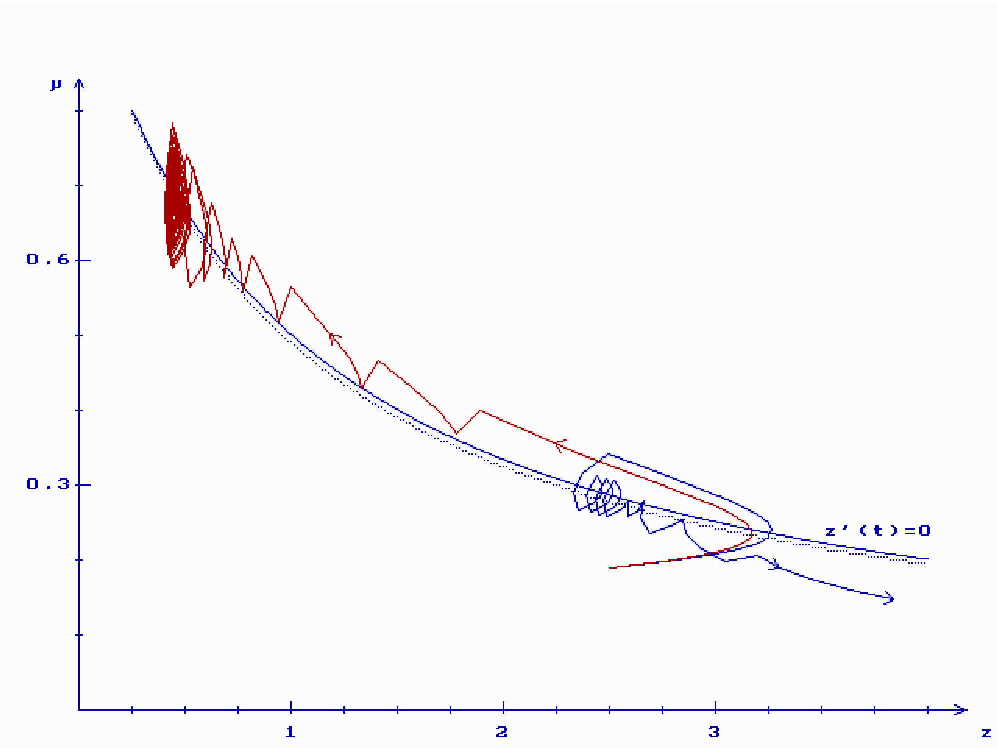
In the simulations to be showed in this section, we always use the parameters of Trajectory 1 presented in Table 1. In this case the economy characterized by equation (4) and (8) is directed to the collapse as showed in Figure 2. This trajectory is still presented, and we analyse how the parameters should be modified to avoid the collapse.

3.1. Technological progress

The determining role of technological advance in economic growth was mentioned in Section 1. Basu et al. (2004), Gali and Rabanal (2004) pointed that technological advance is not an equable process but impacts on different technologies and industries like shocks. Our two sector model allows us to examine the effect of technological shock in one of the two sectors. A shock effect like this is represented by the increase of the parameter A_i in the sector's production function. In Figure 3 we show what happens if the technology applied in the first sector is improving with 5 percent kept the rest of the premises (parameters and the initial point) unchanged.

In the beginning the two trajectories move together tightly, later less tightly, and after a while they split up. The 5 percent improvement of technology is sufficient for economy to reach a trajectory avoiding collapse. In the same time it is also represented that the cyclic fluctuation of economy is still kept up after the technological shock. The reason is that opposite to the cyclic model of Bródy (2002, 2003), the fluctuation is not caused by the multiple sector characteristic of our model but trough the governmental economic policy described by equation (4). The $z'(t) = 0$ line appears twice in Figure 3 because changing the value of A_1 modifies the position of this line. It is easy to check with replacing the left side of equation (6) with zero. The line belonging to the higher parameter value is plotted with broken line in Figure 3.

Figure 3: The effect of positive technological shock



Source: own design

3.2. The effect of investments with better foundations

In spite of the assumption of the neoclassical economics considered as mainstream, our model offers the opportunity of deviance in investment activity if a part of the capital goods manufactured by the first sector is useless pseudo capital good created trough the decision mechanism influenced by corruption. It is obvious to ask whether the reduction of this deviance (i.e. restricting corruption[1]) helps to avoid collapse. In Section 1, we mentioned that it could be represented trough decreasing the value of α. Figure 4 shows what happens if the value of α decrease to 1.05 from 1.1 as it was applied above in simulations and in Table 1.

We point another possible interpretation of α too. Considering equation (5), this parameter determines percentage of increase in the volume of productive investments if the government raises the ratio of capital installed in the second sector manufacturing consumption goods (assumed corruption-free). If investment decisions are free from corruption in both sector then the value of α is zero.

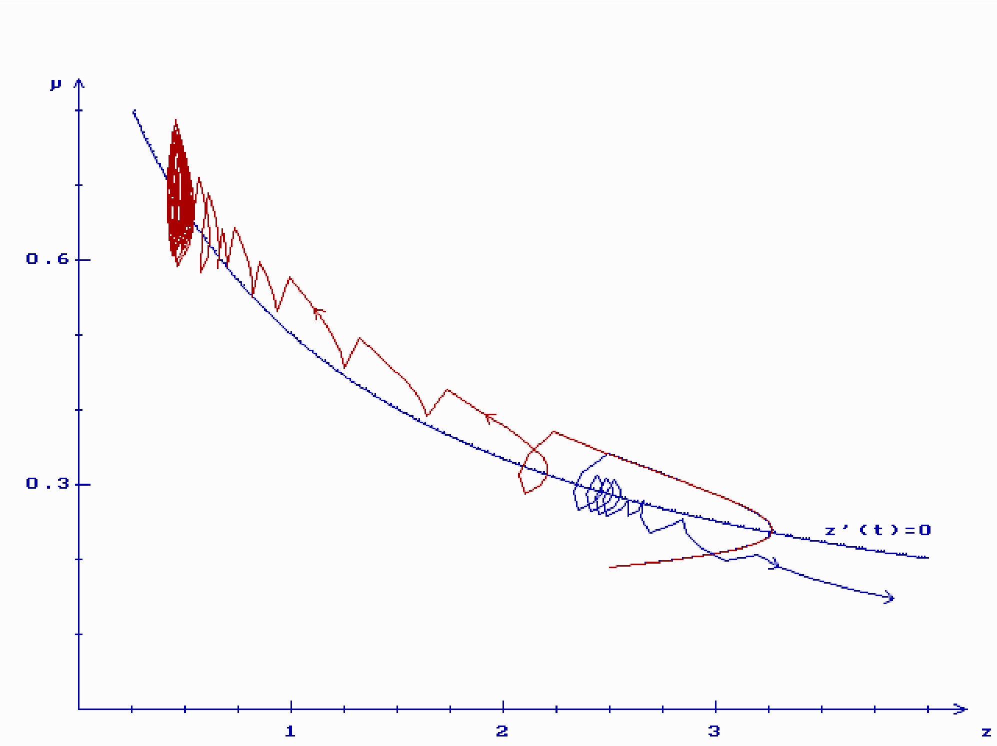
According to the comparative dynamic analysis, the effect of reducing corruption is not significant first. The two trajectories move together much further than they did in the case of technological shock. It is almost impossible to separate them. But later the difference becomes significant like in Figure 3.

We could attach the same notifications to Figure 4 with one addition: α has also an effect on the position of the $z'(t) = 0$ line according to the equation (8). Therefore the change of parameters

[1] Petschnig (1993) interprets corruption as the deviance of bureaucracy.

modifies the position of the line again. However, in this case the two lines are so close to each other that is not visible in the diagram.

Figure 4: The effect of better foundation of investment decisions



Source: own design

4. Conclusions

The Nobel-prize winner economist Gerard Debreu wrote about the relationship between theoretic economics and informatics in a quite pessimistic way: "Most of the economists (unlike physicians) count rather on the back of an envelop than they switch on a computer" (Debreu, 1991). Shone (2002) and this paper prove that the situation was significantly improved. Our analysis represents that application of informatics in economics is also reasonable because such a simple macroeconomic model like the one introduced here can have quite complex dynamic features. Herewith it is represented by the lack of the fixed point in the dynamic system, thus the long standing mathematical tools of examining dynamic systems can not be applied. In this case the method of computer simulation can be used well for macroeconomic forecast. Visualization of results was facilitated by the fact that our model is a planar system, therefore it contains only two endogenous variables. In case of more endogenous variables, designing figures with the plane phase diagram technique would be not sufficient[2].

Computer simulation allows us to earn more important consequences. Here we have demonstrated some of them only. Accordingly, there are more opportunities to reverse the macroeconomic process directing to the collapse of economy:

1. Preferring the sector manufacturing investment goods (heavy industry) (Figure 2)

[2] Our model has originally three endogenous variables: $\hat{Y}_1(t)$, $\hat{Y}_2(t)$ and $\mu(t)$. Introducing $z(t)$ was necessary just to reduce the number of endogenous variables to two.

2. Positive technological shock in the sector manufacturing investment goods (Figure 3)
3. Restricting corruption (Figure 4)

The ideal situation can be seen in Figure 1 which was designed with the assumption that there is no wrong investment decision (no corruption). In this case the government is able to resist against the intention of big companies to increase μ, therefore it does not need to apply an economic policy to reduce investment from time to time. However, the reality of these assumptions is quite low. It is enough to think of the study of recently departed András Bródy (2003) who quoting the Sanskrit Arthasastra notes that it is so hard to disclose the corruption of a state official as to answer the question whether a fish drinks from the water in which it lives. Staying at the Sanskrit metaphor, the computer simulation introduced in this paper allows us to conclude that from the point of economic growth it is not irrelevant how much that fish drinks.

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