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Creation and Transfer of Technology in CEE Countries

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Abstract: This paper gives an insight into the role of technology in economic development in transition countries of Central and East Europe (CEE). The study analyses nature and type of relationships among different measures of technology (R&D) and output, and technology transfer possibilities through influence of foreign direct investment on output. The analysis uses unbalanced panel with fixed effects and first differencing methods on the sample of selected CEE economies.

JEL Classification: O30

Keywords: R&D, foreign direct investment, central and east Europe, unbalanced panel data

Introduction

Terms like technology, technological change, and technological improvements may seem to have simple definitions. Alas! They are not. In fact, the perimeter of technology is not so easy to grasp. Technology is usually divided into inventions and innovations, and innovations into product innovations and process innovations. Inventions in themselves need not become innovations, or may take time before they do. If an invention has not become a part of some business process it cannot be said that such an invention has any economic influence. On the other hand, an invention that has been a part of a business process has economic impact, and may be considered as innovation.

In Economics, term 'technology' has been widely used and had been taken to carry a wide range of subjects such as technological change, technical progress, technical capacity, technology transfer, technology diffusion, productivity and productivity change, etc. These concepts have been used in context of economic development in a variety of ways. Development literature is crowded with theoretical and policy details. Most writers have been interested in connecting various aspects of technology with major changes in the production and distribution of wealth, income

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and economic power within a country. Technology has been seen as a determinant factor in economic development of developing countries. Therefore, economists have treated the subject with various degrees of interest and depth.

First section of the paper deals with theoretical background of technology creation and technology transfer. The second and third sections deal with specific issues of thechnology transfer (FDI) and technology creation (R&D) respectively. The fourth section gives model description, and the fifth section gives the results of the research.

Background

The first instance in history where a society broke through from agrarian society to industrial domination is associated with the First Industrial Revolution. How big was the difference between the life before the First Industrial Revolution, sometimes compared to the change after discovery of fire, is coined in Landes' words (2003: 5): '…the Englishmen of 1750 was closer in material things to Caesar's legionnaires than to his own great-grand-children.'

Even in 18th century, Adam Smith (1776) recognized new technologies as very important in process of growth and development. It was viewed as the engine of growth in terms of per capita income. Furthermore, he stressed the division of labour to be one of the key issues due to three different circumstances. First one is dexterity of every particular workman; second, saving of time, commonly lost in passing from one species of work to another; and third, the invention of a number of machines which facilitate and abridge labour and enable one man to do the work of many.

We have seen that new inventions and innovations are not adopted automatically with their discovery. It takes time for invention or innovation to be diffused in an economy. There are few factors that influence this slow down in technology implementation. One is the efficiency of the old technology. It may be so that old technology is cost efficient and owners are reluctant to change it because they are still making profits. Furthermore, the old technology may be improved so as to be more efficient than before, stopping the new technology to enter. This may happen even though the new technology may be more efficient than the old one. This effect is called the 'sailing ship' effect. On the other hand, some technologies become useful after series of innovations, e.g. the steam engine, where it took some 100 years to come from the invention to railroad. Once the railroad was established diffusion was fast.

Young (1993) suggest that most new technologies are initially broadly inferior to the older technologies they seek to replace and are only competitive in a narrow range of specialised functions. Subsequent improvements that take place over time allow new technologies to ultimately dominate. For example, the steam engine of James

Watt in 1765 was at the time crudely engineered piston, which was used mainly in the mines for pumping water. In terms of provision of power, it was not a substitute for widely used water wheel. It was after the innovations by John Wilkinson[1] in 1776 and William Murdock[2] in 1781 that the steam engine was useful for converting vertical motion into rotary force. Only after these inventions the steam engine became generally useful source of power.

Some authors consider technology to be a very pulp term that is hardly definable. Radošević (1999) is of the view that technology as a concept has no clear boundaries, and where generation and diffusion process is deeply embedded in the institutional fabric of economy and society. The forms of technology may vary according to the level of disembodiment from patents and licences to those embodied into machines or persons, i.e. tacit knowledge.

Even the most important inventions had a very modest impact initially. The full potential developed and materialised only after the potential of a technology was explored. This was often done through using the technologies themselves and as they become cheaper and widely diffused. One example is the 'social savings'. This stipulates reduction in real resource costs, and an estimate for the steam engine suggests it to be at no more than 0.2 percent of GDP in 1800. However, usage of the steam engine in terms of horsepower was 35,000 in the year 1800 and about two million in 1870. By 1870, the implications of the steam engine were fully realised and social savings went up to about 3.5 percent of GDP, excluding the larger impact of the railways (Crafts, 1998).

Abramovitz (1986) attributes technological backwardness to the social conditions of a country, where tenacious societal characteristics attribute for a portion of a country's failure to achieve the level of productivity of more advanced economies. He coined the term 'social capability'. When social capability is incorporated, it follows that a country's potential for rapid growth is strong not when it is backward without qualifications, but rather when it is technologically backward but socially advanced.

On the same line as Abramovitz (1986) with 'social capability', Hall and Jones (1998) developed the hypothesis of social infrastructure. In their hypothesis it is argued that differences in capital accumulation, productivity and thus output per worker are fundamentally related to differences in social infrastructure among countries. The social infrastructure in this context is defined as 'institutions and government policies that determine the economic environment within which individuals accumulate skills, and firms accumulate capital and produce output. A social infrastructure favourable to high levels of output per worker provides an environment that supports productive activities and encourages capital accumulation, skill acquisition, invention, and technology transfer.' It is further argued that the social infrastructure has the right price when private returns capture social returns. However, even though the government is the most influential provider of social infrastructure that protects against diversion (e.g. thievery, squatting, Mafia), it is in practice a prime source of diversion throughout the world: 'Regulations and laws may protect against diversion, but they all too often constitute the chief vehicle of diversion in an economy.' Countries with high levels of corruption among government officials are likely to have severe constraints in trade, poor contract enforcement, and government intervention in production will not be able to achieve income level associated with Western Europe, North America or Eastern Asia.

While the problem of knowledge creation is a problem in some Asian and African countries, the same cannot be said for the transition countries. However, both groups of countries share the disproportion in creation of new knowledge. Furthermore, in Central and Eastern Europe, the accumulated stock of knowledge is significant, but it is not utilised. Thus, creation of knowledge by itself does not automatically mean a country will benefit from it. Much of the research and development (R&D) in ex-communist countries went on military research. While the military R&D may have spin-off effect in other areas, it seems that these countries did not benefit from it to a greater extent.

The advances of today's developed countries after the World War II in Europe have shown unprecedented growth performance. It is argued that this performance was due to the backlog of unexploited technology. This is particularly viewed in the light of methods already in use in the US, but has not been employed. Here, the US can be seen as the leader and other countries as followers. However, the initial backlog and its reduction with time cannot be a sole explanation for either speeding-up or slowdown, but it constitutes an important part.

It can be seen that mere technology is not enough, but rather it is support for social advancement that should prelude before advantages from technological advances can be achieved. This is one of the issues that some countries (e.g. Eastern Europe and ex-USSR) have not capitalised in terms of faster productivity growth in situation where the backlog of technology was very much present. For Western Europe and Japan it can be said that they were able to exploit the backlog into their own advantage for rapid productivity growth. However, the capacity for a country to change may vary over time. The existing technology may be fully exploited with educational content, but it does not necessary present the foundation and requirements for change.

When a country moves from lower to higher technology level, the cost of moving from one level to another is an increasing function of the level of technology already in use. On the other hand, as country develops, the speed of development slows down as country reaches higher levels of development. This is so because changes required for advancement are more infrequent (Ames, Rosenberg, 1963).

In the case that advanced technology is largely scale-dependent, with further obstacles to trade, political obstacles etc., which prove to be important, large countries will have a stronger potential for growth than smaller countries (Abramovitz, 1986).

Young (1993) stresses the fact of limited possibility of any given technology and knowledge. With invention of new technology comes learning, by virtue of experience, by which the productive potential is further explored and innovations follow. However, after a certain time limitations (physical) of a technology are reached in terms of productivity and learning will slow down, and even ultimately stop. If there is absence of new technological advances and introduction of new technological processes, it is likely that any given environment has simply a finite amount of knowledge to be serendipitously acquired from experience in productive activity, as opposed to purposeful investigation.

Abramovitz (1993) notes a two-way connection between technological progress and economies of scale, tangible capital accumulation, and human and other intangible capital accumulation. The interdependence is stipulated by Arrow (1962) and his hypothesis on learning by doing, and learning by using by Rosenberg (1982). Views expressed by Arrow and Rosenberg deal with the contributions of experience with new way of doing things, thus with the effects of past technological progress.

Technology Transfer

Ever since economies took off from agricultural to industrial, and some even to information, societies, technology transfer was an option for faster catch-up possibility. Economists have supported this idea with a question in mind. Why the developing countries fail to resolve their development problems when technology can be transferred? This question was posed by H. W. Singer (1965) where he stressed the importance of technology transfer as a strategy for development. He supported the idea with the fact that the US and Germany developed faster than the UK, where industrial development took place first. The impossibility of developing countries to resolve their problems is attributed here to high population growth, and the other is the severe disproportion of knowledge creation among countries. While the problem of high population is distinct in Africa and Asia, it cannot be said the same for the countries of Central and Eastern Europe. Furthermore, number of Asian countries have succeeded in technology transfer, and knowledge creation (Japan, Taiwan, South Korea, Singapore, and more recently, China, Malaysia, Thailand and Indonesia), and Central European Countries are stepping up the pace, especially in the light of EU enlargement, but African countries still lag far behind. On the second account, knowledge creation is disproportionate in favour of developed countries.

Sachs (2000) points out that only 15 percent of total world population provides almost all technology innovations, while the part accounting for some half of the world population are able to adopt new technologies, leaving the rest of the world technologically disconnected.

In terms of transfer of technology from leader to a follower country, situation is similar to diffusion of technology in one country. The process is far from automatic. While some simple technologies can be readily transferred, and some with greater difficulty when substantial knowledge endowments are necessary, still one technology is not likely to work in different geographical location in the same way. The example here is one in Egypt (Landes, 1998), where it was decided after World War II to invest in cotton-spinning mills. The idea seemed reasonable and foolproof. After all, Egypt grew finest long-fibre cotton in the world and cotton-spinning mills seemed as done deal in order to gain some value added from cotton, and not just from export of cotton. However, the yarn produced there was not of international quality. Furthermore, other growers of cotton found ways to improve their raw cotton and weavers looked for ways to make high quality cloth with poorer brands of cotton. In the end Egyptians were stuck with poor cloth for home market, and lost part of the export markets for raw cotton.

As Landes (1998) points out, ‘even in later ages of scientific diffusion and transparency, even with sample products and equipment, even with blueprints and explicit instructions, some know-how can be learned only by experience’. This is what Michael Polanyi (1967) calls tacit knowledge, Kenneth Arrow (1962) refers to it as learning by doing, and Adam Smith (1776) labels dexterity.

Radošević (1999) points out a historical dimension of technology transfer. We have seen the importance of the movement of people as a key element for technology transfer during the industrialization of Europe and the US. However, there are limits to which these elements of industrialization in terms of technology transfer can be an insight for today’s developing countries. The measurement of migrations of researchers and engineers, and understanding of their contribution to their home countries produce little beyond anecdotal evidence.

Radošević (1999) further distinguishes four aspects of new technologies whose characteristics have implications for technology policy, and technology transfer policy in particular. These are: (1) the rising complexity of technical change; (2) changing appropriability and transferability of new technologies; (3) increasing knowledge intensity of new technologies and production; and (4) the increasing significance of organizational change. The mentioned aspects of technology transferred are labelled with a change from predominant electromechanical industries to dominantly electronics based technologies. This trend toward electronic has shifted ways of learning and technology transfer which has profound influence on the ways learning and technology transfer policies are created. In this light it is important to understand institutional framework and policies that have been satisfactory in some previous period do not have to be effective at present.

Even though we have mentioned many aspects of technology transfer, some of them are not easily quantifiable. Furthermore we will see what where and what the major technology transfer mechanisms today are. We already mentioned some of them, but we will stick here to those quantifiable where some aspects of not so quantifiable effects can come into play as well. Here we will distinguish foreign direct investments (FDI) and take a look at the aspects of technology transfer through this mean. Furthermore, we will distinguish why we think the FDI worth analysing in the aspect of technology transfer.

Gains from FDI by the recipient country are not merely capital and foreign exchange. There are further benefits to FDI inflows in the shape of managerial abilities, technical knowledge, technical personnel, technological knowledge, administrative organization, and innovations in products and processes. The knowledge that foreign capital may provide is of great benefit to the recipient country. The importance of such knowledge stems from the fact that such knowledge may provide a successful tool in closing a managerial and technological gap. These benefits may be treated as 'private technical assistance'. Furthermore, such technical assistance and the demonstration effect accompanying the assistance may positively influence other sectors of an economy, or spur positive movements in areas where FDI is being implemented (Arrow, 1962).

The new techniques that enter an economy through FDI, by the example they set, promote the diffusion of technology in the recipient economy, which plays a significant role in economic development process. In a model of technology diffusion, usually the growth rate of a developing country depends on the extent to which it can adopt technologies already in use in developed countries, or to be more precise, in technologically leading countries (Borensztein, De Gregorio, Lee, 1998).

Technology diffusion can take place through a variety of channels that involve the transmission of ideas and new technologies. Imports of high technology products, adoption of foreign technology and acquisition of human capital through various means are certainly important conduits for the international diffusion of technology. Beside these channels, foreign direct investment by multinational corporations (MNCs) is considered to be a major channel for the access to advanced technologies by developing countries (UN, 2002).

Research provided by Findley (1978) states that FDI increases the rate of technical progress in the host economy through a 'contagion' effect from the more advanced technologies, management, practices, etc., used by foreign firms. Research by Wang (1990) is more in the line with neoclassical growth framework, by assuming that the increase in 'knowledge', applied to production is determined as a function of foreign direct investment. Furthermore, research conducted by Balasubramanyam, Salisu and Sapsford (1996) suggest that due to the spill-over effects and externalities associated with FDI (as opposed to domestic investment) it is expected that for the export oriented countries foreign investment is a more powerful driving force in the growth process than domestic investments.

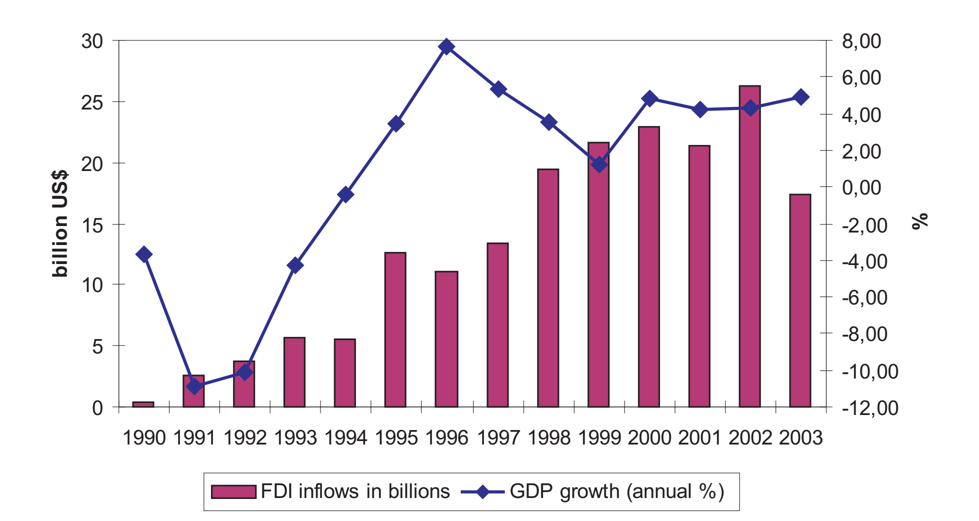
The opening up of previously closed economies of Central and Eastern Europe changes models and patterns of how economies are integrated into the global economy. Prior to 1990s, these countries were linked to the global economy predominantly through trade, with the import of equipment and licenses serving as a main vehicle of technology transfer. Now there is whole range of mechanism at their disposal. Simple trade, FDI and the various forms of minority equity or non-equity type of relationships are possible vehicles for technology transfer.

Before the transition process started, and at the early stages of transition, foreign investors were mostly concentrated on joint ventures (JVs). It is estimated that over the period 1988-1990 the number of JVs in these countries rose from 383 to over 10000. In practice, this was very much a transitional phase and many of these JVs transformed into direct investment after 1990 (Radošević, Dyker, 1997).

Figures for CEEC (see figure 1) reveal dramatic developments in the earlier stages of the transition process. We can see that things went from bad to worse until 1992, with a recovery period up until 1995, when the region entered a positive growth rate pattern. All transition countries experienced a transition slump during the first half of the 1990s. In other words, FDI inflows were not nearly enough to offset the negative trends associated with transition. Thus, the data shows a negative trend between the two variables up until 1992. Naturally, increasing growth rates cannot be attributed solely to FDI inflows, but rather to improved conditions in countries accompanied by an increase in FDI inflows. We can also see a positive trend in both FDI inflows and GDP growth collapses after 1996. Since that year, we observe contradictory trends in FDI inflows and GDP growth. However, the impact of FDI does not, and more importantly, is not likely, to influence GDP in the year of implementation, but rather after a certain time lapse. Thus, it is difficult, if not impossible, to distinguish the effects of FDI using the descriptive analysis only.

The growth rates for this region are likely to increase in the next few years, according to IMF (2003) data. In 2002, the growth rate remained steady at 4.27 percent, and increased to 4.87 percent in 2003, and a slight drop to 4.3 percent in 2004 is forecasted. Whether this is a positive indicator of FDI growth remains to be seen. However, investors are more likely to invest in those countries where policies are oriented towards long-run lasting reforms, rather than to countries with temporary higher growth rates, but no serious long-term reforms, which may lead to lower growth rates in the long-term.

Figure 1: FDI Inflows and Real Growth Rates of GDP in CEEC, 1990-2003



Source: World Bank, 2005.

R&D

Like many authors, Goto and Suzuki (1989) point out that technology possesses characteristics of public good in the sense that an additional user without additional cost can consume it. The usual diffusion channels include licensing, reverse engineering, academic and trade journals, and/or turnover of researchers.

As argued by Bania, Eberts and Fogarty (1993), the incentive for firms to engage in R&D is to increase innovations and productivity growth. Furthermore, the incentives also exist as firms appropriate information from other firms and institutions performing R&D, including universities. It is further argued here that geographic proximity may facilitate spillovers and shorten the time between invention and innovation. Benefit for local firms is in region's technical infrastructure in many ways. Graduates are hired from local universities, local firms may use consultants from local universities, or they can engage in university-industry joint research centres. Local firms may use universities for education and training of their work force or utilise university facilities, e.g. laboratories, libraries, specialised equipment and by attending seminars. The clear-cut case of spillovers is hiring labour from local universities that embody fruits of academic research, education and training.

As suggested by Helpman and Coe (1995), in the light of openness to international trade in goods and services, FDI, and international exchange of information and dissemination of knowledge, a country's productivity depends both on its own R&D and on the R&D by its trade partners. A country's own R&D efforts produce traded and nontraded goods and services that induce more effective use of existing resources and thus raise productivity levels. On the other hand, own R&D makes acceptance benefits from foreign technical advances possible. The more a country is able to take advantage of these benefits the more productivity it becomes. Furthermore, the benefits of foreign R&D can be direct and indirect. Direct benefits are those which relate to learning about new technologies and materials, production processes, or organisational methods, while indirect benefits stem from imports of goods and services that have been developed by trade partners. In both cases the foreign R&D affects a country's productivity.

Griliches (1997) points out that education becomes more valuable in periods of rapid technological change due to rising price of 'skill' as the result of a technology induced rising demand for it. Furthermore, in conventional measure of education per worker is limited by the finiteness of the measure itself, and more substantially by the finiteness of human life. This is the reason why education cannot be a source of indefinite growth if externalities are produced by education. These externalities encompass direct accumulation via investment in science and R&D, and indirect effects via learning by doing and other knowledge spillovers.

In terms of organizational capacities to perform R&D, we have seen that by the outbreak of the Second World War there was extensive research network with organized research laboratories along with the related institutions in government, university and industry. The researchers in said institutions were employed on a full time basis. As any other industry, R&D industry can be a subject to an economic analysis, with recognition of some unique characteristics. The 'output' of a research process is a flow of new knowledge, both of general character (basic research) or specific application (applied research). The output may be incorporated as flow of models, sketches, designs, manuals and prototypes for new products, or of pilot plants and experimental rigs for new processes (experimental development) (Freeman, Soete, 1997).

As stipulated by Romer (2001) once a particular knowledge has been discovered, its marginal cost for an additional user is zero. This would suggest the rental price of knowledge in a competitive market to be zero. However, in this case creation of knowledge would not be motivated by private economic gains. The conclusion here is that either knowledge is sold at above its marginal cost or market forces do not motivate its development. Therefore, competitive model cannot be fully applied here. However, there is another possibility. Although knowledge is non-rival in essence, it can be excludable. This is the case when we are able to prevent others from using it. The excludability in the case of knowledge will depend both on the nature of the knowledge itself and on law, regulations and institutions governing property rights.

In conventional thinking of economists, R&D is seen as generating one product: new information. Cohen and Levinthal (1989) suggest additional aspect, where R&D is not only generation of new information, but also enhancement of the firm’s ability to assimilate and exploit existing information. It is further argued that R&D obviously generates innovations, however, at the same time it also develops the firm’s ability to identify, assimilate, and exploit knowledge from the environment. This is also called a firm’s ‘learning’ or ‘absorptive’ capacity. On these lines, a firm’s ability to imitate fits into the scope of absorptive capacity, but it also includes the firm’s ability to exploit outside knowledge of a more intermediate sort. This includes basic research findings that provide the basis for subsequent applied research and development.

Regarding the size of firms and their involvement in R&D ventures, Mansfield[3] (1981) argues that in most industries increases in size of firms are associated with more than proportional increases in the amount spent on basic research. More specific, a 1 percent increase in a firm’s sales is associated with about a 1.65 percent increase in basic research expenditure. However, there is evidence that in most industries increases in firm size are associated with less than proportional increases in the amount spent on R&D projects aimed at entirely new products and processes. To be more specific, a 1 percent increase in a firm’s sales seems to be associated with about a 0.78 percent increase in the amount spent on such projects. So, the largest firms carry out disproportionately large share of the basic research in most industries. However, there is no tendency for the same firms to carry out disproportionately larger but smaller share of R&D aimed at entirely new products and processes. This is not contradictory because basic research and R&D aimed at entirely new products and processes are not one and the same thing. Furthermore, results provided by Mansfield suggest that innovative output seems to be directly related to the percentage of R&D expenditure going for basic research.

The models that incorporate R&D directly are mostly related to the new growth theory. The basis of such thinking is the plausibility of the fact that technological progress is the reason that more output can be created today than with the same inputs (capital and labour) a century ago. Furthermore, there are some simplifications that have to be taken into consideration. The functions are generalised Cobb-Douglas functions, and in the spirit of Solow, fractions of labour and capital used in the R&D sector are exogenous and constant (e.g. Romer (1990), Grossman and Helpman (1991), and Aghion and Howit (1992)).

On traditional lines, R&D capital represents the stock of knowledge a firm of an industry possess in a certain point in time. This capital is combined with other inputs to produce output. The accumulation process of R&D proceeds through R&D efforts of a firm or an industry, which depreciates over time and eventually becomes obsolete due to changes in external circumstances, development of superior techniques or products by other firms or institutions. Furthermore there is the decline in the appropriability of knowledge as it diffuses. The obsolescence of R&D capital is interesting in itself. As argued by Pakes and Schankerman (1984), the rate of obsolescence of R&D capital must be higher than that of physical capital because it depreciates and becomes obsolete, not only because new knowledge replaces old knowledge, but also because the appropriability of knowledge decreases as the diffusion takes place. To a certain extent, the rate of obsolescence of R&D capital reflects the rate of replacement of the old knowledge by new knowledge. This may in turn reflect advancement in knowledge creation, and it can additionally indicate the amount of replacement investment in R&D.

Model Specification, Data and Variables

In this section we move to more formal inference about technology. It is know from the discussion above that production of knowledge is unequally distributed among nations. As argued by Keller (2004), most countries have foreign sources of technology that is attributed to their productivity growth. On the other hand, there is only a minority of rich countries that account for most of the world's creation of new technology. The G-7 countries account for some 84 percent of the world's R&D spending, but their share in world GDP is only 64 percent. One of the major channels for technology diffusion is FDI, along with international trade. However, effects of international trade will not be included in our formal analysis, but the analysis of FDI is provided in this research.

On the account of more direct measures of technologies there are several approaches to this problem. As stipulated by Keller (2004), technology is an intangible that is difficult to measure directly; however, there are three widely used approaches. These are inputs (R&D), outputs (patents), and the effect of technology (higher productivity). Regarding the data on R&D, not too many countries report substantial amounts of R&D. Because this measure capture primarily resources spent towards innovation, with omitted resources spent on imitation and adoption of technology, the data for R&D cannot typically be analysed for middle and poor countries. However, the data on R&D becomes more available as countries income's rise. There is further information because surveys include R&D conducted by affiliates of multinational companies located abroad. One important aspect of R&D is that the returns on publicly funded R&D are lower than the returns to privately funded R&D. In our analysis, R&D data will be used for countries that are converging to high-income group, with some already there.

Even though there are limitations on the part of data used here, this does not invalidate overall conclusions, given limitations that will be provided in the analysis.

Even though countries of CEE cannot be said to produce significant portion of R&D, but rather could be seen as adopters of foreign technologies, it is important to see the influence of R&D on selected economies. Some authors stipulate that R&D analysis should not be done for middle and poor countries. However, there is strong presence of multinationals in most selected countries, so there is increasing information in R&D activity. Since sampled countries have strong R&D backgrounds the analysis of the same is welcome on this account also.

All countries in the sample have had sound foundations in their education policies for science. Why is this fact important? It is often argued that, for example Germany in the post World War II period experienced tremendous expansion due to backlog of educated labour force. This education stemmed from the pre-war years. In the same way, science potential in CEE countries may be viewed in this light.

The second line of reasoning may be seen in increased ability of countries to transfer and implement advanced technologies from the technology frontier countries. R&D activity and FDI certainly contribute to the ability of a country to make the most of foreign technologies. Thus, there is ground to perform analysis using R&D figures for the selected sample of CEE countries.

The data source used for the analysis is World Development Indicators Database (World Bank, 2005). Countries being tested are selected CEE countries that have joined the EU in May 2004, or are negotiating to enter by 2010 or earlier. Namely, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic and Slovenia.

The following data is used for the analysis: exports of goods and services (constant 2000 US$); GDP (constant 2000 US$); gross capital formation (% of GDP) (formerly gross domestic investment), employment, foreign direct investment (% GDP), research and development expenditure (% of GDP).

The hypothesis being tested is that FDI has significant influence on GDP of CEE countries. Furthermore, as suggested by the theory above, the influence of FDI should be greater than that of domestic investment. As we have seen, FDI has become the main vehicle of technology transfer. Thus, this effect should make FDI even more significant for recipient economies. Furthermore, it is often stressed that FDI has an impact on the domestic entities through demonstration and contagion effects; thus, indirectly boosting productivity and technology advances in environments where FDI has come.

It should also be noted that countries differ in their ability to create and absorb technology. CEE countries generally fit into countries able to assimilate foreign technology to a greater extent and show some ability to create knowledge on their own.

The model derived here to test mentioned hypothesis stems from a production function where FDI is introduced as an input in addition to labour and domestic capital. The FDI variable is introduced in order to capture the effects of externalities, demonstration and spillover effects associated with FDI. Exports are also included as the addition to the production function[4]. The production function can be written as

$$Y = f(L, K, F, X, t) \tag{1}$$

Y = real GDP
L = labour
K = domestic capital
F = foreign capital
X = exports
t = time trend

It is assumed that (1) is linear in logs. Due to well-known problems of measuring capital stock, FDI and domestic investment will be measured as a share of GDP. Procedures used for the analysis is panel data fixed effects estimation so we have:

$$y_{it} = \beta_1 + \beta_2 l_{it} + \beta_3 (I / Y)_{it} + \beta_4 (FDI / Y)_{it} + \beta_5 x_{it} + a_i + u_{it} \tag{2}$$

where lower case letters represent growth rates of respective variables and the parameters β_j represent output elasticities of labour, domestic capital, foreign capital and exports respectively. In (2) *i* denotes the country and *t* denotes the time period. The variable a_i captures all unobserved, time constant factors that affect y_{it}. The variable a_i is referred to as unobserved or fixed effect. Furthermore, in application it may be referred to as unobserved heterogeneity (in our case country heterogeneity). The other part of the error term, u_{it} is often called the idiosyncratic error or time-varying error, because it represents unobserved factors that change over time and affect y_{it}.

The second hypothesis tested here is that R&D as an input in the production function has positive influence on output. From the methodological definition of R&D, we know it consists of both applied and basic research. It is well known that appropriability of basic research extends longer in time (if ever) than the of applied research. Furthermore, as both private and public expenditures are contained jointly in the data, it should be noted that the returns to publicly funded R&D is lower than the return to privately funded R&D. In the absence of data that divides along private-public or basic-applied research, the joint data will be used here.

The models derived here to test mentioned hypothesis stems from a production function where R&D is introduced as an input in addition to labour and domestic capital. The R&D variable is introduced in order to capture the effects of research activity on the performance of selected economies. The production function can be written as

$$Y = f(L, K, R\&D, t) \tag{3}$$

Y = real GDP
L = labour
K = domestic capital
R&D = research and development expenditures
t = time trend

It is assumed that (3) is linear in logs and by using panel with first differencing we get the determinants of GDP growth where lower case letters represent growth rates of respective variables and the parameters β_j represent output elasticities of labour, domestic capital, and R&D. Due to well-known problems of measuring capital, R&D and domestic investment will be measured as a share of GDP. These adjustments yield the following equation:

$$y_{it} = \beta_1 + \beta_2 l_{it} + \beta_3 (I/Y)_{it} + \beta_4 (R\&D/Y)_{it} + \beta_5 x_{it} + a_i + u_{it} \tag{9}$$

Following the discussion in previous sections we expect the parameter β_4, the elasticity of output with respect to R&D to be positive. We can view R&D as knowledge capital and domestic investment as physical capital. Furthermore, we will introduce lags to (R&D/Y) variable in order to investigate whether lags yield additional information. As already mentioned, returns to research are expected within three to five years. Naturally, this is true for applied research, but it is controversial for basic research. Similarly as with the fixed effects estimation, unobserved heterogeneity,, is differenced away.

Empirical Results and Discussion

The results related to technology transfer measured through FDI is shown in table 1.

Why did we choose the different time intervals? First interval, 1990-2002, has more data and represents the start of the transition process in respective countries, which includes transition slump. Second interval, 1993-2002, represents a sample when most of the selected countries started to come out of the transition slump, which was dominant in all transition countries. Third interval, 1995-2003, represents a sample for the period when most transition countries have stabilised and started to attract more FDI, which was not the case during the transition slump, except in

Hungary. The last interval, 1998-2002, represents an interval when the structure of FDI started to change from dominantly privatisation related, and market and resource seeking to more efficiency seeking.

Table 1: Analysis of Determinants of real GDP in CEE

Equation	Sample	FDI/Y	I/Y	l	x	R2
1	1990-2002 N = 106	-.015** (005)	.046** (.014)	-.003 (.005)	.243** (.033)	0.52
2	1993-2002 N = 95	-.012* (.005)	.062** (.018)	-.003 (.005)	.193** (.039)	0.34
3	1995-2002 N = 77	-.012* (.006)	.10 (.021)	.067 (.15)	.173** (.04)	0.44
4	1998-2002 N = 44	-.009 (.006)	.056 (.039)	.536** (.195)	.255** (.041)	0.69

Notes: Figures in brackets are respective standard error values. A single asterisk denotes an estimated coefficient, which is significantly different from zero at the 5 per cent level, and double asterisk denotes significance at the 1 per cent level. R^2 from estimating using fixed effects is interpreted as the amount of time variation in the y_{it} that is explained by the time variation in the explanatory variables.
Serial correlation AR(1) was detected using Wooldridge (2002) test for autocorrelation in panel data. Due to this fact, autoregressive fixed effects model was used. Furthermore, this model allows unbalanced panel with unequally spaced observations (Baltagi, Wu, 1999; Im, Pesaran, Shin, 2003), which is characteristic of used panel. The procedure uses Cochrane-Orcutt transformation.
Testing for unit root was done using the Fisher type unit root test for panel data developed by Maddala and Wu (1999), using Phillips-Perron procedure. Test results showed variables to be stationary. Results of the Hausman test yield fixed effects as appropriate.

Furthermore, the data sample is relatively small due to a short time period available and number of countries. The estimates will be probably much better in few years time when longer time series become available. Additionally, it will be possible to construct estimates for respective countries separately, which now yield coefficients that are not significantly different from zero. The data after 1995 is likely to yield better and more accurate results, so this remains to be investigated in the next period when data becomes available.

As we can see from the estimates in the table above, we did not confirm the hypothesis of greater efficiency of foreign capital compared to domestic capital. Elasticities of GDP with respect to domestic investment are greater than that of foreign capital in all equations.

Estimated equations show similar result for all sampled periods. However, the coefficient for FDI/Y has diminishing trend as the sample becomes shorter. This trend is not due to smaller data sample only, but rather due to different type of FDI entering countries and it captures the fact that the spillover effect is taking place. Greenfield investments are likely to have greater initial effect than privatisation related FDI. Furthermore, it is likely that the contagion and demonstration effects along with technology transfer have set in on a larger scale by the end of 1990s.

Would have a lagged variable for FDI/Y made any difference? This option was explored as well, but the lagged variable did not reveal anything new. Coefficient for FDI/Y_{t-1} was found to be marginally negative. Naturally, the model as a whole did not hold so this approach was abandoned.

Are the conclusions from tables above surprising? Not entirely. Naturally, it cannot be concluded that FDI has no positive influence for recipient economies; thus, the results show that there are some other variables influencing GDP stronger than ones selected in the model. However, these factors cannot be easily captured.

First factor that could explain the results of the analysis is aforementioned transition slump. Although there were FDI flowing into respective countries, growth performance was not significantly affected, thus, FDI inflow was not of such magnitude in the beginning of the transition process to reverse negative effects of transition. By the end of 1990s some countries experienced recessions which coincided with the sale of some valuable companies to foreigners. In doing this, governments tried to solve their financial problems so we have large inflow of FDI and recession at the same time.

The second factor that may have influenced the analysis is the nature of FDI, especially in the first half of 1990s, but later as well. FDI was in most cases privatisation related, and market and resource seeking. This meant just change of ownership, and funds that governments received were largely used to cover budget deficits. Furthermore, companies that were sold to foreigners were already solid and profit making, recording above average productivity, e.g. telecommunication sector or oil industry sector. In many cases these industries were monopolies, so the new owners reaped the benefits of this position, which is unlikely in developed countries. Such FDI did not contribute to technology transfer and diffusion to a greater extent, and the spillover effect was marginal.

It should be further noted that in the case of privatisation of monopolies prior to implementing effective regulatory authority might simply replace a government monopoly with a private monopoly, even more ruthless in exploiting the consumers (Stiglitz, 2002).

The third factor was the speed of privatisation. Countries, which privatised faster, received greater FDI inflow than those with slower privatisation. This does not necessarily mean that privatisation-lagging countries were worse off. On the contrary, e.g. Slovenia and Poland had a very slow pace of the privatisation process. There was no rush too sell off the most valuable assets. Slovenia is the best performing transition economy and under the World Bank classification is the only high-income country in the region. Furthermore, the FDI inflow into Slovenia was very modest during the observed period. However, performance of the economy did not suffer because of that fact. On the other hand, Hungary, Poland and Czech Republic received significant portion of FDI inflow for the region, which positively influenced their economies. It should be noted that size of countries played a role, which makes differences between Slovenia and aforementioned countries more understandable.

Additionally, in the ten-year review of transition provided by the World Bank, it became apparent that the process of privatisation in the absence of institutional infrastructure had no positive effect on growth (Stiglitz, 2002).

The fifth issue is collection of FDI data. The problem is that cross-border merger and acquisitions are not captured under FDI. Thus, there may be significant foreign capital inflow that is not recorded as FDI. The drop in FDI during the late 1990s is contributed largely to increase in cross-border mergers and acquisitions[5].

It seems that FDI in 1990s was not aiming at efficiency, but rather at market penetration. It is expected that FDI in the following decade will be much more efficiency seeking driven, giving advantage to countries with sound and long-run reaching reforms, and with solid infrastructure. Countries with sound legal systems that protect investors are likely to see more FDI and of a better 'quality'.

One issue that will be of interest, especially in coming years, is the influence of FDI on balance of payments. As FDI 'settles in', which may take few years, the pressures to withdraw profits will grow stronger, thus putting additional pressure to the capital account. This activity may diminish benefits of FDI on local economy in medium and long run. This does not suggest that FDI is unwelcome, but rather states that there are some negative consequences of FDI as well along with all positive consequences for economies.

According to the IMF, countries that engaged in the shock therapy might feel some pain in the short run, but benefits would be felt in the long run. Gradualist policies in countries like Hungary, Slovenia and Poland have yielded less pain in the short-run, greater social and political stability, and faster growth in the long run. 'In the race between the tortoise and the hare, it appears that the tortoise has won again. The radical reformers, whether the star pupils like the Czech Republic or the slightly unruly ones like Russia, have lost' (Stiglitz, 2002: 188).

The results for R&D analysis are provided in table 2. The time series length is chosen very simple: the availability of the data. Since prior to 1995 many countries have no recorded data, we may say that the analysis was done using data manly between 1995 and 2002. In all our equations we have estimated unbalanced panels, which, in addition to first differencing, reduces the number of data points available.

Table 2: Analysis of R&D in CEE, 1990-2002

Equation	Sample	Constant	R&D/Y	R&D/Y t-1	R&D/Y t-2	R&D/Y t-3	I/Y	l	R2
Dependent variable: GDP									
1	n = 82	.033** (.003)	.053* (.025)	-	-	-	.1** (.036)	.342** (.13)	0.42
2	n = 68	.035** (.003)	.042 (.028)	.043 (.026)	-	-	.11** (.037)	.273* (.109)	0.42
3	n = 54	.037** (.003)	.027 (.027)	.049* (.02)	.048* (.023)	-	.102** (.03)	.101 (.149)	0.56
4	n = 41	.036** (.003)	.027 (.036)	.043 (.026)	.079** (.027)	-.01 (.027)	.109 (.026)	.068 (.152)	0.61

Notes: Figures in brackets are respective standard error values. A single asterisk denotes an estimated coefficient, which is significantly different from zero at the 5 per cent level, and double asterisk denotes significance at the 1 per cent level. Autocorrelation and heteroscedasticity were tested using Breusch-Pegan and Breusch-Godfrey tests respectively. In all equations we did not detect autocorrelation or heteroscedasticity.
Testing for unit root was done using the Fisher type unit root test for panel data developed by Maddala and Wu (1999), using Phillips-Perron procedure. Test results showed variables to be stationary.

The hypothesis that R&D has a positive influence on GDP has a positive outcome. Even though there are great limitations for estimating such equation for selected countries that are not considered to be on a technology frontier, it does point out to a positive influence of R&D. Since performing R&D is not only about being on the frontier but also being able to transfer knowledge and best practices from the frontier countries.

What about lags in R&D activity? As stipulated throughout this text, there is considerable time lag between actual research expenditures and actual invention or innovation. This lag is larger for basic research, if it is possible to talk about lags since benefits may be accrued after considerable number of years. On the other hand, applied research is estimated to have a lag of three to five years. Even though the time span is rather short we managed to retrieve some conclusions from the lagged variables. As can be seen from the table above in first four equations we have estimated R&D with no lag, with one, two and finally four lags. Even though the estimated coefficients do not have separate significance for all variables of R&D, they do exhibit joint significance (10% or 5%) in all equations. Due to shortness of the data period the analysis was constrained to three lags only. We can observe from the table above that the second lag performs much better then the other lag. Thus we may conclude that the second lag has the highest explanatory power. With third lag we get a negative value, but this coefficient is not significant.

We can conclude that the performance of R&D does come with a lag. However, due to data limitations we managed to explore up to three lags. This does not invalidate our conclusions of three to five years lag, but rather confirms the hypothesis of a lag in R&D activity. With more data in coming years we will be able to estimate R&D process more thoroughly.

Even with obvious limitations to the data, it may be concluded that there are benefits to performing R&D in transition economies. This is more of essence when we think of past educational levels in the sample countries, which are relatively high. All this may contribute to further and faster appropriate technology transfer. Along these lines we may say that increased R&D activity may have positive influence on catch-up process.

Conclusion

The findings of this research suggest that technology transfer, as measured by FDI, does not contribute to output to a great extent, and certainly it is not found to be more influential than domestic investment. However, we cannot disregard importance of FDI that is likely to surface after the privatisation process is completed in respective countries.

The findings of direct measures of technology in terms of R&D, we find that that there is a positive relationship of R&D to output, however, this research mostly facilitates appropriate technology transfer for selected countries rather than creation of new technologies, since selected countries are not at the technology frontier.

In general we can conclude that technology plays a role in growth and development of selected transition economies. However, channels of importance of selected indicators differ from technology frontier countries.

NOTES

[1] John Wilkinson eliminated gaps between piston and cylinders, which have previously been stuffed with rags.

[2] William Murdock provided the sun and planet gearing system that actually made it possible to have rotary force.

[3] Research on 108 US firms.

[4] For further analysis on the role of exports see Salvatore and Hatcher (1991).

[5] See World Investment Report (2000)

REFERENCES

Abramovitz, M., (1986), Catching Up, Forging Ahead, and Falling Behind, *The Journal of Economic History*, Vol. 46, No.2, June, 385-406.

Abramovitz, M., (1993), The Search for the Sources of Growth: Areas of Ignorance, Old and New, *The Journal of Economic History*, Vol. 53, No. 2, June, 217-243.

Aghion, P., Howitt, P., (1992), A Model of Growth through Creative Destruction, *Econometrica*, Vol. 60, March, 323-351.

Ames, E., Rosenberg, N., (1963), Changing Technological Leadership and Industrial Growth, *The Economic Journal*, Vol. 73, No. 289, March, 13-31.

Arrow, K., (1962), The Economic Implications of Learning by Doing, *Review of Economic Studies*, No. 29, June, 155-173.

Balasubramanyam, V. N., Salisu, M., Sapsford, D, (1996), Foreign Direct Investment and Growth in EP and IS Countries, *The Economic Journal*, Vol. 106, January, 92-105

Baltagi, B. H., Wu, P. X., (1999), Unequally Spaced Panel Data Regressions with AR(1) Disturbances, *Econometric Theory*, 15, 814-823.

Bania, N, Eberts, R. W., Forgarty, M. S., (1993), Universities and the Startup of New Companies: Can We Generalize from Route 128 and Silicon Valley? *The Review of Economics and Statistics*, Vol. 75, No. 4, November, 761-766.

Borensztein, E, De Gregorio, J, Lee, J-W. (1998), 'How Does Foreign Direct Investment Affect Economic Growth', *Journal of International Economics*, No. 45.

Cohen, W. M., Levinthal, D. A., (1989), Innovation and Learning: The Two Faces of R&D, The Economic Journal, Vol. 99, No. 397, September, 569-596.

Crafts, N., (1998), Forging Ahead and Falling behind: The Rise and Relative Decline of the First Industrial Nation, *The Journal of Economic Perspectives*, Vol. 12, No. 2, Spring, 193-210.

Findlay, R., (1978), 'Relative Backwardness, Direct Foreign Investment, and the Transfer of Technology: A Simple Dynamic Model', *Quarterly Journal of Economics*, Vol. 92, No. 1, February, 1-16.

Freeman, C., Soete, L., (1997), The Economics of Industrial Innovation, third edition, MIT Press, Cambridge, Massachusetts.

Goto, A., Suzuki, K, (1989), R & D Capital, Rate of Return on R & D Investment and Spillover of R & D in Japanese Manufacturing Industries, *The Review of Economics and Statistics*, Vol. 71, No. 4., November, 555-564.

Griliches, Z., (1997), Education, Human Capital, and Growth: A Personal Perspective, *Journal of Labor Economics,* Vol. 15, No. 1, Part 2: Essays in Honor of Yoram Ben-Porath, January, S330-S334.

Grossman, G. M., Helpman, E., (1991), Innovation and Growth in the Global Economy, Cambridge, MA, MIT Press.

Hall, R. E., Jones, C. I., (1998), Why Do Some Countries Produce So Much More Output per Worker than Others?, *NBER working paper*.

Helpman, E, Coe, D. T., (1995) International R&D Spillovers, *European Economic Review,* Vol. 39, No. 5, 859-887.

Im, K. S., Pesaran, M. H., Shin, Y., (2003), Testing for Unit Roots in Heterogenous Panels, *Journal of Econometrics*, 15, 53-74.

International Monetary Fund, (2003), World Economic Outlook, Washington D.C., April

Keller, W., (2004), International Technology Diffusion, *Journal of Economic Literature*, Vol. XLII, September, 752-782.

Landes, D. S., (1998), The Wealth and Poverty of Nations: Why some Are So Rich and Some So Poor, W. W. Norton & Company, New York-London.

Landes, D. S., (2003), The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present, second edition, Cambridge University Press.

Maddala, G. S., Wu, S., (1999), A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test, *Oxford Bulletin of Economics and Statistics*, special issue.

Mansfield, E., (1981), Composition of R and D Expenditures: Relationship to Size of Firm, Concentration, and Innovative Output, *The Review of Economics and Statistics*, Vol. 63, No. 4, November, 610.615.

Marsden, K., (1970), Progressive Technologies for Development, *International Labour Review*, May.

Polanyi, M., (1967), The Tacit Dimension, Routledge & Kegan Paul, London.

Radošević, S, Dyker, D., (1997), Technical Integration and Global Marginalization of Central and East European Economies: The role of FDI and Alliances, in Sharma, S. (ed): Restructuring Eastern Europe, Cheltenham: Edward Elgar.

Romer, D., (2001), Advanced Macoreconomics, McGraw Hill, second edition.

Romer, P. M. (1990) Endogenous Technological Change, *The Journal of Political Economy*, Vol. 98, Issue 5, Part 2, The University of Chicago Press.

Rosenberg, N., (1982), Inside the Black Box, Cambridge, Cambridge University Press.

Radosevic, S., (1999), International Technology Transfer and Catch-up in Economic Development, Edward Elgar, Cheltenham, UK, Notrhampton, USA.

Sachs, J., (2000), A New Map of the World, *The Economist*, June 24th-30th, 99-101.

Salvatore, D., Hatcher, T., (1991), Inward Oriented and Outward Oriented Trade Strategies, *Journal of Development Studies*, vol. 27, 7-25.

Singer, H. W. (1965), External Aid – For Plans or Projects, *The Economic Journal*, Vol. 75, No. 299, September, 539-545.

Smith, A., (1776), The Inquiry into the Nature and Causes of the Wealth of Nations, reprint (1994), Modern Library Edition.

Stiglitz, J., (2002), Globalization and its Discontents, Penguin: London.

Wang, J-Y., (1990), Growth, Technology Transfer, and the Long-Run Theory of International Capital Movements, *Journal of International Economics*, Vol. 29, Issues 3-4, November, 255-271.

Wooldridge, J. M., (2002), Econometric Analysis of Cross Section and Panel Data, MIT Press, Cambridge. Massachusetts.

World Bank, (2005), World Development Indicators Database, CD-ROM, New York.

World Investment Report, (2002), United Nations, New York.

World Investment Report, (2000), UNCTAD, New York.

Young, A., (1993), Invention and Bounded Learning by Doing, The Journal of Political Economy, Vol. 101, No.3, June, 443-472.