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Imperfections in International Technology Flows

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Abstract

The question why total factor productivity (TFP) is not equal among countries is a serious problem of the process of globalization. A simple theoretical growth model is developed in order to explain this phenomenon. The model illustrates the differences in TFP using structural characteristics and foreign investors. It also captures the connection between foreign direct investments and international technology flows by using these structural characteristics as a link between the two. This way the developed model can explain paradoxes in international transfers of capital and technologies.

Keywords: FDI; growth; TFP; technology waves; Lucas Paradox

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1 Introduction

Over the last three decades, foreign direct investments (FDI), have become increasingly important for developing countries. According to the neoclassical growth models, the effect of FDI on growth is identical to that of domestic investments, and they should flow from rich to poor countries, because of the differences in the marginal product of capital (MPK). Poor countries will have high MPK and a unit of capital there will be more productive. In reality, that is not always the case. This observation is known as The Lucas Paradox (Lucas, 1990). While there are indeed some rich countries that invest in poor ones, why investors are restraining themselves from investing in countries like Burundi, Niger or Malawi? A number of solutions to the Lucas paradox have been proposed in the literature (Jiandong and Shang-Jin, 2006): (1) thinking of a worker in a rich country as effectively equivalent to multiple workers in a poor country, (2) adding human capital as a new factor of production, (3) allowing for sovereign risk, and (4) adding trade costs. But FDI are not the only factor that can flow from country to country. In the past two decades we observe an intense technology transfers between countries. Again these transfers are not perfect. Some countries will adopt them and grow faster and others will not and grow slower. One of the empirical studies on the subject (Borensztein et al. 1998) shows that FDI affects output not only as an additional source of capital, but also as an additional source of total factor productivity (TFP). This leads to the main theoretical proposition of this paper - that there exists a link between FDI, specific economic characteristics and a leading technological sector which can be used to explain the differences in TFP between countries.

The first part of this link is based on the Lucas Paradox and the second on a paper by Prescott (1997). In this paper he argues that human capital is not enough to describe the difference in TFP and output between rich and poor countries. In order to explain these differences, we introduce cyclical movements of technological progress and structural characteristics of the economic system. These structural characteristics include, but are not limit to, what Prescott calls *resistance to the adoption of new technologies* (Prescott, 1997). For an underdeveloped country this link can create a productivity trap. First the country does not produce much knowledge and its TFP growth rate is low. Second it cannot attract foreign investors, because its structurally unattractive. Third it cannot absorb the current leading technology, because there is no one interested in delivering it. After some time this economic system is able to catch up, but then a new technology is already at work.

To illustrate our proposition and for the purpose of keeping the presented model as simple as possibl we limit ourselves from considering labor movements. We assume that there exists a long run growth pattern that affects one sector, which was first proposed by Kondratieff (1935). In a recent study, Koroyatev and Tsirel (2010) use spectral analysis to confirm such pattern do exists. An example for that theory is the railroad expansion in USA during the second half of 19th century. Donaldson and Hornbeck (2016) estimate that during the period of 1870-1890, the newly introduced railroads were critical for the agricultural sector, and removing them will lead to annual economic losses equal to 5.35% of GNP. A more modern example for such a technological wave is the expansion of the IT and telecommunication sectors. The cyclical nature of technological progress is used to illustrate the dynamics of FDI under the conditions of slow and fast growth.

The properties of these technological waves are described by Aghion et al. (2012) and Helpman and Trajtenberg (1994). *First* when a new wave starts, the technology will grow very slowly, until a potential is reached. *Second* the effects of these growth waves will affect other sectors. *Third* they will enhance creation of new and better technologies. To capture these processes Helpman and Trajtenberg (1994) develop an endogenous growth model, based on Romer (1990), in which they call the technologies produced by the Kondratieff waves General Purpose Technologies (GPT) and defined them as innovations that are affecting the entire economic system. The presented approach replicates most of their results by using exogenous R & D sector.

In order to explain how this cyclical behavior is connected to FDI, we assume that the foreign investors look for the sector with the highest rate of return and try to earn as much profit as possible. To maximize their rate of return, aside from physical capital, the investors will bring some knowledge and new technologies from outside the economy in order to increase the output of the chosen sector. When the sector is only one, the impact of these increases affects production in two ways, firstly by increasing the stock of physical capital, and secondly by introducing new technologies. But when the investors are not interested in moving capital and technologies between countries, this creates a slowdown and the TFP in the poor country is unable to catch up with the TFP in the rich one.

Our model incorporates the country's structural characteristics in order to includes cases of imperfections in technology and FDI flows. While this characteristics are different, all of them have one thing in common - they are system specific. For example in some of the countries in Central Africa the corruption and wars are common, and no investor will build a company there, despite the high MPK and the low average wage. Further, because the growth rate of the TFP is slow, there is no evidence that convergence will occur. If we move to Asia, the entry barriers in Japan also partly prevents foreign companies from starting business there, despite the quality of labor and technological advancements. The other situation is also possible: when the structure of the economy allows FDI, and the investors are interested in investing, capital and ideas will flow. A clear example for this is China - cheap labor force, almost no barriers for investing and clustered infrastructure. Changes in this characteristics will be considered exogenous in order to show how the economic system reacts to different structural policies.

This structural characteristics include the effects of the institutions via the effect of policies, laws and regulations. As shown in many studies in New institutional economics (NIE), for example Acemoglu et al. (2001, 2008), institutions are highly correlated with the growth rate of the real GDP, but there are some problems with the way their effects are measured. Lee and Lloyd (2016) point out that the institutional analysis have shortcomings, mainly that the distinction between institutions and policies is arbitrary and artificial, because it is their combined effects on incentives which matter for individual choices. Since in the presented model the effect of institutions and policies is captured using a single parameter, we are also not distinguishing between the two. Also when we talk about increase in the structural parameter (defined below) we mean that it makes the whole system better. This is because of an effect dubbed by Acomoglu et al. (2003) as the *see-saw* effect. For an example, directly reforming specific institutions may not be enough to improve the whole economic system, and may even backfire.

Shadow economy also affects economic growth, but its effect is not one sided. Schneider and Enste (2000) argue that the negative impact of the shadow economy on the real one is not broadly accepted. For example Loayza (1997) shows that the size of the shadow economy is negatively correlated with the GDP per capita, but Schneider (1998) and Bhattacharyya (1993, 1999) found that the correlation between GDP and the size of the shadow economy is positive. That is because most of the income earned in the shadow economy is then immediately spend in the formal one, which has a positive effect on consumers expenditures. Taking into account this mixed views and empirical evidences, we will exclude the shadow economy from the structural characteristics parameter.

Firstly we will develop the basic framework of the model with perfect technology absorption, that is the technology produced outside the country will enter into the economic system without any barriers. Secondly we will consider what happen with the economic system when we introduce a separate structural parameters for both FDI and TFP. Thirdly a final version of the model will be shown that captures the *productivity trap* of TFP. In contrast with the most models, which are solved by searching for long run equilibrium, the presented model uses the steady state only as an illustration for the Lucas Paradox, imperfect technology absorption and imperfections in institutions.

2 The Model

We start with the FDI, to describe our theoretical economic system. Each period there is an investor who invests some capital into the economy and acts as an additional capital lender. As previously assumed, FDI depends on the structural characteristics of the economy: the law system, market barriers, infrastructure, openness, corruption, political risk, institutions and so on. When the system is more attractive for the investment process, i.e. lower systemic risk, better law system, better infrastructure, lower corruption, better public administration and new technologies the inflow of FDI increases. The rate of return for the investors will be connected not only with the interest rate, but also with the profit their investment generate, so they seek to invest only in a growing sector. If the sector grows fast, more investments will enter the economy from outside, because the rate of return is high.

The technological growth rate of a single sector exhibits a wave pattern with a single peak, as according to Kondratieff. When the cycle is near its end, a new sector is introduced, and the investors shift their investments from the old to the new sector. The technological progress in some sectors can be missing, but the sector will still produce output. If we continue our analysis, we can assume that Kondratieff waves can have multiple peaks, which will show that a sector can reach its maximum potential many times. In the same spirit a sector can *reemerge* after a certain period with zero technological advancements, because it depends on other sectors. This assumption leads to a model where the growth rate of technological progress in different sectors is partly correlated. An example for this is that the IT sector is connected with almost every other product - from washing machines and fridges to TV's and Air Conditioners.

The interest rate in the country that receives the FDI and the interest rate outside of it are equal. That is the flow of FDI is not affected by interest rates and the international parity condition holds. Also there exists only one economy in which the investors can invest their capital, so they are not evaluating alternative investments. We also assume that exports equal imports and there is no government.

Time is discrete and there exists one economy with one sector and one representative firm. The production function is Hicks neutral:

$$Y_t = A_t F(K_t, L_t)$$

Written in a Cobb-Douglas form:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

The production function satisfies the condition for constant returns to scale (CRS) and diminishing marginal productivity of capital and labor. The technological progress A evolves linearly:

$$A_t = (1 + g_t) A_{t-1} \tag{1.1}$$

Where g denotes the growth rate of technology, which is cyclical in nature :

$$g_t = a s_t \tag{2}$$

Where a is the maximum rate of growth that can be achieved during the peak of the wave. The growth rate accelerator is then a modified Gaussian function:

$$s_t = e^{-\frac{(\tau-b)^2}{2l}} \tag{3}$$

It creates a cyclical movements in the growth rate g with length l, peak at period b, current period of the wave τ and maximum growth rate a. Each time τ reaches l, a new K-Wave with length l starts, and τ assumes the value of 1. Substituting (3) into (2):

$$g_t = ae^{-\frac{(\tau-b)^2}{2l}} \tag{4}$$

When τ approaches b, g_t approaches its maximum a:

$$\lim_{\tau \to b} g_t = a \tag{4.1}$$

Because:

$$\lim_{\tau \to b} e^{-\frac{(\tau-b)^2}{2l}} = 1 \tag{4.2}$$

This form of innovation catches some important characteristics of the technological waves:

(1) The growth rate of technology during a new wave is low, because the technology is still new and needs time to develop.

(2) After the peak is reached, a slowdown of the growth rate of technology will eventually follow. Of course it is possible that certain technology stays at its peak for a long time.

(3) There exists a period when the old technology will were off or transform, so a new wave can start.

In this initial setup there can only exist one technology without the possibility of branches or overlapping waves. In the basic framework the technology is produced outside of the economy and the absorption is not connected with the FDI or the structure of the economy.

In the initial setup the FDI are entering the economy as an additional source of capital:

$$O_t = \theta + \rho o_t \tag{5}$$

$$\rho \in [0,1]$$

Where ρ is the structural parameter of the model and θ is the cyclical neutral FDI. ρ captures structural characteristics of the economic system. But how we can define what those structural characteristics are? We said that they include laws, levels of corruption, political risks, trade barriers, quality of institutions and so on. What we underline here is that ρ does not include factors of production. This is very important, because it means that investors do not take into account human capital or resource limits. The structural parameter only includes variables with qualitative nature. This limits the model, because one needs to modify the Cobb-Douglass production function in order to include differences in human capital between countries, which can lead to difference in FDI. It can be argued, that because the structural parameter includes quality of institutions, it indirectly includes human capital. In this case the investors also take into account difference in human capital using institutions as proxies. It should be noted that the model also do not incorporate the effects of institutions directly, but is doing it indirectly trough the investors. The econometric transformation of the presented theoretical abstraction can be difficult to do, because ρ is defined only theoretical. The structural parameter will vary between 0 and 1. The closer it is to zero, the less investments will flow and vice verse. However it should be noted that an increase in ρ indicates economic wide changes in attractiveness for investment. In terms of institutions this means that we are observing increase in the quality of all the institutional organizations. As said in the introduction this is according to the *see-saw* effect.

The term o_t describes the choice based FDI, at time t, and can be written as:

$$o_t = s_t \rho_t q_t \tag{6}$$

$$q_t = \pi_t s_t$$

Where q denotes the investors available resources for an investment. The structural parameter ρ is taken into account twice, first it serves as a barrier for the FDI and second it is used in the decision making by the investors. We assume that households own the factors of production, and investors own additional capital which they are willing to lend at the same interest rate r. The zero profit condition for the sector also holds, indicating a competitive market. The output is then distributed between the households and the foreign investors:

$$Y_t = w_t L_t + r_t(K_t - o_t) + r_t o_t + s_t \rho \pi_t Y_t \tag{7}$$

$$0 < \pi_t < 1$$

The terms $-o_t$ and $+o_t$ are here to show what is happening with the distribution of the capital costs - one part of the output is going to the domestic lenders and other part to the foreign ones. We denote the profit of the foreign investor with $\pi_t Y$ where π_t represents the part of the income is distributed to them. The profit of the investors also vary, because it is connected with s_t and ρ. This is the reason for introducing s_t in eq.(6): if the investors are not investing they will not reap profit or receive interest. As assumed there is no government, net exports equal net imports and there is no difference between foreign and domestic interest rates. Under these conditions the income equation is:

$$Y_t = w_t L_t + r_t(K_t - o_t) = C_t + I_t = cY_t + sY_t \tag{8}$$

We know that $c + s = 1$ so the equation for the motion of the capital with the added FDI flow can be written as:

$$K_{t+1} = K_t + sY_t + O_t - \delta K_t \tag{9}$$

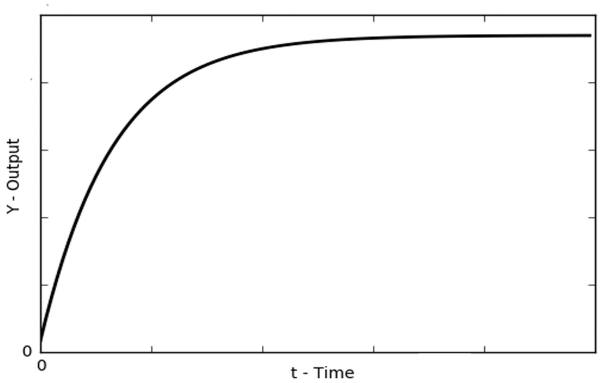
3 Dynamics of the System

If we assume $g_t = 0$ and $O_t = 0$ the system is reduced to a standard neoclassical growth model with a steady state condition at $sY = \delta K$ (because sY - $\delta K = 0$) and optimal capital stock K^*. When both equations (4) and (5) are introduced the model does not posses long run equilibrium, but instead we observe cyclical behavior generated by the Gaussian accelerator. The length of the cycles can be exogenous or stochastic. The second form has a particularly interesting property - it allows each new technology to posses a different lifespan. As observed foreign investors are not interested where to invest, but rather how much to invest. In the simplest version there is no other economy or sector, so how different countries and sectors are evaluated is not discussed here.

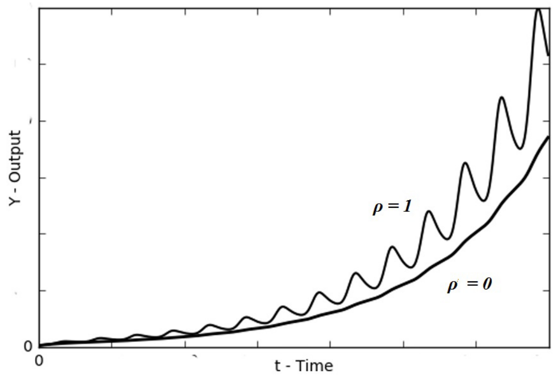
In order to choose how much to invest into the economy, the investors are looking at the structural parameter ρ and the growth rate of the current leading sector s_t jointly. So the necessary and sufficient condition for FDI flow can simply be written as :

$$0 < \rho \leq 1 \quad , \quad 0 < s_t \leq 1 \tag{10}$$

If the second of these inequalities is not satisfied, i.e. if $s_t = 0$, there will be no investment activity and the economic system will converge to a steady state as shown at Fig. 1(a). If the first inequality is not satisfied, i.e. if $\rho = 0$, output only grows due to the changes in capital and will converge to a cyclical growth path. If both conditions hold the system will exhibit cyclical patterns of technological growth and growth in investment activity. Both of these cases are presented at Figure 1(b). This is the first part of the main theoretical proposition of this paper: the only way an economy can attract FDI, is to raise its structural parameter ρ and in the same time there must exist a sector that will attract investors. As illustrated at Figure 1(b), we can observe that the closer ρ is to one, the more visible the technological cycles are. An interesting observation is that the attractiveness of this theoretical economic system is connected with the long run instability of the equilibrium. This leads to the following conclusion: the openness of this theoretical economic system contributes to two things: non defined long run equilibrium and growth.



(a)



(b)

Figure 1: Dynamics of the output under different conditions

A note must be made here about this conclusions. We did not said anything about the size of q. In the previous paragraph, we assumed that the size of q_t is proportional to the rate of the profit π_t times the current capital K_t. This is the reason why the economy will not converge to a lower growth path. The higher rate of profit is linked with higher investment flows. The intuition behind this is that if the investor wants to receive a higher payoff for his investment, he must invest more. This statement is oversimplified, because in this model the investors react only to the current situation, without considering the future. Also there is no consumption smoothing under a budget constraint, and there is no connection between risk and profits. So if we introduce a utility maximization approach, q_t will be subject to a budget constraint, which will include future interests and profits discounted to the current period. The problem with this is that the investors must optimize their utility flows under the assumption of an infinite time horizon, which implies that they are aware how of long the technological cycles are and when their peaks will be reached.

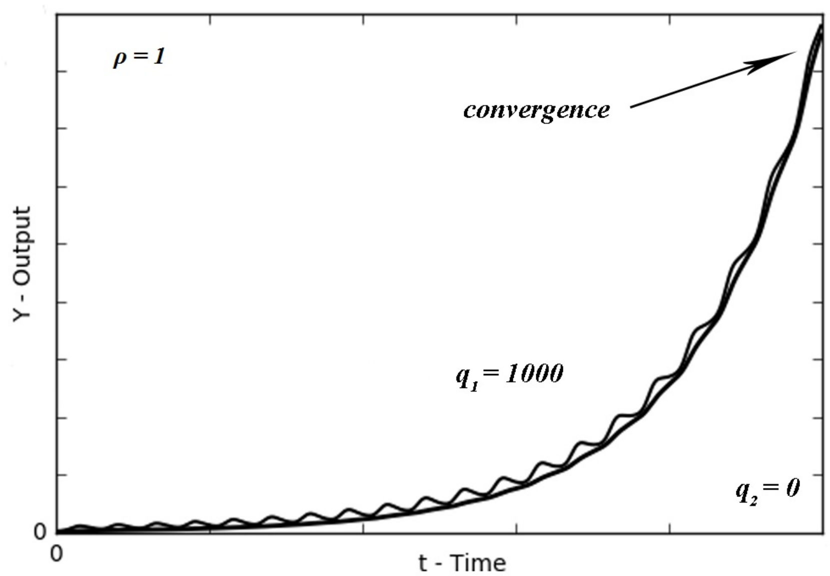


Figure 2: Convergence under a fixed q

What will happen if we assume that q_t is fixed, and it does not evolve under any conditions? If we invoke the property of the Cobb-Douglass production function for decreasing marginal productivity, the fixed value of q_t will depreciate after certain time, the cycles will again become barely visible. As shown in Figure 2 if we simulate the same economies side by side with $q_1 = 10000$ and $q_2 = 0$ after some time the growth rate of the both economic systems will converge. That is because even if we add a fixed amount of capital over time, the amount that depreciates will catch up.

This result leads to an important conclusion: in the initial case the foreign direct investments must be constantly increasing in order to increase the output. If they stop at some time an identical economy, without FDI flows, will eventually catch up in terms of output growth. This conclusions is important, because it shows that under a free transfers of technology, constant FDI flows are not enough to keep the differences in output.

There is one more aspect that is worth mentioning, i.e. the possibility of a low ρ and high FDI. This is possible due to some way of exploiting the economic system, a clear example being investing under the protection of a dictator, especially in gold and diamond mines. This means that a small ρ can be misleading, because there may be a way of evading the system characteristics. In order to model this we can include a random term in eq. (5).

This basic framework can next be extended to incorporate imperfection in international technology absorption and replicate *the link* that connects FDI and the leading technological sector in the poor countries.

In the previous case, we assumed a perfect absorption of technologies from outside the country. This is not always the case and can be easily illustrated by adding an absorption parameter in eq. (3) denoted by μ. What μ captures is, for example, laws for international technology exchanges, the liberty of ideas sharing, the absorption of scientific discoveries, etc. But in the current digital world ideas and blueprints can be easily shared, which implies that some technologies may become available for production in a certain countries without paying the necessary legal rights. This leads to forgery and imitation, but not under the market rules. Production of imitated products does raise the technological advancement of the country, because the firm understands how the product works, but does not raise the FDI. No investor will want to invest in a sector where firms do not pay for the copyrights that the investor owns. Here the crucial role of providing and enforcing these laws of copyright falls to the institutions. The equation for technology absorption is now:

$$s_t = \mu a e^{-\frac{(\tau - b)^2}{2l}} \tag{11}$$

$$0 \le \mu \le 1$$

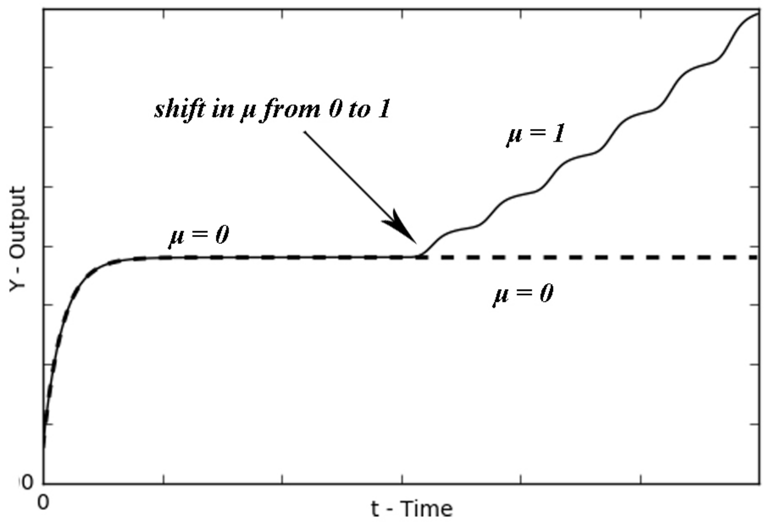


Figure 3: Shift in the technology absorption parameter with $\rho = 0$

The introduced parameter μ is the same as ρ, but affects s_t instead of O_t. This way the choice function (6) is the same, because its already taking into account changes in s_t. Condition (10) can be rewritten as:

$$0 < \rho \le 1 \quad , \quad 0 < \mu \le 1 \tag{12}$$

If ρ is zero the growth path of the output will be cyclical, but the cycles will be almost invisible in the trend, because they are not augmented by FDI. Changes in μ increases the output and the rate of growth as illustrated in Figure 3.

In this version the growth rate depends jointly on changes in ρ and μ. Under the assumption that $\mu = 0$, the growth path is reduced to a standard neoclassical steady state at $sY = \delta K$, even if $0 < \rho \le 1$ (Figure 4 (a)).

An imperfection in technology absorption leads to another question: How the FDI brings TFP from outside the economy? The basic illustration to this observation is straightforward.

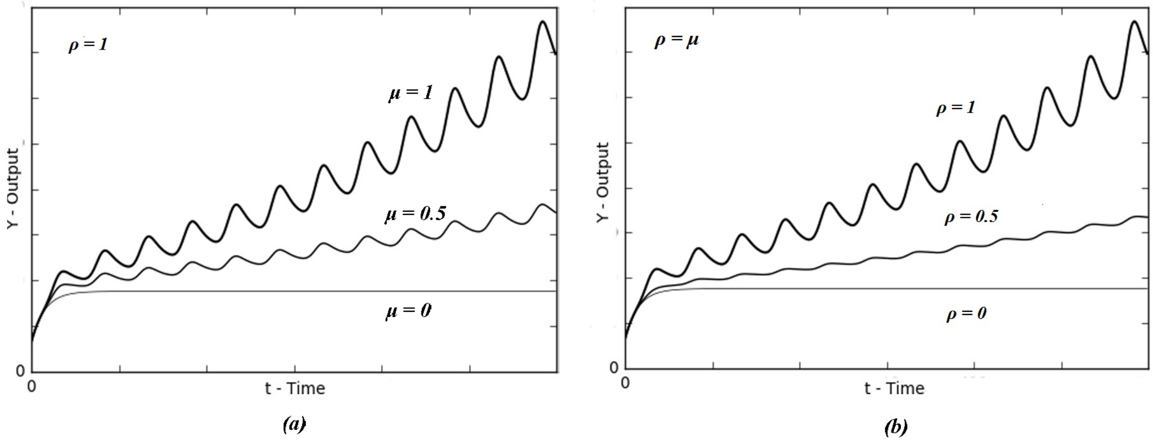


Figure 4: Dynamics of the system under imperfect technology absorption

Lets assume that the foreign investors have access to the cyclical technology, which is not available in the country that will be receiving FDI. They do not produce this technology, but can distribute it freely. This means that they are again taking into account the changes in s_t, because if g_t is zero there is no growing sector in which the capital can be invested. The technology from outside the country will be proportional to the amount of the FDI that the investors are investing into the economy, in case they invest the maximum amount of capital, they will also import as much as possible technologies. We can write $\mu = \rho$, because now they are jointly dependent. If $\rho = 0$, there will be no FDI flow, and no technology absorption. Because $g_t = s_t = 0$ the steady state condition $sY = \delta K$ holds. The opposite is also true: if $0 < \rho \leq 1$ the FDI will flow together with technology advancements (Figure 4 (b)).

The last described case is interesting. The information about these new technologies is free, but their blueprints are not. Even today with free transfers of information, patent rights must be paid. This is a main problem of the modern growth theory. What μ in the first case and ρ in the second case do is to capture this property, which in the scope of the presented model can be used as a cause for the slow development of the TFP. Following this the second part of the main theoretical proposition is: if there is no conditions for investment, the investors will not move their capital and the available technology, which in turn slows down TFP. Under the assumption of this paper, these *productivity traps* are explained using the decisions of the foreign investors. However these decisions are influenced by changes in the structural characteristics of the economic system.

This can be illustrated easily with the following example: lets assume that there are two economies, but this time the first one will absorb perfectly the technologies from outside and the second will grow with a small fixed exogenous growth rate. When both of them are at their respective growth paths the output of the first one will be much higher, because the TFP of the second one will grow very slow. Following this logic there is no reason to observe convergence between countries with different values of ρ or μ, because the presented rules of how investors evaluate them does not allow that. In reality there is always some transfer of TFP between countries, but the principle remains the same - the model tells us that convergence between TFP will not happen, because some countries will be too slow in absorbing the new technologies, and the market will not help them either. Of course a good microfoundations are required to precisely explain how this mechanism works.

The only solution that the model give us in order to speed up the TFP accumulation is to change ρ and μ. But these changes are hard to evaluate and apply. Changes in the two parameters are tightly connected with some specific structural policies and economic institutions. As said in the introduction one should be very careful if conducts such a policies, because of the *see saw* effect. The effect of these policies cannot be evaluated by this model, so in the scope of the paper no proposition for policy making will be given.

4 Conclusions

With this paper we outlined a model that combines multiple economic theories in order to explain the evolution of TFP, FDI flows and the key link between them. The main contribution compared to the literature is that we modify the neoclassical growth model in order to capture system specific parameters which cause imperfections in the international movements of capital and technology. These imperfections will lead to slowdowns in the rate with which poor countries can reach the current level of technological progress, because they are not attractive for investors. This is consistent with one of the main propositions of the NIE, that institutions matter for the long run development of the country.

However, the model presents some limitations, mainly the lack of utility maximizing agents and the potential problems that can arise with the hypothesis testing. Future work may include overlapping technology waves in order to illustrate exactly how one country falls behind the leading technological sector. Also a good microfoundations will play a crucial role in describing the investors behavior, because their decisions will drive the international flows of capital and technology.

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