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Foreign Direct Investments, Energy Efficiency and Innovation Dynamics

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Summary: Rapid growth in energy consumption influences on the one hand energy prices and endangers energy supply security; on the other hand it distresses ecological balances. In this respect, the efficient use of energy resources plays a key role for challenging these problems in the long run. Thus, without innovations and its diffusion to broad regions, global energy efficiency improvements cannot be realized. In this context, Foreign Direct Investments (FDI) are important elements of technology transfer to developing countries and to emerging economies. The aim of this paper is to explain the relationship between FDIs and technology determined energy efficiency. For this purpose, the change of industrial energy intensity has been analyzed with the decomposition methodology that adjusts structural effects from energy intensity changes. Finally, a panel data analysis has been conducted that points out that there is a significant correlation between FDI and technology determined energy efficiency improvements in the eastern EU-members and Cohesion countries.

Zusammenfassung: Rasantes Wachstum im Energieverbrauch beeinflusst einerseits die Energiepreise und riskiert die Sicherheit der Energieversorgung. Andererseits gefährdet es das ökologische Gleichgewicht. In dieser Hinsicht spielt langfristig der effiziente Einsatz von Energie-Ressourcen eine Schlüsselrolle. Allerdings können Energieeffizienzfortschritte auf einer globalen Ebene ohne Innovationen und ihre Diffusion auf weite Regionen nicht realisiert werden. In diesem Zusammenhang sind die ausländischen Direktinvestitionen (FDI) wichtige Elemente des Technologietransfers in Entwicklungs- und Schwellenländer. Diese ändern allerdings auch die Struktur der Wirtschaft und der Produktion im Gastland. Diese strukturellen Änderungen und deren Auswirkung auf den Energiekonsum wurden in der Literatur häufig ignoriert. Das Ziel dieses Papiers ist es, den Zusammenhang zwischen ausländischen Direktinvestitionen und die durch die Technologie determinierte Energieeffizienz zu untersuchen, wobei die strukturellen Effekte aus dem Datensatz anhand einer Zerlegungsanalyse (Decomposition analysis) bereinigt werden. Schließlich wurde eine Panel-Daten-Analyse mit „country-specific-effects“ durchgeführt, welche einen signifikanten Zusammenhang zwischen ausländischen Direktinvestitionen und Technologie-determinierter Energieeffizienz in den östlichen und südlichen EU-Mitgliedsländern aufweist. Diese Ergebnisse bekräftigen die bestehenden theoretischen Grundlagen in Bezug auf positive Effekte von ausländischen Direktinvestitionen auf das technologische Niveau der Gastländer einerseits. Eine weitere Schlussfolgerung, andererseits, ist, dass die wirtschaftliche Integration mittelbar zu einer effizienteren Nutzung von Ressourcen beiträgt.

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Table of Contents

List of Tables

List of Figures

1. Introduction

Since the beginning of industrialization and even more so since the globalization of modern economies, a worldwide rise in the demand for energy has been observed. Despite the use of new technologies, consumption per capita has continuously increased. Economic internationalization trends since the 90s have also contributed to the rising demand for energy. Consequently, the strong global demand for energy has had two major effects. On the one hand, the rapid growth in demand has accelerated the exhaustion of resources and has contributed to relative price increases in certain periods. On the other hand, such a rapid economic growth of the world economy and global energy consumption threaten the global ecological equilibrium. In this context, one can emphasize that especially end use activities like industrial production (incl. Electricity&Heat production) stand for the lion share of the CO_2 emission. The following figure shows the impact of selected sectors on global greenhouse gas emissions.

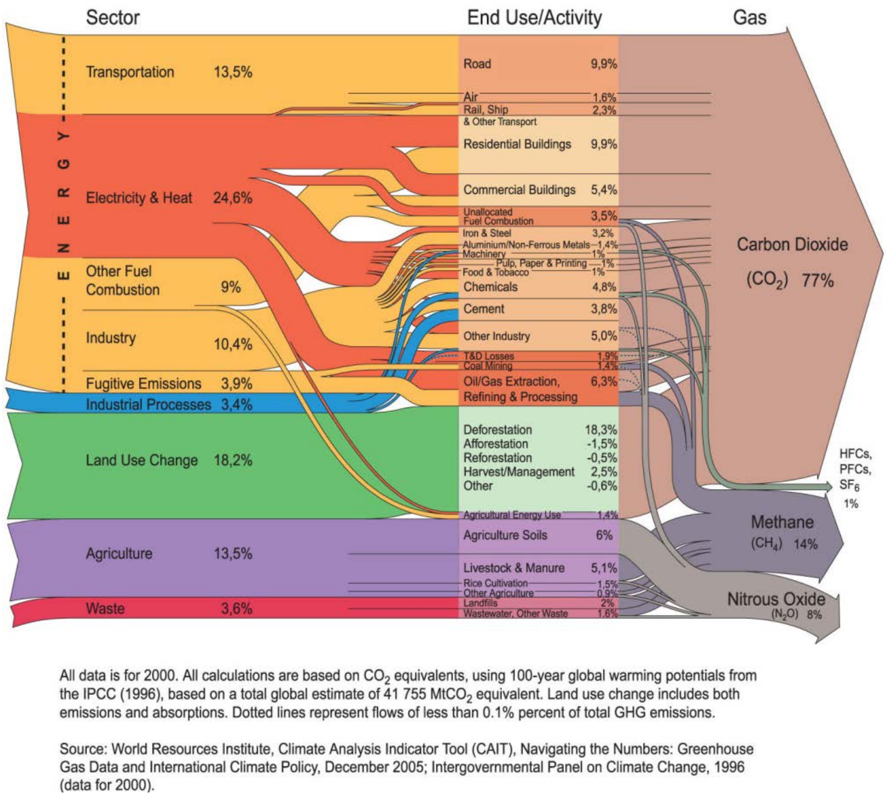

Fig. 1. Global greenhouse emission by sector, 2000

In this respect, the efficient use of energy resources in industry plays a key role and technological progress is a crucial factor in energy efficiency improvements. Thus, it is important to adopt both a broader focus of innovation on the intensively energy demanding sector in leading OECD countries and to accelerate the upgrading of energy technology in newly developed countries and LDCs (Less Developed Countries). However, foreign sources of technology account for 90% or more of the domestic productivity growth in most developing countries. At present only a handful of OECD countries account for most of the world’s creation of new technology. G-7 Countries accounted for 84% of the world‘s research and development (Keller, 2004). Furthermore, ambitious political goals set in the international arena with respect to energy efficiency have raised the interest in economic and technological catching up; this points to the importance of understanding the Schumpeterian dynamics and the role of Foreign Direct Investments (FDIs) and multinational companies (MNCs), which are a key resource of technology transfer and know-how diffusion for developing countries. World Development Report (WB, 2010) in chapter 7 also emphasizes the importance of international cooperation and technology diffusion.

The aim of this study is to explain and to test the relationship between FDIs and technology determined energy efficiency. In this context, the research question of this paper serves, in particular, to the remarkable research area in international economics: to what extent multinationals do contribute to the knowledge accumulation of developing countries. However, there are fewer attempts on the adjustment of structural effects in the relevant literature. A further contribution of this study would be to consider and to adjust the structural change caused FDI inflows while we analyze the “pure” technology determined energy efficiency.

The paper consists of five sections. In the following chapter, we will briefly discuss to what extent the general innovation and diffusion theory can be applied to energy saving technologies. A further focus will be on the specifics of environmentally friendly and energy saving innovations technologies. Next (2.3), we will try to construct a theoretical foundation for the hypothesis that FDIs increase the technology level in the host country and that this improved technology level contributes to the efficient use of energy. In this context, it will be important to consider various elements of international innovation dynamics.

Answering these question would help clarify technological effects of FDI. In the light of the requirement for detailed data, a decomposition analysis will therefore be conducted in third chapter on a macroeconomic rather than a microeconomic level (2-digit sectors). After giving a brief overview on FDI facts in the fourth chapter, the correlation between FDI and technology determined energy efficiency improvements in the EU-Accession countries will be tested econometrically. In the fifth chapter, the paper will draw conclusions which can be useful for policy makers.

2. Key questions related to innovation theory, environmental technologies and its diffusion

In the neoclassical literature, the technological change is described as the change in the economy’s information set detailing the relationship between inputs and outputs in the economy. In other words, a technological advance enables the economy to produce more from the same level of input as time proceeds. There are two main concepts in the neoclassical theory of technical change: The first one is the difference between embodied and disembodied technical change, and the second is the bias and direction of the technical change (see for further discussion Stoneman, 1983).

However, innovation processes cannot always be described by formal models and methods, rather evolutionary and neoclassical theories can be used complementary or in a ‘dual’ way. During the research into the reasons and effects of innovations, the analytical precision and stringency of neo-classical models that are related to the equilibrium concept should not be disclaimed. Another reason for a complementary analysis is the isomorphs to evolutionary theoretical assumption in other disciplines: For example, selection and mutation concepts can be also considered as exigency (necessity) and randomized processes that may point to the mathematical and economic equilibrium concept. The third reason for a “dual” analysis is the well established and empirically proven evidence of the neoclassical innovation theory that could create positive effects if it could be integrated with its evolution of theoretically based approaches. For this reasons, we will conduct in the following section a “dual” analysis.

Karl Marx claims, in his work ‘Capital’, that firms will be able to stay competitive only if they can increase their productivity by introducing new technologies and more efficient machinery while those, who fail to adopt new technologies, will eventually not survive. Schumpeter adopts and improves this argument in his theory. Other than the traditional assumptions related to “price” competition, he claims that competition based on the technology and related quality is the nature of a capitalistic system (Schumpeter, 1943, p. 84):

> *“… in capitalist reality as distinguished from its textbook picture, it is not that kind of competition that counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization (…) - competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives.”*

In this way, Schumpeter (1912) broadens the existing approach by defining the innovations not only by process innovation (reducing the costs), but also by:

- Product innovations,
- Carrying out of the new organization,
- Opening a new market,
- Development of new sources, using new raw materials or new combinations of input,

According to the OSLO Manual (2005, pp. 31-32), product innovations can take two forms:

- “A *technologically new product* is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can involve radically new technologies, can be based on combining existing technologies in new uses, or can be derived from the use of new knowledge. (…)
- *A technologically improved product* is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better performance or lower cost) through the use of higher-performance components or materials, or a complex product which consists of a number of integrated technical sub-systems may be improved by partial changes to one of the sub-systems.”

According to the same Manual (2005), process innovations can be characterized by "its adoption of technologically new or improved production methods, including methods of product delivery. These methods may involve changes in equipment, or production organization, or a combination of these changes, and may be derived from the use of new knowledge. The methods may be intended to produce or deliver technologically new or improved products, which cannot be produced or delivered using conventional production methods, or essentially to increase the production or delivery efficiency of existing products." In comparison to product innovations, an organizational innovation is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations.

A simple (linear) model of innovation process contains three phases. It is often considered to provide a useful categorization. The first phase is the invention process and stands for the generation of new ideas. The second phase is the innovation process and symbolizes the development of new ideas into concrete products and processes. The last phase is the diffusion stage, in which the new products and processes spread across the potential market. The impact of a new technology occurs at the diffusion phase and opens up its economic potential (Stoneman, 1983). Diffusion can also be driven by the imitator, which can contribute to the process with further improvements. This process can also be considered as a circle, where feedbacks between single stages can affect each other.

In the relevant literature, there are numerous findings about the determinants of the innovation process (Steger et.al, 2005, pp. 37):

1. Innovation through a "technology push": Innovation can be created systematically. R&D (manpower, equipment, materials etc.) is one of the most crucial inputs. Economic environments and related changes can influence this process. E.g. relative factor price ratios can influence the direction of innovation. (Hicks 1932, Popp 2002). Popp (2002) shows in his study, that both energy prices and the quality of existing knowledge have significantly positive effects on innovation. Additionally he proves that omitting the quality of knowledge adversely affects the estimation results. In another research, Grupp (1999) shows that high-energy price signals stimulate innovations. In addition, the political measures related to pricing are effective in environmental issues.
2. Innovation through "demand pull": The innovation process is shaped, by the prospect of profits. With free and unrestricted competition, these profits are always only head-start profits, meaning they will be destroyed by imitators.
3. Cost advantages in the innovation process: First-mover advantage enables the innovator to benefit and to shape a new market according to its preference (e.g. through setting standards).
4. "Embodied" and "disembodied" technical change: Apart from the "embodied" type of technical change, there is also "disembodied" technical change that includes the management and economic organization of the production process (organizational innovation).
5. Trajectory-dependence of the innovation process: The direction and process of innovations can only be changed at high costs when they are in their so-called

trajectories. When the trajectory is fixed, incremental and continuous improvements can take place that contribute to its further consolidation.

6. Regional clusters: Regional concentrations (clusters) of e.g. intellectual properties and competences enhance the macroeconomic innovation activity. Such clusters are mainly the result of geographic proximity and social proximity.
7. Cooperation (R&D joint ventures, strategic alliances): The success of innovation processes can be enhanced by the cooperation of various agents.
8. National innovation systems: It describes, in a systematic manner, the cooperation between agents and institutions involved in the production, transfer and utilization of knowledge.
9. International links in the innovation process: Intensive foreign trade relations produce learning effects, which in turn accelerate innovation activities. As an outcome of globalization, technology and knowledge transfer, the innovation process is enhanced on an international scope.

However, without diffusion of a technology and a product, an innovation cannot have any economic impact. Diffusion of a technology[1] is the way in which innovations spread through different channels from their very first implementation to different consumers, countries, regions, sectors, markets and firms. The minimum requirement for a change in a firm's products or functions to be considered an innovation is that it is to be new (or significantly improved) to the firm (OECD OSLO Manual, 2005).

2.1 Environmentally friendly innovations and their diffusion

Innovation theory is neutral regarding its generalization. Nonetheless, the environmental-saving innovations have to contribute to the sustainability regarding its content and orientation. However, "usual" business innovations may have environmental gains as well (e.g. through the company cost saving etc.)[2]. FIU (1998) defines eco-innovations as follows:

> "Eco-innovations are all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which develop new ideas, behavior, products and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets„

Eco-innovations can be created by companies or non-profit organizations, and they can be traded on markets or not, their source can be technological, organizational, social or institutional. However, improvements in environmental technologies are broadly as each improvement in processes and products that conserves or restores environmental qualities

[1] In a neoclassical way, in the literature there are different models describing the diffusion of technologies like epidemic diffusion models: see e.g. Griliches (1957) and Mansfield (1963). Another variante is rational choice models (see e.g. Beckenbach, 2010).

[2] MIP (Mannheimer Innovationspanel, 1996 in Rennings, 1999) supports this evidence: Almost 80% of innovative companies contribute to environmental innovations.

(like water, natural resources e.g.). They can conserve environmental qualities directly through the treatment of pollution (like recycling) or they can contribute to the production of less harmful outputs. OECD classifies the environmental technologies into six main groups plus monitoring technologies that can contribute to the pollution preventing (Kemp, 1997):

1. Pollution control technology
2. Waste management technologies
3. Clean technologies
4. Recycling technologies
5. Clean product technology
6. Clean-up technology

\+ Monitoring technologies

In this point, we have to mention that deployment of energy efficient processes can be counted under a variety of technology types like clean technologies or pollution control technologies.

The reason why companies and households invest in environmentally friendly products and capital can be explained by economic, political, technical and social factors. Regulations and policies, people's awareness of the existing technology, the costs of technology, and their capability to use them are some of the important factors influencing the diffusion of environmental technologies. Kemp (1997) describes the most important factors in three groups:

Table 1. Determinants of the decision to adopt an environmentally beneficial technology

Adoption decisions		
System of information transfer	***Features of the innovation***	***Characteristics of the adapter environment***
- Information channels	-Purchase price	-Environmental standards
		-Acceptance of environmental policies
-Information supply	-Performance characteristics (in comparison to competing technologies) etc.	-Environmental awareness and attitudes
		-Price and cost structure
		-Availability and costs of complementary techniques and skills
-Credibility of Information		-Age of capital stock
		-Competitive pressure
		-Resistance to change
		-Availability of financial means & credits
		-Societal pressure to reduce environmental impact

Source: Kemp (1997, p. 97)

In this manner, the determinants of energy efficiency improvements depend also to the firm rules, corporate culture and the company's perception of it level of energy efficiency. The lack of knowledge, perceived risks of adaption, limited number of technology providers, uncertainties related to energy prices or capital limits, or relatively slow rate of industrial capital stock turn over are some of the barriers against the implementation of better technologies (UNIDO, 2010, p 11-13).

However, the theoretical facts we revised briefly are not yet satisfactory to explain the diffusion of environmental technologies on an international level. In the next section, we will study briefly the background of international technology transfer and try to answer the question from an economic point of view why domestic companies should employ new technologies after the introduction of FDI and foreign products to the local market.

2.2 International technology diffusion issues and impact of FDIs on innovation and energy efficiency

2.2.1 Spillover effects and technology transfer through FDI and imports

Since the globalization of modern economies, a worldwide rise in trade and investments has been observed and international trade[3] and capital movements –especially direct investments[4]- are widely accepted as keys to economic growth. They have contributed to the increase of wealth e.g. in the transition process of formerly centrally planned economies, and they are currently contributing to the economic growth of developing countries. Therefore most developing and transition countries have designed and developed their economic strategies on this base.

FDI can improve productivity in the host country if it is more productive than the domestic companies. FDI indirectly creates demonstration effects and productivity spillovers to domestic firms via product and process imitation and increases knowledge level via exchange of employees or horizontal and vertical spillover linkages. However, sharp national productivity differences have remained for some countries, explaining a large part of the difference in national incomes because technology plays an important role in shaping productivity. In this respect, technology and know-how transfer from abroad are sine qua non conditions for sustainable growth in developing countries. For this reason, many policymakers in developing countries are offering attractive incentives like lower income taxes/income tax holidays, import duty exemptions, subsidies for infrastructure, etc. to foreign investors. However, there is evidence that the productivity[5] growth effects of FDIs are quite heterogeneous.

Mansfield and Romeo (1980) state, in their study on developing countries, that only a few MNCs (MultiNational Companies) contribute to technology transfer, while according to Rhee and Belot (1989) FDIs contributed to a domestic productivity and export boom in e.g. Bangledesh and Mauritis. Nevertheless, Germidis (1977) could not find any evidence of productivity growth in the 12 developing countries (65 Firms). He explains this to be due to:

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[3] The positive relationship between trade and growth has been intensively studied in the literature. (see Krugman, 1983; Horstmann/ Markusen, 1992; Helpman, 1984; Markusen, 1984; Tadesse/Ryan, 2004; Bloningen, 2005; Bloningen, 2001; Buckley/Casson, 1981; Helpman/Melitz/Yeaple, 2004; Yeaple, 2008; Aizenman/Noy, 2005; Lipsey/Weiss, 1981)

[4] See e.g. Findlay, 1978; Rivera-Batiz/Rivera-Batiz, 1991; Borensztein/De Gregorio/Lee, 1998; De Mello, 1997; Blomström/Lipsey/Zejan, 1994)

[5] In our context, productivity can also be assumed as energy efficiency.

- The lack of domestic employees in higher positions
- Little labor mobility between domestic and foreign companies
- Limited subcontracting in local firms
- No domestic R&D and no incentive to diffuse know-how

Other authors find a positive relationship between FDI and productivity or related indicators like value added per worker. (see Caves (1974) for Australia and Globerman (1979) for Canada; see also Blomstrom/Persson (1983), Blomstrom (1986), Blomstrom/Wolff (1989) for further discussion). Aitken and Harrison (1999) find that foreign equity participation increases the plant's productivity, but evidence was only observed in small enterprises. In the Venezuelan case, there is no spillover observed from foreign firms to domestic: The result is that the net productivity increase effect is very small.

Eaton/Kortum (1999) emphasize that FDI and international trade are one of the crucial channels of technology diffusion. Their model has three concluding remarks:

1. **Foreign R&D can raise domestic TFP (Total Factor Productivity):** An increase in foreign research enables a greater inflow of technologies and higher TFP in both the short and the long run.
2. **Technology diffusion from abroad and its speed:** A given research effort abroad has a greater effect on domestic TFP when foreign technologies can diffuse faster in the domestic economy.
3. **Global sources of technology:** A country is important in determining the world's rate of growth if it has a relatively high share of the world's research labor and technologies, and/or a relatively high rate of technology diffusion compared to other countries.

As in the second point indicated, developing countries can benefit from a technology transfer only if they reach a minimum level of human capital (see Blomström/Lipsey/Zejan, 1994), which again requires investment in education. Ciruelos and Wang (2005) find that both FDI and trade serve as important channels of international technology diffusion. However, there are fewer studies where the importance of energy efficiency is emphasized, while all of the studies cited before focus on technology transfer, spillover and productivity gains (see Saggi (2002) for a further discussion). Hübler (2010) formulates the positive relation based on general productivity gains via FDI and imports and the spillover effects in the way same way as Nelson and Phelps (1966) and Findlay (1978):

$$\dot{A}^t = \phi(\varphi,k,m)\left[T^t - A^t\right] \Leftrightarrow \frac{\dot{A}^t}{A^t} = \phi(\varphi,k,m)\left[\frac{T^t}{A^t} - 1\right]$$

$$\frac{\partial\phi(\varphi,k,m)}{\partial h} > 0; \frac{\partial\phi(\varphi,k,m)}{\partial k} > 0; \frac{\partial\phi(\varphi,k,m)}{\partial h\partial k} > 0; \frac{\partial\phi(\varphi,k,m)}{\partial m} > 0; \frac{\partial\phi(\varphi,k,m)}{\partial h\partial m} > 0$$

A_t is the technology (or total factor productivity) in practice in the host country, changing over time *t*.

Technological development via technology diffusion is described as the time derivative of A_t, denoted by $\dot{A}^t$. T_t is the level of the exogenous technology frontier[6] in the industrialized region (IND). The level of technology diffusion is dependent on the IND-H technology gap, T_t minus A_t. Φ is the spillover strength, which depends positively on the level of human capital (φ) in H, which is exogenous. In a broader sense, φ also contains other factors like property rights, telecommunication possibilities, infrastructure etc. We assume that Φ increases with foreign capital intensity k and import intensity m. φ, k and m are complements, they boost each other. At this point, Hübler (2010) takes this forward and considers backward and horizontal spillovers across industries separately, while capital and import shares in each sector and year play an important role:

Horizontal technology spillovers — Vertical technology spillovers

$$\frac{\Delta A_H^{it}}{A_H^{it}} = \varphi_H^t \mu_H * \left(\mu_K \frac{K_{IND}^{it}}{K_H^{it}} + \mu_M \frac{M_{IND}^{it}}{Y_H^{it}} + \mu_B \sum_{b,b\neq i} \frac{K_{IND}^{it}}{K_H^{it}} + \frac{D_H^{bit}}{Y_H^{it}} + \mu_F \sum_{b,b\neq i} \frac{K_{IND}^{ft}}{K_H^{ft}} + \frac{D_H^{ift}}{Y_H^{it}} \right) * \left(\frac{\frac{Y_{IND}^{it}}{L_{IND}^{it}}}{\frac{Y_H^{it}}{L_H^{it}}} - 1 \right) + \alpha_H$$

Total factor productivity a_H increases exogenously: Exogenous total factor productivity growth is the only source of technological progress in most of the developing regions. K stands for capital, while Y/L denotes productivity. Higher capital intensity means higher technology diffusion speed. μ is a constant parameter that stands for the general spillover strength in the host country. μ_K (spillover effect via investments) and μ_M (spillover effect via imports) describe *horizontal* technology spillovers across firms within a sector *i*. Technology diffusion associated with μ_B and μ_F determine *vertical* technology spillovers across firms between sectors in the production chain while D^{bit} stands for the value of intermediate goods transferred from the backward sector b to sector i. In the same way e.g. K^{ft} denotes foreign capital in a forward downstream sector. Summing up over all upstream and downstream sectors, all inter-sectoral vertical spillovers are captured. *A, K, D, M, L* and *Y* are endogenous and *φ* rises exogenously.

Empirical findings on the basic impact of international capital movements on the environment can be summarized as follows: Investments and new production factors can increase the technology level of the host country through know-how transfer (and competition effects provided such effects really occur). In addition, improvements in productivity and energy efficiency cause “crowding-out effects” and force inefficient local firms to integrate their production processes[7].

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[6] It is assumed that capital invested and goods imported from IND to host country (H) contain technologies up to this frontier level. But there is a time lag of availability in the host country.

[7] One assumption should be that the MNCs are competition and not export oriented.

Briefly, the model demonstrates that as long as there are no barriers to spillover effects and technology transfer, a rise in FDIs and imports should increase the knowledge level in the host country and its related productivity. In the described model, Hübler (2010) shows the increase of labor productivity via FDI. In a further model, this argument can be expanded by an increase in the productivity of energy (or efficient use of energy).

2.2.2 Compulsive innovation effects of FDI and imports through enhanced competition

In this context, Bertschek (1995) answers the question of why domestic companies should implement new technologies in their own processes and use the resources more efficiently or minimize their costs after the entrance of FDIs and imports, with the following theoretical framework:

The price p_i that a single domestic firm can achieve:

(1) $$p_i = p_i(q_i, Q_{-i}^D, Q^F, M, PD_i)$$

The price p_i is dependent on the domestic market volume Q, which is covered by the domestic firm q_i, plus the other domestic companies Q^D_{-I}, firms with foreign owners Q^F, as well as on imports M[8]. Another determinant of the prices is product quality, which can be increased by product innovations PD_i.

The output is dependent on the stocks of FDI at the end of the previous period

(2) $$Q_t^F = Q_t^F(FDI_{t-1})$$

Furthermore, the marginal costs c_i depend on the factor prices w_i, product innovations PD_i and process innovations PC_i .We assume that process innovations cause fixed costs C_{PC}.

(3) $$c_i = c_i(w_i, PD_i, PC_i)$$

The profit function for the domestic firm can be read as:

(4) $$\prod i = pi(q_i, Q_{-i}^D, Q^F, M, PD_i)q_i - c_i(w_i, PD_i, PC_i)q_i - C_{PC}$$

while an increase in the factor prices w_i or product innovations PD_i increase marginal costs, process innovations PC_i reduce them.

Bertschek (1995) supposes that the domestic firm attempts to maintain its previous profits, therefore the total differentiation of Equation (4) yields:

(5) $$\begin{aligned} d\prod_i &= \left(\frac{\partial p_i}{\partial q_i}dq_i + \frac{\partial p_i}{\partial Q_{-i}^D}dQ_{-i}^D + \frac{\partial p_i}{\partial Q^F}dQ^F + \frac{\partial p_i}{\partial M}dM + \frac{\partial p_i}{\partial PD_i}dPD_i\right)q_i \\ &+ p_i(.)dq_i - \left(\frac{\partial c_i}{\partial w_i}dw_i + \frac{\partial c_i}{\partial PD_i}dPD_i + \frac{\partial c_i}{\partial PC_i}dPC_i\right)q_i + c_i(.)dq_i - dC_{PC} = 0 \end{aligned}$$

In context with this, the effects of the two forms of foreign competition on innovation activities can be distinguished. For process innovations we can conclude that:

(6) $$\frac{dPC_i}{dQ^F} = \frac{\partial p_i}{\partial Q^F} \bigg/ \frac{\partial c_i}{\partial PC_i} > 0 \; and \; \frac{dPC_i}{dM} = \frac{\partial p_i}{\partial M} \bigg/ \frac{\partial c_i}{\partial PC_i} > 0.$$

8 An increase in Q^D_{-i} Q^F or M exercises a negative influence on the price p_i.

Assuming that the marginal return of a product innovation is higher than its marginal costs, the expression for product innovations follows:

(7)
$$\frac{dPD_i}{dQ^F} = -\frac{dp_i}{dQ^F} \Bigg/ \frac{\partial p_i}{\partial PD_i} - \frac{\partial c_i}{\partial PD_i} > 0 \ and$$
$$\frac{dPD_i}{dM} = -\frac{dp_i}{dM} \Bigg/ \frac{\partial p_i}{\partial PD_i} - \frac{\partial c_i}{\partial PD_i} > 0 \ .$$

According to this model, it can be concluded that FDI and imports stimulate product as well as process innovations: We can associate the shortcoming of the model with our hypothesis that FDIs should increase the technology level and enhance innovations as well as related efficiency of energy use.

2.2.3 FDI, imports and environmental issues: A brief literature review

The relationship between the internationalization of economies and environmental sustainability has been a key issue since the late 1970s. The interest in the topic has tremendously increased since the 90s, in the wake of Environmental Kuznets Curve; A national income per capita over a certain level is a turning point for increasing demand for environmental quality (see Dietrich, 2011 for further insights).

FDI and imports can decrease energy consumption per capita in a direct and an indirect way. The first one is over technology transfer channels and spillover effects described before. The second one is through competition. Foreign firms can stimulate innovation and raise capital endowment through competition. Keller and Levinson (2002) investigate the relationship between FDI inflow to the USA and environmental costs. They find that there is a positive relationship between FDI and environmental protection. Similar findings have been provided by Antweiler, Copeland and Taylor (2001). They find that technology transfer is coupled with the effects of scale created by international trade, resulting in the reduction of e.g. sulphur dioxide pollution. Above all, trade liberalization enables policy makers and non-governmental organizations (NGOs) to put pressure on inefficient domestic companies. Nevertheless, unintended adverse side effects can occur because of neglecting other policy, market or institutional imperfections during the catching-up process of developing countries. On the political level, the debate on climate change after the Kyoto process and the Stern Review (2007) have increased the popularity of the belief to a positive relationship between FDI/trade and the environment[9]. Thus, according to Munashinghe, developing countries could learn from the experiences of industrialized countries, and restructure growth and development to ‘tunnel’ through any potential EKC (Environmental Kuznets Curve)-thereby avoiding going through the same stages of growth that involve relatively high (and even irreversible) levels of environmental harm.

Thereby, domestic firms can realize improvements in energy efficiency and decrease their energy intensity by getting rid of old technologies. Higher productivity results from the spillover effects of advanced technologies and educational improvement, but also from advanced management skills. This conjecture largely holds if over time there is a rising technology level, successful restructuring of production processes and a higher level of

[9] However, it is also useful to take research into consideration on aspects of the “pollution havens” hypothesis (see e.g. Sprenger, 1999).

competition. The assumptions of many of the relevant researchers are mostly based on the advantages brought by capital movements, and above all, the results of FDI. The theoretical background of most studies fits to the model developed by Grossman/Helpman (1994) that allows the examination not only of how technology affects trade, but also how trade affects technology, too.

Another important question is whether the effects of international trade on energy use can be measured via environmental indicators. Dean (2002) discusses the question of the relationship between economic openness and the environment, taking the example of China's water pollution levels. She claims that freer trade boosts environmental damage via the terms of trade, but mitigates it via income growth.

3. Beyond the energy intensity – A decomposition analysis[10] of the energy intensity for the manufacturing sector in selected EU-Member Countries

3.1 FDI and energy efficiency: Focusing on the technology

The hypothesis that foreign companies are more efficient/productive than their indigenous counterparts in developing countries is confirmed by studies based on micro and firm-level data (see Eskeland and Harrison (2003) for Cote d'Ivoire, Mexico and Venezuela). A similar result is documented by Fisher-Vanden et al. (2004), who found a negative impact of foreign ownership on the energy intensity of Chinese companies. These examples suggest that the more efficient technology of foreign firms can indeed contribute to an energy reducing effect via technology transfer.

On an aggregated level, Mielnik and Goldemberg (2002) conclude that FDIs have a reducing impact on energy intensity. They conduct a regression analysis of 20 developing countries. Hübler and Keller (2010) examine in their panel analysis the relationship between energy intensity and FDI in 60 developing countries on an aggregate level and they find no empirical evidence. Nevertheless, both papers with an aggregated level assume change in energy intensity as a technological change, which is not completely consistent. Nonetheless, aggregated energy intensity alone is not a perfect indicator for measuring technology transfer, because an improvement in energy intensity (=energy efficiency) can contain two components:

- Structural effect: A structural change in the composition of economy on a sectoral basis and a shift to the less energy-intensive sectors
- Technological effect: A technological change or improvement e.g. new organizational or process innovation.

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10 This kind of an analysis can only be conducted for the manufacturing sector. See appendix for the considered sectors.

3.2 Methodology

To standardize the findings about innovation dynamics, specified tools are needed for energy efficiency, which can be narrowly described as a value-based, philosophical concept. According to EIA, two different concepts of energy efficiency can be discussed, a technical and a broader, more subjective concept:

> In the technical concept, increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy input. In the more subjective concept, energy efficiency is the relative thrift or extravagance with which energy inputs are used to provide goods or services. (EIA, 1995)

Energy intensity, however, refers to the energy used per unit of output or activity. The total energy consumed in a sector, for example, is a product of energy intensity and total output. When output is measured in physical units, an estimate of physical energy intensity is obtained (e.g. TJ/Tonne). Economic energy intensity, on the other hand, is calculated using dollar value output measures (e.g. TJ/Gross Domestic Product in $).

Nevertheless, energy intensity alone doesn't give a consistent insight into the technological level of a country (compare e.g. OECD-Countries to LDCs). However, change in the energy intensity is the most commonly used basis for assessing trends in energy consumption per unit. Energy intensity is thought to be inversely related to efficiency, the less energy required to produce a unit of output or service, the greater the efficiency. A common conclusion in the literature (see e.g. Mielnik and Goldemberg, 2002) is that declining energy intensities on a national and aggregated level over time may be an indicator of improvements in technology levels and energy efficiency[11]. Nevertheless, on an aggregate level, the ratio of energy use to output (or GDP) can be used to interpret the structure of the economy as well, because it also depends on the production structure of the country[12, 13].

The effects described above can be explained by the following expression:

$$I_t = \sum_j \left(S_{j,t}\right)\left(I_{j,t}\right)$$

I_t : aggregated energy intensity of the whole industry at t,

$S_{j,t}$: the production share of the sector j at the entire production and at t,

$I_{j,t}$: the energy intensity of the sector j at t.

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11 A truly technical definition of energy efficiency can only be obtained through measurements at the level of a particular process or plant.

12 However, it can be also expected that a country X with important energy-intensive heavy industries can experience structural changes compared to non-energy intensive sectors like services that "improve" its aggregated energy intensity.

13 Nevertheless, there are some concerns about the generalization grade of the empirical analysis of energy intensity. Walz and Eichhammer (2010) emphasize that a comparison of intensities or changes over time can contain two caveats. On the one hand different exchange rates or conversion methods, on the other hand different structure of economies can complicate a benchmarking among the countries. We try to overcome these concerns by following Ang/Zhang (2000) and APERC (2001).

The changes of the effects mentioned above can be represented either as sum or as a product of the components. With the additive method, the decomposed terms are independently determined, whereby their sum differs from the total energy consumption or the total energy intensity by R (residual term).

$$\Delta I_{total} = I_t - I_0 = \Delta S + \Delta I + R$$

With the multiplicative method, the components are separately determined, whereby their product differs from the change of total energy intensity by R (the residual term of the multiplicative method). S and I thereby stand for the estimated structural effect and the estimated intensity effect.

$$RI = {}^{I_t}\!\big/_{I_0} = (S) * (I) + R$$

We use an index decomposition methodology to examine the impact of a sector's structure and technological improvements on energy intensity change. There are different decomposition methods; Ang and Zhang (2000) give a survey of different decomposition methodologies. This study chooses to apply a Multiplicative Log-Mean Divisia Method, which has exposed to be "perfect in decomposition but also consistent in aggregation" (Ang and Zhang, 2000)[14]:

$Y_{it} =$ unit of activity or subsector`s production in year t

$$El_{it} = \frac{E_{it}}{Y_{it}}$$

El_{it} = energy intensity of subsectors

$$S_{it} = \frac{Y_{it}}{Y_t}$$

S_{it} = structural parameter

Energy intensity approach:

$$El_{agg} = \sum_i S_{it} * El_{it}$$

El_{agg} = aggregate energy intensity

$S_{i,t}$ = Production share of sector $\boldsymbol{i}$ in year $t \left(= \frac{Y_{i,t}}{Y_t} \right)$

$El_{i,t}$ = Energy intensity of sector $\boldsymbol{i}$ in year $t \left(= \frac{El_{i,t}}{Y_{i,t}} \right)$

14 In our analysis, we use index time set '0' as a synonym for the basis/comparison year, t-1. In the entire data set, relative changes are based on the previous year.

$$F_{tot} = \frac{El_{aggt}}{El_{agg0}} = F_{str} * F_{\text{int}}$$

F_{tot} = total change in aggregate energy intensity

F_{str} = structural effects

F_{int} = intensity effects

$$F_{str} = \exp\left\{\sum_i \frac{L(\omega_{i,t}\omega_{i,0})}{\sum_j L(\omega_{j,t}\omega_{j,0})}\ln\left(\frac{S_{i,t}}{S_{i,0}}\right)\right\}$$

$$F_{\text{int}} = \exp\left\{\sum_i \frac{L(\omega_{i,t}\omega_{i,0})}{\sum_j L(\omega_{j,t}\omega_{j,0})}\ln\left(\frac{El_{i,t}}{El_{i,0}}\right)\right\}$$

ω_x = Energy share of sector $\boldsymbol{i}$ in year $t\left(=\frac{E_{i,t}}{E_t}\right)$

where $L(x,y)=\frac{(y-x)}{\ln(y/x)}$

Following Martinez (2010), when expressing relative changes in energy intensity, we use log percentage change (L%) instead of ordinary percentage. Tornqvist and Vartia (1985) show that the log percentage change (L%) has asymmetric and non-additive properties The relative change of numbers X_1 and X_2 is expressed as:

$$L\% = \ln(\frac{X_1}{X_2})*100 = \left[\frac{(X_1 - X_2)}{L(X_2, X_1)}\right]*100$$

indicating that the log difference is literally a relative difference with respect to the logarithmic meaning.

3.3 Data and results of decomposition methodology for selected countries

Here, we will analyze the different results obtained for three factors such as the total industrial intensity, intensity change due to the technical change and energy intensity change due to the structural effect. In the following discussions, we will try to identify the decomposed factors influencing the change in the total energy intensity in the selected industrial sectors of the new European Union members and some accession countries[15]. The conducted decomposition analysis is based on the industrial real production value (mill. Euro, nominal values are from Eurostat and real values are calculated via the GDP

15 Due to the lack of detailed FDI and industrial energy data of developing countries, we will only analyze selected EU-Members. If not otherwise stated, Eurostat is used as the main source of the sectoral energy, production data. Data on the GDP deflator and FDIs is obtained from the WDI online database.

deflator), final energy consumption in Terajoules[16]. The industries investigated here are the:[17]

- Iron and steel industry,
- Non-ferrous metal industry,
- Chemical industry,
- Non-metallic mineral products industry,
- Food, drink and tobacco industry,
- Textile, leather and clothing industry,
- Paper and printing industry,
- Engineering and other metal industry,
- Other non-classified industries,

Whereby, the first three, particularly the paper industries, can be supposed as energy intensive sectors. The results for the aggregated intensity change decomposed to intensity and structural effects for new EU-members are given in the next figures.

We can see that the changes in energy intensity of most EU Countries are driven both by structural and technological change. Nevertheless, in case of the Estonia, Latvia and Slovenia, the effect of structural change cannot be drawn clearly. Ireland is a remarkable case for having no clear relationship between intensity and technology effect; hence the positive relationship after 2002. In general, most of the countries practiced negative energy intensity changes[18]. Eastern European countries (incl. Romania, Lithuania, Czech Republic, Bulgaria and Slovakia plus Finland) are realizing energy intensity effects based on the technology change between 1997 and 2007.

Ireland is an exception, where the total intensity has been increasing in the last years. The same is also valid for Spain, Estonia and Portugal, which are counted as accession countries. The increasing energy intensity from 2006 can be explained by the influence of monetary terms or a relative decrease in production values.

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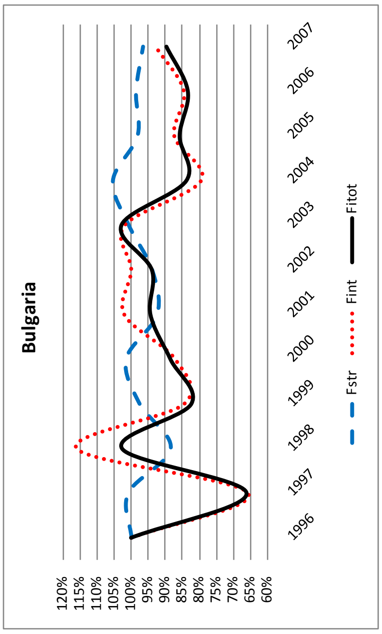
16 The relationship between energy consumption and the value of output as calculated via a monetary proxy like GDP is considered weaker than the linkage between physical production and energy consumption values. Indeed, there is a major lack of data.

17 The industrial data offered by Eurostat for energy consumption and production values use different classifications. We dealt with the problem by using different concordance values described by CODED (Eurostat's Concepts and Definitions Database and RAMON). The ore extraction industry is not considered due to the lack of data. See appendix 1 for detailed information.

CODED: http://circa.europa.eu/irc/dsis/coded/info/data/coded/en/Theme9.htm

18 We have to underpin that the analysis is based on the changes in comparison to the year before (t-1)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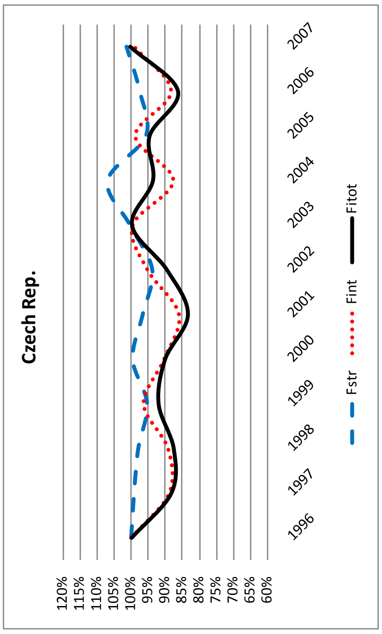
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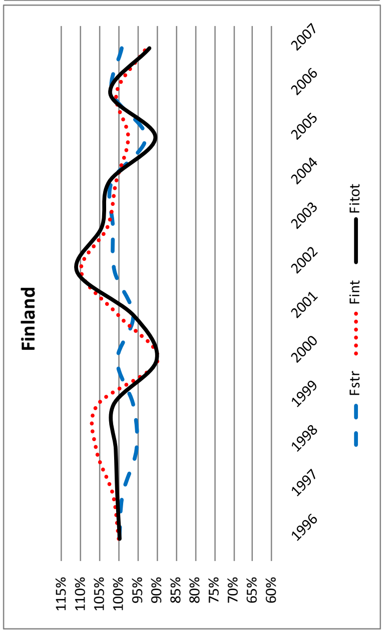
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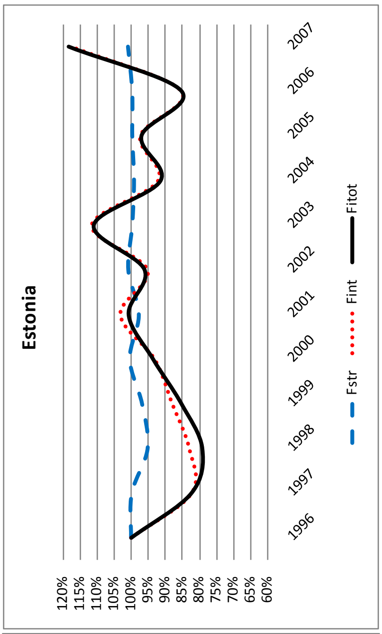
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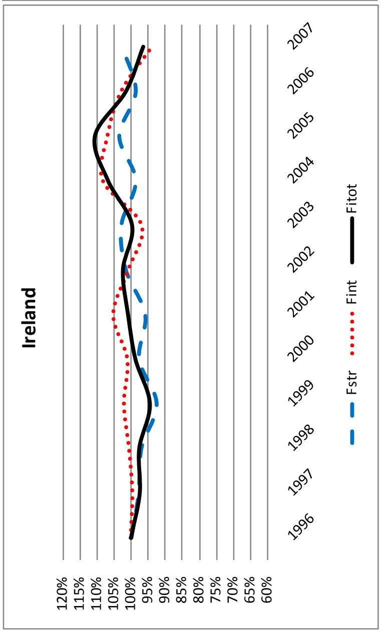
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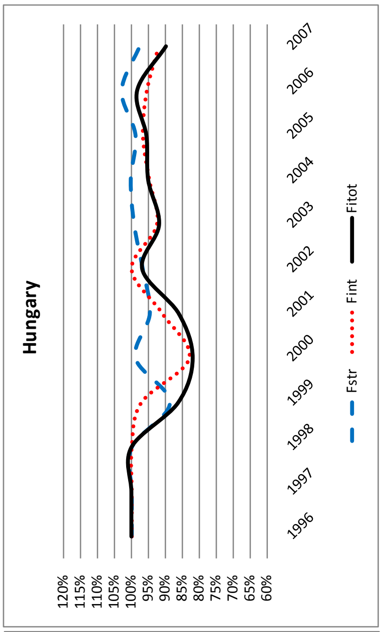
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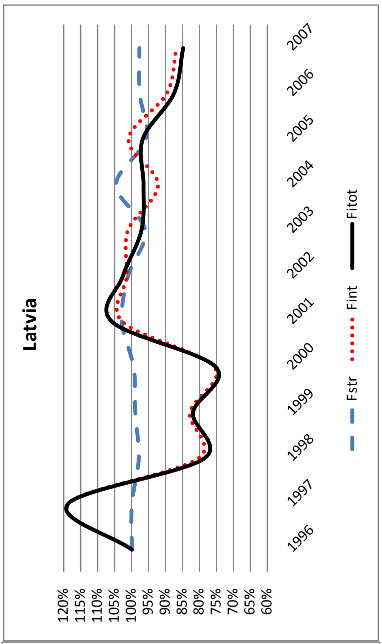
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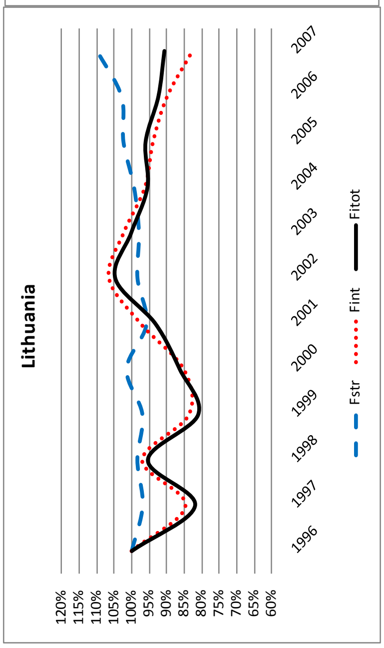
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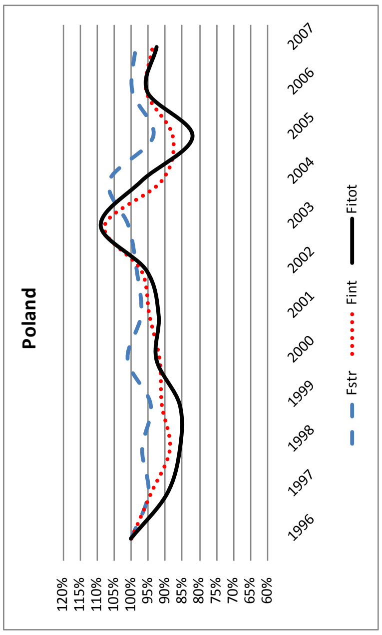
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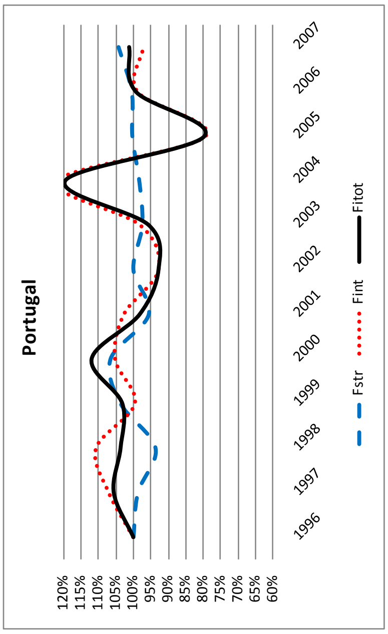
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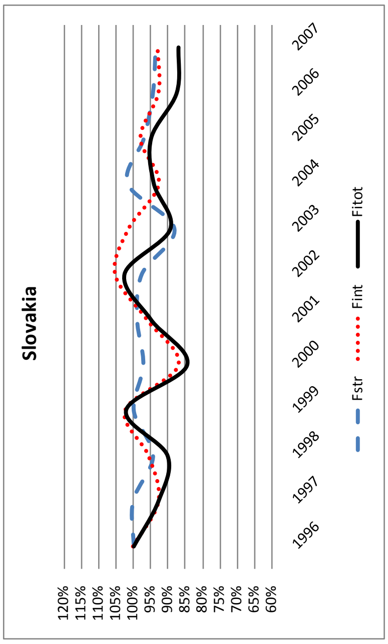
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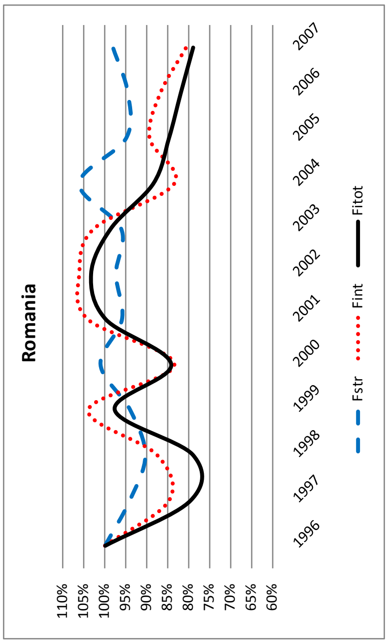
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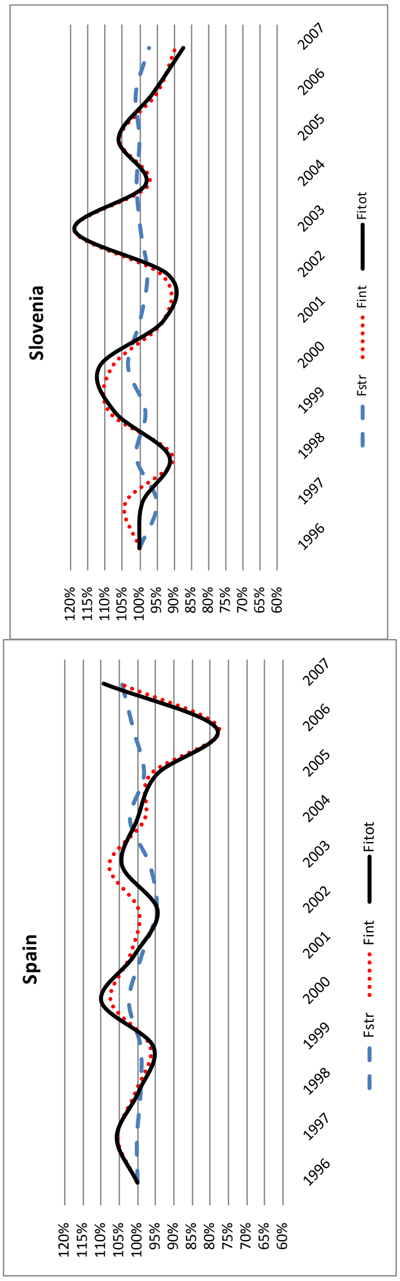


Source: Own calculations, 100% = 1996, changes for (t-1)

Fig. 2. Decomposition analysis of energy intensity change for selected EU-Countries

4. FDI trends and influence of FDI on technology effect: A panel analysis

4.1. Global FDI trends since 80's

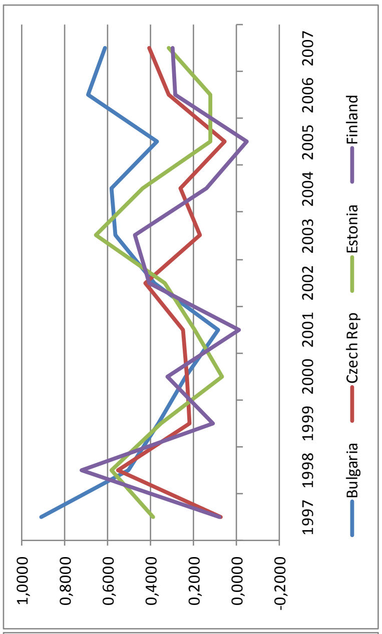
FDIs are assumed to be an important driver of economic growth in EU countries for the reason that the internationalization of production contributes to better exploiting the comparative advantages of enterprises and countries. In addition, internationalization enhances competition in the host country and accelerates technology transfer and innovation activities.

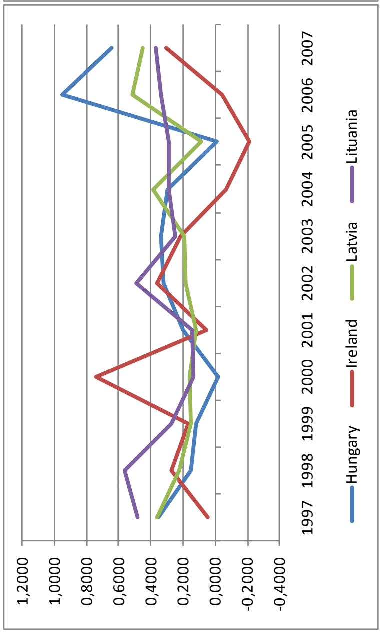
Due to the economic opening of transition countries and changes in an economic expansion in Asia, international FDI flows were relatively high and had a positive trend during the 1990s. Thus, it fell back somewhat in 2001. During this process, Greenfield investments were playing an important role for the new Central European members of the EU. According to the statistics, internationalization activities of production increased significantly during the 1990s, approximately doubling the real inward FDI position of the average OECD country (measured in constant 1996 purchasing power parities) from $81 billion to $158 billion over the period between 1990 and 2000. Nowadays OECD countries account for over 80 per cent of global outward FDI and the United States and the EU countries hold almost three-quarters of total OECD inward and outward FDI positions. Of the EU countries, the United Kingdom, Belgium/Luxembourg, the Netherlands, Germany and France were the largest suppliers and receivers of FDI. Openness and proximity factors are important factors for some of these patterns: A significant share of global FDI flows takes place between countries in the same region. Regional trade agreements are crucial drivers of FDI flows: Thus, most European countries tend to host relatively more FDI originating from EU countries than from elsewhere, while FDI in Canada and Mexico originates to a large extent from the United States. Similarly, Pacific shore countries tend to host more FDI from the United States and/or Japan than from other OECD countries. (OECD, 2003).

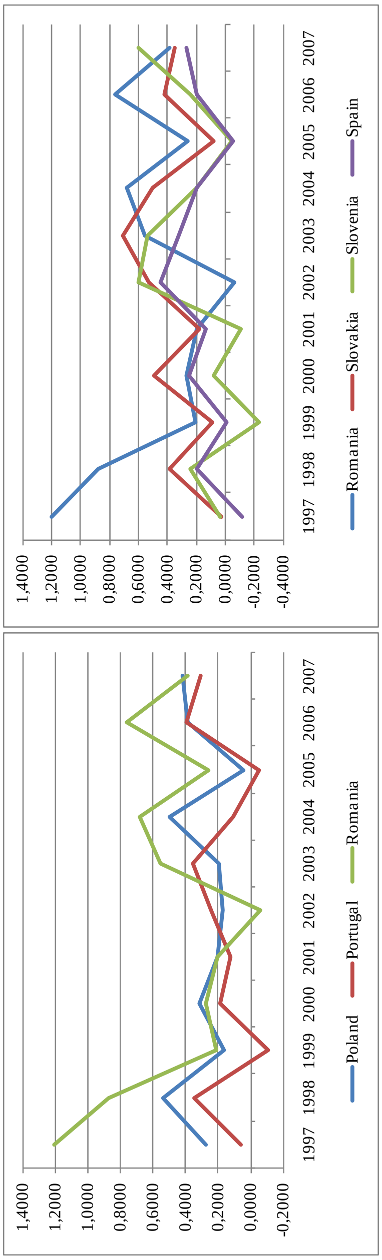
From an historical point of view, due to the economic opening of transition countries and changes in an economic expansion in Asia, international FDI flows were relatively high and had a positive trend during the 1990s and fell back somewhat in 2001. During this process, Greenfield investments were playing an important role for the new Central European members of the EU. According to the OECD (2002), internationalization activities of production increased significantly during the 1990s, approximately doubling the real inward FDI position of the average OECD country (measured in constant 1996 purchasing power parities) from $81 billion to $158 billion over the period between 1990 and 2000. Nowadays OECD countries account for over 80 per cent of global outward FDI and the United States and the EU countries hold almost three-quarters of total OECD inward and outward FDI positions. Of the EU countries, the United Kingdom, Belgium/Luxembourg, the Netherlands, Germany and France were the largest suppliers and receivers of FDI. Openness and proximity factors are important factors for some of these patterns: A significant share of global FDI flows takes place between countries in the same region. Regional trade agreements are crucial drivers of FDI flows: Thus, most European countries tend to host relatively more FDI originating from EU countries than from elsewhere, while FDI in Canada and Mexico originates to a large extent from the United States. Similarly, Pacific shore countries tend to host more FDI from the United States and/or Japan than from other OECD countries. (OECD, 2003).

FDI inflows into the transition economies of South-East Europe and CIS increased significantly by 50% to reach a new record of $86 billion in 2007 – the seventh year of continuous growth of FDI flows to this territory (WIR, 2009). Following figures show the

FDI trends to the East European and accession Countries which are also subject to our econometrical analysis.







Data Source: UNCTAD Online

Fig. 3. Change in FDI stock in selected countries

4.2. Panel analysis

For the empirical analysis, we use FDI and energy data of 14 EU-Countries: Bulgaria, Czech Rep., Estonia, Finland, Hungary, Ireland, Lithuania, Latvia, Poland, Portugal, Slovakia, Slovenia and Spain. One of the most important reasons was the availability of data. Unfortunately, there is very limited data for decomposition analysis of developing countries so that we cannot conduct a solid analysis. The countries we chose are particularly new members of the EU and East European Countries that experienced transition period during 90's and in the beginning of the century. The rest of the examined countries are cohesion countries that are still attractive for FDIs. We captured the data from Eurostat and WIR-UNCTAD databases. Thus, there is just very limited data on energy and production of Greece so that we could not take this country into consideration.

Table 2. Data: definitions of variables

Variable	Definition	Source
FDI stock as a share of GDP	Foreign direct investment (FDI) is defined as an investment involving a long-term relationship and reflecting a lasting interest in and control by a resident entity in one economy (foreign direct investor or parent enterprise) of an enterprise resident in a different economy (FDI enterprise or affiliate enterprise or foreign affiliate). Such investment involves both the initial transaction between the two entities and all subsequent transactions between them and among foreign affiliates. FDI stock is the value of the share of their capital and reserves (including retained profits) attributable to the parent enterprise, plus the net indebtedness of affiliates to the parent enterprises..	World Investment Report / UNCTAD
Sectoral energy consumption	It covers the consumption in all manufacturing sectors with the exception of the "Energy sector" (in TJ)	EUROSTAT
Production value	The production value measures the amount actually produced by the unit, based on sales, including changes in stocks and the resale of goods and services[19].	EUROSTAT
R&D expenditure (% of GDP)	Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development	World Development Indicators / World Bank
Imports of goods and services (% of GDP)	Imports of goods and services represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	

We used change rates for the indicated variables (based on t-1)

We should limit our analysis only by 11 years, 1997-2007 plus the data for 1996 as the basis year, because of the unavailability of disaggregated production data for new EU Members. For calculating “pure” energy intensity within the decomposition methodology, we use a GDP deflator for the reason that the production data of sectoral output is given in nominal monetary values. For the reason that inflation and different valuations of production hinders year-to-year comparisons and comparisons across countries, we converted and normalized all nominal GDP data used for calculating indicators by the value of a 1995 international dollar at purchasing power parity following (APERC, 2001). Sectoral energy data was given in KJ so that there is no need for any adjustment. Finally, we interpreted the “pure” intensity effect as a change in technological change.

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19 The production value is defined as turnover, plus or minus the changes in stocks of finished products, work in progress and goods and services purchased for resale, minus the purchases of goods and services for resale, plus capitalised production, plus other operating income (excluding subsidies). Income and expenditure classified as financial or extra-ordinary in company accounts is excluded from production value. Included in purchases of goods and services for resale are the purchases of services purchased in order to be rendered to third parties in the same condition (Eurostat's Concepts and Definitions Database, CODED)

Table 3. Descriptive statistics

	Energy Intensity (EI)	Change in FDI Stock as a share of GDP (ChFDIStGDP)	Change of Import share in GDP (ChImSh)	Change of R&D share in GDP (ChRD)
Mean	0.000000	0.000000	0.000000	0.000000
Median	-0.003282	-0.015950	0.003848	8.27E-05
Maximum	0.250502	0.906763	0.377897	0.289406
Minimum	-0.253890	-0.475547	-0.183739	-0.217917
Std. Dev.	0.083718	0.193200	0.076153	0.082294
Skewness	0.187227	1.294.009	0.518764	0.310055
Kurtosis	3.964.386	7.205.269	5.928.058	4.038.868
Jarque-Bera	6.867.479	1.564.520	6.192.076	9.392.602
Probability	0.032266	0.000000	0.000000	0.009129
Observations	154	154	154	154

To estimate the regression, we use the pooled general least square method with both time and country specific fixed effects. The Durbin Watson test indicates no linear association between adjacent residuals from the regression models at the 5% level. The results confirm the finding of Mielnik and Goldemberg (2003) which is underpinning there is a negative relationship between FDIs and energy intensity. However, they used an overall change in energy intensity without considering the structural components. Thus, the data used in their analysis was not stationary (see Hübler and Keller, 2010). Before running a panel analysis, we conducted a unit root test for all of the variables, the results are unsuspicious.

In our main model, we test by considering period fixed effects. The assumption is that in the model not-considered factors like energy prices, absorption capacities, tax policies, elasticities etc., which vary over time, can influence our endogenous variable. Thus, we couldn’t obtain related data.

Table 4. Regression results (Period specific effects)[20]

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.976841	0.010434	9.361.876	0.0000
?CHFDISTGDP	-0.117053	0.040137	-2.916.329	0.0041
?CHIMSH	0.150702	0.105235	1.432.057	0.1544
?CHRD	-0.055773	0.083790	-0.665622	0.5067
Fixed Effects (Period)				
1997—C	-0.001738			
1998—C	0.016029			
1999—C	0.000812			
2000—C	-0.038920			
2001—C	0.016590			
2002—C	0.051157			
2003—C	0.066972			
2004—C	-0.018674			
2005—C	-0.028680			
2006—C	-0.041259			
2007—C	-0.022290			

R-squared	0.192599	Mean dependent var	0.961195
Adjusted R-squared	0.117626	S.D. dependent var	0.091313
S.E. of regression	0.085774	Akaike info criterion	-1.987.688
Sum squared resid	1.030.010	Schwarz criterion	-1.711.602
Log likelihood	1.670.520	Hannan-Quinn criter.	-1.875.543
F-statistic	2.568.912	Durbin-Watson stat	2.051.976
Prob(F-statistic)	0.003264		

The coefficient of FDI is reflecting that there is a negative relationship which is already explained in the theoretical chapter. Hereby, we should emphasize that our control variables -import shares and R&D changes- have no significant effect on technology induced energy efficiency improvements. However, the import products structure could explain this result; while R&D investments yield initial in the long-run (see Enos, 1962). Unfortunately, our data set on the selected countries are limited.

5. Conclusions

Since the opening of new markets in Asia and Euro-Asia zone, the debate on the security supply is getting for the reason more important that a faster exhaustibility of resources is

[20] In an attendant model, we tested the country specific random effects. The results didn't change: Additionally, if we investigate the coefficients of single countries, we differ that new members / Eastern EU countries have a negative constant (Slovenia is an extension) while cohesion countries and Finland have a positive constant. This can be explained by having different degrees of economic development.

setting the economic growth dynamics under pressure. On the other hand an increase of energy demand in the last decades and current energy supply system endanger the ecological equilibrium while one can handle global warming issues only by international cooperation. In this context, the innovations and diffusion of environmental and energy-saving technologies are playing a key role. However, differences in knowledge stock and innovativeness is a crucial challenge the developing countries are facing while FDIs are one of the most important channels of technology transfer.

In the literature, there are numerous empirical and theoretical studies on the innovation effects of direct investments. There are also several researches on the correlation between trade, investments and the innovations that enhance environmental quality improvements. However, we could find only a limited number of studies on the energy efficiency and direct investments in a macroeconomic level. However, we could find only a limited number of studies on the relationship between direct investments and energy efficiency. Thus, the studies of Eskeland/Harrison (2003), Yue/Long/Zhuang (2011) and Fisher-Vanden et al. (2004) are using micro data while the studies of Mielnik/Goldemberg (2002) and Hübler/Keller (2010) are using macro data by handling energy intensity and change energy intensity as an indicator of technological improvement. Nevertheless, a change in energy intensity on the macroeconomic level can contain structural components as well.

In this study, we removed the structural effects from the change in energy intensity in manufacturing sector by using a decomposition analysis with a multiplicative log-mean Divisia method. We used 2-digit level industrial data of 14 EU-Countries, namely Bulgaria, Czech Rep., Estonia, Finland, Hungary, Ireland, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia, Spain. The main reasons for this choice were the availability of data plus the features of new members and cohesion countries. After adjustment from structural components from the change in energy intensity we implemented a pool data analysis for 12 years. We interpreted the "pure" intensity effect as a technological progress which can be perceived also as an improved indicator. The results of our panel data analysis showed that there is a relationship between FDIs and energy efficiency. This result supports the findings of Mielnik/Goldemberg (2002) and the majority of empirical studies about productivity increasing effects of FDIs via technology transfer and competition effects.

However, technology transfer isn't an easy process and is more complex than macro data can cover while political, institutional and sociological factors as well should be adapted beside economic components. In this context, a qualitative analysis based on micro data and interviews can justify our empirical analysis and give policy makers further insights.

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Appendix: Description of studied industries

The following industries are considered in this study. The classification is based on the Eurostat's data on sectoral energy consumption to which the existing production values (Nace 1.1.) are fitted.

Basic metal industry (combination of Iron & steel and non-ferrous metal industries.)	Iron & steel industry covers quantities consumed in the Iron and steel industry (NACE 27.1 Manufacture of basic iron and steel and of ferrous-alloys + 27.2 Manufacture of tubes + 27.3 Other first processing of iron and steel + 27.51 Casting of iron + 27.52 Casting of steel). Non-ferrous metal industry covers quantities consumed in non-ferrous metals industry (NACE 27.4 Manufacture of basic precious and non-ferrous metals + 27.53 Casting of light metals + 27.54 Casting of other non-ferrous metals).
Chemical industry	Chemical industry covers quantities consumed in the chemical industry (NACE 24 Manufacture of chemicals and chemical products).
Non-metallic mineral products industry	Non-metallic mineral products industry covers quantities consumed in the non-metallic mineral products industry (NACE 26 Manufacture of other non-metallic mineral products).
Food, drink and tobacco industry	Food, drink & tobacco industry covers quantities consumed in the food, drink and tobacco industry (NACE 15 Manufacture of food products and beverages + 16 Manufacture of tobacco products).
Textile, leather and clothing industry	Textile, leather & clothing industry covers quantities consumed in the textile, leather and clothing industry (NACE 17 Manufacture of textiles + 18 Manufacture of wearing apparel; dressing and dyeing of fur + 19 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear).
Paper and printing industry	Paper & printing industry covers quantities consumed in the paper and printing industry (NACE 21 Manufacture of pulp, paper and paper products + 22 Publishing, printing and reproduction of recorded media).
Engineering and other metal industry	Engineering & other metal industry covers quantities consumed in the engineering and other metal industries (NACE 28 Manufacture of fabricated metal products, except machinery and equipment + 29 Manufacture of machinery and equipments n.e.c. + 30 Manufacture of office machinery and computers + 31 Manufacture of electrical machinery and apparatus n.e.c. + 32 Manufacture of radio, television and communication equipment and apparatus + 34 Manufacture of motor vehicles, trailers and semi-trailers + 35 Manufacture of other transport equipment).
Other non-classified industries	Other non-classified industries cover quantities consumed in other, non-classified industries (NACE 20 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials + 25 Manufacture of rubber and plastic products + 33 Manufacture of medical, precision and optical instruments, watches and clocks + 36 Manufacture of furniture; manufacturing n.e.c. + 37 Recycling + 45 Construction).

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