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Three Essays on Transition Economics

Doctoral Dissertation

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Declaration

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Summary

This doctoral dissertation explores some previously untouched aspects of transition economics pertinent to 15 former Soviet Union (FSU) countries, namely Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Lithuania, Latvia, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan. FSU economies are developing young states that are less studied and characterized with complex economic and institutional processes. In this document we shed light on economic processes in these countries from macro-level perspective since the data constraint on firm level. The methodological approach we undertake is an empirical one.

The structure of the dissertation consists of three independent but inter-related essays in the form of working papers. First Essay 1 (Chapter 2) looks at the external financial inflows, foreign direct investment (FDI), Official Development Assistance (ODA) and their interaction with domestic investment in five economies of the Central Asian region, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Second Essay 2(Chapter 3) deals with the issues of total factor productivity (TFP), efficiency and external foreign channels interactions. Third Essay 3 (Chapter 4) presents analysis on environmental pollution. It explores environmental efficiency related to carbon dioxide(CO_2) emissions in 15 FSU nations.

On the methodological side we demonstrate the application of three different panel data econometric techniques. In Essay 1 we apply seemingly unrelated regression (SUR) estimation technique. The second paper, Essay 2, shows the application of stochastic frontier analysis (SFA) in calculating efficiency and TFP measures. Data envelopment analysis (DEA) window analysis technique is used in Essay 3 to calculate the carbon dioxide environmental efficiency ratio.

The main results from this dissertation point out on important policy implications. The Essay 1 indicates a positive correlation between FDI and ODA, also called foreign aid. We learn that trade in capital equipment renders positive effect on increasing technical efficiency and eventually enhances total factor productivity (TFP) in gross domestic product (GDP) production from Essay 2. Essay 3 shows that the 15 FSU economies are enhancing their carbon dioxide environmental efficiency which means that they are learning to adopt advanced technological techniques in production mix facilitating control of carbon dioxide emissions.

All three essays are original contributions to the empirical literature on studies on

FSU economies to the best of our knowledge.

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Abbreviations

CO_2	Carbon dioxide
CIS	Commonwealth of Independent States
DEA	Data Envelopment Analysis
DEA-WA	Data Envelopment Analysis-Window Analysis
EC	Efficiency Change
EU	European Union
FDI	Foreign Direct Investment
FE	Fixed Effect
FSU	Former Soviet Union
GMM	Generalized Method of Moments
GLS	Generalized Least Squares
GHG	Greenhouse Gases
HC	Human Capital
IME	Imports of Machinery and Equipment
IMF	International Monetary Fund
IPCC	International Panel on Climate Change
IV	Instrumental Variable
KOF	Index of Globalization
MDG	Millennium Development Goals
NRR	Non Resource-Rich Countries
ODA	Official Development Assistance
OLS	Ordinary Least Squares

PIM Perpetual Inventory Method

POLS pooled OLS

RR Resource-Rich Countries

SFA Stochastic Frontier Analysis

SO_x Sulphur Oxide x

SUR Seemeengly Unrelated Regression

TC Technical Change

TE Technical Efficiency

TFP Total Factor Productivity

VRS Variable Returns to Scale

WB World Bank

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Chapter 1

Introduction

Fifteen transition economies of former Soviet Union (FSU) recently celebrated twenty years of their independence after the breakup of Soviet Union in 1991. Since then formal collaborations among these states were dynamic and characterized by forming various trade unions and cooperation organizations. For example, Latvia, Lithuania and Estonia have joined European Union (EU) in 2004, while others, Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, Turkmenistan and Uzbekistan have constituted the Commonwealth of Independent States (CIS) group in 1994. The first decade of independence challenged FSU economies' economic growth and development depicted by decline in economic output and enervating institutions that was defined as a puzzle by Blanchard (Blanchard, 1997). In his book *The Economics of Post-Communist Transition* he hypothesizes that after removing barriers from previous regime these countries should have raised their national output as opposed to the fall as was observed in initial 10-year period. However, in the second decade FSU countries slowly recovered augmenting their macroeconomic performance, stability and implementing occasional welfare policy reforms. To date, these countries have shown heterogeneous growth path based on their internal and external policy mechanisms.

As Nobel Prize laureate Amartya Sen pointed out *"economic growth is one aspect of the process of economic development..."*, we observe robust economic growth, gross domestic product (GDP) growth, but weak economic development that is about policy intervention aimed at improving human capital, health and well-being (Sen, 1983). Economic development and growth were always on the agenda of economists. The main reason was the fact of striking differentiated economic growth (and also development) patterns in the world. Even though globalization tends to bring positive effects boosting trade and domestic production, there is still a dramatic gap between industrialized countries of the Western hemisphere and developing FSU economies, for example.

Transition economies have various issues of ultimate priority to be addressed such as economic growth, international trade, job creation and production schemes, along with institutional development and policy building. Understanding the processes of past economic trends and causes affecting them is a very important topic in economic literature. First, transition economies are potential markets for industrialized economies for trade and investment. Second, keeping macroeconomic stability and peace are essential for transition economies to satisfy financial needs, attracting investors from oversees. Third, to satisfy and oblige to world community rules and regulations stated by Millennium Development Goals (MDG) FSU economies should reach optimal standard of living. Finally, to comply with environmental regulation and norms these economies should be able to cope with international standards. Research on transition economies also benefits local policy makers as it equips them with understanding of domestic economic processes to make sound modern decisions in favor of improving the well-being of people.

This dissertation focuses on above mentioned issues of newly created transition economies and explores three facets of the economic modernization, i.e., growth and development. It empirically addresses (1) the external financial flows to developing countries such as foreign direct investment (FDI) and official development assistance (ODA), (2) focuses on economic productivity and external channels affecting it and (3) discusses environmental efficiency with particular attention to carbon dioxide (CO_2) emissions. The structure of dissertation consists of three independent but closely inter-related working papers.

The need for financial capital at the early stages of independence literally pushed FSU economies to deal with the need for external financial transfers. In Essay 1 (Chapter 2) we look at the vital issue of external financial flows into the local developing economies such as FDI and foreign aid. Since the possibility of foreign intervention strictly depends on domestic market condition and the effect of these flows are generally positive, it is vital to analyze whether they have some sort of correlation. In case these two *unrelated financial flows* have connection the world technical cooperation organizations such as World Bank, International Monetary Fund and United Nations divisions could benefit from *partnership* with private FDI investors. Another aspect of this interaction is how external channels affect domestic investment. We would like to see whether external investors finance domestic investment. If so, this could not bring to long-term economic development but to dependence. We found that FDI and foreign aid are complementing each other on macro country level analysis. Moreover, FDI positively affects *crowding in* domestic investment. It means that better domestic business environment attracts multinational enterprises (MNEs). From domestic policy making view this is good news since it shows that (1) local economies are enhancing domestic policies, (2) conducting favorable reforms and (3) opening markets for collaboration.

Production of GDP is an important process, especially in transition economies. More important is the production process itself: its factors, technological mix and efficiency. As was said by W.E. Simon *"Productivity and the growth of productivity must be the first economic consideration at all times, not the last. That is the source of technological innovation, jobs, and wealth. . . ."* (Simon, 1978). Even though we observed a rapid economic growth of GDP in FSU economies we still don't know well what is the "price" of that endeavor. To be precise, if this spectacular GDP growth comes at high cost, then it is not feasible since some markets go dominated and stall. The focus of Chapter 3 (Essay 2) is to unravel the sources of productivity in fifteen FSU economies. Additionally, we study whether external financial flows (FDI, foreign aid, imports of machinery and equipment (IME) and human capital) are driving up or improve domestic GDP production process. Our results show that IME and human capital improve technical efficiency: i.e. producing the same amount of output with lesser production factors. Further, these factors also improve total factor productivity that is shift in production frontier due to technological progress. These results point on advice to encourage cross-border technology flows and also invest in education. We found that human factor is essential in better absorbing and utilizing the foreign transfers.

Since environmental problem is a global issue and touches all world countries regardless of their economic development, in Chapter 4 (Essay 3) we undertake analyses of environmental efficiency and apply it to carbon dioxide emissions. Today, it is well known that greenhouse gases (GHG), mainly the concentration of $CO2$ causes global warming and is the main agenda of International Panel on Climate Change (IPCC) and Kyoto Protocol. The main danger is that when some countries are heavily investing in protecting environment scarifying huge costs, the majority of other countries are refuting previous investments since the carbon dioxide is a global pollutant and affects world population more or less equally via climate warming and connected calamities. Basing on the raising $CO2$ statistics we aimed to compute an environmental index to compare FSU economies on their efforts to curb carbon leakage. From empirical results we observe that there is a trade–off: FSU economies are improving carbon dioxide environmental efficiency, 1.59 percent, but reducing their GDP production tenfold, -15.9 percent.

Chapter 2

Foreign Aid, Foreign Direct Investment and Domestic Investment Nexus in landlocked Economies of Central Asia

Abstract This paper investigates the relationship between official development assistance, foreign direct investment (FDI) and domestic investment in landlocked and less studied young economies of Central Asia. It is important for donor countries to understand whether their investments induce foreign direct investment or not. If they do, it creates ground for public-private partnership. If they do not, then it points to reassessing mechanisms to 'aid architecture'. For public multinational enterprises, it is important to gain positive public opinions and further explore new markets. For governments, it is crucial to devise policies to favor foreign transfers that bring more welfare improvements. Our results from seemingly unrelated regression for regional sample demonstrate that: (a) foreign aid and FDI are complementing flows, and, (b) we found crowding-in effect: domestic investments increase FDI and vice versa, but not foreign aid. We conclude that there is evidence of public-private investment partnership.
JEL Classification: F21, F30, P33, O11
Keywords: Central Asia, transition economies, foreign direct investment, official development assistance

2.1 Introduction

Do external financial flows help developing countries to grow? This is one of the most important questions in economic growth and development literature, especially as financial resources in developed economies are becoming more limited. Every year, OECD[1] donors give enormous amount of financial resource to five landlocked post-communist and complex Central Asian economies CA(5)[2] in terms of official development assistance (ODA), which is broadly humanitarian assistance from developed countries [3] ODA is administered by OECD Development Assistance Committee (DAC) that consists of 24 developed countries[4]. On the other side, multinationals launch their projects via foreign direct investment (FDI) searching for more profit. Both of these transfers are crucial to transition low-income nations. FDI helps recipient countries to encourage rise in specialization and rising income of low-skilled that would eventually lift their wages and decrease inequality (Heckscher-Ohlin-Samuelson theorem). ODA aims to improve social welfare, decrease inequality and raise skilled workers pool through technical assistance. At least on a conceptual level, both flows extend common features to recipient countries.

In a historically important International Conference for Development (2002) document, *The Monterey Consensus*[5], and follow-up Doha Declaration on Financing for Development outcome report, FDI is viewed as an addition to ODA.[6] UNCTAD also

[1]Organization for Economic Co-operation and Development (OECD) has a development assistance committee (DAC) that base their decision on disbursing financial aid. It has four categories: 1.Least Developed Countries; 2. Other Low Income Countries (per capita GNI<$935 in 2007): Kyrgyzstan, Tajikistan, Uzbekistan; 3. Lower Middle Income Countries and Territories (per capita GNI $936–$3.705): Turkmenistan; GNI $3.706–11.455): Kazakhstan. DAC reviews every 3 years GNI per capita reported by World Bank and make a list of potential recipients. (OECD website:`www.oecd.com`.

[2]Central Asian economies comprise of: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

[3]On principles, mechanism and opinions on effects of ODA see (Hansen and Tarp, 2000; Dalgaard et al., 2004; Lahiri and K., 2006; Bourguignon and Sundberg, 2007; Easterly, 2007; Mavrotas and Nunnenkamp, 2007; Selaya and Sunasen, 2008). We interchangeably call ODA as foreign aid in this paper.

[4]Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States and the European Commission (EC). The World Bank, the International Monetary Fund (IMF) and the United Nations Development Programme (UNDP) participate as permanent observers. (OECD, Inside the DAC, A Guide to the OECD Development Assistance Committee, 2009-2010).

[5]The United Nations-sponsored summit-level meeting was held in Monterrey, Mexico, from 18 to 22 March 2002.

[6]Doha Declaration on Financing for Development: outcome document of the Follow-up International Conference on Financing for Development to Review the Implementation of the Monterrey Consen-

stress this point in advising local governments:*Channelling some ODA into investment projects financed jointly with domestic financial institutions.*[7] It is important for donor countries to understand whether their investments also induce foreign direct investment. At first it seems they are two different flows and no link exists because FDI is a capital account item and ODA is a transfer payment of current account though both constituent balance of payments entries. On the other hand, donors who give assistance are also ones who conduct FDI, called 'vanguard effect'(Kimura and Todo, 2010). If there is in fact a connection, then it could create grounds for public-private partnership, such as tiding aid with domestic private sector investments. If there is no connection, then it points to reassessing the mechanisms of 'aid architecture' for long-term civil society building goals. For public multinational enterprises (MNEs) it is equally important to gain positive public opinion and to further explore new markets for profit seeking motives. For recipient local societies and their governments, it is crucial to devise policies to favor a particular foreign capital that brings tangible contribution to domestic welfare improvements.

The central focus of this paper is to explore a possible link between aggregate ODA and FDI in five landlocked Central Asian countries with similar socio-economic situations and financial systems. (Harms and Lutz, 2006) studied 76 developing countries before 2000, excluding CA(5) economies, and found that ODA is a complement to FDI. Moreover, they also found that stimulating effect of ODA is higher in countries with unfavorable institutional environment. We specifically test their latter conclusion to see whether this also holds for Central Asia economies.

The link between FDI-ODA was studied only by few scholars and there is no specific consensus yet. For example, (Kosak and Tobin, 2006) state in their panel study of 90 various growth level group of countries from 1970 to 2001 that FDI and ODA are unrelated, as each had specific effects on economic growth. (Caselli and Feyrer, 2007) study groups of developed and developing countries also emphasize that foreign investment and foreign aid are more like substitutes than complements. None of mentioned studies above includes Central Asian economies. According to the theory of FDI, private investments are favored more when certain business conditions in host countries are met, such as macroeconomic stability, infrastructure, regulation and financial system intact (Navaretti and Venables, 2004; Globerman and Shapiro, 2002;

sus,www.un.org/esa/ffd/doha/documents/Doha-Declaration-FFD.pdf; United Nations, 2009.

[7]Trade and Development Report 2008, UNCTAD: http://www.unctad.org/Templates/webflyer.asp?docid=10438&intItemID=2068&lang=1, Accessed 15 December 2011.

Davies, 2011). Foreign aid is essentially targeted at improving these conditions.

To quantify the above concerns we built a panel data set and estimated our data by simultaneous equation modeling of seemingly unrelated regressions (SUR) proposed by (Zellner, 1962) to account the issue about simultaneity and cross-section error correlation. Different panel data techniques were employed in their research on FDI for post-communist transition economies (Lansbury et al., 1996; Bengoa and Sanches-Robles, 2003; Campos and Kinoshita, 2003; Johnson, 2006; Kenisarin, 2008) among others.

Our result on regional (pooled) regression level supports (Harms and Lutz, 2006) conclusions and we found positive influence of ODA on FDI inflows into CA(5). The same complementary effect of ODA is also corroborated in studies by (Hien, 2008; Selaya and Sunasen, 2008; Asiedu et al., 2009; Bhavan et al., 2011). Moreover, we also found reverse effect, that FDI also attracts foreign aid (ODA).

We contribute to the empirical literature on FDI-ODA link by bringing new insights about foreign aid effects in less studied Central Asian regions that could be helpful for international donor organizations, so that they could better devise their programs and do 'aid architecture', possibly enable better predictions of future aid packages. It could also provide thoughts on re-assessing public-private collaboration. Our understanding is that, the present paper is the first paper that studies foreign transfer flows' link in five remote economies in Central Asia.

The structure of the paper is as follows. Section 2.2 covers related past literature. Section 2.3 discusses FDI-ODA trends in Central Asian region. Section 2.4 covers our empirical investigation and Section 2.5 the data used. Section 2.6 contains a discussion on our results. Section 2.7 summarizes the principal results and highlights future research prospects.

2.2 Theoretical Considerations

There are various ways foreign aid could affect foreign direct investment in host countries. According to Harms and Lutz (2006), if foreign aid is directed to infrastructure projects, human capital and complementary inputs could have "infrastructure effect". Enhanced domestic conditions could lure foreign investors. Inflows of foreign aid are also expected to raise countries marginal product of capital (MPC) of domestic firms, which in turn attracts FDI. Another effect, 'rent-seeking', might also appear, possibly arrive from the fact that local firms compete for rents from foreign aid. This situation reduces MPC that would results in less innovation activities, R&D spending and reduction in efficiency (Svensson, 2000; Harms and Lutz, 2006). The outcome of this behavior would be more reliance on aid, which would discourage FDI. Clearly, foreign aid could add to 'financing effect' that directly augments the balance of payment of the recipient country, as it helps foreigners to secure their profit repatriation. (Arellano et al., 2009) argues that aid could increase the supply of tradable goods and reduce the price of non-tradable goods. They call it 'Dutch-disease effect' that discourages the FDI. (Kimura and Todo, 2010) claim that there is also 'vanguard effect' of foreign aid, meaning countries who give aid also tend to place an FDI in specific host economies. (Mody et al., 2003) state that there is an 'information effect' that foreign aid is carrying into host countries. Private information which is not accessible to the foreigner is revealed to investor via foreign aid. Aid programs help investors to collect data and build a picture of recipient countries.

In general, channels of foreign capital entering the region could be outlined as follows: foreign aid is directed into social infrastructure targeting complementary inputs, namely, health, education, water related projects and/or economic infrastructure, including energy, communication, and transportation. FDI is focused on physical capital projects, production, manufacturing, banking industries and natural resource extracting sectors. Numerous researches were devoted to analyses of FDI, but very few researches addressed the Central Asian (CA) region that is located in the middle of the East and West continents trade route.[8] Only several studies focused on FDI effects of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (De Melo et al., 1997; Gylfason, 2000; Edmiston et al., 2003; Bayulgen, 2005; Boudier-Bensebaa, 2005; Penev, 2007; Kenisarin, 2008), but they were under the framework of Commonwealth of Independent States (CIS)[9] or Central and Eastern Europe (CEE)[10] that included countries with different economic setup. Studies that focused solely on these five countries are scarce

[8]For example, in USA, (Bobonis and Shatz, 2007), in Latin America, (Bengoa and Sanches-Robles, 2003), in Europe and Asia, (Jaumotte, 2004) among other comprehensive studies.

[9]CIS is the abbreviation for Commonwealth of Independent States that created in December 08, 1991. It consists of twelve countries: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan and Georgia (that left CIS on August 14, 2008). The three Baltic States (also former Soviet Republics): Estonia, Latvia and Lithuania did not join the CIS.

[10]CEE or CEES-stands for Central and Eastern Europe former communist countries: Baltic States-Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Albania; states of former Yugoslavia- Slovenia, Croatia, Bosnia-Herzegovina , Serbia, Kosovo, Montenegro and Macedonia.

and addressed primarily the social and political structure (such as in (Gleason, 2001) and (Dowling and Wignaraja, 2006)). Some studies presented a narrative of economic policy developments in the region. For example, (Dikkaya and Keles, 2006) address the FDI in Kyrgyzstan through a case study approach. Other scholars, for instance (Venables, 2009) showed benefits of regional integration in Central Asia via general equilibrium tools. (Pomfret, 2005, 2010) addressed Central Asian regional trade relations and policies, energy institutions, regionalism and integration into the world economy. (Hoen, 2010) expressed his opinion on transitional path of Central Asian countries. (Kalyuzhnova, 2003; Kalyuzhnova and Nygaard, 2008, 2011) thoughtfully reflects on social and economic developments, and energy related issues.

Moreover, the direct link between FDI and ODA was studied only in a handful of papers to the best of our knowledge. For example, Karakaplan et al. (2005); Harms and Lutz (2006); Kosak and Tobin (2006); Selaya and Sunasen (2008) study broad groups of developing countries.(Kimura and Todo, 2010) and (Blaise, 2005) focus on Japanese FDI and aid flow interactions. (Carro and Larru, 2010) look at FDI-ODA link in Argentina and Brazil. Kapfer et al. (2007) construct infrastructure aid-FDI links for 59 countries. (Asiedu et al., 2009) show that aid mitigate appropriation risk on FDI for 35 low-income and 28 Sub-Saharan Africa. (Hien, 2008) looks at FDI-ODA in 28 provinces of Vietnam. (Bhavan et al., 2011) analyze nexus between FDI and ODA for South Asian economies. (Beladi and Oladi, 2006) apply the FDI-ODA link into a three-goods general equilibrium model and found that when foreign aid is directed to public good, it could crowd out foreign investment in the recipient country, when given a factor intensity condition.

The findings on FDI-ODA link are mixed. (Karakaplan et al., 2005) found that aid has a negative effect on FDI. On the other hand, (Kosak and Tobin, 2006) state that FDI and ODA are unrelated due to aid goes to support human capital, and FDI is private and thus goes to physical capital. (Carro and Larru, 2010) also could not find any systematic relationship between FDI and ODA flows. (Caselli and Feyrer, 2007) studied marginal product of capital (MPC) and report that MPC is roughly the same across developing countries, and inflow of foreign aid only reduces MPC. In their study, foreign aid is more substituted to FDI. In their study of 81 developing countries (excluding Central Asia) from 1988-1999, (Harms and Lutz, 2006) claims that FDI and ODA are complements. Moreover, they argue that after controlling for regulation in host countries, catalyzing effect of aid is stronger in countries with unfavorable institutional environment. In South Asian countries foreign aid drives the FDI in the study of (Bhavan et al., 2011).

2.3 Foreign Transfers' in Central Asia

From 1991, all five countries declared their independence and started building their economies. Kazakhstan is the largest and by territory is the half the size of Europe.[11] Central Asia is under energy related political game between USA, Russia and China, according to Financial Times "Investing in Central Asia 2008" Special Report (FT.com, 2010). The importance of studying capital flows into these countries is justified by its strategic geographical location, which gives European Union economies, USA, Japan and China trading route to Afghanistan and further to the Middle East. Prospective growth and stability in the region could stimulate international trade, capital movements and intra Central Asian collaboration that could favor foreign investors. The region is rich in natural resources, especially in oil and natural gas, minerals and metals - they are of primary interest to multinational enterprises as input factors. For European Union, Central Asia is the potential source of future energy supply, especially natural gas.

Another reason to investigate FDI inflows would be that local firms are restricted and have constrains to external funding opportunities. Availability of finance to support their businesses via FDI inflows (stock, portfolio and loans) is a very favorable condition to revive the landlocked region's economic development.[12] Liquidity constraints would prevent local firms from creating competitive advantages through rigidities of exporting their goods. The region demonstrated high potential for market growth and trade relations. Industrial structure of Central Asian region characterized by oligopolistic markets in the main industrial sectors affiliated to mineral resources/energy, and with monopolistic domestic competition. At the same time countries have their particular outlook for economic reforms and international policy and local developments.

The major type of FDI in Central Asia is Greenfield investment.[13] This is when

[11] According to reports from World Bank and International Monetary Fund Former Soviet Union (FSU), economies classified as Energy Exporters are Azerbaijan, Kazakhstan, Turkmenistan, Uzbekistan and Russia and Energy Importers are Armenia, Belarus, Georgia, Kyrgyzstan, Moldova, Moldavia, Tajikistan and Ukraine.

[12] More detailed analysis on FDI effects on recipient countries consult Navaretti and Venables (2004);Mody (2004);Krkoska (2001);Kirkpatrick et al. (2006);Tndel (2001); Carstensen and Toubal (2004);Mileva (2008);Dobrinsky (2007) and recently Hanousek et al. (2011).

[13] FDI is classified as "Greenfield investment" when the MNEs invest by building new factories, plants, offices, entities and buildings in host country. These new economic units have their own

Table 2.1: Inward FDI, ODA and Domesic investment for the period 1992-2009.

Country	Average FDI Flows ($)	Annual Average FDI growth (%)	Average ODA flows ($)	Annual Average ODA growth (%)	Average DOM Flows ($)	Annual Average DOM growth (%)	Average GDP ($)	Annual Average GDP growth (%)
KAZ	1,100.90	7.9	78.55	-10.5	41,440.50	-10	2,945.78	3.6
KYR	20.96	51.3	117.08	-13.7	675.47	-8.3	451.56	0.7
TAJ	794.9	48.1	1,134.64	-21.9	19,606.27	-16.5	313.97	0.3
TKM	4,994.02	5	14,175.18	-17.4	1,322.909.27	-26.5	1,684.77	2.3
UZB	19.69	-23.7	80.17	-23.7	4,686.86	-26.6	474.44	2.8

Note: KAZ-Kazakhstan, KYR-Kyrgyzstan, TAJ-Tajikistan, TKM-Turkmenistan and UZB-Uzbekistan. All data for FDI -inward foreign direct investment, ODA- total official development assistance net, DOM-gross fixed capital formation and GDP-gross domestic product are measured in per capital real US Dollars in millions. GDP-in thousands values. *Source*: UNCTAD , UNCTADstat (online database,2011) and own calculations.

MNEs create their foreign operation units overseas and integrate vertically. Also, FDI inflows are mostly export oriented and not directed to serve local market according to ADB World Investment Report (2010). Major investors are firms from USA, Japan, China, and developing Asia. Foreign capital lands in oil and energy sector, while service sector is almost untouched. This may be due to fact that still after 1991, economies could not efficiently build sound regulations, functioning financial services and advances in structural reforms. MNEs entered the domestic economies of CA(5) vertically thus reducing the transfer costs and financial risks. The major types of foreign investment only happen after reaching agreement with top government officials. The weak domestic firms' competition gives competitive advantage to multinational firms. MNEs that possess superior knowledge and technology simply enjoy the amateur markets of CA(5). In practice, MNEs enter the markets with political stability in the region as the only concern according to (Krugman, 1979).

From Table 2.1 we can see that, on average, Central Asian countries are different in terms of attracting FDI with the leading position of Turkmenistan. If all nations average growth was positive, Uzbekistan on average would end on a big negative side, with 23.7 percent decline in real terms per capita. The first three countries in the ranking of the most attractive destinations for FDI flows are Kazakhstan and Turkmenistan, which both have abundant oil and gas resources.

Moreover, the average growth of ODA was negative for all economies. The foreign

accounting books.

aid also declined approximately fourfold from $242 million to $51 million between the sample periods. On the other hand, Kyrgyzstan is in second place for ODA after Turkmenistan and has huge mineral resources of non-ferrous metals (mercury ores and antimony), substantial coal reserves and gold, while Tajikistan is another region attracting much of the foreign aid and very rich in mineral deposits such as metallic ores (zinc, iron, mercury, gold, tin and lead) and common salts (such as carbonates, fluorites). On the other hand, domestic investment (DOM) had decreased on average terms. Turkmenistan, Tajikistan and Kazakhstan per capita real gross fixed investments surged. Overall, annual growth is still negative. We observe the pattern of increase of FDI and decline of DOM that raise a question on whether FDI served financing the domestic investment in the region. We discuss this issue later in the paper.

2.4 Econometric Methodology

2.4.1 Empirical Model

We build a model with three equations: one for foreign direct investment (FDI), one for foreign aid (ODA) and one for domestic investment (DOM). The reason is that each foreign flow has its own mechanism based on previous contributions. FDI is administered through a private channel and aid is through a public one. Both of these flows are part of balance of payments. Hence, we would assume some reverse association between them. Additionally, we would like to test external flows' effect on investments by local economies. This carries a crucial point: if foreign flows reduce domestic investment, such as financing, this means that economies of CA (5) are less concerned with long-term growth prospects. If they complement domestic flows then we consider it as a positive event that meliorates process of transition. Since we deal with capital movement, we also include KOF globalisation index (Glob) to control for rigidities of recipient economies (Dreher, 2006). The year variable (Year) is included due to the need to control for individual country effects and because our sample is in long form (Cameron and Trivedi, 2009). Allowing for reverse causality or simultaneity, meaning FDI, ODA and domestic investment (DOM) are defined simultaneously, we estimate our model, through solving three equations simultaneously using seemingly unrelated regressions (SUR) technique. In this way we are better able to reveal the possible link between these investment flows. Thus, our empirical model is set up as follows:

$$\ln(FDI)_{i,t} = \gamma_0 + \gamma_1 \ln(ODA)_{i,t} + \gamma_2 \ln(DOM - FDI)_{i,t} + \gamma_3(Glob)_{i,t} + \gamma_4(Year) + \epsilon_{i,t}$$
$$\ln(ODA)_{i,t} = \beta_0 + \beta_1 \ln(FDI)_{i,t} + \beta_2 \ln(DOM - FDI)_{i,t} + \beta_3(Glob)_{i,t} + \beta_4(Year) + \varepsilon_{i,t}$$
$$\ln(DOM - FDI)_{i,t} = \delta_0 + \delta_1 \ln(FDI)_{i,t} + \delta_2 \ln(ODA)_{i,t} + \delta_3(Glob)_{i,t} + \delta_4(Year) + \omega_{i,t}$$
$$i = 1 \ldots, N; t = 1 \ldots, T \tag{2.1}$$

where i- countries (N=5) and t-time frame (T=18), FDI- foreign direct investment, ODA- official development assistance, ala- foreign aid, DOM- gross fixed capital formation in host country minus FDI since fixed capital portion of external flows (Younas, 2011), Glob- KOF is the globalization index.

We have included *Year* to account for country effects and also for technological progress. Given dimensions of our sample the estimation was implemented by employing SUR estimation technique proposed by (Zellner, 1962). This method allows us to jointly estimate three equations for our sample. Also, SUR estimator is based on small N=5 and large T=18 that is the feature of our sample.[14] SUR imposes each country to have its own coefficient vector unlike pooled OLS or even fixed effect (FE) estimators Baum (2006, p.238). Moreover, it allows cross-section error component correlation, i.e. contemporaneous correlation. Estimator is efficient under the homoscedasticity condition which is managed by imposing bootstrapped standard errors. SUR estimation permits us to allow for the serial correlation over panels. Our estimates are complacent with maximum likelihood estimates due to specification of iteration over disturbance covariance matrix and parameter estimates. The panel data advantage over cross section and time series is that we get bigger sample which increase degrees of freedom and reduce collinearity between variables. According to literature, using SUR would improve the efficiency of our estimates over the traditional pooled OLS (POLS) methods, where we cannot simultaneously estimate two equations gives more efficiency gain. Hence, we prefer the SUR methodology.

[14]Since our sample is in long panel format we technically cannot apply traditional fixed (FE) or random effects (FE) modelling or similar estimators such as instrumental variable (IV) generalized method of moments (GMM),that are based on large N and small T assumption regarding a sample. However, we could apply pooled estimators such as generalised least squares GLS but it does not allow us simultaneity estimate our equations. Baum (2006) and Cameron and Trivedi (2009).

2.5 Data

We construct a long form panel data where time dimension (T=18) exceeds the number of countries (N=5). All yearly aggregate variables are in real values[15] transformed into natural log to reduce variability and expressed in per capita terms to make feasible comparisons. We include a few explanatory variables because of our data dimensions; otherwise we will lose degrees of freedom. The data summary, variables descriptions and sources are presented in Tables 2.3–2.4 in the Appendix.

Firstly, we chose these five countries, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, because they share similar economic, geographic and political setup. The remaining ten Former Soviet Union (FSU) Republics were different from the historical and geo-political view.[16] From 1991, all our five Republics broke away from the Soviet Union and established their sovereign states.[17] Secondly, the so-called initial conditions principle appears if we were to look at the economic factors driving foreign direct investment into this region (De Melo et al., 1997). Not all Soviet Union countries were the same before the break; Baltic, Transcaucasus and Eastern Europe countries had industrial bases, while Central Asian countries could be classified as agricultural and natural resources regions. Thirdly, the inclusion of only these five countries avoids the problem of sampling bias, for example, comparing countries with different levels of industrial setup that is very important in empirical investigation. Following our initial theoretical discussion and from past literature as mentioned in earlier sections, we have constructed relevant variables for our model. Statistical reporting in home countries is not comprehensive and is underdeveloped, so we use aggregate databases from international organizations, such as Nations Conference on Trade and Development (UNCTAD) and IMF. This is coherent with the objective of our ex-post study; to understand FDI-ODA link after 18 years of independence, 1992-2009.[18]

[15]We deflated monetary variables by the Consumer Price Index (CPI) from IMF (2000=100).

[16]Soviet Union had 15 Republics that after the break were all collectively called Commonwealth of Independent States (CIS). The breakdown of countries by geographical markup is following: Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan); Baltic (Estonia, Latvia, Lithuania); Eastern Europe (Belarus, Moldova, Ukraine); Eurasia (Russia); Transcaucasus (Armenia, Azerbaijan, Georgia).

[17]Independence status officially declared: Kazakhstan (December 16, 1991); Kyrgyzstan (August 31, 1991); Tajikistan (September 9, 1991); Turkmenistan (October 27, 1991) and Uzbekistan (September 1, 1991).

[18]Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan were included in the sample. Mongolia was the part of the Soviet Union as well and some institutions include it into the Central

2.6 Results

The simultaneous estimation of equation 2.1 in our total sample is presented in Table 2.2. Explanatory variables explain variability in FDI and ODA equations quite well, at 80% and 63.5% respectively. We observe that the coefficient for ODA is highly significant, with a one unit increase raise FDI by 0.34 units. Since our model is in log-log form, estimates can be interpreted as elasticities. This means one percent invested in foreign aid would only induce 0.34% increase in FDI, which is relatively inelastic At first sight the elasticity appears very low, but upon careful inspection at the institutional and social-economic situation this result is plausible. This suggests that donors are at least trying to create investment atmosphere through their humanitarian projects in CA(5) economies.

From the ODA equation we infer that 0.49 percent increase in foreign aid is due to one percent increase in FDI - this is supported statistically. As one can easily observes, the same link produces different and richer results depending from which observation point we select. Most importantly, we try to capture the link on the regional level that depicts political decision making. Our elaboration on the result is that the ODA arrived earlier than FDI, because it is a support to assist countries at the beginning of transition in 1991. The FDI lagged behind due to uncertain political and economic situation in the first few years of independence. For that reason we started our analysis from 1992 to give lead time for ODA to be absorbed. Through their contacts and establishing offices, representations and embassies of donor countries made introduction of their foreign policies to host CA(5) economies.

The common logic of donor aid is that the aid should stimulate self-sustainable development. In another word, donors expect from aid recipients that they will have their own initiatives and stimulate economic/social progress after the aid term has finished. Agencies such as World Bank, IMF, ADB, UN, USAID and various embassies carry out their missions and have settled offices in CA(5). They served as a connection (or first-hand information) to private foreign investors to learn about these countries, make contacts, find the right people, and ultimately invest into these countries. Private investors, who are public MNEs, could not individually conduct their investment projects, because they had to deal with hidden uncertainty. We suggest that ODA

Asian group countries. We did not include Mongolia because it is more related to Afghanistan, northern-Pakistan, north-eastern Iran and north-western India, western parts of China and southern parts of Siberia (Russia) group. Source: http://en.wikipedia.org/wiki/Central-Asia, Accessed 15 December 2011.

helped them to mitigate these risks up to certain degree that are also shown by our empirical results. This fact is also illustrated in study of Asiedu et al. (2009) where they demonstrate that foreign aid indeed reduce adverse effect of expropriation risk on FDI. They found that ODA effect helped to mitigate host country governments' rigidities. For example, any foreign investor could rely on his embassy in CA(5) to get a back-support and assistance as the only legitimate "insiders" channel. Our estimates show that ODA had a very important role for FDI attraction in Central Asian region from the 1992-2009 period.

Table 2.2: SUR Regional Regression.

Dep.Var: FDI		**FDI**	**(B.SE)**	**(z)**	**P-value)**
ODA	γ_1	0.335	0.137	2.45	0.014
DOM	γ_2	0.89	0.084	10.6	0.00
GLOB	γ_3	0.028	0.021	1.31	0.19
YEAR	γ_4	0.136	0.06	2.25	0.024
CONSTANT	γ_0	-275.616	120.433	-2.29	0.022
Dep.Var: ODA		**ODA**	**(B.SE)**	**(z)**	**(P-value)**
FDI	β_1	0.489	0.215	2.27	0.023
DOM	β_2	0.061	0.241	0.25	0.799
GLOB	β_3	-0.002	0.024	-0.08	0.934
YEAR	β_4	-0.14	0.068	-2.06	0.039
CONSTANT	β_0	280.647	135.45	2.07	0.038
Dep.Var: DOM		**DOM**	**(B.SE)**	**(z)**	**(P-value)**
FDI	δ_1	0.871	0.084	10.36	0
ODA	δ_2	0.041	0.155	0.27	0.79
GLOB	δ_3	-0.027	0.02	-1.35	0.177
YEAR	δ_4	-0.102	0.059	-1.74	0.082
CONSTANT	δ_0	207.537	117.146	1.77	0.076
FDI		ODA		DOM	
Equation: N	75	Equation: N	75	Equation: N	75
R2	0.807	R2	0.6313	R2	0.8312
RMSE	1.187041	RMSE	1.379153	RMSE	1.147229
F-stat value	/P-509.71/0.0000	F-stat value	/P-142.14/0.0000	F-stat value	/P-516.82/0.0000

Note: FDI-real log of FDI per capita, DOM-log of real gross fixed capital formation per capita, ODA-log of real official development assistance per capita, GLOB-KOF globalization index. N-number of observations, R2-goodness of model fit, B.SE-bootstrapped standard errors (under 400 replications). RMSE-room mean square error. F-stat/P-value- shows whether the model's coefficients are statistically significant.

The positive sign of domestic investment variable (DOM) in FDI equation also makes sense, because improvements in domestic infrastructure, coupled with abandoned natural resources, would attract investors. This means domestic capital drives increases in foreign direct investment. This is natural according to us. Economies that are growing would be demanding more of FDI. In opposite, even though ODA grew over time we could not find positive effect of domestic investment (DOM) in foreign aid. One possible explanation is that at the early stages of economic development, transition countries are more concerned with economic growth and not human capital development, for example, complementary inputs. Countries' current accounts' have increased due to revenues from mineral endowments or other means, which brings increased foreign currency reserves. If so, this added to domestic savings which in turn would allow substantial investments directed into building infrastructure, plants, and facilities by local governments in later years.

Domestic investment is complemented by FDI shown by statistically significant positive sign at 0.87. This finding is also corroborated by looking at FDI equation. Foreign aid (ODA) does not seem to influence domestic investment. To be more precise, people are not informed enough to participate in money allocation and investment decisions in CA(5) in general. This is also likely due to the priority FDI receives in fulfilling the immediate needs of CA(5) economies. It also means that FDI has more power to instigate positive changes in local economies. Even though FDI is broadly considered as export oriented, which means that it is not oriented to serve local markets, it would render slight positive spillovers. The detailed mechanism of this process can be included in future studies.

Since FDI and ODA complement each other according to our findings, we surmise that increase of quality of foreign aid could prepare fertile grounds for FDI activities and vice versa, though indirectly. What is more important here is that they are not competing flows - FDI improves industrial and foreign aid helps human aspects of growing CA (5) economies.

2.7 Concluding Remarks

We were able to draw conclusions on the complicated task of FDI-ODA link on a regional level. The main conclusion of our paper is that, on a regional level, aggregate foreign aid had a minor facilitating effect, for example, complementing foreign direct investment in Central Asian economies. The reverse effect is also present, so we accept the finding of some positive association or link between FDI and ODA in the region. Our observation is supported by findings of Harms and Lutz (2006), especially, in amateur institutional environments that are present in Central Asian economies.

Another important observation from our study is that FDI flows positively affect complementing domestic investment. As it is well known that domestic investment determines the size of the stock of capital, and therefore helps determine the long-run growth. Thus, for example, foreign aid equally raises the local complimentary inputs quality such as education, health while foreign direct investment bring advanced technology and possibly shift the production frontier upward and ultimately contribute to a raise in efficiency and productivity. Regarding FDI, this also implies that domestic firms are learning to better combine external technology with domestic inputs in production process.

If our finding in the interaction of donor aid to foreign private investment flows nexus is true, then international humanitarian organizations indeed could boost positive changes in domestic economies in collaboration with multinational companies. This means better understanding in the role and value of donor aid could substantially reduce outflows, and increase its efficiency via a sort of public-private partnership. MNEs are most likely to be more collaborative with international donors operating in Central Asia and other developing economies around the world.

The future avenues for research on foreign transfers could include juxtaposing different models and estimations to results we obtained in the present study. It would be very interesting indeed to analyze the effect of disaggregated ODA on aggregate FDI, and also on disaggregated one if available data permit us doing so. Understanding which industries accommodate ODA are more complements to FDI, could give us clues on location decisions of foreign aid to donor agencies. Also, more in-depth studies in disaggregated FDI, such as Greenfield investment (building a plant, factory etc.) and portfolio investment (joint ventures, subsidiaries, branches) could shed better light on complex relationships and assist in advancing research in Central Asian economies.

2.8 Appendices

Table 2.3: Data Sources and Descriptions.

Variable	Name	Description	Source
FDI	FDI	The Foreign Direct Investment. The value of capital of MNEs in host country in real terms. US Dollars at current prices in millions.	UNCTAD
Official Development Assistance	ODA	Net official Development Assistance received and aid received, US Dollars at current prices in millions.	World Bank Development Indicators (WDI online)
Domestic Investment	DOM	Gross Fixed Capital Formation minus FDI inflows. This way we can obtain local investments by government and private sector into fixed assets and human capital less payments for foreign debt. US Dollars at current prices in millions.	UNCTAD
Globalization Index	Glob	Globalization Index by KOF.	KOF
Pop	Pop	Population.	UNCTAD
CPI	CPI	Consumer Price Index.	IMF

Table 2.4: Descriptive Statistics Summary:Total Sample.

Variable	Units	Obs.	Mean	Std. Dev.	Min.	Max.
FDI	million U.S$	90	1386.098	8860.164	-1.04715	82458.3
ODA	million U.S.$	90	3117.122	23620.93	0.366339	221794.4
DOM	million U.S.$	90	1198388	9383478	-1028.76	8.84E+07
Glob	0-100	85	38.42625	11.10762	15.14242	59.74965
Pop	million U.S.$	90	11.13199	7.945662	3.881973	27.12806
CPI	percent	90	2.759488	3.828602	1.00E-05	19.14858
Year	years	90			1992	2009

2.8.1 Variables of the Model

Dependent Variables

Foreign Direct Investment (FDI) - this is an aggregate per capita real value in current million of US dollars converted into real values dividing by Consumer Price Index (CPI) index. The reason for choosing flow and not stock value is because we seek to capture the link between FDI-ODA and we cannot do so in the case where FDI is stock, which means it is a part of domestic capital.

Official Development Assistance (ODA) - taken from UNCTAD database and in aggregate form. It includes what is actually received (and not disbursed meaning it was allocated, but not yet transferred to recipient county) as official development assistance and aid made by DAC donor countries. We use yearly aggregate data in this study. Variable was deflated by CPI and expressed in natural logarithmic form per capita.

Gross Fixed Capital Formation (Capital) - this variable is the domestic investment of the government into fixed assets such as plants, buildings, roads and infrastructure. Variable was deflated by CPI and expressed in natural logarithmic form per capita. Note that this variable is also in flow form and it is not a net value (after depreciation). It is investment to domestic capital stock.

Chapter 3

Determinants of Total Factor Productivity in Former Soviet Union Economies: A Stochastic Frontier Approach

Abstract[1] This paper investigates the process of GDP generation in Former Soviet Union (FSU) economies to provide understanding of the impact of technology channels on countries' efficiency. We apply a stochastic frontier approach to 15 FSU economies over the period 1995-2008, and we find that machinery imports and human capital improve a country's efficiency. Furthermore, we show that trade in capital goods and human capital also have a positive effect on total factor productivity (TFP), which, in turn, improves real GDP growth. Hence, our results suggest that FSU countries should improve public policies that provide incentives to invest in cross-country technology transfer and in domestic education in order to improve their economic growth. Additionally, our empirical evidence argues against the resource-curse hypothesis. We also show, by computing the efficiency change and technological change indices at the country level, that FSU economies are benefiting more from catching up to the best practice frontier than from exploiting technological progress.
JEL Classification: O33, O47, O57

Keywords: Eurasia, Former Soviet Union (FSU), Technology Channels, Total Factor

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Productivity (TFP), Stochastic Frontier Analysis

3.1 Introduction

Post-communist countries are challenged by complex tasks, which are, essentially, improving economic growth and reallocating resources to their best uses. (Campos and Coricelli, 2002). This mandate is also pertinent to the fifteen former Soviet Union (FSU) economies.[2] FSU countries are transition economies with a considerable disparity in economic output.[3] As faster economic growth is achieved when countries' productivity is improved, there is a need to identify which channels help to increase it. However, no robust econometric studies have investigated the process of generating output across different FSU countries and its determinants. Previous contributions provide either single-country or agricultural studies estimating total factor productivity (TFP) through growth accounting and neoclassical production modeling (Zhang, 1997; De Broeck and Koen, 2000; Iradian, 2007), parametric stochastic frontier analysis (SFA)(Danilin et al., 1985; Deliktas and Balcilar, 2005) or non-parametric data envelopment analysis (DEA)(Deliktas and Balcilar, 2005).

These approaches present some drawbacks. Those applying the Solow residual(Solow, 1956) neoclassical approach assume that all countries operate on the efficient frontier and under constant returns to scale; these assumptions seem to be too restrictive. The SFA/DEA studies are applied to either a single sector or to a single country, and, above all, they do not investigate which factors affect countries' productivity.[4] This paper aims to fill these gaps by applying a stochastic frontier approach to FSU economies and by analyzing the impact of different technology-transfer channels on productivity.

Many previous contributions emphasize the importance of technology-transfer channels for improving economic growth, especially in developing countries such as FSU economies. They consider two technology-transfer channels: foreign direct investment

[2]FSU economies in our study consist of: Armenia (ARM), Azerbaijan (AZE), Belarus (BLR), Estonia (EST), Georgia (GEO), Kazakhstan (KAZ), Kyrgyzstan (KGZ), Lithuania (LTU), Latvia (LVA), Moldova (MDA), Russian Federation (RUS), Tajikistan (TJK), Turkmenistan (TKM), Ukraine (UKR) and Uzbekistan (UZB). Country nomenclature and country codes in brackets are from the World Bank.

[3]The World Bank online database (2010) reports that the average yearly value of real GDP per capita in thousands of U.S. dollars for the period 1993-2007 of Estonia (6,153.58, highest) is twenty-seven-fold higher than that of Tajikistan (192.43, lowest).

[4]Furthermore, the non-parametric approach is deterministic and, hence, it does not take into account the impact of random shocks in the production model.

(FDI) and trade in goods and services. [5].In this contribution, we consider FDI and, as a proxy for transferring technology through trade, the imports of machinery and equipment. Furthermore, we also consider human capital since the well-known contributions of economic growth theory (Nelson and Phelps, 1966; Romer, 1986, 1990; Lucas, 1988; Barro, 1991, 2001; Benhabib and Spiegel, 1994; Barro and Sala-i Martin, 1995) point out the importance of the stock of human capital for economic growth.[6]. Hence, our goal is to test the impact of these channels (i.e., FDI, imports of machinery and equipment, and human capital) on countries' efficiency levels by applying a time-varying stochastic production frontier model (Battese and Coelli, 1995) to a panel data set composed of 15 FSU countries over a 14-year period (1995-2008). We estimate a production frontier and compute countries' technical efficiency levels. This econometric approach allows us to compute yearly TFP growth at the country level and, through its decomposition into efficiency change (EC) and technical change (TC), to derive the second-order effects of technology-transfer channels on TFP.

These are our main results. First, we provide evidence that the amount of imported machinery and equipment has a positive impact on technical efficiency in FSU countries. Second, human capital is a crucial factor in increasing technical efficiency, both alone and when combined with imports of machinery and equipment. Third, we find that the effect of FDI on technical efficiency of FSU economies is not statistically significant. This result is different from that of Mastromarco and Ghosh (2009), who, however, did not investigate FSU countries. Fourth, we show that trade both in machinery and equipment and in human capital have a positive second-order effect on TFP, through their positive first-order effect on the estimated countries' index of efficiency change (EC). The latter, in turn, has a positive and statistically significant effect on TFP. Fifth, given that the average efficiency change (EC) is positive and equal to 2.19% (yearly), while average technical change (TC) exhibits only a tiny positive increment (0.29% yearly), we provide empirical evidence that FSU economies are more effective

[5]The findings of (Hoekman et al., 2004) identify three channels of technology transfer that could boost economic growth and convergence of poor countries toward developed economies: (1) trade in goods and services, (2) foreign domestic investment (FDI), and (3) trade in knowledge via technology licensing. The theoretical foundations of international technology transfer were established by Romer (1990); Grossman and Helpman (1991, 1993); Aghion (1992). FDI is associated with fostering economic growth in the presence of certain economic, financial, and institutional characteristics of recipient countries Ellingstad (1997); Dunning (1993, 1998); Borensztein et al. (1998); Barrell (2000); Blomstrm (2001); Konings (2001); Lipsey (2002); Jensen (2006); Navaretti and Venables (2004); Büthe (2008).

[6]Economists' early notable contributions to the theory and formation of human capital on the micro level were brought by (Mincer, 1958), (Schultz, 1960), (Denison, 1962) and (Becker, 1975).

in catching up to the efficient frontier rather than in exploiting technological progress. Sixth, we find that FSU countries have positive TFP growth rates (+2.37% yearly) for the 1995-2008 period, a much bigger estimate than those obtained in previously mentioned FSU studies.[7] Finally, we found no support for the resource-rich curse hypothesis: on the contrary, our results demonstrate a positive relationship between abundant resource possessions and economic development.

Our results yield the following policy implications. First, since openness to trade in capital goods exerts positive results on technical efficiency and, hence, on TFP, FSU countries should provide further incentives to facilitate terms of trade. Second, investments in education to raise labor capabilities are crucial for better absorbing foreign technology, especially for exploiting the benefits coming from imported foreign technology.[8]

Our paper is closely related, to the best of our knowledge, with few previous contributions. Mastromarco and Ghosh (2009) were the first to analyze the impact of FDI, imported *R&D*, imports of machinery and equipment, and human capital as channels of technology transfer in 57 developing countries in Africa, Asia, and Latin America during 1960-2000.[9] (Deliktas and Balcilar, 2005) studied 25 transition post-communist economies (including our sample countries) by using both stochastic frontier analysis (SFA) and data envelopment analysis (DEA) methods for the 1991-2000 period. However, they did not analyze the impact of technology channels on countries' productivity. Hence we extend these studies in several directions. First, we focus on technology channels, and we enlarge the time horizon up to 2008. Second, we decompose output growth into efficiency change, technical change, and TFP change. Third, we investigate the relation between country efficiency scores, TFP, and growth

[7]For example, De Broeck and Koen (2000) report -6.6% TFP growths for FSU countries between 1991-1997, and Deliktas and Balcilar (2005) found -2% for 25 transition economies, including FSU, for 1991-2000.

[8]Absorptive capacity is considered an important component in technology adoption and diffusion from developed countries. Previous studies point out that on the level of economic development, human capital resources and business environment are factors affecting absorptive capacity. For a more detailed discussion, please consult (Benhabib and Spiegel, 1994; Xu, 2000; Eaton and Kortum, 2001; Keller, 2004; Nunnenkamp, 2004; Kneller, 2005; Kneller and Stevens, 2006). According to international trade theory, openness to trade positively contributes to economic growth and reduces barriers to technology adoption that are major factors in differences in per capita income(Parente and Prescott, 1994). The recent study by Calderón and Poggio (2010) finds support for the positive impact of trade on the economic growth of 160 countries over 1960-2010.

[9]We do not use local *R&D* investment due to unsystematic reforms in the *R&D* sector in FSU countries (see Yegorov (2009) for Russia and Ukraine) and problems with lack of data. However, looking at most of our FSU countries we could see that *R&D* investments were scarce.

rates.

The paper is organized as follows. In Section 3.2, the econometric model is presented and our research questions are stated. In Section 3.3, we discuss the data. Section 3.4 delivers our econometric results. Section 3.5 concludes the paper. In the Appendix, we describe data sources and provide some further econometric results.

3.2 Econometric Model

Technical efficiency refers to the ability to maximize outputs from a given vector of inputs or to minimize input utilization in the production process of a given vector of outputs (Coelli et al., 2005). Estimation is usually done by applying either a parametric approach (i.e., SFA) or a non-parametric approach (i.e., DEA).

The main advantage of SFA (see the seminal contributions by (Aigner et al., 1977; Meeusen and van den Broeck, 1977) is that, differently from DEA, it considers the possible influence of noise on the shape and positioning of the frontier, thanks to its two-component error term: a symmetric term ($v_{i,t}$) representing noise and an asymmetric term ($u_{i,t}$) accounting for technical efficiency. [10]

Moreover, SFA easily allows the utilization of panel data and the incorporation of variables that are neither inputs to the production process nor outputs of it but which affect technical efficiency (Kumbhakar and Lovell, 2000).

Furthermore, the stochastic frontier approach is also more appropriate than the neoclassical growth-accounting technique, allowing introduction of shocks and unobserved cross-country effects in modeling, which is important on country-level studies. Moreover, SFA allows the estimation of the TFP change as the combination of its two main sources, which are technical change (i.e., the shift in the production function), and efficiency change (i.e., the movement toward or away from the frontier). On the contrary, the growth-accounting technique identifies technological progress in the Solow residual-i.e., the change of the output level that cannot be explained by input growth rates. Since no distinction is possible between technical and efficiency change, this would be reasonable only if all countries are producing on their frontier.

The stochastic frontier model could be expressed in case of countries' production functions as:

[10] For a comprehensive review of stochastic production functions, see (Førsund et al., 1980; Schmidt and Sickles, 1984; Atkinson and Cornwell, 1994a,b) address modeling and estimation of SFA for panel data production frontiers.

$$Y_{i,t} = f(L_{i,t}, K_{i,t}) + v_{i,t} - u_{i,t} \tag{3.1}$$

where $Y_{i,t}$ is the output observed at time t of country i, $L_{i,t}$ (labor) and $K_{i,t}$ (capital) are the inputs observed at time t of country i, and the term ($v_{i,t}$ - $u_{i,t}$) represents the composed error term. $v_{i,t}$ are random variables that are assumed to be iid, $N(0, \sigma_v^2)$, and independent of the uit; uit are assumed to be independently distributed as truncations at zero of the $N(m_{i,t}, \sigma_u^2)$ distribution and represent technical efficiency. Furthermore, it is possible to investigate the determinants of efficiency by applying a single-stage, maximum-likelihood estimation procedure. (Kumbhakar et al., 1991; Reifschneider and Stevenson, 1991) propose stochastic frontier models in which the efficiency levels are expressed as an explicit function of a vector of determinants and a random error. In particular, we adopt the (Battese and Coelli, 1995) specification because it extends the model proposed by (Kumbhakar et al., 1991) allowing the utilization of panel data. According to this model, efficiency is given by the following equation:

$$u_{i,t} = \delta \mathbf{z}_{i,t} + \omega_{i,t} \tag{3.2}$$

where $\mathbf{z}_{i,t}$ is the vector of explanatory variables, δ is the vector of coefficient to estimate, and $\omega_{i,t}$ is the error term.[11] Our main goal is to understand whether technological transfer channels can affect the GDP production through their effect on technical efficiency. Hence, we would like to test the following hypotheses.

Hypothesis #1. Imports of machinery and equipment (IME) reduce technical inefficiency in an FSU country's production by enhancing its technological endowment.

Hypothesis #2. Human capital (HC) plays a positive role as a facilitating channel of technology diffusion by reducing technical inefficiency in FSU economies.

Hypothesis #3. Inward aggregate foreign direct investment (FDI) has a stimulating effect on countries' technical efficiency.

In order to test Hps. 1-3, the mean of the truncated normal representing the distribution of the inefficiency term $u_{i,t}$ can be expressed, according to Eq.(3.2), as follows:

[11] $\omega_{i,t}$ are random disturbances that follow truncated normal or half-normal distribution, $N(0, \sigma^2)$, so that the truncation point is $-\delta \mathbf{z}_{i,t}$, making $\omega_{i,t} \geq -\delta \mathbf{z}_{i,t}$. According to (Battese and Coelli, 1995), this condition should be maintained for $u_{i,t}$ to be a non-negative truncation of the $N(\delta \mathbf{z}_{i,t}, \sigma_u^2)$.

$$u_{i,t} = \alpha_0 + \alpha_1 FDI_{i,t} + \alpha_2 IME_{i,t} + \alpha_3 HC_{i,t} + \alpha_{13} HC \times FDI_{i,t} + \alpha_{23} HC \times IME_{i,t} + \omega_{i,t} \quad (3.3)$$

where FDI represents foreign direct investment, IME the imports of machinery and equipment, and HC the human capital stock. The variables $HC \times FDI$, and $HC \times IME$ are interaction terms. One important issue in the academic debate regarding developing countries is the so-called resource-curse hypothesis (Sachs and Warner, 1995, 2001).[12] The latter comes from the observation that countries rich in natural resources tend to perform badly. The explanation for the curse is a crowding-out argument: there are some variables that drive economic growth and the developing countries' richness in natural resources crowds out such activities. For instance, natural resource abundance might crowd out innovation or entrepreneurial activities, which are economic growth drivers. We aim to test the resource-curse hypothesis for FSU economies, since some of them are rich in natural resources, mainly oil and gas. For this purpose, we divide our sample of FSU countries into two groups-resource-rich (RR) and non-resource-rich (NRR)[13] - and test the following hypothesis.

Hypothesis #4. Resource-rich countries (RR) are less productive than non-resource-rich countries (NRR).

To investigate this hypothesis, we introduce a dummy variable in our estimated frontier: (D_{rr}) is equal to 1 if the country is classified as resource-rich (RR) and 0 otherwise. Following the approach of (Mastromarco, 2008; Mastromarco and Ghosh, 2009), we adopt a translog specification of the production function. Hence, the production function in Eq.(3.1) becomes as follows:

[12] Sachs and Warner (1995, 2001) papers spurred research on the natural-resource curse hypothesis or whether resource richness is stopping increased productivity and economic growth in developing countries. In relation to transition economies, this phenomenon is considered to bring negative effects on economic growth, but empirical research points to differentiated conclusions that are often against resource curse and in favor of resource dependence (Neumayer, 2004; Bulte et al., 2005; Stijns, 2005, 2006; Brunnschweiler, 2008; Brunnschweiler and Bulte, 2008; Murshed and Serino, 2011)

[13] We have five resource-rich (RR) countries (that are considered energy exporters) in our study-i.e., Russia, Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan. This leaves ten countries as non-resource-rich (NRR). We classify our sample based solely on petroleum and gas possessions. As stated by Sachs and Warner (2001), the rents obtained from oil and gas exports may induce rent seeking and possible corruption from government officials rather than pro-growth reforms.

$$ln(Y_{i,t}) = \beta_0 + \beta_1 ln(L_{i,t}) + \beta_2 ln(K_{i,t}) + \beta_3 t + \frac{1}{2}\beta_{11} ln(L_{i,t})^2 + \frac{1}{2}\beta_{22} ln(K_{i,t})^2 + \frac{1}{2}\beta_{33}(t)^2 + \beta_{12} ln(L_{i,t}) \times ln(K_{i,t}) + \beta_{13} ln(L_{i,t}) \times t + \beta_{23} ln(K_{i,t} \times t) + \upsilon_{i,t} - u_{i,t} \tag{3.4}$$

Hence, we obtain the time-varying technical efficiency (TE) scores for country i at time t as follows:

$$TE_{i,t} = \exp(-u_{i,t}) \tag{3.5}$$

Technical efficiency change (EC) between period t and period $t-1$ can be expressed as:

$$EC_{i,t} = \frac{TE_{i,t}}{TE_{i,t-1}} \tag{3.6}$$

According to (Coelli et al., 1998, 2005), we compute the technical change (TC) index as the geometric mean between two consecutive years of partial derivatives of the production function with respect to time.[14] Hence, we have:

$$TE_{i,t} = \sqrt{(1 + f_t(Y_{i,t}, L_{i,t}, K_{i,t}, t, \beta_0, \beta)) \times (1 + f_{t-1}(Y_{i,t-1}, L_{i,t-1}, K_{i,t-1}, t, \beta_0, \beta))} \tag{3.7}$$

where f_t is the partial derivative of the translog production function with respect to time t, and f_{t-1} is the partial derivative of the translog production function with respect to time $t-1$.

The estimation of TFP is essential in order to investigate empirically the role of the technology-transfer channels in explaining countries' productive performances. We compute it as the product of technical efficiency change and technological change (Seo et al., 2010):

[14] Nishimuzi and Page (1982) show another formulation of the technical change index in which instead of the geometric mean they use the arithmetic mean. Furthermore, they calculate TC using a deterministic frontier. Our measure is for the stochastic frontier approach, which was also used in the recent study by Seo et al. (2010), where the authors justify the use of the geometric mean due to the fact that the technological change is considered firm specific. Their intuition is that technology is common to all firms, but a change in technology affects each firm differently if the production frontier does not shift in a parallel manner.

$$TFP_{i,t} = EC_{i,t} \times TC_{i,t} \tag{3.8}$$

We will analyze second-order effects of technology-transfer channels on countries' TFP. Their first-order effect on TE is estimated through Eqs. (3.2), (3.3), and (3.5). Hence, if we define $\frac{\partial TE}{\partial z}$ as the technology-transfer channel $\mathbf{z}'s$ first-order effect on technical efficiency, we have that (from Eq. (3.5)):

$$\frac{\partial TE}{\partial z} = -\frac{\partial u_{i,t}}{\partial z} \times \exp^{-u_{i,t}} \tag{3.9}$$

Hence, if for instance ($\frac{\partial TE}{\partial z} < 0$), then the factor $\mathbf{z}$ increases country i's efficiency level. From Eq.(3.6), we can write the following effect of $\mathbf{z}$ on EC (after some simplifications and assuming negligible per-country changes in imports of transfer channels):

$$\frac{\partial EC}{\partial z} = \frac{(\frac{\partial TE_t}{\partial z} \times (TE_{t-1} - TE_t))}{(TE_{t-1})^2} \tag{3.10}$$

Hence, from Eq. (3.10), the effect of a variation in transfer channel $\mathbf{z}$ on EC is positive if the variation of TE as function of $\mathbf{z}$ is positive (i.e., the sign of Eq. (3.9) is positive)[15]. This means that if TE increases as a function of mathbfz, EC, in turn, also rises (i.e., the impact of a transfer channel mathbfz on EC has the same sign as its effect on TE).

From Eq. (3.3), it is clear that time has no impact on the inefficiency scores and, hence, TC is not influenced by the transfer channels. We can then write the following expression to identify the impact of transfer channels on TFP (from Eq.(3.8)):

$$\frac{\partial TFP}{\partial z} = \frac{\partial EC}{\partial z} \times (TC) + \frac{\partial TC}{\partial z} \times (EC) \tag{3.11}$$

with ($\frac{\partial TC}{\partial z} = 0$, so that only the first term in the right-hand side of Eq.(3.11) matters. Hence, the impact of a transfer channel $\mathbf{z}$ on TFP has the same sign as its effect on TE. We will test these effects empirically.

3.3 Data

We build up a panel of 15 FSU countries: Armenia (ARM), Azerbaijan (AZE), Belarus (BLR), Estonia (EST), Georgia (GEO), Kazakhstan (KAZ), Kyrgyzstan (KGZ),

[15] We assume that the difference between TE_{t-1} and TE_t is negative.

Lithuania (LTU), Latvia (LVA), Moldova (MDA), Russia (RUS), Tajikistan (TJK), Turkmenistan (TKM), Ukraine (UKR), and Uzbekistan (UZB). We consider the period 1995-2008 because the starting period is already 4 years later than 1991, when the FSU countries became independent from the USSR (ex-Soviet Union). This time spell was enough for market forces to play a role in macroeconomic stabilization (Bodenstein, 2003, p.240). Our data source is derived from the UNCTAD database and World Bank Development Indicators online (2010). The sources and descriptions of data are presented in the Appendix at the end of the paper (Table 3.9). The sample is chosen following two criteria. First, all of the 15 included countries shared the same political and economic system under the Soviet Union before 1991. Second, we follow the principle of initial conditions introduced by (De Melo et al., 1997; Blonigen and Wang, 2004).[16] Our empirical approach is a panel-data stochastic frontier analysis (Cornwell and Sickles, 1990; Kumbhakar, 1990; Kumbhakar et al., 1991; Battese and Coelli, 1992; Simar, 1992; Hadri et al., 2003; Greene, 2005)

The dependent variable representing the country's output level is the real GDP. The independent (input) variables of countries' production functions are physical capital (K) and labor force (L). Physical capital (K_{it}) is measured in terms of accumulated capital according to the perpetual inventory method (PIM):

$$K_{i,t} = (1 - \xi)K_{i,t-1} + I_{i,t} \tag{3.12}$$

where, ξ is the depreciation rate set to 10% and $I_{i,t}$ is real gross capital formation.[17] The PIM method follows (Chowdhury, 2008), and the calibration of the depreciation rate is in line with (Bu, 2006), who analyzed seven developing countries. Labor (L) is measured in terms of total labor force in millions.

[16]Initial conditions are an important factor and should be taken into account when comparing countries that had similar historical and socioeconomic development. In a sense, this helps to reduce disparity in unobserved intrinsic country effects.

[17]Since our sample starts from 1995, we begin measuring the capital accumulation from 1992 using a 10% depreciation rate for capital. For $K_{i,1992}$, we had to depreciate $I_{i,1992}$ only due to the unavailability of statistics for $K_{i,1991}$. We underline that FSU economies experienced physical capital destruction during transition to independence in 1991 and had to build or re-build most of physical capital. Regarding the depreciation rate of capital, for example, Bu (2006) reports the mean of capital depreciations based on a sample of firms as Cote dIvoire (27.3%), Ghana (34.4%), Zimbabwe (11.8%), Kenya(-14.9%), Indonesia (84%), Philippines (25.8%), and South Korea (9.3%). On the other hand, the study by Mastromarco and Ghosh (2009) uses 4% for 57 developing countries of Africa, Asia, and Latin America. We believe that measurement errors in capital stock are not correlated with efficiency scores as pointed out by (Mastromarco and Ghosh, 2009, note 16). For that reason, we surmise that our variable captures the major part of its development.

We consider as technological transfer determinants of efficiency foreign direct investments (FDI), imports of machinery and equipment (IME), and human capital (HC). FDI is the aggregate foreign direct investments in the host country measured as percentage of incoming countries' GDP. Imports of machinery and equipment are measured in thousands of U.S. dollars. We specifically chose only IME, because transition economies had a weak technological basis and obtained new equipment from developed countries in the early years. HC is an index accounting for knowledge accumulation. According to (Verdier, 2008), it is measured in stock form in two steps as follows:

$$HC_{i,t} = ln(\frac{\rho_{i,t}}{(1+\eta_{i,t})*(1-\gamma)-(1-\tau)})$$
$$\rho_{i,t} = ln(\frac{(PrYr_{i,t}*P_{i,t})+(SdYr_{i,t}*S_{i,t})+(HsYr_{i,t}*H_{i,t})}{\sum Yr_{i,t}}) \quad (3.13)$$

where $P_{i,t}$, $S_{i,t}$ and $H_{i,t}$ mean, respectively, primary, secondary, and high school gross enrollment rates (according to Barro (1993); Barro and Lee (2010)), and $PrYr_{i,t}$, $SdYr_{it}$, and $HsYr_{i,t}$ are the years of schooling at primary, secondary, and high schools, which are different and varying for each country and each year.$\sum Y_{i,t}$ is the sum of each year of schooling varying by country and year. $\nu_{i,t}$ is the labor growth rate, γ is the exogenous rate of technological progress set to 2%, and τ is the depreciation rate of human capital. We calibrate it as equal to 5%: this is slightly higher than the rate used in other contributions (e.g., Verdier (2008)) because FSU countries experience faster rates of human capital depreciation (Yegorov, 2009).[18] Table 3.1 shows the descriptive statistics of the variables included in the analysis.

Notice that all variables have been divided by their geometric mean in order to avoid convergence problems. This means that coefficients of first-order regressors can be explained as output elasticities evaluated at the sample mean (Alvares et al., 2004).

[18] Verdier (2008) studies the factors driving long-term capital flows for the 66 developing countries of Asia and Latin America and uses 3% for the depreciation rate τ in the calculation of the accumulated human capital stock variable.

Table 3.1: Data Summary.

Variable	Units	Obs	Mean	Std. Dev.	Min	Max
RGDP	million U.S.$	210	29,420.13	74,872.69	715.7888	429,549.20
Labor	million people	210	9,227.36	18,085.34	642.835	76,078.74
Capital	million U.S.$	210	6.87E+10	1.80E+11	1.25E+09	1.11E+12
FDI	% of GDP	210	27.21926	21.91189	0.359693	140.4942
IME	thousands U.S.$	210	4,142.57	1.24E+07	40.132	1.29E+08
HC	index	210	46.5152	37.01572	22.76206	442.9474

Note: RGDP - real gross domestic product, Labor - total labor force, Capital - accumulated capital stock, FDI - aggregate inward foreign direct investment, IME - imports of machinery and equipment, and HC - accumulated human capital stock. *Source*: own calculations.

3.4 Empirical Results and Discussion

Table 3.2 shows the results of our econometric approach represented by Eqs.(3.2)-(3.4)-i.e., Model (1). Furthermore, for comparative purposes, we also ran a second model-i.e., Model (2)-where factors affecting inefficiency and the resource-rich dummy are not considered.[19] As far as Model (1) is concerned, notice that the relevant role of technical efficiency is confirmed by both the magnitude and the significance of γ-i.e., the parameter depending on the variability of the two components of the error term ($\gamma = \frac{\sigma_u^2}{\sigma^2}$): a value of $\gamma = 0.948$ implies that 94.8% of the distance from the frontier is explained by technical inefficiency.[20] This result confirms the importance of considering inefficiency in classical production functions. The relevant role of inefficiency was also confirmed by Model (2): again, γ is statistically significant and very high. Furthermore, we also test the hypothesis of a Hicks-neutral production function with no technical change, and both hypotheses are rejected (see Table 3.3).[21]

Looking at inputs' first-order coefficients of Model (1), we observe that both capital (K) and labor (L) are significant and have the expected positive sign. This means that, as expected and pointed out by previous works (Mastromarco, 2008; Mastromarco and Ghosh, 2009; Deliktas and Balcilar, 2005), they positively contribute to producing GDP. Notice that the greater magnitude of the accumulated capital stock (K) with respect

[19] We employed the R software package Frontier written by Tim Coelli and Arne Henningsen to obtain our estimates for 15 FSU countries for the period 1995-2008. For producing graphs and statistical tests, STATA software was utilized.

[20] If $\gamma = 0$, then it means that all deviations from the stochastic production frontier are due to the statistical noise part of the composite error term $v_{i,t}$ of Eq. (3.1).

[21] Notice that we also check whether our translog specification was the best choice (for example, over Cobb-Douglas) looking at σ^2, that is also significant. This points out that the translog specification of the production function could be used in assessing the inefficiency.

Table 3.2: Efficiency Effects' Stochastic Frontier Results.

		Model 1		Model 2	
Variable	Parameter	Estimate	St. Error	Estimate	St. Error
Constant	β_0	0.2767*	0.1333	0.7460***	0.0924
$ln(L)$	β_1	0.1695*	0.0818	0.5138***	0.0986
$ln(K)$	β_2	0.2412*	0.0952	0.2983***	0.0634
t	β_3	0.0305	0.0301	-0.0138	0.0095
$ln(L)^2$	β_{11}	0.1564*	0.0702	-0.2533***	0.0746
$lnL \times lnK$	β_{12}	0.0782	0.0537	0.1427***	0.032
$lnL \times t$	β_{13}	-0.0134†	0.0079	-0.0114**	0.004
$ln(K)^2$	β_{22}	-0.0534	0.054	-0.0268	0.0384
$lnK \times t$	β_{23}	0.0174**	0.0062	0.0054	0.0036
t^2	β_{33}	-0.003	0.003	0.0048***	0.0009
Dummy	D_{rr}	0.3330***	0.0563		
ZIntercept	α_0	0.9166***	0.1849		
$ZFDI$	α_1	-0.0377	0.0504		
$ZIME$	α_2	-0.1552*	0.066		
ZHC	α_3	-0.5963***	0.15		
$ZHC \times FDI$	α_{13}	0.1989***	0.0552		
$ZHC \times IME$	α_{23}	-0.2529***	0.0572		
$Sigma^2$	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.0794***	0.0063	1.1661*	0.4528
Gamma	$\gamma = \sigma_u^2/\sigma^2$	0.9480***	0.1126	0.9947***	0.0021
Log − Likelihood	*LogL*	15.4591		187.6503	

Note:Significance levels: *** - 0.1%, ** - 1%, * - 5% and † -10%. The upper part of Table 3.2 gives the estimated coefficients (β) for Eq. (3.4)-i.e., a translog production function. All the variables are in logarithmic form, except the time variable (t). The second part of Table 3.2 shows the estimated coefficients for the **Z** variables (α) representing inefficiency (Eq. 3.3). FDI-foreign direct investment (% of GDP), IME-machinery and equipment imports measured in thousands of U.S. dollars, and HC-accumulated human capital stock calculated according to formula (3.13).*Source*: own calculations.

to labor (L) (0.24 versus 0.17) may be related to the importance of gross domestic investments in FSU economies.

Concerning second-order and interaction coefficients, the variables that are statistically significant are labor (L^2) and the interaction between capital and time. In Model (2) first-order coefficients are again statistically significant and greater in magnitude. This means that without considering the factors affecting inefficiency, we get an upward bias in the impact of inputs on GDP.

Table 3.3: Tests for Hicks-Neutral Production Function and No Technical Change.

Null Hypothesis (H0)	Log-Likelihood[a]	Test Statistic[b]	Critical Value(5%)[c]	d.f.	Decision
H0:Hicks-neutral production function $\beta_{13} = \beta_{23} = 0$	-18.962	-7.016	5.138	2	H0 rejected
H0:No technical change $\beta_{13} = \beta_{23} = \beta_{33} = \beta_3 = 0$	22.823	-14.727	8.761	4	H0 rejected

Note: [a] The magnitude to Log-Likelihood under H0. [b] The test statistic λ was calculated by the following formula: - 2*[LogLikelihood(H0)- LogLikelihood(H1)]. H0 is the log-likelihood from the restricted model and H1 is the log-likelihood from Translog with non-neutral technical change. H1 in our model is 15.459. We reject the H0 if our test statistic is bigger than critical value. [c] Critical values were taken from Kodde and Palm (1986) for the 5% level of significance. d.f. stands for degrees of freedom. *Source*: own calculations.

3.4.1 Elasticities and Substitutability of Inputs

According to (Morrison et al., 2000), we compute the output elasticities from Eq. 3.1 (in order to obtain the percentage change in the output level due to a 1% increase in the input j) as follows:

$$\varepsilon_{y,x_j} = \frac{\partial lny}{\partial lnx_j} = \frac{\partial y}{\partial x_j} \times \frac{x_j}{y} \tag{3.14}$$

The variable (ε_{y,x_j}) may be interpreted as an indicator of the returns to input x_j. This varies by observation and Table 3.4 only shows the average values across the sample. Notice that the elasticities for labor and capital have the expected positive sign that could be interpreted as their specific contribution to production. It is important to underline that the impact of capital on GDP in FSU countries is 10 times greater than the impact of labor.

Table 3.4: Average Output Elasticity and Substitutability of Labor(L) and Capital(K).

Inputs	Labor (L)	Capital (K)	Sub_l, k of Labor (L) and Capital (K)
ε_y, x	0,0425	0,4064	0.1046

Note:$\varepsilon_{y,x}$ is the average output elasticity with respect to inputs, labor (L), and capital (K). $Sub_{l,k}$ is the substitutability of labor and capital inputs from the below equation. *Source*: own calculations.

Moreover, since the marginal product of input j is $MP_j = \frac{\partial y}{\partial x_j} = \frac{\partial(lny)}{\partial(lnx_j)} \times \frac{y}{x_j}$ and the ratio between the marginal product of labor and the marginal product of capital reflects the slope of the isoquants in the labor-capital space (i.e., the marginal rate of substitution), the ratio between the elasticities of labor and capital can be interpreted as a normalized indicator of substitutability, as in (Grosskopf et al., 1995):

$$Sub_{L,K} = \frac{MP_L}{MP_K}\frac{L}{K} = \frac{\varepsilon_y L}{\varepsilon_y K} \tag{3.15}$$

In our sample, the ratio between the average elasticities of labor and capital is equal to about 0.10, meaning that one unit of labor is compensated, on average, by an extra 0.1 unit of capital.

3.4.2 Technology Channels and Efficiency

The results related to Model (1) also show the obtained empirical evidence regarding Hypotheses. #1-4-i.e., on the determinants of technical efficiency and on the resource-curse hypothesis (Table 3.2). Notice that both imported machinery and equipment and human capital have negative, statistically significant coefficients. Hence, we provide evidence that they both have a positive impact on technical efficiency. This implies that Hypotheses #1 and #2 are positively verified. In contrast, the coefficient of FDI is not significant, which rejects our Hypothesis #3.

Interestingly, HC has a greater impact on efficiency than IME. This result highlights the greater importance of human capital also for an efficient use of inputs. As for the non-significance of FDI, this could be due to the fact that multinational enterprises (MNE) enjoy rents in nascent markets of FSU economies. Further possible explanations could be that foreign investors are vertically oriented and not targeted to local market services. These arguments are in line with the study of (van Pottelsberghe de la Potterie and F., 2001), who conclude that FDI investors tend to take advantage of the technology base of domestic markets rather than to diffuse the technological advantage.

Last, notice that both interaction terms $HC \times FDI$ and $HC \times IME$ are statistically significant, but with opposite signs. The interaction between HC and FDI has a negative effect on efficiency, which could mean that the domestic human capital employed in foreign companies within FSU economies does not spread outside the necessary knowledge for a better use of inputs. On the other hand, the interaction term $HC \times IME$ has a positive effect on efficiency. This is exactly the opposite of the previous result: if domestic human capital is employed to cooperate with imported capital goods in domestic activities, this allows the disclosure of a better use of inputs.

Regarding the well-known debate on the resource-curse hypothesis in developing countries, the dummy variable has a statistically significant and positive coefficient (see Table 3.2). This suggests that countries richly endowed with natural resources produce more GDP than non-resource-rich countries. Notice that, on average, resource-rich countries' technical efficiency is greater than that of non-resource-rich ones by 18.8% (0.63 versus 0.53, Table 3.5). Hence, we reject also Hypothesis #4. This means that we find support for rejecting the resource-curse hypothesis for FSU countries during the period 1995-2008, differently from previous contributions.[22]

Table 3.5 displays the estimated technical efficiency (TE) scores according to Eq. (3.5), ranging from 0 to 1 (full efficiency-i.e., being on the production frontier). None of our sample economies are fully efficient. Table 3.10 in the Appendix also shows that on average technical efficiency has increased by about 21% from 1995 through 2008. The mean efficiency for the whole sample over these years was 0.563322[23], as indicated in Table 3.5 and in Fig. 3.1 (the mean of the continuous line). We also observe a gradual increase in technical efficiency after 2000.

According to the estimated technical efficiency scores, FSU countries that are close to Europe are more efficient than the ones closer to Asia, since on average, for the period 1995-2008, the leaders are Russia (94.4%), Lithuania (94.1%), Ukraine (85.4%), and Latvia (77.7%). Surprisingly, we observe an unexpected high level of efficiency from Uzbekistan (76.6%), a country that is described as a controlled economy. In contrast, Moldova (22.5%), Tajikistan (22.9%), Kyrgyzstan (27.6%), Turkmenistan (31.4%), and Armenia (34.3%) are the least efficient.[24]

For a more detailed benchmarking, countries' estimated efficiencies have been partitioned into two sub-periods-1995-2000 and 2001-2008-due to the fact that we observed the growth shift in technical efficiency scores in 2000 (see Fig. 3.1). Notice that between these periods notable improvements in efficiency were demonstrated by Tajikistan (+73.2%) and Azerbaijan (+55.8%). Surprisingly, only a little increase in efficiency is observed for the Baltic States countries; for example, Latvia (+0.49%), Estonia (+0.79%), Lithuania (+1.83%). Furthermore, we also observe some decreases:

[22]For example, a similar result to ours has also been found for other resource-rich countries in previous studies by (Brunnschweiler, 2008; Brunnschweiler and Bulte, 2008), underlying the positive direct relationship between economic growth and natural resource abundance.

[23]For Model (2) in Table 3.2, the mean efficiency for the whole sample over 1995–2008 is equal to 0.50, which is slightly lower than from our main model of interest.

[24]These low technical efficiency scores could also be correlated with the fact that Armenia, Azerbaijan, Georgia, Moldova, Tajikistan, and Ukraine (except Turkmenistan) were involved in prolonged interstate violent conflicts.

Table 3.5: Average Efficiency and TFP Decomposition for FSU Economies over 1995-2008.

	Technical Efficiency (TE)			Efficiency Change (EC)			Technical Change (TC)			Total Factor Prod.(TFP)		
Country/Period	95-00	01-08	95-08	95-00	01-08	95-08	95-00	01-08	95-08	95-00	01-08	95-08
Armenia[c,f]	0.28	0.39	0.34	1.00	1.06	1.04	0.99	0.99	0.99	1.00	1.04	1.03
Azerbaijan[*,c,f]	0.34	0.53	0.45	1.01	1.11	1.07	1.00	1.00	1.00	1.02	1.11	1.07
Belarus[b,e]	0.66	0.77	0.73	1.01	1.03	1.02	1.02	1.01	1.01	1.03	1.04	1.03
Estonia[b,e]	0.49	0.49	0.49	0.98	1.01	1.00	1.02	1.02	1.02	1.00	1.03	1.02
Georgia[b,e]	0.42	0.45	0.43	0.98	1.04	1.02	0.99	0.99	0.99	0.97	1.03	1.01
Kazakhstan[*,b,e]	0.60	0.75	0.68	0.99	1.03	1.02	1.03	1.01	1.02	1.02	1.05	1.03
Kyrgyzstan[a,e]	0.24	0.31	0.28	1.03	1.04	1.04	0.98	0.97	0.98	1.02	1.01	1.01
Lithuania[b,e]	0.93	0.95	0.94	0.99	1.01	1.00	1.02	1.02	1.02	1.01	1.02	1.02
Latvia[b,e]	0.77	0.78	0.78	0.97	1.01	1.00	1.01	1.01	1.01	0.99	1.02	1.01
Moldova[a,d]	0.21	0.24	0.23	0.95	1.04	1.01	0.99	0.98	0.99	0.94	1.03	0.99
Russia[*,a,e]	0.95	0.94	0.94	0.99	1.00	1.00	1.04	1.02	1.03	1.03	1.03	1.03
Tajikistan[a,d]	0.16	0.28	0.23	1.00	1.08	1.05	0.98	0.96	0.97	0.99	1.04	1.02
Turkmenistan[*,b,e]	0.26	0.35	0.31	0.99	1.09	1.05	1.02	1.00	1.01	1.01	1.09	1.06
Ukraine[a,d]	0.79	0.90	0.85	0.96	1.03	1.00	1.02	1.01	1.01	0.98	1.03	1.01
Uzbekistan[*,b,e]	0.71	0.80	0.76	0.98	1.04	1.02	1.00	0.99	0.99	0.98	1.03	1.01
Mean A	0.52	0.60	0.56	0.99	1.04	1.02	1.01	1.00	1.00	1.00	1.04	1.02
Mean RR*	0.57	0.67	0.63	0.99	1.05	1.03	1.02	1.00	1.01	1.01	1.06	1.04
Mean NRR	0.50	0.56	0.53	0.99	1.03	1.02	1.00	1.00	1.00	0.99	1.03	1.02

Note:The 95-08 stands for 1995-2008, which is average value for our estimation's time dimension. Mean A is the arithmetic mean of the sample. Mean RR^* is the arithmetic mean for the resource-rich group. Countries with asterisks * belong to the resource-rich group. Mean NRR is the non-resource-rich group countries' arithmetic mean. The superscripts: [a,b,c,d,e,f] are related to the real GDP growth groups and are presented in separate Table 3.8.*Source*: own calculations.

Russia has decreased by -0.31%. Interestingly, when we divide the sample into resource-rich (RR)[25] and non-resource-rich (NRR) countries we obtain some non-trivial results: on average for the whole period 1995-2008 the mean of TE for RR (0.6299) is higher than for NRR countries (0.5300) by 18.84%. Hence, this result provides further evidence to reject Hypothesis #4.

Table 3.5 also reports efficiency change (EC) (obtained according to Eq. (3.6)), technical change (obtained from Eq. (3.7)) and TFP (obtained from Eq. (3.8)) estimates. EC estimates represent the change in capacity utilization between two adjacent periods. On average, for the whole period FSU countries show an increase in

[25]Resource-rich countries are highlighted by an asterisk (*) in Table 3.5.

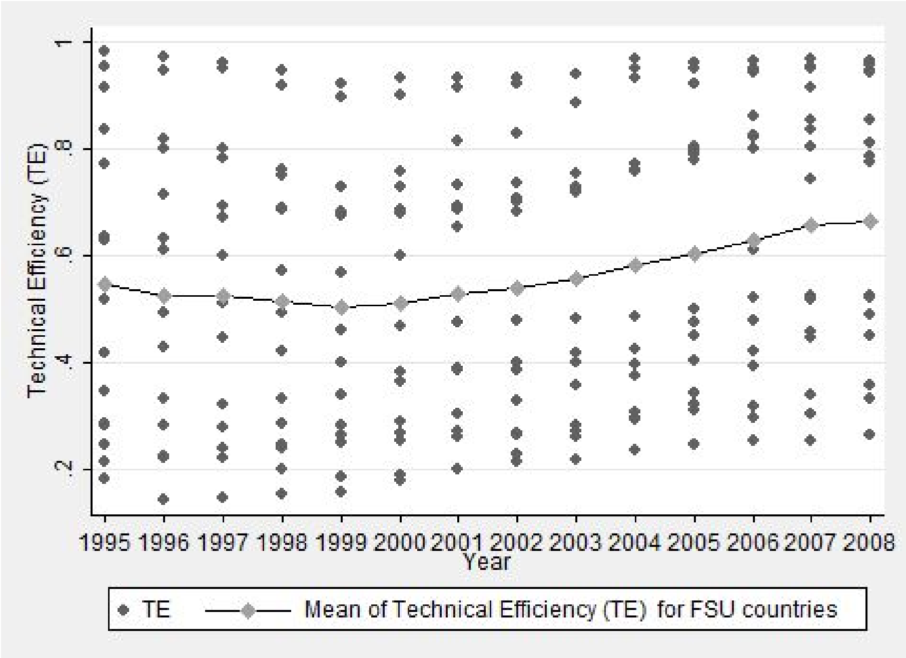

Figure 3.1: Countries and Average Annual Technical Efficiency(TE) Evolution for 15 FDU Countries over 1995-2008.

their capacity utilization equal to +2.19% yearly. Notice that, on average, RR countries are outperforming NRR ones: RR economies' average efficiency growth is 3.08%, while for NRR countries it is only 1.74%. The highest EC scores are achieved by Azerbaijan (7.2%), Tajikistan (5.3%), Turkmenistan (5.1%), Kyrgyzstan (4.0%) and Armenia (3.7%). Surprisingly, countries that are close to Europe and have better business environments are lagging behind. For example, Estonia (-0.41%), Latvia (-0.42%), and Russia (-0.19%) perform better in terms of technical efficiency but display a negative efficiency change. Columns 7-9 of Table 3.5 display the TC estimates. The average value for all FSU countries is 1.0021, meaning a technological progress equal to +0.21%. Eight countries show progress, on average, for the period 1995-2008: Belarus, Estonia, Lithuania, Latvia, Russia, Ukraine, Kazakhstan, and Turkmenistan. The rest of the countries displayed technological regress. Furthermore, RR economies performed much better on average (TC = 1.0087) than NRR ones, since the latter had no technological progress (TC = 0.9989). However, if we look at sub-periods, we can see that negative (i.e., lower than 1) average values are brought due to the fact that many countries performed worse after 2000. All of the countries (with the exception of Latvia) show a decrease in the technical change index in the period 2000-2008.

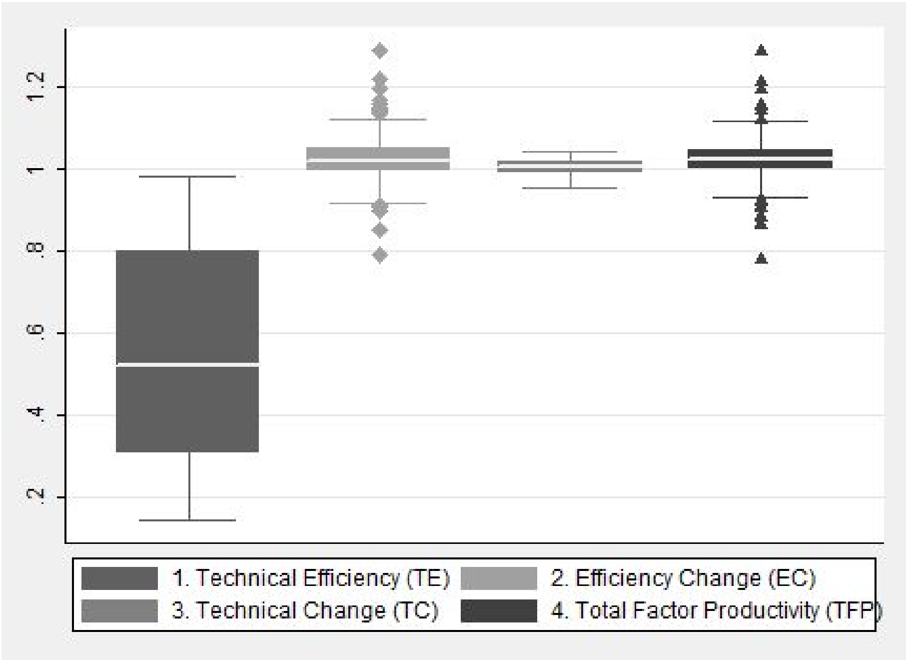

Figure 3.2: Distribution of TE, EC, TC, and TFP Scores for 15 FSU Countries over 1995-2008.

The last three columns of Table 3.5 show the estimated TFP indexes. On average, for the whole sample period, we find positive TFP growth mainly due to a robust increase of efficiency change (+2.19%) rather than in technical change (+0.21%). Only Moldova shows very small negative (-0.58%) regress in TFP, because negative technical change outweighed positive efficiency change. Moldova's fall in TFP on average could be attributed to negative technical change or using different technologies. Again, we reject our Hypothesis #4, since RR economies perform better than NRR ones. They show a positive growth rate in TFP equal to 3.94%, much higher than that of NRR countries, which is equal to 1.58%. If we look at sub-periods, during the period 1995-2000 only eight countries demonstrate positive productivity growth, but after 2000 until 2008 all 15 FSU economies have positive TFP indexes. Figure 3.2 shows that the distribution of TE, EC, TC, and TFP estimates over the observed period, using box-plot diagrams. It is evident that the distributions of EC, TC, and TFP are much narrower with respect to the distribution of TE scores.

Table 3.6 shows that the mean of RR countries in all productivity indexes is always higher than that of NRR countries. Moreover, their mean differences are statistically significant, with the exception of EC.

Table 3.6: Mean Difference Tests for Resource-Rich (RR) and Non-Resource Rich (NRR) Groups.

Over	Mean	Std. Err	[95% C.I.]		Over	Mean	Std. Err	[95% C.I.]	
TE					**TC**				
NRR[†,a,b]	0.53	0.0223	0.4853	0.5762	NRR[†,a,b]	0.9989	0.0016	0.9957	1.002
RR	0.6299	0.0293	0.5723	0.6917	RR	1.0087	0.0019	1.005	1.0125
EC					**TFP**				
NRR	1.0174	0.0042	1.0086	1.0262	NRR[†,b]	1.0158	0.0041	1.0078	1.0239
RR	1.0308	0.0087	1.0137	1.048	RR	1.0394	0.0081	1.0235	1.0552

Note:TE-technical efficiency, EC-efficiency change, TC-technical change, and TFP-total factor productivity. RR stands for the resource-rich countries group, and NRR is the non-resource-rich countries.C.I.-is the confidence interval. [a] Kruskal-Wallis equality-of-populations rank tests: [†] is the statistically significant difference between the RR and NRR groups of countries. TE- chi-squared = 6.731 with 1 d.f. and prob. = 0.0095; EC- chi-squared = 0.022 with 1 d.f. and prob. = 0.8824; TC- chi-squared = 10.591 with 1 d.f. and prob.= 0.0011; chi-squared = 3.204 with 1 d.f. and prob. = 0.0735. [b] Two sample t-tests on means with unequal variances: TE- t = -2.7111 and Pr ($| T | > |t|$) = 0.0075; EC- t = -1.3743 and Pr ($|T| > |t|$) = 0.1725; TC- t = -3.9685 and 0.0001; TFP- t = -2.6047 and Pr($|T| > |t|$) = 0.0106. Source: own calculations. *Source*: own calculations.

3.4.3 Correlation Between Productivity Indexes and GDP Growth

In this subsection, we observe whether there is any correlation between the estimated productivity indexes and countries' real GDP and real GDP growth. The aim is to investigate whether there is a significant impact of productivity on GDP. The results are presented in Table 3.7, reporting variables' correlation measured using the Pearson, Kendall, and Spearman indexes (the latter two being non-parametric).

We find that real GDP is not correlated to productivity indexes. The association between real GDP growth and TFP is instead positive and statistically significant and equal to +0.87 (Pearson's rho). From this, we could conclude that TFP could explain differences in real output growth in FSU economies. Moreover, our results report high positive association (+0.84) between real GDP growth and EC. Non-parametric tests of Spearman and Kendall corroborate our findings. Notice, that TFP has a slightly stronger relation with real GDP growth than EC. If TFP is an important factor for economic growth, then FSU economies should focus on channels that improve TFP. In Eqs. (3.9)-(3.11) we have shown that factors affecting technical efficiency also matter for TFP (and with the same sign). This implies that FSU countries should focus on transfer channels and human capital in order to sustain their economic growth.

Table 3.7: Pairwise Correlations of Real GDP, Real GDP Growth and Efficiency Scores.§

		rGDP	rGDPgr	EC	TC	TFP
rGDP	Pearson's rho	1				
rGDPgr		0.0175	1			
EC		-0.0147	0.8420*	1		
TC		0.1188	-0.0962	-0.3583*	1	
TFP		0.0234	0.8710*	0.9490*	-0.0461	1
rGDP	Kendall's tau	1				
rGDPgr		-0.0446	1			
EC		-0.0278	0.5684*	1		
TC		0.0044	-0.0876	-0.3162*	1	
TFP		-0.0121	0.6160*	0.7249*	-0.0411	1
rGDP	Spearman's rho	1				
rGDPgr		-0.0641	1			
EC		-0.0395	0.7578*	1		
TC		0.0059	-0.1205	-0.4648*	1	
TFP		-0.0204	0.8048*	0.8838*	-0.0616	1

Note:rGDP is the real gross domestic product; GDPgr is the real GDP growth rates, EC is efficiency change, TC is technical change, and TFP is total factor productivity. The results reported at the 1% (0.01) significance level with significant correlations are marked with an asterisk *.
§ -For a robustness check on the pair-wise rank correlations of real GDP (rGDP) and efficiency estimates, we divided rGDP by its geometric mean and performed our tests again. We observed change neither in significance and magnitudes nor in the signs of variables. *Source*: The data for rGDP and rGDPgr variables are from the UNCTAD database and own calculations.

We find a very high significant positive correlation (+0.95) between EC and TFP. Furthermore, TC is significantly negatively associated with EC (-0.36 (Pearson)). It seems that in FSU countries there is a sort of tradeoff between technical change (TC) and efficiency change (EC).

Table 3.8 shows the partition of FSU countries according to real GDP growth. Countries are divided according to output growth into three groups: slow (GDP $<$ 4.0%), medium (GDP 4.0-8.0%) and high (GDP $>$ 8.0%) growers. We have already mentioned that real GDP growth and TFP are positively correlated.

Figure 3.3 confirms the observed relationship between TFP and economic growth. The dotted line fitting the observations has a positive relationship. This result confirms for FSU economies the previous empirical evidence stressing the importance of TFP in explaining the differences in the growth of countries outputs (Klenow and Rodriguez-

Table 3.8: Real GDP Growth and Efficiency Scores.

	(TE)			(EC)			(TC)			(TFP)		
Country/Period	95-00	01-08	95-08	95-00	01-08	95-08	95-00	01-08	95-08	95-00	01-08	95-08
GDP[a] < 2.5%	0.47	0.53	0.51	0.99	1.04	1.02	1.00	0.99	0.99	0.99	1.03	1.01
GDP[b] 2.5-5.0%	0.61	0.67	0.64	0.99	1.03	1.01	1.01	1.01	1.01	1.00	1.04	1.02
GDP[c] > 5.0%	0.31	0.46	0.40	1.01	1.08	1.05	1.00	0.99	0.99	1.01	1.08	1.05
GDP[d] < 4.0%	0.39	0.47	0.44	0.97	1.05	1.02	1.00	0.98	0.99	0.97	1.03	1.01
GDP[e] 4.0-8.0%	0.60	0.66	0.64	0.99	1.03	1.02	1.01	1.00	1.01	1.01	1.03	1.02
GDP[f] > 8.0%	0.31	0.46	0.40	1.01	1.08	1.05	1.00	0.99	0.99	1.01	1.08	1.05

Note:TE-technical efficiency, EC-efficiency change, TC-technical change, and TFP-total factor productivity.We grouped countries on (slow, medium, high) GDP growth for our sample period, 1995-2008: [d] <4.0% is the arithmetic mean for the countries with GDP growth rate less than 4.0%; [e] 4.0 8.0% is the arithmetic mean for the countries with GDP growth rate from 4.0% 8.0%; and [f] > 8.0% is the arithmetic mean for the countries with GDP growth rate higher than 8.0%. Additionally, we checked GDP growth rates for the period 1993 2008, due to the fact that we started computing accumulated the physical capital (K) variable from 1993 and wanted to see its effects.
[a] < 2.5% is the arithmetic mean for the countries with GDP growth rate less than 2.5%; [b] 2.5 5.0% is the arithmetic mean for the countries with GDP growth rate from 2.5% 5.0%; and [c] > 5.0% is the arithmetic mean for the countries with GDP growth rate higher than 5.0%.*Source*: own calculations.

Clare, 1997; Hall and Jones, 1999; Hsieh and Klenow, 2010). They point out the need for identifying the drives of TFP. We have found that in FSU economies both human capital and imports of machinery and equipment increase countries TFP.

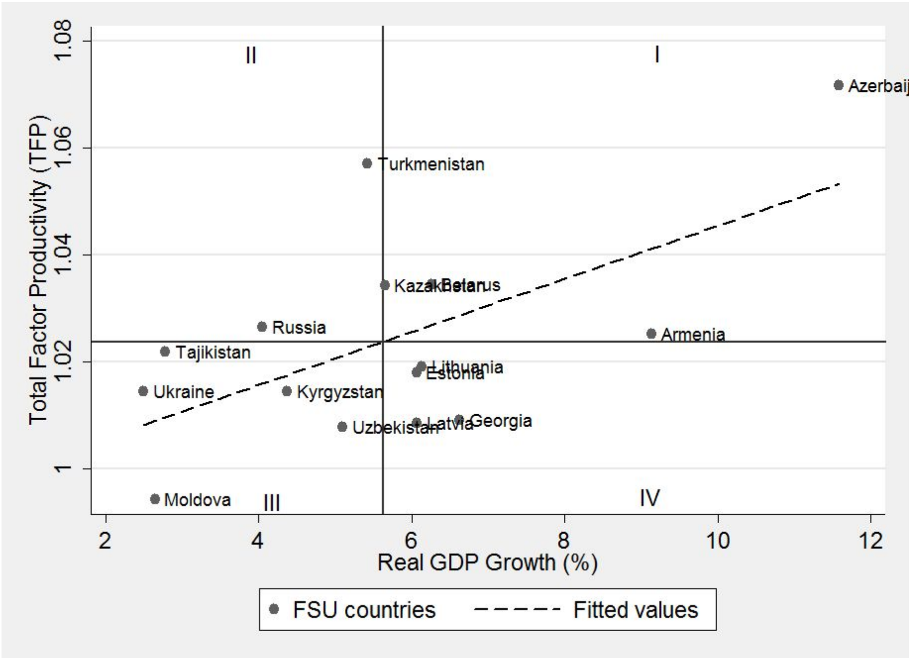

Figure 3.3: Countries and Average Annual Technical Efficiency(TE) Evolution for 15 FSU Countries over 1995-2008.

[a] *Note*: Quadrant I: Armenia, Azerbaijan, Belarus, Kazakhstan; Quadrant II: Kazakhstan, Russia, Turkmenistan; Quadrant III: Kyrgyzstan, Moldova, Tajikistan, Ukraine, Uzbekistan; Quadrant IV: Georgia, Estonia, Lithuania, Latvia.*Source*: authors calculations.

3.5 Conclusion

In this paper, we contribute to the literature on technology channels effects on economic growth by investigating the process of GDP production in 15 former Soviet Union economies by applying a time-varying, stochastic-frontier-analysis efficiency model in order to investigate the effects on productivity of technology diffusion channels (FDI and imports of machinery and equipment) and of human capital. We found that there still exists room for improving the utilization of inputs in FSU economies. However, all these countries show, on average, a positive rise in efficiency during the observed period.

Our empirical results demonstrate that both the import of machinery and equipment and human capital have a positive influence on technical efficiency of FSU countries. Furthermore, we demonstrate also that these variables exert a positive effect on total factor productivity thanks to the influence they exert on efficiency change, which was found to be a crucial determinant (much more than technical change) of total factor productivity index growth in our sample. Moreover, we find that the value of knowledge capital could be further improved if combined with foreign capital trade and investments. Furthermore, differently from many previous contributions, we did not observe the presence of the resource-curse hypothesis. On the contrary, we revealed the presence of a positive relationship between natural resource abundance and economic growth in FSU economies after the breaking up of the former Soviet Union.

Our statistical analysis points out an important positive relation between real GDP growth and TFP. Hence, since human capital and trade in capital goods are factors positively affecting TFP, governments of FSU countries should implement policies to improve domestic human capital and facilitate trade in capital goods. We found support for the ideas of (Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999), and the recent study by (Hsieh and Klenow, 2010), who underline the importance of TFP in explaining countries output growth.

Moreover, we think that launching market-oriented reforms, selective openness to foreign interventions, and following free trade policies could dramatically assist most of the FSU countries in reaching their best potential output. Similar conclusions for post-communist economies have been made by (Kolodko, 2005, 2009) for the case of Poland, the first country embracing a market economy among post-communist systems.

3.6 Appendix

Table 3.9: Data Description and Sources.

Variable	Description	Units	Source
		Translog Model	
RGDP	Real gross domestic product in	Millions USD	UNCTAD, http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sCS_referer=&sCS_ChosenLang=en
	U..S dollars at constant prices (2000) and constant exchange rates (2000) per capita		
Labor (L)	Total labor force in a country	Thousands	UNCTAD, http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sCS_referer=&sCS_ChosenLang=en
Capital (K)	Accumulated capital stock measured by perpetual inventory method (PIM)	Millions USD	UN Statistics Division, http://unstats.un.org/unsd/snaama/introduction.asp
		Inefficiency Model	
Time	Years. Code is 1- (1995) and14-(2008)	Years	
FDI	Aggregate foreign direct investment into FSU economies	Percentage of gross domestic product	UNCTAD, http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sCS_referer=&sCS_ChosenLang=en
IME	Imports of machinery and transport equipment (SITC 7)	Thousands USD	UNCTAD, http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sCS_referer=&sCS_ChosenLang=en
HC	Accumulated human capital stock.	Units	World Bank and authors' calculations, http://data.worldbank.org/data-catalog/world-development-indicators
D_{rr}	Dummy variable for the resource-rich countries; 1 = resource-rich: 0 = otherwise	1, 0	Authors

Table 3.10: Technical Efficiency (TE) Scores for the FSU Countries.

TE	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	95-00	01-08	Mean
Armenia	0.28	0.28	0.28	0.29	0.28	0.29	0.31	0.33	0.36	0.37	0.40	0.42	0.45	0.45	0.28	0.39	0.34
Azerbaijan*	0.35	0.33	0.32	0.33	0.34	0.37	0.39	0.40	0.40	0.40	0.47	0.61	0.74	0.81	0.34	0.53	0.45
Belarus	0.63	0.63	0.67	0.69	0.67	0.68	0.69	0.70	0.72	0.77	0.80	0.82	0.83	0.85	0.66	0.77	0.73
Estonia	0.52	0.49	0.51	0.49	0.46	0.47	0.47	0.48	0.48	0.49	0.50	0.52	0.52	0.49	0.49	0.49	0.49
Georgia	0.42	0.43	0.45	0.42	0.40	0.38	0.38	0.39	0.42	0.43	0.45	0.48	0.52	0.53	0.42	0.45	0.43
Kazakhstan*	0.63	0.61	0.60	0.57	0.57	0.60	0.65	0.68	0.72	0.76	0.78	0.80	0.80	0.77	0.60	0.75	0.68
Kyrgyzstan	0.22	0.22	0.24	0.25	0.25	0.26	0.26	0.26	0.28	0.31	0.31	0.32	0.34	0.36	0.24	0.31	0.28
Lithuania	0.95	0.95	0.95	0.95	0.90	0.90	0.91	0.92	0.94	0.97	0.96	0.96	0.97	0.96	0.93	0.95	0.94
Latvia	0.84	0.80	0.80	0.76	0.73	0.73	0.73	0.74	0.75	0.76	0.79	0.82	0.85	0.78	0.77	0.78	0.78
Moldova	0.25	0.22	0.22	0.20	0.19	0.19	0.20	0.21	0.22	0.24	0.25	0.25	0.25	0.26	0.21	0.24	0.23
Russia*	0.98	0.97	0.96	0.92	0.92	0.93	0.93	0.93	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.94	0.94
Tajikistan	0.18	0.14	0.15	0.16	0.16	0.18	0.20	0.23	0.26	0.30	0.32	0.30	0.30	0.33	0.16	0.28	0.23
Turkmenistan*	0.29	0.28	0.24	0.24	0.26	0.27	0.27	0.27	0.27	0.30	0.34	0.39	0.46	0.52	0.26	0.35	0.31
Ukraine	0.91	0.82	0.78	0.75	0.73	0.76	0.81	0.83	0.88	0.93	0.92	0.94	0.95	0.94	0.79	0.90	0.85
Uzbekistan*	0.77	0.71	0.69	0.68	0.68	0.69	0.69	0.71	0.73	0.77	0.80	0.86	0.91	0.95	0.71	0.80	0.76
Mean A	0.55	0.53	0.52	0.51	0.50	0.51	0.53	0.54	0.56	0.58	0.60	0.63	0.66	0.66	0.52	0.60	0.56
Mean RR	0.60	0.58	0.56	0.55	0.55	0.57	0.59	0.60	0.61	0.63	0.67	0.72	0.77	0.80	0.57	0.67	0.63
Mean NRR	0.52	0.50	0.50	0.49	0.48	0.48	0.50	0.51	0.53	0.56	0.57	0.58	0.60	0.60	0.50	0.56	0.53
GDP^{a}<2.5 %	0.51	0.48	0.47	0.45	0.45	0.46	0.48	0.49	0.52	0.54	0.55	0.55	0.56	0.57	0.47	0.53	0.51
GDP^{b}2.5–5.0%	0.63	0.61	0.61	0.60	0.58	0.59	0.60	0.61	0.63	0.65	0.68	0.71	0.73	0.73	0.61	0.67	0.64
GDP^{c}> 5.0%	0.31	0.31	0.30	0.31	0.31	0.33	0.35	0.37	0.38	0.39	0.44	0.52	0.60	0.63	0.31	0.46	0.40
GDP<4.0%	0.45	0.40	0.38	0.37	0.36	0.38	0.40	0.42	0.46	0.49	0.50	0.50	0.50	0.51	0.39	0.47	0.44
GDP 4.0-8.0%	0.62	0.61	0.61	0.60	0.58	0.59	0.60	0.61	0.63	0.65	0.67	0.69	0.72	0.72	0.60	0.66	0.64
GDP > 8.0%	0.31	0.31	0.30	0.31	0.31	0.33	0.35	0.37	0.38	0.39	0.44	0.52	0.60	0.63	0.31	0.46	0.40

Note:Mean is the arithmetic mean of the sample. Mean RR is the mean for the resource-rich group. Countries with asterisks * belong to the resource rich group. Mean NRR-s the non resource rich group countries. This is for 1993-2008 period:
[a] – are the countries with GDP growth rate less than 2.5%. [b] – are the countries with GDP growth rate from 2.5%-5.0% and [c] – are the countries with GDP growth rate higher than 5.1%. The same logic for GDP $<$ 4%, GDP 4.0-8.0% and GDP $>$ 8.0% and it is for the 1995-2008 period.*Source*: own calculations.

Table 3.11: Efficiency Change (EC) for the 15 FSU countries.

EC	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	95-00	01-08	Mean
Armenia	1.00	0.98	1.03	0.99	1.02	1.06	1.08	1.08	1.05	1.08	1.05	1.06	1.00	1.00	1.06	1.04
Azerbaijan*	0.96	0.97	1.03	1.02	1.08	1.07	1.03	1.00	0.99	1.19	1.29	1.22	1.09	1.01	1.11	1.07
Belarus	1.00	1.06	1.03	0.98	1.01	1.01	1.02	1.03	1.07	1.03	1.03	1.01	1.02	1.01	1.03	1.02
Estonia	0.95	1.03	0.97	0.93	1.01	1.01	1.01	1.01	1.01	1.03	1.04	1.00	0.93	0.98	1.01	1.00
Georgia	1.02	1.04	0.95	0.94	0.96	1.01	1.00	1.08	1.02	1.06	1.06	1.09	1.01	0.98	1.04	1.02
Kazakhstan*	0.97	0.98	0.95	0.99	1.06	1.09	1.05	1.05	1.05	1.03	1.03	1.01	0.96	0.99	1.03	1.02
Kyrgyzstan	1.04	1.08	1.02	1.02	1.02	1.03	1.00	1.08	1.08	1.01	1.02	1.06	1.06	1.03	1.04	1.04
Lithuania	0.99	1.00	1.00	0.95	1.00	1.02	1.01	1.02	1.03	0.99	1.00	1.00	1.00	0.99	1.01	1.00
Latvia	0.96	1.00	0.95	0.96	1.00	1.01	1.01	1.02	1.01	1.03	1.04	1.04	0.92	0.97	1.01	1.00
Moldova	0.91	0.98	0.91	0.93	1.01	1.06	1.07	1.03	1.07	1.06	1.02	1.00	1.04	0.95	1.04	1.01
Russia*	0.99	0.99	0.95	1.00	1.01	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.01	0.99	1.00	1.00
Tajikistan	0.79	1.03	1.05	1.03	1.12	1.11	1.14	1.14	1.14	1.08	0.92	1.03	1.10	1.00	1.08	1.05
Turkmenistan*	0.98	0.85	1.00	1.10	1.02	1.01	0.98	1.02	1.08	1.16	1.15	1.17	1.14	0.99	1.09	1.05
Ukraine	0.90	0.96	0.96	0.97	1.04	1.07	1.02	1.07	1.05	0.99	1.02	1.01	0.99	0.96	1.03	1.00
Uzbekistan*	0.93	0.97	0.99	1.00	1.00	1.01	1.02	1.03	1.06	1.05	1.07	1.06	1.04	0.98	1.04	1.02
Mean A	0.96	0.99	0.99	0.99	1.02	1.04	1.03	1.04	1.05	1.05	1.05	1.05	1.02	0.99	1.04	1.02
Mean RR	0.97	0.95	0.99	1.02	1.03	1.04	1.01	1.02	1.04	1.08	1.11	1.09	1.05	0.99	1.05	1.03
Mean NRR	0.96	1.02	0.99	0.97	1.02	1.04	1.04	1.06	1.05	1.04	1.02	1.03	1.01	0.99	1.03	1.02
GDP[a]<2.5 %	0.92	1.01	0.98	0.99	1.04	1.05	1.05	1.06	1.07	1.03	1.00	1.02	1.04	0.99	1.04	1.02
GDP[b]2.5-5.0%	0.98	0.99	0.98	0.98	1.01	1.02	1.01	1.03	1.04	1.05	1.05	1.05	1.00	0.99	1.03	1.01
GDP[c]> 5.0%	0.98	0.97	1.03	1.01	1.05	1.06	1.06	1.04	1.02	1.13	1.17	1.14	1.05	1.01	1.08	1.05
GDP<4.0%	0.87	0.99	0.97	0.98	1.06	1.08	1.08	1.08	1.09	1.04	0.99	1.01	1.04	0.97	1.05	1.02
GDP 4.0-8.0%	0.98	1.00	0.98	0.99	1.01	1.02	1.01	1.04	1.04	1.04	1.04	1.04	1.01	0.99	1.03	1.02
GDP > 8.0%	0.98	0.97	1.03	1.01	1.05	1.06	1.06	1.04	1.02	1.13	1.17	1.14	1.05	1.01	1.08	1.05

Note:Mean is the arithmetic mean of the sample. Mean RR is the mean for the resource-rich group. Countries with asterisks [*] belong to the resource rich group. Mean NRR-s the non resource rich group countries. This is for 1993-2008 period:
[a] – are the countries with GDP growth rate less than 2.5%. [b] – are the countries with GDP growth rate from 2.5%-5.0% and [c] – are the countries with GDP growth rate higher than 5.1%. The same logic for GDP< 4%, GDP 4.0-8.0% and GDP > 8.0% and it is for the 1995-2008 period.*Source*: own calculations.

Table 3.12: Technical Change (TC) for the 15 FSU Countries.

TC	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	95-00	01-08	Mean
Armenia	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Azerbaijan*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Belarus	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.02	1.01	1.01
Estonia	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Georgia	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Kazakhstan*	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.03	1.01	1.02
Kyrgyzstan	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.98	0.97	0.98
Lithuania	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.02	1.02	1.02
Latvia	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Moldova	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.99	0.98	0.99
Russia*	1.04	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.04	1.02	1.03
Tajikistan	0.99	0.99	0.98	0.98	0.98	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.95	0.98	0.96	0.97
Turkmenistan*	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.00	1.00	0.99	0.99	0.98	1.02	1.00	1.01
Ukraine	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.02	1.01	1.01
Uzbekistan*	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.98	0.98	1.00	0.99	0.99
Mean A	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.01	1.00	1.00
Mean RR	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.02	1.00	1.01
Mean NRR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00
GDP[a]<2.5 %	1.01	1.01	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98	1.00	0.99	0.99
GDP[b]2.5-5.0%	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.01
GDP[c]> 5.0%	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	0.99	0.99
GDP<4.0%	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	1.00	0.98	0.99
GDP 4.0-8.0%	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.01
GDP > 8.0%	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	0.99	0.99

Note:Mean is the arithmetic mean of the sample. Mean RR is the mean for the resource-rich group. Countries with asterisks * belong to the resource rich group. Mean NRR-s the non resource rich group countries. This is for 1993-2008 period:
[a] – are the countries with GDP growth rate less than 2.5%. [b] – are the countries with GDP growth rate from 2.5%-5.0% and [c] – are the countries with GDP growth rate higher than 5.1%. The same logic for GDP< 4%, GDP 4.0-8.0% and GDP > 8.0% and it is for the 1995-2008 period.*Source*: own calculations.

Table 3.13: Total Factor Productivity (TFP) Change for the 15 FSU Countries.

TFP	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	1995-2000	2001-2008	Mean
Armenia	0.99	0.97	1.02	0.98	1.01	1.04	1.07	1.07	1.03	1.06	1.04	1.05	0.99	1.00	1.04	1.03
Azerbaijan*	0.96	0.97	1.04	1.03	1.08	1.07	1.03	1.00	0.99	1.19	1.29	1.21	1.08	1.02	1.11	1.07
Belarus	1.02	1.08	1.04	1.00	1.02	1.03	1.03	1.04	1.08	1.04	1.04	1.02	1.03	1.03	1.04	1.03
Estonia	0.97	1.05	0.99	0.96	1.04	1.04	1.03	1.03	1.03	1.05	1.06	1.02	0.95	1.00	1.03	1.02
Georgia	1.01	1.03	0.94	0.94	0.95	1.00	1.00	1.07	1.01	1.05	1.05	1.07	1.00	0.97	1.03	1.01
Kazakhstan*	1.00	1.01	0.98	1.01	1.08	1.11	1.06	1.07	1.06	1.04	1.04	1.02	0.97	1.02	1.05	1.03
Kyrgyzstan	1.02	1.06	1.00	1.00	1.00	1.01	0.98	1.05	1.05	0.98	0.99	1.03	1.02	1.02	1.01	1.01
Lithuania	1.02	1.03	1.02	0.97	1.02	1.04	1.03	1.04	1.05	1.01	1.02	1.02	1.01	1.01	1.02	1.02
Latvia	0.97	1.01	0.96	0.97	1.01	1.02	1.02	1.04	1.03	1.05	1.05	1.05	0.93	0.99	1.02	1.01
Moldova	0.91	0.98	0.90	0.92	1.00	1.04	1.06	1.01	1.05	1.04	1.00	0.98	1.02	0.94	1.03	0.99
Russia*	1.03	1.03	0.99	1.04	1.05	1.03	1.03	1.04	1.03	1.02	1.02	1.02	1.02	1.03	1.03	1.03
Tajikistan	0.78	1.02	1.03	1.01	1.10	1.09	1.11	1.10	1.10	1.04	0.88	0.99	1.05	0.99	1.04	1.02
Turkmenistan*	1.00	0.86	1.02	1.12	1.04	1.03	0.99	1.03	1.08	1.16	1.14	1.15	1.12	1.01	1.09	1.06
Ukraine	0.92	0.98	0.98	0.99	1.06	1.09	1.03	1.08	1.06	0.99	1.02	1.01	0.99	0.98	1.03	1.01
Uzbekistan*	0.93	0.97	0.99	1.00	1.00	1.01	1.01	1.02	1.04	1.03	1.05	1.04	1.01	0.98	1.03	1.01
Mean A	0.97	1.00	0.99	1.00	1.03	1.04	1.03	1.04	1.05	1.05	1.05	1.04	1.01	1.00	1.04	1.02
Mean RR	0.98	0.97	1.00	1.04	1.05	1.05	1.02	1.03	1.04	1.09	1.11	1.09	1.04	1.01	1.06	1.04
Mean NRR	0.96	1.02	0.99	0.97	1.02	1.04	1.04	1.05	1.05	1.03	1.02	1.02	1.00	0.99	1.03	1.02
GDP[a]<2.5 %	0.93	1.01	0.98	0.99	1.04	1.05	1.04	1.06	1.06	1.01	0.98	1.00	1.02	0.99	1.03	1.01
GDP[b]2.5-5.0%	0.99	1.01	0.99	1.00	1.02	1.03	1.02	1.04	1.05	1.05	1.06	1.05	1.00	1.00	1.04	1.02
GDP[c]> 5.0%	0.98	0.97	1.03	1.00	1.04	1.06	1.05	1.03	1.01	1.13	1.16	1.13	1.04	1.01	1.08	1.05
GDP<4.0%	0.87	0.99	0.97	0.97	1.05	1.07	1.07	1.06	1.07	1.02	0.97	0.99	1.02	0.97	1.03	1.01
GDP 4.0-8.0%	1.00	1.01	0.99	1.00	1.02	1.03	1.02	1.04	1.05	1.04	1.05	1.04	1.01	1.01	1.03	1.02
GDP > 8.0%	0.98	0.97	1.03	1.00	1.04	1.06	1.05	1.03	1.01	1.13	1.16	1.13	1.04	1.01	1.08	1.05

Note:Mean is the arithmetic mean of the sample. Mean RR is the mean for the resource-rich group. Countries with asterisks * belong to the resource rich group. Mean NRR-s the non resource rich group countries. This is for 1993-2008 period: [a] – are the countries with GDP growth rate less than 2.5%. [b] – are the countries with GDP growth rate from 2.5%-5.0% and [c] – are the countries with GDP growth rate higher than 5.1%. The same logic for GDP< 4%, GDP 4.0-8.0% and GDP > 8.0% and it is for the 1995-2008 period.*Source*: own calculations.

Chapter 4

Energy Consumption and Carbon Dioxide Environmental Efficiency for Former Soviet Union Economies. Evidence from Data Envelopment Analysis

Abstract The main source of convertible energyfossil-fuel combustiongenerates desirable means for production of national output (GDP) along with an undesirable by-productcarbon dioxide (CO_2) emissions. This paper investigates the effect of this supply process for environmental quality. By introducing energy and non-energy production factors, we estimate economic and CO_2 efficiency. We build an alternative environmental efficiency indicator with respect to CO_2 emissions by applying non-parametric data-envelopment analysis (DEA)window analysis under variable returns to scale (VRS)to 15 former Soviet Union (FSU) economies for the period 1992-2008. There is a clear distinction between three FSU economiesEstonia, Latvia, and Lithuania (now EU member states)and the rest of the sample in that they display better environmental performance. In these three countries, economic efficiency directly influences the environmental performance. Results also show that over time FSU economies improve their CO_2 environmental efficiency and head toward the Kyoto Protocol directives. However, this positive gain comes with costs; it seems there is a tradeoff between positive output production (GDP) and controlling for carbon emission. On average, we observe a 15.9-percent drop in producing GDP, while there is a 1.59 -percent rise in positive environmental CO_2 efficiency.

JEL Classification: O13, C23

Keywords: Eurasia; carbon dioxide emissions; environmental efficiency; DEA window analysis.

4.1 Introduction

The reduction of anthropologic carbon dioxide (CO_2) emissions is one the major tasks confronting our civilization because it could lead to a global food supply shortage along with many others calamities, according to the Intergovernmental Panel on Climate Change (IPCC) .[1] As is well known, transition economies in the early stages put economic development in front of environmental performance, which is understandable. The problem is that if this process continues it could lead to irreversible results. In addition, CO_2 emissions are global; it is not feasible when some countries put enormous efforts into curbing emissions while others pollutethus refuting previous investments. An effective policy requires collective action. Transition economies with reckless consumption, population growth, and obsession with economic growth coupled with a lack of functioning environmental regulation drive global greenhouse gas (GHG) emissions; among them are the 15 former Soviet Union (FSU) economies.[2] All FSU economies have ratified the Kyoto Protocol (KP), which is aimed at combating global warming. In regard to CO_2 emissions, which are the main agenda of the KP, FSU countries all together produce 8.68 percent of global CO2 emissions from fuel combustion.[3] This is fairly high amount if compared with the worlds four emission

[1] The Intergovernmental Panel on Climate Change (IPCC) was established on December 6, 1988 by the United Nations General Assembly and is primarily concerned with producing reports related to climate change, based on the UN Convention on Climate Change (UNFCCC). Carbon dioxide is one of the GHGs, along with methane, nitrous oxide, and sulphur hexafluoride. CO_2 comes from the burning of carbonaceous fuels (also known as fossil fuels) such as coal, oil, and gas. CO_2 emissions have dramatically increased since 2000, and it is considered a bulk element in the global warming problem. Emissions of CO_2 have increased due to petroleum and natural gas consumption, according to the Energy Information Association (EIA) (2011). Different countries contribute different levels of heat-trapping gases to the atmosphere such as CO_2. Please refer to the Appendix for the CO_2 emissions table.

[2] The FSU consist of Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

[3] The Kyoto Protocol was the outcome of the implementation of UNFCCC, which deals with issues of global warming. This protocol, which was signed by 169 states (including all fifteen FSU countries) and entered into force on February 16, 2005, aims at stabilizing GHG emission levels in the atmosphere

leaders: it is more than the emissions of India (5.78 percent), more than half those of all the European Union 27 (14.04 percent), nearly half those of the USA (18.11 percent), and nearly one-third those of China (23.33 percent).[4]

Given the above figures, the less-developed FSU transition economies are subject to difficult circumstances. The data from Figs. 4.1-4.2 point to co-movement between economic development and carbon emissions. Do these trends go at a decreasing rate? To what degree is economic production able to control carbon emissions? Emissions or undesirable outputs are inevitable, but manageable. Firms could reduce these negative outcomes to some degree by increasing their efficiencye.g., utilizing a proper technology and input mix. The economic scale of production is considered an important notion since the increase of scale improves production efficiency, which ultimately reduces pollution in emission-prone industries (Hettige et al., 2000; Wheeler, 2001; Lucas et al., 2002).

There is a growing impact and a need for environmental regulation of private sector activities worldwide. Also, environmental efficiency is important and is a part of the economic policy goals of the European countries related to Lisbon Strategy and Gteborg priorities for sustainable development. This is pertinent to three of our sample FSU economies, which are now EU member states: Estonia, Latvia and Lithuania. The importance of identifying environmental efficiency metrics has been mentioned by many scholars. For example, Tyteca (1996), Allen (1999), Thoresen (1999) present broad literature reviews and discussions on the need for environmental indicators that could provide warning signals calling for appropriate actions and policy decisions. Hence, it is important to assess empirically the environmental performance of these FSU economies with regard to CO_2. In this respect, we propose to combine the economic and environmental sides of economic development to shed light on the efficient use of available resources by constructing an environmental efficiency index for CO_2. We believe that carbon emissions-related indictors are better assessed by efficiency methods because they are mainly generated by human behavior. We do this by applying popular non-parametric data-envelopment analysis (DEA) methodology.[5]

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so as to prevent the hazardous effects on climate.

[4]The data are for 2008 were presented by CDIAC and prepared for the United Nations. Source: `http://cdiac.ornl.gov/` Accessed on December 08, 2011.

[5]For the popularity of the DEA approach, please refer to the study of Emrouznejad et al. (2008), in which the authors present advantages and applications of this non-parametric technique for the past 30 years. Zhou et al. (2008) display the applications of DEA to various environmental problems, and Cooper et al. (2004) overview applications of DEA for different countries.

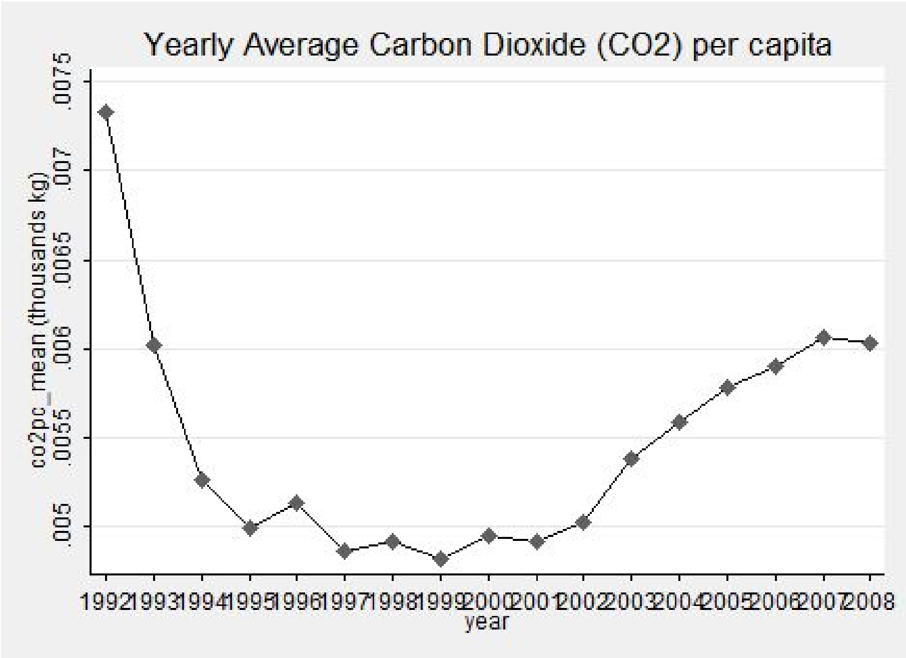

Figure 4.1: Carbon dioxide (CO2) evolution.

Previously, many scholars used production-frontier analysis, called the DEA directional distance function approach, in building environmental efficiency measures that considered desirable and also undesirable outputs (Färe et al., 1989; Färe and Grosskopf, 1994; Färe et al., 1996; Färe and Grosskopf, 2004; Färe et al., 2004a; Chung et al., 1997; Tyteca, 1997; Zaim and Taskin, 2000; Zaim, 2004).These studies considered joint production of positive and negative outputs and use direction as a policy variable that is designed to reduce inputs or increase outputs, which is a powerful technique that provides flexibility in decision making Färe et al. (2004b). Nevertheless,Coelli et al. (1998) and Halkos and Tzeremes (2009c) pointed out that it is possible to consider the negative outputCO_2 in our caseas a neutral variable that is similar to conditions of imposing strict inequality constraints on negative outputs.Haynes et al. (1993) used similar arguments in their study of pollution.

Following the aforementioned contributions, we apply variation of the traditional DEA method, called DEA window analysis (DEA-WA), which takes account of the dynamic or inter-temporal scheme of the production process to obtain a CO_2 environmental efficiency index. That said, it is suitable for panel data, as in our case: 15 countries and 17 years, 1992–2008. The advantage of DEA window analysis is that it takes account of the time dimension and simultaneously assesses the stability

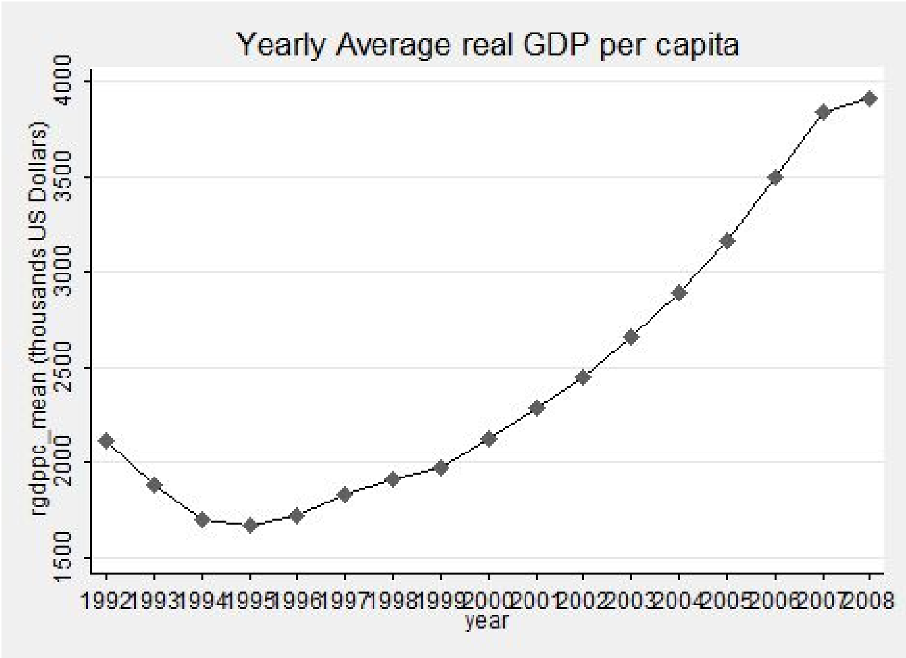

Figure 4.2: Real GDP per capita development.

of efficiency evaluation across and within the chosen window (Yue, 1992; Hartman and Storbeck, 1996; Webb, 2003; Asmild et al., 2004; Cooper et al., 2007; Halkos and Tzeremes, 2008, 2009c,b,a, 2011) Specifically, this method was used in the study by Halkos and Tzeremes (2009c) but in assessing sulfur emissions and building an environmental efficiency index for 21 Organization for Economic Cooperation and Development (OECD) countries. In their paper, the authors use a production-function approach with capital and labor as inputs and GDP and sulphur emissions (SO_x) as outputs. In our study, for the first time (to the best of our knowledge) we propose inclusion of a third input variable, which is energy consumption, to obtain efficiency metrics. Moreover, we assess the CO_2 efficiency using transition FSU post-communist economies that were not studied before in this framework.

In our study, we contribute to and extend existing research in the following ways. First, we focus on the previously unstudied fifteen FSU countries. Second, we employ inter-temporal DEA window analysis to estimate each countrys efficiency score employing different outputs (real GDP and CO_2 emissions). This is based on three main points: first, DEA window analysis takes account of the time dimension (dynamics) of each countrys efficiency trend, a major concern of stochastic approaches that incorporates external shocks; second, it accommodates multiple inputs in production of

Table 4.1: A Three-Year Window of Environmental-Efficiency Ratio for Armenia.

Year→ Window↓	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	Mean
window 1	1	1	1															1
window 2		1	1	1														1
window 3			1	1	0.99													1
window 4				1	0.99	1												1
window 5					1	1	1											1
window 6						1	1	1										1
window 7							1	1	0.99									1
window 8								1	0.99	0.99								0.99
window 9									1	1	1							1
window 10										1	1	1						1
window 11											1	1	1					1
window 12												1.03	1.04	1.03				1.03
window 13													1.03	1.02	1.02			1.02
window 14														1.02	1.01	1.01		1.01
window 15															1.01	1.01	1	1.01
Mean	1	1	1	1	0.99	1	1	1	1	1	1	1.01	1.03	1.02	1.01	1.01	1	1

desirable and undesirable outputs; and third, it allows comparison (benchmarking) of heterogeneous sample countries, which is not the case in most parametric panel-data analyses that produce single expected-value estimates for the whole sample (e.g., mean). However, it is a good complement to other panel estimation techniques, especially for decision-making purposes. For example, when access to detailed statistics is absent, DEA methodology could provide an alternative opportunity for conducting research.

Our main results are the following: (1) a huge decline in positive (GDP) efficiency of 15.9 percent is experienced by the FSU economies, (2) the FSU economies are still struggling to better control CO_2 emissions in their production processes, (3) there is a minor positive increase in environmental efficiency with regard to CO_2 on average for the period 1992–2008, and (4) it seems that domestic firms experience a trade-off during the positive output (GDP) production process.

This paper is organized as follows. Section 4.2, Econometric Modeling, describes the data and techniques employed. Then, Section 4.3 discusses the main findings, and Section 4.4 presents a summary and the conclusions.

4.2 Econometric Modeling

A priori, we assume that the FSU countries, except the EU member states, are less concerned with environmental issues than developed countries and hence are more polluting. Further, they may use more energy-consuming technologies due to delayed technological advancement and the use old transportation vehicles. We also assume that energy consumption is higher compared with developed countries that use sophisticated energy-saving equipment. The relationship between energy use from fossil-fuel combustion and carbon emissions has been extensively researched (Ang, 1999, 2007; Ozturk and Acaravci, 2010; Niu et al., 2011; Pao and Tsai, 2011; Wang et al., 2011). For example, studies report a direct causality from energy consumption to carbon dioxide emissions Soytas et al. (2007); Apergis and Payne (2010). Energy-efficiency enhancements could bring substantial productivity, reducing fossil-fuel burning and hence curbing CO_2 emissions along with other greenhouse gases (Barker et al., 2007; Scott et al., 2008).

The majority of FSU economies rely on agricultural and production sectors that use natural resources, chemicals, and basic metals that are considered environmentally sensitive Lee and Roland-Holst (1997). These industries are principal polluters due to the large volume of production, GHG emissions, and production of hazardous chemical by-products. Another point is that the governments of most of the FSU economies heavily subsidize these industries, which often results in increased pollution due to sizable inefficiencies in the use of resources. Reduction of these subsidies could decrease the scale of production and improve environmental performance (Lucas et al., 1992; Birdsall and Wheeler, 1993; Dasgupta et al., 1997).

The literature strands on environmental pollution and economic policies discuss various policy responses that are very pertinent to the FSU economies. Some scholars propose elimination of energy subsidies, which could increase energy efficiency by shifting industry away from energy-intensive sectors and thus reducing demand for pollution-intensive power (Vukina et al., 1999). Other researchers argue that higher energy prices also induce shifts from capital- and energy-intensive production techniques to labor- and materials-intensive techniques, which are often more pollution-intensive in other ways (Mani et al., 2000). The extent and potential effects of this production technology shift in environmental quality related to carbon emissions is the scope of this study. Hence, we focus our attention on the production process side since it gives us an opportunity to analyze countries production efficiency (or efforts) by combining multiple inputs and outputs. We aim to construct the CO_2 environmental-efficiency ratio by first obtaining an efficiency score for each country from production of good output (GDP), separately from undesirable, or bad output (CO_2), using the same inputs: labor, capital, and energy consumption.

4.2.1 Data and Measurements

We used an updated online United Nations Conference on Trade and Development (UNCTAD) database (2011) for our variables. The input variables are labor (L), which is measured as total workers; capital (K), which is the gross capital formation of the economy; and total energy consumption (E). The output variables are undesirable (CO_2), which is measured in metric tons, and desirable (GDP), which is gross domestic product. The energy consumption and CO_2 emissions variables were taken from the U.S. Energy Information Administration (EIA), and all monetary variables are in real terms. Our sample consists of 15 former Soviet Union economies, three of which (Estonia, Latvia, and Lithuania) are European Union member states. This composition of the sample helps us to build a global production frontier and compare countries on their efficiency performance. The data description and sources are given in the Appendix.

4.2.2 Production Function: Inputs and Outputs

We assume that firms in the FSU economies are under the same environmental constraint, due to carbon dioxide CO_2 being considered a global polluter, which that is regulated by tradable pollution tax among KP countries. BIn building the production function, we include energy consumption (E) along with labor (L) and capital (K) as input factors. Since we are aiming to assess negative output (CO_2) and are basing our analysis on the previous contributions mentioned, we believe that it is the energy consumption is the main factor driving carbon dioxide CO_2 emissions and thus should be included in the production function in efficiency estimation. Hence, the production function in our study follows the following formulation for desirable Y^{GDP} and undesirable Y^{CO_2} outputs:

$$Y^{GDP} = f(K, L, E) \tag{4.1}$$

$$Y^{CO_2} = f(K, L, E) \tag{4.2}$$

where we use the same input factors but different outputs, one for good (GDP) and one for bad output (CO_2). K (capital), L (labor), and E (energy consumption) are the input production factors.

Assuming weak substitutability of inputs, DEA-WA is favorable for our purpose because (1) we could rank countries according to their efficiency; and (2) it serves for decision makinge.g., to assess best performers. Furthermore, DEA-WA allows us to accommodate heterogeneity across countries without regard to collecting information on input and output prices, technological production schemes, market structure, etc. Another feature of DEA-WA is that it accommodates variables with different measurement units. It also exempts us from specifying the precise form of the production function.

Table 4.2: Good (GDP) Efficiency.

Country/Year	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	Mean
Armenia	1	1	1	1	0.99	0.99	0.99	1	1	0.98	0.98	0.95	0.96	0.92	0.86	0.83	0.81	0.96
Azerbaijan	1	0.47	0.58	0.52	0.49	0.45	0.48	0.56	0.72	0.76	0.52	0.41	0.4	0.52	0.68	0.94	1	0.62
Belarus	0.42	0.44	0.44	0.51	0.54	0.57	0.61	0.72	0.73	0.81	0.88	0.79	0.75	0.74	0.65	0.62	0.6	0.64
Estonia	0.99	1	1	1	1	1	0.99	1	1	1	1	1	1	1	1	1	1	1
Georgia	0.5	1	0.96	0.92	0.92	0.97	0.81	0.87	0.89	0.94	0.87	0.97	0.98	0.91	1	0.92	1	0.91
Kazakhstan	0.56	0.71	0.56	0.68	0.87	0.79	0.74	0.69	0.74	0.71	0.73	0.81	0.79	0.71	0.66	0.71	0.78	0.72
Kyrgyzstan	0.69	0.8	0.92	0.87	0.84	0.84	0.98	0.87	0.82	0.89	0.97	1	0.97	0.97	0.9	0.93	1	0.9
Latvia	1	1	0.98	0.98	1	0.99	0.99	0.97	1	1	1	1	0.96	1	1	0.99	1	0.99
Lithuania	0.96	1	1	1	0.99	1	0.97	1	1	0.99	1	1	1	1	0.99	1	1	0.99
Moldova	0.55	0.7	0.87	0.97	0.91	0.89	0.93	1	1	1	1	1	1	1	0.99	1	0.99	0.93
Russia	1	1	1	1	0.99	1	0.98	1	1	0.97	1	1	1	1	1	1	1	1
Tajikistan	0.59	0.62	0.7	0.81	1	1	1	0.97	1	0.95	0.98	0.96	0.98	0.99	0.99	0.91	1	0.91
Turkmenistan	0.58	0.63	0.59	0.58	0.58	0.58	0.62	0.56	0.62	0.67	0.73	0.75	1	1	1	1	0.97	0.73
Ukraine	0.63	0.61	0.6	0.9	0.89	0.73	0.58	0.66	0.67	0.74	0.88	0.78	0.84	0.79	0.75	0.67	0.68	0.73
Uzbekistan	0.21	0.44	0.43	0.43	0.51	0.63	0.54	0.63	0.63	0.71	0.66	0.56	0.42	0.44	0.48	0.47	0.51	0.51
Mean	0.71	0.76	0.78	0.81	0.83	0.83	0.81	0.83	0.85	0.88	0.88	0.87	0.87	0.87	0.86	0.87	0.89	0.84

4.2.3 DEA window analysis method and Environmental Efficiency Index

The DEA window analysis is either time dependent or a dynamic type of DEA. The method was initially introduced by Klopp (1985) in studies of U.S. Army recruitment

Cooper et al. (2007, p.321).

We adopt the formulation as in (Asmild et al., 2004; Halkos and Tzeremes, 2009c, 2011) as follows. Lets us assume that the N decision -making units (DMUs), with countries in our case (n = 1,... N), are under T period of time (t = 1,... T), using **z** inputs and producing **q** outputs. Then we have a panel data where in which an $DMU_{n,t}$, e.g. a country n in period t will have an **s** dimensional input vector: of $\mathbf{z}_t^n = (z_{1t}^n, z_{2t}^n, \ldots, z_{st}^n)'$ and a p dimensional output vector: of $\mathbf{q}_t^n = (q_{1t^n}, q_{2t}^n, \ldots, q_{pt}^n)'$. Further, the window j_w with $j * w$ observations will be with width w, $1 \leq w \leq T_j$, and start at time j, $1 \leq j \leq T$. Then the matrix of inputs (1) and outputs (2) will be the following:

$$\mathbf{Z}_{jw} = (z_j^1, z_j^2, \ldots, z_j^N, z_{j+1}^1, z_{j+1}^2, \ldots, z_{j+1}^N, \ldots, z_{j+w}^1, z_{j+w}^2, \ldots, z_{j+w}^N) \tag{4.3}$$

$$\mathbf{Q}_{jw} = (q_j^1, q_j^2, \ldots, q_j^N, q_{j+1}^1, q_{j+1}^2, \ldots, q_{j+1}^N, \ldots, q_{j+w}^1, q_{j+w}^2, \ldots, q_{j+w}^N) \tag{4.4}$$

The window analysis problem that needs to be solved is as follows:

$$\begin{gathered}
\theta_{j_w,t} = \min_{\theta,y}\theta \\
\text{s.t.} - \mathbf{Z}_{jw}\gamma + \theta z_t{}^{\prime\prime} \geq 0 \\
Q_{j_w,t}\gamma - q_t^{'} \geq 0 \\
\gamma_n \geq 0 \quad (n = 1, \ldots, Nw)
\end{gathered} \tag{4.5}$$

We insert a variable returns to scale (VRS) restriction in our estimation for formula #3 that allows for variable returns to scale across sample$\sum_{n=1}^{N} \gamma_n = 1$ Banker et al. (1984). This is important because our sample countries are heterogeneous with different production mixes and corresponding levels of economic regulation and laws in regard to domestic firms. As noted, we use an input-oriented (or input-saving) approach that is toconsists of minimizinge inputs while keeping a given output level. This is feasible when a decision maker (e.g., a firm) can control its inputs, which are in our case, are labor, and capital, and energy consumption. Since we deal with undesirable output (CO_2), we want increased inputs for a given level of negative output. For example, 100 tons of CO_2 output produced by 1,000 units of labor (workers) and 1,000 units of capital is *socially* better than the same output produced by 100 workers and 100 units

Table 4.3: DEA Window Analysis Numerical Illustration.

Definition	Formula	Solution
# of windows	W = K-P+1	15 = 17-3+1
# of different DMUs	N*P*W	15*3*15 = 675
Δ# of DMUs	N(P-1)(K-P)	15(3-1)(17-3) = 420
Our sample (DMUs)	K*W	17*15 = 255

Note:DMUs relates to decision-making units: countries in our case. W-number of windows (15); K-number of periods (17 years); P-length of window (3 years), and N-number of countries (15 DMUs).*Source*: (Cooper et al., 2007).

of capital. However, the opposite logic applies for positive (GDP) output.

We obtain separate efficiency scores according to equations Eqs. #4.1 and # 4.2 by with the help of the DEA window -analysis technique. [6] Then we construct the carbon dioxide CO_2 environmental -efficiency (^{CO_2}) index for each FSU country according to following equation:

$$\omega^{CO_2} = \frac{GoodEfficiency}{BadEfficiency} = \frac{\theta^{GDP}}{\theta^{CO_2}} \tag{4.6}$$

Table 4.1 demonstrates the principle of window analysis for Armenia. As can be seen, we have 15 windows, calculated by using the formula in row 1 of Table 4.3. The DEA window principle is dynamic since it is based on the principle of moving averages. In addition, each country is benchmarked with itself in current and preceding years, and also with other countries. By this method, we gain 420 more observations (from an original 255) in obtaining efficiency scores (675 - 255 = 420), as explained in Table 4.3, third row. This is especially favorable to our small sample of 15 countries and asymptotic properties.

4.3 Empirical Findings

Environmental efficiency's dynamic development under the DEA-WA method is illustrated in Table 4.1. A three-year window (w = 3) and 15 countries gives us 45 observations for Armenia. So the first window is the years 1992, 1993, and 1994, and in each year the country is treated as a different observation. The second window drops the initial year (1993, 1994, and 1995), and this continues until 2008. This table

[6]The DEA window-analysis model was run with the help of DEA-Solver software developed by Kaoru Tone (Cooper et al., 2007).

could be interpreted in two ways: the "column view" that gives the stability of the environmental-efficiency score for Armenia across different data sets that is generated by the replacement procedure, and the "row view", which shows the inter-temporal development or trend. From the table, we could say that Armenias performance was better in the years 2000-2008 vs. 1992-2000 by observing the higher average scores (bottom row). The higher the score, the better is the environmental performance of the country.

Tables 4.2,4.4 and 4.5 guide us through building the environmental index according to Eq. 4.6 and its components. Table 4.2 provides good (GDP) efficiency scores for all countries. Here, the efficiency scores are bound and range from 0 to 1 (100 percent), with 1 being fully efficient. In our case, since we used an input-oriented model, it means being able to minimize inputs to produce a given countrys desirable (or positive) output (GDP). Hence, the higher the score, the better is the country in this production process. The best performers on a yearly average for the period 1992-2008 are the EU member statesEstonia (100 percent), Latvia (99 percent), and Lithuania (99 percent)and also Russia (100 percent). The laggards are Uzbekistan (51 percent) and Azerbaijan (62 percent). This means there are 49 percent and 38 percent "inefficiencies", respectively.

Bad or negative output (CO_2) efficiency scores are presented in Table 4.4. Here, the scores are also bound in a 0-1 scale, but they have a different meaning from the positive (GDP) ones. From the efficiency point of view, we aim to reduce pollution per unit of inputs used, spreading the observed level of pollution to more utilized inputs in production. The lower the score, the better is the performance in regard to carbon reduction.[7] Put simply, if you are unable to minimize the inputs in producing for a given level of CO_2, then it is favorable. If, in contrast, the country is goode.g., has a higher efficiency scorethen it produces carbon emissions with lower levels of labor, capital, and energy use. On a yearly average for the period studied, we obtained: Latvia (58 percent), Belarus (76 percent), Georgia (83 percent), and Azerbaijan (88 percent). Hence, Latvia, for example, is the leader, having 42 percent (100 percent

[7] To further explain "negative efficiency" scores, we strive to obtain lower values of bad (CO_2) efficiency because only in that case would it be *positive*. The lower the value, the better an economy is controlling CO_2 emissions. In other words, given high efficiency scores, the country is *inefficient* in reducing input factors for a given level of CO_2 emissions because it would be ideal if it produced a given level of carbon emissions with more production factors (capital, labor, and energy consumption). Maybe an example could clarify this further. Assume that country A produces 1 ton of CO_2 with one unit each of capital, labor, and energy. Also assume that country B produces the same amount of negative output (CO_2) with 4 units each of the factor inputs. Which country is better? The answer is B due to more input factors producing the same amount of pollution.

58 percent) of *good efficiency* we may call it. Still, sample total yearly average is a warning due to the fact that countries are unable to better curb their carbon emissions, which is shown by (90 percent)–e.g., only 10 percent of positive efficiency.

Table 4.4: Bad (CO_2) Efficiency.

Country/Year	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	Mean
Armenia	1	1	1	1	1	0.99	0.99	1	1	0.98	0.98	0.95	0.93	0.9	0.85	0.83	0.81	0.95
Azerbaijan	1	0.95	0.97	0.98	0.92	0.85	1	1	1	0.83	0.78	0.74	0.73	0.76	0.8	0.82	0.84	0.88
Belarus	0.74	0.81	0.78	0.82	0.78	0.75	0.72	0.74	0.73	0.73	0.76	0.76	0.75	0.76	0.76	0.75	0.73	0.76
Estonia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Georgia	0.62	1	0.87	0.89	0.86	0.8	0.75	0.76	0.79	0.85	0.77	0.88	0.9	0.84	0.94	0.81	0.79	0.83
Kazakhstan	1	1	0.94	0.97	1	0.96	0.95	1	1	1	1	1	1	1	1	1	1	0.99
Kyrgyzstan	0.71	0.85	0.93	0.87	0.85	0.87	1	0.9	0.82	0.86	0.95	1	0.97	0.96	0.9	0.92	1	0.9
Latvia	0.61	0.6	0.69	0.62	0.54	0.55	0.53	0.57	0.58	0.56	0.55	0.53	0.55	0.57	0.6	0.58	0.58	0.58
Lithuania	0.76	0.92	0.94	0.9	0.93	0.98	0.97	1	0.99	0.97	1	0.99	0.96	0.95	0.96	0.95	1	0.95
Moldova	0.82	0.88	1	1	0.98	0.97	0.97	1	1	1	0.99	1	1	1	0.99	1	0.99	0.98
Russia	1	1	1	1	1	0.99	0.99	1	1	0.98	0.99	1	1	1	1	0.96	0.99	0.99
Tajikistan	0.59	0.62	0.7	0.81	1	1	1	0.98	1	0.95	0.96	0.95	0.98	0.99	0.98	0.92	1	0.91
Turkmenistan	0.74	0.81	0.73	0.72	0.71	0.74	0.75	0.72	0.8	0.91	0.96	0.96	1	1	1	1	1	0.86
Ukraine	0.95	0.95	0.95	1	1	0.97	0.97	1	0.97	0.96	0.99	1	0.98	0.98	0.98	0.96	0.96	0.97
Uzbekistan	0.78	1	0.95	0.98	0.98	1	0.97	1	0.99	0.99	1	0.99	0.99	0.97	1	1	0.98	0.98
Mean	0.82	0.89	0.9	0.9	0.9	0.89	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.91	0.92	0.9	0.91	0.9

Table 4.5 depicts the main results of this study: CO_2 environmental-efficiency scores. The meaning of this index is that it is a ratio: the lower the denominator (CO_2 efficiency, Eq. 4.6), the higher the score. In other words, the better countries are in reducing carbon emissions during the production process of positive output (GDP), the higher are the scores. Again, the EU member states Estonia, Latvia, and Lithuania demonstrate good performance. However, some other countries of the old Soviet Block–Armenia, Georgia, Russia, and Tajikistan–also display good results. In our estimation, we could obtain relatively low carbon environmental–efficiency indexes compared with other closely related emission-related studies. Since there is no study with which to compare our obtained estimates, we could only compare them with a similar index measure for sulfur emissions. As an example, Halkos and Tzeremes (2009a) report an environmental-efficiency ratio obtained by DEA–WA for SO_x ranging from min 0.81 for Canada and max 32.47 for Denmark. In our study, the range is from 0.52 (Uzbekistan) to 1.73 (Latvia).

Table 4.6 gives us a condensed view to compare obtained measures from DEA-WA, where we could can observe the strong decline in productive efficiency for positive

Table 4.5: Environmental-Efficiency Ratio (Good/Bad Efficiency).

Country/Year	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	Mean
Armenia	1	1	1	1	0.99	1	1	1	1	1	1	1.01	1.03	1.02	1.01	1.01	1	1
Azerbaijan	1	0.49	0.61	0.53	0.53	0.53	0.48	0.56	0.72	0.92	0.66	0.55	0.54	0.68	0.85	1.15	1.18	0.71
Belarus	0.56	0.55	0.57	0.62	0.69	0.76	0.85	0.98	0.99	1.1	1.16	1.04	1	0.97	0.85	0.83	0.82	0.84
Estonia	0.99	1	1	1	1	1	0.99	1	1	1	1	1	1	1	1	1	1	1
Georgia	0.82	1	1.1	1.04	1.08	1.22	1.08	1.14	1.14	1.11	1.14	1.1	1.09	1.09	1.06	1.13	1.26	1.09
Kazakhstan	0.56	0.71	0.6	0.7	0.87	0.83	0.77	0.69	0.74	0.71	0.73	0.81	0.79	0.71	0.66	0.71	0.78	0.73
Kyrgyzstan	0.97	0.94	0.99	1	0.98	0.96	0.98	0.97	0.99	1.03	1.02	1	1.01	1.01	1	1.01	1	0.99
Latvia	1.63	1.66	1.42	1.59	1.85	1.79	1.85	1.71	1.73	1.79	1.82	1.89	1.75	1.74	1.66	1.71	1.72	1.73
Lithuania	1.26	1.09	1.07	1.12	1.07	1.02	1.01	1	1.01	1.02	1	1.01	1.04	1.05	1.03	1.06	1	1.05
Moldova	0.68	0.79	0.87	0.97	0.92	0.92	0.96	1	1	1	1	1	1	1	1	1	1	0.95
Russia	1	1	1	1	0.99	1.01	0.99	1	1	0.99	1.01	1	1	1	1	1.04	1.01	1
Tajikistan	1	1	1	1	1	1	1	0.99	1	1	1.03	1.01	1	1.01	1.01	0.99	1	1
Turkmenistan	0.79	0.79	0.81	0.8	0.81	0.79	0.82	0.79	0.78	0.73	0.76	0.78	1	1	1	1	0.97	0.85
Ukraine	0.66	0.64	0.63	0.9	0.89	0.75	0.6	0.66	0.69	0.78	0.89	0.78	0.86	0.8	0.77	0.7	0.71	0.75
Uzbekistan	0.26	0.44	0.45	0.44	0.52	0.63	0.56	0.63	0.64	0.72	0.66	0.57	0.42	0.45	0.48	0.47	0.52	0.52
Mean	0.88	0.87	0.87	0.91	0.95	0.95	0.93	0.94	0.96	0.99	0.99	0.97	0.97	0.97	0.96	0.99	1	0.95

national output (GDP), a yearly average decline of -16 percent. On the other hand, on average carbon -controlling efficiency rose during the sample period by around +1 percent annually. The lower the CO2 efficiency is the better, but we obtained 0.90 (or 90 percent), which is a very high and negative result for purposes of controlling carbon emissions. In regard to environmental efficiency (ω^{CO_2}): as mentioned before the higher value is better. The best performers are Latvia (1.73), and Georgia (1.09), followed by Armenia, Tajikistan, Russia, and Estonia, which all have (1.00).

The striking fact is the dramatic reduction in positive (GDP) efficiency of non -EU post -communist economies. On average, we observe a drastic drop in national output production efficiency for the whole period 1992-2008: Uzbekistan (- 47 percent), Azerbaijan (-41 percent), Belarus (-35 percent), Ukraine (-26 percent), and Turkmenistan (-26 percent). In contrast, EU member states have only a slight decline: Estonia (-0.12 percent), Latvia (-0.92 percent) and Lithuania (-0.39 percent). The positive message is that on average FSU economies are learning to deal with carbon emissions (columns 3-4 in Table 4.6). For example, Tajikistan (3.58 percent), Georgia (2.79 percent), Kyrgyzstan (2.42 percent), and Turkmenistan (2.04 percent) and improve their carbon -related efficiency.

From Fig. 4.3, we observe the positive rising trend of environmental improvement, which is a yearly average of 1.59 percent increase. This observation points out effective

Table 4.6: Average Environmental-Efficiency Ratios (1992-2008).

	Good(θ^{GDP})Efficiency		Bad (θ^{CO_2}) Efficiency		Environmental-Efficiency Ratio(ω^{CO_2})	
Countries	Average Overall Efficiency scores (1992-2008)	Average Annual Growth (1992-2008, % change)	Average Overall Efficiency scores (1992-2008)	Average Annual Growth (1992-2008, % change)	Average Overall Efficiency Scores (1992-2008)	Average Annual Growth (1992-2008, % change)
Armenia	0.96	-4.58%	0.95	-1.27%	1	0.00%
Azerbaijan	0.62	-40.59%	0.88	-0.79%	0.71	4.10%
Belarus	0.64	-34.87%	0.76	0.01%	0.84	2.73%
Estonia	1.00	-0.12%	1	0.00%	1	0.08%
Georgia	0.91	-6.58%	0.83	2.79%	1.09	3.05%
Kazakhstan	0.72	-26.92%	0.99	0.03%	0.73	2.80%
Kyrgyzstan	0.90	-9.05%	0.90	2.42%	0.99	0.24%
Latvia	0.99	-0.92%	0.58	-0.13%	1.73	0.60%
Lithuania	0.99	-0.39%	0.95	1.91%	1.05	-1.36%
Moldova	0.93	-4.82%	0.98	1.24%	0.95	2.62%
Russia	1.00	-0.41%	0.99	-0.05%	1	0.08%
Tajikistan	0.91	-7.04%	0.91	3.58%	1	0.01%
Turkmenistan	0.73	-25.73%	0.86	2.04%	0.85	1.57%
Ukraine	0.73	-26.45%	0.97	0.09%	0.75	1.35%
Uzbekistan	0.51	-46.98%	0.98	1.65%	0.52	5.94%
Mean	0.84	-15.70%	0.90	0.90%	0.95	1.59%

domestic policies for raising the efficiency of firms that lead to curbing carbon emissions. This also could be due to globalizatione.g., FSU economies are heavily involved in international trade, purchasing already-advanced technology from developed countries that possibly improves input mix in the production process. It is hard to believe that this positive climb of the environmental index is due to strong enforcement of domestic environmental regulation. However, the threat of potential *huge* expenses due to the Kyoto Protocol agreement may have stimulated the transition of low-income FSU economies.

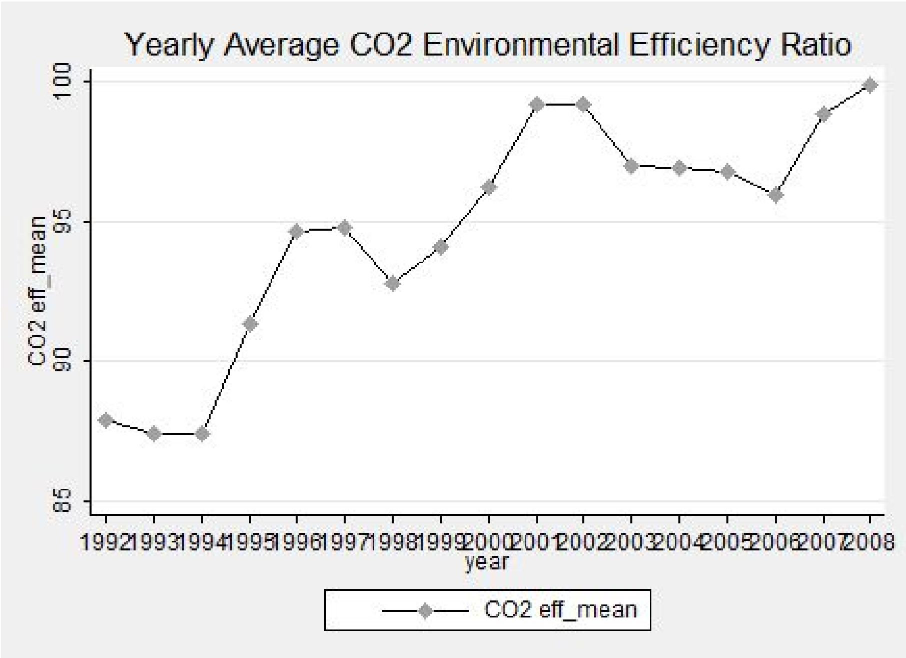

Figure 4.3: Average CO2 environmental-efficiency index for 15 FSU economies for 1992-2008.

4.4 Conclusion

This paper investigates carbon dioxide environmental-efficiency performance of 15 former Soviet Union economies by applying a non-parametric data-envelopment analysis (DEA)window analysis framework for the period 1992-2008. In general, FSU economies have improved their environmental efficiency with regard to the main greenhouse pollutant (CO2) by 1.59 percent per year during 1992-2008. This finding supports the aims of the Kyoto Protocol on arresting pollutant greenhouse emissions. However, it seems that this positive gain comes at a very high cost, as we observe the dramatic decline in positive output (GDP) production efficiency. It seems that there is a tradeoff and that firms sacrifice output level for reducing carbon emissions.

This study shows that it is not an economic development per se; it is more an economic structure, especially the production mix (combination of inputs), matters involved in curbing carbon emissions, and correspondingly the enhancement of environmental efficiency. We saw that CO_2 emissions are rising in the FSU economies but that the ability (or efficiency) in curbing them is also rising, as our results demonstrate. Hence, it would be more feasible to assess countries on efficiency grounds. Countries that are members of EU such as Estonia, Latvia, and Lithuania are corroborating this finding even though their economic growth is miserable.

To effectively control carbon emissions and other related pollutants, FSU economies should pay attention to creating sound environmental regulations that can provide incentives for domestic firms to comply with emission restrictions today in order to plant eco-culture seeds that could bring fruits for future generations. This is very important due to emission-related ecological problems that arrive with a 50-100- year lag.

We believe that external channels such as international trade, foreign direct investment (FDI), and foreign aid could bring a positive effect in introducing environmentally friendly production and collaborationsand in some cases even imposing them. This requires further research in these lines due to the increase of FDI and foreign-aid allocations in FSU economies.

4.5 Appendix

Table 4.7: Data Summary.

Variable	Obs	Mean	Std. Dev.	Min	Max
Labor	255	9.219619	18.10378	0.642835	76.07874
Capital	255	14008.7	40133.15	-63.5489	306377.3
Energy Consumption	255	2.877288	7.086848	0.10728	34.11568
GDP	255	58621.84	162759.1	1211.461	939581.3
CO_2	255	165.8714	404.8731	3.5972	2020.194

Table 4.8: Data Description.

Variable	Symbol	Input(I)/Output(O)	Units	Description	Source
GDP	GDP	O	Millions of USD	Real gross domestic product. Desirable output	UNCTAD
CO_2	CO_2	O	Metric tons	Carbon dioxide emissions from fossil-fuel combustion. Undesirable output.	US EIA
Labor	L	I	Thousands of workers,	Total employed population.	UNCTAD
Capital	K	I	Millions of USD	Total capital stock. Gross Capital Formation.	UNCTAD
Energy Consumption	E	I	British Thermal Units (Btus)	Total Energy Consumption	US EIA

Chapter 5

Conclusion

Economic development is a crucial matter especially for the fifteen former Soviet Union (FSU) economies because they are transition states. Globalization and trade also affect growing nations since these countries exchange raw materials for the advanced technology from developed countries of Western hemisphere. The mechanism of transactions and regulatory bases are diverse and country-tailored. External financial flows such as foreign direct investment provided by multinational enterprises (MNEs) are growing on a world wide scale. MNEs are looking for new markets and expanding their realms. FSU economies have become such a market receiving substantial foreign investments that went mainly into resource industries. Since the FSU countries are considered developing nations with relatively low per capita national income they host sizeable amounts of official development assistance (ODA), that is also known as foreign aid. The motivation of world structures such as World Bank and International Monetary Fund was to assist these recipients in establishing structural grounds for stability and economic growth that are the main priorities of Millennium Development Goals. This aid especially was directed to developing complementary inputs such as human capital, health and social projects. Another important current issue is the environmental protection that is directly pertinent to FSU economies. Because these countries are young nations they put economic growth in front of environmental matters. However, the issue related to greenhouse emissions, particularly carbon dioxide, CO_2, is global and necessitates collective world community actions. In this regard FSU economies are in constraint due to economic rigidities present in their markets. Environmental matters are still considered second-order issues.

The Introduction displays the importance of economic aspects related to FSU economies. It highlights the necessity and rationality of addressing current matters such as flows of foreign direct investment and foreign aid, production structure and efficiency, and carbon emissions on the macroeconomic level.

In Essay 1 we analysed two important issues of hosting foreign direct investment (FDI) and foreign aid (ODA). Especially, we looked at their correlation. That said, we searched for the private (FDI) and public (ODA) partnership i.e. possible cooperation between private MNEs and humanitarian donors. We found an indication of flowing together between them. This finding points out on crucial policy implication. If these two flows indeed have common grounds in FSU economies, then: Firstly, it gives a clue to international donors to re-assess their agendas and to closely look at cooperation with multinational enterprises in conducting their projects. For example, donors could launch their projects attached to FDI investments in particular transition countries's industry. Or they could rationalize (or save) enormous amounts of money funds by avoiding double(overlapping) investments. This may happen in case when private investment could bring tangible effect on human capital improvement and also impose changes in social, legislative environment that retrospectively influence the aim of foreign aid projects, that is, building a well-functioning democratic society. Another point is that FDI and ODA complement domestic investment which means FSU economies are not solely dependent on foreign flows but, on the opposite, are able to accommodate it in a way that augments the contribution to economic growth. It also says that donors are not financing local investments, but positively adding to it.

The Essay 2 takes the issues of first paper further by considering the national output, gross domestic product (GDP), production process and effects of foreign financial flows on it. At the first stage we calculate the efficiency and productivity scores of each FSU economy. In particular, we obtain production related scores of each country such as technical efficiency (TE), efficiency change (EC), technical change (TC) and total factor productivity (TFP). These metrics are important and give relative comparison between FSU economies. They address the effort of each country in producing GDP using available production inputs such as labour and capital. How foreign capital flows affect this domestic production process was the second stage of analysis. Results demonstrate that in order to improve their economic growth FSU economies should create incentives for cross-border technology trade and invest in human capital. Policy implications are the following: in order to better absorb the foreign technology FSU economies should improve the quality of workers and second, since imported machinery and equipment enhance domestic production, there should be appropriate regulation to sustain these positive effects.

The final Essay 3 studies environmental efficiency of FSU economies related to carbon dioxide emissions. In other words, how these economies are efficient in curbing the pollutant while producing GDP. We constructed carbon dioxide environmental efficiency index for each FSU country and compare them. We found that countries of Eastern Europe, former FSU members, with better structural reforms and regulations such as Latvia, Lithuania and Estonia display superior performance in reducing carbon emissions compared to the rest of sample. What we have empirically learnt from our study is that emissions could be controlled given certain economic and social conditions. From policy point of view FSU economies should favour utilization of modern technologies. For that they better off in creating conditions and incentives for private sector (as well as government sector) in obtaining and incorporating them in production process. Even though these invoke substantial costs given economic earnings of FSU economies it is imperative to sustain long-term environmental sanity for coming generations.

In sum, this dissertation has looked at internal and external crucial matters of FSU economies on macroeconomic level. There is no simple message we can derive from this thesis. The main conclusion is that there is a window for improvement and space for enhancing policy responses on a big or gradual way. At last, it is the crucial role of state to launch favourable reforms and conditions that could shape the future development of FSU economies.

Resume

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