

The Last Great Depression of the XXth Century: a Dynamical Approach

IULIA IGESCU
Global Insight, Inc.
Taubenstr. 7-9
60313 Frankfurt am Main
Germany
Tel: +49 69 20973312
Fax: +49 69 20973500
e-mail:iulia.igescu@globalinsight.com*

August 7, 2005

*I would like to thank David DeJong and John Duffy from University of Pittsburgh for their comments

THE LAST GREAT DEPRESSION OF THE XXTH CENTURY: A DYNAMICAL APPROACH

Abstract

The dramatic fall in output in eastern Europe in the 90s was a result of the institutional structure imposed by the state - taken here as exogenous - on the production process. Consider therefore an economic system where the state is promoting a policy of 'forced capital formation' to fund a technology that produces higher output. The drawback is that such an economic system becomes internally unstable: even though economic growth takes place in the short run, in the long run the economy moves into a transition towards a stable lower income (unless the relationship between the political sector and the economy changes and the state withdraws from the capital formation process). As output loss reached the level of another Great Depression, peculiarities of this phenomenon in East Europe can bring new insight into what is triggering great depressions.

1 Forced Capital Formation or Disorganization?

LET US START from the 'peculiar' evolution of per capita output in eastern European countries during the so-called transition process which officially started in 1989. It is peculiar because the current theory of endogenous growth cannot give us a satisfactory answer as to why that happened. For example Poland had two consecutive years of distress, so that by 1991 it had lost one quarter of its 1989-GDP. The economy recovered fast, and in 2004 stood at 40% above its 1989 output.

On the other hand dramatic cases such as Russia existed, too. By 1998 it had lost almost half of its starting output - a result of nine consecutive years of negative growth rates. The economy began to recover, yet in 2004 the output was still 15% below its 1989 level (see figure 1). In 2004 Romania was still 6% and Bulgaria 15% below their pre-transition GDP level. For fifteen years these countries have faced widely spread idle human and physical capital. Partly responsible for the decline were the external shocks, such as the disintegration of the trade system that linked these countries (and in the case of Russia the disintegration of the Soviet Union). However, that alone could not explain these persistently different transition paths after such a long period of time.

Leaving aside the already mentioned external factors, Blanchard and Kremer (1997) explore the possibility of lower output levels in these countries due to internal changes, such as 'disorganization'. Under central planning, write the authors, many firms relied on a single supplier. When transition started it was enough for specialized producers to be unable to fulfill their contracts (because the coercive power of the state disappeared) to generate a chain-reaction whose end-result was a decline in output. Their paper acknowledges the particularity of the production process in these countries: the massive implication of the state in production, as a force centrally responsible for capital accumulation and investment decisions. However, their explanation would also mean that the withdrawal of the state from production caused the output to decline. In this case it is no clear why any state would want to generate large scale unemployment and poverty. One could again give as an example central-eastern Europe where output was in 2004 30-40% higher than at the starting point in 1989 - and claim therefore as rationale for a state withdrawal higher output in the long-run. On the other hand there is also the example of eastern European countries - after 15 years of transition still below their 1989 output level - case in which the state withdrawal could be accused of another Great Depression.

In order to find an explanation for this rather abrupt economic policy change of the state, I would like to point out another feature of these economies: an accelerated industrialization process and notable output growth in the first years of state intervention through forced redistribution of resources from agriculture and consumption. Industrialization was made possible by a policy of 'forced capital formation': the state made the investment decisions and asked from the population mandatory savings by deciding how much output was directed to investment. Savings were directed to 'strategic' industries, owned by the state. Successful in the short-run, its shine started fading away in the 80s when the first signs surfaced that the system needed a fundamental structural reform.

With this aspect in mind, a possible theoretical explanation for the peculiar evolution of output in the above mentioned countries could be that an economic system where state intervenes to force capital accumulation, even though it might have positive effects on output in the short run, is internally unstable in the long run. Therefore the state had to withdraw from the production process because the institutional structure imposed on the economy by its intervention had brought the system into a crisis long before 'transition' officially started - negative rates of growth hidden under barter and financial arrears were ubiquitous in the late 80s. It had become obvious that this institutional structure could bring an economic system into a deeper crises, even Great Depression - if a reform of the production process did not occur. This paper will look at the output 'transition' paths from this perspective. In this way it becomes possible to bring new insight into the current debate about the nature of great depressions. Cole and Ohanian (1999) as well as a series of articles in RED (2002) looked at great depressions using neoclassical growth theory in order to find out what might have caused this type of crisis in the XXth century around the world - starting with depressions in the 30s in Western Europe, Norden America, and ending with those of Latin America in the 80s. Even though the debate remains open, one major conclusion seems to be that the decline of output in the 30s was an unintended consequence of new labor market institutions and industrial policies designed to improve the performance of the economy. Especially in Europe, as Beaudry and Portier (2002) or Fisher and Hornstein (2002) show, an increase in the role of state in designing labor institutions (the government imposed collective bargaining on wage, the workweek was reduced) and increased public expenditure for production (preparing the economies for war) explain most of the economic decline in the depression, as well as the recovery. The puzzle of the slow recovery in the US remains.

Ohanian (2001) finds organization capital (the knowledge firms used to organize production - as defined by Prescott and Visscher (1980)) a promising explanation for the productivity decrease in the US in the 1930's. Breakdowns in supplier-customer relationships, says the author, have reduced the efficiency of production by requiring managers to shift from production into market search activities. These breakdowns could have also forced firms to adopt leading-edge technologies. Atkeson and Kehoe (2001) show that the productivity of plants that adopt new technologies is initially lower because firms have to accumulate new organization capital to operate them efficiently - that might have also caused the lower productivity in the US in the 1930's.

If the Great Depression of the 30s became associated with higher state intervention in production, the Great Depression of the 90s in East Europe had as consequence a withdrawal of the state from production. Moreover, the need for organization capital accumulation played an important role in East Europe, too. The goal therefore is to incorporate the effects of state intervention in the dynamics of capital accumulation (and its component organization capital). Organization capital at the level of the firm, as in Prescott and Visscher (1980), includes improved matching between personnel and jobs, the ability to create efficient teams, the human capital of its employees. Organization capital at the level of the economy should also include the position of the state regarding how firms deal with suppliers and customers, or how they deal with their own employees, access to information about the organization structure of other firms, access to infrastructure and funding for improved working conditions.

The starting point is a Diamond overlapping generation model where agents work and save when young and consume when old. The main feature of the production function is a state presence in capital accumulation, justified by the existence of a low-development equilibrium as in Azariadis and Drazen (1990). Productive government has previously been modelled in the literature mostly as a flow of government expenditure. Examples are Barro (1989) and (1990), Turnovsky and Fischer (1995), Turnovsky (1996). This specification makes models easy to track, yet since insofar public expenditure represented mainly infrastructure, it is in fact an accumulated stock rather than a flow. Arrow and Kurz (1970) were the first to model government expenditure as a form of investment, as a stock. Baxter and King (1993), Fisher and Turnovsky (1998) followed suit. Futagami, Morita and Shibata (1993) are different, in the sense that they introduce government capital as pure public good, along with private capital. I will approach this

issue differently - the state is imposing an institutional structure onto the production function, embedded through organization capital into total capital (let aside the fact that in former command economies there was almost no private capital). This institutional structure is modelled as an extension of Day (1982, 1983) and with a variable forcing parameter. The higher is the level of this parameter, the heavier is the government presence in capital accumulation. In countries that are poor in organization capital governments will opt for high forcing parameters because they generate faster rates of capital growth in the short run. As long as the total capital in the economy is lower than the organization capital needed by the technology to operate efficiently, the institutional structure will play a positive role in overall capital accumulation. The drawback is the inherent dynamical instability of such an economy. Once total capital is above the organization capital level, the economy can move into a transition path towards a lower stable income and experience capital destruction. This transition path is modelled in the following way: when the forcing parameter is allowed to vary, at some points the dynamics of the system changes; new output equilibria are created and the stability of the old ones changes, too (theory calls them bifurcation points). In this case the equilibrium with high output becomes unstable. At this point the economy has to change its institutional structure to take advantage of its level of organization capital already attained and shift its current capital into a production function able to generate growth without state intervention.

Parts 2 and 3 present the model and propose a production function that acknowledges the presence of the state's forcing factor in capital accumulation. Parts 4 and 5 include a numerical simulation that looks at the evolution of capital in equilibrium under various degrees of forcing. They describe a new type of bifurcation called 'crisis' induced by the presence of the state in capital accumulation, which could wipe out physical capital. Part 6 concludes.

2 The Model

THE PRODUCTION function is integrated into a two-period scalar Diamond overlapping generation model. The time t good is produced with a technology that uses as input labor and the time $t-1$ good, stored from time $t-1$ to time t , which is time t capital. A number of simplifying assumptions are made: there are no government bonds and no storage. Individuals are paid

wages for their labor inputs. They are endowed with labor only in the first period of their life. When young, individuals can choose to save some part of their wage. As this is a closed economy where capital is scarce, wages are the only source of savings in the model. In equilibrium the aggregate savings of the young will be the next period's capital stock. All capital carried over from date t depreciates during period $t+1$. Given some initial level of capital stock carried over from period 0, the equilibrium paths of the capital stock and output from time 1 to ∞ is found. The agents solve the following problem:

$$(1) \quad \max_{c_t^t, c_{t+1}^t} U_t = u(c_t^t, c_{t+1}^t),$$

s.t.

$$(2) \quad c_t^t = w_t - z_t,$$

$$(3) \quad c_{t+1}^t = z_t R_{t+1}.$$

Here, c_t^t is consumption at time t of an agent born at time t , while c_{t+1}^t is consumption at time $t+1$ of an agent born at time t . Savings at time t are z_t , interest rates R_{t+1} and wages w_t . Moreover, it is assumed that agents smooth consumption over time, which means that their savings are always a constant share of wage (Azariadis, 1993, pp. 75-78).

Goodfriend and McDermott (1995) model an economy where each household produces its own consumption goods because individual households are too small to use specialized inputs economically with a modern technology. Azariadis and Drazen (1990) point to the existence of low-development equilibria in the context of an OLG model with human capital accumulation. They develop a case in which the education technology displays positive threshold externalities. Then, if the previous generation has insufficiently invested in education, investing in education becomes unattractive for the current generations. Therefore an equilibrium of low growth can naturally coexist with a high-growth path where all generations invest above the threshold level. They also suggest a role for government intervention in the education sector, to avoid low-development equilibria. Following their idea, I will modify the production function to allow for a positive threshold externality in capital accumulation, and make room therefore for the

government intervention in this process. The threshold will be now the organization capital, aggregate at the level of economy, specific to the new technology.

In particular suppose that the production function $f(k)$ is of the following form:

$$f(k_t) = \begin{cases} k_s & \text{if } k_t < \bar{k} \\ g(k_t) & \text{if } k_t \geq \bar{k} \end{cases}$$

where $g(k_t)$ is continuous and twice differentiable, and $\frac{dg}{dk}$ as well as $\frac{d^2g}{dk^2}$ are positive. This form of production suggests a less developed economy that produces at the subsistence level k_s as long as the stock of capital in the economy is below the organization capital level (\bar{k}) needed by a modern technology.

The technology described in the first part of the above equation could be seen as simple techniques requiring a certain quantity of labor to produce an output able to assure the subsistence of labor rather than capital accumulation. If previous generations have produced at subsistence, and had therefore no possibility to add to the organization capital needed to adopt modern technologies (with increasing returns to scale), the new generations will not find attractive to accumulate capital. In this way the economy remains in a stable equilibrium, with the old way of subsistence production.

Consider therefore a government which assumes a policy of 'forced capital formation' model as a function of the form $p(k, \mathbb{E})$, so that $f(k_t)$ becomes now:

$$f(k_t) = \max \{k_s, g(k_t)p(k_t, \mathbb{E})\} \quad \text{if } k_t < \bar{k}$$

Azariadis and Drazen (1990) study the dynamic equilibria of a Diamond model augmented by a function A_t that depends on social inputs not controlled by any producer. Among these inputs the literature counts for economy-wide averages of private inputs (Lucas, 1988), lagged values of output or input (Arrow, 1962), knowledge (Romer, 1986). The A_t function becomes now $p(k, \mathbb{E})$, is called a 'forcing factor', and depends on the organization capital of the economy. For example in East Europe government found suppliers and clients for firms and actively intervened in matching jobs and people. It also set wages for all types of workers. This is probably what Blanchard and Kremer (1997) call 'coercive power' of the state.

The degree of state intervention in capital accumulation is measured by the forcing parameter \mathbb{E} . One would suspect that the lower the initial stocks of capital in the economy, the stronger should the government intervene in forcing capital accumulation, therefore the bigger \mathbb{E} has to be.

Knowing that the real interest rate is $R_{t+1} = f'(k_{t+1}) + 1 - \delta$ and the wage is $w_t = \max \{k_s, f(k_t) - k_t f'(k_t)\}$, the result of the optimization problem is reduced to

$$(4) \quad u'(c_t) = \beta u'(c_{t+1}) [f'(k_{t+1}) + 1 - \delta].$$

In this case, the savings function, $z(R, w)$ is determined as

$$z(R, w) = \arg \max_{0 \leq z \leq w} u(w - z, Rz)$$

and the optimum consumption pair $(\tilde{c}_t^t, \tilde{c}_{t+1}^t)$ is given by: $\tilde{c}_t^t = w_t - z(R_{t+1}, w_t)$ and $\tilde{c}_{t+1}^t = R_{t+1} z(R_{t+1}, w_t)$.

The capital market clears when

$$(5) \quad (1 + n)k_{t+1} - z [f'(k_{t+1}) + 1 - \delta, f(k_t) - k_t f'(k_t)] = 0,$$

where n is the population growth rate. The solution to this equation describes how the economy may behave at any point in time when it starts from a given capital position $k_0 < k_s$. If the two dated consumption goods are not substitutes, the savings function can be locally decreasing in the interest factor R . That makes the existence of multiple forward-looking equilibria possible (Azariadis, 1993, pp. 75-78).

2.1 *Capital Accumulation*

Consider the following notation:

$$G(k_t, \mathbb{E}) = z [f'(k_{t+1}) + 1 - \delta, f(k_t) - k_t f'(k_t)].$$

Solve equation (5) to get:

$$(6) \quad k_{t+1} = \max \{(1 - s)k_s, G(k_t, \mathbb{E})\}.$$

The map considered here has $\left[\frac{G(k)}{k} \right]$ going to zero in the long run, but it is flatter than the 45 degree line at the origin and has an even number of

nontrivial steady states. Because savings are not everywhere increasing in the interest rate, equation (6) can be solved only locally and it is not mandatory that two stable steady states are separated by an unstable one. That could give rise to bifurcations: points at which a steady state is changing its stability properties. The political sector exogenously acts through the forcing parameter \mathbb{E} , taken as given by the optimizing agents, to transform the stability of the positive steady states. As long as the capital stock is below the threshold level, the state has a positive influence on growth. However, once the organization capital \bar{k} has been reached, the political sector deters further capital accumulation. In this case the state has to withdraw from capital accumulation. Note that organization capital is embedded in total capital. As Atkeson and Kehoe (2001) estimated, organization capital was about two thirds of total physical capital stock in the US in 1959-1999. Therefore by accumulating capital, an economy is accumulating organization capital, too.

3 A Production Function with a Forcing Factor

IT IS EASIER TO GRASP THE STATEMENTS in the previous section by looking at a concrete form of the production function,

$$(7) \quad f(k_t) = \begin{cases} k_s & \text{if } k_t < \bar{k} \\ k_t^{1+a} & \text{if } k_t \geq \bar{k} \end{cases}$$

with $a \in (0, 1]$, and $k_s < k_t$. As long as the level of social capital is not met the economy chooses a subsistence path.

Day (1982, 1983) introduced a pollution effect caused by increasing concentrations of capital (the logistic map) into the neoclassical production function with constant savings ratio. I consider a modified version of Day's function to model the forcing factor of capital accumulation. The aggregate production function of the economy becomes now:

$$(8) \quad f(k_t) = k_t^{1+a} \exp \left[-\mathbb{E} (k_t - \bar{k}) \right]$$

where the term $p(k_t) = \exp \left[-\mathbb{E} (k_t - \bar{k}) \right]$ is the government 'forcing factor', whose role is to switch to the new, capital intensive production function. At low levels of indigenous capital ($k_t < \bar{k}$) its effect on capital accumulation is positive, but it becomes negative once the society has

accumulated capital ($k_t > \bar{k}$): it has a 'polluting' effect resembling Day's function. Normalize the threshold capital level to 1.

Notice that with a and \mathbb{E} fixed, for high levels of capital $1 + a < \mathbb{E}k$ and the production function exhibits decreasing returns to scale. For low values of capital $1 + a > \mathbb{E}k$, increasing returns to scale occur. If k is given, a higher a needs bigger forcing parameters (big \mathbb{E}) to keep the above inequalities unchanged. Moreover, if a is given, the lower the initial starting point k is, the bigger has \mathbb{E} to be.

It is straightforward to prove that the function $J(k_t, k_{t+1}) = k_{t+1} - G(k_t, \mathbb{E})$ is in this case invertible (see appendix). In this way it eliminates equilibria with the same initial conditions that could display different asymptotic behavior, as in Boldrin (1992); the existence of external factors that can push a country to a high or a low output level is ruled out. Moreover, it also is easy to prove that for some positive levels of capital the ratio $\left[\frac{w(k)}{k}\right]$ is increasing in capital (showing the positive effects the government has in capital accumulation).

The next step is to describe the numerical evolution of the capital stock for various forcing parameters \mathbb{E} .

4 A Numerical Example

IN THE PRODUCTION function (8) with no population growth, i.e. n is 0, and with a logarithmic utility function the fraction of savings is $s = \frac{1}{2}$ of the wage. To compute numerical solutions or interpret results, one more change in notation is made: define k_t to be the stock of capital in excess of the capital levels chosen by an economy in subsistence. With consumers that save only a constant share of the wage, the only way to increase capital stocks is by influencing the wage levels (a policy often used by governments in East Europe, for example). That is why the government intervention can be viewed as one of 'forced capital formation'.

$$(9) \quad k_{t+1} = \max \left\{ 0, \frac{1}{2} (\mathbb{E} k_t - a) k_t^{a+1} \exp[-\mathbb{E}(k_t - 1)] \right\}$$

Utility maximization agents would have saved zero capital ($k = 0$) in excess of the level required for reproducing the subsistence output. The government forces them now to take some capital level k_0 in excess of $k = 0$ and use it for the new way of production.

The role of the government is to help the economy accumulate enough resources to pay for the organization capital $\bar{k} = 1$. The firms are taking the institutional structure imposed by the government to the production function as given. The optimization problem of the government and of the private agent is therefore identical, case in which the capital therefore cannot be viewed as merely private capital. Due the influence of government part of it is being accumulated as organization capital needed by modern technologies. Organization capital will in turn increase production levels, the wage level of the agents, and will allow for higher consumption. In this way the policy of forced capital formation generates positive effects in the economy.

4.1 *Returns to Capital - Calibrating a*

Increasing returns to scale generate multiple equilibria. In calibrating the present model I take into account Cole and Ohanian (1999) who show that aggregate returns cannot be measured with precision. A conservative level for a could be $a = 0.5$. Later on, I will study the effects of different values of a on \mathbb{E} and examine how the degree of returns to capital changes the results.

4.2 *The Forcing Factor - Calibrating \mathbb{E}*

\mathbb{E} is taken by agents as given, and it is therefore an exogenous variable imposed on the economy by the government. Government, on the other hand, chooses its level based on its economic policies. One such policy, for example, could be as in Barro (1990) a government that maximizes the savings of the agents at the starting point $t = 0$. However, in this model, \mathbb{E} depends on the level of a . Therefore, in the beginning I will keep a fixed and use numerical simulations to find out those values of \mathbb{E} able to generate dynamics matching the evolution of output in East Europe. I will later on let a vary and find the range in which \mathbb{E} has economic meaning - this should therefore be the range of \mathbb{E} values available to the government. Since this is an exogenous variable, given by a , and government actions are embedded in total capital, the maximization policy of the private agent cannot be different from that of the government. There will therefore be range of values rather one optimum level of \mathbb{E} .

5 Dynamics

As an example, figure 2 shows an economy with a forcing factor that could well describe the evolution of the former communist countries. The starting point is a low capital level. Forced capital accumulation induces economic growth. However, after approximately two generations, the institutional structure imposed by a government that allows no freedom in investment patterns becomes visible in the negative externalities it generates in production. Unless a reform occurs to reduce forced investments, the country could start a new transition whose outcome is a stable and lower output level, a transition whose characteristic is negative growth rates in capital and output. Note that zero output, a subsistence economy, is always a stable equilibrium in this model. The subsistence equilibrium aside, there are two more steady states whose stability changes with $\mathbb{C}\mathbb{E}$. The levels of $\mathbb{C}\mathbb{E}$ at which the dynamical properties of the system change are called bifurcation points (a complete bifurcation diagram is presented in the appendix). For example we would like to find out when an economy would move from a system with one stable subsistence equilibrium, to a system with two or three equilibria, eventually stable and with higher output levels. In particular, we are interested in finding those levels of the forcing parameter at which an economy will experience transition movements between levels of capital and output as described in figure 2.

As already stated, the poorer in capital is the economy at the starting point, the higher should be the forcing parameter. Simulations show that with an $a = 0.5$ and an economy starting very low in capital, close to subsistence - an assumption made for the former-communist countries - a bifurcation called 'crisis' (see Grebogi et al., 1983 for a more detailed description) occurs when the forcing parameter is $\mathbb{C}\mathbb{E} = 3.974$. Hence all forcing parameteres above this level generate dynamics as expected: one or two periods (generations) of positive growth, followed by consequent periods of negative growth rates implying losses in capital stock and output. In this case a movement - a transition - to a new production structure is required. Slow transitions, such as those in Russia or Romania, experience long periods of negative growth - because this means that the country still has most of its capital on the old production function, which brings it slowly into the stable subsistence output.

The appendix describe the various bifurcations points, as well as the relationship between a and $\mathbb{C}\mathbb{E}$. It shows graphically that the forcing parameter is an increasing function of a , and that $\mathbb{C}\mathbb{E}$ takes values between 2 and

5, when $a \in (0, 1]$.

6 Conclusion

AN INSTITUTIONAL STRUCTURE imposed by the state was used in a model of economic growth in order to capture the long-run effects of forced capital accumulation and to explain the large loss in output in eastern Europe. The decrease in output was generated by the economic system itself, rather than by some external shocks.

Some conclusions are to be drawn here. It is most likely that no modern economy can take advantage of technological progress without organization capital. Ohanian (2001) seems to lean on this side when he claims that in the 1930s shocks - which are still to be identified - caused a loss of organization capital and contributed to the Great Depression. However, at that time East Europe was confronted with the agrarian nature of its production process. Governments stepped in to help these economies accumulate enough capital such that modern large-scale technologies could be implemented. However, these countries were also lacking organization capital. What the state did was to force capital accumulation by investing into human capital formation and infrastructure, by creating for each firm suppliers and clients through planned investments, by setting up a wage scale for all employees, and fixing consumer price levels. The failure of this mode of production fifty years later in all countries in East Europe, after some notable progress, probably means that this kind of intervention is desirable only when a country remains poor in organization capital. That might also be the reason why the Great Depression in the 30s had as consequence more state intervention in the production process (for a longer time in Europe, for a shorter time in the US). Only the state can stop a hemorrhage of organization capital, or only the state can pay for some of its components - for example by demanding better working conditions for workers, or by investing in better infrastructure. Most likely these newly added components to capital organization help the economy replace old technologies and restart the cycle of physical and human capital accumulation at a new level, qualitatively and quantitatively higher.

Second, once enough organization capital has been accumulated, the economy should choose on its own its future investment patterns, otherwise "crises" that generate transitions to low levels of output occur. That was more evident in eastern Europe rather than in central-eastern Europe, which

recovered much faster. One explanation for these different paths, as given by the model presented here, could be that the successive negative rates of growth in output in the former countries were signs of a slow reform. With state being forced out of the production process, the relationship between firms and state had to change. Firms had to search on their own for new suppliers and clients - an important part of their organization capital and previously an attribute of the state. To find or develop new markets is a slow process. Firms were losing both physical and organizational capital, and the state could not intervene further - without generating corruption and inefficiencies. With domestic capital diminishing countries that managed to attract foreign capital and successfully incorporate new elements of organization capital into their economies recovered faster. However, the economy of the model presented above is a closed one and this process was not addressed.

It seems plausible that there are cycles when organization capital, or some of its components, moves from being state-owned to being privately-owned. As this paper does not consider a dynamic interaction between physical and organization capital further research in this area is still required to better explain the relationship between state and organization capital, and between capital and capital organization.

A Bifurcations - Numerical Results

These results are done with a level of a fixed at 0.5. There are three points at which the dynamics of the system changes -there are therefore three bifurcation points. One is at an \bar{E} of 2.366, a saddle-node bifurcation, when neoclassical growth starts. One is when \bar{E} equals 3.122, a period-doubling bifurcation, when long run evolutions of capital cannot be predicted. The last one starts at 3.974 and it is a “crisis” bifurcation (see Grebogi et al., 1983 for a more detailed description): the system is expected to collapse after one or two generations of growth.

The bifurcation diagram is presented in figure 3. Note the following four intervals:

- *\bar{E} is below 2.366*

The economy remains trapped at subsistence levels of capital, the only stable equilibrium.

- \mathbb{E} is between 2.366 and 3.122

The graph has two branches now. Equilibria on the lower, full line branch are unstable. The dotted upper line represents stable and higher capital levels. Countries that are historically endowed with higher levels of capital (all capital levels above the full line) will behave like the neo-classical, Solow-type models and will end up at the higher, stable capital level. Practically there is no role for the state in the process of capital accumulation. The region is therefore not interesting for our theoretical exercise.

- \mathbb{E} is between 3.122 and 3.974

In this region, the economy moves from a neoclassical type of growth to one where stable output equilibria exhibit business cycles, as shown in the upper branch of the diagram, making the evolution of the capital in the long-run difficult to predict (Sarkovskii's theorem indicates that at a cycle of 3 any type of cycle is possible, including chaos). Note that these variations are stable. However, this region has been previously studied by the economic literature with other type of externalities; its dynamics is of no interest to our question.

- \mathbb{E} is above 3.974

As the economy starts close to subsistence (all levels below the full line), governments are justified to introduce a forcing factor. In this case the upper branch with stable equilibria touches the lower, unstable branch, and a "crisis" surfaces: after periods of positive growth, the economy starts a transition to the subsistence level of output, the only stable equilibrium in this case. The region could be associated to East Europe, where levels of intervention between 3.974 and 5 generate one, or two periods of growth and then a loss of capital stock.

B The Degree of Intervention and Returns to Capital

Figure 4 describes the relationship between a and \mathbb{E} at two main bifurcation points: when the stable and unstable branches meet in one unique equilibrium (the saddle-node point), and when the capital starts its cycle-chaotic behavior (the period-doubling point); it shows that the bigger a , the bigger \mathbb{E} . A third bifurcation point, the 'crisis', it is unstable and cannot

be shown in the picture. At the same time, the range of \mathbb{E} is between 2 and 5, with 'crisis' surfacing between 3 and 5.

C Bifurcations - Definitions

The general conditions for a map G to have a saddle-node bifurcation at a non-hyperbolic fixed point (k, \mathbb{E}) equal to $(0, 0)$ are described by

$$\left. \begin{array}{l} G(0, 0) = 0 \\ \frac{\delta G}{\delta k}(0, 0) = 1 \end{array} \right\} \text{nonhyperbolic fixed point}$$

and

1. $\frac{\delta G}{\delta \mathbb{E}}(0, 0) \neq 0$,
2. $\frac{\delta^2 G}{\delta k^2}(0, 0) \neq 0$.

A pair $(k, \mathbb{E}) = (0, 0)$ is a flip bifurcation point if:

$$\left. \begin{array}{l} G(0, 0) = 0 \\ \frac{\delta G}{\delta k}(0, 0) = -1 \end{array} \right\} \text{nonhyperbolic fixed point}$$

and

$$\left. \begin{array}{l} \frac{\delta G^2}{\delta \mathbb{E}}(0, 0) = 0 \\ \frac{\delta^2 G^2}{\delta k^2}(0, 0) = 0 \\ \frac{\delta^2 G^2}{\delta k \delta \mathbb{E}}(0, 0) \neq 0 \\ \frac{\delta^3 G^2}{\delta k^3}(0, 0) \neq 0 \end{array} \right\} \begin{array}{l} \text{the second iterate of map } G \\ \text{undergoes a pitchfork bifurcation} \\ \text{at the same nonhyperbolic fixed point.} \end{array}$$

D Various Proofs

D.1 The map $J(y)$ is invertible

Let y denote k_{t+1} , and define the map $J(y)$ as:

$$J(y) = y - z(R(y), w(x)).$$

With a logarithmic utility function, the savings function $z(y,x)$ is just a constant s of the wage and:

$$z(y,x) = s \cdot x \cdot \frac{\omega(x)}{x}.$$

In this case, with $\frac{\delta J}{\delta y} = 1$, $J(y)$ has no subsets with different signs and it is invertible. Given one level of x , there will be only one future y .

REFERENCES

- ARROW, K. (1962): "The Economic Implications of Learning by Doing," *Review of Economic Studies*, XXIX, 155-173,
- ARROW, K., AND M. KURZ (1970): "Public Investment, the Rate of Return, and Optimal Fiscal Policy. Baltimore: John Hopkins University Press,
- ATKESON, A., AND P.J. KEHOE (2001): "Measuring Organization Capital," Research Department Staff Report 291, Federal Reserve Bank of Minneapolis,
- AZARIADIS, C. (1993): *Intertemporal Macroeconomics*, Oxford: Blackwell,
- AZARIADIS, C., AND A. DRAZEN (1990): "Threshold Externalities in Economic Development," *Quarterly Journal of Economics*, 105, 501-526,
- BARRO, R. J. (1989): "The Neoclassical Approach to Fiscal Policy." In Barro, ed. *Modern Business Cycle Theory*, Cambridge, MA; Harvard University Press,
- BARRO, R. J. (1990): "Government Spending in a Simple Model of Endogenous Growth," *Journal of Political Economy*, 98, 103-125,
- BAXTER, M., AND R. G. KING (1993): "Fiscal Policy in General Equilibrium" *American Economic Review*, 83, 315-334,
- BEAUDRY P., AND F. PORTIER (2002): "The French Depression in the 1930s," *Review of Economic Dynamics*, 5, 73-99,
- BLANCHARD, O., AND M. KREMER (1997): "Disorganization," *Quarterly Journal of Economics*, 112, 1091-1126,
- BOLDRIN, M. (1992): "Dynamic Externalities, Multiple Equilibria, and Growth," *Journal of Economic Theory*, 58, 198-218,
- COLE, H.L., AND L.E. OHANIAN, (1999): "Aggregate Returns to Scale: Why Measurements are Imprecise?," *Federal Reserve Bank of Minneapolis Quarterly Review*, Summer, 19-28,

- DAY, R. H. (1982): "Irregular Growth Cycles," *American Economic Review*, 3, 406-414,
- (1983): "The Emergence of Chaos from Classical Economic Growth," *Quarterly Journal of Economics*, 98, 201-213,
- FISHER J. D. M., AND A. HORNSTEIN (2002): "The Role of Real Wages, Productivity, and Fiscal Policy in Germany's Great Depression 1928-1937," *Review of Economic Dynamics*, 5, 100-127,
- FISHER W.H., AND S. J. TURNOVSKY (1998): "Public Investment, Congestion, and Private Capital Accumulation," *Economic Journal*, 108, 339-413.
- FUTAGAMI, K., Y. MORITA, AND A. SHIBATA (1993): "Dynamic Analysis of an Endogenous Growth Model with Public Capital," *Scandinavian Journal of Economics*, 607-625,
- GOODFRIEND, M., AND J. McDERMOTT (1995): "Early Development," *American Economic Review*, 85, 116-133,
- GREBOGI, C., E. OTT, and J.A.YORKE (1983): "Crises, Sudden Changes in Chaotic Attractors, and Transient Chaos," *Physica*, 7D,
- LUCAS, P. (1988): "On the Mechanics of Economic Development," *Journal of Monetary Economics*, XXI, 3-42,
- OHANIAN, L. E. (2001): "Why Did Productivity Fall So Much During the Great Depression?," *American Economic Review*, 91(2), 34-38,
- PRESCOTT, E. C., AND M. VISSCHER (1980): "Organization Capital," *Journal of Political Economy*, 88(3), 446-461,
- ROMER, P. (1986): "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, XCIV, 1002-37,
- TURNOVSKY, S.J. (1996): "Optimal Tax, Debt, and Expenditure Policies in a Growing Economy," *Journal of Public Economics*, 60, 21-44,
- TURNOVSKY, S.J., AND W.H. FISHER (1995): "The Composition of Government Expenditure and its Consequences for Macroeconomic Performance," *Journal of Economic Dynamics and Control*, 19, 747-786,



Figure 1: Russia - Output Path after 1989

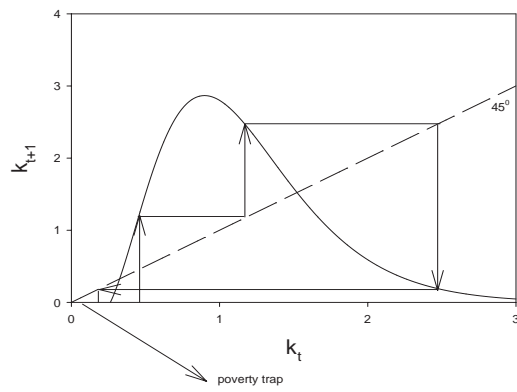


Figure 2: Capital Accumulation with High Forcing Factors is not Sustainable in the Long Run

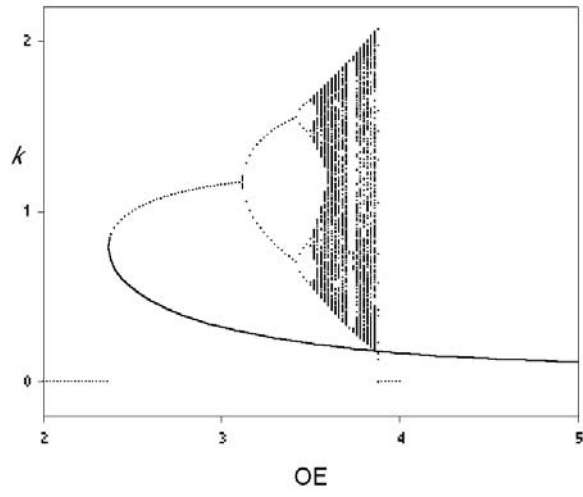


Figure 3: Bifurcation Diagram for \mathcal{OE} , with $a = 0.5$

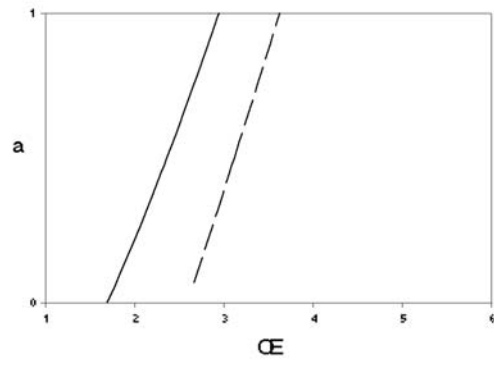


Figure 4: The Relationship between a and CE