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SYSTEM DYNAMICS MODEL FOR CAPITAL AND PRODUCTIVITY IN UKRAINIAN ECONOMY

Capital and productivity is a part of supply side model that shows how efficiently capital is used to generate output. It reflects the joint influence of labour input per unit of capital used and multifactor productivity (reflecting the overall efficiency of production). Investment in information and communication technologies in particular enables new technologies to enter the production process and is seen as an important driver of productivity growth. This model help you to learn about structure and performance of the Ukraine economy.

The main factors which we used in our model are: labour productivity, capital, real investment, emloyed, technology etc. Also for this model we used such Ukrainian historical data for the period from 2006 to 2017: employed, initial labor productivity, average standard hours per worker, initial active capital labor ratio and normal capital utilization.

Let us start with *the labor productivity*. Labor productivity measures the hourly output of a country's economy. Specifically, it charts the amount of real gross

domestic product (GDP) produced by an hour of labor. Productivity changes result from changes in capital's average technology and the capital-labor ratio. And there is some inefficiency during the transition. Growth in labor productivity depends on three main factors: the active capital-labor ratio (K/L), the level of average installed technology, the time needed to achieve efficient use of the capital (also we use Ukrainian initial value for labor productivity).

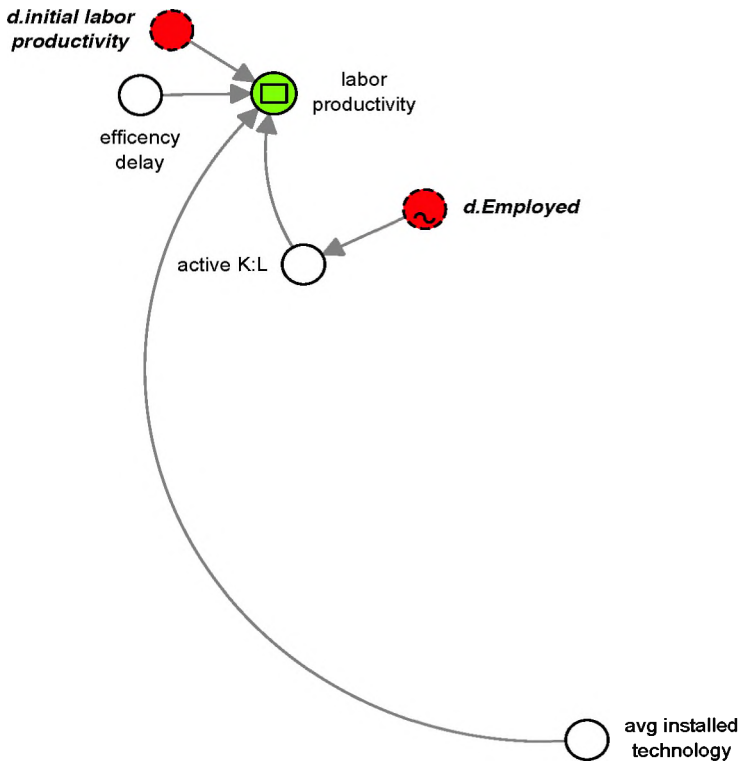

Figure 1. Values that affect labor productivity

Let's take a closer look at each variable:

Active capital refers to the capital equipment and structures actually being used. The active capital-labor ratio we can to calculate as active capital divided by emloyement.

Efficiency refers to the level of both managerial and worker efficiency. This is observed when employees are highly skilled, but with the introduction of new technologies, it takes time to upgrade or find new employees.

Average installed technology is installed technology divided by capital.

If we have labor productivity then we can easily calculate *labor hour productivity* required labor productivity divided by normal hours per worker. For Ukraine *normal hours per worker* are 2000 hours.

Capital utilization influences active capital (active capital =Capital*capital utilization). Capital utilization is the degree of utilization by an enterprise or nation of installed production capacity.

The desired active capital-labor ratio (K/L) depends on the level of installed technology and it is affect desired active capital. Changes in the desired capital-labor ratio result from changes in average installed technology. *The desired active capital* also depends on quantity of *employed* (The employment is defined as the number people engaged in productive activities in an economy. In our case, employed person is a person aged 15 to 70.).

Normal capital utilization is the average over the past several years and for Ukraine the capital utilization is 0.75.

The desired active capital also depends on quantity of *employed* This value influences desired capital.

Desired real investment is the change in desired capital.

Desired real investment depends on: depreciation, capital, expected delivery delay

Depreciation represents how much of an asset's value has been used up.

A change in *capital* has an impact on: capital utilization, active capital, depreciation.

The expected delivery delay determines how fast investment occurs. We assume the delay in closing a gap between desired and actual capital is the same as the expected delivery delay.

Installed Technology is the technology embedded in the current stock of Capital.

Adding and discarding Capital also adds and discards the embedded technology in those capital inflows and outflows. *Change of available technology* this is technological innovation. Technological innovation explains in the model the changes in labor productivity caused by technological shocks.

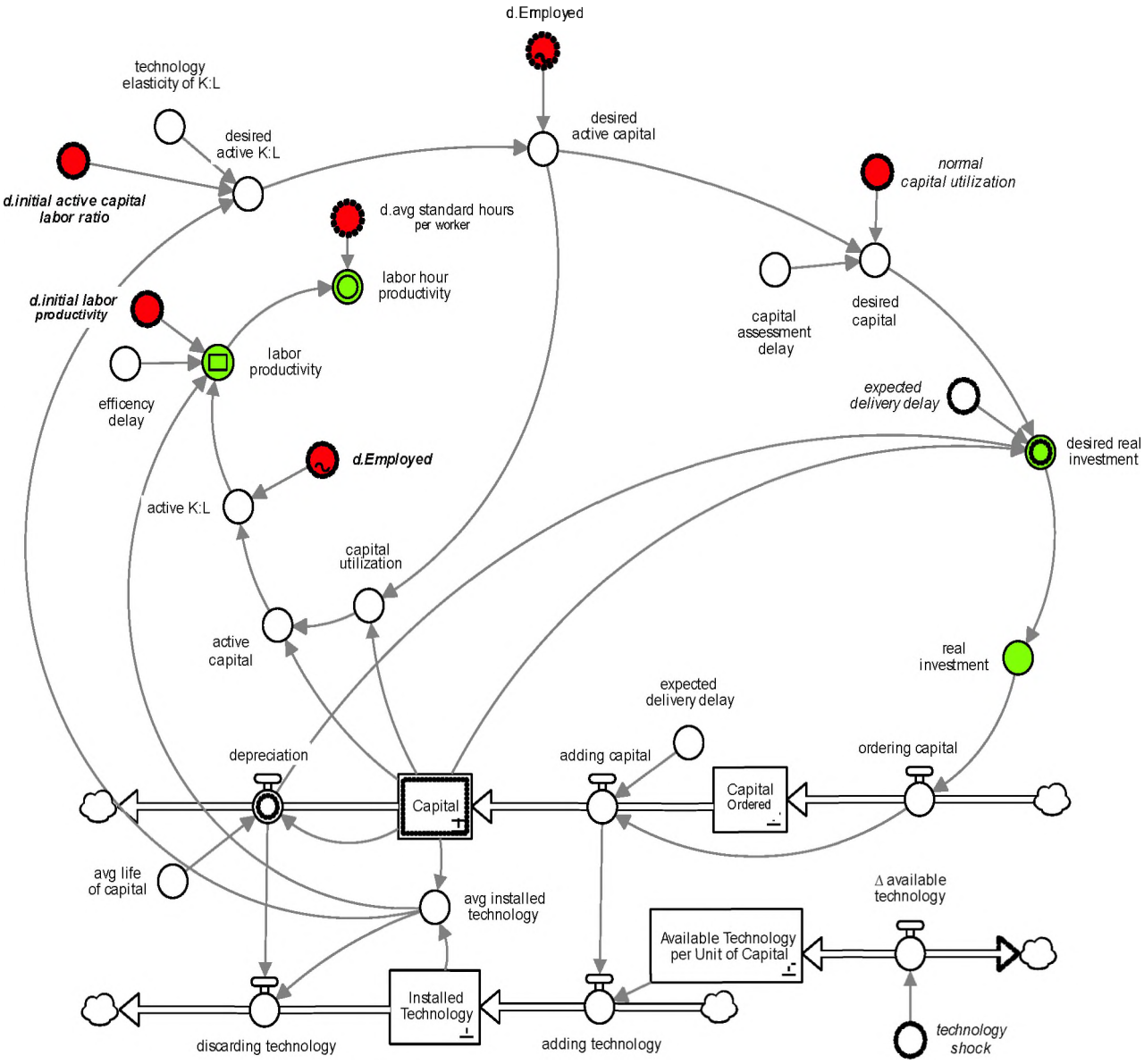

Figure 2. Model of Capital & Productivity Behavior

This values are based on data from the National Bank of Ukraine, UkrStat (State Statistics Service of Ukraine) and World Bank.

We have five values in our sub-models that cannot be measured accurately: Technology elasticity of K:L, efficency delay, capital assessment delay, expected delivery delay and avg life of capital. Consider each of these options.

Technology elasticity of K/L=1

If we assume that elasticity of substitution = 0 when efficiency and technology are constant; I.e., a Leontief production function where capital and labor are perfect complements ('recipe' assumption) and cannot substitute for each other. When technology changes (and efficiency catches up and becomes 1 again), a new optimal

K/L ratio will prevail, and the elasticity of substitution = 1; I.e., a Cobb-Douglas production function. C-D will also govern during the efficiency catch-up period. Since in our submodel technologies are constantly changing with new implementations, we assume that the elasticity is equal to 1.

Efficency delay = 1 year

This is observed when employees are highly skilled, but with the introduction of new technologies, it takes time to change skills or find new employees. We assume that this delay lasts for 1 year.

Capital assessment delay = 1 year

Capital change delay, even if we think the information has already been forwarded, we are still waiting for a certain amount of time. Decision-making also takes time.

Expected delivery delay = 3 years. *Avg life of capital = 10 years*

Technologies are changing very quickly. The correlation between technology and life is based on assumptions, so the value of capital is our assumption and reflects only an approximate number for Ukraine.

Also we have some outputs which we will be compare with Ukrainian historical data: Labor productivity, Labor hour productivity, Real investment

The crisis of 2014-2015 years highlighted a number of fragilities inherent in the Ukrainian economy. Growth in incomes during the decade before the crisis was largely driven by favourable prices for commodity exports rather than much-needed improvements in productivity and competitiveness. Consistent delays in implementing structural reforms and recurrent political instability left the economy stuck in transition and overly exposed to external shocks.

This graph shows historical data and simulated data of labor productivity. When technology changes, the labor productivity changes by the same proportion. However, when the capital:labor ratio changes, the labor productivity change will be less than proportional; it depends on the technology elasticity of productivity. Due to the situation in Ukraine 2014-2015 in the historical data from 2014, we can observe a sharp change in labor productivity, since the data contain statistics of Ukraine, except the occupied area.

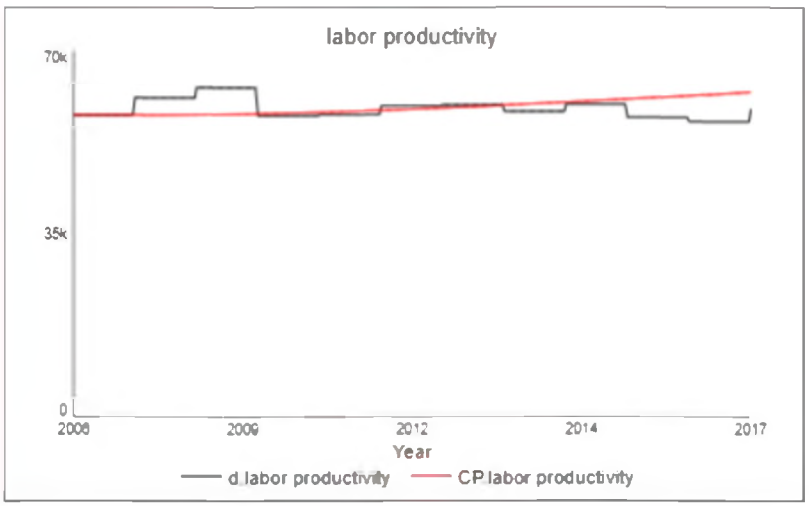

Figure 3. Model-simulated data and historical data of labor productivity

This graph shows historical data and simulated data of labor hour productivity. Labor hour productivity depends on labor productivity and standard hours per worker. The steady increase in both historical and actual data of Labor hour productivity means an increase in existing labor productivity in overall.

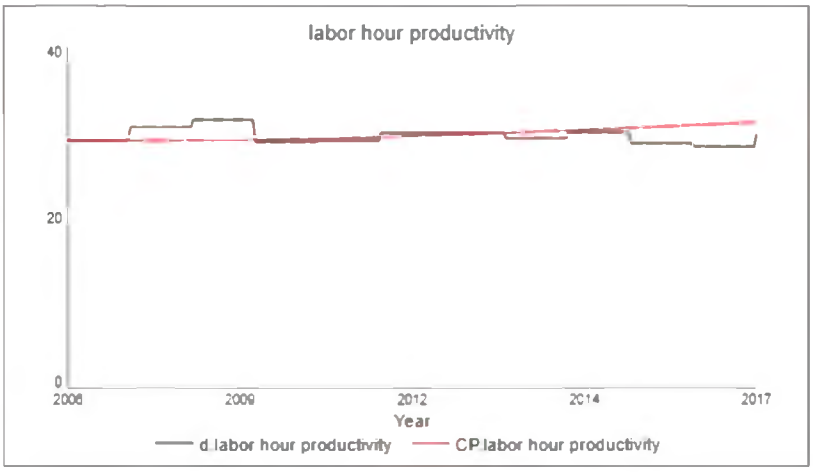

Figure 4. Model-simulated data and historical data of labor hour productivity

This graph shows historical real investment data and simulated data of real investment. The steady increase in both historical and actual data of real investment means an increase in existing capital stock.

With this model, we can learn about the structure and efficiency of Ukraine's economy, explore capital and productivity in more detail. This sub - model good reflects the main economics features of capital and productivity.

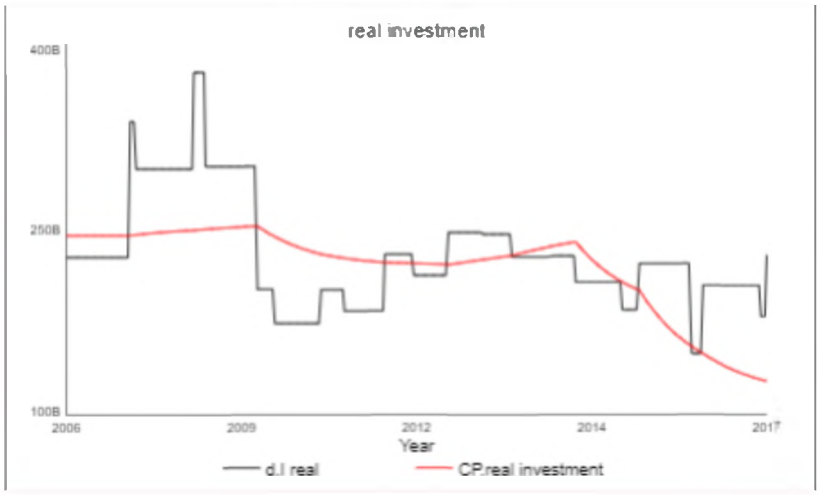

Figure 5. Model-simulated data and historical data of real investment

There are values that sub-model cannot explore and analyze as these values are not realistically measured in real life: model does not take into account overtime (so 2000 hours is an approximate number of hours that is not really accurate), average life of capital, expected delivery delay, efficiency delay, capital assessment delay.

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