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Measuring cost efficiency of banks with different ownership types: Evidence from Belarus

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Abstract

This study investigates the correlation between the level of a bank's cost efficiency and its belonging to one of the four ownership types existing in the Belarusian banking sector: core state-controlled, other state-controlled, foreign-controlled and domestic private banks. In order to analyze the data from the financial statements of all registered banks in Belarus under the period of 2010-2016, the Stochastic Frontier Analysis (SFA) is applied. I find core state banks to be the most cost-efficient group, which is followed by other state and domestic private banks, and the foreign-controlled banks as the least efficient. These results contradict the general findings of the papers about cost efficiency of banks in transition economies of the other East European countries, where foreign-controlled banks are found to be the most cost-efficient group but are in line with the studies of the Russian banking sector. Some of the potential reasons for such results may be: grants and discounts from the government to the core state-controlled banks; obligatory participation of the core state banks in the state housing programs, which lowers the borrowers-skimming costs; economy of scale.

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1 Introduction

Efficiency of the financial system, including banks, can be one of the determinants of the country's economic growth and is especially important for transition economies (Anderson, 1998). According to J.P. Bonin et al. (1998), bank efficiency is affected by the type of ownership. The knowledge of this effect in a particular country can be useful for the broad range of agents: from the government to investors and consumers. The focus of this thesis is on how different ownership types affect cost efficiency of banks in the Belarusian transitional economy.

First, the concept of bank's cost efficiency should be discussed. It is determined by Fries and Taci (2005) and Coelli (2005) as how close a bank's costs lie to the efficient cost frontier for a given technology. This efficient frontier is determined by minimum use of inputs to achieve the output (technical efficiency) and optimal mix of inputs to maximize output given prices of inputs (allocative efficiency). As the cost function of a bank is not exactly known, inefficiencies can be measured relative to an efficient cost frontier that is estimated from data. Bank cost inefficiency is then defined by Fries and Taci (2005) as the difference between observed costs and predicted minimum costs for a given scale and mix of outputs, factor prices and other variables.

The reasoning behind studying banks' cost efficiency is based on the paper of Fries and Taci (2005). Greater cost efficiency in the banking sector contributes to overall economic development via the reduction of the resources needed for intermediation of savings into investments. Also, greater relative cost efficiency may be a result of changes in incentives and constraints in banking due to efficient structural and institutional reforms, better provision of public services by the state, for example the rule of law. Moreover, the analysis of relative cost efficiency can help to find out if the existing regulations affect banks with different ownership types in the same or in different ways.

Generally, all the investigated cross-country literature on the cost efficiency of banks in transition economies (mostly include East European countries that are now the part of the European Union, some include Russia and Ukraine as well) claims foreign owned banks to be more cost efficient than state or domestic private banks, even though applied models and methods as well as samples of countries differ across the papers. Single country studies on the same topic are mostly in line with the cross-country studies. At the same time, Mamonov and Vernikov (2017) show contradictory results in their study of Russian case: core state banks are almost as efficient as private banks, when foreign banks appear to be the least efficient in terms of costs. They describe the case of the Russian Federation as a unique: public banks still have a market share of around 60% of the banking sector, whereas this type of ownership is almost not existing in Central and Eastern Europe. It is possible to argue that the Republic of Belarus represents the same case:

on the 1st of January 2017 the 3 major banks controlled by the state had 66.65% of assets of the banking sector (the National Bank of the Republic of Belarus, 2017).

There is an ongoing debate in the financial media (Zayac (2017), Select.by - all banks of Belarus (2016)) about privatization of at least small shares of the major Belarusian state banks and its effect on the banks' efficiency. The government opts for the termination of this transaction and doesn't provide any information if they are going to resume the consideration of privatization or not. At the same time no clear arguments for and against privatization are presented by the government. There are only several reasons discussed in the media are open to the public, where some of them could be of a speculative character. For example, the arguments for privatization are that it will attract investments to the country and increase their competitiveness. At the same time, the discussed argument against is that the government is reluctant to lose the control over the main banks, which will create problems with implementation of some of the state programs such as housing and agricultural investments programs (Zayac (2017), Select.by - all banks of Belarus (2016)). In this context investigation of the efficiency of different groups of banks (controlled by the state, private, foreign-controlled) can be useful for the decision-making process. At the same time, the investigation of the cost efficiency of banks is the only one piece of the general efficiency puzzle, and further research, such as the investigation of the profit efficiency is needed in order to give clear conclusions about the process of privatization of the state banks.

No profound research papers on the efficiency of Belarusian banking system were found, except some minor papers from student conferences and the reports of the National Bank of the Republic of Belarus, which analyze profitability applying method of financial ratios.

In contrast to financial ratios, frontier methods are able to provide an objective numerical efficiency value and ranking of firms, which exclude market price effects and other exogenous factors that may influence observed performance of the entity (Yaw-Shun, 2014). Thus, using data from banks' annual financial reports, one of the frontier methods, namely Stochastic Frontier Analysis (SFA), is performed. This study aims to show differences in cost efficiency of the following four categories of the Belarusian banks: core state-controlled banks, other state-controlled banks, foreign-controlled banks and domestic private banks. The argument behind the division of the state-controlled banks into two groups is that three major state banks can be seen as agents pursuing government's objectives, whereas minor state banks can act in the same manner as private domestic ones. The goal is to investigate the period of 2010-2016, including 2010 – the year before the structural crisis in Belarus[1], as well as 2011 – the year of the crisis. This is done to

[1] Structural crisis in Belarus – crisis of 2011 which is characterized by the collapse of the exchange rate and sharp growth in prices. The reason for the crisis according to Alachnovič A. and Naŭrodski S. (2011) is the growing current account deficit in the country traced from 2007, which was accompanied by expansionary monetary and fiscal policies in.

see the differences in cost efficiency of banks with different ownership types before, during and after the crisis.

Based on the short discussion of the existing literature findings presented above, I hypothesize that in Belarus banks with state ownership have higher cost efficiency than private and foreign banks. The idea behind this hypothesis is that Belarusian economy is more similar to the Russian than to those in western neighbor countries due to the common historical unity within The Russian Empire and The Soviet Union. The motivation is that in Belarus, the same as in Russia, economy is still not a capitalistic one, the governments are participating in a lot of processes in the economy, which are transferred to the private actors in the European countries. Banking sector is not an exception, with the group of the major state-controlled banks serving the purposes of the government.

The contributions of this study can be stated as following. Foremost, it will be the first attempt to analyze the cost efficiency of Belarusian banks with different ownership types applying SFA. Second, novel aggregated panel data on banks' financial measures will be produced, which then can be used in the future studies. Third, state-controlled banks will be divided into the two groups: core and other state-controlled banks. Fourth, analysis of the sources of differences in the levels of cost efficiency can show the general climate of the Belarusian banking sector, potential constraints applied by the regulations towards particular ownership types. Moreover, one of the potential counter-arguments to the decision of the government to terminate privatization of the state banks can emerge if the state-controlled banks will appear to be less cost efficient than private or foreign ones.

The remainder of this paper is organized as follows. Section 2 provides a literature review of previous studies on this topic; Section 3 describes data sources, explanatory and response variables, as well as provide the descriptive statistics of the sample; Section 4 describes SFA in general, its application for the investigation of banks' cost efficiency and the estimation approach; in Section 5 the main findings of the analysis are discussed; Section 6 contains concluding remarks.

2 Literature review

In general, the type of ownership is claimed to affect bank efficiency. To be more precise, J.P. Bonin et al. (1998) argue that public ownership of banks is less efficient than private ownership. Existing research papers cover both cross-country and single-country studies on the bank efficiency. For the purpose of this paper, studies on transitional banking sector are of interest, as Belarus is still considered as a country with transitional economy by The United Nations (2017).

Starting with a broader picture, there are several studies which execute cross-country analysis of banks' efficiency in transition countries. For example, Fries and Taci (2005) examine the cost efficiency of 289 banks in 15 East European countries in 1994-2001 by using SFA. They find banks with foreign ownership to be the most efficient and those with domestic ownership the least. Moreover, they illustrate the fact that in their sample of countries in transition, those with foreign-owned banks comprising larger share of total assets in banking systems, record lower costs. J. P. Bonin et al. (2005) investigate the effects of ownership on bank efficiency for 11 transition countries under the period of 1996-2000. Applying SFA to calculate both cost and profit efficiency they find that foreign-owned banks have higher cost-efficiency than other banks as well as that they provide better service. State-owned banks are claimed to be not less efficient than domestic private banks. These results are in line with the findings of Fries and Taci (2005). Semih Yildirim and Philippatos (2007) study cost and profit efficiency of banking sectors in 12 transition economies of Central and Eastern Europe under the period of 1993–2000 applying SFA. They find that foreign-owned banks are appeared to be more cost efficient but less profit efficient than domestically owned private banks and state-owned banks. The two last described studies add value to the previous literature, as the authors also consider profit efficiency.

Manole (2002) investigates efficiency of banks of transition countries as well but applies a different method – Data Envelopment Analysis (DEA). He states that foreign ownership with controlling power enhances bank efficiency. Thus, all the considered cross-country studies of transition banking systems find foreign ownership to be more cost efficient.

In order to get information on cost efficiency on a country level, it is reasonable to move from the cross-country comparative literature to single country studies. When looking at the papers on the transitional banking systems of a single country, which investigated correlations between bank ownership and cost (and in some cases profit) efficiency, it can be noted that their results are mixed. Kraft and Tırtıroğlu (1998), applying SFA, find state-owned and privatized banks in Croatia in 1994-1995 to have higher cost efficiency and lower profitability than newly established private banks. At the same time, Hasan and Marton (2003), Nikiel and Opiela (2002) and Jemric and Vujcic (2002) study Hungary (during the period of 1993-1997), Poland (1997-2000) and Croatia (1995-2000), respectively. All of them find that foreign-owned banks are more efficient than domestically owned banks. It is important to note that all these studies use different methods. Also, it is important to mention here that these studies do not tell unequivocally that privatization brings economic benefits as state owned banks appear to be not the least efficient entities. Moreover, from these studies it does not seem obvious that market entry of new domestic and foreign banks is beneficial for the transition economy.

Most of the studies of the transitional banking system in the East European countries were conducted in the end of the 20th or the beginning of the 21st century, when the transition process took place. All the described countries are now considered as developed countries (United Nations, 2017). The closest economies to Belarusian that are still considered in transition are Ukraine and Russia. In Ukraine, Pilyavskyy (2012) find foreign and Ukrainian banks to have almost the same cost efficiency. The latest paper on the same problem in the case of Russia is written by Mamonov and Vernikov (2017), in which they investigate the comparative efficiency of Russian banks depending on ownership type (public, private or foreign), risk preference, and asset structure under the period of 2005–2013, using SFA. While multi-country studies that include Russia in their sample claim for the highest efficiency of the foreign banks, single-country studies on Russia used to contradict this claim. So did their paper: the results reveal that the core state banks were nearly as efficient as private banks during and after the crisis of 2008–2009. At the same time, foreign banks appear to be the least efficient market participants in terms of costs.

When privatization is considered by the government, the evaluation of banks efficiency with different ownership types can provide valuable information. Despite the fact that Belarus is now at the stage of such consideration, no profound studies tackling this question were found. According to the report of the National Bank of the Republic of Belarus, which is based on the financial ratios that measure profitability (Return on Assets, Return on Equity), foreign banks are the most efficient, whereas public banks are the least. Cost efficiency is not investigated in this report. Moreover, the financial ratios method has some drawbacks, which are described in Section 4.2 of this paper. Lomako (2013) applies DEA and finds the banks with state capital to be the most cost-efficient, whereas the private to be the least. This paper does not explain what period is investigated. Moreover, it is worthwhile to point out that the author presents only the results of the research, but no model is shown. Because of this it can't be seen which factors are considered and, thus, deeper analysis of the model cannot be performed.

Different papers analyze numerous factors affecting cost efficiency. As one example, Manole (2002) finds bank cost efficiency to be significant and positively associated with GDP per capita, while weakly and positively correlated with institutional reform. He also claims that higher banking market concentration is associated with greater cost efficiency. Fries and Taci (2005) prove a logical dependency that the nominal interest rate is positively correlated with costs. At the same time, they find the level of overall economic development to be not significantly related to costs.

From the review of the existing literature, the following question arise: does the Belarusian case resemble western neighbor countries or Russia in terms of cost efficiency of banks with different ownership? This research aims to fill the existing gap in the literature and investigate the

cost efficiency of Belarusian banks applying Stochastic Frontier Analysis. Then, potential factors that may influence differences in cost efficiency are also established and analyzed.

3 Data

3.1 Data sources

The data section starts with the description of the Belarusian banking sector, which is followed by the argumentation behind the choices encountered in the data selection process as well as the data sources description.

My sample includes all registered by the National Banks of the Republic of Belarus active banks (complete sample). The list of active banks during the period of 2010-2016 is presented in Table A1 of Appendix A. In general, Belarusian banking sector includes 24 active banks (as on 01.2017), which can be divided into the three groups: controlled by the state (5), domestic private (5), foreign-controlled (14). According to the classification of the National Bank of the Republic of Belarus, state banks are the banks with the largest share of capital owned by the Belarusian state bodies or state legal entities. Foreign banks are the banks which largest share of capital is formed by foreign capital, including state capital of any foreign country.

Foreign banks can be controlled by either foreign private individuals, foreign banks or foreign governments. Some of the foreign-controlled banks are operating only on the territory of Belarus, while others are the subsidiaries of some other banks (BPS-Sberbank, VTB Bank, BTA Bank). Domestic private banks are banks which are not included into the first two groups. All the banks are operating under the same regulations from the National Bank of the Republic of Belarus.

As on the 1st of January 2017 the 3 major banks controlled by the state were: Belarusbank, Belinvestbank and Belagroprombank. They had 66.65% of assets of the banking sector. It is reasonable to divide banks owed by the state into two groups as it was done by Mamonov and Vernikov (2015) in the case of Russia: core state-owned banks (3) and other state-owned banks (2). The core state banks were established in order to serve certain purposes. Namely, Belarusbank was originally authorized to implement state programs related to housing construction for households, which meant that this bank was obliged to lend loans to the households in a que at a preferential rate, and development of the agricultural sector. Belagroprombank serve state programs to support the agricultural sector. Belinvestbank is authorized by the government to serve government programs primarily concerning investments and innovations (Myfin.by). Now they are functioning as the normal commercial banks, but at the same time still serve their original

purposes. At the same time, other state banks can be seen as more similar agents to the domestic private ones by their structure, size and behavior.

Sometimes it can be impossible to define the only owner of the company, due to the fact that there is no investor with share 50% or higher: for the Russian-controlled Belgazprombank, for example, in order not to become a subject to economic sanctions, not more than 50% of shares can be owned by a company from the sanctions list. In this case Russian companies which are included into the sanction list, "Gazprom" and "Gazprombank", each owned 49.6% of shares of the Belgazprombank (in 2016), making the bank not operating under economic restrictions. For the purpose of the research it doesn't matter because the major owners are considered to be foreign investors.

Licenses of some of the banks were stopped by the National Bank of the Republic of Belarus (NBRB). These are considered to be in a process of liquidation: Delta Bank, Eurobank, NEB Bank, BIT-Bank. Thus, even if they still publish their statements of financial position no bank activity is going on and they have no statements of profit or loss to publish. These banks are present in the sample only until the last full year they realized banking services[2].

There is one active non-bank financial institution, Home-Credit, which became so in 2016 after being a bank. Non-bank financial institutions are not allowed to hold deposits, open and handle bank accounts. Thus, Home-Credit is excluded from the sample in 2016. Also, Non-bank financial institution SSIS were excluded as it was established only to conduct online operations on its online platform, which is mostly used by the core state banks such as Belarusbank, no other banking operations are conducted.

In some cases, there are two major owners, where one of them is the "offshore" registered investment fund, which is actually controlled by the other owner. This is the case of BNB Bank, where 43.46% is owned by the investment company registered on Cyprus, and 36.53% by the Bank of Georgia, when in fact the latter is a 100% owner of the investment company. For the purpose of this research it doesn't matter because the major owners are considered to be foreign investors. At the same time, when a bank is registered "offshore" but the ultimate owners are possibly residents of Belarus (Statusbank in 2010-2011), these banks are considered as foreign (as it is considered by the National Bank) as it is not possible to trace the true origin of the invested capital. Also, when the ultimate owner of the "offshore" registered bank is not defined (BIT-Bank), such a bank is considered as foreign following NBRB.

[2] Here, the limitation of gathering of annual data can be stressed, as even if a bank stopped banking activity in the 4th quarter, the whole year will not be included into the sample. Thus, the number of banks in the sample will be consistent with those provided by NBRB in the end of each year.

The shares of a bank could have been sold by a foreign investor to a domestic private investor by the end of the year (Absolutbank, November 2014), meaning that a bank was managed by a foreign investor larger part of the year, and became a domestic one only in the last month of a year. Thus, such a bank will be considered as foreign for a year of such a transaction. Thus, the group division performed in this paper will *not* be consistent with the number of banks in each category by the end of the year provided by the NBRB, as this can be seen as not an optimal division.

The period of interest includes 2016 (as annual financial reports for 2017 are available to the public only from the late April in the following year) back to 2010, the year before the structural crisis in Belarus, to see the differences in cost efficiency of banks with different ownership types before, during and after the crisis. From 2010 to 2016, one bank was liquidated, four are in a process of liquidation, two banks were merged and one was reorganized into non-bank financial institution (the National Bank of the Republic of Belarus). Thus, the data will represent an unbalanced panel which can pose potential limitations to the analysis. Further discussion of the ownership types of liquidated, merged and reorganized banks as well as potential reasons for that is held in Section 3.3.

Bank-level variables that are used in the analysis are obtained from the banks' statements of financial position and profit and loss statements constructed according to National standards[3]. This information is publicly available via the website of the National Bank of the Republic of Belarus, section "Information on financial standing of the banks operating in the Republic of Belarus" (https://www.nbrb.by/engl/system/Banks/FinancialPosition/BalanceSheet). As information was collected manually, annual reports were used (instead of quarterly) in order to be able to cover more years. I transcribed the data from the printable versions of the pages with necessary information to Excel and then exported it to Stata. The general aggregated information on the bank sector level and the list of active as well as liquidated banks is available at the National Bank of the Republic of Belarus website.

The alternative source would be financial reports according to International Financial Reporting Standards (IFRS). I chose financial reports according to National standards as the data source for the following reasons. One of them is that small private banks report fewer years according to IFRS than international and core state banks. Thus, if such a selection constraint as reporting according to IFRS was applied as a proxy for reliable financial information, the small group of domestic private banks would be even more poorly represented. This group is important for the study, because these banks are not subsidized by the government and are not financed by

[3] On the 1st of July 2016 denomination of 10 000 to 1 occurred in Belarus. Thus, in the financial statements of 2016 money values are scaled down. To get values comparable with the previous years' the numbers of 2016 were multiplied by 10 000.

foreign investors. Thus, it would be interesting to compare their cost efficiency with such of state and foreign banks. Also, only data according to the National standards can be obtained for merged or liquidated banks. These banks are interesting to have in the sample as by analysis of their cost efficiency it can be revealed if there were correlation between merger/liquidation/reorganization and their cost efficiency level. Moreover, some of the active banks presented financial information according to IFRS only for the last two to four years, whereas (to get better estimation of the frontier) more observations are needed.

The following strengths of using financial data according to National standards can be stated. First, faster data gathering process was possible given the time constraints. Second, compared to IFRS consolidated statements disaggregated bank-level data can be obtained, which is not distorted by subsidiaries of banks. This allows to evaluate solely the performance of banks, not the whole group, which is the aim of this research.

At the same time, there are the following drawbacks. First, less detailed data with less measures for the analysis (no personnel expenses or amortization) is available. Second, due to the more general character of the data the share of state deposits and state loans cannot be eliminated, which can distort the results especially in the case of core state banks.

Even if the sources of data seem to be plausible, some typos in financial statements can possibly take place, leading to (random) measurement error. This limitation is claimed by the literature to be possible to overcome by applying the Stochastic Frontier Analysis. However, changes in accounting standards over time can distort the data.

3.2 Variables

In this section the variables used in the analysis are described as well as the reasoning behind the choice of these variables. First, it is necessary to note that the stochastic frontier method for the estimation of banks' cost efficiency generally takes into account total or operating costs as a dependent variable, while prices of inputs and quantities of outputs as independent variables (Turk Ariss (2010), Fiordelisi et al. (2011), Mamonov and Vernikov (2015)).

There is a debate in the literature regarding the choice between total or operating costs as well as the choice of inputs and outputs. Fortin (2007) shows in his paper that the average efficiency score varies significantly across the models with different inputs and outputs. The two main approaches to execute these choices that are discussed in the papers are intermediation and production ones. Generally, the literature on bank cost efficiency reflects different views on the definitions of intermediation and production approach when applied to financial institutions.

According to Camanho and Dyson (2004), Berger et al. (1987) and Fortin (2007), the production approach includes only physical variables (such as labor, materials) or their associated costs, as only physical inputs are considered to be needed for transaction performance, financial documents processing, providing of advisory services. Interest costs are excluded from this approach because only the operational process is of interest. The output according to this approach represents data on the stock of deposit and loan accounts as a proxy for the amount of services provided. Thus, operational costs (OC) are used as a dependent variable, whereas labor and capital costs (non-interest costs) as inputs, loans, deposits and commission income can be included as outputs.

Under the intermediation approach, however, banks are viewed as institutions which intermediate funds between savers and investors. Here, both operating and interest expenses are considered as inputs (Fortin (2007), Camanho and Dyson (2004), Berger et al. (1987)), whereas loans and other major assets of financial institutions are treated as outputs. However, there is no common view whether deposits should be seen as inputs or outputs. According to Fortin (2007), deposits shouldn't be viewed as an output. Berger and Humphrey (1997) highlight that some studies use the so called "dual approach" including interest paid for deposits into input prices and the amount of deposits into outputs.

One of the versions of the intermediation approach is the value-added approach (Camanho and Dyson, 2004), according to which produced deposits as well as loans are viewed as important outputs because they are responsible for the great majority of value added. Camanho and Dyson (2004) also give examples of studies to show that a lot of papers also include non-interest income as one of the outputs (commission income). Thus, according to this approach total costs (TC) are a dependent variable; price of labor, capital, funds are input prices; loans, deposits and commission income are outputs.

Mamonov and Vernikov (2015) call their approach a production approach, but it differs from its standard description. They also include price of funds as financial costs. In the intermediation approach in the robustness check they keep only loans as an output variable. As they refer in their choice of approach to Fortin (2007), whose vision of the production approach was discussed above, it is worthwhile to note that they could have misinterpreted the definition of each approach and, thus, outputs and inputs included into the specification of each of them.

As it can be noted from the literature, the value-added approach is the most common (Fries and Taci (2005), J. n. Maudos et al. (2002)). However, the majority of authors don't specify this approach and just generally call it as an intermediation approach. This approach is seen by Fortin (2007) as the most efficient approach to evaluate cost efficiency.

Thus, in this thesis, the value-added model of the intermediation approach will be the main model, but with replacing TC by OC following the reasoning by Mamonov and Vernikov (2015), Berger and Deyoung (1997), J. Maudos and de Guevara (2007) and Solís and Maudos (2008), that interest expenses reflect a bank's market power rather than its efficiency. This argument is reasonable in the case of Belarusian banking system for the reasons discussed earlier in this paper. Standard value-added models of intermediation approach with total costs as a dependent variable; price of labor, capital, funds as input prices; loans, deposits and commission income as outputs will be executed as a robustness check. Also, standard production approach with operational costs, labor and capital prices (non-financial costs), loans deposits and commission income will be applied in the robustness check section.

Before the description of the variables themselves, it should be said that it is reflected by Poghosyan and Borovička (2007) that different specification of cost function are employed by different authors: Fries and Taci (2005) use a variant of specification with two outputs and one input price, Semih Yildirim and Philippatos (2007), Mamonov and Vernikov (2015) and Rossi et al. (2004) employ three outputs and three inputs, Lensink et al. (2008) assume two outputs and two input prices.

Data availability is a constraint to the choice of appropriate output and input measures. However, it should be noted that no unique set of variables exists and output and input measures as well as correlates of bank cost inefficiency differ across the studies. The set of variables chosen for this study is consistent with the existing literature on the similar topic regarding transitional economies. The sources of the variables included into the main model of the frontier, as well as the method of their calculation are presented in Table 1. As it can be seen from the table, OC is a dependent variable, Y1, Y2 and Y3 are the three outputs, w1 and w2 are the input prices. All the variables or the data necessary to their calculation can be found either in Statement of financial position or Income statement of each bank in the sample.

The variables included into the main model of the cost frontier estimation will be now described. Let's start with the *output* variables. *Credit (loans) to clients* includes loans to corporate customers and entrepreneurs, individuals, state bodies. It could be a better option to eliminate loans to state bodies as it was done in the similar study of different groups of Russian banks by Mamonov and Vernikov (2015), but this information cannot be extracted from the ordinary financial statements, which serve as the source of data for this study, only from the annual reports.

Client's funds (deposits) includes deposits to individuals, government and local authorities, legal entities. The same case regarding state bodies would be a better option with deposits but cannot be executed due to the same reason. It is one possible direction for future research.

Table 1 – Description of the dependent variable, outputs and input prices

Variable name	Variable label	Source of variable/ Calculation of the variable
OC	Operational costs	Income statement
Y1	Credits to clients	Statement of financial position, item of Assets
Y2	Clients' funds (deposits)	Statement of financial position, item of Liabilities
Y3	Commission income	Income statement
w1	Price of non-interest inputs	Operational costs/Assets. Operational costs – from Income statement
w2	Price of funds	Interest expense/ Interest bearing liabilities * Interest expense – from Income statement Interest bearing liabilities – from Statement of financial position, item of Liabilities

Notes: This table shows the names of the main variables of the cost frontier estimation, their labels as well as their source and the method of calculation. OC is the dependent variable and the others are independent variables.
*Interest bearing liabilities (IBL) – liabilities that a company has to pay some interest to finance: Funds of the National Bank+ Funds of banks+ Clients' funds+ Securities issued by the Bank+ Derivative financial liabilities.
Source: Own table based on the collected data from financial statements of banks.

Commission income is used as a proxy for noninterest-based output following Mamonov and Vernikov (2015).

There are the two *input prices*: price of non-interest inputs and price of funds. *Price of non-interest inputs* is a ratio of non-interest expenses (operational costs) to assets. This ratio is used as a proxy for the price of both physical capital and labor. Usually, as it is done by Hasan and Marton (2003), Mamonov and Vernikov (2015), labor costs are presented separately from the other non-financial costs either dividing non-interest expense by the number of workers or personnel expense by total assets. In the case of Belarussian banks, general financial reports do not include neither information on number of workers nor personnel expense. Thus, the approach of Fries and Taci (2005) will be employed.

Price of funds is taken as a proxy for financial costs and is calculated by dividing interest expense by interest bearing liabilities following Hasan and Marton (2003), Mamonov and Vernikov (2015).

In order to investigate the potential causes of the differences in cost efficiency levels between groups of banks, additional bank-specific characteristics should be considered. The issue of what variables should be included in the analysis is complicated by the fact that there is no guidance exists in the literature on bank efficiency (Perera et al., 2007). The most common bank specific variables used across studies which are included into the analysis of heterogeneity in the case of Belarusian banking are described in the following paragraphs.

As the aim of this study is to investigate the differences in the cost efficiency levels across the banks with different ownership types, *dummy variables for the type of ownership*: core state-controlled, other state-controlled, foreign-controlled, domestic private are included into the

analysis. This approach is typical for the studies of the transitional economies: Mamonov and Vernikov (2015), Nikiel and Opiela (2002), Hasan and Marton (2003), Berger et al. (2009).

Return on equity is used to capture the relationship between the profitability and inefficient performance of banks and is calculated as profit before tax divided by equity (Johansson, 2014). The measures of profitability are exploited in their studies of efficiency analysis by Carbo et al. (2002) and Perera et al. (2007).

Equity-to-assets ratio is an inverse indicator of a bank's leverage (Poghosyan & Borovička, 2007), which is used to control for variation in risk across banks (Fries & Taci, 2005). There is no common view regarding the effect of higher equity-to-assets ratio on the bank's cost efficiency. From the point of view of Berger (1997), prudent banks have a higher ratio, which leads to higher levels of cost efficiency. That can be explained by the fact that large equity can stimulate an expansion of loans (which are included in the cost function as one of the outputs) but keeping costs at the same level, as high leverage (or low equity-to-assets ratio) leads to an increase in borrowing costs (Casu & Molyneux, 2003). On the other hand, some authors like Mamonov and Vernikov (2015), Hasan and Marton (2003), Poghosyan and Borovička (2007) notice that holding more equity for stability reasons may be costly to the risk-averse bank and decrease its cost efficiency if it implies lower lending activities. To investigate the relationship between equity-to-assets ratio and cost efficiency in the Belarusian banking system it is reasonable to include equity capital into the analysis of the cost efficiency.

Loans-to-assets ratio reflects lending activities. Their intensification may facilitate the economy-of-scale and, thus, positively affect cost efficiency (Solís & Maudos, 2008). On the other hand, increase in lending can create additional borrower-screening costs (checking the cases of potential borrowers), lowering cost efficiency (Berger, 1997). As with effect of equity, it can be reasonable to empirically define the effect which prevails in the case of Belarusian banking system.

Loans-to-deposits ratio (intermediation ratio) is included into the cost efficiency analysis of the banking sector by Mamonov and Vernikov (2015) and Fries and Taci (2005). This ratio is calculated as credits to clients divided by the clients' funds (the location of these items in the financial statements is described in Table 1**)** and measures the liquidity of the bank: if the ratio is high – it can mean that in case when depositors unexpectedly claim their money from the bank, banks can have a problem to cover such requirements; if the ratio is low – a bank is lending less funds than it can, earning less than it potentially could.

Logarithm of assets is used in the studies of Mamonov and Vernikov (2015), Hasan and Marton (2003), Kaparakis et al. (1994) and Cavallo and Rossi (2002) as a proxy for the size of the bank. The expected positive relationship with cost efficiency can be explained by expanding of activities into different areas of the banking business, which can facilitate the economy-of-scale

from growth and joint production resulting in higher efficiency. In the context of USA, Deyoung (1996) explains it as ability of larger banks to hire better managers.

The dummy for the reorganized, liquidated or merged bank can give an insight whether there exists correlation between the reorganization, liquidation or merger of the banks and their level of cost efficiency. A similar variable is used by Hasan and Marton (2003) in their paper on Hungarian transitional banking system.

3.3 Descriptive statistics

In this subsection the sample is described. The total number of registered banks as well as their division into the groups according to their ownership types for the observation period is presented in Table 2.

The number of banks decreased during the period from 31 to 24, which can be attributed to the period of 2014-2016. The decrease occurred mostly in the group of foreign-controlled banks and the subgroup "Controlled by investors from other countries": from 14 in 2014 to 9 in 2016. This is a result of the checks executed by the National Bank of the Republic of Belarus. According to this checks the liquidated and reorganized banks didn't comply with the requirements about the minimum regulatory capital and some other license requirements, which threatened the interests of the investors[4]. The reasons for these checks are not stated.

Generally, the structure of the banking system in Belarus can be considered as unique: core state banks have the largest share in the total equity capital and assets of the banking sector, whereas the largest group is the group of foreign banks. Among these banks considerable positions are taken by Russian banks, which reflects Belarus as a strategic market for the Russian capital, especially after the introduction of economic sanctions on major Russian companies including banks in 2014. This can be easily executed because of the common economic space of Russia and Belarus.

To get to the more detailed description of the Belarusian banking sector, the discussion moves to the specification of the market concentration. Some of the options for the description of the market concentration are to show the shares of different groups of banks in the total amount of assets, as well as their shares in the markets of outputs: loans, deposits and commission income. The average picture of the growth in the Belarusian banking industry can be seen through dynamics of the total assets, which is presented on Figure 1 as well as in Table B1 of Appendix B.

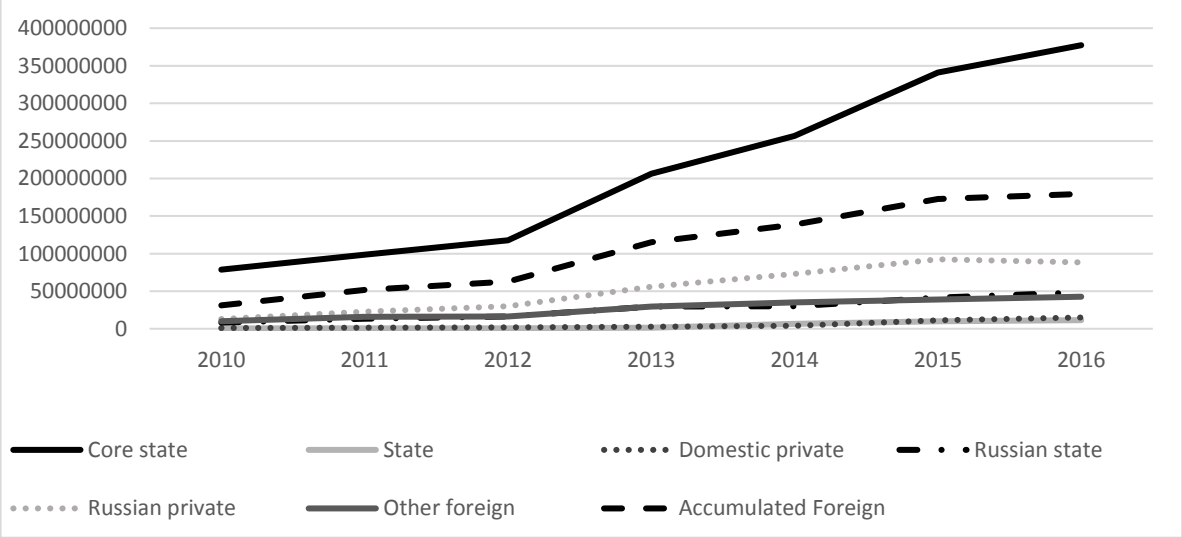
[4] This information is collected from the website of the National Bank of the Republic of Belarus, financial news websites such as naviny.by, https://www.kp.by/daily/26361/3243344/, websites of the liquidated/reorganized banks (http://www.nebbank.by/).

Table 2 – Division of the banks in the sample into the ownership groups (2010-2016)[5]

	Total number of banks	Core state	State	Domestic Private	Foreign		
					Controlled by Russian state*	Controlled by Russian individuals	Controlled by investors from other countries
2010	31	3	1	4	3	4	16
2011	31	3	1	4	3	4	16
2012	32	3	1	5	3	5	15
2013	31	3	1	5	3	5	14
2014	31	3	2	5	2	5	14
2015	26	3	2	5	2	3	11
2016	24	3	2	5	2	3	9

Notes: This table shows the total number of banks throughout the period of 2010-2016, as well as the division of this number of banks into the specified groups according to their ownership types. In this table, controlled means the largest share of the share capital owned by the entities or individuals considered as state, domestic or foreign.
*Belgazprombank is included as not Russian state-controlled.
Source: Own table based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Figure 1 – Division of the total assets in the banking sector for the ownership types groups, mln BYR*



Notes: This figure shows the amount of assets each of the ownership groups possessed in each year from 2010 to 2016.
*Adjusted for inflation, GDP deflator (retrieved from The World Bank).
Source: Own figure based on the collected data from nbrb.by, data.worldbank.org and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

As it can be seen from Figure 1, even if adjusted for inflation, the amount of total assets in the banking industry is growing. The highest growth can be seen in the leading group of the core state-controlled banks. The second largest group – the group of the foreign-controlled banks –

[5] The division of the Foreign group to Controlled by Russian state, Controlled by Russian individuals and Controlled by investors from other countries executed in this section only for the illustrational purposes of the intensive participation of Russian-controlled banks in the Belarusian banking sector. This division will not be present in the following analysis of the cost efficiency due to the slightly different purpose of this paper and the time and volume constraints.

Table 3 – Shares of the six largest banks in the amount of the total assets in the Belarusian banking sector

6 largest banks 01.01.2017	Type of ownership	Assets, mln BYR	Share of total assets
Belarusbank	Core state	278,508,130	44.32
Belagroprom Bank	Core state	92,686,100	14.75
BPS-Sberbank	Foreign (Russian private)	50,533,340	8.04
BelVEB	Foreign (Russian state)	39,998,360	6.36
Belinvestbank	Core state	35,437,770	5.64
Belgazprom Bank	Foreign (Russian private)	31,527,190	5.02

Notes: This table shows the shares of the six largest banks in Belarus in the total amount of assets in the sector.

Source: Own table based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

show an increase in the amount of total assets, but at a lower rate than the core state banks. This increase can be mostly attributed to the intensified participation of Russian private banks in the Belarusian banking industry.

One more option to show the existing market concentration is to show the shares of the six largest banks in the amount of the total assets (Table 3). In Table 3 a significant difference between the banks within the largest top six with respect to the amount of assets can be seen. The share of one of the core state-controlled banks – Belarusbank in the total assets is almost a half – 44.3%. The second largest bank – Belagroprom Bank (also one of the core state banks) has a share of 14.8%, which is almost 30% less than the share of Belarusbank.

If to look closer at the banking industry, the shares of groups in the main outputs: loans, deposits and commission income and their changes over time can be considered. This data is presented in Tables B2-B4 of Appendix B. It can be seen that in both loans and deposits the core state banks clearly dominate during the whole period considered in the paper. However, their shares decreased from 75.3% and 72.5% in 2010 to 64.7% and 66.9% in 2016 in loans and deposits, respectively. The sharpest drop happened in 2011 – the year of the structural crisis in Belarus: share in total loans to customers decreased by 5.46%, whereas the share in total deposits by 6.15%. At the same time, the share of the foreign-controlled banks in the shares of these outputs increased from 23.6% and 26.2% in 2010 to 30.9% and 28.2% in 2016. It is worth to mention that this growth is attributed to the rise in activity of both state- and private-controlled Russian banks. At the same time, shares of banks owned by investors from other countries declined during the period. Other state and domestic private increased their shares as well. The most part of the banks that were merged/reorganized/liquidated are non-Russian foreign-controlled banks, which can be the reason for the reduction in their share in the total loans and deposits in the banking sector. Described changes in shares of the core state and foreign banks in the mentioned outputs could

have happened due to the loss of trust to the core state banks, or, for example, due to the higher ability of the foreign-controlled banks to attract funds on the international markets and loan then to the Belarusian companies with good credit rating, which Belarusian both state and private banks were not able to do.

At the same time, the shares of commission income are distributed differently. The largest share of 51.7% in 2010 is taken by the foreign banks. During the considered period this share dropped due to the number of non-Russian banks being merged/reorganized/liquidated. The share of core state banks decreased from 45.6% to 41.7%, while the shares of other state and domestic private rose. Thus, the core state-controlled banks are dominating in the markets of loans and deposits but lose the leading position to the foreign-controlled banks in the market of commission income. Thereby, the markets of both loans and deposits are highly concentrated, while in the market of commission income competition presents, making it possible to call it as moderately concentrated: different types of transactions, handling accounts are provided by higher variety of banks.

In order to strengthen the choice of the dependent variable, discussed in Section 3.2, the shares of both interest and operating costs in the amount of the total costs in the Belarusian banking sector as well as their ratio for the different groups of banks should be looked at. The average costs in the Belarusian banking system divided into the interest and operating ones are presented as a percent of total assets on Figure C1 of Appendix C.

In general, during the whole period the largest share of costs is attributed to the interest costs. Average costs in the whole industry increased in 2012 – the year after the structural crisis, and mostly because of the increase in interest expense. One potential reason is the increase in the refinancing rate from 12% in the beginning of the 2011 to 45% in the end of the same year (the National Bank of the Republic of Belarus).

In order to trace the differences in the shares of interest and operating costs between the different ownership groups, Figure C2 of Appendix C should be examined. As it can be seen from the presented graphs, the level of total costs generally fluctuates around 10% of the total assets. Interest costs constitute the largest share in the case of the core state-controlled banks – 70-83%. It can be explained by their monopoly on the mortgages issuing for the state housing programs (Belarusbank), which are popular in Belarus because the prices are lower than in the private housing market. At the same time, as the core state banks are obliged to participate, they sometimes need to lend risky loans. So, they don't always conduct meticulous investigations of all the cases, which helps to cut operating costs, but can lead to the high amount of non-performing loans and lower profits. In the case of the foreign banks, interest costs take 50-70% of the total costs – lower share than this for the core state banks. For the other state interest expenses comprise 37-53%,

while for the domestic private – 27-47%. The differences are substantial, so, in order to eliminate the monopoly of the core state-controlled banks on the market of loans, the decision to exploit the operating costs solely in the cost frontier estimation was made.

As the last part of this section, the descriptive statistics for the main variables of both stages of the cost efficiency analysis – cost frontier estimation and regressions of cost efficiency scores on the ownership types as well as other organization-specific variables should be presented. This data can be found in Table D1 of Appendix D. Columns 2-5 present the descriptive statistics over the whole sample, while columns 6-9 present the mean of the variables by ownership category. The average operating costs differ significantly across the sample, which can be seen from the standard deviation, as well as the difference between the minimum and maximum values. The same heterogeneity can be traced from the means of the different ownership groups, where core-state controlled is the group with the much higher operational costs than any other group. The same outstanding role of the core state-controlled banks can be seen for the credit to clients, assets and equity variables. The dominance of these banks can be explained by their size and role granted by the government. Much lower differences can be seen in the case of commission income, as it was already discussed in this section.

If to look at the prices of non-interest inputs such as labor and capital, the mean value is 6%, while core state banks have the lower average rate of 2.7%, other state – 4.7%, foreign – 6.3% and domestic private – 9.7%. It is not easy to find the reasons for these differences, but it is likely that the core state-controlled banks can benefit from grants and discounts from the government on the rent fees for the office buildings, can use the economy of scale in terms of investments in the IT, can pay lower salaries to their employees.

At the same time, while the average price of funds in the sector is 10%, foreign, other state and core state are operating below this rate: on average at 7.2%, 7.4% and 9.8% respectively. Domestic private have a high rate of 20.8%, but mostly because of the outliers such as BBSB bank, which had the rate of 463% in 2014 – a year before its reorganization.

With respect to profitability measure, return on equity, the industry has a high 15.5% return, with foreign banks in the leading position – 17.8%, far higher than this of domestic private – 11.2%, other state – 10.1% and core state – 9.8%. It can be explained by the same fact of obligatory participation of the core state banks in the state housing programs, while the owners of the foreign banks are mostly interested in their dividends. Thus, the investigation of the profit efficiency would be interesting to implement in future research.

Equity-to-assets ratio is 0.24 in the overall sample. Mamonov and Vernikov (2015) find this ratio to be equal to 18.6 in the Russian banking sector in 2005-2013. Loans-to-deposits ratios is high in the sector – 6.28. A prudent bank will choose this ratio to be around or lower than 1 in

order to be able to return deposits in the case depositors will claim them back. Thus, foreign banks can be called as the less prudent group, but at the same time such a risky strategy could have led them to a higher profitability. The average loans-to-assets ratio in the industry is 0.49, while was 0.55 in Russia, which means that Belarusian banks are on average more risk-averse than Russian banks and lend the relatively lower amount of loans.

4 Empirical strategy

After describing the dataset, the empirical strategy to process this data in order to tackle the cost efficiency analysis of the Belarusian banking sector will be explained.

4.1 Stochastic frontier analysis

To investigate the cost efficiency of Belarusian banks with different ownership types the Stochastic Frontier Analysis (SFA) is applied. Intuitively, SFA specifies the form of the production (or cost) function (usually a translog[6] one) and allows for random errors. It assumes that these errors include random errors which follow a symmetric distribution (usually standard normal distribution) and inefficiencies which follow an asymmetric distribution (usually truncated or half-normal). The structure of the error term is explained by the fact that inefficiencies by definition cannot be negative (Fries & Taci, 2005).

First, SFA was independently proposed by Aigner et al. (1977) and Meeusen (1977) for the production function. Explanations of SFA in the studied literature are given on the example of production function and investigation of technical efficiency. Thus, the description of SFA in this paper is based on the production function as well. After this the application to the cost function is presented.

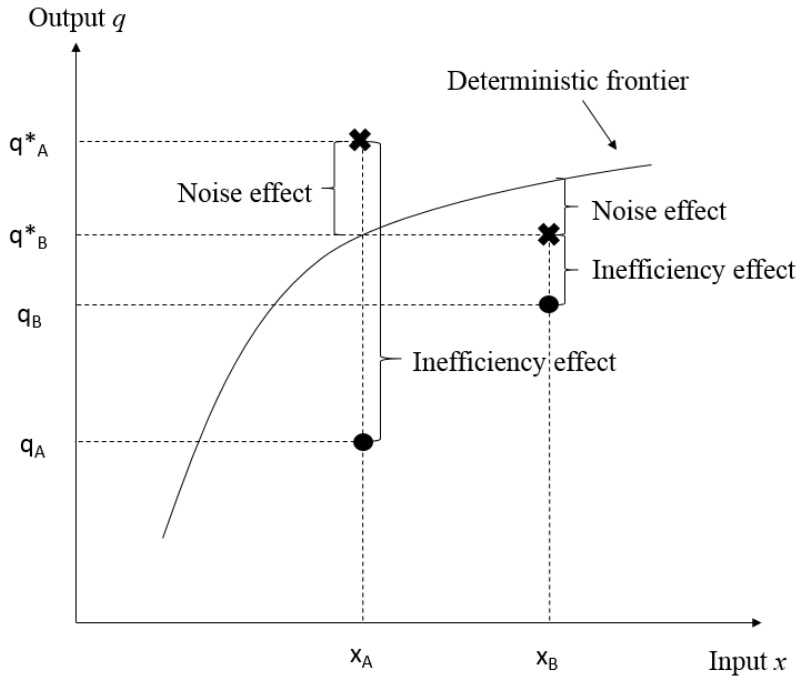
The basic production function and the concept of technical efficiency is presented by Coelli (2005) and based on the assumption that a firm produces an output q_i using only one input x_i.
In this case, a Cobb-Douglas stochastic frontier model takes the form (Equation (1)):

$$\ln q_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i \quad (1)$$

where q_i represents the output of the i-th firm; x_i is the input of i-th firm; β_1 is a vector of unknown parameters; v_i is a classical random error (noise effect); u_i is a one-sided error that measures inefficiency effects; and $\beta_0+\beta_1 \ln x_i$ represent deterministic component of the production function.

[6] Transcendental logarithmic cost function, which imposes no *a priori* restrictions on the substitution possibilities between the factor inputs, by relaxing the assumption of strong separability (Kymn, 2001).

Figure 2 - Stochastic frontier production function



Notes: This figure shows the concept of stochastic frontier production function for firms A and B. ● represents observed values, ✖ represents unobserved values (if inefficiency u_i is equal to zero).
Source: Modified figure, based on Coelli (2005).

Figure 2 illustrates that concept for two firms, A and B. Empirically, the production function is estimated on the basis of observed input and output values, which constitute the deterministic component of the production function, and noise (Coelli, 2005). Thus, the deterministic frontier on the graph is defined by $\beta_0+\beta_1 \ln x_i$. Observed values are plotted as ● on the graph. If inefficiency u_i is equal to zero, then the production frontier output (which is also called unobserved) can be plotted on Figure 2 as ✖. The vertical distance between the unobserved frontier values (✖) and the observed values (●) is called technical inefficiency effect. The larger is the distance, the larger is the inefficiency (Lien et al., 2007).

Frontier outputs can either be above (if noise effect is positive and larger than the inefficiency) or below (if noise effect is negative) the estimated deterministic frontier function (Lien et al., 2007). However, observed outputs usually lie below the deterministic part of the frontier (Coelli, 2005).

4.2 Application of the stochastic frontier analysis to the cost function

To study cost efficiency of Belarusian banks with different ownership types the concept of production frontier analysis is transferred to the cost frontier. Since the cost function is not directly observable, inefficiencies are measured in relation to the efficient cost frontier, which is estimated

from the observed data (Fries & Taci, 2005). Thus, inefficiency measurement is based on a bank's costs deviation from the minimal costs observed in the data rather than from some technologically feasible efficient frontier. According to Fries and Taci (2005) bank cost inefficiency can be defined as the difference between observed costs and predicted minimum costs for a given scale and mix of outputs, factor prices and other country- or bank-level variables. To put it differently, each bank in the sample is compared to the "ideal" bank in the sample (Fries & Taci, 2005).

According to Agrell (2015), the basic cost function for the frontier estimation can look like Equation (2):

$$x_i = C(y_i) + v_i + u_i \tag{2}$$

where x_i represents the costs of the i-th firm; C is the cost function; y_i is the output of the i-th firm; v_i is a classical random error (noise effect); u_i is a one-sided error that measures inefficiency effects. In the case of the of the cost function there is a plus sign before the inefficiency term, as inefficiency can only increase costs. The concept of cost efficiency frontier for the two firms, A and B, is presented on Figure 3.

The explanation is similar to this of Figure 2. x_A and x_B are the observed values of the firms A and B respectively. Observed values are plotted as ● on the graph. The distance between the observed values and the frontier is divided into the two parts: noise effect v_i and inefficiency effect u_i. Frontier outputs can either be below (if noise effect is negative and larger than the inefficiency) or above (if noise effect is positive) the estimated deterministic cost frontier function. However, observed outputs in the case of the cost efficiency usually lie above the deterministic part of the frontier.

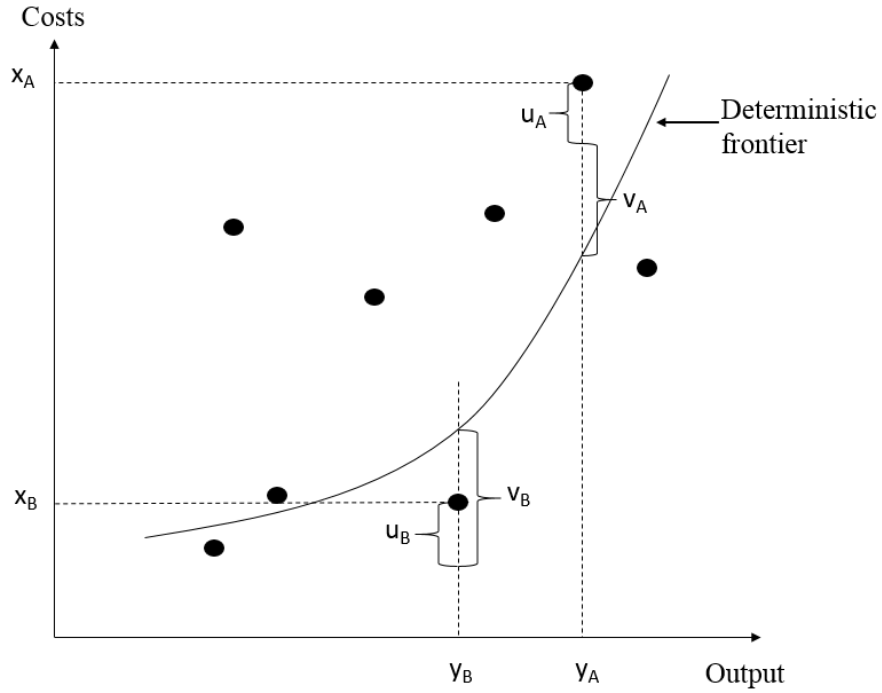
Now, the basic empirical cost function, which is of the interest in this paper, should be derived. The cost function is specified by Kumbhakar (2000) as in Equation (3):

$$\ln C_{it} = \beta_0 + \Sigma_{j=0} \beta_j^y \ln y_{jit} + \Sigma_{k=0} \beta_k^w \ln w_{kit} + \varepsilon_{it}$$
$$\text{and } \varepsilon_{it} = v_{it} - a u_{it} \tag{3}$$

where C_{it} is the cost, y_{jit} is one of the j outputs for the firm i in the period t, w_{kit} is the price of the one of the k inputs for the firm i in the period t, $\beta_{j,k}$ is a vector of unknown parameters. ε_{it} is the composite error term, v_{it} is a random error that stands for, for example, luck, strikes, errors in books; u_{it} is believed to reflect technical and allocative inefficiency[7] of the firm (bank in the case of this paper) that can be influenced by management. By assumption both u_{it} and v_{it} are independent and identically distributed, the assumptions about distribution of u_{it} and v_{it} are the same as in the

[7] The definitions of similar technical and allocative efficiencies were discussed in the Introduction.

Figure 3 – Stochastic frontier cost function



Notes: This figure shows the concept of stochastic frontier production function applied to the cost function for firms A and B. ● represents observed values.
Source: Agrell (2015).

case of production function. $a = -1$ for the cost function, which is because inefficiency u_{it},can only increase costs (move costs only above the frontier). v_{it}, may either increase or decrease costs.

The described SFA will be used because of the weaknesses of other common methods applied for the investigation of the cost efficiency of banks. The standard efficiency ratios, as stated by Yaw-Shun (2014), can be misleading as the differences in inputs and outputs combinations as well as their prices are not properly accounted for. Also, SFA is preferred over the Data Envelopment Analysis (DEA) which, as well as SFA, is one of the most used models to calculate cost efficiency (Kumar, 2006). The reason behind this choice is that the DEA does not allow for the presence of a random error term, which means that any deviation from the efficiency frontier is considered as inefficiency (Spulbar & Nitoi, 2014). Moreover, banks may be interested in manipulation with book profits and capital figures to get the results that management or lenders are interested in, and SFA is robust with respect to errors in data (Styrin, 2005). At the same time, the drawback of this method is described by Berger and Humphrey (1997). They state that the parametric approaches impose a particular functional form as well as associated behavioral assumptions that predefine the shape of the frontier. Therefore, if the functional form is wrongly specified, measured efficiency may be confounded with the specification errors.

4.3 Estimation approach

There exist two approaches to execute estimation of the frontier and detect causes of inefficiencies: the one-step – simultaneous estimation of the cost efficiency measures and the factors influencing differences among such estimates, and the two-step approaches – separate estimations (Mamonov & Vernikov, 2015).

The one-step approach is used for simultaneous estimation of both frontier and inefficiency covariates. Authors like Perera et al. (2007) and Fries and Taci (2005) deploy this approach. According to Mamonov and Vernikov (2015), this approach is limited when more covariates are considered: not only dummies for bank groups, but also bank-specific characteristics.

The two-step approach separates the estimation of the frontier from the evaluation of inefficiency covariates (Mamonov & Vernikov, 2015). Its benefits are discussed by G. Battese and Coelli (1995). This approach is used by the papers which include measures of market power such as the Lerner index into the set of covariates: J. Maudos and de Guevara (2007), Solís and Maudos (2008), Turk Ariss (2010), Mamonov and Vernikov (2015) as some market power measures are based on the estimates of marginal costs which are calculated after the frontier estimation. Moreover, some papers not evaluating the effect of market power such as Berger et al. (2009), Hasan and Marton (2003) Nikiel and Opiela (2002) employ the two-step approach.

However, Chen et al. (2014) and Wang and Schmidt (2002) show that the two-step approach usually leads to biased estimates. They explain this bias by the fact that the inefficiency term is treated as a one-side (positive) disturbance in the first step, while as a two-side disturbance in the second step. Moreover, Fries and Taci (2005) argue that in the second step the assumption made in the first step that the banks' inefficiencies are independently and identically distributed is violated.

Although it is widely recognized that two-step procedures are biased (Wang & Schmidt, 2002), there seems to be little evidence on the severity of this bias. For example, Caudill and Ford (1993) provide evidence on the bias of the estimated technological parameters, but not on the efficiency levels themselves or their relationship to the explanatory variables.

Despite the drawbacks of the two-stage approach this method will be implemented for the case of the Belarusian banking sector for the following reasons. First, the papers, which use the two-step approach, investigate the cost efficiency of a single country: Russia by Mamonov and Vernikov (2015), China by Berger et al. (2009), Hungary by Hasan and Marton (2003), Poland by Nikiel and Opiela (2002), whereas the one-step approach is widely used in the multi-country studies: Fries and Taci (2005), Perera et al. (2007). These mentioned countries of the single-country studies in their periods of transition will be interesting to compare with the Belarusian

case, especially Russia and Poland, as economical and historical ties with these countries are strong. It is important to mention here that comparison can be made only generally as there are differences in the frontier model specifications across the papers. Moreover, the adaptation of the frontier model to the Belarusian case is executed. Second, the single step estimation doesn't allow to control for the size of the banks (according to the results of the preliminary estimations of the one-step models) as well as for the intermediation ratio: ability to transfer deposits to loans.

Taking into account drawbacks of the two-stage approach, according to Berger (1997) and Hasan and Marton (2003) the results of the second stage should be interpreted cautiously. They provide information on correlations rather than causality, as covariates may suffer from endogeneity and thereby bias the coefficient estimates. Berger (1997) highlights that "simple correlation as an alternative to regression analysis attempts to make a point that causation may run in both directions".

As the panel data is available, a single panel estimation is applied instead of a set of annual cross-section estimations. The reason is that the degrees of freedom are not reduced, and estimated coefficients of a cost function are not that sensitive to the sample outliers in each year (Fries & Taci, 2005). It is even more important as the number of observations is relatively small.

Applying SFA and the specifications for the cost efficiency analysis of Belarusian banks discussed above, an empirical frontier model is proposed which is similar to those applied in the relevant literature. The intention of this empirical frontier model is to use multi-product function shapes: three inputs, two outputs, and their combinations[8]. Thus, the specific empirical cost function, which is derived from the basic empirical cost function (Equation (3)) has the following translog form (Equation (4)):

$$\begin{aligned}\ln(OC/W_1Z)_{it} = {} & \alpha_0+\sum_j^k \alpha_j\cdot\ln(Y_j/Z)_{it} \\ & +\frac{1}{2}\sum_j^k \sum_k^j \alpha_{jk}\cdot\ln(Y_j/Z)_{it}\cdot\ln(Y_k/Z)_{it} \\ & +\beta_1\cdot\ln(W_2/W_1)_{it} \\ & +\frac{1}{2}\beta_{11}\cdot\ln(W_2/W_1)_{it}\cdot\ln(W_2/W_1)_{it} \\ & +\sum_j^k \delta_j\cdot\ln(W_2/W_1)_{it}\cdot\ln(Y_j/Z)_{it} + v_{it}+u_{it} \end{aligned} \quad (4)$$

In this frontier model OC_{it} are operating costs for bank i at time t. $Y_{j,it}$ is an output, ranging from j to k, where k is equal to 3: loans to clients (j=1), client's funds (deposits) (j=2), and commission income as a proxy for noninterest-based output (j=3). W_1 is the price of both physical capital and labor, W_2 is the price of funds. $v_{it}+u_{it}$ is a composite error term. As the assumption is the same across the literature on the same topic, the v_{it} term – classical random error (noise effect)

[8] General description of variables is provided in Section 3.2.

is assumed to be identically and normally distributed with zero mean $v_{it} \sim N(0,\sigma^2_v)$ (J. P. Bonin et al., 2005). The inefficiency term, according to G. Battese and Coelli (1995), is defined as non-negative random variables which are assumed to be independently but not identically distributed. At the same time, different distributional assumptions are imposed on the inefficiency term by various authors. According to Stevenson (1980), truncated normal distribution applied to a stochastic cost frontier estimation gives more flexibility than the assumption of the half-normal distribution. At the same time, Berger and Deyoung (1997) in their paper show that the truncated normal distribution can lead to lower estimates of average cost inefficiency for banks than it does the half-normal, but at the same time the rank efficiency order of banks remains the same. For the purposes of this paper the inefficiency component is assumed to be a nonnegative random variable with a (positive) truncated normal distribution $u_{it} \sim N^{+}(\mu_u,\sigma^2_u)$ and truncated below zero (Fries & Taci, 2005). In this distributional assumption this paper follows the major stream of the literature on similar topics, some of examples are Fries and Taci (2005), Hasan and Marton (2003), and their arguments.

The standard constraint on symmetry $\alpha_{jk} = \alpha_{kj}$ is imposed following Fries and Taci (2005), Perera et al. (2007), Mamonov and Vernikov (2015), Hasan and Marton (2003), Nikiel and Opiela (2002).

There are various ways used by the authors to impose linear homogeneity on the input prices and the cost variable by applying normalization (scaling) of costs and input prices by the other input price (arbitrarily chosen) (Perera et al. (2007) and Hasan and Marton (2003)). At the same time costs as well as output variables are scaled by a netput (Hasan and Marton (2003) and Berger et al. (2009)) to adjust for the scale bias, control for heteroscedasticity and allow to have comparable residual terms, from which the efficiencies are calculated across the banks, with different size and different risk preference (Berger et al., 2009). The same procedures are followed in the case of Belarusian banking sector as the banks are substantially different in their characteristics: the normalization of costs (OC) and outputs by netput (equity capital Z) and normalization of costs (OC) and of the price of funds (W_2) by the price of labor and physical capital (W_1) (arbitrarily chosen). Moreover, the robust option is used, following Mamonov and Vernikov (2015).

Besides the symmetry constraints and linear homogeneity imposition, time fixed effects should be accounted for. There are different approaches to control for these effects and to try to eliminate estimation biases that may arise because of the technological progress or changes in a country's economic and regulatory environments (Berger et al. (2009), J. P. Bonin et al. (2005)). One of the possible ways to eliminate such a bias is to add year dummy variables directly into the frontier estimation, whereas the other is to include them into the second step – the evaluation of

efficiency covariates. According to Berger et al. (2009), adding time fixed effects in the secondary regression impose different constant for each year, which doesn't allow to capture the effects of bank's conversion to another type of ownership in the later years, which happened to some Belarusian banks**.**

The two described frontier models (with year dummies included into the first or the second stage of the analysis) have constant mean and variance of inefficiency. There are also frontier models in which the mean of cost inefficiency is allowed to shift during the time period, as well as frontier models where the heteroscedastic variance of inefficiency can vary over time[9]. As this is the first attempt to evaluate Belarusian banks' cost efficiency depending on the ownership type, only the two described frontier models with constant mean and variance of inefficiency will be compared.

Not all the authors mention the type of the frontier model they use for the panel data (fixed or random effects). Some of them, like Hasan and Marton (2003), refer to the paper of Berger (1997), some others, like Perera et al. (2007), Fries and Taci (2005), Poghosyan and Borovička (2007), refer to the paper by G. Battese and Coelli (1995), while some also mention the Frontier program[10]. This program is developed by Battese and Coelli. Therefore, the model of "Maximum Likelihood random-effects time-varying inefficiency effects" proposed by G. Battese and Coelli (1995) is used in this paper, which is incorporated into the *sfpanel* function of Stata program as it is discussed by Belotti et al. (2013). This function allows for heterogeneity in inefficiency across banks. Moreover, random effects are default for the idiosyncratic error term estimation (i.e. for the error term that is different between individuals – banks in the case of this paper), because inefficiency cannot be heteroscedastic if the inefficiency are fixed effects (Perera et al., 2007).

After the cost function is estimated, cost efficiency scores for bank i at time t can be computed. The efficiency score is estimated for each bank in the sample using the method suggested by Jondrow et al. (1982) and applied by G. E. Battese and Coelli (1988) (Equation 5):

$$SFA_{it} = \exp(-\hat{u}_{it} | \varepsilon_{it}) \quad (5)$$

where $\hat{u}_{it}$ is the estimated value of inefficiency term u_{it} from the Equation (4). As from the estimation of the cost frontier only the composite error term $\varepsilon_{it} = v_{it} + u_{it}$ can be observed, the best predictor of inefficiency is then the conditional expectation of u_{it}, given the conditional error term ε_{it}. SFA scores are measured from 0 (absolutely inefficient bank) to 1 (absolutely efficient bank)[11].

[9] The more detailed discussion of these models can be found in the paper by J. P. Bonin et al. (2005).
[10] There are both one- and two-step approaches applied in these papers.
[11] Discussed by Fries and Taci (2005) and J. P. Bonin et al. (2005).

Once the cost efficiency scores are estimated, one can investigate the possible sources of their heterogeneity such as the type of ownership and other relevant organization-specific as well as other related variables (Equation (6))**:**

$$SFA_{it}=\alpha_0+\sum_{j=1}^{3}\beta_j Group_j+\sum_{k=1}^{K}\delta_k BSV_{k,it}+\sum_{t=2011}^{2016}\gamma Year\_dummy_t+\varepsilon_{it} \quad (6)$$

where SFA is the estimated cost efficiency score from the first stage of the analysis (Equation (5)). *Group* are dummy variables for the groups of banks according to their ownership type, where *j*=1 are core state-controlled banks, *j*=2 are other state-controlled banks and *j*=3 are foreign-controlled banks. Private domestic banks are treated as the reference group. *BSV* are factors (control variables) that are potentially responsible for heterogeneity in cost efficiency such as return on equity, equity to assets ratio, loans to assets ratio, intermediation ratio (loans to deposits ratio), logarithm of assets as a proxy for the size of banks, dummy which is equal to 1 if the bank was merged, reorganized or liquidated during the investigated period and is equal to 0 otherwise. *Year_dummy* are the year dummy variables for all sample years *t*, except for the year 2010, which is omitted and treated as a reference year. This binary variable is reflected in the intercept. ε_{it} is the error term.

Different authors apply different methods to investigate the effects of different variables on the banks' efficiency/inefficiency scores: Ordinary least squares (OLS), Tobit, Generalized method of moments (GMM). As this is the first attempt to analyze the cost efficiency of Belarusian banks, I use simple OLS as done by Berger et al. (2009), Hasan and Marton (2003), J. P. Bonin et al. (2005), Nikiel and Opiela (2002). J. P. Bonin et al. (2005) uses White's correction for heteroskedasticity so that the standard errors will be consistent estimates. The same method to account for heteroscedasticity is applied.

As the aim of this paper is to investigate the differences in cost efficiency between banks from different ownership groups, no bank fixed effects can be included. The reason is that with the bank fixed effects the core state group is omitted because banks only from this group do not change the ownership type during the investigated time period. At the same time, frontier models both with and without time fixed effects will be investigated.

According to Berger (1997) the problem of endogeneity can bias the coefficient estimates and, thus, make it problematic to make conclusions about causation. Therefore, the results of the regressions should be interpreted cautiously, with awareness that the causation may run in both directions.

5 Results

5.1 First stage

The results of the first stage of the cost efficiency analysis – frontier estimation – are presented in Table E1 of Appendix E[12]. The column "Frontier 1" doesn't include year dummies, whereas the column "Frontier 2" includes the time fixed effects.

I start the analysis with inspection of the regression output table. First, the presence or absence of cost inefficiency in the sector should be checked. Lambda reflects the presence of inefficiency and is calculated as $\lambda = \sigma_u/\sigma_v$. If there is no cost inefficiency in the banking sector, σ_u will be equal to zero, turning lambda into zero. In Frontier 1 column lambda is expected to be significantly different from zero (146.23), which indicates the presence of inefficiency. The convergence in Maximum Likelihood was achieved after 243 iterations. Frontier 2 column shows a significant presence of cost inefficiency as well, but of a smaller size.

It is also important, that the regression parameters in the output table are reasonable and are in line with economic expectations. Thereby, both output and price logarithms should not be significantly negative, as the increase in output and prices cannot lead to the decrease in costs. Even if commission income ($\ln(Y_3/Z)$) and the price of inputs ($\ln(W_2/W_1)$) have negative signs, these coefficients are not statistically significant in the two models. From the output table it can also be seen that such outputs as loans and deposits to clients are positively associated with banks' operating costs. Moreover, the production of loans consumes a greater share of operating costs comparing to deposits.

In order to proceed with the further analysis and compare the mean values of efficiency scores among the groups of banks with different ownership types, one of the frontiers should be chosen to be a baseline frontier[13]. The comparison of the two described cost efficiency frontiers can be executed by looking at Frontier 1 and Frontier 2 models in Table E1 of Appendix E. Likelihood ratio test to compare nested models cannot be performed with the robust models as it is the case in this paper. Therefore, Wald test could be an alternative, according to which the null hypothesis that there are no time fixed effects in the cost efficiency frontier estimation cannot be rejected with probability of 0.423[14].

[12] Several models besides the main one were estimated. Some of these models and their results are discussed in Section 5.3. Moreover, preliminary checks of the one-step approach showed that this method doesn't allow to control for the size of the as well as for the intermediation ratio: ability to transfer deposits to loans.

[13] That would be interesting to proceed with the both models to the second-stage analysis of the cost efficiency and compare the results, but due to the time constraints only one model is chosen.

[14] From all the year dummies in the Frontier 2 only the estimate for 2011 is significant, which reflects the presence of the crisis' effect. Thus, it cannot be stated that Frontier 2 model is better than the model with no time fixed effects – Frontier 1.

Table 4 – Descriptive statistics of the cost efficiency scores estimated by the two alternative models: Frontier 1 and Frontier 2 under the period of 2010-2016

Model	Observations	Mean	Standard deviation	Minimum value	Maximum value
Frontier 1	206	0.837	0.148	0.116	0.989
Frontier 2	206	0.850	0.139	0.140	0.987

Notes: This table shows the descriptive statistics of the cost efficiency scores estimated by Equation (5) and the two alternative models: Frontier 1 and Frontier 2 under the period of 2010-2016.
Source: Own analysis of collected data from nbrb.by

The summary statistics of the cost efficiency scores according to both Frontier 1 and Frontier 2 are presented in Table 4. If to compare mean efficiency scores in the models without (Frontier 1) and with (Frontier 2) time effects, we can notice that in the model with them the scores are slightly higher, which means that when included into the frontier estimation, time trend reflects the negative effect of the crisis of 2011 on the cost efficiency scores[15, 16]. Generally, if years are included into the frontier estimation, bank efficiency then reflects variation that can be primarily attributed to bank level factors including ownership type, eliminating the effect of the time trend (crisis, changes in economic environment, regulations).

The changes in the mean efficiency scores estimated by Frontier 1 and Frontier 2 under the period of 2010-2016 are presented on Figure 4. From Figure 4 it is clearly seen that the efficiency scores of the two models follow almost the same pattern despite the year of 2011, when the structural crisis took place, highlighting one more time that the bias from the exogenous shock from the country's economic environment is mitigated by inclusion of the year dummies.

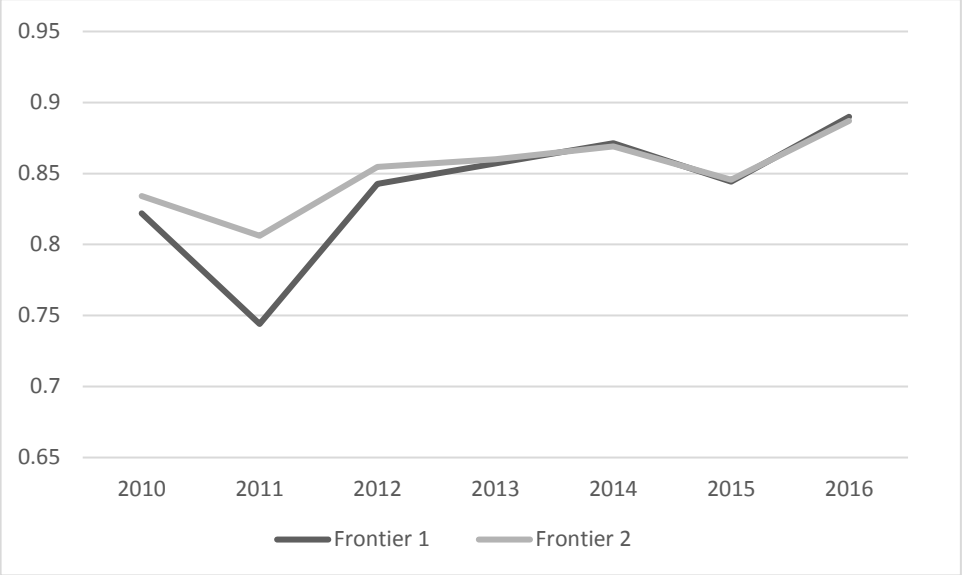
The second stage of the cost efficiency analysis is proceeded with the model without year dummies in the frontier estimation (Frontier 1). This choice is based on the comparison of the two models discussed in this section, as well as on the fact that such a model is considered as the basic model in the mainstream of the literature and is widely exploited by the authors such as Fries and Taci (2005), Hasan and Marton (2003) and Nikiel and Opiela (2002) in their studies of the banks' cost efficiency.

As the baseline frontier is chosen, the summary statistics of the efficiency scores among the groups of banks with different ownership types are provided. Moreover, the changes of the mean value as well as maximum and minimum values across the years of 2010-2016 are presented. Descriptive statistics for the estimated efficiency scores are shown in Table 5.

[15] The estimate for the year 2011 – the crisis year – is the only one significant estimate from the years under consideration.

[16] Note that the ranking of banks remains the same in the two discussed specifications with the core state-controlled banks as the most efficient, followed by other state-controlled and domestic private, whereas foreign-controlled appear to be on average the least efficient group.

Figure 4 – Time trend of the mean efficiency scores estimated by the two alternative models: Frontier 1 and Frontier 2 under the period of 2010-2016



Notes: This figure shows the time trend of the mean efficiency scores estimated by Equation (5) and the two alternative models: Frontier 1 and Frontier 2 under the period of 2010-2016.
Source: Own figure based on the collected data from nbrb.by

The measure of cost efficiency can take values from 0 to 1, where 1 corresponds to the most cost-efficient bank that can potentially exists in the Belarusian banking sector based on the observed characteristics of the banks in the sample. From the descriptive statistics, a typical Belarusian bank operates at 0.84 level, which means that an average bank can improve its operating cost category by 16%. Further, the core state banks are on average the most cost-efficient banks, operating on average on almost 0.93 level. They are followed by the other state-controlled and domestic private banks with 0.89 and 0.87 cost efficiency scores respectively. Such a slight difference means that other state-controlled and domestic private banks can be seen as agents with similar behavior, as it was discussed in Section 3.1, which is in row with the theory of Mamonov and Vernikov (2015). The reason is that the smaller state banks are usually not included into the lending to the government-supported projects. However, this comparison should be made cautiously as the sample sizes of these two groups are relatively small. All three mentioned groups are operating with higher efficiency than the average level in the sector.

Foreign banks appear to be the least efficient category, operating on average 19% from the optimal level. Also, the difference between the most and the least efficient bank is the biggest in the group of foreign banks. One of the potential reasons is that they have the highest number of observations in the sample (142 from 206), thus the diversity is larger, and, therefore, the larger is heterogeneity in the group. The other potential reason is that they are indeed the least cost-efficient group, which can be explained by the relatively numerous cases of their reorganization/liquidation and the reasons behind them, discussed in Section 3.3. Moreover, the core state banks where

Table 5 – Descriptive statistics of the cost efficiency scores grouped by the ownership types and years

Groups and years	Mean	Standard Deviation	Maximum value	Minimum value
Core state-controlled	0.930	0.046	0.979	0.815
Other state-controlled	0.891	0.091	0.972	0.723
Foreign controlled	0.811	0.162	0.985	0.116
Domestic private	0.874	0.103	0.989	0.648
2010	0.822	0.160	0.989	0.213
2011	0.744	0.153	0.984	0.325
2012	0.843	0.126	0.984	0.433
2013	0.857	0.141	0.985	0.377
2014	0.871	0.122	0.979	0.389
2015	0.844	0.202	0.979	0.116
2016	0.890	0.062	0.982	0.780
Total	0.837	0.148	0.989	0.116

Notes: This table shows the descriptive statistics of the cost efficiency scores estimated by Equation (5) (Frontier 1 model) and grouped by the ownership types and years.
Source: Own table based on the collected data from nbrb.by

financed by the government in the end of 2011 – the crisis year – via emission and loans from the National Bank of the Republic of Belarus in order to increase their liquidity after the crisis (Tut.by). At the same time, foreign banks lost large parts of their equity capital due to devaluation but got no compensation from the Belarusian government.

It would be interesting to see how the ranking of banks with ownership types looks like in other countries, especially when they were in the state of transitional economies. Generally, Fries and Taci (2005) find private banks to be significantly more cost efficient (they use total cost as a dependent variable) than state-owned banks in the 15 post-communist countries in the late 1990s. In the Chinese case, investigated by Berger et al. (2009), smaller state-owned banks and majority foreign appear to be the most (total) cost efficient, while the majority private are the least efficient under the period of 1994-2003. In the Hungarian transitional economy of the late 1990s domestic banks are less (total) cost efficient than foreign, while average cost efficiency increased with the increase of foreign involvement (Hasan & Marton, 2003). Nikiel and Opiela (2002) find that in Poland foreign banks are much more efficient than both private and state banks in the period of the late 1990s. Eventually, in the case of Russia other state and private banks are almost the same in terms of the (operating) cost efficiency, followed by the core state, and with the group of foreign at the last place, laying much behind the other groups in the period of 2005-2013 (Mamonov & Vernikov, 2015). The Belarussian banking system seems to resemble more the Russian one with the foreign banks as the least cost-efficient group. Moreover, the time period in the paper by Mamonov and Vernikov (2015) is close to the period investigated in this paper.

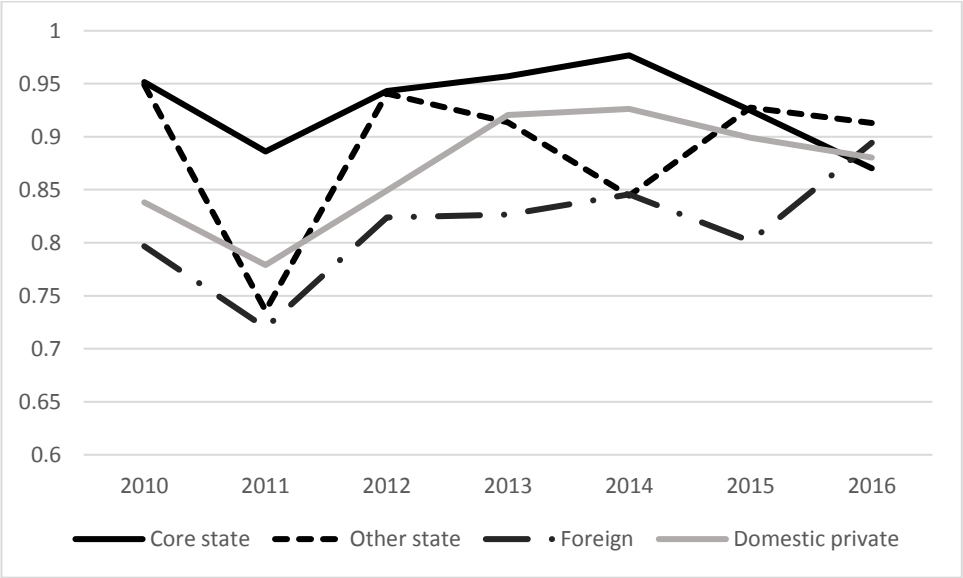
In their study, Berger et al. (2009) find the Big Four state Chinese banks to be very profit-inefficient and slightly more cost-inefficient agents among the other groups of banks. The same slightly lower cost efficiency of the core state banks comparing to the other state and is found in the Russian case (Mamonov & Vernikov, 2015). In Belarus the core state banks are the most cost efficient. It can be explained by the fact that the core state banks are obliged to participate in various projects launched by the government, such as privileged mortgage to people registered in a state queue. A lot of people in such queues are parents of large families, people with low or average income. Thus, as core state banks are the main lenders and are obliged to participate, they sometimes need to give out risky loans. Hence, they don't conduct meticulous investigations of all the cases, as they need to lend anyway. This helps to cut operating costs but can lead to the high amount of non-performing loans and lower profits. This is consistent with the findings of Berger et al. (2009). Also, higher cost efficiency can be potentially explained by the presence of government subsidies, below-market rent fees for the office buildings. The effect of such a possible promotion from the government side on the cost efficiency of the core state banks will not be examined in this paper but can be denoted as one of the directions for the future research.

With respect to cost inefficiency over the sample years, there is a clear negative effect of the crisis of 2011 on the banks' cost efficiency. With a 3%-drop in 2015, the mean cost efficiency increased by almost 7% throughout the period and by almost 15% since the year of the crisis. It can be explained by the overall technological improvement in the sector, and stabilization of the economic situation in the country in the post-crisis period. To state reasons for such an improvement, more bank-specific data as well as country level data on economic development and changes in regulations should be analyzed. The necessary bank-level data may include the changes in personal and expenses on personal, IT-expenses and investments, the amount of non-performing loans, which cannot be extracted from the basic financial statements which were used as the data source for this paper.

The efficiency scores of the different groups of banks are displayed on Figure 5. From Figure 5 it becomes visible that the other state banks experienced the largest decline in their cost efficiency during the year of the crisis. It can be possibly explained by more attention from the government to diminish the impact of the crisis for the core state banks, while other state banks could have been left on their own. At the same time, the owners of foreign and domestic private banks were trying to mitigate the impact of the crisis on their banks as their financial results is of the highest interest for their owners.

After the description of the first stage of the cost efficiency analysis (estimation of the cost efficiency frontier) it is reasonable to proceed with the second stage: the investigation of

Figure 5 – Time trend of the cost efficiency scores for the banks with different ownership



Notes: This figure shows the time trend of the cost efficiency scores estimated by Equation (5) and Frontier 1 model under the period of 2010-2016, which are grouped by the ownership types.
Source: Own figure based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

correlation between the ownership types and cost efficiency scores when controlling for other sources of heterogeneity.

5.2 Second stage

The results of the second-stage regressions (regressions of cost efficiency scores on the ownership types as well as other organization-specific variables) are presented in Table F1 of Appendix F[17].

The first two regressions focus on the relationship between the type of ownership and the bank's efficiency scores. First, Model 1 – the model with only the dummies for the ownership types, and Model 2 – the model with the dummies for the ownership types and included time fixed effects – are considered. These models produce similar parameter estimates. The hypothesis that the core state-controlled banks are the most cost-efficient group is supported by the positive and significant (at 1% level) estimate in Models 1 and 2, with higher probability of being cost efficient relatively to a domestic private bank by 5.6 percentage points (pp) and 5.9 pp accordingly. Moreover, foreign-controlled banks have significantly lower probability of being cost efficient relatively to a domestic private bank by 6.3 pp and 5.7 pp in Models 1 and 2 respectively. At the same time, there is no significant difference between other state-controlled banks and domestic

[17] The description of the variables can be found in Section 3.2. The main models, discussed in this section are Models 1-4. Time fixed effects are included into Models 2-4.

private banks, which can occur due to the small number of observations in the both groups or can support the theory that these banks can be seen as similar agents in the banking system of Belarus[18]. These results are in line with the ranking of the mean efficiency scores of different groups presented in Table 5. It is important to mention that adjusted R-squared are low in both models: 0.078 and 0.117 respectively, which means that there exist numerous omitted factors that can explain the differences in the cost efficiency scores. It is important to keep in mind that due to endogeneity problem the results of this models should be interpreted cautiously, therefore no statements about the causality can be made, only about the correlation between the particular ownership type and the level of cost efficiency. Potential omitted variables could be controls for the income of the households, profits of the non-banking firms as it was done by Mamonov and Vernikov (2015). However, this information is not available.

Testing of the joint significance of the year dummies in Model 2 by the Wald test shows that the null hypothesis that the coefficients on the year dummies are jointly equal to zero is rejected at the 1% level with a p-value of 0.0022. Thus, time fixed effect will be accounted for in the next regressions.

Now, let's consider Models 3 and 4, which besides the ownership dummies and fixed effects include bank specific variables, such as return on equity, (measure of profitability), equity to assets ratio (measure of a risk preference), loans to assets ratio (measure of intensity of the lending activity), loans to deposits ratio (measure of a bank's ability to transfer deposits into loans), logarithm of assets (proxy for the size of a bank). Model 4 includes the additional dummy, which is equal to 1 if a bank was reorganized, liquidated or merged. This dummy, as it was discussed in Section 3.2, may show whether the banks from the sample were reorganized, liquidated or merged because of their cost inefficiency or due to other reasons. From Model 3 it can be seen that, when controlling for the main bank specific characteristics according to the literature, core state ownership remains to be positively correlated with the cost efficiency if to compare with the domestic private ownership, but now only significant at the 10% level. Foreign-controlled banks remains the only one group, which is significantly less cost efficient than the domestic private one (at the 10% level). The group of the other state-controlled banks remain slightly but insignificantly more cost efficient than the reference group of domestic private banks.

The magnitude of the estimates changed: for the core state-controlled and other state-controlled banks the difference in the probability of being more cost efficient with respect to the reference group of domestic private banks increases from 5.9 pp and 1.2 pp in Model 2[19] to 7.7 pp and 2.5 pp in Model 3 when the other bank specific variables are included into the regression. At

[18] It was discussed in Sections 3.1 and 5.1.

[19] Model 3 is compared to Model 2 but not Model 1 as the both of them include the time fixed effects.

the same time the estimated difference in the probability of being more cost efficient between the foreign-controlled banks and the reference group of domestic private banks increases from -5.7 pp in Model 2 to -3.3 pp in Model 3. Thus, with the bank specific variables included into the regression, estimates for the ownership types generally increase. It can be explained by the existence of a negative omitted variable bias due to negative correlation of the ownership types with some of the bank specific variables[20]. In general, the results for the estimates of the ownership dummies in Models 1 and 2 are supported by those of Models 3 and 4.

Adjusted R-squared are similar in Models 3 and 4: 0.419 and 0.417 respectively, which are substantially higher than those in Models 1 and 2, meaning that bank specific variables explain the large part of the variance in the estimated cost efficiency levels between the banks. Slightly lower adjusted R-squared in Model 4 compared to Model 3 can mean that the dummy for variable reorganized, liquidated or merged banks doesn't fit the model. Moreover, the dummy for the reorganized, liquidated or merged banks in Model 4 is negative but not significant. Therefore, it cannot be stated that during the investigated period of 2010-2016 some banks had lower cost efficiency because of the processes of reorganization, liquidation or mergers. Generally, adjusted R-squared for Models 3 and 4 shows that the proposed model fits that data well.

The test of the joint significance of the ownership dummies in Model 3 by the Wald test shows that the null hypothesis that there is no effect of the ownership types on the cost efficiency score is rejected at 1% level with a p-value of 0.000. Thus, even if the bank specific variables are included, there is still a correlation between the type of ownership and the level of the cost efficiency.

Potentially, belonging of banks to the core state group can determine their higher cost efficiency. The possible explanations to this are discussed in Section 5.1. Some of them are: obligatory participation of the core state-controlled banks in the state mortgages programs and, by this, decreasing the borrowers-skimming costs; market power in the market of the mortgages; government subsidies; below-market rent fees on office buildings from the government.

As for the foreign-controlled banks, their lower cost efficiency can be explained by their 142 observations out of 206 and, therefore higher diversity of banks and the levels of their cost efficiency; or their real lower cost efficiency, which can be potentially explained by their riskier lending policy, which aims at the profitability increase, but not the decrease of costs.

[20] If to put the bank specific variables one by one into the regression, it can be seen which of them has higher correlation with the ownership types. For example, if to add return on equity, the estimate for the core state banks increase by 0.005, while the one for the foreign-controlled decrease by 0.014. This means positive correlation between the state-controlled ownership and the measure of profitability, while negative correlation between the foreign ownership and the measure of profitability.

If to compare the results of this paper with the other studies on the same topic, it can be seen that in Russia the ranking of banks is similar with the only change between core state and the other state, but the GMM instead of the OLS was used for the estimation by Mamonov and Vernikov (2015). At the same time, in the other neighbor country (Poland), in the period of transition foreign-controlled banks were more cost efficient than domestic private according to coefficients estimated by Tobit Nikiel and Opiela (2002). Thus, the conclusion is that Belarusian transitional banking system resembles the Russian banking sector more than that of the western neighbor. The reason may be that Belarus has historically stronger ties with Russia, as well as tighter economic relationships in the contemporary history than those from the Western side.

If to shortly describe the effect of the bank specific variables on the cost efficiency scores, as they are not of the main interest in this paper, it can be seen that return on equity is positively associated with the cost efficiency and is significant at the 1% level, which is also shown by Perera et al. (2007) in the case of South Asian banking system. Equity-to-assets ratio is also positively associated with the cost efficiency and is significant at the 5% level, which supports one of the theories discussed in Section 3.2 that prudent banks have higher cost efficiency, as the lower ratio can lead to the increase of borrowing costs. The same results are found by Mamonov and Vernikov (2015) in the Russian banking system. Loans-to-assets ratio is significantly positively associated with the level of cost efficiency, but with the two times lower magnitude than the equity-to-assets ratio. The same positive results are found by Mamonov and Vernikov (2015). This supports one of the views discussed in Section 3.2 that intensification of lending activities may facilitate the economy-of-scale and, therefore, positively affect cost efficiency. Loans-to-deposits ratio doesn't show any significant relationships with the cost efficiency. At the same time, estimates of logarithm of assets change signs across the models presented in Appendix F**,** becoming negative and significant at the 10% level when the dummy for reorganized, liquidated and merged bank is included into the regression. Thus, no interpretation can be given regarding this estimate.

A future extension of the research could include the division of the banks into the groups (quartiles) according to the equity involvement of foreign institutions in the domestic banking institutions in order to explore how much the degree of the foreign involvement influence cost efficiency scores. Also, the effect of particular levels of different bank-specific variables on banks with different ownership types can be explored.

5.3 Robustness tests

To analyze the robustness of the cost frontier efficiency measures as well as the effect of the covariates, several checks of the other specifications applied in the literature on the similar topics should be executed.[21, 22]

First, time fixed effects are replaced in Model 3 of the second stage of the cost efficiency analysis by macroeconomic variables[23]: logarithm of GDP in Model 5; logarithm of GDP, inflation measured by GDP deflator and real interest rate in Model 6. The results are presented in Table F1 of Appendix F.

First, the arguments behind the choice of the macroeconomic variables, as well as the discussion of the results are presented. Different measures of GDP are used by Mamonov and Vernikov (2015), Poghosyan and Borovička (2007) and Fries and Taci (2005) as a as a proxy measure for the general level of country's development. Bank's costs may decrease with country's development because improvements in the quality of state institutions can take place. In the Belarusian banking sector, the effect of this variable on the cost efficiency is insignificant and the adjusted R-squared decreases from 0.419 in Model 3 to 0.37 in Model 5.

Fries and Taci (2005) in their study included level of nominal interest rates as their high values can raise the interest costs of banks. In their study they probably used interest rate for deposits. The nominal interest rate is calculated by the World Data Bank as a lending rate. This measure will be applied in the case of Belarus. As there is a high level of inflation in Belarus, the measure of nominal interest rate is decided to be replaced by the real interest rate. According to the World Data Bank, real interest rate can be defined as the lending interest rate adjusted for inflation measured by the GDP deflator. The results are presented as Model 6 in Table F1 of Appendix F. The real interest rate has a significant positive effect on the level of cost efficiency, meaning that higher lending rates and lower inflation increase the cost efficiency of banks in Belarus. The adjusted R-squared of 0.37 is still lower than 0.419 in Model 3, which is the model with time fixed effects. This means that there exist other time variant exogenous factors that affect the level of cost efficiency of banks in Belarus.

[21] Some more robustness checks were conducted than discussed in this section, such as the standard production approach with operational costs as a dependent variable, non-financial cost as an input price, excluding the price of funds from the frontier estimation; the same loans, deposits and commission income as outputs (it was discussed in Section 3.2). In this estimation convergence wasn't achieved. Another one, robust normalized by equity and price of non-financial costs frontier model – standard one-step approach, where conditional mean is allowed to shift with ownership groups and years is not converged. Not normalized model converged, but standard errors, z statistics and confidence intervals of variance of inefficiency and lambda are not reported in the output table. Probably the reason is the relatively small sample.

[22] The estimation of the second-stage models based on Frontier 2 (with included year dummies) was not conducted due to the arguments about similarity of Frontier 1 and Frontier 2 and arguments for Frontier 1 provided in Section 5.1.

[23] Macroeconomic variables for the period of observation are retrieved from the World Data Bank.

Second, in Frontier 1, the model of the first stage of the analysis without year fixed effects, the truncated normal distribution is replaced by the half-normal. This distribution was exploited by Mamonov and Vernikov (2015) and Perera et al. (2007). The results are presented in Table E1 of Appendix E as Frontier 3. Coefficients for logarithm of normalized loans $\ln(Y_{1,}/Z)$ and logarithm of normalized deposits $\ln(Y_{2,}/Z)$ remain significant and change slightly. Some interaction coefficients even change signs but remaining insignificant. The variance of the random error term *v* becomes insignificant. Lambda – the indicator of the inefficiency presence – became smaller. Mean cost efficiencies are as expected lower than those estimated by Frontier 1, but the ranking of the groups of banks remains the same. Results of the second-step regressions based on Frontier 3 are presented in Table F1 of Appendix F, where Model 7 is a regression with time fixed effects and without bank specific variables, Model 8 is a regression with both time fixed effects and bank specific variables. Thus, they should be compared to Models 2 and 3 respectively. The adjusted R-squared increases, but the estimates as well as the standard errors remain qualitatively similar and ranking of the ownership types remains the same.

Third, modified value-added model of intermediation approach is replaced by the standard value-added with total costs as a dependent variable. The results are presented in Table E1 of Appendix E as Frontier 4. Most of the coefficients remain qualitatively the same, but the number of significant coefficients increases. Mean cost efficiencies are lower than estimated by Frontier 1, but the ranking of the groups of banks remains the same. Results of the second-step regressions based on Frontier 4 are presented in Table F1 of Appendix F, where Model 9 is a regression with time fixed effects and without bank specific variables, Model 10 is a regression with both time fixed effects and bank specific variables. These models should be compared to Models 2 and 3 respectively. The main difference when it concerns total costs as a dependent variable is that core state banks appear not to be a significantly the most efficient group, which means that there can be a negative effect of their participation in the state programs – they are probably not able to efficiently manage their interest expenses. Otherwise it can be stated that there are slight differences between the estimates in the models, but mainly in precision. The adjusted R-squared is lower in Model 9 compared to Model 2. At the same time adjusted R-squared increases from 0.419 in Model 3 to 0.459 in Model 10. In Model 10 estimate for the core state-controlled banks becomes insignificant, whereas size (logarithm of assets) becomes negative and significant at 10% level.

This section shows that there is a room for the improvement of the proposed model. In the defense of the baseline model of this paper it can be said that this is the first attempt to analyze the cost efficiency of banks in Belarus, considering ownership types. The main model follows the proposed arguments, based on the discussion and results in the existing literature. Even if some

model seems potentially fit the existing data slightly better, the ranking of the banks – the main goal of this paper, appears to be robust to the change in the model's specification.

6 Conclusion

In this paper, I execute the first attempt to investigate the correlation between the level of a bank's cost efficiency and its belonging to one of the four main ownership types existing in the Belarusian banking sector: core state-controlled, other state-controlled, foreign-controlled and domestic private. Also, I put forward explanations for the revealed ranking: core state banks, which is followed by other state and domestic private, and foreign-controlled as the least efficient group. Moreover, the possible reasons for the uncovered differences in the cost efficiency levels are discussed as well as comparisons with the results of some other papers about the countries in transition are provided.

In order to perform the cost efficiency analysis of the Belarusian banking sector, the data from the financial statements of all registered banks in Belarus under the period of 2010-2016 was collected from the website of the National Bank of the Republic of Belarus. Then, the Stochastic Frontier Analysis (SFA) was applied in order to perform the cost efficiency analysis, which in the first stage provided the cost efficiency scores for each bank in the sample, and in the second – evaluation of efficiency covariates. According to the results of this analysis based on the chosen specifications of the model, core state banks appear to be the most cost-efficient group, whereas other state and domestic private banks show approximately the same level of cost efficiency and the foreign-controlled banks closing this ranking. The potential reasons for these results are numerous: grants and discounts from the government to the core state banks or obligatory participation of the core state banks in the state housing programs, which lowers the borrowers-skimming costs. Grants from the government can potentially distort the results by positively affecting the cost efficiency level of the core state-controlled banks, especially during the more unstable times in the economy of Belarus, which was demonstrated in 2011. At the same time, one can consider the amount of loans the core state-controlled banks issue as well as their share in the total amount of loans in the sector (65% in 2016). This dominance in the main bank's output is accompanied by the obligatory participation of the core state banks in various state lending programs, which leads to the positive effect from lower borrower-skimming costs on the cost efficiency of the core state-controlled banks. Due to this fact, I believe that the positive effect of the lower borrower-skimming is stronger than this of the state grants. This means that the suggestion is that the core state-controlled banks will remain as a more cost-efficient group even if the state grants are eliminated from the data used for the analysis. The problem is that these

grants are presented not only as one of the items in the state of financial position, but also as various discounts such as on the rental fees. This makes it difficult to completely eliminate this category of grants from the analysis. One also should not forget the potential positive effect of scale on the cost efficiency of the major state banks due to their large shares in the outputs of the banking sector.

Some more limitations of this paper despite the plausibility of the data sources are potential typos in financial statements and the changes in accounting standards over time. The first one is claimed by the literature to be possible to overcome by the applied SFA, while the second one can distort the data.

Robustness checks of the chosen model specifications show that the estimates for the ownership types as well as for the other bank-specific characteristics appear to be consistent. At the same time, the robustness section shows that there is a room for improvement of the proposed model.

Generally, the literature on bank efficiency in transition economies in Eastern Europe suggests that foreign banks lead in terms of efficiency, whereas state-owned banks stay behind. However, the hypothesis stated in the introduction that state-controlled banks are more cost efficient than private and foreign banks both with and without controlling for other bank-specific characteristics, is supported by the presented results. Moreover, from the results of the cost efficiency analysis and the comparisons with some other countries discussed in this paper, the following conclusion can be made: Belarusian transitional banking system resembles the Russian banking sector more than that of the western neighbors or other transitional economies. The potential reason is that Belarus has historically stronger ties with Russia, as well as tighter economic relationships in the current period than those from the Western side, which led to a resembling each other economies and their management principles.

Thus, concluding from the discussions presented in this paper, as well as the fact that this is the first attempt to analyze the cost efficiency of banks in Belarus considering ownership types, there are several possible direction for future research/improvements of this paper: comparison of different models and model specifications (discussed as well as not discussed in this paper), as well as their effect on the results of the analysis; extending the period of investigation back to 1991 (the year of independency of the Republic of Belarus); investigation of profit efficiency, which can complete the picture of the Belarusian banking sector, as well as show the reverse ranking of the banks than revealed by the cost efficiency analysis; the division of the banks into the groups (quartiles) according to the equity involvement of foreign institutions in the domestic banking institutions as well as extraction of the Russian-controlled banks into the separate group as it was

described in Section 3.3 or investigation of the effect of particular levels of different bank-specific variables on banks with different ownership types.

Judging from the results, the termination of the privatization process seems reasonable until all the possible consequences for the banks and the economy of the country in general are evaluated; and the question whether the size of the potential benefits of the foreign investments and new technologies will outweigh the lost of the control over the major state banks, which will lead to the search of the new tools to implement and finance some of the state programs, will be answered. From the cost efficiency perspective, state-controlled banks are the most efficient, but there are several potential reasons for that connected to their ownership status. Thus, no unequivocal answer to the question whether the Belarusian government should proceed with the privatization of the state banks could be made at this stage of the research, as the analysis of the general efficiency of banks includes more elements than cost efficiency, which were not analyzed due to the time constraints. The described directions for the future studies can bring us closer to the answer to this important and topical question. Thus, this paper can be seen as a starting point for the future analysis of the efficiency of banks in Belarus which can be then empirically implemented.

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Appendix A

Table A1 – List of active banks registered by the National Bank of the Republic of Belarus in 2010-2016

	Name	Ownership	Investor	Established	Stopped operating	Merged/ reorganized	Liquidated
1	Belinvest	Core state	State equity committee (Belarus)	2001			
2	Belarusbank	Core state	State equity committee (Belarus)	1995			
3	Belagroprom	Core state	State equity committee (Belarus)	1991			
4	Paritetbank	Other state	National Bank of the Republic of Belarus, Administration of the President (Belarus)	1991			
5	BPS-Sberbank	Foreign	Sberbank (Russia)	1991			
6	Priorbank	Foreign	Raiffeisen Bank International AG (Austria)	1991			
7	BelVEB	Foreign	Vnesheconombank (Russia), ultimate – Russian government	1991			
8	BNB Bank	Foreign	Investment company from Cyprus, ultimate – Bank of Georgia	1992			
9	Belgazprombank	Foreign	Gazprom/Gazprombank (Russia)	1991			
10	Absolutbank	Foreign (2010-2014), Domestic private (2015-2016)	Greek investment companies (2010-2014), Interservice (2015-2016) (Belarus)	1993			
11	RDB bank	Domestic Private	V. A. Tsybulin (Belarus)	1994			
12	MTBank	Foreign (2010-2014), Domestic private (2015-2016)	Owners from Cyprus, ultimate – Russian private individuals (2010-2014), Belneftegaz (2015-2016) (Belarus)	1994			
13	Technobank	Domestic Private	Belarusian companies	1994			
14	Fransabank	Foreign	Owner from Lebanon	1994			
15	R-bank	Foreign	Alm Investments (United Arab Emirates)	1994			
16	VTB Bank	Foreign	VTBBank (Russia), ultimate – Russian Federation	1996			
17	Alfa Bank	Foreign	Owners from Cyprus, ultimate – Russian private individuals (2010-2013), Russian private individuals (2014-2016)	1999			
18	Status Bank	Foreign (2010-2011), Domestic Private (2012-2016)	Owners from Cyprus, Ultimate – Belarusian individuals (2010-2011), owners from Belarus (2012-2016)	2002			
19	Moscow-Minsk	Foreign (2010-2013), Other state (2014-2016)	Russian Government (2010-2013), National Bank of the Republic of Belarus (2014-2016)	2007			
20	Home Credit	Foreign	Owners from the Netherlands, Czech Republic	2002		2016	
21	BTA Bank	Foreign	BTA Bank (Kazakhstan), ultimate – Kazakh Government (2010-2014), Kazakh private individuals (2015-2016)	2002			

Continued on next page

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22	BelSwissBank	Foreign	Owners from Switzerland	2002			
23	Idea Bank	Foreign	Owners from Luxemburg, ultimate – owners from Poland (2010-2012); private individuals from Poland (2013-2016)	2004			
24	TC Bank	Foreign	Bank Tedzarat (Iran)	2008			
25	Zepter Bank	Foreign	Owners from Switzerland and Monaco	2008			
26	Delta Bank	Foreign	Ukrainian private individuals	2001	2015		
27	InterPay Bank	Foreign	Owners from Switzerland (2010-2012), owners from Russia (2013-2014)	2001	2015		2017
28	EuroBank	Domestic Private	Owners from Belarus	2009	2015		
29	N.E.B. Bank	Foreign	Owners from Iran (2010-2012), Owners from Iran/Germany (2013-2015)	2009	2016		
30	BIT-Bank	Foreign	Owners from Cyprus	2012	2015		
31	Alfa Bank-Finance	Foreign	Owners from Cyprus, Ultimate – Alfa Bank Russia	2003		2013	
32	BBSB Bank	Domestic Private	Belarusian owners	2008		2015	

Notes: This table presents the full sample of the registered by the National Bank of the Republic of Belarus active banks during the period of 2010-2016. The information regarding the major investor, year of establishment and years of reorganization/merge/liquidation is presented. In the column "Investor" stated those who possess more than 50% of a bank's shares. If there is no information regarding the investors: company or individuals, then it is stated as "owner" with no further specification. In some cases, there are two major owners, where one of them is an "offshore" registered investment fund, which is actually controlled by another owner. For the purpose of this research it doesn't matter because in all such cases the major owners are foreign investors. At the same time, when a bank is registered "offshore" but the ultimate owners are possibly residents of Belarus (Statusbank in 2010-2011), these banks are considered as foreign (as it is considered by the National Bank of the Republic of Belarus) as it is not possible to trace the true origin of the invested capital. Also, when an ultimate owner of the "offshore" registered bank is not defined (BIT-Bank), such a bank is considered as a foreign following the National Bank of the Republic of Belarus.

Source: Own table based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Appendix B

Table B1 – Time trend and shares of ownership groups in the total assets

Year	Total Assets, mln BYR	Percent of total assets						
		Core state	Other state	Domestic Private	Foreign			Accumulated foreign
					Controlled by Russian state*	Controlled by Russian individuals	Controlled by investors from other countries	
2010	128,052,666.7	70.69	0.44	0.89	7.34	11.64	9.00	27.98
2011	260,727,214.6	64.66	0.44	0.99	8.74	14.86	10.30	33.90
2012	320,058,046.0	64.41	0.33	0.95	9.02	16.38	8.92	34.32
2013	394,885,027.8	63.37	0.40	0.87	9.05	17.20	9.11	35.36
2014	479,342,065.0	63.25	1.66	0.98	7.42	18.02	8.68	34.12
2015	620,364,796.0	63.78	1.83	2.07	7.79	17.27	7.26	32.32
2016	628,412,320.0	64.71	1.96	2.57	8.29	15.15	7.31	30.75

Notes: This table shows the shares of ownership groups in the total loans in the Belarusian banking sector and their changes over the period of 2010-2016.
*Belgazprombank is included as not Russian state-controlled.
Source: Own calculations based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Table B2 – Time trend and shares of ownership groups in the total loans

Year	Total Loans to customers, mln BYR	Percent of total loans to customers						
		Core state	Other state	Domestic Private	Foreign			Accumulated foreign
					Controlled by Russian state*	Controlled by Russian individuals	Controlled by investors from other countries	
2010	90,444,037.3	75.28	0.41	0.67	5.32	10.66	7.66	23.64
2011	150,589,436.1	69.82	0.30	0.67	7.51	13.37	8.33	29.21
2012	205,097,196.2	68.31	0.25	0.63	9.06	14.60	7.15	30.81
2013	264,723,221.4	66.71	0.29	0.62	8.97	15.94	7.47	32.38
2014	323,793,954.0	66.72	1.55	0.71	7.25	16.63	7.15	31.03
2015	376,819,700.0	64.62	1.82	1.82	8.02	18.04	5.68	31.74
2016	349,798,640.0	64.70	1.99	2.45	8.61	16.10	6.15	30.86

Notes: This table shows the shares of ownership groups in the total loans in the Belarusian banking sector and their changes over the period of 2010-2016.
*Belgazprombank is included as not Russian state-controlled.
Source: Own calculations based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Table B3 – Time trend and shares of ownership groups in the total deposits

Year	Total Deposits, mln BYR	Percent of total deposits						
		Core state	Other state	Domestic Private	Foreign			Accumulated foreign
					Controlled by Russian state*	Controlled by Russian individuals	Controlled by investors from other countries	
2010	59,489,201.8	72.45	0.47	0.90	5.46	11.65	9.07	26.18
2011	123,960,781.8	66.30	0.50	1.19	6.13	15.23	10.66	32.02
2012	180,712,299.4	66.92	0.34	1.03	6.55	16.12	9.04	31.71
2013	222,012,693.2	68.66	0.35	0.98	6.36	14.84	8.81	30.01
2014	278,430,893.0	68.94	1.54	0.98	4.86	15.54	8.15	28.55
2015	359,522,614.0	66.74	1.98	2.29	6.31	15.25	7.44	29.00
2016	376,601,280.0	66.94	2.05	2.83	7.11	13.75	7.32	28.18

Notes: This table shows the shares of ownership groups in the total deposits in the Belarusian banking sector and their changes over the period of 2010-2016.
*Belgazprombank is included as not Russian state-controlled.
Source: Own calculations based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

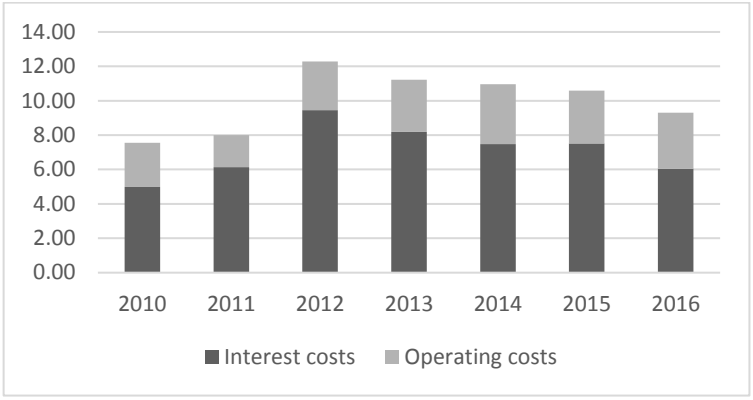
Table B4 – Time trend and shares of ownership groups in the total commission income

Year	Total Commission income, mln BYR	Percent of Commission income						
		Core state	Other state	Domestic Private	Foreign			Accumulated foreign
					Controlled by Russian state*	Controlled by Russian individuals	Controlled by investors from other countries	
2010	2,242,423.0	45.63	0.40	2.28	8.24	17.06	26.40	51.70
2011	4,120,390.0	40.92	0.35	1.99	9.53	18.11	29.09	56.73
2012	7,339,879.3	36.78	0.35	1.93	10.72	20.47	29.75	60.94
2013	9,468,015.2	38.59	0.36	1.81	11.04	21.42	26.78	59.24
2014	11,244,360.0	38.71	2.38	2.02	10.47	24.04	22.39	56.90
2015	11,701,864.0	39.07	1.75	6.82	11.73	20.87	19.76	52.36
2016	12,275,800.0	41.72	1.54	9.25	10.89	20.48	16.12	47.49

Notes: This table shows the shares of ownership groups in the total commission income in the Belarusian banking sector and their changes over the period of 2010-2016.
*Belgazprombank is included as not Russian state-controlled.
Source: Own calculations based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

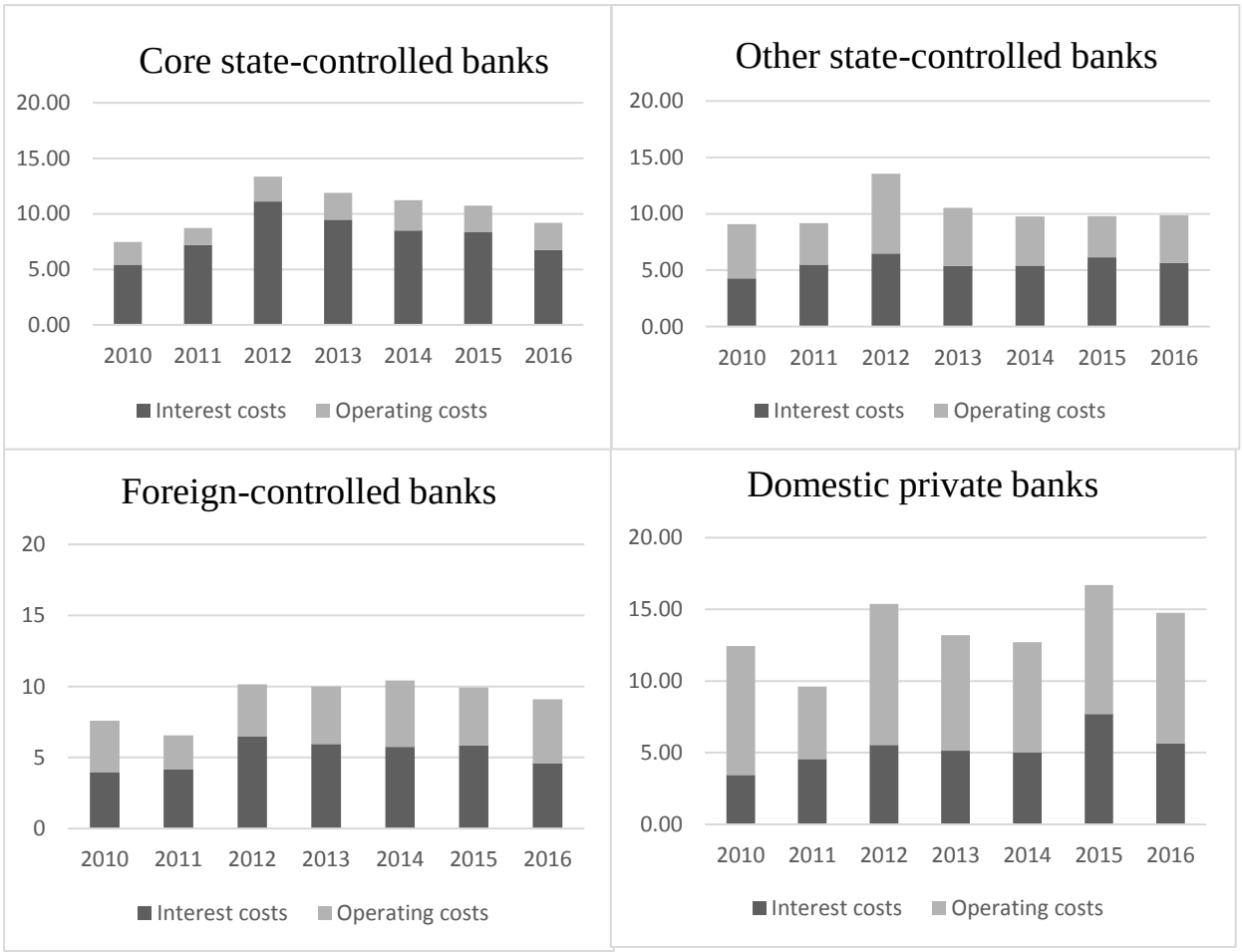
Appendix C

Figure C1 – Average costs in the Belarusian banking system (% total assets)



Notes: This figure shows the costs in the Belarusian banking system measured relatively to total assets and their changes throughout the period of 2010-2016. Costs are divided into two groups: interest and operating costs.
Source: Own figure based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Figure C2 – Average costs in the Belarusian banking system (% total assets) grouped by the ownership types



Notes: These figures show the costs in the Belarusian banking system measured relatively to total assets and their changes throughout the period of 2010-2016 for the four ownership groups: core state-controlled, other state-controlled, foreign-controlled and domestic private. Costs are divided into two groups: interest and operating costs.
Source: Own figure based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Appendix D

Table D1 – The descriptive statistics of the dependent variable, outputs and inputs included into the frontier estimation, as well as of the bank specific characteristics

	Overall sample (206)				Mean by ownership category			
	Mean	Standard deviation	Minimum value	Maximum value	Core state (21)	Other state (10)	Foreign (142)	Domestic private (33)
Dependent variable								
Operating costs, mln BYR	414,798	828,071	3,159	6,139,350	2,023,488	151,192	265,093	115,153
Variables for outputs/inputs								
Credits to clients, mln BYR	8,549,836	22,803,861	111	158,466,980	55,989,177	2,091,351	3,818,919	675,559
Clients' funds (deposits), mln BYR	7,770,533	21,778,299	95	171,154,640	51,553,899	2,138,081	3,303,140	838,521
Commission income, mln BYR	283,471	469,858	11	2,796,670	1,100,386	74,407	224,901	79,001
Price of non-interest inputs, mln BYR	0.06	0.04	0.01	0.34	0.027	0.047	0.063	0.097
Price of funds	0.10	0.32	0.005	4.63	0.098	0.074	0.072	0.208
Bank size								
Assets, mln BYR	13,746,806	36,171,506	19,360	278,508,130	86,710,782	3,595,985	6,556,859	1,329,753
Equity, mln BYR	1,889,953	4,856,985	17,715	35,968,950	12,039,411	612,782	855,854	267,985
Bank specific characteristics								
Return on equity	0.155	0.13	-0.19	0.61	0.086	.101	0.178	0.112
Equity to assets ratio	0.24	0.17	0.05	0.96	0.137	0.223	0.243	0.302
Loans to deposits ratio	6.28	42.63	0.02	511.43	1.157	0.937	8.642	1.023
Loans to assets ratio	0.49	0.18	0.001	0.81	0.66	0.52	0.47	0.47

Notes: This table shows the descriptive statistics of the dependent variable, outputs and input prices which are included into the frontier estimation, as well as of the bank specific characteristics, which are included into the second stage of the cost efficiency analysis (correlates of the cost efficiency scores). Number of bank observations is in parentheses.
Source: Own calculations based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Appendix E

Table E1 – Panel estimation of the Stochastic cost efficiency frontier models (first stage)

	Frontier 1	Frontier 2	Frontier 3	Frontier 4
Dependent variable	OC	OC	OC	TC
$\ln(Y_1/Z)$	0.381***	0.356***	0.289***	0.456***
	(0.084)	(0.059)	(0.075)	(0.150)
$\ln(Y_2/Z)$	0.237**	0.256***	0.246***	0.290***
	(0.104)	(0.037)	(0.053)	(0.070)
$\ln(Y_3/Z)$	-0.0353	-0.00288	0.0943	-0.0240
	(0.082)	(0.061)	(0.069)	(0.116)
$\ln(W_2/W_1)$	-0.035	-0.062	-0.063	0.362***
	(0.130)	(0.058)	(0.049)	(0.046)
$\frac{1}{2}(\ln(W_2/W_1))^2$	-0.051	-0.068	-0.059	0.187***
	(0.046)	(0.046)	(0.065)	(0.068)
$\frac{1}{2}(\ln(Y_1/Z))^2$	0.151	0.159***	0.144***	0.143***
	(0.114)	(0.035)	(0.039)	(0.039)
$\frac{1}{2}(\ln(Y_2/Z))^2$	0.139***	0.120***	0.090***	0.148***
	(0.043)	(0.020)	(0.027)	(0.032)
$\frac{1}{2}(\ln(Y_3/Z))^2$	-0.007	0.010	0.046*	0.002
	(0.035)	(0.026)	(0.025)	(0.048)
$\ln(Y_1/Z)\cdot\ln(Y_2/Z)$	-0.030	-0.025	0.006	-0.037
	(0.089)	(0.028)	(0.025)	(0.028)
$\ln(Y_1/Z)\cdot\ln(Y_3/Z)$	0.038	0.022	-0.019	0.026
	(0.027)	(0.022)	(0.028)	(0.045)
$\ln(Y_2/Z)\cdot\ln(Y_3/Z)$	-0.030**	-0.022***	-0.014	-0.032***
	(0.015)	(0.008)	(0.020)	(0.009)
$\ln(Y_3/Z)\cdot\ln(W_2/W_1)$	-0.006	-0.011	-0.010	0.011
	(0.036)	(0.018)	(0.024)	(0.023)
$\ln(Y_2/Z)\cdot\ln(W_2/W_1)$	-0.067	-0.061	-0.067**	-0.054
	(0.178)	(0.0486)	(0.0323)	(0.0557)
$\ln(Y_1/Z)\cdot\ln(W_2/W_1)$	0.092	0.087***	0.097***	0.124***
	(0.103)	(0.028)	(0.020)	(0.026)
2011.year		0.082**		
		(0.035)		
2012.year		0.015		
		(0.032)		
2013.year		-0.010		
		(0.029)		
2014.year		-0.015		
		(0.030)		
2015.year		-0.010		
		(0.029)		
2016.year		-0.018		
		(0.033)		
Constant	0.693***	0.730***		
	(0.101)	(0.077)		
Log Likelihood	92.132	97.000	65.057	52.632
Distribution of the inefficiency term	Truncated normal	Truncated normal	Half-normal	Truncated normal

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	Frontier 1	Frontier 2	Frontier 3	Frontier 4
σ_u	4.916*** (0.920)	4.680*** (1.030)	0.336*** (0.040)	5.070*** (0.870)
σ_v	0.034*** (0.010)	0.047 (0.020) **	0.025 (0.050)	0.042*** (0.400)
Lambda	146.200*** (0.920)	100.020*** (1.040)	13.540*** (0.090)	121.330*** (0.870)
N	206	206	206	206

Notes: This table shows the panel estimation of stochastic cost efficiency frontier models using Stata command *sfpanel*, based on the Maximum Likelihood estimation, where standard errors are consistent estimates with White's correction for heteroscedasticity and are shown in the parentheses. ***, **, * are significant at 1, 5, and 10 percent significance levels respectively. All the Frontiers are normalized as discussed in Section 4.3. The description of variables can be found in Section 3.2 and 4.3. Frontier 2 include year dummies. Frontiers 3 and 4 are robustness check specifications. Lambda (measure of the inefficiency presence): $\lambda = \sigma_u/\sigma_v$.

Source: Own table based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.

Appendix F

Table F1 – Correlates of the cost efficiency scores (second stage)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Dependent variable	Cost efficiency score estimated in the first stage – frontier estimation (Appendix D)									
Based on the Frontier model	1	1	1	1	1	1	3	3	4	4
VARIABLES										
Core state-controlled banks	0.056***	0.059***	0.077*	0.078**	-0.006	0.015	0.062***	0.090***	0.056**	0.069
	(0.020)	(0.021)	(0.040)	(0.038)	(0.032)	(0.035)	(0.023)	(0.033)	(0.022)	(0.042)
Other state-controlled banks	0.017	0.012	0.025	0.022	0.013	0.014	0.004	0.020	0.003	0.013
	(0.033)	(0.031)	(0.020)	(0.021)	(0.019)	(0.019)	(0.034)	(0.019)	(0.035)	(0.020)
Foreign -controlled banks	-0.063***	-0.057***	-0.033*	-0.033*	-0.057***	-0.051***	-0.059***	-0.031*	-0.069***	-0.035*
	(0.022)	(0.022)	(0.020)	(0.020)	(0.018)	(0.019)	(0.023)	(0.017)	(0.024)	(0.020)
Return on equity			0.211***	0.206***	0.159**	0.170**		0.210***		0.163**
			(0.065)	(0.066)	(0.070)	(0.069)		(0.063)		(0.083)
Equity to assets ratio			0.232**	0.232**	0.351***	0.304***		0.241***		0.230**
			(0.090)	(0.091)	(0.085)	(0.090)		(0.087)		(0.095)
Loans to assets ratio			0.463***	0.462***	0.456***	0.441***		0.500***		0.621***
			(0.095)	(0.096)	(0.093)	(0.094)		(0.087)		(0.111)
Loans to deposits ratio			-0.001	-0.001	-0.001	-0.001		-0.001		-0.001
			(0.001)	(0.001)	(0.001)	(0.001)		(0.000)		(0.000)
Logarithm of assets			-0.013	-0.014*	0.009	0.003		-0.017**		-0.019*
			(0.009)	(0.008)	(0.007)	(0.001)		(0.007)		(0.010)
Reorganized, liquidated, merged bank				-0.0128						
				(0.0274)						
Logarithm of GDP (constant USD)					-0.026	-0.012				
					(0.0478)	(0.046)				
Real interest rate						0.001**				
						(0.001)				
Constant	0.874***	0.858***	0.682***	0.700***	1.075	0.832	0.837***	0.682***	0.853***	0.671***
	(0.018)	(0.031)	(0.144)	(0.132)	(1.195)	(1.154)	(0.032)	(0.117)	(0.033)	(0.154)
Time fixed effects	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Observations	206	206	206	206	206	206	206	206	206	206
R-squared	0.078	0.156	0.459	0.460	0.397	0.412	0.178	0.535	0.137	0.496
Adjusted R-squared	0.065	0.117	0.419	0.417	.370	.382	0.141	0.501	0.097	0.459

Notes: This table shows the OLS regressions of cost efficiency, where standard errors are consistent estimates with White's correction for heteroscedasticity and are shown in the parentheses. Domestic private banks are considered as a reference group and therefore is omitted in the regression. ***, **, * are significant at 1, 5, and 10 percent significance levels respectively. Models 5-10 are robustness check specifications. Models 2-4 and 7-10 include year dummies. Models 5-6 include macroeconomic variables Bank specific variables as well as macroeconomic variables are discussed in Section 3.2.

Source: Own table based on the collected data from nbrb.by and the information in the annual financial statements of the banks in the sample regarding the residence of their owners.