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Industrialization Vs. Urbanization Environmental Impact: The Case of Former Soviet Union Republics, 1990-2013

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Abstract: While global carbon dioxide emissions increase considerably over the past decades, the former Soviet Union republics experience a substantial decrease of the environmental indicator since the dissolution of the USSR. Nonetheless, considering the prominent Soviet heritage in a form of energy intensive heavy manufacturing, industrialization remains one of the strong determinants for the environmental change. In contrast, urbanization demonstrates consistent insignificance. Therefore, positive and negative legacies of the Soviet urban systems are not persistent in the modern times. The study also identifies some disparities among different country groups justifying a necessity to take into consideration a big diversity across the post-Soviet countries.

Key words: CO_2 emissions, industrialization, urbanization, STIRPAT, former Soviet Union republics

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1. Introduction

1.1. Research Problems

Nowadays there are growing environmental concerns in the world. Many nations, their governments and particularly researchers through their studies facilitate spread of awareness and signal about an urgent necessity to reduce anthropogenic environmental impacts. One of the strong environmental concerns is increasing concentrations of greenhouse gas emissions (GHGs) in the atmosphere which threaten to lead to dramatic climate changes such as global warming (Dietz & Rosa, 1997).

Extensive scientific literature suggests that in order to be able to mitigate the problem and formulate appropriate strategies it is essential to investigate its driving forces. Along with some key determinants such as income, population size and energy intensity researchers attempt to identify possible environmental impacts of other factors. The studies by Jones (1991), Sadorsky (2013), Elliot, Sun and Zhu (2014), Li and Lin (2015) and many others justify that industrialization and urbanization might have a significant contribution to increasing energy consumption and consequently carbon dioxide (CO_2) emissions – the largest source of GHGs. Even though these two processes are often closely associated, their environmental impacts vary. Thus, industrialization and urbanization influence the environment via distinguishable mechanisms, and for some countries the effect of one factor might overshadow the effect of another.

Noteworthy, not all world's nations experience a substantial increase in CO_2 emissions. Brizga, Feng and Hubacek (2013) provide an illustrative example: while the world's total CO_2 emissions from fuel combustion rose by 45 % during the period of 1990-2010, a few countries, namely the former Soviet Union (FSU) republics, managed to decrease their emissions. Known for their rapid industrialization and urbanization in the past, this study aims to investigate the following research question:

1) *Whether and to which extent do the processes of industrialization and urbanization have environmental impact in the FSU economies after the dissolution of the USSR?*

In addition, the research works by Fan, Liu, Wu and Wei (2006), Paumanyvong and Kaneko (2010), Li and Lin (2015) and others find that it is important to consider heterogeneity among countries because environmental impacts of industrialization and urbanization might differ considerably. Brizga, Feng and Hubacek (2013) also outline a big diversity among the FSU economies which always differ economically, environmentally and culturally. Subsequently, this study sets an objective to explore the second research question:

2) *Whether do varying environmental impacts of industrialization and urbanization take place in a case of the post-Soviet countries?*

In order to address these questions, the empirical analysis is conducted on all fifteen FSU republics (Map 1 in Appendix A). The time period which is covered in the study starts in 1990, when the very first countries as Estonia, Latvia and Lithuania declared their independence, and ends in the year of 2013, the last time point for which the data on all required variables is available.

1.2. Contribution and Limitations

The contribution of this paper is two-fold. First, in order to identify environmental impacts of industrialization and urbanization this study implements the theoretical framework of Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT), which to the best of the author's knowledge has not been considered in the previous literature for investigating a case of the post-Soviet economies. This framework is developed by Dietz and Rosa (1994; 1997) through the revision of the original IPAT model (Impact = Population * Affluence * Technology). The scholars reformulate a stochastic form of IPAT in order to allow for non-proportional and non-monotonic effects of explanatories. In addition, Dietz and Rosa (1994) suggest various reformulation of the model elements (*I, P, A* and *T*) with a purpose to make STIRPAT identity more flexible, so other factors may enter the model to explain the environmental impact.

Second, the study aims to provide some insights regarding varying impacts of industrialization and urbanization in the FSU countries. In order to do so, besides estimating common impacts for the entire sample of post-Soviet republics the evaluation is also conducted regarding different sub-samples. Thus, at first, following the scientific literature the FSU economies are classified by their income level into two groups – lower and higher income states. Next, considering other aspects of the diverse FSU regions (as culture and geography), the whole sample is divided into the southern and northern countries.

Using the methods of random effects and fixed effects, the estimation results identify that industrialization is a strong determinant for carbon dioxide emissions in the post-Soviet republics, which stands in accordance with the previous studies that stress a remaining importance of the Soviet heritage in the FSU economies. In contrast, urbanization does not seem to have a significant effect on the environment. In addition, varying environmental impacts indeed exist among different classes of countries justifying a necessity to consider effects of driving forces for the environmental change separately for sub-samples.

Despite the outlined potentials to make a contribution to the scientific literature, this study has several limitations. Thus, it does not take into account other possible indicators of urbanization as in the study by Elliot, Sun and Zhu (2014). The consideration of alternative measures might provide more robust results to check if urbanization truly does not demonstrate any significant environmental impact. Additionally, although the outlined classifications are based on criteria derived from the scientific literature, assuming large disparities among the countries it is still possible to expect some heterogeneity left even within sub-samples.

1.3. Outline

The remainder of this study is organized as follows. Section 2 discusses the empirical studies which investigate environmental impacts of urbanization and industrialization (their nature, mechanisms and variation) as well as gives insights into the STIRPAT framework. Section 3 provides background information about the post-Soviet economies and offers possible classifications of the countries. Section 4 outlines *a priori* expectations. The following section 5 describes the econometric model, data and estimation methods used in the study. Section 6 discusses development trends inherent for the entire sample and sub-samples and demonstrates estimation results. Finally, section 7 provides conclusive remarks.

2. Theory

2.1. Literature Review

2.1.1. Urbanization and Industrialization as Drivers of the Environmental Impact

As Li and Lin (2015) note the environmental impact of urbanization and industrialization is a substantially interesting topic for scholars to investigate. There is extensive scientific literature that identifies linkages between these two determinants and any of environmental impact indicators – typically GHGs (in particular CO_2 emissions), energy use or energy intensity. Such studies are summarized in Table 2-1.

Numerous research works recognize the importance of industrialization (to name a few Paumanyvong & Kaneko 2010; Sadorsky, 2013; Brizga, Feng & Hubacek 2013; Li & Lin, 2015). It is usually defined as an industry share to total GDP or value added, yet sometimes other measures of economic structure can be analyzed. For instance, the studies of York, Rosa and Dietz (2003a) as well as Dietz, Rosa and York (2007) use such indicator as a proportion of nonservice sectors in total GDP. Nonetheless, despite different industrialization measures the consideration of them rests on the same logic. In comparison with an agriculture or service sector industry tends to increase an environmental impact indicator (Sadorsky, 2013; Elliot, Sun & Zhu 2014). Consequently, the relationship between the variables appears to look as follows: industrialization has a positive effect on CO_2 emissions, energy use or energy intensity. Empirical studies strongly confirm this assumption and demonstrate positive and significant impact of industry (or nonservice) share.

Jones (1991) who investigates the impact on energy use in developing countries finds the industrialization elasticity to be equal 1.35. It implies that holding other variables constant 1 % increase in industry share is associated with 1.35 % increase in total energy use. In the research on factors of CO_2 emissions York, Rosa and Dietz (2003b) also identify a significant and positive influence of industrialization which elasticity is a little above one. Though more recent studies conclude about rather smaller size of the effect. For instance, considering energy intensity in developing countries Sadorsky (2013) finds that the industry share has an elasticity which is equal to around 0.20. In addition, while analyzing a model specification with the first differences the industrialization coefficient sinks to 0.04. A similar finding regarding a smaller size of the industry share elasticity is drawn in the studies by Paumanyvong and Kaneko (2010) as well as Li and Lin (2013). The scholars explore determinants of energy use and CO_2 emissions respectively in a model with first differences. The former study estimates the industrialization elasticity to be about 0.06, while the latter finds its value of 0.02. Nevertheless, regardless the size of the effect the previous research clarifies one common conclusion: industrialization tends to demonstrate consistently significant and positive impact on an environmental impact indicator.

Another process which is tightly related to industrialization is urbanization. Generally, both processes enforce industrial transformation and changes in consumption behaviors (increase in demand for energy intensive products), and consequently rise of energy use and emissions. Hence, urbanization can be also considered as an environmental stressor. Nonetheless, the scholars notify that two processes of industrialization and urbanization should not be viewed as identical (Jones, 1991; Li & Lin, 2015). They influence an environmental indicator through distinguishable channels which are discussed in the following section 2.1.2.

Table 2-1. Previous research on the environmental impact of urbanization and industrialization

Author	**Context**	**Dependent variable**	**Definitions and impacts (in parentheses) of explanatories**	
			Urbanization	**Industrialization**
Cole & Neumayer, (2004)	86 countries, the period of 1975-1998	CO_2 emissions	% of population living in urban areas (+)	% of GDP from industry (+-)[1]
Dietz, Rosa & York, (2007)	UN sample, the year of 2001	Ecological footprint	% of population living in urban areas (+)	% of GDP from a service sector (-)
Elliot, Sun & Zhu, (2014)	29 Chinese provinces, the period of 1997-2010	Energy intensity	% of population living in urban areas (+) % of non-agricultural population (+-)[1] % of workers employed in the non-agricultural sector (+)	% of GDP from industry (+)
Jones, (1991)	59 developing countries, the year of 1980	Energy consumption	% of population living in urban areas (+)	% of GDP from industry (+)
Li & Lin, (2015)	73 countries, the period of 1971-2010	Energy use CO_2 emissions	% of population living in urban areas (+-)[2]	Added value of secondary industry divided by primary (+-)[2]
Martinez-Zarzoso, Bengochea-Morancho & Morales-Lage, (2007)	23 EU members, the period of 1975-1999	CO_2 emissions		% of GDP from industry (+)
Martinez-Zarzoso & Maruotti, (2011)	88 developing countries, the period of 1975-2005	CO_2 emissions	% of population living in urban areas (+-)[2]	% of GDP from industry (+)
Paumanyvong & Kaneko, (2010)	99 countries, the period of 1975-2005	Energy use	% of population living in urban areas (+-)[2]	% of GDP from industry (+)
		CO_2 emissions	% of population living in urban areas (+)	% of GDP from industry (+)
Rafiq, Salim & Nielsen, (2016)	20 developing countries	Energy intensity	% of population living in urban areas (+)	
Sadorsky, (2013)	76 developing countries, the period of 1980-2010	Energy intensity	% of population living in urban areas (+)	% of GDP from industry (+)
Shi, (2003)	93 countries, the period of 1975-1996	CO_2 emissions		% of GDP from industry (+)
Yan, (2015)	30 Chinese provinces, the period of 2000-2012	Energy intensity	% of population living in urban areas (+)	% of GDP from industry (+)
York, Rosa & Dietz, (2003a)	142 countries, the year of 1996	Ecological footprint	% of population living in urban areas (+)	% of GDP from nonservice sector (+)
York, Rosa & Dietz, (2003b)	146 countries, the year of 1996	CO_2 emissions	% of population living in urban areas (+)	% of GDP from industry (+)
York, (2007)	14 EU countries, the period of 1960-2000	Energy consumption	% of population living in urban areas (+)	

[1] For some of model specifications a variable has a minor and insignificant elasticity.
[2] An effect varies by income level of countries.
Source: Author's own compilation.

Urbanization is usually measured by the population living in urban areas to total, yet other indicators are possible to consider as well. For example, in the study on Chinese provinces by Elliot, Sun and Zhu (2014) urbanization is defined as a percentage share of nonagricultural population or a proportion of workers employed in nonagricultural sectors. As in a case with industrialization, regardless various measure types urbanization is generally expected to possess a significant and positive effect on an environmental impact indicator, however empirical analyses provide rather inconclusive results.

Thus, in line with *a priori* expectation the studies by Jones (1991) and York, Rosa and Dietz (2003b) find that urbanization has positive elasticity coefficients of 0.35 and 0.62 respectively. Also significant yet more considerable impact of urbanization is registered by Rafiq, Salim and

Nielsen (2016) who analyze drivers of energy intensity in emerging economies. Depending on a model specification, the elasticity of urbanization varies between 0.89 and 1.50.

Interestingly, some studies find a smaller size of the urbanization effect in comparison with industrialization (Jones, 1991; York, Rosa & Dietz, 2003b; Sadorsky, 2013). However, such outcome cannot be considered as conclusive since other research works outline an opposite conclusion: urbanization has a larger effect than an economic structure indicator (York, Rosa & Dietz, 2003a; Yan, 2015; Li & Lin, 2015).

Noteworthy, this contradiction is not the only one when it comes to analyzing the environmental impact of urbanization. Some studies provide mixed results which do not always support the above outlined expectation. First of all, the finding by Dietz, Rosa and York (2007) demonstrates that urbanization has no significant impact on an aggregate measure of ecological footprint (consumption converted into hypothetical amount of land hectares and sea area). The same conclusion is drawn by Elliot et al. (2014) who consider a model specification with the first differences. In their research urbanization has a minor and insignificant elasticity coefficient.

Second, some studies assume that the relationship between urbanization and an environmental indicator is non-linear (York, Rosa & Dietz, 2003b; York, Rosa & Dietz, 2006). Thus, in accordance with the concept of Environmental Kuznets curves (EKC) the scholars introduce a polynomial (quadratic) term of urbanization in estimation models and identify an inverted U-shape relation. While expecting this non-linear relationship, other empirical studies aim to identify on which side of the U-shaped curve a particular group of countries locate, i.e. whether they are on a left upward or right downward side. The former implies the existence of a positive association between urbanization and an environmental indicator, while the latter can be indicated by a negative association. Thus, Martinez-Zarzoso and Maruotti (2011), Paumanyvong and Kaneko (2010), and Li and Lin (2015) infer that the effect of urbanization varies by income class of countries. Paumanyvong and Kaneko (2010) find that the share of urban population to total decreases energy consumption in low-income states (i.e. its elasticity is negative), while middle- and high-income countries experience an opposite tendency. However, considering CO_2 emissions the urbanization effect is positive for all classes of countries, yet with its size varies. The studies by Martinez-Zarzoso and Maruotti (2011) as well as Li and Lin (2015) identify that the relationship urbanization-CO_2 emissions is negative for more developed economies and positive for less developed countries.

Importantly, all the related literature also examines impacts of primary driving forces such as per capita income/GDP and population size. According to empirical estimations in the studies both have positive elasticities implying that their increase consequently leads to increase in an environmental impact indicator. Besides, in the research where energy intensity is not considered as a dependent variable, it is included as another essential determinant that influences an environmental indicator such as GHG emissions (Cole & Neumayer, 2004; Martinez-Zarzoso, Bengochea-Morancho & Morales-Lage, 2007; Martinez-Zarzoso & Maruotti, 2011; Paumanyvong & Kaneko 2010; Brizga, Feng & Hubacek, 2013). The previous research illustrates that the energy intensity elasticity appears to be significant and positive.

2.1.2. Mechanisms of Influence

While analyzing outcomes of the previously mentioned studies, two important questions arise. First, by which mechanisms/channels urbanization and industrialization influence an environmental impact indicator? And, second, how can the distinguished differences in the effects be explained? Therefore, a current sub-section addresses the former question, whilst the next sub-section 2.1.3 compiles researchers' interpretations regarding the latter issue.

The mechanism of the industrialization impact on the environment appears to be rather straightforward. The process of industrialization typically refers to the transformation of a society from agricultural to one based on higher value added manufacturing (Elliot, Sun & Zhu, 2014). In a historical perspective the rising industrial activity is strongly associated with dramatic increase in GHG emissions. Thus, since the first industrial revolution an expanding manufacturing sector has been heavily relying on extensive energy use of fossil fuels (Kander, Malanima & Warde, 2013). Subsequently, as known the combustion of them became the largest anthropogenic source of CO_2 emissions. According to Jones (1991) the increasing demand for fossil fuels has taken place due to the following factors: (1) mass manufacturing production concentrated in cities, and (2) wide expansion of materials as metals and plastics which substituted outdated leather and wood products. The former requires easier transportability of energy resources to urban areas for which fossil fuels were more suitable. The latter reflects in rising importance of energy intensive industries in total GDP (e.g. petroleum refining, metallurgy, chemicals, etc.).

Thus, considering this evident relation between industrialization and emissions the literature pays larger attention to comprehend more complicated nature of the urbanization impact (Li & Lin 2015). Its mechanisms are outlined by Jones (1991), Madlener and Sunak (2011), Sadorsky (2013) as well as Elliot, Sun and Zhu (2014). The scholars distinguish four main channels by which urbanization influences energy use, energy intensity and consequently GHG emissions (Figure 2-1).

The first channel (urban production in Figure 2-1) largely refers to the industrialization mechanism in developing economies. Thus, more concentrated urban population permits larger labor forces in cities which are transferred from low energy intensive agricultural[1] to high energy intensive industry sector (Jones, 1991). This structural change results in the establishment of large scale manufacturing which in turn stands in a need of massive inputs as well as their transportation over longer distances. Needless to mention, production outputs have to be delivered to their consumers and therefore also go through the same distances. Hence, energy consumption increases. Besides, urbanization put pressure on producers of agricultural products who diminish in their number due to the labor shift from rural to urban areas (Madlener & Sunik, 2011). In order to meet increasing demand of cities the agriculture becomes more mechanized and intensified, and its production also needs transportation. This development leads to increasing energy usage as well. As noted before, transportation needs plus scarcity of urban lands encourage the consumption of more compact and reliable energy sources, namely fossil fuels.

Another mechanism of the urbanization impact (mobility and transport in Figure 2-1) concerns increasing demand for transport services and supplies. Urbanization increases not only inter-mobility among areas (delivering production to destinations of consumption) but also intra-

[1] However, it is challenged by Kander (2008) who identifies major agriculture-related CO_2 emissions for Sweden's economy in the 19the century.

mobility (Elliot, Sun & Zhu 2014). It implies rising demand for public and private motorized transport. If an advanced system of the former is associated with more environmental friendly impact of urbanization through increasing energy efficiency, the growth of the latter substantially contributes to energy use and pollution.

The next mechanism addresses urban infrastructure. More concentrated population and economic activity in cities rise the problem of land scarcity which brings to the necessity to construct and maintain multi-level housing and office buildings, roads, bridges, power plants, etc. Madlener and Sunik (2011) reckon that direct costs of these processes are not as massive as indirect expenses that consist in increasing related production of such energy intensive goods as cement and steel. At the same time, it is important to note that the literature also highlight the advantage of densely-built dwellings. If an urban area possesses areas with compactly build housing rather than detached houses, there is less chance to release waste heat, since such buildings are often connected to district power grids. Thus, likewise efficiently organized system of public transport densely-built homes have a potential to advance an eco-friendly infrastructure.

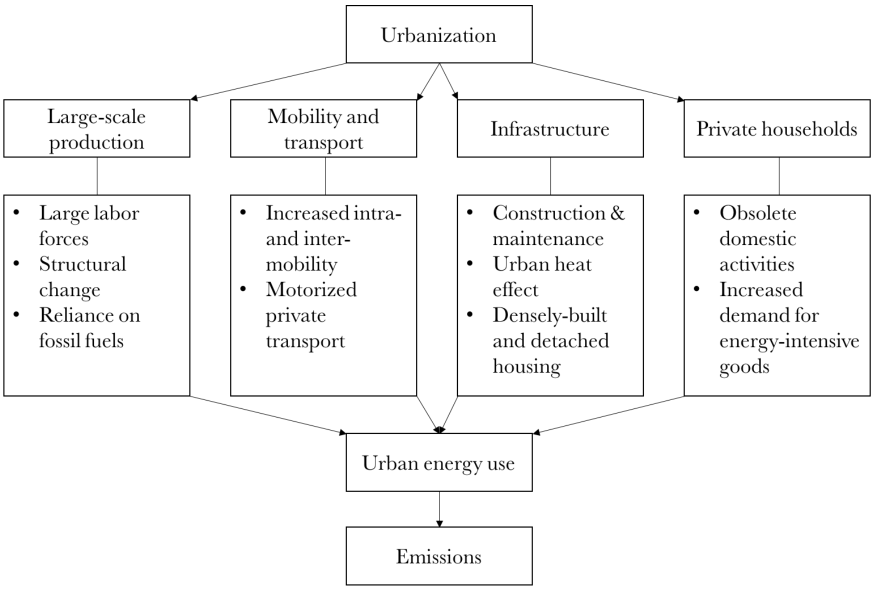

Figure 2-1. Impacts of urbanization on energy consumption and GHG emissions

Source: Author's own illustration derived from Madlener and Sunak (2011)

The last channel concerns the consumer behavior and lifestyles of urban residents (private households in Figure 2-1). Jones (1991) reckon that urbanization leads to particular changes in domestic activities of households. Thus, due to the division of labor and more specialized production in cities many activities which can be conducted in home become obsolete and move outside. For instance, they include baking, food preservation, water heating for cleaning clothes, sewing, etc. On one hand, commercialization of these activities might decrease fuel use per unit of output, however the biggest issue concerns transportation of such products that in opposite increases energy consumption. Urban residents also tend to receive higher incomes than rural inhabitants. Wealthier population of cities changes its consumption pattern by including more energy intensive goods such as automobiles, air conditioners, refrigerators, washing machines and other appliances (Sadorsky, 2013).

2.1.3. Varying Effects among Countries

While investigating the environmental impact, scholars express their strong belief that it is important to identify not only overall trends for a number of countries, yet also distinguish particular tendencies that might be inherent to separate groups of states. The motivation of recognizing heterogeneity and varying effects of the driving forces among economies consists in an emerging potential to formulate and apply the most appropriate energy-saving and emissions-reducing policies for urban areas (Fan et al., 2006).

As noted above, the empirical studies identify varying impacts of industrialization and urbanization among countries (Fan et al., 2006; Martinez-Zarzoso & Maruotti, 2011; Paumanyvong & Kaneko, 2010; Li & Lin, 2015). Thus, the effect of industrialization differs in size, while the urbanization impact varies by both size and character (positive/negative).

In order to address the former, Jones (1991) provides a following explanation. There are four factors which might cause disparities in the industrialization impact among economies. First of all, identical production follows different manufacturing processes in different countries. These processes in turn are characterized by various energy intensities. The researcher illustrates the examples of the cement industry in Turkey and textile manufacturing in the US within which a high variation of energy consumption per unit of output is observed. Second, in each country the industrial sector can be characterized by a different product range. For instance, in a developed economy as the US the manufacturing product variation is considerable which then is referred to a great variation in energy intensities. Another factor which leads to differences in the industrialization effect concerns maintenance and operational procedures. According to Jones (1991) they vary substantially in particular between developing and developed economies. Thus, these procedures might be assumed to be more energy efficient in a developed than developing country. Last but not least, the industrialization impact can change with time since the process of learning-by-doing takes place in industrial and commercial energy usage. For instance, over a period of 5-10 years a firm might advance its production operations and increase energy efficiency. Though, while conducting an analysis at a national level this phenomenon is rather difficult to account for.

Considering a varying impact of urbanization, Madlener and Sunik (2011) highlight specific differences in a type of urban growth between developed and developing countries. The scholars reckon that more developed economies have the majority of their population living in cities for quite a while, thus there the urban growth has already reached its saturation. In the past the process of urbanization was accompanied with massive industrialization and, importantly, rapid economic development. Hence, it resulted in not only quantitative but also qualitative growth of cities. Urban population is characterized by higher incomes and more environmental awareness in developed than developing countries. It contributes to the implementation of larger and better urban management practices and various actions to mitigate increasing energy usage and emissions. In contrast, developing economies are more likely to experience quantitative rather than qualitative urban growth since rising urbanization is not accompanied with the same economic advances as in more developed countries. Unplanned city growth is another peculiar feature. The expansion of informal building sector contributes to city fragmentation which increases the costs of urbanization due to inefficient land use and difficulties to deliver basic supplies (e.g. water and electricity) to urban households avoiding illegal housing. This phenomenon only adds more tasks to the urban planning agenda in order to optimize energy consumption and mitigate pollution in the cities of developing countries.

The studies by Fan et al. (2006) and Paumanyvong and Kaneko (2010) distinguish urbanization effects among categories of countries grouped by their income level according to the World Bank classification. The scholars identify a common result: there is a greater positive impact of urbanization in middle- and low-income economies. The process of modernization, low energy efficiency, energy-saving technologies and awareness lead to substantial environmental issues in these states.

Martinez-Zarzoso and Maruotti (2011) who also consider income classes of countries find even more pronounced disparity in the relationship between urbanization and CO_2 emissions. Following the concept of EKC, the researchers conclude that once the share of urban population to total achieves a certain level, its impact on the emissions turn to be negative implying the contribution to reducing environmental damage. Thus, the low-income group of countries that can be characterized by lower levels of urbanization has the highest positive elasticity of urbanization. Then moving on to lower middle-income class the coefficient diminishes in its size, yet stays positive. While considering upper middle- and high-income groups the elasticity of urbanization gets a negative sign.

A similar outcome is obtained by Li and Lin (2015). In line with Martinez-Zarzoso and Maruotti (2011) they also identify a negative association between urbanization and CO_2 emissions in upper middle- and high-income economies, unlike in the rest. The research interpret such tendency as follows: the richer urban population is, the less it is concerned about poverty related problems (survival and individual living expenses) and more attention is paid to issues of a city environment.

2.2. Theoretical Model

A famous work by Ehrlich and Holdren (1971) is one of the most cited papers in numerous studies that explore anthropogenic impacts on the environment. The reason is that this work has opened a big debate in the early 1970s, which eventually brought to the formulation of a methodological approach, called I=PAT (or IPAT). Since then this framework has been being widely utilized by scholars in estimating environmental impact (*I*, often represented by CO_2 emissions, energy use or energy intensity) of three main drivers as population size (*P*), affluence (*A*, commonly introduced as GDP or GNP per capita in the equation) and technology (*T*, basically everything else but population and affluence). Noteworthy, the known values of *I*, *P* and *A* were typically used to solve for the missing term *T* (Dietz & Rosa, 1997).

The IPAT model became a popular approach due to its certain strengths. Thus, it is considered as a parsimonious specification which combines key driving forces for environmental change. The model underlines that the drivers do not affect independently, and therefore factors are multiplied by one another in the equation. It also assumes that there is no driving force which is singularly responsible for environmental impact (York, Rosa & Dietz, 2003b). However, despite these strengths researchers find particular limitations in applying the model.

Among the criticisms several aspects can be highlighted. First of all, as mentioned before the technology explanatory *T* is derived from other known elements of the equation (*P* and *A*) so that it balances the IPAT identity. The model does not account for various indicators of *T* which might more accurately measure technology itself or provide additional information on technological potential (York, Rosa & Dietz, 2003b). Another drawback of the IPAT model consists in its assumption on proportionality in a relationship between variables (York, Rosa & Dietz, 2003a; Liddle & Lung, 2010). Thus, if one explanatory doubles, *ceteris paribus* it is presumed to lead to a doubling of the environmental impact. Both disadvantages consequently permit certain hypotheses testing on more specific measures of *T* as well as non-proportional and non-monotonic effects of the driving forces.

This limitation was recognized and addressed by scholars who further developed models as ImPACT and EKC (York, Rosa & Dietz, 2003b). The former is based on the original IPAT identity, but disaggregates *T* into two measures – consumption per unit of GDP *(C)* and impact per unit of consumption *(T)*. The latter model also finds its origin in IPAT and holds the Environmental Kuznets curves hypothesis that is discussed earlier. The model suggests that an explanatory has a non-proportional and non-monotonic effect on the measure of environmental impact, hence, the model includes a polynomial term of the variable. The EKC approach is well-known and considered in the previous literature. For instance, the hypothesis on such non-linear relationship between affluence and CO_2 emissions has been supported in the most recent study by Rafiq, Salim and Nielsen (2016).

Another significant approach, which is considered to bring substantial improvements to understanding of driving forces for environmental change, is Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT). Its authors Dietz and Rosa developed the model by revisiting the IPAT identity (Dietz & Rosa, 1994; Dietz & Rosa, 1997). In the discussion of the IPAT's limitations the scholars come to the reformulation of the model and its elements. Thus, first of all, they focus on the reformulated stochastic form of the IPAT equation which looks like (Equation 1):

$$I_i = aP_i^b A_i^c T_i^d e_i \quad (1),$$

where *I*, *P*, *A* and *T* still stand for environmental impact, population, affluence and technology respectively. However, unlike before the model distinguishes the exponents *a*, *b*, *c* and *d* as well as an error term *e* (in the original IPAT the all are equal to 1). The subscript *i* implies that the variables and the error term can vary across different observational units. Such reformulation allows to count for non-proportional effects of the explanatories on environmental change. Also, if considering a log-log form of the model it becomes possible to test some hypotheses regarding the nature of effects (e.g. negative or positive, their size) since the estimated exponents can be then considered as elasticities.

Second, Dietz and Rosa (1994) reckon that it is possible to reformulate all four elements of IPAT. They assert that it is not necessary to stick only with key driving forces (as *P* and *A*) and standard measures of the variables. In fact, elements of Equation 1 can be presented by various measures. This in turn leaves a task for a researcher to identify appropriate indicators according to aims of her or his study. For instance, a researcher can set a goal to look into the impacts of industrialization and urbanization since according to the previously discussed mechanisms of their influence it is logical to assume that: (1) industrial activity increases energy demand and subsequently CO_2 emissions, and (2) rising urban population also positively affects the environmental impact indicator particularly in developing countries. Hence, along with the key drivers (population size and GDP per capita) these additional factors may enter the model as explanatories to explain *I*. Finally, a driving force as technology should not be narrowly considered as technology itself, yet it can be rather attributed to changes in sectoral (in particular industrial) energy intensity.

The STIRPAT framework takes a solid position in today's research on analyzing environmental impacts. This is due to the fact that the model can address main limitations of the original IPAT approach. While implementing STIRPAT in a study, it is possible to obtain coefficients (estimated exponents) which would indicate a percentage change of I in a response to 1 % change of P, A, T. The model is also flexible; in other words, it can include additional measures along with the key driving forces. An important concern here is to ensure that the additional indicators are consistent with the multiplicative specification of the model (York et al. 2003).

Considering these great advantages, this study intends to apply the STIRPAT approach in order to gain new perspectives on the issue of the environmental impact and its drivers in the former Soviet Union republics.

3. Background on the Former Soviet Union Republics

3.1. The Soviet Union Heritage

The Soviet Union was known as one of the world's largest emitter before the collapse in 1991. Together with Eastern European centrally planned economies the country was responsible for one quarter of global CO_2 emissions in the atmosphere (Foell, 1992). Qualitative research highlights several determinants for such high emissions level. The major of them concern the Soviet industrialization and energy intensity and therefore comprise the following aspects.

First of all, energy intensive industries generally were presented by a great share of the socialist economy. They heavily relied on use of fossil fuels. In addition, the quality of these energy sources was poor (Ürge-Vorsatz, Miladinova & Paizs, 2006). Foell (1992) provides an astonishing example of significantly high energy intensity level in the USSR industrial sector which was 170 % larger than that in the United States. Thus, while the Soviet industries consumed 37 % more energy than the US industries, its output was half the American output.

Second, the industrial production was established in a way which did not encourage energy efficiency. For instance, in the beginning of five-year production plans enterprises received allocated resources which were usually reported to be higher than actual (Ürge-Vorsatz, Miladinova & Paizs, 2006). Consequently, it generated massive energy waste. Third, energy prices were fixed in accordance with a principle of a Marxist political economy (Foell, 1992). Hence, there was no mechanism to signal about resource scarcity and raise environmental concerns (Ürge-Vorsatz, Miladinova & Paizs, 2006). Finally, enterprises were also made large and high-volume to produce in oversized scales not for one, but a group of socialist countries (Foell, 1992).

According to the studies (Foell, 1992; Ürge-Vorsatz, Miladinova & Paizs, 2006) among other aspects that drove high energy use and CO_2 emissions in the Soviet economy were mentality (towards energy as a cheap production input), lack of environmental awareness and corruption to energy payments.

Interestingly, the considered studies do not outline urbanization as an aspect of growing energy use or rising CO_2 emissions in the former Soviet Union (FSU) region. In contrast, Ürge-Vorsatz, Miladinova and Paizs (2006) distinguish processes associated with urbanization as positive legacies in centrally planned economies. Thus, before the fall of communism the countries possessed a high share of organized public transportation networks in cities which led to much lower levels of private motorized transport use in comparison with European OECD countries. Another positive legacy concerned the socialist urban land planning. High-rise buildings, multifamily apartments and concentrated settlements grew in Soviet cities. They were typically connected to district heating systems, recognized as more beneficial than individual heating. In addition, sometimes district heating utilized the waste heat of industrial and power plants which also led to energy-saving practices. In the USSR there was also low individual consumerism: population reused and recycled materials. Noteworthy, all these legacies were not driven by consideration of environmental consequences, yet rather by an economic rationale – low incomes and limited supply of consumer products. For instance, in order to buy a light duty car, a Soviet citizen had to wait in a line over several years.

Undoubtedly, in the post-Soviet times these aspects still take place in the FSU countries. Namely, the largest successor – Russia – is still one of the most emitting economies in the world.

It is positioned as the fifth biggest emitter of carbon dioxide in 2011 (US Environmental Protection Agency, n.d.). Russia's CO_2 emissions per capita shows a decline by 26.6 % over the period of 1990-2013, though they stay substantially high – 10.8 metric tons per person (International Energy Agency, 2015; the United Nations, 2015). High levels of emissions per capita are present in other FSU republics such as Estonia, Kazakhstan, Turkmenistan, Belarus and Ukraine. This can be considered as a result of remaining high reliance on emitting fossil fuels as coal or lignite as in Estonia (Brizga, Feng & Hubacek, 2013) as well as big shares of energy intensive heavy industries in economic structures that are largely subsidized by governments (Arazmuradov, 2011). Technologies that were established at industrial plants during the Soviet era became outdated which certainly did not contribute to decrease in energy intensity (Foell, 1992). Considering the above mentioned positive legacies of the urbanization process, Ürge-Vorsatz, Miladinova and Paizs (2006) highlight that with the fall of communism there is an emerging challenge to converse them. If Soviet residents had great incentives to shorten their consumption, after the USSR collapse with widening product ranges and increasing salaries it became difficult to maintain these positive legacies. Also, regarding district heating systems it is important to note that they turn to be leaky, unreliable and obsolete and bring high losses of energy in the modern time.

Despite the previously discussed Soviet heritage, it is hard not to notice an outstanding trend, inherent for the whole block of FSU economies over past two decades. The trend consists in significant decline of CO_2 emissions (Figure 3-1).

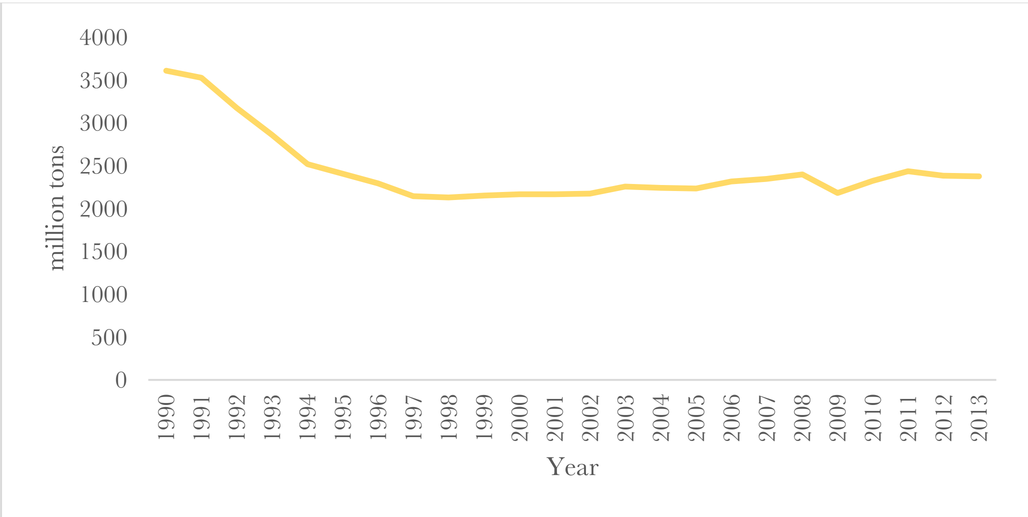

Figure 3-1. Total CO_2 emissions from fuel combustion in the whole FSU region, 1990-2013

Source: Author's own illustration based on the data of International Energy Agency (2015)

Brizga, Feng and Hubacek (2013) argue while in overall the world experiences significant increase in total CO_2 emissions from fuel combustion by 45 % during the period of 1990-2010, the post-Soviet republics go through the decline by 35 %. Hence, it is essential to investigate driving forces of environmental impact in the new period after the dissolution of the Soviet Union and identify whether the above discussed factors such as industrialization, energy intensity and urbanization have persistent impacts in the FSU region.

3.2. Classifying the Post-Soviet Republics

To the best of the author's knowledge, the study by Brizga, Feng and Hubacek (2013) is the first one that highlights the necessity to consider diversity of the FSU republics while identifying the driving forces of environmental impact. The scholars provide examples of substantial disparities in the profiles of post-Soviet countries. Thus, the states differ by income level, economic structure, energy intensity and per capita carbon dioxide emissions. Considering this fact together with the literature written on varying environmental impacts of industrialization and urbanization there is a potential to distinguish the FSU republics into particular classes.

The first classification can be done by a country's income level in line with the studies, discussed in the section 2.1.3. Brizga, Feng and Hubacek (2013) highlight widening differences in GDP per capita within the FSU region in 2010. Thus, according to the World Bank classification the countries are assigned as follows: (a) Estonia belongs to high-income economies; (b) Latvia, Lithuania, Russia, Azerbaijan, Turkmenistan, Kazakhstan and Belarus – to upper middle-income class; (c) Armenia, Georgia, Moldova, Uzbekistan and Ukraine – to lower middle-income countries; and (d) Kyrgyzstan and Tajikistan are defined as low-income states. Hence, based on this classification it is possible to divide the FSU republics into higher (classes *a* and *b*) and lower (classes *c* and *d*) income categories and consider the environmental impacts of industrialization and urbanization, that lie in the focus of this study, separately for each of them. Nonetheless, Li and Lin (2015) notify about a serious disadvantage of classifying countries by income level while working with panel data. Placing a country in a certain income group assumes that during an entire time period the country belonged to this group and did not transcend within income categories. However, there is a reason to believe that transition economies of the FSU region did change their income levels over a relatively long study period of 1990-2013 (Table 3-1).

Table 3-1. The FSU republics classified by income level in 1991, 2000 and 2010

Income group	**Year**		
	1991	***2000***	***2010***
High	-	-	Estonia
Upper middle	Belarus, Estonia, Latvia, Lithuania, Russia	Estonia	Azerbaijan, Belarus, Kazakhstan, Latvia, Lithuania, Russia, Turkmenistan
Lower middle	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, Uzbekistan	Belarus, Kazakhstan, Latvia, Lithuania, Russia, Turkmenistan	Armenia, Georgia, Moldova, Uzbekistan, Ukraine
Low	-	Armenia, Azerbaijan, Georgia, Kyrgyzstan, Moldova, Tajikistan, Ukraine, Uzbekistan	Kyrgyzstan, Tajikistan

Source: Author's own elaboration based on Brizga, Feng & Hubacek (2013) and the data from the World Bank (n.d.a)

Therefore, in this study I suggest to also consider another classification of the FSU republics which might cover some aspects that do not change substantially over the investigated time period of 1990-2013. The countries can be divided into northern and southern. The former consists of seven states as Belarus, Estonia, Latvia, Lithuania, Moldova, Russia and Ukraine. The latter group includes three Caucasus states – Armenia, Azerbaijan and Georgia – as well as five Central Asian republics – Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Such division of the FSU countries might rely on the following reasoning.

First, as the group titles display geographical and climate criteria are considered. The southern countries are known for longer summers and softer winters, while the northern states experience lower year-average temperatures. Map 2 in Appendix A demonstrates that during a year Caucasus and Central Asian republics receive higher dozens of solar radiation than the northern countries, which might subsequently reflect in their energy consumption trends.

Second, the northern and southern countries can differ in their cultural heritages. Cultures form attitudes, lifestyles and consequently consumer behavior that might also be a determinant for the environmental change according to Dietz and Rosa (1997). Pryde (1985) distinguishes two large cultures in the USSR – Slavic-Eastern Orthodox and Turkic-Muslim. He asserts that if there was not the Soviet centralized government which overshadowed cultural considerations and majorly shaped policies it would be logical to consider environmental actions in two different regions dominated by these large cultures. To some extent the second categorization of countries in this paper might resemble the cultural division of the USSR by Pryde (1985): the northern states are more related to Slavic-Eastern Orthodox cultural heritage (except for Baltic countries) and the southern republics – to Turkic-Muslim (except for Armenia and Georgia). The expressive example how culture can be influencing is demonstrated by Rywkin (1979). Thus, there was an evident conflict between standard Soviet dwelling practices (high-rise buildings) and traditional lifestyles in Central Asia. Big-size undivided families tended to prefer living in single-family detached houses both in urban and rural areas. As the result, already in the Soviet times the common features of housing in the region were higher shares of privately owned apartments and initiatives to build one-family townhouse-style units. These characteristics were of a rare occurrence in other parts of the USSR (except for Georgia). Hence, it is possible to assume that the preference to build detached dwelling units in the south rather than compact settlements inherent to the north might result in higher household energy consumption and consequently more profound environmental impact.

In addition, while observing the characteristics of the FSU region (Table 3-2) it is possible to highlight some recent general tendencies inherent to the northern or southern republics.

Table 3-2. Characteristics of the FSU republics in 2010

Country	**CO_2 emissions, tons per person**	**GDP per capita (constant 2005 USD)**	**Industry share to total value added (% to total)**	**Industrial energy intensity, koe/USD 2005p.**	**Urbanization (% to total)**
Belarus	6.31	4 521.76	35.97	0.35	74.62
Estonia	14.00	10 322.14	21.91	0.21	68.10
Latvia	3.56	7 904.34	15.92	0.34	67.69
Lithuania	3.90	8 875.05	24.66	0.15	66.76
Moldova	1.91	857.30	14.02	1.67	44.89
Russia	10.68	6 351.48	28.19	0.58	73.69
Ukraine	5.83	2 055.41	27.51	1.10	68.69
Northern countries[1]	*6.60*	*5841.07*	*24.03*	*0.63*	*66.35*
Armenia	1.37	1 998.24	20.16	0.30	63.58
Azerbaijan	2.59	3 107.38	64.34	0.04	53.40
Georgia	1.17	1 948.51	19.20	0.31	52.87
Kazakhstan	13.56	4 738.71	29.33	0.96	53.73
Kyrgyzstan	1.11	559.29	17.38	0.78	35.30
Tajikistan	0.30	417.11	15.84	1.45	26.52
Turkmenistan	11.35	4 606.62	40.33	0.20	48.40
Uzbekistan	3.50	782.53	21.41	1.72	36.19
Southern countries[1]	*4.37*	*2269.80*	*28.50*	*0.72*	*46.25*
Whole FSU region[1]	***5.41***	***3 936.39***	***26.41***	***0.68***	***55.63***

[1] Average.

Source: Author's own elaboration based on the data from EIA (2015; n.d.), the United Nations (2015; n.d.).

For instance, on average CO_2 emissions per capita are higher in the north, although there are some exceptions with high emissions level in the southern group such as Kazakhstan and Turkmenistan. Also, most of the northern countries higher levels of GDP per capita above 4000 US dollars (except for Ukraine and Moldova), whilst southern republics are featured by considerably lower incomes (again except for Kazakhstan and Turkmenistan). On average, industry share is slightly higher in the south compared to the north, however, within-group disparities exist. The indicator of industrial energy intensity is larger in the south, although industries remain to be energy intensive in other FSU countries as well. Regarding urbanization, most northern countries (except for Moldova) have higher levels of urbanization. Thus, more than 65 % of the population live in urban areas.

4. Testable Hypotheses

Before moving on to the empirical analysis of this study, it is important to outline the hypotheses which are going to be tested. Relying on the previously discussed literature and considering the specificity of the FSU countries, I possess the following expectations regarding the impacts of industrialization, urbanization and key drivers on a dependent variable – CO_2 emissions per capita[2].

Hypotheses for the whole FSU region

1. Industrialization is positively associated with the dependent variable – CO_2 emissions per capita. The majority of the studies define an industry share as a factor with a strong environmental impact in developing countries to which most of the FSU economies belong (Jones, 1991; Martinez-Zarzoso & Maruotti, 2011; Sadorsky, 2013).
2. In overall, urbanization is also positively associated with the regressand. It is expected in line with the research that identifies the positive urbanization impact for a number of countries before classifying them (Paumanyvong & Kaneko, 2010; Martinez-Zarzoso & Maruotti, 2011; Li & Lin, 2015).
3. Additionally, effects of the control variables such as GDP per capita and energy intensity should not be neglected. Both of them are expected to have significant positive elasticity coefficients (Cole & Neumayer, 2004; Martinez-Zarzoso, 2007; Brizga, Feng & Hubacek, 2013).

Hypotheses for different classes of the FSU republics

A. *Lower and higher income economies*

A.1. Industrialization is positively associated with CO_2 emissions per capita for both country groups. Considering the above discussed background of the post-Soviet republics, it is possible to assume that their industry shares still possess significant environmental impact in most of the FSU economies.

A.2. Urbanization is expected to demonstrate varying effects on the environmental impact indicator. Specifically, in line with the previous research (Paumanyvong & Kaneko, 2010; Martinez-Zarzoso & Maruotti, 2011; Li & Lin, 2015) lower and higher income countries have positive and negative elasticity coefficients respectively.

A.3. The control variables are expected to have a positive association with CO_2 emissions per capita for both groups.

B. *Southern and northern economies*

B.1. As in the hypothesis A.1, industrialization is still assumed to have a significant positive parameter.

B.2. Taking into account some disparities between the southern and northern FSU republics, I expect varying urbanization effects here as well. Thus, considering average development trends and some cultural factors which might influence lifestyles and consumer behavior, I hypothesize a negative association between urbanization and CO_2

[2] The choice of the regressand is explained in the following section 5.1.

emissions per capita for the northern economies and, in contrast, a positive association between the variables for the southern republics.

B.3. As before, GDP per capita and energy intensity are expected to have significant positive estimators for both country groups.

5. Empirical Strategy

5.1. Model Specification

Following Dietz and Rosa (1997), in this study I implement the STIRPAT model exposed to some transformations. First, I take natural logarithms on the both sides of the equation (1). Subsequently the model looks like (Equation 2):

$$lnI_{it} = \alpha + \beta_1(lnP_{it}) + \beta_2(lnA_{it}) + \beta_3(lnT_{it}) + e_{it} \quad (2),$$

where the environmental impact *(I_{it})* is a function of population *(P_{it})*, affluence *(A_{it})* and technology *(T_{it})*; α is a constant, the coefficients β_1, β_2 and β_3 are elasticities which indicate a percentage change of a regressand associated with 1 % change of a regressor, and e_{it} is the error term.

Second, as Brizga, Feng and Hubacek (2013) notify the previous studies which attempted to explore the drivers of environmental impact in the post-Soviet countries experience a following issue: estimation results are dominated by Russia as a country with the largest population and emissions in the FSU region. Hence, in order to avoid this problem, it is decided to reformulate a dependent variable *(I_{it})* from total CO_2 emissions to the emissions per capita and consequently remove the explanatory P_{it} from the right side of the model. Such rearrangement brings to a new Equation 3 which looks like:

$$lnI_{it} = \alpha + \beta_1(lnA_{it}) + \beta_2(lnT_{it}) + e_{it} \quad (3),$$

where the environmental impact *(I_{it})* and affluence *(A_{it})* are measured respectively by CO_2 emissions from fuel combustion per capita and GDP per capita in constant prices (2005 US dollars) in a country *i*, a year *t*. As the scholars note there is no clear consensus on a valid indicator of the technology component - T_{it} (York, Rosa & Dietz, 2003b; Fan et al., 2006). Therefore, based on the previous research in this paper T_{it} is decomposed to two variables, and one of them is in a focus of this study (Shi, 2003; Fan et al., 2006; Martinez-Zarzoso, Bengochea-Morancho & Morales-Lage, 2007; Liddle & Lung, 2010; Brizga, Feng & Hubacek, 2013). The first variable is a measure of economic structure – industry share per unit of total value added. Based on the previously discussed literature on the mechanisms of the industrialization influence, a positive association between industry share and CO_2 emissions can be expected. The second variable is industrial energy intensity which reflects changes in the economic structure. Its inclusion relies on the logic: industry is a diverse sector consisting of more and less energy intensive manufacturing, and therefore it is important to capture the sector's diversity by considering industrial energy intensity (Liddle & Lung, 2010). The relationship between the explanatory and CO_2 emissions is expected to be positive as well.

Last but not least, since this study aims to identify the urbanization impact on the environment in the FSU countries, another component enters the model. It is measured by a percentage of population living in urban areas to total and in overall expected to be positively associated with CO_2 emissions per capita for the sample of transition economies. Thus, Equation 3 takes a new form (Equation 4):

$$lnEmissions\_pc_{it} = \alpha + \beta_1(lnGDP\_pc_{it}) + \beta_2(lnInd_{it}) + \beta_3(lnInd\_EI_{it}) + \beta_4(lnUrb_{it}) + e_{it} \quad (4),$$

where CO_2 emissions per capita are a function of GDP per capita, industry share, industrial energy intensity and urbanization.
Therefore, in this study Equation 4 is estimated for the whole sample of the FSU republics. Additionally, bearing in mind possible heterogeneity among different classes of countries outlined in the previous studies the same equation is also estimated separately for: (a) lower and higher income economies, and (b) the southern and northern republics.

5.2. Data

This study uses a balanced panel dataset, which contains 360 observations on all FSU republics during the period of 1990-2013 (thus, $N=15$ and $T=24$).
The data on the constructed dependent variable – total CO_2 emissions from fuel combustion per capita – is originally provided by International Energy Agency and the United Nations. The emissions are calculated based on energy balances of countries, and total midyear population is derived from demographic questionnaires collected annually from national statistics offices.
Moving on to the explanatories, in this study the independent variable GDP per capita is constructed by dividing GDP in constant 2005 US dollars by total midyear population. The data on GDP is also provided by the United Nations which compiles a common dataset for all world nations from their national accounts. The next explanatory – industry share – is calculated as the output of mining, manufacturing and utilities divided by total value added which are both given by the United Nations. Industrial energy intensity is obtained as industrial final energy consumption divided by the output of mining, manufacturing and utilities. The information on industrial energy use is obtained from energy balances of the considered countries. Finally, the data on urbanization is taken from the official World Bank website and reported to be collected and smoothed by the United Nations.
Table 5-1 summarizes basic information on the regressand and regressors that are used in the paper. In addition, descriptive statistics on the variables are given in Tables B-1 and B-2 (Appendix B).

Table 5-1. Variables used in the study

Variable		Definition	Unit of measurement	Source
	Dependent variable			
1.	Total CO_2 emissions per capita	CO_2 emissions from fossil fuel combustion divided by total midyear population	Metric tons of carbon per person	International Energy Agency (2015), the United Nations (2015)
	Independent variables			
2.	GDP per capita	GDP in constant prices divided by total midyear population	US dollars per person per year in constant 2005 prices	The United Nations (2015; n.d.)
3.	Industry share	Output of mining, manufacturing and utilities per unit of total value added	% of total	The United Nations (n.d.)
4.	Industrial energy intensity	Industrial total energy consumed for producing one output unit of mining, manufacturing and utilities	koe/US dollars 2005p.	International Energy Agency (n.d.), the United Nations (n.d.)
5.	Urbanization	Share of population living in urban areas as defined by national statistical offices	% of total	The World Bank (n.d.b)

Source: Author's own elaboration

5.3. Estimation Methods

While working with macro panel data that is characterized with a large number of time periods (T), researchers face the problem of data nonstationarity (Baltagi, Bresson & Pirotte, 2007). This is a big concern since estimating models with nonstationary variables might cause biased parameters. Hence, before running regressions it is essential to check whether the data contains unit roots.

First, in order to obtain an initial clue about the nature of data I graphically inspect the variables. Then the turn for formal testing comes, which might be based on the following tests: (a) Levin-Lin-Chu, (b) Im-Pesaran-Shin, (c) Maddala and Wu, and (d) Pesaran 2007 (also known as cross-sectional Im-Pesaran-Shin test – CIPS). Unlike the latter the first three tests assume cross-sectional independence. Thus, if cross-sectional correlation is identified among countries within the panel the three tests are considered to have low power and, as a consequence, might bring to misleading results (Baltagi, Bresson & Pirotte, 2007; Elliot, Sun & Zhu, 2014). Therefore, at first I run Pesaran cross-sectional dependence (CD) test and afterwards conduct corresponding unit root tests. Thus, the CIPS test is used if cross-sectional dependence is revealed, and other tests are conducted in an opposite case.

Noteworthy, despite the variety of panel unit root tests, none of the known formal methods can provide conclusive results. Hence, a decision regarding data stationarity should be made in the aggregate through the consideration of both graphical and formal testing. Therefore, I plot all the variables and consider graphs along with test outcomes.

Moving on to the model estimation, I apply both methods of fixed effects (FE) and random effects (RE). The former assumes heterogeneity across entities and time periods (N and T) and hence allows for individual intercepts for countries and years. One way to acquire such individual intercepts is to introduce dummy variables for each N and T, however this technique has its drawbacks of losing degrees of freedom and multicollinearity. Therefore, it is possible to turn to another option of the FE within-group estimator which can be obtained by time and cross-sectional demeaning of the original equation and estimated with the pooled ordinary least squares (pooled OLS). Specifically, this technique is used in this study. Notably, FE estimators are considered to be always consistent even if a true model is assumed to be the pooled OLS or RE (Gujarati & Porter, 2009).

Another method of RE generally assumes that a sample of entities as well as a set of time periods are randomly chosen and consequently cross-section and time effects are random components. However, it is possible to believe that common trends exist for the observed variables which might be a source for gaining spurious results (such as decreasing CO_2 emissions, industrial activity and energy intensity since the collapse of the USSR as can be seen in Figure 6-1, section 6 as well as Figures C-1 and C-2, Appendix C). In order to eliminate this problem, I run an RE model with time dummies. Again the issue of losing degrees of freedom emerges, though the sample size (360 observations) seems to allow the inclusion of 24 year dummies. The RE model estimation is based on generalized least squares.

Even if a true model is the pooled OLS, RE estimators are consistent. Nonetheless, it is not a case if an underlying model is FE (Gujarati & Porter, 2009).

Additionally, while working the panel data the problem of heteroscedasticity might arise. It can lead to biased estimates of variance of the coefficients. Therefore, I introduce the option of robust standard errors while running both FE and RE models.
At the next stage, I conduct two post-estimation tests in order to choose a better fitting model. First, a Hausman test helps to identify whether the FE or RE model is preferred. In particular, it tests whether the error term is correlated with explanatories. If it does, then the FE model should be chosen, or otherwise – RE. Second, a Wald test checks whether year dummies are significant in RE and FE models. Thus, if the null hypothesis that dummy coefficients equal to zero cannot be rejected, the specification without dummies should be preferred and *vice versa*.

6. Empirical Analysis

6.1. Descriptive Analysis of the Variables

Before demonstrating and discussing the estimation results, it is important to have a look at inherent tendencies in the FSU republics during the considered period of 1990-2013.
Figure 6-1 shows carbon dioxide emissions per capita for the whole FSU region as well as their values for the distinguished classes of countries. Noteworthy, the figure presents not average, yet aggregate measures (i.e. aggregate CO_2 emissions are divided by aggregate population).

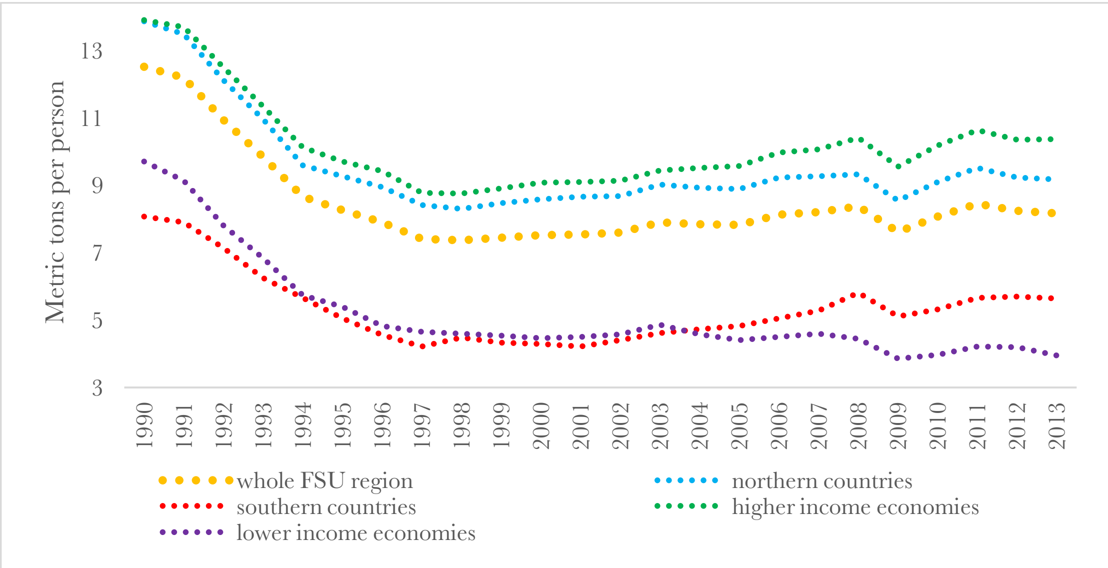

Figure 6-1. CO_2 emissions per capita for the entire FSU region and classes of countries, 1990-2013

Source: Author's own illustration based on the data from International Energy Agency (2015) and the United Nations (2015)

In general, from 1990 to 2013 CO_2 emissions per capita follow an L-shaped trajectory: first, the variable drastically decreases and then demonstrates a slight growth. Specifically, the decline is profound during the first decade after the dissolution of the Soviet Union, and at the turn of the century CO_2 emissions per capita start its gradual increase for the entire sample and country classes. The exception is the group of lower income economies where CO_2 emissions per capita continue to go down.
Figure 6-1 indicates particular disparities among the country categories. First of all, lower income economies were initially responsible for a smaller share of CO_2 emissions compared to higher income countries. Nonetheless, in relative terms the decline of the variable is more substantial for the former than the latter class (59.3 % versus 25.5 % decrease). Second, considering another country classification the southern republics have also lower level of CO_2 emissions per capita already in the beginning of the investigated period, though the northern countries demonstrate a slightly stronger decrease of the variable (33.9 % versus 30.2 %).
Figure 6-2 illustrates a variable of the interest in this study – average industry shares. In overall, over the period industry share declines in the FSU countries by 4.2 percentage points (pp). Differences between country groups are evident. Thus, starting at roughly the same level lower and higher income economies show divergent trends during 1990-2013. The former experience a significant decrease of the variable (by 10.2 pp). In contrast, the latter group increases its

energy share at first, then goes through a gradual decrease and eventually reached the same level as it was in the beginning of the 1990s. The southern and northern groups also differ in their levels of industrialization. Over the investigated period the former have larger industry shares than the latter. Nonetheless, due to a considerable decrease of the variable for the south (by 7.2 pp) and more stable trend for the north, some convergence between two groups is observed.

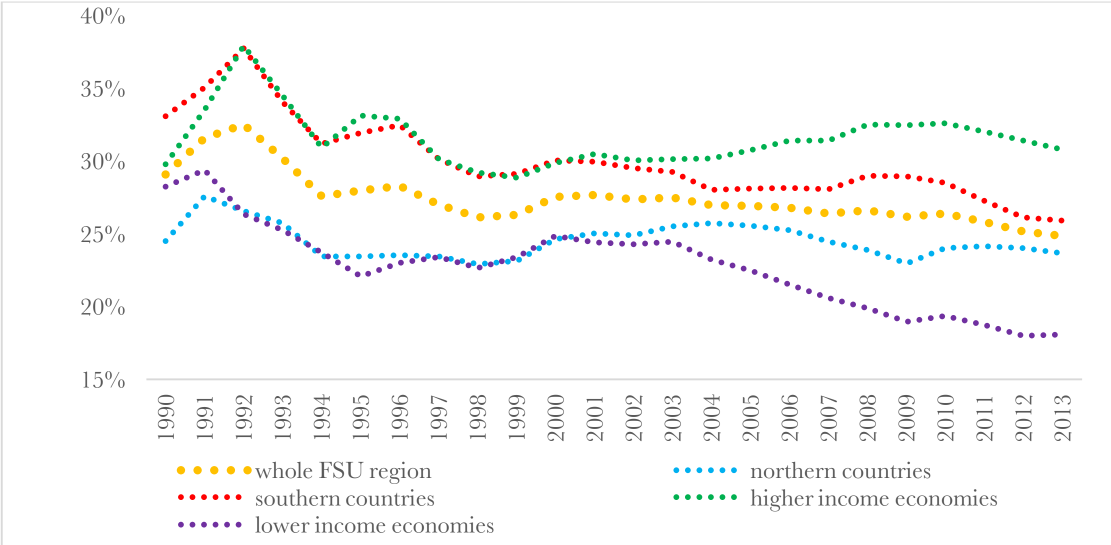

Figure 6-2. Industry shares for the entire FSU region and country classes, 1990-2013

Source: Author's own illustration based on the data from the United Nations (n.d.)

Considering the fact that another variable of the interest – urbanization – demonstrates slow monotonic trends, its changes can be visibly illustrated by Figure 6-3. The figure represents average urbanization levels for the entire FSU region and the country groups considering two benchmark years – 1990 and 2013.

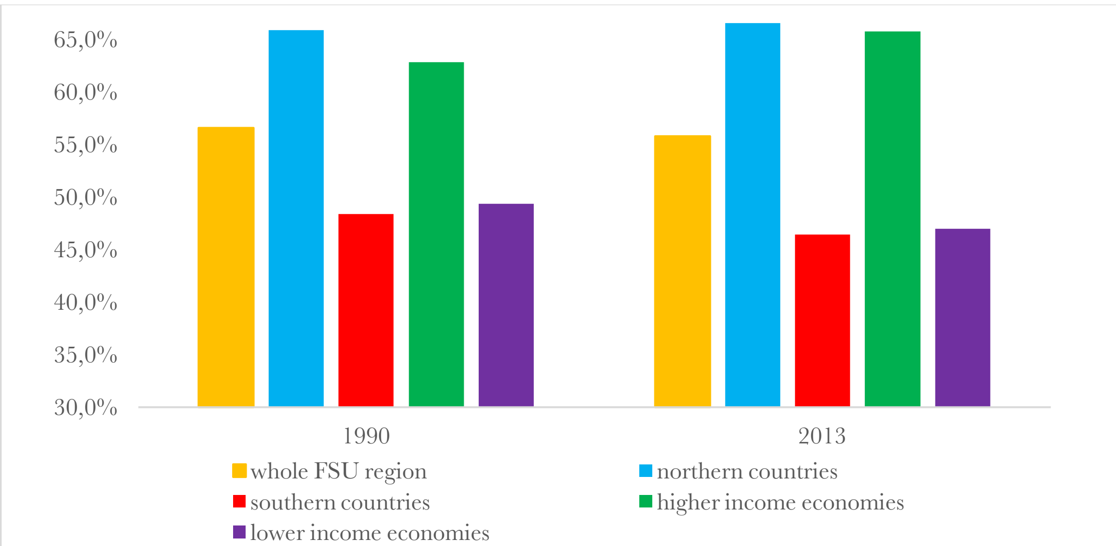

Figure 6-3.Urbanization for the whole FSU region and classes of countries in 1990 and 2013

Source: Author's own illustration based on the data from the World Bank (n.d.b)

As it can be seen, over the investigated period urbanization does not change dramatically for the entire FSU region, it only declines by one pp. The same concerns urbanization levels of the northern republics where the variable shows a slight increase by one pp. However, while observing trends of this variable some disparities between country groups become apparent. Thus, since 1990 the variable demonstrates a visible decline for two country groups: it decreases by 2.0 and 2.4 pp in the southern countries and lower income economies respectively. In contrast, for higher income group urbanization goes up by 2.9 pp.

Noteworthy, even though urbanization does not show drastic changes on average, its trends vary among individual states. One outstanding example is Belarus where the indicator rises considerably by 9.9 pp during 1990-2013. Another case is Tajikistan. In this Central Asian republic urbanization drops by 5.0 pp. At last, considering the control variables – GDP per capita and energy intensity – the following aspects can be highlighted. Figure C-1 in Appendix C demonstrates that GDP per capita declines right after the USSR collapse and then rises gradually in the FSU republics. Disparities between the country classes are remarkable. The northern states are characterized by much higher levels of GDP per capita, while the southern economies lag behind substantially over the entire period of 1990-2013. However, in relative terms the variable shows higher growth for the latter group (55.4 % versus 44.9 % increase). It is straightforward that levels of GDP per capita are larger for higher than lower income economies, and the growth of the variable is more profound for the former group (37.8 % versus 4.8 % increase).

Figure C-2 in Appendix C provides a graphical representation of changes in industrial energy intensity. Thus, on average energy intensity diminishes considerably by 47.6 % in the entire FSU region during 1990-2013. Figure C-2 also shows differences among countries, especially between lower and higher income economies. Over the investigated period the former are characterized by much larger industrial energy intensity levels than the latter. In addition, a decline of the variable is more dramatic for higher income group (52.7 % versus 31.2 % decrease). Starting at roughly the same level, the northern and southern countries demonstrate some divergence closer to 2013. This is due to a remarkable decrease of the variable for the former group: the indicator drops by 64.0 %.

6.2. Estimation Results

This section presents the estimation results. As discussed previously in the section 5.3 it is important to begin with testing stationarity of the variables. Generally, from a graphical inspection, formal testing as well as the common sense from literature, I assume that variables contain unit roots.

At first, Pesaran CD test demonstrates that all variables considered in the study have cross-sectional dependence. Thus, high CD-test statistics and low p-values (<0.05) in the column 3 of Table B-3 in Appendix B indicate for all five series we can reject the null hypothesis of cross-sectional independence. Therefore, in line with above discussed literature (Baltagi, Bresson & Pirotte, 2007; Elliot, Sun & Zhu, 2014) I run CIPS test and obtain the results that are presented in the columns 4-9 of the same Table B-3. The test outcome shows that at 5 % level of significance we can reject the null hypothesis of stationarity for all considered variables. The graphical inspection generally suggests similar conclusions (Figures C-3 to C-7 in Appendix C).

While considering the first differences of four variables – CO_2 emissions per capita, GDP per capita, industry share and industrial energy intensity – CIPS test demonstrates p-values lower 0.05. It allows us to reject the null hypothesis of unit root at 5 % level of significance for these variables which are, in other words, integrated of the order one, *I(1)*. CIPS test also indicates that urbanization has the second order of integration, *I(2)*. However, following the common sense from the previous literature urbanization can hardly be imagined to be *I(2)*. In order to deal with this problem, I would like to refer to the study by Stern and Enflo (2013) who also identify that their variables are integrated of different orders, assume that all variables are *I(1)* and consequently estimate Equation 4 (in the section 5.1) with the logged first differences for the whole FSU region and the country groups.

The estimation results are presented below in Table 6-1. The regressions 1, 3, 5, 7, 9 are the RE models with time dummies; the rest of regressions present the FE within-group estimators with time dummies. The models are estimated with an introduced option of robust standard errors to avoid a possible problem of heteroscedasticity.

As it can be seen, high F-value and low p-values of Wald test confirm that time dummies are essential in most models (with an exception of the models 5, 6 and 8). For the entire sample and all sub-samples Hausman test identifies that RE models are preferred over FE.

Table 6-1. Determinants of CO_2 emissions per capita for the whole FSU sample and the sub-samples, 1990-2013 (random effects and fixed effects estimates)

Variable (logged first differences)	*I. All countries*		*II. Higher income countries*		*III. Lower income countries*		*IV. Northern countries*		*IV. Southern countries*	
	(1) RE	(2) FE	(3) RE	(4) FE	(5) RE	(6) FE	(7) RE	(8) FE	(9) RE	(10) FE
GDP per capita	0.410 (0.092)***	0.387 (0.089)***	0.289 (0.110)***	0.296 (0.110)**	0.474 (0.117)***	0.480 (0.123)***	0.511 (0.126)***	0.519 (0.111)***	0.389 (0.151)***	0.390 (0.155)**
Industry share	0.173 (0.074)**	0.168 (0.078)**	0.346 (0.104)***	0.337 (0.112)**	0.091 (0.103)	0.083 (0.110)	0.406 (0.099)***	0.403 (0.097)***	0.109 (0.076)	0.085 (0.076)
Industrial energy intensity	0.230 (0.058)***	0.227 (0.060)***	0.339 (0.051)***	0.334 (0.050)***	0.197 (0.064)***	0.197 (0.069)**	0.269 (0.078)***	0.261 (0.078)**	0.211 (0.066)***	0.206 (0.067)**
Urbanization	2.993 (0.887)***	2.769 (1.713)	-0.684 (1.046)	-2.241 (1.265)	2.351 (1.685)	1.492 (2.521)	-0.440 (0.908)	-8.170 (4.648)	2.647 (1.302)**	0.265 (2.564)
Constant	-0.027 (0.023)	-0.029 (0.024)	-0.032 (0.020)*	-0.033 (0.020)	-0.039 (0.049)	-0.043 (0.046)	-0.054 (0.020)***	-0.053 (0.015)***	-0.017 (0.039)	-0.031 (0.043)
R^2	0.520	0.520	0.670	0.670	0.574	0.575	0.745	0.748	0.533	0.535
Wald test (F-value)	114.30***	10.32***	27.04***	9.73***	8.28	1.28	10.44*	1.77	46.90***	4.79**
Hausman test (χ^2)	1.7		1.33		0.19		3.25		2.37	
Observations	345	345	184	184	161	161	161	161	184	184

*Significance at 10% level. **Significance at 5% level. ***Significance at 1% level.
Source: Author's own elaboration.

Moving on to the discussion of obtained estimators, at first it is important to consider the regression outcomes for the whole sample of the FSU republics. Thus, the models 1 and 2 demonstrate consistent results regarding the nature of effects (their signs and size). The control variables – GDP per capita and industrial energy intensity – are positively associated with the dependent variable and highly significant (at 1 % level). Thus, growing GDP per capita and energy intensity result in higher CO_2 emissions per capita. These findings support *a priori* expectations (Hypothesis 3 in the section 4), derived from the scientific literature which distinguishes these variables as main drivers for the environmental change (Cole & Neumayer, 2004; Martinez-Zarzoso, 2007; Brizga, Feng & Hubacek, 2013).

In a concern to the effects of explanatories which stand in focus of this study, it is possible to observe that one of them demonstrates a consistent impact in both models 1 and 2. As expected earlier (Hypothesis 1) the coefficient of industry share is positive and significant at 5 % level. Thus, it implies that increasing industrialization leads to more CO_2 emissions per capita. The results illustrate that industrialization remains one of the major factors for carbon dioxide emissions in the post-Soviet countries.

In contrast, urbanization shows inconsistence significance. In addition, although its coefficient is positive as expected (Hypothesis 2), the parameter size is suspiciously large in comparison with significant estimators of other explanatories. The previously discussed literature does not find similarly high effects of urbanization on the environmental impact indicator, hence, it is difficult to justify whether urbanization might have such a big influence on CO_2 emissions per capita in the post-Soviet economies.

In overall, the results clearly demonstrate that, unlike urbanization, industrialization is a strong determinant of carbon dioxide emissions per capita in the FSU region. This outcome is also supported by the findings of the previous research which stresses the role of the Soviet industry heritage (Foell, 1992; Ürge-Vorsatz, Miladinova & Paizs, 2006; Brizga, Feng & Hubacek, 2013).

Considering the first classification of lower and higher income economies, the regressions 3-6 indicate the following. First, in accordance with Hypothesis A.3 the control explanatories are positively associated with CO_2 emissions per capita for both country categories. The coefficients are significant at 5 % level.

Interestingly, parameter sizes vary between lower and higher income economies. Thus, in line with the studies by Fan et al. (2006) and Paumanyvong and Kaneko (2010) who identify heterogeneous impacts of income across different country groups the estimated results of the models 3-6 demonstrate a larger impact of GDP per capita on emissions in lower income countries. Fan et al. (2006) also highlight the varying impacts of energy intensity across sub-samples by finding a greater effect of the variable in upper middle-income countries in a comparison with other groups. In this regard the parameters of energy intensity of models 3-6 are corresponding. Thus, the coefficient is larger for the higher income group which mainly comprises upper middle-income FSU economies (except for Estonia).

Second, industrialization demonstrates consistent results for higher income countries (models 3 and 4). Its coefficient is positive and significant (at 5 % level) as expected in Hypothesis A.1. The parameter size indicates that industrialization is a strong determinant for higher income countries which can be expected for the post-Soviet economies where industries still play a vital role in economic development. Conversely, industrialization has no significant impact for the lower income group, although its coefficient is positive as expected (Hypothesis A.1). It might be due to a substantial decrease of industry share in economies of the group (Figure 6-2) and the fact that the impacts of other explanatories overshadow the industrialization effect. In addition, the effect size of lower income economies is smaller. Following the interpretation by Jones (1991), more developed countries are more likely to possess considerably wider ranges of manufacturing products with a big variation in energy intensities than developing states, and therefore the industrialization impact can be expected to be strong in higher income countries.

Third, urbanization tends to have inconsistent impact on CO_2 emissions per capita for both country categories. Nonetheless, signs of the parameters are as assumed in Hypothesis A.2

implying a negative association between the environmental indicator and urbanization for higher income countries, and a positive association – for lower income economies.

As in a case of the whole FSU sample industrialization is a stronger driver for the environmental impact rather than urbanization in higher income countries.

Turning to the discussion of the second country classification, the models 7-10 provide the following outcomes. First, GDP per capita and industrial energy intensity remain to be major driving forces for CO_2 emissions. In accordance with Hypothesis B.3, their estimators are positive and significant at 5 % level. Notably, the effect of GDP per capita is now larger in the northern countries.

Second, according to *a priori* expectation (Hypothesis B.1) industrialization demonstrates a significant positive coefficient for the sub-sample of the northern countries. Industry share has a consistently insignificant parameter, even though its sign is positive as expected. As in a case of the lower income group, it might be explained by a considerable decrease of the variable (Figure 6-2).

Third, the urbanization coefficients have expected negative sign but are insignificant for the northern countries as shown in the models 7 and 8. In contrast, the estimated model 9 shows a positive association between urbanization and the dependent variable for the southern economies as assumed earlier (Hypothesis B.2). As for the entire FSU sample although the coefficient is positive, its size is remarkably large. In addition, considering the result of the model 10 the effect of urbanization is not consistent. Thus, it is hard to conclude on a true environmental impact of urbanization for the southern republics.

In overall, the outcomes of the models 7-10 support the previously drawn conclusion on a stronger impact of industrialization rather than urbanization for most FSU economies.

7. Conclusion

The environmental concern about increasing carbon dioxide emissions motivate the extensive scientific research. While searching for key driving forces, many scholars attempt to find linkages between the environmental indicator and different processes, including industrialization and urbanization. Subsequently, the studies provide varying results regarding the environmental impact of both industrialization and urbanization.

The former Soviet Union countries are known for their big contribution to global GHGs. The past of rapid industrialization and urbanization in the 20^{th} century brought the prominent heritage in a form of energy intensive heavy industries and some positive as well as negative legacies of the Soviet urban systems. However, after the collapse of the USSR the countries succeeded to decrease their emissions substantially.

Following the aim to investigate whether industrialization and urbanization have environmental impacts in the post-Soviet countries during 1990-2013, the study identifies the following.

First of all, as outlined by numerous studies the control variables – GDP per capita and industrial energy intensity – are positively associated with an environmental impact indicator such as CO_2 emissions per capita.

Second, the results also allow to range industrialization in a class of strong determinants for the emissions in the FSU region. Its impact is also profound for more economically developed countries of the higher income group. The same concerns the category of the northern states.

Third, urbanization does not seem to be a crucial factor for the environmental change. However, the estimated parameters might justify a consideration of non-linear relationship between urbanization and CO_2 emissions. Thus, in line with the studies the classes of higher income and northern countries possess a negative coefficient of urbanization, while the groups of lower income and southern economies are characterized by a positive estimator.

The quantitative analysis illustrates that it is worth considering sub-samples of the post-Soviet countries since environmental impacts of the explanatories vary remarkably. A diversity of the FSU republics is enormous and hence provides a base for various classifications.

As the final point, I would like to outline a few suggestions for further research. First, as noted in the introduction the country classifications considered in this study do not fully eliminate heterogeneity. Thus, I assume in order to advance the research on the FSU region it would be beneficial to distinguish more sub-samples. Second, Brizga, Feng and Hubacek (2013) find changing effects of the explanatories in a case of the FSU republics across distinguishable sub-periods within 1990-2010. Therefore, it is possible to believe that in order to acquire more detailed understanding of environmental impacts and their dynamics a future study can take into consideration different time sub-periods.

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Appendix A

Figure A-1. Fifteen former Soviet Union Republics after the dissolution

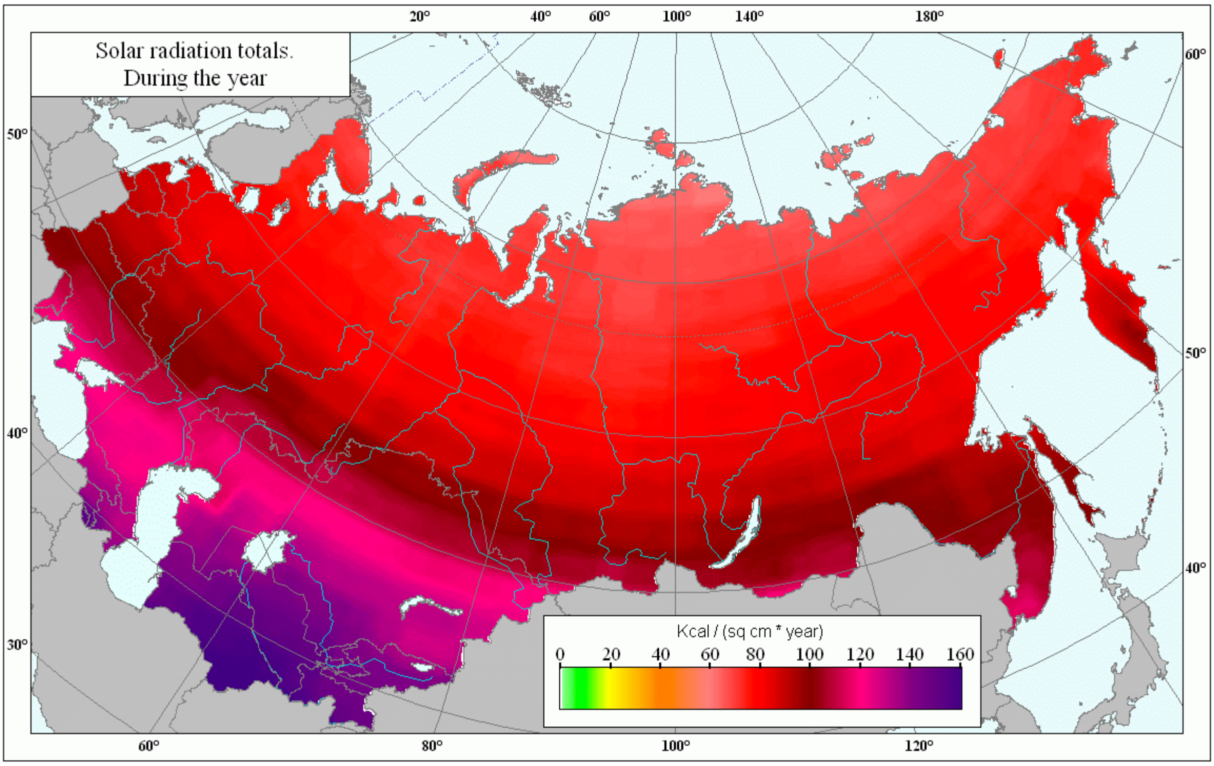

Figure A-2. Yearly map of averaged mean annual total solar radiation in Former Soviet Union republics

Source: Afonin, A.N., Lipiyaynen, K.L. and V.Y. Tsepelev (2005), Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries, Available Online: http://www.agroatlas.ru/en/content/Climatic_maps/Ir/Ir/index.html [Accessed 10.05.2016].

Appendix B

Table B-1. Description of the variables used in the study

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Total emissions per capita	360	5.501	4.216	0.304	22.982
GDP per capita	360	2 941.729	2 751.407	206.391	12 377.58
Industry share	360	27.447	10.857	6.340	74.151
Industrial energy intensity	360	0.964	0.789	0.043	4.654
Urbanization	360	55.682	14.115	26.400	75.877

Source: Author's own elaboration.

Table B-2. Correlation between the variables

Variable (in levels)	GDP per capita	Industry share	Industrial energy intensity	Urbanization
Total CO_2 emissions per capita	0.748	0.397	-0.250	0.631
GDP per capita	1.000	0.156	-0.652	0.831
Industry share		1.000	-0.330	0.143
Industrial energy intensity			1.000	-0.425
Urbanization				1.000

Source: Author's own elaboration.

Table B-3. Tests for cross-section dependence and unit roots

Variable (in levels)	CD-test	p-value	CIPS (2 lags)	p-value	CIPS (2 lags, trend)	p-value	CIPS (first differences, 2 lags)	p-value
Dependent variable								
Total CO_2 emissions per capita	35.14	0.000	-1.759	0.517	-2.664	0.076	-3.051	0.000
Independent variables								
GDP per capita	41.03	0.000	-2.136	0.072	-2.637	0.094	-3.085	0.000
Industry share	2.90	0.004	-1.927	0.265	-2.361	0.432	-2.533	0.001
Industrial energy intensity	14.56	0.000	-1.854	0.369	-1.791	0.986	-2.568	0.001
Urbanization[1]	7.74	0.000	0.021	1.000	-1.386	1.000	-1.676	0.646

[1] CIPS tests identifies that urbanization is integrated of the second order, *I(2)*.
Source: Author's own elaboration.

Appendix C

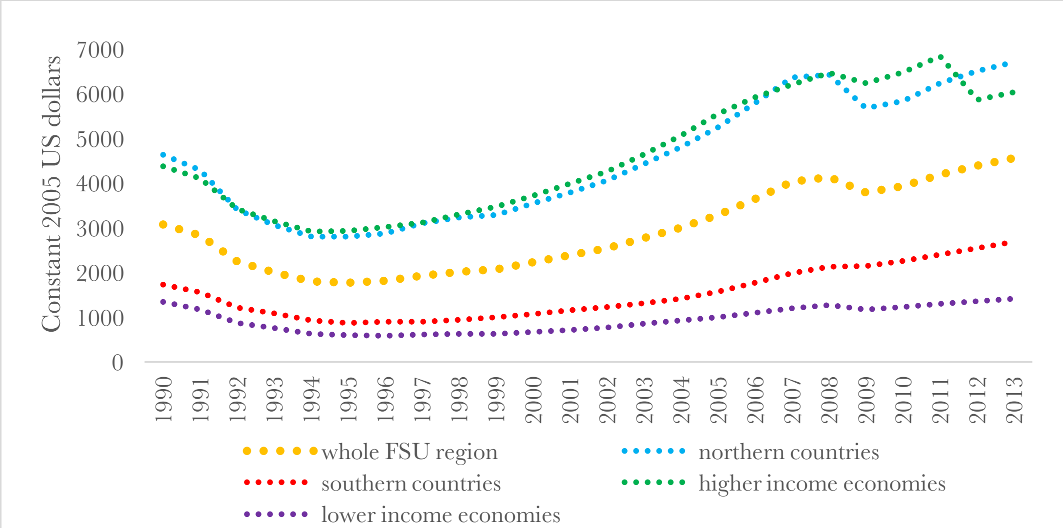

Figure C-1. GDP per capita (in constant prices) for the whole FSU region and classes of countries, 1990-2013

Source: Author's own illustration based on the data from the United Nations (2015; n.d.)

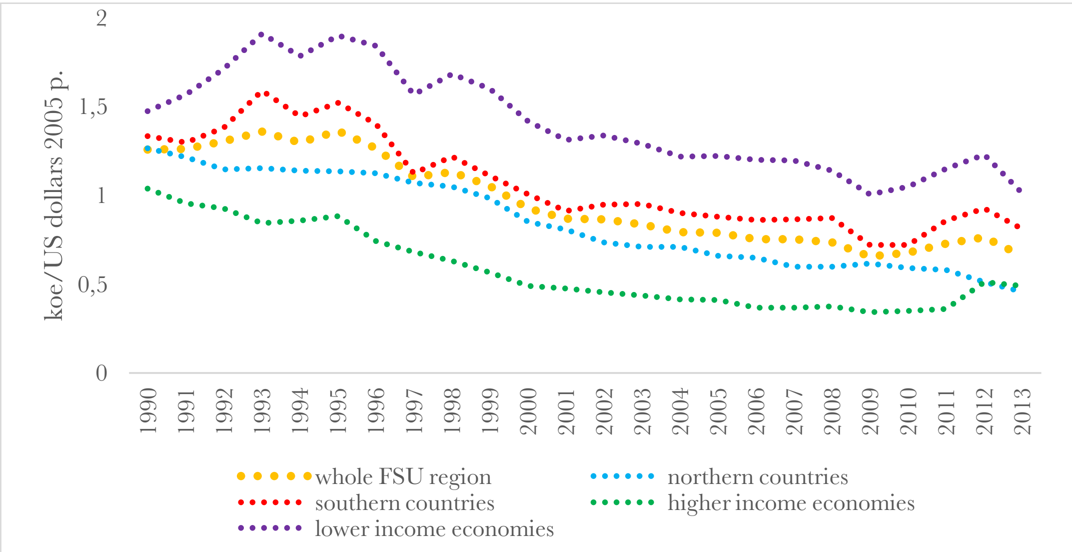

Figure C-2. Industrial energy intensity for the whole FSU region and classes of countries, 1990-2013

Source: Author's own illustration based on the data from International Energy Agency (n.d.) and the United Nations (n.d.)

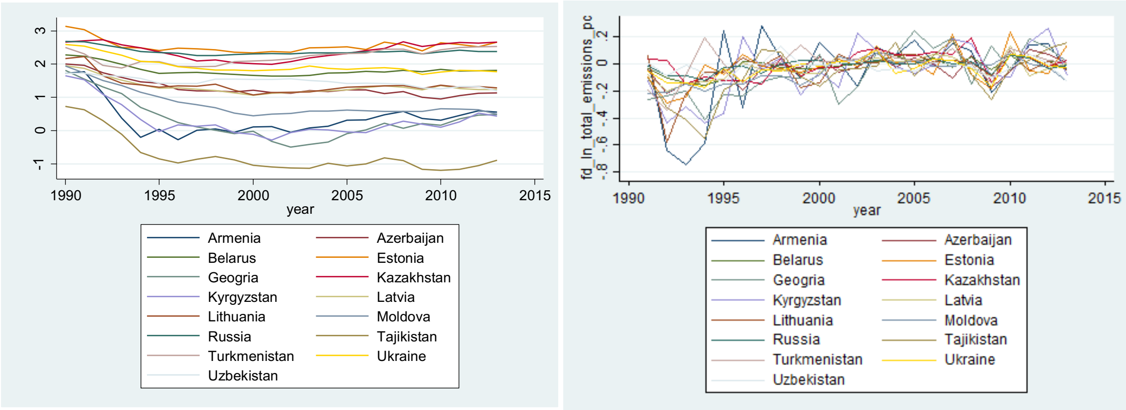

Figure C-3. Logged CO_2 emissions per capita (on the left) and logged first differences of CO_2 emissions per capita (on the right) for all FSU countries, 1990-2013

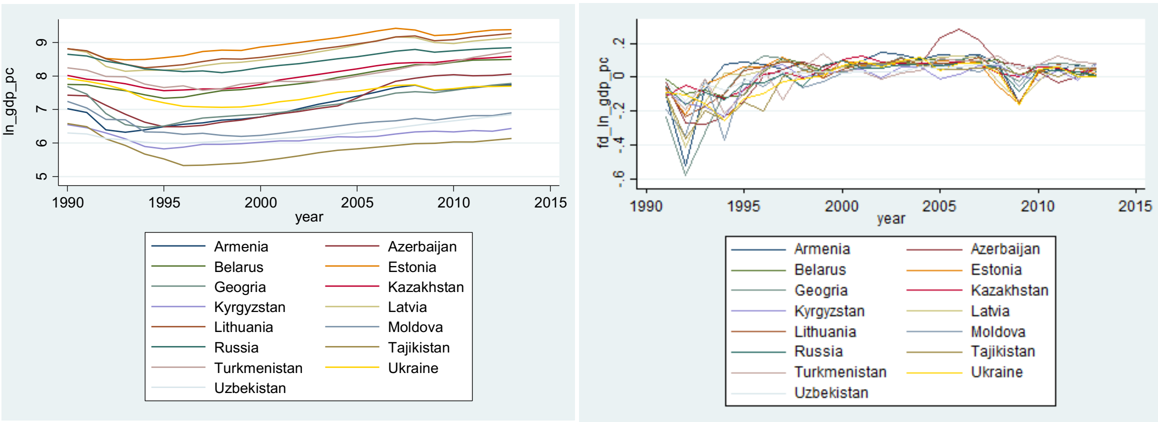

Figure C-4. Logged GDP per capita (on the left) and logged first differences of GDP per capita (on the right) for all FSU countries, 1990-2013

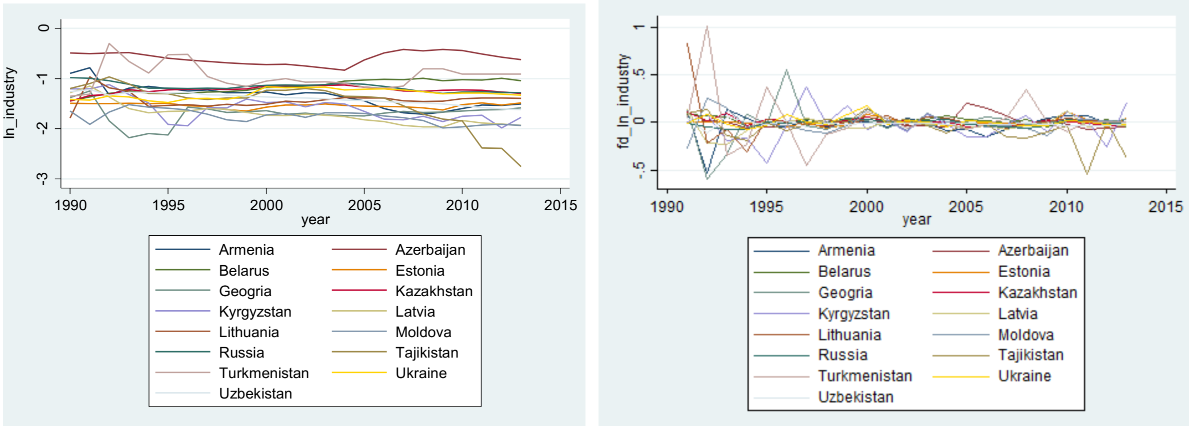

Figure C-5. Logged industry shares (on the left) and logged first differences of industry shares (on the right) for all FSU countries, 1990-2013

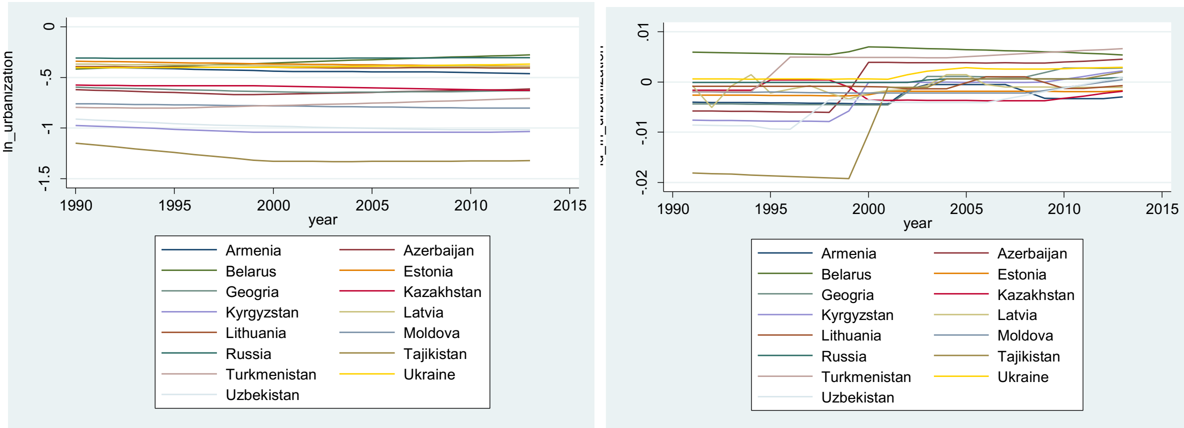

Figure C-6. Logged urbanization (on the left) and logged first differences of urbanization (on the right) for all FSU countries, 1990-2013

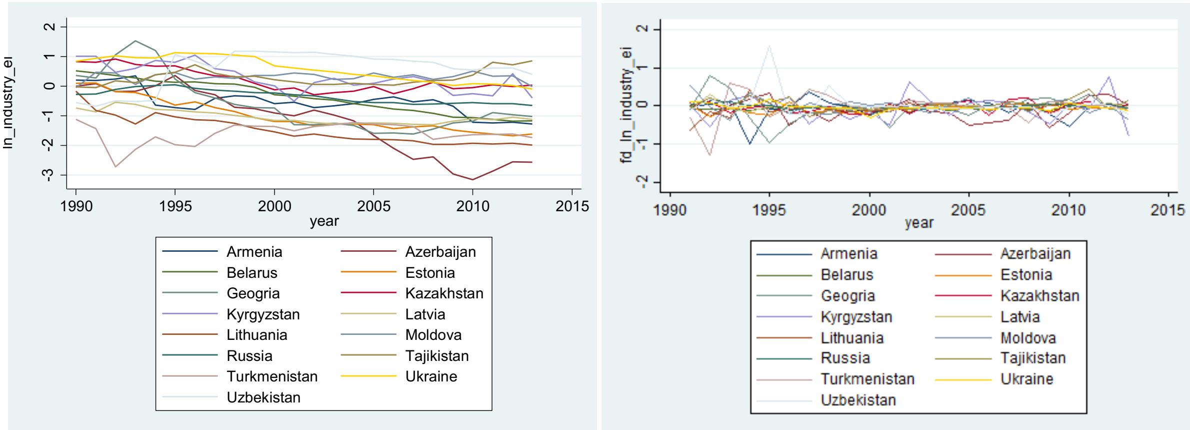

Figure C-7. Logged industrial energy intensity (on the left) and logged first differences of industrial energy intensity (on the right) for all FSU countries, 1990-2013