NEXUS OF NATURAL GAS CONSUMPTION AND REGIONAL ECONOMIC GROWTH IN UKRAINE. POLICY IMPLICATION

by

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Kyiv School of Economics
Abstract

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This paper considers the nexus of natural gas consumption and regional economic growth in Ukraine. The main question to answer is the type of causality between natural gas consumption and regional economic growth, which is important to know, when country makes choice on appropriate energy conservation policy. Panel data for 25 Ukrainian regions and the city of Kyiv is used. The analyzed period covers nine years: 2000-2008. With natural gas consumption and real gross regional product two more variable are added into the model: real gross fixed capital formation and labor force. Then panel integration, panel cointegration and panel causality analysis follow. With Arellano-Bond (2001) estimator for dynamic panel positive impact of natural gas consumption on regional economic growth in Ukraine is found. Policy implications of results are discussed.

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Chapter 1

INTRODUCTION

Natural gas is an essential input for almost all industries in the Ukrainian economy; its consumption corresponds to almost 40% of country's energy consumption profile.

On the other hand, natural gas is a kind of fossil fuel that generates relatively less carbon dioxide emissions than other fossil fuels. So, it would be efficient to optimize the use of natural gas consumption by industries and individuals, partially, in order to meet Kyoto Protocol requirements. Within this framework, in the literature question of the nexus of natural gas consumption and economic growth arises. In fact, consensus is not found.

The mainstream of discussion is the type of causality between natural gas consumption and economic growth. If natural gas consumption causes economic growth and country is energy dependent then energy conservation policy may harm economic growth. If economic growth causes natural gas consumption or bidirectional causality exists, then energy conservation policy implementation will not have negative effect on economic growth.

The aim of this thesis is to study the nexus of natural gas consumption and regional economic growth in Ukraine.

Ukraine is chosen as there are only few studies that analyze this country and all of them are panel based, none paper is found with country specific analysis of the causality between natural gas consumption and economic growth in Ukraine. Also there is no consensus in conclusions.

Regional aspect is considered with two purposes. First is to extend dataset and get efficient number of observations, second, to analyze place of every Ukrainian regions or their groups in natural gas consumption profile of the country. In fact, some disproportions in regional natural gas consumption in Ukraine exist. For example, in 2008 only four Ukrainian regions, Dnipropetrovsk, Donetsk, Luhansk and Kharkiv, consume 44.4% of all industrial natural gas consumption in the country. Conclusions for these regions about optimum energy consumption profile are expected to be different and possible to cover with panel dataset across regions. In fact, no regional studies of the nexus of natural gas consumption and economic growth in Ukraine are found, so this is one of the contributions of this thesis.

Moreover, in this thesis only industrial natural gas consumption is studied as residential is defined by habits, health, social status, consumption preferences and wealth rather than by changes in economic activity, Hondroyiannis et al. (2002).

Also multivariable framework is used instead of bivariate in order to deal with the problem of omitted variable, mentioned by Apergis and Payne (2010). Analyzed time series are real gross regional product (GRP), natural gas consumption, real gross fixed capital formation and labor force. Annual panel data across 25 regions of Ukraine and the city of Kyiv is studied for 2000-2008. That is 234 observations. In order to use advantages of dynamic panel dataset Arellano and Bond (2001) estimator is applied.

This thesis is organized as follows. Chapter 1 is Introduction, where motivation and research question is presented. Chapter 2 is devoted to Literature Review, Chapter 3 – to Methodology. Chapter 4 provides with Data description. Chapter 5 presents Results, and Conclusions are in Chapter 6.

Chapter 2

LITERATURE REVIEW

This section provides analysis of existing literature on the nexus of natural gas consumption and economic growth. Panel versus country specific analysis follows first. Then results obtained for developed, developing and transition countries are discussed. The last part covers studies where bivariate and multivariate approaches are used.

Panel versus country specific analysis

Apergis and Payne (2010) study the panel of 67 countries for the period of fourteen years: from 1992 to 2005. Countries included into the analysis are at the different levels of economic development, so studied panel is heterogeneous. At the very beginning of every time-series analysis, variables should be checked on stationarity. The reasons for that are difficulties in the analysis of non-stationary time series, as its statistical characteristics over time, what is defined as a random process. That's why variables are needed to be stationary with means and variances that do not depend on time.

Apergis and Payne (2010) use Im et al. (2003) panel unit root test to check stationarity. If hypothesis about the presence of unit root is accepted, time series is non-stationary. It is found that series of natural gas consumption, labor, capital and economic growth are integrated of order one. It means that these series are stationary in the first differences.

On the other hand, integrated time series can be also cointegrated. It means that their linear combination has lower order of integration. If time-series are integrated of order one and they are cointegrated, then linear combination of these series forms series of order zero or stationary series. To check cointegration in the panel data, seven Pedroni (1999) tests are applied and hypothesis about the presence of cointegration is accepted. Then panel vector error correction model is estimated to conclude on the Engle and Granger (1987) causality in short run and long run.

Results show that in the short run natural gas consumption has positive and statistically significant impact on economic growth and vice-a-versa. The same conclusion is made for the long run.

Nguyen-Van (2010) studies the nexus of energy consumption and income for the panel of 158 countries during 1980-2004. Here to conclude on cointegration, Westerlund and Edgerton (2008), which allows for structural breaks in panel, is used. Main difference of this test with Pedroni (1999) tests is allowing for structural breaks in panel. Costantini and Martini (2010) also use Westerlund and Edgerton (2008) test to conclude on causality between energy consumption and economic growth in 71 countries for the period from 1970 to 2005. And, as during this period there were several energy crises, Westerlund and Edgerton (2008) test is more powerful if to compare with Pedroni (1999) tests. In this thesis, series of real gross regional product, natural gas consumption, real gross capital and labor in Ukraine are studied from 2000 to 2008. As during this period no drastic change in natural gas consumption was observed, Pedroni (1999) tests are used for panel cointegration analysis.

After concluding on cointegration, Nguyen-Van (2010) use semiparametric partially linear panel model. They find out that energy consumption increases with income but the effect of changes in energy consumption structure, specifically, the natural gas and petroleum share, is not significant.

Difference between country and panel specific studies is determined by the methodologies which are used for integration, cointegration and causality analyses.

In order to define cointegration, Reynolds and Kolodziej (2008) in their country study of the Former Soviet Union uses Engle and Granger (1987) causality test. It is found that there is no causality relationship between natural gas consumption and economic growth in the Former Soviet Union. The main reason for this is stable level of natural gas consumption in the country due to low variable costs production of natural gas.

Zamani (2007), Sari et al. (2008), Lee and Chang (2005) use Johansen and Juselius (1990) procedure to identify cointegration relationship between natural gas consumption and economic growth. This procedure is possible for country specific analysis and, in fact, is more powerful than Engle and Granger (1987) test. Johansen and Juselius (1990) methodology is based on maximum-likelihood estimation and allows for long-run equilibrium with multiple cointegrating vectors, while in Engle and Granger (1987) test only one cointegration vector is possible. Moreover, as Engle and Granger (1987) uses a two step estimation method, the residuals of the first step being used in the second step. Also in Engle and Granger (1987) methodology there is a choice of the left hand side variables, so one can get different conclusions about cointegration. Johansen and Juselius (1990) procedure avoids all mentioned problems and allows for restrictions testing.

After vector error correction model estimation for Iran economy during 1967-2003, Zamani (2007) concludes that in the long run gas consumption causes

GDP and vise-a-versa. Sari et al. (2008) focus on the monthly data for the United States economy during 2001:1-2005:6. They use autoregressive distributive lag (ARDL) approach which can deal with nonstationary time series and detect cointegration even in small samples. It is found that in the long run industrial production has no significant impact on natural gas consumption.

Study of disaggregated energy consumption and economic growth for Taiwan is made by Lee and Chang (2005) and Hu and Lin (2008). Lee and Chang (2005) estimate annually for time-period from 1965 to 2003, Hu and Lin (2008) use shorter time period (1982:1 – 2006:4), but with quarterly data. Both of them use cointegration tests which allow for a structural break, what corresponds to Taiwan's economic development. Lee and Chang (2005) accept the hypothesis of no cointegration with using Gregory and Hansen (1996) test. Hu and Lin (2008) accept the same hypothesis with Hansen and Seo (2002) methodology.

Finally, Lee and Chang (2005) find that in Taiwan natural gas consumption causes GDP and decrease in the volumes of natural gas consumption will slow economic growth in the country. With conventional vector-error correction model, Lee and Chang (2005) do not find long-run equilibrium. For this purpose, Hu and Lin (2008) use threshold vector-error correction model with two regimes and confirm that long-run equilibrium exists with faster adjustments of natural gas consumption than GDP.

So, according to the literature review for country studies, Engel and Granger (1987) methodology is applicable to find cointegration, but more powerful procedure is Johansen and Juselius (1990). To define cointegration in panel data, the most popular way is seven Pedroni (1999) tests, but, in case of time series with structural breaks, Westerlund and Edgerton (2008) test is used. As there are no structural breaks in natural gas consumption during 2000-2008, Pedroni

(1999) tests are used in this thesis. Causality in panel data is testing with using panel vector error correction model, Pesaran, Shin and Smith (1999).

Developed versus developing and transition countries

Apergis and Payne (2010) and Nguyen-Van (2010) include American economy in their panel studies of the relationship between natural gas consumption and GDP. Common result of these papers is that economic growth and increase in income causes increase in natural gas consumption. Sari et al. (2008) conclude that industrial production has no significant impact on natural gas consumption in the United States.

Opposite type of causality is found for Taiwan's economy by Lee and Chang (2005), so decrease in natural gas consumption may harm economic development in the country.

Conclusions made for developing and transition countries are also different. Zamani (2006) considers Iran's economy and shows that natural gas consumption stimulates economic growth and economic growth also leads to increase in the consumption of natural gas.

For Ukrainian economy, the same conclusion is made in the panel study of Apergis and Payne (2010). On the other hand, Reynolds and Kolodziej (2008) confirm the absence of causality for Ukraine, as for the country from the Former Soviet Union. No long run equilibrium is found between electricity energy consumption and economic growth in Ukraine in the research of Acaravci and Ozturk (2009) for 15 transition countries. Apergis and Payne (2009) conclude that total energy consumption has an impact on economic growth and vise-a-versa in the panel of Commonwealth of Independent States including Ukraine.

According to Sari et al. (2008), possible reasons of differences in the results obtained for developed, developing and transition countries are differences in stages of their economic development. But literature review on the nexus of natural gas consumption and economic growth also shows different results for countries which are at the same level of economic development. Soytas and Sari (2007) conclude that causality might be different because these countries have different energy profiles and patterns of energy consumption. They also stress on the importance of examining disaggregate energy at the micro level, for example, at the level of industries. This study also disaggregates energy consumption and uses micro level. This thesis is concentrated on the consumption of natural gas in the regions of Ukraine.

Bivariate versus multivariate approaches

Lee and Chang (2005), Zamani (2007), Hu and Lin (2008), Reynolds and Kolodziej (2008) and Nguyen-Van (2010) study causality between natural gas consumption and economic growth with bivariate approach, so only with time series of natural gas consumption and economic growth.

Sari et al. (2008) add employment as a proxy for total labor force and find that it does not have impact on natural gas consumption in the short and long run for American economy. Hondroyiannis et al. (2002) add energy prices to study the effect of industrial energy consumption on economic growth in Greece during 1960-1996. But it makes sense only for oil energy consumption or total energy consumption studies. Prices on natural gas in Ukraine is not highly volatile and determined by government rather than by market force.

To examine causality between natural gas consumption and economic growth in the panel of 67 countries, Apergis and Payne (2010) use multivariate approach with real GDP, real gross fixed capital formation, total labor force and natural gas consumption. In the short run, all these variables have positive and significant impact on economic growth. At the same time, impact of labor force on natural gas consumption is not statistically significant. On the other hand, natural gas consumption itself does not influence real gross fixed capital formation and labor force. The main conclusion from multivariate approach of Apergis and Payne (2010) is that labor force and gross capital formation are complementary parts of economic growth. Panel studied by Apergis and Payne (2010) includes Ukraine, so real gross fixed capital formation and labor force are also to be included into presented regional study of Ukraine. That is also decrease the possibility of problems with omitted variables.

Moreover, in this thesis only the series of industrial natural gas consumption, that reported by Ukrainian companies, are included. In fact, this approach is new for natural gas consumption studies. Before, Hondroyiannis et al. (2002) divides total energy consumption into industrial and residential parts and finds no causality between economic growth and residential energy consumption, as the last one is defined by habits, health, social status, consumption preferences and wealth and not by changes in economic activity.

To conclude, there are only few papers that study the nexus of natural gas consumption and economic growth in Ukraine. Also Ukraine is always in the panel analysis, no papers are found with Ukraine specific analysis. On the other hand, in the literature there is no consensus in conclusions on the nexus of natural gas consumption and economic growth. Also only in one paper multivariable approach is considered, Apergis and Payne (2010). No studies, which cover regional aspect of this nexus, are found. So in this thesis multivariable approach is used to study causality relationship between economic growth and natural gas consumption in Ukrainian regions.

Chapter 3

METHODOLOGY

In this section methodology of thesis is presented. First, the logic of integration analysis and relevant tests follow, then methodology of panel cointegration analysis is presented. And, finally, panel causality analysis is explained.

In order to conclude on the direction of causality between natural gas consumption and regional economic growth in Ukraine, some preliminary types of analyses for panel time series are needed.

In this thesis annual panel data across 25 regions of Ukraine and the city of Kyiv is studied for 2000-2008. Analyzed time series are real gross regional product (GRP), natural gas consumption, real gross fixed capital formation and labor force. That is 234 observations.

First, *panel integration analysis* should be performed. This analysis implies testing time series on stationarity with the use of panel unit roots tests. If hypothesis about the presence of unit roots is accepted, then time series is non-stationary, so their statistical characteristics depend on time that is defined as a random process and is hard to analyze. If hypothesis about the presence of unit roots is rejected, then time series is stationary, so their means and variances do not depend on time itself but depend only on the time lags.

Most time series in the real world are non-stationary, but in differences they are stationary. If time series becomes stationary in the first difference, then it is integration of order one. If time series is stationary in levels without differencing then this is integration of order zero. In fact, the aim of integration analysis in this thesis is to define the order of integration for the time series of natural gas consumption, real GRP, real gross capital formation and labor force, so find the level of differencing, when these time series become stationary.

To check stationarity first graph representation of time series can be used. If time series has strong trend to increase or decrease, then nonstationarity is suspected. If time series' deviation is around one mean, then they are supposed to be stationary.

Next, to check stationarity, tests are needed. In this thesis three unit roots tests are used: Levin et al. (2002), Fisher-types tests using Augmented Dickey–Fuller and Phillips-Perron tests proposed by Maddala and Wu (1999) and Choi (2001).

Levin et al. (2002) test has a null hypothesis that the time series contains a unit root, so they are nonstationary. According to the assumption of this test, each individual unit root of times series has the same share for individual autoregressive parameter in the panel. For example, the series of natural gas consumption would contain unit roots for all regions, not for specific ones.

Autoregressive process in the panel data is explained by:

$$y_{it} = \rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it}, \qquad (1)$$

where *i* – observed time series over the period $t = 1,2, \ldots, T_i$; X_{it} - exogenous variables; ρ_i - autoregressive parameter; e_{it} - error term.

If $|\rho_i|$<1, then y_{it} is stationary. And from $|\rho_i|$=1 follows that the series of y_{it} contain a unit root.

The presence of variable, which corresponds to the exogenous variables, allows for individual effects or time trend in the Levin et al. (2002) test. The same share for each individual unit root of a time series in the panel is presented when $\rho_i = \rho$ for all *i*.

So Levin et al. (2002) consider the following specification of the test:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X_{it}' \delta + \varepsilon_{it} \quad (2)$$

where $\alpha = \rho - 1$; p_i - the order of lags for the difference term.

Coefficient $\alpha = 0$ under the null hypothesis of a unit root absence and $\alpha < 0$ under the alternative hypothesis.

In the solid panel integration analysis, the effect of individual unit roots of time-series should be also considered. Fisher-types tests on the basis of Augmented Dickey–Fuller (ADF) and Phillips-Perron (PP) tests, presented by Maddala and Wu (1999) and Choi (2001), imply this effect.

For every cross-section of the analyzed time series, regression (2) is used. Now unit root exists under the null hypothesis $\alpha_i = 0$ for all observed time series *i* over the period $t = 1, 2, \ldots T_i$. Then in the tests *p*-values for every individual unit root tests are combined and Chi-square χ^2 distribution is reported.

Under the null hypothesis $\chi^2 = 0$, there is a unit root. When $\chi^2 < 0$, alternative hypothesis is accepted.

After panel integration analysis, *panel cointegration analysis* follows. Cointegration takes place, when linear combination of integrated time series has lower order of integration. So, if time-series are integrated of order one and they are cointegrated, then linear combination of these series forms series of order zero or stationary series.

In data analysis section of this thesis it is shown that analyzed panel does not have structural breaks, so Pedroni (1999) methodology can be applied to test cointegration. But in case of data with structural breaks, Westerlund and Edgerton (2008) methodology would be more appropriate.

Primarily, regression proposed by Pedroni (1999) is:

$$y_{it} = \alpha_i + \delta_i t + \beta_i X_{it} + \varepsilon_{it}, \quad (3)$$

where y_{it}, X_{it} are variables integrated of order one for members *i=1,…N* over time periods *t = 1,…T*.

In this thesis, Pedroni (1999) regression is:

$$Y_{it} = \alpha_i + \delta_i t + \beta_{1i} NG_{it} + \beta_{2i} L_{it} + \beta_{3i} K_{it} + \varepsilon_{it} \quad (4)$$

Coefficient α_i from (3) and (4) allows for individual effect and δ_i allows for time trends. β's are also varied over the time periods, so heterogeneous cointegration vectors are possible. Moreover, as β's are in natural logarithms, they can be interpreted as elasticity coefficients.

Then the following unit root test for the estimated residuals is performed:

$$\varepsilon_{it} = \rho_i \varepsilon_{it-1} + w_{it} \quad (5)$$

Under the null hypothesis of no cointegration, $\rho_i = 1$.

On the basis of estimated residuals from the model (2), Pedroni (1999) proposes seven residual based tests. First four tests are panel based and include four statistics: panel *v*, panel ρ , panel *PP* and panel *ADF*.

Panel *v*-statistics: $Z_v = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} e_{it-1}^{2} \right)^{-1}$ (6)

Panel ρ -statistics: $Z_\rho = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} e_{it-1}^{2} \right)^{-1} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} (e_{it-1} \Delta e_{it} - \lambda_i \right)$ (7)

Panel *PP*-statistics: $Z_t = \left(\sigma^2 \sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} e_{it-1}^{2} \right)^{-1/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} (e_{it-1} \Delta e_{it} - \lambda_i \right)$ (8)

Panel *ADF*-statistics: $Z_t^* = \left(s^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} e_{it-1}^{*2} \right)^{-1/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} R_{11i}^{-2} (e_{it-1}^{*} \Delta e_{it}^{*} \right)$ (9)

In Pedroni (1999) tests, e_{it} - residuals estimated from (4) and R_{11i}^{2}- estimated long-run covariance matrix for Δe_{it}.

Group Pedroni (1999) tests are presented as three statistics: group ρ , group *PP* and group *ADF*. These statistics (10)-(12) are computed as the averages of individual autoregressive parameters along the between dimensions of the panel, while statistics (6)-(9) are based on the pooling the residuals within dimension of the panel.

Group ρ -statistics: $\tilde{Z}_\rho = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} e_{it-1}^{2} \right)^{-1} \sum_{t=1}^{T} (e_{it-1} \Delta e_{it} - \lambda_i)$ (10)

Group *PP*-statistics: $\tilde{Z}_t = \sum_{i=1}^{N}\left(\sigma^2 \sum_{t=1}^{T} e_{it-1}^2\right)^{-1/2} \sum_{t=1}^{T}(e_{it-1}\Delta e_{it} - \lambda_i)$ (11)

Group *ADF*-statistics: $\tilde{Z}_t^* = \sum_{i=1}^{N}\left(\sum_{t=1}^{T} s_i^2 e_{it-1}^{*2}\right)^{-1/2} \sum_{t=1}^{T}(e_{it-1}^*\Delta e_{it}^* - \lambda_i)$ (12)

All seven Pedroni (1999) tests are asymptotically normal distributed. On the basis of critical values for these tests, calculated by Pedroni (1999), null hypothesis of no cointegration can be accepted or rejected.

Panel cointegration analysis is able to show whether long run equilibrium between time series exist, but it does not give information about the direction of causality. So *panel causality analysis* is needed.

In panels causality is tested on the basis of Enlge and Granger (1987) two step procedure.

First step is to find coefficients for the long run equilibrium by estimating the following model:

$$\begin{aligned} Y_{it} &= \alpha_i + \delta_i t + \beta_{1i} NG_{it} + \beta_{2i} L_{it} + \beta_{3i} K_{it} + \varepsilon_{1it} \\ NG_{it} &= \alpha_i + \delta_i t + \beta_{1i} Y_{it} + \beta_{2i} L_{it} + \beta_{3i} K_{it} + \varepsilon_{2it} \\ L_{it} &= \alpha_i + \delta_i t + \beta_{1i} NG_{it} + \beta_{2i} Y_{it} + \beta_{3i} K_{it} + \varepsilon_{3it} \\ K_{it} &= \alpha_i + \delta_i t + \beta_{1i} NG_{it} + \beta_{2i} L_{it} + \beta_{3i} Y_{it} + \varepsilon_{4it} \end{aligned}, \quad (13)$$

where Y_{it} - real gross regional product, NG_{it} – natural gas consumption, L_{it} – real gross fixed capital formation, K_{it} – labor force.

In order to avoid the problem of omitted variables, multivariable approach is used. Choice of coefficients is motivated by the panel study of Apergis and Payne

(2010), with Ukraine included. In their model, significant impact of labor force and gross capital formation and natural gas consumption, is found. Here the question about prices of natural gas as important variable may also arise. In fact, Hondroyiannis et al. (2002) add total energy prices in the model, but for the study of natural gas consumption in Ukraine it does not make sense as gas prices are more regulated by government than forced by market.

Finally, as four variables are included into the panel vector error correction model, estimations for four error correction terms should be finally obtained from the model (13): $\varepsilon_{it}, \eta_{it}, \varphi_{it}, \mu_{it}$.

Second step of Engel and Granger (1987) procedure implies estimation of vector error correction model with error correction terms (ECT) obtained at the first step. Narayan and Smyth (2008) mention that error correction terms recover long-run information that is partially lost in the system with differenced coefficients. So these terms are needed to gain model stability in the long-run.

Then dynamic panel error correction model specification is:

$$\Delta Y_{it} = \alpha_{1j} + \sum_{k=1}^{m} \alpha_{11ik} \Delta Y_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} \Delta NC_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} \Delta K_{it-k} +$$

$$+ \sum_{k=1}^{m} \alpha_{14ik} \Delta L_{it-k} + \lambda_{1i} ECT_{1it-1} + u_{1it}$$

$$\Delta NC_{it} = \alpha_{2j} + \sum_{k=1}^{m} \alpha_{21ik} \Delta Y_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} \Delta NC_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} \Delta K_{it-k} +$$

$$+ \sum_{k=1}^{m} \alpha_{24ik} \Delta L_{it-k} + \lambda_{2i} ECT_{2it-1} + u_{2it}$$

$$\Delta K_{it} = \alpha_{3j} + \sum_{k=1}^{m} \alpha_{31ik} \Delta Y_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} \Delta NC_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} \Delta K_{it-k} +$$

$$+ \sum_{k=1}^{m} \alpha_{34ik} \Delta L_{it-k} + \lambda_{3i} ECT_{3it-1} + u_{3it}$$

$$\Delta L_{it} = \alpha_{4j} + \sum_{k=1}^{m} \alpha_{41ik} \Delta Y_{it-k} + \sum_{k=1}^{m} \alpha_{42ik} \Delta NC_{it-k} + \sum_{k=1}^{m} \alpha_{43ik} \Delta K_{it-k} +$$

$$+ \sum_{k=1}^{m} \alpha_{44ik} \Delta L_{it-k} + \lambda_{4i} ECT_{4it-1} + u_{4it} \tag{14}$$

With model (14) short and long run causality are tested. Existence of causality in the short run is tested under the following null hypothesizes.

1) for real GRP:

$$\alpha_{11ik} = 0; \;\; \alpha_{21ik} = 0; \;\; \alpha_{31ik} = 0; \;\; \alpha_{41ik} = 0, \quad \forall i \, ;$$

2) for natural gas consumption:

$$\alpha_{12ik} = 0; \;\; \alpha_{22ik} = 0; \;\; \alpha_{32ik} = 0; \;\; \alpha_{42ik} = 0, \quad \forall i \, ;$$

3) for real gross fixed capital formation:

$$\alpha_{13ik} = 0; \;\; \alpha_{23ik} = 0; \;\; \alpha_{33ik} = 0; \;\; \alpha_{43ik} = 0, \quad \forall i \, ;$$

4) for labor force:

$\alpha_{14ik} = 0; \ \alpha_{24ik} = 0; \ \alpha_{34ik} = 0; \ \alpha_{44ik} = 0, \ \ \forall i.$

If null hypothesis is rejected then causality is present.

To check causality in the long run the following hypothesis are tested:

1) for error correction terms: $\lambda_{1i} = 0; \ \lambda_{2i} = 0; \ \lambda_{3i} = 0; \ \lambda_{4i} = 0; \ \ \forall i.$

If null hypothesis is rejected then causality in the long run is present.

Acaravci and Ozturk (2009) and Costantini and Martini (2010) call causality in the short run as weak causality and causality in the long run as strong causality.

In fact, error correction terms, estimated in (14), present speed of adjustment to the long-run equilibrium. The larger these coefficients, the faster system will reach equilibrium in the long run.

So from model (14) causality relationships between variables are determined and then with variables that caused each other, Arellano and Bond (2001) estimation procedure is used.

In Arellano and Bond (2001) is based on generalized method of moments (GMM). Roodman (2006) indicates increasingly popularity of the Arellano-Bond (1991) procedure as it has the number of advantages. First, it makes more likely to hold assumption about no autocorrelation in error terms. Autocorrelation is defined as the presence of cross-correlations in error terms with itself what makes estimation procedure inappropriate. Second, independent variables might be not strictly exogenous, so some causality between dependent and independent variable may exist. In this thesis, it might be applicable to gross capital formation and GRP, GRP and natural gas consumption. But Arellano and Bond (2001) methodology solve this problem. Third, heteroscedasticity problem, when variance of error terms is not constant, is also eliminated with Arellano and Bond (1991) estimator as it is designed for time series with heteroscedasticity within individuals. Finally, this estimator is efficient with fixed individual effects. And the presence of these effects is demonstrated in data analysis, when four regions with common characteristics are chosen: West, East, South and Center.

On the other hand, Arellano and Bond (1991) estimator is designed for datasets with few time periods and many regions. But dataset studied in this thesis contains 26 regions what may seem to be not large enough. Anyway, the gains with Arellano and Bond (1991) estimator are strong enough to choose this estimation method.

In Arellano and Bond (1991) methodology, predetermined lags of variable from the model are used as instrumental variables.

To check the consistency of these estimates Sargan test of overidentifying restrictions is used. In this test regression of residuals from equation with instrumental variables is estimated. Sargan statistics is the product of the goodness-of-fit statistics and the number of observations. This statistics is distributed as χ^2_{m-r}, where *m* stands for the number of instruments and *r* stands for the number of endogenous variables. Null hypothesis of Sargan test is that all variables are exogenous.

So, to conclude on the causality between natural gas consumption and economic growth, first, panel integration analysis with three unit roots test is used. For this purpose, three panel unit root tests are used: Levin, Lin and Chu (2002) test with common unit root process and Fisher-types using ADF and PP tests with individual unit root processes. When the order of integration in the panel is known, analysis proceeds with cointegration study on the basis of seven Pedroni (1999) tests: four of them based on pooling within the panel and three are based on pooling along the between dimension of the panel. Finally, direction of causality is found with Engle and Granger (1987) two step procedure: estimations of error correction terms and dynamic panel vector error correction model. After results of causality testing, Arellano and Bond (2001) methodology is used.

Chapter 4

DATA

This section presents data used in the analysis of the nexus of natural gas consumption and economic growth in Ukraine. First, data sources and choice is explained. Then, analysis of four time series with descriptive statistics over analyzed period and across regions follows. Third, preliminary results of natural gas consumption and economic growth nexus are discussed.

The sources of regional data on gross fixed capital investment, number of economically active population, consumer price index (CPI) to December of previous year and gross regional product (GRP) are Statistical Yearbooks of Ukraine and Regions of Ukraine designed by State Statistic Committee of Ukraine.

Data on natural gas consumption comes from the Information Analytic Agency "Stat Inform Consulting". In 2008 data is collected from 114 098 Ukrainian companies, so in this thesis natural gas consumption represents only industrial gas consumption, that is important and can be considered as advantages of studied dataset, as residential energy consumption behaves independently from economic growth, Hondroyiannis et al. (2002).

Also companies' reports on the volumes of their natural gas consumption are collected on the basis of companies' actual address, where their productive capacities are located. In this way, problems of data misspecification, when company is registered in one region, but its productive capacity is located in another region, are eliminated.

All data is collected on the annual basis for the period from 2000 to 2008 years for 26 Ukrainian regions. To deal with the problem of outlier, data on Sevastopol is included into the Crimea region, the city of Kyiv is considered separately from Kyiv region. In fact, data on natural gas consumption is reported monthly and quarterly. Monthly information for this variable is not representative as this information is obligatory to report only for big industrial companies. Quarterly information on natural gas consumption is available and could be seasonally adjusted.

But the problem of comparability for some regional time series exists. For example, information on the number of economically active population by regions is available quarterly only for two years, 2008 and 2009. Apergis and Payne (2010) show that information on labor force can not be neglected in the analysis and labor force with natural gas consumption has significant and positive impact on economic growth. Also Apergis and Payne (2009) prove that impact of total energy consumption and labor force on economic growth in Commonwealth of Independent States is statistically significant.

On the other hand, at this moment data on natural gas consumption for 2009 is not ready yet, so for regional labor force there are only four quarterly observations of 2008, that is small sample for analysis.

Quarterly data on gross fixed capital formation and gross regional product in regions is available from 2006 to 2009. And, if to consider time series of natural gas consumption, real gross regional product and fixed capital formation, they would be comparable only for the period across sixteen periods from 2005 to 2008 years.

But even with ideally comparable quarterly dataset, annual dataset is widely used and more preferable as annual effect of one variable dynamics on the other is usually considered in statistics as more representative, than the effect of one quarter dynamics on the other.

Finally, panel dataset of 26 regions of Ukraine across nine years is studied, that is 234 observations.

Dataset consists of the following variables:

1. *Real Gross Regional Product* is calculated as the natural logarithm of nominal gross regional product in the prices of 2000, millions of UAH. Gross regional product is transformed in the prices of 2000 using consumer price index (CPI).

2. *Natural Gas Consumption* is measured in thousands cubic meters and taking into natural logarithms. Only industrial part of natural gas consumption is taking into account.

3. *Real Gross Fixed Capital Formation* is the natural logarithm of capital investment which consists of expenditures for capital construction, purchase of machinery and equipment without capital construction, and is measured in millions of UAH. Capital investment is transformed in the prices of 2000 using consumer price index (CPI). Real Gross Fixed Capital Formation is the proxy for capital.

4. *Labor Force* is measured in thousands and presented as the number of economically active population aged 15-70, taking into natural logarithms. Labor Force is the proxy for labor.

Descriptive statistics for these four variables during 2000-2008 and across regions are given in Table 1.

Table 1

Descriptive Statistics

Sample: 2000-2008

	Real GRP, mln.UAH	Natural Gas Consumption, mln. cub.m.	Real Gross Fixed Capital Formation, mln.UAH	Labor Force, thsd.
Mean	10441.69	2021.91	2317.34	787.95
Median	6389.64	1350.67	1392.41	576.15
Maximum	71802.17	9841.65	19721.84	2153.20
Minimum	1313.00	134.75	141.00	284.10
Std. Dev.	11292.59	2078.51	2716.32	419.58
Observations	234	234	234	234

For the analyzed period average value of real GRP in Ukraine is 10441.69 millions UAH. Maximum level is fixed in Kyiv in 2008. This number is seven times more than the average and equals to 71802.17 millions UAH. In fact, minimum level of regional gross product in Ukraine more diverges from the mean than maximum level. Minimum GRP equals to 1313.00 millions of UAH and is fixed in Chernivtsi region in 2000.

Mean of natural gas consumption in Ukraine is 2021.91 millions cubic meters. Maximum volume of natural gas is consumed by Donetsk region in 2000. This number is 9841.65 millions of cubic meters or five times more, than the average regional level of natural gas consumption in Ukraine. Minimum level is consumed in Chernivtsi region in 2000.

Average level of real gross fixed capital formation per region is 2317.34 millions UAH and the highest level, that is eight times more, is indicated in the city of Kyiv in 2008. Minimum level is again fixed in Chernivtsi region. Mean for labor force is 787.96 thousands, maximum number 2153.2 thousands is fixed in Donetsk region in 2000.

Descriptive statistics shows that Donetsk region and the city of Kyiv are two leaders in the maximums, while Chernivtsi region shows permanent minimums. Such characteristics for Chernivtsi region can be explained by its small size and comparatively not high level of industrial production. Kyiv looks like city with capital intensive production while labor intensive production is concentrated in Donetsk region.

At this moment, three typical regions in Ukraine could be easily defined. Two of them are industrially intensive: East and Center with Donetsk and the city of Kyiv, respectively, as leaders. Third region is low industrialized West with Chernivtci as the representative. South is forth region, which is in-between of maximum and minimum levels of industrial production development and is, in fact, geographically logical. Table 1A in the Appendix presents the list of other representatives from mentioned regions. With this division the existence of some individual effects in the considered sample, is confirmed. To incorporate estimations with these effects, Arellano and Bond (2001) methodology is used in this thesis.

Also individual characteristics of Center, East, West and South regions can be easily defined from the Table 2A of the Appendix. Here loading of Center, East, West and South regions in the total GDP of Ukraine over time is presented. The largest level of contribution to the gross domestic product of Ukraine has Center region, where, in 2008, 36.3% of all GDP is produced. Part of East region equals to 33.9%. West and South regions produce 13.5% and 16.3%, respectively. So Center region produces the sum of regional domestic products from West and South regions. The same is true for the East.

In 2008, 44.4% of natural gas consumption in Ukraine is concentrated on the East. This sum is expected, as Ukrainian East is more industrialized, than other regions and only industrial natural gas consumption is considered. The Center consumes 28% of all natural gas and that is 16.4% less, than for East region. On the other hand, in 2008, Center region accumulates 41.7% of real gross fixed capital formation and is more capital intensive than the East, where 25.8% of gross fixed capital is located.

All regions have very similar profiles of labor force location. 31.2% of Ukrainian labor force in concentrated in the Center, 28.6% - in the East. 21.1% - in the West and 19.1% - in the South.

So main possible sources of heterogeneity of Ukrainian regions is explained with the differences in the amount of capital, volumes of natural gas consumption and contributions of the regions into the gross domestic product.

In Table 2 absolute values of real GRP, natural gas consumption, real gross fixed capital formation and labor force between Center, East, West and South regions are presented. In order to consider dynamic changes in variables, data is rated for two years, 2000 as the beginning of the studied time period and 2008 as the end.

Table 2

Distributions of Real GRP, Natural Gas Consumption, Real Gross Fixed Capital Formation, Labor Force over Center, East, West and South Regions in Ukraine in 2000 and 2008

	Regions							
	Center		East		West		South	
Variables	2000	2008	2000	2008	2000	2008	2000	2008
Real GRP, bln. UAH	47.21	150.64	45.12	138.97	21.94	62.51	25.04	68.44
Natural Gas Consumption, mln. cub. m.	14.32	12.99	25.08	20.57	7.06	6.29	7.34	6.50
Real Gross Fixed Capital Formation, bln. UAH	8.59	42.73	7.56	26.20	3.44	18.71	4.20	16.91
Labor Force, mln.	6.32	6.67	5.97	6.10	4.35	4.50	3.83	4.08

According to Table 2, real GRP in all regions tripled from 2000 to 2008. The highest increase is indicated in Center region, where real GRP increases in 3.19 times, from 41.21 billions UAH in 2000 to 150.64 billions UAH in 2008. The lowest speed of GRP growth is fixed in the South, its GRP in 2008 is 2.73 times more than GRP in 2000.

Absolute values of the series of natural gas consumption in all regions have decreasing character. The highest reduce in the volumes of natural gas consumption in indicated in East region, where the value goes down from 25.08 to 20.57 or by 18%. In the West and the South drops in volumes are 11%, in the Center – 9%. At this moment, one can conclude on opposite direction in dynamics of natural gas consumption and economic growth associated with increase in GRP.

On the other hand, time series of real gross fixed capital formation demonstrates the highest increase during 2000-2008. Volumes of capital in the West increase in 5.45 times, in Center, South and East regions – in 4.98, 4.03 and 3.47 times, respectively. So the series of gross fixed capital formation are going up together with real gross regional product.

Dynamic of labor force number is, in fact, also positive. On the other hand, this variable itself is not highly volatile. Increase in its dynamics over nine years equals to 2-6% and is mainly explained by labor force migration and some positive changes in demographical situation in Ukraine.

Annual changes of studied parameters for 25 regions of Ukraine and the city of Kyiv, during 2000-2008, are presented in Table 3A-6A of the Appendix. There are no rapid changes in the coefficients during analyzed period. Maximum annual level of growth across panel and over 2000-2008 is 1.8 times for real GRP, 1.7 times - for gas consumption, 2.2 times for capital and 1.1 times for labor. These numbers are fixed in different period and for different regions. So growth shown in Table 2 from 2000 to 2008 is smooth and without structural breaks. Then, in cointegration analysis Pedroni (1999) test is appropriate tool. But for panels with structural breaks Westerlund and Edgerton (2008) procedure could be more powerful.

At the very beginning, stationarity of time series can be tested with graphs. Figure 1 presents the scatter plot of the real GRP distribution from 2000 to 2008, where every dot from vertical line that corresponds to year 2000 represents regional GRP in natural logarithms. As there are 26 regions in the sample, every vertical line has 26 dots. The higher the dot, the higher GRP in the region represented with this dot.

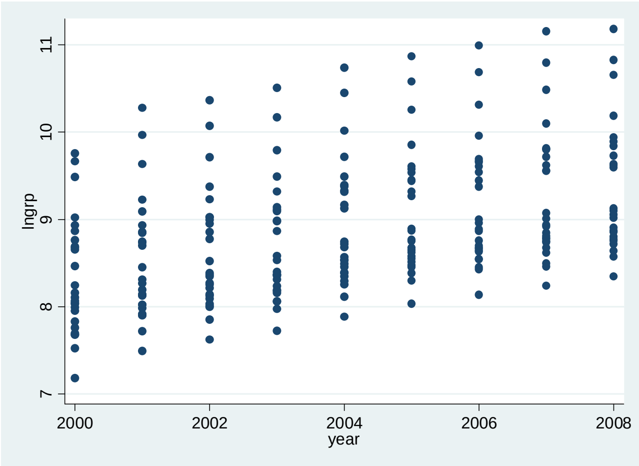

Figure 1. Distribution of Real GRP over 2000-2008

First, in Figure 1 strong increasing tendency over years is observed. Also year by year several groups with similar levels of real GRP values can be defined. As it is shown, that all time series grow smoothly without structural breaks, one can conclude that time series of regional GRP has trend, so its statistical characteristics change over time and this time series is suspected to be nonstationary.

In Figure 2, scatter plot for regional gross fixed capital is presented. Here every dot in vertical line that corresponds to 2000 year represents the amount of real gross fixed capital formation in one region. This amount is expressed in natural logarithms. As in case with real GRP, capital time series has strong increasing trend, so nonstationarity is also suspected.

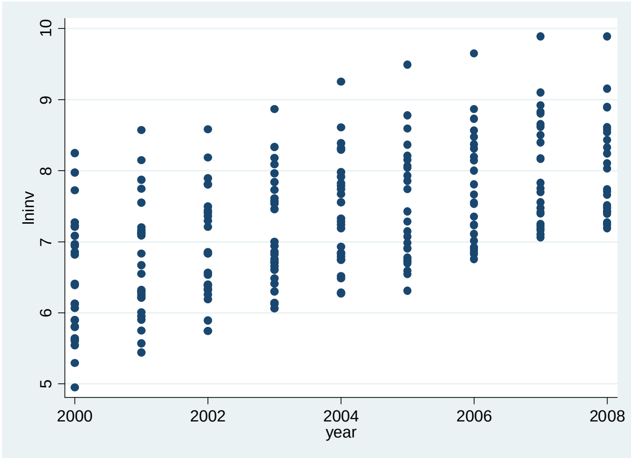

Figure 2. Distribution of Regional Real Gross Fixed Capital Formation in Ukraine over 2000-2008

Figure 3 presents scatter plot of distribution of natural gas consumption in Ukraine over 2000-2008. Before, from Tables 3A-6A in the Appendix, conclusion about the absence of structural breaks is made.

So now from Figure 3, one can conclude, that series of natural gas consumption does not have trend and is suspected to have statistical characteristics that do not change over time, so this series is suspected to be stationary.

In Figure 4 distribution of labor force in Ukraine over regions across analyzed years is presented. It seems that dynamics of this time series look similar to the series of natural gas consumption, presented at Figure 3, so stationarity for labor force is also suspected.

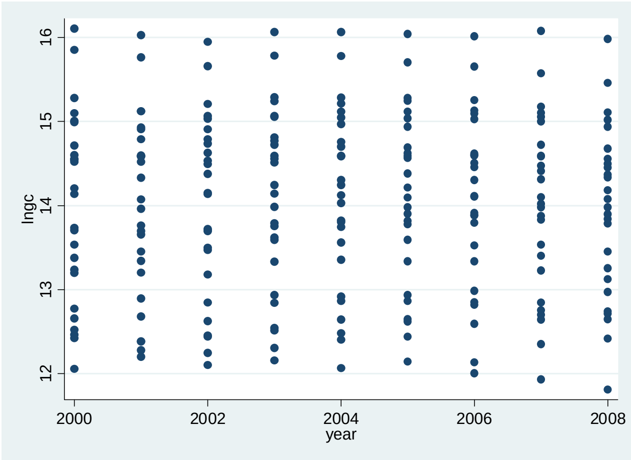

Figure 3. Distribution of Regional Natural Gas Consumption in Ukraine over 2000-2008

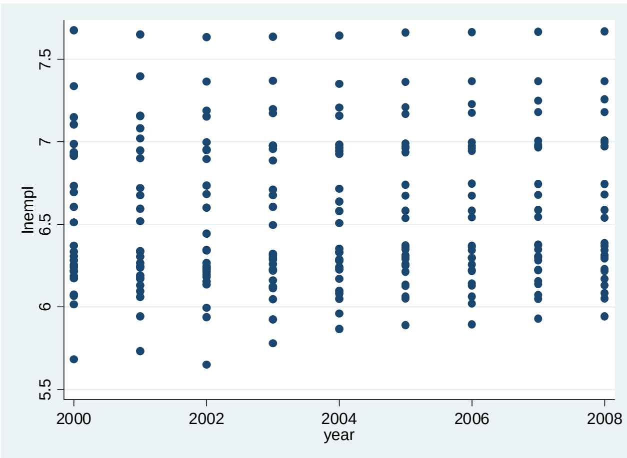

Figure 4. Regional Distribution of Labor Force in Ukraine over Years, 2000-2008

In Figure 5, natural gas consumption values in natural logarithms for all regions and across years are plotted as the function of real GRP with the same characteristics. Functional relations look like linear. According to this dynamics, natural gas consumption is going to go up with increase in real GRP.

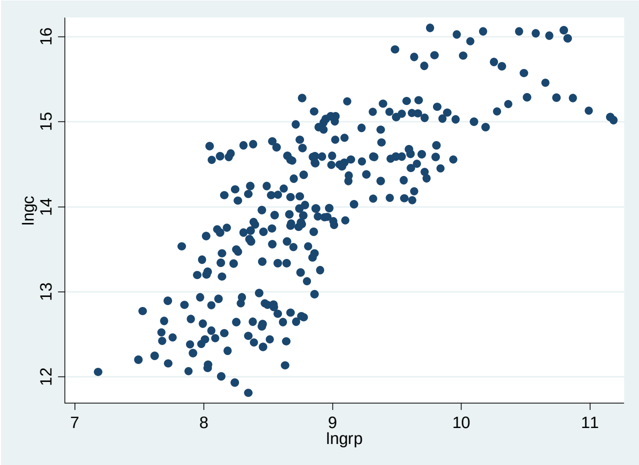

Figure 5. Preliminary Analysis of the Natural Gas Consumption and Real GRP Nexus

In fact, it contradicts with results, obtained from Table 2 analysis, where over 2000-2008 period natural gas consumption decreases, while real GRP goes up. In order to make final conclusions, model estimation is needed and that is to be presented in the next section.

So in Chapter 4, data sources and the logic of variables choice are discussed. Then, with using descriptive statistics for four variables across regions and time, four different regions are defined: Center, East, West and South. After, possible sources of heterogeneity for these regions are determined as differences in the amount of capital, volumes of natural gas consumption and contributions of the regions into the gross domestic product. As individual effect is presented in the studied panel, Arellano and Bond (2001) methodology may produce efficient estimations. After detailed analysis of growth dynamics it is concluded, that during 2000-2008, there are no structural breaks in the studied time series, so Pedroni (1999) tests to define cointegration may be appropriate. Otherwise, Westerlund and Edgerton (2008) procedure for panel with structural breaks is more appropriate. Finally, preliminary analysis of integration and causality is provided. In time series of gross GRP and capital investments non stationarity is suspected. And contradiction results concerning real GRP and natural gas consumption nexus are found. Final conclusions come after model estimation, using Arellano and Bond (2001).

Chapter 5

RESULTS

In this section estimation results of natural gas consumption and regional economic growth nexus in Ukraine are presented. First, integration analysis follows. Next, results of cointegration analysis on the basis of Pedroni (1999) tests are discussed. After, causality analysis on the basis of Engle and Granger (1987) methodology is presented. And then, Arellano and Bond (2001) estimator is implemented for variables found to be in causality relations at previous step. This section ends up with conclusions for policy implications.

Panel Integration Analysis

In this thesis four time series are studied over 2000-2008 for 25 regions of Ukraine and the city of Kyiv: real gross regional product, natural gas consumption, real gross fixed capital formation and labor force. That is 234 observations. Preliminary analysis of previous section shows that series of real gross regional product and gross fixed capital formation are likely to be nonstationary, so have statistical characteristics that are unstable over time. However, almost all time series in the real world are found to be nonstationary, in the first differences these time series could be stationary. If this is so, these time series are integrated of order one.

Table 3 presents results of integration testing in the studied time series. No differencing is made for the time series here, so they are in levels. Three tests are used: Levin et al. (2002), Fisher-types tests using Augmented Dickey–Fuller and Phillips-Perron tests proposed by Maddala and Wu (1999) and Choi (2001).

Table 3

Panel Unit Roots Tests in Levels

	LnGRP	Ln Gas Consumption	LnCapital	LnLabour
Method	Statistic			
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	1.718 (0.957)**	-2.456 (0.007)	1.973 (0.976)	-4.953 (0.000)
Null: Unit root (assumes individual unit root process)				
ADF - Fisher Chi-square	4.646 (1.000)	20.170 (0.572)	0.019 (0.991)	56.757 (0.064)
PP - Fisher Chi-square	3.669 (1.000)	15.373 (0.846)	0.009 (0.996)	63.620 (0.017)
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				

Levin et al. (2002) test has a null hypothesis that a unit root is present, so time series is nonstationary. Under the alternative hypothesis, time series is stationary. In Table 3, hypothesis about the presence of unit roots can not be rejected with 5% significance level for time series of real gross regional product and for real gross fixed capital formation. Series of gas consumption and labor force are stationary with Levin et al. (2002) test.

Levin et al. (2002) test considers common unit root process, while Fisher-types tests using Augmented Dickey–Fuller and Phillips-Perron tests allow for individual unit roots processes. These two tests are also run for time series in levels. Under Fisher type of Augmented Dickey–Fuller test, hypothesis about the presence of unit roots can not be rejected for all times series with 5% significance level. Under Fisher type of Phillips-Perron tests null hypothesis about the presence of unit roots can not be rejected for all time series except labor force. The same tests can be run in the first differences of time series. If time series is found to be stationary in first differences, then this time series is integrated of order one. Results of panel unit roots for time series in the first differences are presented in Table 4.

Table 4

Panel Unit Roots Tests in the First Differences

	LnGRP	LnGC	LnCapital	Lnlabour
Method	Statistic			
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-5.093 (0.000)**	-3.256 (0.000)	0.172 (0.018)	-11.604 (0.000)
Null: Unit root (assumes individual unit root process)				
ADF - Fisher Chi-square	36.545 (0.191)	35.044 (0.041)	52.691 (0.125)	108.632 (0.000)
PP - Fisher Chi-square	55.693 (0.000)	56.000 (0.003)	138.327 (0.000)	184.841 (0.000)
** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.				

According to Table 4, with Levin et al. (2002) test for all time series hypothesis about the presence of unit root is rejected, so time series are stationary in the first differences or they are integrated of order one. The same conclusion comes from Fisher type of Phillips-Perron tests. With Fisher type of Augmented Dickey–Fuller test hypothesis is rejected only for the series of gas consumption and labor force. In general, time series are concluded to be integrated of order one.

Panel Cointegration Analysis

Also integrated series can be cointegrated and then their linear combination produces lower order of integration. In data analysis section of this thesis it is shown that studied time series do not have structural breaks, so Pedroni (1999) tests to check cointegration can be used.

Results of Pedroni (1999) test estimations are presented in Table 5.

Table 5

Pedroni (1999) Panel Cointegration Test

	Weighted Statistics (Prob.)
Panel v-Statistic	0.921 (0.179)
Panel rho-Statistic	2.112 (0.983)
Panel PP-Statistic	-4.378 (0.000)
Panel ADF-Statistic	-3.062 (0.001)
	Statistics (Prob.)
Group rho-Statistic	3.810 (0.999)
Group PP-Statistic	-9.872 (0.000)
Group ADF-Statistic	-6.627 (0.000)

Null hypothesis of Pedroni (1999) tests is no cointegration. Hypothesis is testing on the basis of seven statistics. Four out of these seven statistics are panel based: panel *v,* panel ρ , panel *PP* and panel *ADF*. They are computed after the polling residuals within dimension of the panel. At the same time, Pedroni (1999) also reports three group based statistics: group ρ , group *PP* and group *ADF*. They are calculated after the pooling residuals along the between dimensions of the panel.

With Panel v-Statistic, Panel rho-Statistic and Group rho-Statistic null hypothesis can not be rejected. With Panel PP-Statistic, Panel ADF-Statistic, Group PP-Statistic and Group ADF-Statistic null hypothesis is rejected, so cointegration is present. Three out of seven Pedroni (1999) tests say that hypothesis about cointegration can not be accepted. On the other hand, four tests conclude that cointegration exists. So one can not conclude on the strong evidence of cointegration, but still may conclude on the weak evidence of cointegration relations. In fact, cointegration relations are needed to define cointegration vector that could run panel vector error correction model (14) into the long run equilibrium.

Panel Causality Analysis

As the evidence of weak panel cointegration is found, Engle and Granger (1987) two step procedure is used. Results of Granger causality testing is presenting in Table 6.

Table 6

Granger Causality Tests

Null Hypothesis:	F-Statistic	Prob.
GAS_C does not Granger Cause GRP	10.094	0.002
GRP does not Granger Cause GAS_C	0.843	0.360
CAPITAL does not Granger Cause GRP	3.832	0.052
GRP does not Granger Cause CAPITAL	13.926	0.000
LABOR does not Granger Cause GRP	12.882	0.000
GRP does not Granger Cause LABOR	4.713	0.031
CAPITAL does not Granger Cause GAS_C	2.516	0.114
GAS_C does not Granger Cause CAPITAL	2.170	0.142
LABOR does not Granger Cause GAS_C	2.219	0.138
GAS_C does not Granger Cause LABOR	0.371	0.543
LABOR does not Granger Cause CAPITAL	3.627	0.058
CAPITAL does not Granger Cause LABOR	4.110	0.044

In Table 6, p-values and F-Statistics are reported for 12 types of null hypothesis. Causality defined with Engle and Granger (1987) methodology is often called Granger causality. With significance level of 5%, the following null hypothesizes can not be rejected for the panel study of Ukrainian regions over 2000-2008:

1. GRP does not Granger cause Gas Consumption;

2. Capital does not Granger cause GRP;

3. Capital does not Granger cause Gas Consumption;

4. Gas consumption does not Granger cause Capital;

5. Labor does not Granger cause Gas Consumption;

6. Gas Consumption does not Granger cause Labor;

7. Labor does not Granger cause Capital.

On the other hand, null hypothesis is rejected in all other pair-wise causality relations from Table 6, so the following holds:

1. Gas consumption Granger causes GRP;

2. GRP Granger causes Capital;

3. Labor Granger causes GRP;

4. GRP Granger causes Labor;

5. Capital Granger causes Labor.

Out of last five causality relations, the first directly corresponds to the causality studied in this thesis. According to Engle and Granger (1987) test, causality runs from natural gas consumption to GRP. GRP also depends on labor. With this information, specification of Arellano and Bond (2001) estimation is made, GRP is defined as a function that depends on natural gas consumption and labor force.

First, model that does not include individual effects is considered. This model is estimated under the following specification:

$$Y_{it} = \alpha_1 Y_{it-1} + \alpha_2 Y_{it-2} + \alpha_3 NG_{it} + \alpha_4 L_{it} + e_{it} \quad (15)$$

Results of model (15) estimation are presented in Table 7.

Table 7

Estimation Results for GRP as Dependent Variable,

Instrumental Variable is Capital

Estimated Variables	Coeff.	p-value
lnGRP, first lag	-0.600	0.060
lnGRP, second lag	0.634	0.043
lnNG	0.026	0.959
lnL	11.078	0.007

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.619

Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.212

Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.170

According to Table 7, the effect of labor on GRP is statistically significant. First and second lags of GRP may also explain dynamics in current GRP, as coefficients near these variables are significant, if significant level is 10%. At the same time, estimations for natural gas consumption are not significant. But one can find out that they are positive, so correspond with some preliminary analysis of data, where GRP is positively depends on natural gas consumption. In fact, Sargan test of this model says that model is overidentified, null hypothesis about overidentification is accepted. Assumptions of the model hold if Arellano-Bond test for autoregressive AR(1) process in the first differences is rejected and for autoregressive AR(2) process is accepted. In fact, hypothesis of Arellano-Bond test for autoregressive AR(1) process in the first differences can not be rejected. So, inappropriate specification of the model exists. Possible reason for this is individual effect that is indicated in the studied data set. To deal with this problem differenced specification of model (15) estimated with using Arellano and Bond (2001) estimator:

$$\Delta Y_{it} = \alpha_1 \Delta Y_{it-1} + \alpha_2 \Delta Y_{it-2} + \alpha_3 \Delta NG_{it} + \alpha_4 \Delta L_{it} + e_{it} \qquad (16)$$

Results of model (16) estimations are presented in Table 8.

Table 8

Estimation Results for GRP in Differences as Dependent Variable,

Instrumental Variable is Capital in Differences

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-3.694	0.030
lnGRP, second lag difference	-0.593	0.027
lnNG, first difference	0.609	0.079
lnL, first difference	-1.703	0.037

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.186
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.177
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.850

Here, coefficient near natural has consumption is positive and significant with 10% significance level. First lag and second lag of differences in GRP are negative and significant with 5% significance level. But, impact of labor is insignificant. Sargan test rejects hypothesis that model is overidentified, Arellano-Bond test for autoregressive AR (2) process is accepted, as for autoregressive AR (1) process is rejected with 20% significance interval.

In the model (15) lagged values of capital is used as instrumental variables for lagged values of GRP. It means that amount of gross capital formation in current period does not influence volumes of GRP in the period t-1. But it is shown that this instrument is not valid as model specification do not allow for individual effect that present in studied panel dataset.

At the same time, in model (16), estimations are in Table 8, differences of values of capital are used as instrumental variable for differences of GRP values. So it is assumed, that differences in gross capital formation in period t do not correlate with differences in GRP in period t, but correlate with the lag of differences in GRP. Model (16) is correctly specified, so instrumental variable for lag of difference in GRP is valid.

Here one more specification for instrument can be used: lag of differences of values of capital formation. Results of model (16) estimation with this instrument are presented in Table 7A. of the Appendix. In this case, conclusions for Sargan test and for Arellano-Bond test for autoregressive AR(1) and AR(2) processes coincide with conclusions for model (16) presented in Table 8. But estimates of first lag differences of GRP are insignificant. So instrument with differences of values of capital is better as it produces significant coefficients for first lag and second lag of differences in GRP.

The same conclusions come from Tables 8A-13A of the Appendix, where estimations for other sets of possible instruments are presented: labor in differences; lag of differences in labor; differences in labor and capital as pair; lag of differences in capital and differences in labor as pair; lag of difference in labor and differences in capital as pair.

Results show that the best choice of instrumental variables is with lag of capital in differences, the one presented in Table 8.

With presented results of Sargan tests, Arellano-Bond test for autoregressive AR(1) and AR(2) processes and conclusions on the validness of instrumental variable, one can consider model (16) as model with right specification. With 10% significance interval for estimated values of variables in the model (16), presented in Table 8, natural gas consumption has positive and significant impact on regional economic growth in Ukraine. The same is true for coefficient natural gas consumption for all models presented in Tables 7A-13A of the Appendix.

On the basis of this analysis, regional economic growth in Ukraine is found to be positively dependent on natural gas consumption. In fact, this is one of the results of preliminary data analysis. On the other hand, as only industrial natural gas consumption is included into the model, obtained results are more relevant to regions of Ukraine with relatively high volumes of natural gas consumption by companies. It is found that in 2008, 44.4% of all natural gas consumption is related with companies in the East: from Dnipropetrovsk, Donetsk, Luhansk and Kharkiv regions, according to specification from Table 1A in the Appendix. So, under estimated model positive effect of natural gas consumption on regional economic growth is expected to be more sensible in these regions.

But this conclusion should not be seen as the axiom, logically that every increase in natural gas consumption should coincide with increase in efficiency of energy use, technological improvements. Otherwise, positive effect from increase in natural gas consumption on regional economic growth will inefficiently disperse.

Furthermore, in the framework of energy conservation policy or political instability, consumption of natural gas can be limited, what will harm economic development of energy dependent regions. Recommended policy in this situation is to decrease energy dependency using new technologies and diversified sources of energy including alternative.

To conclude, in this section results of panel integration, cointegration and causality relations testing are presented. Then, with Arrelano and Bond (2001) estimator defined that for studied panel of Ukrainian regions over 2000-2008, natural gas consumption has positive and significant impact on gross regional product. Results found after specified model estimation coincide with results obtained by Apergis and Payne (2009) in their studies for total energy consumption and economic growth in the panel of Commonwealth of Independent States including Ukraine. Results partially coincide with Apergis and Payne (2010) study of causality between natural gas consumption and economic growth in the panel of 67 countries including Ukraine, where causality runs in both directions.

Chapter 6

CONCLUSIONS

This paper studies the nexus of natural gas consumption and economic growth using the panel of 25 regions in Ukraine and the city of Kyiv across 2000-2008. In the literature there is no consensus on the direction of causality between natural gas use and economic growth. Also there are only few papers that include Ukraine into the panel analysis.

This thesis is the first attempt to make country specific analysis for Ukraine with panel dataset across regions. Within multivariable approach four time series are considered: real gross regional product, natural gas consumption, real gross fixed capital formation and labor force. Natural gas consumption series includes only industrial gas consumption in Ukraine as residential gas consumption is not defined by changes in economic activities, Hondroyiannis et al. (2002).

It is detected that studied time series are integrated of order one. With Pedroni (1999) panel cointegration analysis conclusion about the weak evidence of cointegration is made. Panel causality analysis shows that natural gas consumption Granger causes gross regional product, the same impact is defined for labor force. Then, model with natural gas consumption and labor force as independent variables and gross regional product as dependent variable is estimated with Arellano and Bond (2001) methodology for dynamic panel data. Differences of gross fixed capital formation are used as an instrument variable for differences of GRP values.

It is found that economic development of the regions in Ukraine positively depends on the volumes of natural gas consumption. This effect is suspected to be larger for industrialized regions of Ukraine as only industrial natural gas consumption is studied. These finding coincides with previous findings for panel studies that include Ukraine.

However, the found nexus of natural gas consumption and economic growth can be harmful for energy dependent regions, especially, for Dnipropetrovsk, Donetsk, Luhansk and Kharkiv, that is Ukrainian East, where in 2008 44.4% of the total natural gas consumption is concentrated. In case of limitations of energy use under energy conservation policy or fails of natural gas delivering may economic growth may go down here. Recommended policy is to use gains from positive nexus of natural gas consumption and economic growth while they exist to decrease energy dependency of regions by investing in new technologies and alternative sources of energy.

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APPENDIX

Table 1A

Center, East, West and South Regions of Ukraine

Center		*East*		*West*		*South*	
Region	Number in data set	Region	Number in data set	Region	Number in data set	Region	Number in data set
Vinnytsya	2	Dnipropetrovsk	4	Volyn	3	Autonomous Republic of Crimea	1
Zhytomyr	6	Donetsk	5	Zakarpattya	7	Zaporizhya	8
Kyiv	10	Luhansk	12	Ivano-Frankivsk	9	Mykolayiv	14
Kirovohrad	11	Kharkiv	20	Lviv	13	Odesa	15
Poltava	16			Rivne	17	Kherson	21
Sumy	18			Ternopil	19		
Cherkasy	23			Khmelnytskiy	22		
Chernihiv	25			Chernivtsi	24		
City of Kyiv	26						

Table 2A

Loading of Center, East, West and South Regions in the Real Gross Domestic Product, Natural Gas Consumption, Real Gross Fixed Capital Formation and Labor Force in Ukraine over 2000-2008

Variables	*Percentage in the Whole Volume*								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Center									
Real Gross Domestic Product, %	33.9	37.0	36.7	36.8	36.8	36.2	36.3	38.1	35.8
Natural Gas Consumption, %	26.6	27.8	31.1	30.4	29.7	30.1	29.4	29.0	28.0
Real Gross Fixed Capital, %	36.1	36.2	35.8	36.5	37.5	39.1	39.2	40.0	40.9
Labor Force, %	30.9	30.5	30.9	31.5	31.3	31.3	31.3	31.3	31.2
East									
Real Gross Domestic Product, %	32.4	30.9	31.0	30.8	31.6	32.3	31.9	29.4	33.0
Natural Gas Consumption, %	46.6	44.6	41.5	43.0	42.5	42.1	43.5	43.8	44.4
Real Gross Fixed Capital, %	31.8	29.7	28.4	28.3	27.6	29.4	27.6	27.7	25.1
Labor Force, %	29.2	29.0	29.2	29.0	28.8	28.8	28.8	28.6	28.6
West									
Real Gross Domestic Product, %	15.8	15.2	15.5	15.9	15.2	15.3	15.5	15.8	14.9
Natural Gas Consumption, %	13.1	13.7	14.1	13.6	15.0	15.2	14.0	13.2	13.6
Real Gross Fixed Capital, %	14.5	15.1	16.3	16.7	16.8	14.6	16.4	16.1	17.9
Labor Force, %	21.3	20.8	20.4	20.5	20.7	20.9	20.8	20.9	21.1
South									
Real Gross Domestic Product, %	18.0	16.9	16.8	16.5	16.4	16.1	16.2	16.6	16.3
Natural Gas Consumption, %	13.6	13.8	13.2	13.0	12.9	12.7	13.2	14.1	14.0
Real Gross Fixed Capital, %	17.6	19.0	19.4	18.5	18.1	16.9	16.8	16.2	16.2
Labor Force, %	18.7	19.7	19.5	18.9	19.1	19.0	19.1	19.1	19.1

Table 3A

Dynamics of Real Gross Regional Product across Regions in Ukraine over 2000-2008, Number of Times

Regions	*Years*							
	2001	2002	2003	2004	2005	2006	2007	2008
Crimea	1.313	1.126	1.128	1.210	1.163	1.137	1.118	1.065
Vinnytsya	1.231	1.074	1.058	1.180	1.135	1.091	1.052	1.097
Volyn	1.232	1.097	1.067	1.260	1.203	1.070	1.138	1.046
Dnipropetrovsk	1.161	1.084	1.080	1.251	1.271	1.060	1.188	1.182
Donetsk	1.232	1.111	1.102	1.326	1.137	1.112	1.117	1.030
Zhytomyr	1.073	1.130	1.094	1.249	1.128	1.072	1.112	1.054
Zakarpattya	1.248	1.144	1.171	1.224	1.133	1.124	1.153	1.089
Zaporizhya	0.999	1.097	1.073	1.332	1.170	1.125	1.161	1.036
Ivano-Frankivsk	1.162	1.209	1.158	1.204	1.193	1.109	1.079	1.055
Kyiv	1.013	1.081	1.094	1.295	1.148	1.118	1.196	1.084
Kirovograd	1.356	1.114	1.072	1.204	1.118	1.091	1.076	1.151
Lugansk	1.097	1.185	1.093	1.320	1.200	1.098	1.158	1.080
Lviv	1.189	1.157	1.160	1.203	1.133	1.168	1.115	1.015
Mykolaiv	1.225	1.057	1.037	1.321	1.080	1.139	1.053	1.079
Odesa	1.255	1.148	1.092	1.192	1.121	1.090	1.116	1.147
Poltava	1.102	1.223	1.038	1.388	1.138	1.102	1.081	0.974
Rivne	1.210	1.113	1.056	1.230	1.176	1.121	1.080	1.031
Sumy	1.111	1.083	1.017	1.139	1.140	1.052	1.122	1.086
Ternopil	1.217	1.139	1.130	1.151	1.200	1.142	1.068	1.082
Kharkiv	1.228	1.160	1.125	1.252	1.146	1.109	1.150	1.094
Cherson	1.168	1.096	1.053	1.213	1.139	1.071	1.009	1.196
Khmelnytskyi	1.164	1.119	1.108	1.190	1.156	1.089	1.090	1.061
Cherkasy	1.063	1.088	1.104	1.292	1.222	1.103	1.057	1.144
Chernivtsi	1.366	1.136	1.109	1.174	1.161	1.109	1.110	1.113
Chernigiv	1.107	1.146	1.105	1.178	1.123	1.051	1.120	1.051
City of Kyiv	1.854	1.090	1.154	1.259	1.138	1.131	1.179	1.026

Table 4A

Dynamics of Natural Gas Consumption across Regions in Ukraine over 2000-2008, Number of Times

Regions	*Years*							
	2001	2002	2003	2004	2005	2006	2007	2008
Crimea	1.059	0.946	1.320	1.049	1.062	1.011	0.993	0.980
Vinnytsya	0.787	1.189	1.003	0.981	0.869	0.903	0.951	1.009
Volyn	1.026	0.944	1.239	1.027	1.000	0.983	0.912	0.898
Dnipropetrovsk	0.917	0.901	1.131	0.993	0.931	0.952	0.923	0.890
Donetsk	0.927	0.921	1.125	1.002	0.977	0.972	1.066	0.910
Zhytomyr	1.002	0.978	1.170	1.021	0.983	1.001	0.896	0.899
Zakarpattya	0.865	0.759	1.226	1.102	1.039	0.737	1.757	1.313
Zaporizhya	0.916	0.886	1.026	0.947	0.847	0.918	1.246	0.760
Ivano-Frankivsk	0.879	1.163	1.034	1.222	0.967	0.715	0.879	0.899
Kyiv	0.814	1.046	1.139	0.814	1.082	0.927	1.008	0.877
Kirovograd	0.965	1.072	1.061	0.966	1.155	1.216	0.840	1.069
Lugansk	0.852	0.949	1.188	0.972	1.032	1.007	0.925	0.935
Lviv	1.033	0.912	1.062	1.035	0.976	0.896	0.957	0.927
Mykolaiv	0.965	1.026	1.070	1.012	1.014	1.073	0.989	0.914
Odesa	1.001	1.014	1.060	1.002	1.032	0.996	0.965	0.972
Poltava	1.203	1.277	1.033	1.054	1.001	0.976	1.009	0.654
Rivne	1.132	1.041	1.057	1.071	1.085	1.008	1.068	0.922
Sumy	0.936	1.081	1.098	1.003	0.967	0.904	0.914	0.961
Ternopil	1.131	0.951	1.095	0.983	1.015	1.052	0.871	0.897
Kharkiv	0.926	0.977	1.166	0.988	0.994	0.988	0.976	0.937
Cherson	0.831	1.173	1.114	1.103	1.007	0.944	0.787	1.063
Khmelnytskyi	1.074	1.049	1.130	1.130	1.033	1.017	0.677	0.865
Cherkasy	1.046	1.030	1.102	0.975	0.993	0.909	0.993	0.910
Chernivtsi	1.156	1.046	0.914	0.911	1.079	0.873	0.932	0.883
Chernigiv	1.112	1.136	1.132	0.966	1.034	0.933	1.011	0.922
City of Kyiv	1.023	1.088	1.085	0.997	0.995	0.859	0.932	0.966

Table 5A

Dynamics of Real Gross Fixed Capital Formation in Ukraine over 2000-2008, Number of Times

Regions	*Years*							
	2001	2002	2003	2004	2005	2006	2007	2008
Crimea	1.378	1.310	1.225	1.237	1.113	1.236	1.293	1.031
Vinnytsya	1.421	1.157	1.231	1.208	1.324	1.321	1.408	0.965
Volyn	1.795	1.190	1.103	1.296	1.022	1.415	1.354	1.003
Dnipropetrovsk	1.162	1.023	1.331	1.234	1.222	1.150	1.211	0.976
Donetsk	1.191	1.036	1.164	1.316	1.185	1.090	1.265	1.056
Zhytomyr	1.225	1.665	1.044	1.238	1.199	1.235	1.387	1.166
Zakarpattya	1.509	1.130	1.615	1.011	0.898	1.666	1.176	1.083
Zaporizhya	1.041	1.186	1.279	1.135	1.074	1.071	1.428	0.942
Ivano-Frankivsk	1.306	1.170	1.117	1.284	0.960	1.469	1.341	1.219
Kyiv	1.302	1.269	1.628	1.077	1.131	1.393	1.575	1.064
Kirovograd	1.420	1.265	1.249	1.681	0.861	1.268	1.232	1.012
Lugansk	1.162	1.129	1.285	1.385	1.325	1.137	1.526	0.748
Lviv	1.218	1.312	1.336	1.287	1.189	1.173	1.208	1.042
Mykolaiv	1.519	1.355	1.155	1.330	1.158	1.128	1.005	0.962
Odesa	1.708	1.070	1.168	1.390	0.922	1.294	1.200	0.961
Poltava	0.931	1.347	1.079	1.176	1.130	1.154	1.185	1.073
Rivne	1.527	1.229	1.387	1.600	0.554	1.652	1.176	1.029
Sumy	1.549	1.003	0.892	1.036	1.165	0.924	1.404	1.023
Ternopil	1.323	1.183	1.372	1.252	1.299	1.240	1.357	1.211
Kharkiv	1.382	1.299	1.318	1.260	1.049	1.223	1.272	0.792
Cherson	1.300	0.989	1.261	1.431	1.113	1.278	1.306	1.388
Khmelnytskyi	1.187	1.311	1.153	1.706	0.772	1.282	1.281	1.261
Cherkasy	1.230	1.370	1.548	2.217	0.763	1.465	1.087	0.990
Chernivtsi	1.638	1.348	1.488	1.148	1.034	1.760	1.370	1.345
Chernigiv	1.257	1.101	1.301	1.205	1.064	1.022	1.386	1.024
City of Kyiv	1.384	1.011	1.328	1.472	1.271	1.169	1.271	1.002

Table 6A

Dynamics of Labor Force across Regions in Ukraine over 2000-2008, Number of Times

Regions	*Years*							
	2001	2002	2003	2004	2005	2006	2007	2008
Crimea	1.157	0.919	0.982	1.003	1.009	1.005	1.011	1.002
Vinnytsya	0.944	1.008	1.029	0.878	1.003	0.999	1.006	0.998
Volyn	0.989	1.019	0.923	0.936	1.014	1.001	1.009	1.011
Dnipropetrovsk	1.061	0.969	1.005	0.981	1.012	1.005	1.000	0.998
Donetsk	0.976	0.985	1.002	1.006	1.019	1.003	1.001	1.002
Zhytomyr	0.934	0.990	0.992	1.117	1.016	0.996	1.004	0.996
Zakarpattya	0.913	1.053	1.139	0.976	1.025	0.986	1.008	1.008
Zaporizhya	1.027	1.015	0.943	1.040	1.026	1.005	1.000	1.000
Ivano-Frankivsk	0.934	0.937	0.925	1.085	1.018	1.000	1.026	1.012
Kyiv	0.990	1.005	1.005	1.034	1.035	1.001	1.004	1.001
Kirovograd	0.986	1.095	0.968	0.977	1.029	1.003	1.008	0.993
Lugansk	0.985	0.995	0.990	1.042	1.034	1.000	1.011	1.002
Lviv	1.034	0.931	1.026	0.988	1.007	1.005	1.007	1.014
Mykolaiv	1.050	1.000	0.962	1.055	1.010	1.005	1.008	1.003
Odesa	1.026	1.004	1.006	0.988	0.989	1.011	1.020	1.007
Poltava	1.008	0.929	1.053	1.011	1.030	1.003	1.004	0.995
Rivne	1.028	0.903	1.055	1.035	1.055	1.008	1.014	1.013
Sumy	0.950	1.056	1.079	0.961	1.022	0.993	1.002	1.001
Ternopil	0.931	0.996	0.985	1.036	1.096	0.968	1.029	1.003
Kharkiv	1.007	1.034	0.983	0.988	1.009	1.007	1.004	1.001
Cherson	0.998	0.966	0.988	1.046	1.047	1.009	1.002	1.004
Khmelnytskyi	1.000	1.007	0.958	1.056	1.022	0.998	1.007	1.009
Cherkasy	1.057	1.008	0.945	1.043	1.031	1.004	1.008	0.996
Chernivtsi	1.051	0.920	1.139	1.092	1.023	1.005	1.035	1.013
Chernigiv	0.992	0.968	1.047	0.968	1.023	0.970	1.003	0.995
City of Kyiv	1.054	0.997	1.043	1.010	1.002	1.017	1.022	1.011

Table 7A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variable is Capital in Lag Differences

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.368	0.280
lnGRP, second lag difference	-0.514	0.001
lnNG, first difference	0.397	0.012
lnL, first difference	-0.226	0.745

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.183
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.175
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.169

Table 8A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variable is Labor in Differences

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.342	0.282
lnGRP, second lag difference	-0.469	0.000
lnNG, first difference	0.303	0.004
lnL, first difference	0.297	0.211

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.194
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.104
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.274

Table 9A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variable is Lag of Differences in Labor

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.344	0.278
lnGRP, second lag difference	-0.460	0.000
lnNG, first difference	0.290	0.011
lnL, first difference	0.404	0.174

Sargan test of overid. Restrictions: chi2(6) = 8.79 Prob > chi2 = 0.195
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.095
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.272

Table 10A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variables are Differences in Labor and Capital

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.481	0.211
lnGRP, second lag difference	-0.477	0.000
lnNG, first difference	0.407	0.011
lnL, first difference	0.355	0.174

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.162
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.214
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.153

Table 11A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variables are Lags of Differences in Labor and Capital

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.399	0.250
lnGRP, second lag difference	-0.476	0.000
lnNG, first difference	0.321	0.006
lnL, first difference	0.475	0.273

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.182
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.113
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.225

Table 12A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variables are Lags of Differences in Capital and Differences in Labor

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.395	0.252
lnGRP, second lag difference	-0.478	0.000
lnNG, first difference	0.326	0.003
lnL, first difference	0.430	0.140

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.182
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.114
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.227

Table 13A

Estimation Results for GRP in Differences as Dependent Variable, Instrumental Variables are Lags of Differences in Labor and Differences in Capital

Estimated Variables	Coeff.	p-value
lnGRP, first lag difference	-0.390	0.238
lnGRP, second lag difference	-0.380	0.000
lnNG, first difference	0.214	0.066
lnL, first difference	0.914	0.155

Sargan test of overid. restrictions: chi2(6) = 8.79 Prob > chi2 = 0.191
Arellano-Bond test for AR(1) in first differences: z = -1.35 Pr > z = 0.062
Arellano-Bond test for AR(2) in first differences: z = 0.19 Pr > z = 0.268