COLLEGIUM OF ECONOMIC ANALYSIS
WORKING PAPER SERIES

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Aneta Hryckiewicz and Piotr Mielus and
Karolina Skorulska and Małgorzata Snarska

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Aneta Hryckiewicz*
Kozminski University

Piotr Mielus**
Warsaw School of Economics

Karolina Skorulska***
Kozminski University

Małgorzata Snarska****
Cracow University of Economics

Abstract:

The crisis has shown that a drop in liquidity, as well as the shortened maturity of interbank transactions, has caused many problems for banks. We analyze how the introduction of a bank levy on bank assets in Poland has affected the interbank market, as well as money market pricing. Analyzing daily volume and number of interbank transactions, along with daily bank quotes, we document that the bank levy has significantly reduced trading intensity on the market, shortening the maturity of transactions. We also find that it has increased the dispersion of bank quotes for short-term transactions, while at the same time "killing" interbank long-term transactions, including the pricing for this market. The regulators should re-think the nature of bank levies in several countries, as they negatively affect the functioning of the interbank market and brings into question the credibility of interbank benchmarks.

JEL codes: C32, G28, E43, C54

Keywords: bank levy, interbank market, liquidity, money market, money market, friction

* Economic Institute for Empirical Analysis; Center for Analysis of Financial Systems (CAFS), Kozminski University, Jagiellonska Street 57/59, 03-301 Warsaw, Poland, phone number: +48 22 519 21 69, e-mail: ahryckiewicz@alk.edu.pl
** Collegium of Economic Analysis, Warsaw School of Economics, Madalińskiego 6/8, 02-513 Warsaw, Poland, phone number: +48 22 22 564 93 95, e-mail: piotr.mielus@sgh.waw.pl
*** Kozminski University, Accounting Department, Jagiellonska Street 57/59, 03-301 Warsaw, Poland, phone number: +48 22 519 21 69, e-mail: kskorulska@alk.edu.pl
**** Faculty of Finance and Law, Department of Financial Markets, Cracow University of Economics, Rakowicka 27, 31-510 Kraków, phone number: +48 12 2935081, email: malgorzata.snarska@uek.krakow.pl

I.   Introduction

The financial crisis of 2007 has shown that banks' engagement in risky operations have resulted in dramatic consequences. Numerous governments had to increase their public debt, in order to rescue collapsing banks. As a result, many countries were threatened with bankruptcy (Reinhart and Rogoff, 2011, 2013). To reduce the likelihood of further crises, worldwide organizations and financial market supervisors decided to introduce new reforms in the banking sector. One of the suggestions proposed by the IMF (2010) was the introduction of a bank levy. The main purpose of introducing a banking tax is to limit bank involvement in risky transactions (asset tax), as well as bank exposure toward short-term risky funding on the interbank market (liabilities tax) (IMF, 2010; Cannas et al., 2014). The introduction of a banking tax brings the hope of reducing risk in the banking sector and limiting the likelihood of potential systemic crises, such as those experienced during 2008 and 2010. Recently, many countries decided to apply this regulation: Austria (2011), Belgium (2012), Cyprus (2011), Finland (2013), France (2011), Netherlands (2012), Latvia (2011), Germany (2011), Portugal (2011), Romania (2011), Slovakia (2012), Slovenia (2011), Sweden (2009), Hungary (2010), United Kingdom (2011) and Poland (2016).

Though the first empirical investigation documents a positive effect of bank levies on decreasing leverage and short-term funding (Devereux et al., 2015 and Buch et al., 2014), the anecdotal evidence suggests that bank levies might intensify frictions on the interbank market. Banks seem to intensively reduce their exposure on the interbank market, especially on the day when the tax is due. Moreover, as bank levies increase the tax burden, banks seem to balance their liquidity needs in a way that limits the tax burden. This is especially evident on the term market where the number of long-term transactions significantly dropped after the introduction

of a bank levy, as Graph 1 suggests. In turn, banks seem to prefer short-term transactions before the end of month, as Graph 2 documents.

Graph 1: Monthly averages of transaction numbers on interbank market for maturities greater than 1 week
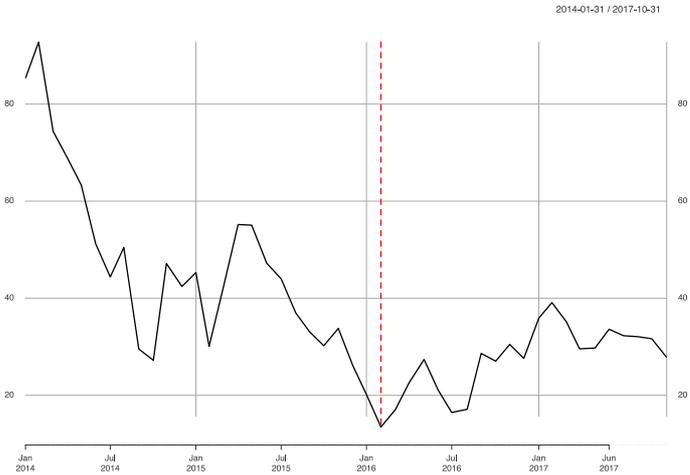
Source: Money Market Monitoring System. Red dashed line represents the date, when bank levy become effective (2016-02-01).

Graph 2: Monthly averages of transaction numbers on interbank market for maturities below 1 week
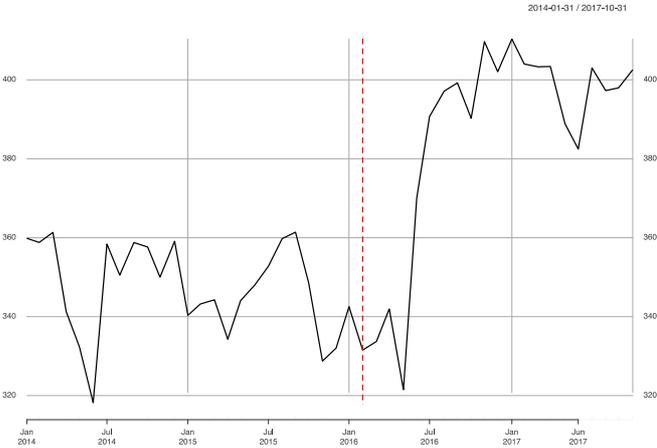
Source: Money Market Monitoring System. Red dashed line represents the date, when bank levy become effective (2016-02-01).

The new changes might increase frictions on the interbank market, question its efficient functioning, and raise questions around the credibility of money rates.

With our study we investigate how the introduction of a bank levy has affected trading volume, number, and the nature of transactions, as well as the behavior of interbank rates. To this end, we contribute to a very timely, but still very limited, literature on frictions on the interbank market. Current literature in this field is insufficient, and mostly focuses on the causes of the interbank market collapse during the financial crisis of 2008-2010, particularly after Lehman Brothers' bankruptcy. Crucial in this research was the question of the reasons for the limited activity of the interbank market during this time. Some studies indicate that asymmetric information leads to frictions on the interbank market, and that this was a main cause of credit rationing and the dry-up of the interbank market during the crisis of 2008. More specifically, McAndrews et al. (2008), Michaud and Upper (2008), Taylor and Williams (2009), Eisenschmidt and Tapking (2009), Gorton (2009), Schwartz (2010), Filipovic and Trolle (2013) and Heider et al. (2015) and document the implications of asymmetric information around borrower liquidity and credit risk, and how it affects credit risk spreads and leads to a freeze in the unsecured interbank market. Moreover, the existing literature also documents that the interbank market is extremely concentrated, and this unequal distribution of liquidity might lead to frictions (Cocco et al., 2009; Afonso et al., 2011; Bräuning and Fecht, 2016). However, Bech and Atalay (2010), Brousseau et al. (2013), Finger et al. (2013), Craig and von Peter (2014), Mielus and Mironczuk (2015) and Colliard et al. (2016) point out the importance of market segmentation on interbank trading and pricing. Some studies look at the effect of the new regulatory framework initiated by central banks and how it affects trading on the interbank market (Afonso et al., 2011; Copeland et al., 2014; Gorton and Metrick, 2012; Klee et al., 2016). The authors document how trading intensity decreased after the financial crisis of 2008, as a result of central bank intervention, an asset purchase program, and new regulations on bank liquidity management.

However, Adrian et al. (2013) look at the effect of new regulations on leverage and the risk-aversion of broker dealers. We add to this array of studies and analyze how the new regulation and the introduction of a bank levy affect the behavior of the interbank market. We argue that higher tax burden for banks might decrease bank incentive to become involved in the interbank market, which might intensify market frictions. This might especially happen at the period approaching levy payment. Such a situation might be very dangerous in times of higher uncertainty or liquidity shock, as getting funding will be more difficult to obtain, if not impossible. We also argue that the term structure of transactions might change. Banks might be more reluctant to enter into long-term transactions as they will increase the tax burden. Instead, they will prefer to rely on short-term funding, which is more sensitive to market frictions and, therefore, higher risk.

Moreover, we contribute to the debate on interbank rates behavior and their anomalies. Generally, studies show that interbank rates tend to behave cyclically. For example, Baglioni and Monticini (2008b, a) show that the overnight rate displays a clear downward pattern throughout the trading session, with banks borrowing at a premium early in the morning and at a discount at the end of the day. Campbell (1987), Lasser (1992), Rudebusch (1995), Hamilton (1996), Balduzzi et al. (1997), Lee (2003), Mancini (2015), and Renne (2016) find that interbank rates increase at the end of the reserve requirement period, at the beginning of the week, and after the holidays. More recently, Munyan (2015) and Duffie and Krishnamurthy (2016) document the effect of end of accounting periods on financial reporting dates. Furfine (2000), Prati et al. (2000), and Gaspar et al. (2004) document that, in a period of increased demand for funds, market rates become more volatile as trading on the interbank market increases. Also, a greater market segmentation increases price volatility, as suggested by Colliard et al. (2016) and Koijen et al. (2017). In a similar vein, Gaspar et al. (2004) present

that dispersion in prices on the money market increases depending on the period and consequent demand for funds. However, central bank intervention, as well as greater aggregate reserves in the banking market, decrease the price volatility of monetary market funding (Bech and Monnet, 2016; Afonso and Lagos, 2015, Klee et al., 2017). Interestingly, Bech and Klee (2011) document that central bank liquidity injection into the banking sector has put downward price pressure on the federal funds market. Recently, some studies looked at how regulatory changes on the interbank market, such as monetary policy implementation, and operational framework of the interbank market, such as interest on reserves or incentives for banks to lend at rates below the reserve interest, affect pricing of money market funding (Afonso et al., 2011; Gorton and Metrick, 2012; Yoldas and Senyuz, 2015; Klee et al., 2016). In general, these studies show that there is a pass-through effect of new regulatory changes into interbank prices stabilizing the volatile prices. We add to this debate and verify whether bank levy introduction intensifies the end of period effect on the money market, and how it affects the volatility and dispersion of prices in the unsecured market. We argue that, as bank levies shift the trade into short-term funding, they might intensify volatility and dispersion of prices in the short term, while flattening the effects in the long term.

Finally, we add to the debate on the credibility of IBORs as a real cost of capital. Hartheiser and Spieser (2010), Snider and Youle (2010) Abrantes-Metz et al. (2011) and Liu, et al. (2014) document that banks either keep their quotes down to mislead the market about their financial positions, or they want to profit from trading. Mollenkamp and Whitehouse (2008), Hartheiser and Spieser (2010), Snider and Youle (2010) and Mielus (2018) look at panel banks' submissions and estimate the clustering of LIBOR submissions. The authors show that several banks create a cartel and keep the fixing down to get cash at a low rate, especially in a tense market. Thus, these studies argue that the LIBOR fixing process should be reformed as banks

use it for their own interest (Duffie and Stein 2015, Mielus 2017). We contribute to the discussion, arguing that banks will manage their liquidity in a way not to be affected by tax. This should be reflected in a price that might include such behavioral elements. Consequently, we argue that the quoted rate will not reflect the true cost of capital on the market.

The interbank market plays a key role in banks' liquidity management by allowing financial institutions to exchange capital, which helps to overcome liquidity shocks. It is also crucial for banks to cope with liquidity fluctuations and to meet reserve requirements (Allen et al, 2014). Thus, interbank dynamics influence the whole economic system (Hatzopoulos et al. 2015). However, the interbank rates are the basis for the borrowing costs of households and firms, as well as a settlement reference rate for hundreds of trillions of dollars' worth of interest rate derivatives (Hatzopoulos et al. 2015, Intercontinental Exchange Group, 2016; Gallitschke et al. 2017). Therefore, their credibility should be of the highest importance for policymakers and regulators.

To test our research questions, we use the novel database covering the volume and number of interbank transactions on the Polish interbank market. To this end, we use daily data from interbank deposit transactions, their number, as well as their volume, with different maturities of one day (1D), one week (1W), and longer maturities (Term). We estimate the model following the convention of Hautsch (2003) and Bauwens and Hautsch (2006) for the periods between January 4, 2014 and October 31, 2017. This represents the period before and after the introduction of a bank levy, which happened in Feb. 2016. We then test how the introduction of the bank tax has affected the liquidity of the market, as well as the number of transactions. To this end we run the regression for two different sub-samples and use equality tests to verify whether differences between these two periods are observable. In line with the existing

literature, we additionally check the seasonality effect, i.t., whether there is a change in bank behavior at the end of month when the tax is due. In the second part of the study, we also analyze how bank levy affects bank quotations. More specifically, we ask the question of how banks incorporate bank levy into their quotations. To this end, we use the volatility in bank quotation, defined as the annual standard deviation on daily differences of fixing for single maturity. We also test quote dispersion measured as the difference between daily maximum and minimal quote rates for individual maturities. Using statistical tests, we then check whether the difference in volatility and dispersion of bank quote rates has increased or decreased after the introduction of a bank levy, and how they were correlated with trade intensity.

Our study presents strong statistical evidence that the introduction of a bank levy has significantly affected the functioning of the interbank market, questioning its efficiency, as well as the credibility of money market rates. More specifically, our data shows that the introduction of a bank levy has diminished the intensity of trading and the volume of transactions on the interbank market. Particularly, the effect is observable at the end of the month when the bank levy is due. Our evidence proves that the interbank money market significantly shrinks, as banks do not want to increase the tax burden. We argue that it might be very dangerous, especially in periods of increased risk-aversion. Furthermore, our results also document that the term structure of transactions has significantly changed. The bank levy has reduced the maturity of transactions following the argument that banks try to manage their liquidity in a way that does not affect the tax burden. We also observe statistically significant changes in panel bank quotations. Our results seem to suggest that the volatility of bank quotes for term transactions significantly decreased because of reduced trading after bank levy implementation. This effect is especially observable for transactions with maturities longer than 2W. Again, this seems to confirm that bank liquidity management is matched to the period when tax is not due. These

conclusions have also been supported by the dispersion measures. Our results indicate that there is a significantly higher dispersion after the implementation of the bank levy for ON, TN and 1W transactions – short-term transactions. The banks compete for these funds as they allow them to avoid a tax burden and, thus, use short-term maturity funding to manage their liquidity. Consequently, we can conclude that money market rates are behaviorally biased, which questions its credibility for the true cost of capital.

This paper is organized as follows. Section 2 describes the interbank market in Poland and the specifics of the bank levy, while Section 3 presents and develops the hypothesis. Section 4 provides the data description and discusses our model. Section 5 provides our results and Section 6 concludes.

2. Bank levy and interbank market in Poland

On 15th January, 2016 Polish President has signed the Act introducing a bank levy. The Act came into force on the 1st February 2016. The new tax covers most financial institutions operating in Poland as: domestic banks, insurance companies as well as branches of foreign banks. The tax is collected on a monthly basis (beginning from February 2016) and the tax rate is set at the level of 0.0366% of the asset base. Importantly, the bank levy has to be paid on the whole banking asset including the interbank transactions, however excluding the government bonds.

The Polish banking sector is prevailingly financed by deposits collected from non-financial institutions. Interbank market is limited to short-term maturities and the main instruments

traded are unsecured deposits and foreign exchange swaps. Repo market is weak due to infrastructural, legal and tax reasons (NBP, 2017).

WIBOR is the interest rate at which Polish banks are willing to lend money to another banks for a specific term. It is accompanied by WIBID that is the interest rate at which banks are willing to borrow cash. The difference between WIBID and WIBOR is a regular bid-ask spread and is limited by the code of conduct (GPWB, 2017). The rate is quoted by 11 banks (so-called money market dealers, selected by the NBP and invited by the administrator of the index), every business day, at 11 am. The trimmed average of the quotation is the WIBID or WIBOR rate. Contributors are obliged to trade at a minimum size and at the defined spread in a 15 minutes window after the fixing is announced (GPWB, 2017). Thus, WIBID and WIBOR constitute an important expert judgment. However, it is rather a declarative rate, as the transactions might be settled at different prices after this time.

3. Hypothesis Development

The current literature shows that banks strongly react to changes in tax rates. In particular, there are studies documenting the ways banks try to avoid higher tax burdens by smoothing their income or shifting their profits (Demirguc-Kunt and Huizinga, 1999; 2001; Chiorazzi and Milani, 2011, Rydqvist et al., 2014; Merz and Overesch, 2016). However, the studies on bank levies document that their introduction has reduced bank exposure on the interbank market, and thus bank leverage (Devereux et al., 2015; Buch et al., 2014). In addition, Buch et al. (2014) also show that levy introduction in Germany has translated into lower loan volumes. Following these studies, we state our first hypothesis that:

H1: The introduction of a bank levy reduces interbank trading as banks are discouraged from entering into transactions with higher tax burdens. More specifically, we argue that volume, as well as the number of transactions, should decrease after the introduction of a bank levy.

The literature on bank liquidity shows that banks try to manage their liquidity efficiently. Gasper et al. (2004) document that banks keep an average liquidity buffer during a maintenance period, which increases at the end of the period. Moreover, banks with greater access to capital markets and more frequent cash flows prefer to have lower liquidity ratios (DeYoung and Jang 2016). Larger banks also tend to resort to internal financing as a way of building a capital buffer (Almeida et al. 2004; Aspachs et al. 2005). Consequently, the studies show that banks try to actively manage their liquidity to optimize the cost of a liquidity buffer. Following these studies, we argue that:

H2: The introduction of a bank levy shortens the maturity of interbank transactions as banks seek to avoid tax burden. This is because banks try to manage their liquidity in a way that balances their liquidity needs and tax burden. The effect is likely to intensify at the end of month when the bank levy is due.

We also argue that the introduction of a bank levy is likely to affect interbank rates, as well as the way in which banks quote them. Many researchers report that bank dealers tend to cyclically quote their rates. For example, Cambell (1987), Lasser (1992), Hamilton (1996), Furfine (2000, 2001, 2002), Palobini (2003), Gaspa et al. (2004), and Acharya and Merrouche (2013) show that interest rates increase when banks need to maintain higher reserves as required at the end of a reserve period, the beginning of a week, or after the holidays. Higher payment activity

raises transaction demand for liquidity, as well as precautionary demand for liquidity. Thus, the volatility of bank quotes increases. In turn, when banks desire less liquidity, they tend to quote at lower rates compared to other periods. Similarly, Baglioni and Monticini (2008b, a) show the presence of an intraday term structure of interest rates, as the overnight rate displays a clear downward pattern throughout the trading session, with banks borrowing at a premium early in the morning and at a discount at the end of the day. Therefore, we state that:

H3: Since bank levy increases the tax burden for banks, the trade intensity increases and thus the volatility of rates is lower. This is especially the case at the end of the month when bank levy is due. In a similar vein, we should see a lower price volatility for long-term transactions, as they will all incur tax burden.

The recent studies show that dispersion of bank quotes is higher in periods of increased demand for funds (Klein, 1971; Donaldson, 1992; Ongena and Popov, 2011). Moreover, the studies also document that higher price dispersion exists when there is a higher volume of trading in the market (Furfine, 2000; Gasper et al., 2004; Kiu et al., 2014, Klee et al., 2017). Consequently, we formulate our next hypothesis:

H4: Tax levy decreases the dispersion of interbank rates as a result of reduced bank exposure on the interbank market. In particular, we should notice this effect at the end of the month, as well as for transactions with longer maturities. In turn, as short-term transactions become more desirable, the increased trading volume will lead to higher dispersion between bank quotes.

4. Data and methodology

4.1. Data source and description of our variables

To verify our hypotheses on how a levy on bank assets affects the interbank market, we use the sample of banks in Poland over the period 2014-2017. More specifically, we take data on the volume and number of interbank deposits with maturities of one day (1D), one week (1W) and longer than one week (Term). We use the daily data within the period 2014-01-05 and 2017-10-31, which gives us 967 observations in total. This data has been kindly provided by Gdansk Institute of Market Research, the operator of the Money Market Monitoring System[1]. As a second type of data, we use quotes of money market dealers with the following maturities: ON, TN, 1W, 2W, 1M, 3M, 6M, 9M, 1Y. The data have been obtained from Thomson Reuters.

To test our hypothesis into how bank levy has affected the panel bank fixing, we calculate volatility, along with dispersion in panel bank quotations for a single available maturity. We define the volatility of interbank deposit rates measured as the annual standard deviation of daily differences for bank fixing for each maturity. Moreover, we analyze the dispersion as a range between the maximum and the minimum quotation among the panel banks for a given day. We calculate the ranges separately for each maturity. All the measures have been calculated by the authors based on Thomson Reuters information.

The existing literature documents that interbank rates react to calendar effects. Therefore, we have cleaned up our dataset from these effects to make sure that our bank levy effect is not harmed by any of the calendar dates. According to the existing literature, the interbank rates

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[1] Money Market Monitoring System is a data warehouse of negotiable PLN deposits collected by local banks from various client segments since 2012, more information: www.smrp.pl.

change from the effect of: the final day of the reserve maintenance period, which usually results in increased volatility of overnight rates and in significant divergence from CB reference rates, end of quarter and end of year, fiscal payment day (15th day for social security payments, 20th day for PIT and CIT payments, and 25th for VAT payments), as well as the day when the bank levy is due – the last working day of each month. We exclude from our database all these dates, except for the day of the bank levy, as well as the reserve maintenance period. Table 1 presents the descriptive statistics. These results serve as a starting point for empirical model development.

[Table 1]

The data on interbank trading suggest that short-term transactions of up to 1W are the most popular, whereas longer ones are of limited importance. Moreover, we also see that our bank quotes data do not suffer from unit root problems, and, therefore, are stationary, as suggested by ADF-stat. These conditions allow us to draw further conclusions and provide further analysis of our research problem. Interestingly, our daily ranges of panellist quotations follow two distinct patterns. The first is a quite homogeneous group for transactions up to 1W (except for TN), and the second shows similar characteristics as for 1M and longer. At the same time, we see significant difference for quotes on transactions 2W and TN. One of the reasons why see different pattern of quotes for these transactions is because of limited popularity of such transactions term and consequently the limited trading on the market.

4.2. Methodology

To test our main research question of how bank levy affects the interbank deposit market, we use three distinct models, depending on the hypothesis under study. More specifically, we test how the introduction of a bank levy affects the liquidity of the interbank market, as well as the

term of transactions. Then, we analyze how the new bank levy affects the panel bank quotations and their patterns.

Following results of the unit root tests presented in Table 1, which indicate stationarity of the time series under study, we use a general autoregressive model setup, where the number and volume of transactions are used for trade intensity. Consequently, we test the first and second hypotheses, that is, how a bank levy affects the volume, number, and the term structure of transactions by estimating the model, following the convention of Hautsch (2003) and Bauwens and Hautsch (2006):

$$y_{ijt} = \beta_0 + \beta_1 y_{ijt-1} + \lambda d_{ij} + \varepsilon_{ijt} \text{ where } \varepsilon_{ijt} \sim iid(0,1) \tag{1}$$

where y_{ijt} represents the trading intensity, like volume or number of transactions of the bank i at time t for maturity j, where j is either 1D or 1W. As the tax is due at the end of the month, we include the dummy variable d_{ij}, which equals 1 for the last trading day or last trading week, and 0 for all other periods. We run our regressions with a dummy variable only for the short-term transactions, that is, 1D and 1W, as only these transactions will be used by banks to effectively manage the tax burden. For transactions with longer maturities, for example one month, we assume that all days in the data sample will be affected. Thus, our model will look as follows:

$$y_{imt} = \beta_0 + \beta_1 y_{imt-1} + \varepsilon_{imt} \text{ where } \varepsilon_{imt} \sim iid(0,1) \tag{2}$$

where m indicates maturities longer than 1W.

We estimate our models for two sub-samples, that is, for the period before the implementation of the tax covering data from January 4, 2014 to January 31, 2016, and after the implementation of the bank levy, from February 1, 2016 to October 31, 2017. We then analyze whether the calendar effect of interbank trading, measured by the λ coefficient, is statistically evident before and after the bank levy introduction. To this end, we perform the statistical test for the two above specified models:

$$H_0: \lambda = 0 \; vs. \; H_1 \lambda < 0 \; and \; H_0: \beta_0 = 0 \; vs \; H_1: \beta_0 < 0$$

We then test whether the effects on two sub-samples are statistically different between two sub-periods: before (bt; before tax) and after (after tax) the introduction of bank levy:

$$H_0: \lambda^{bt} = \lambda^{at} \; vs: H_1 \; \lambda^{bt} > \lambda^{at} \; and \; H_0: \beta_0^{bt} = \beta_0^{at} \; H_1: \beta_0^{bt} > \beta_0^{at}$$

In order to make an inference about the regression coefficients between two subsamples, we adopt Fisher's (1970) methodology to use Welch's t-test of unequal variances, that is, a standard two sample location test typically used to verify a hypothesis that two populations have equal means. This test generally works well and gives more reliable results when samples, as in our case, have unequal variances and an unequal sample size, and are considered non-overlapping.

The test statistic can then be formulated in the form of:

$$t = \frac{\beta_i^1 - \beta_i^2}{\sqrt{\frac{D^2(\beta_i^1)}{T_1} + \frac{D^2(\beta_i^2)}{T_2}}} \sim t(v)$$

where T_1, T_2 are sample sizes, β_i^1, β_i^2 are parameter estimates in the first and second sample respectively, and $D^2(\beta_i^1), D^2(\beta_i^2)$ represent coefficient variance estimates. The degrees of

freedom v associated with variance estimates are approximated via the Welch-Satterthwaite equation. To deal with the heteroskedasticity of the data sample, we have used the approach of Moreno, Torres, and Casella (2005).

To verify the third and fourth hypotheses about how bank levies affect the interbank rates, the models (1) and (2) are used to measure money rate volatility by share of price changes. We then apply the t-test, which allows us to analyze whether the volatility and dispersion of quotes between banks is statistically different before and after the bank levy introduction. Similarly, as for trading intensity, we check our effect for transactions for individual maturities.

The test statistic can be then formulated in the form of a Welch statistic:

$$t = \frac{\sigma^1 - \sigma^2}{\sqrt{\frac{D^2(\sigma^1)}{T_1} + \frac{D^2(\sigma^2)}{T_2}}} \sim t(v)$$

where this time T_1, T_2 are sample sizes, σ^1, σ^2 are sample standard deviations in the first and second sub-samples respectively, and $D^2(\sigma^1), D^2(\sigma^2)$ represents sample dispersions.

5. Results

Tables 2 to 5 present the results concerning the link between bank levy and the functioning of the interbank money market.

5.1. The effect of bank levy on trade intensity and term structure of transactions – Hypothesis (1) and (2)

Table 2 presents the results of testing our hypotheses on the effect of introduction of bank levy on trade intensity on the interbank market. To this end, we regress the model described in the Methodology section to see whether the introduction of a bank levy has changed the number and the volume of interbank transactions. More specifically, we check whether banks' behavior has changed at the times when tax is due. We expect that tax effect intensifies the calendar effect in bank behavior, that is, the volume and number of transactions is lower at the end of month compared to other periods. In addition, we also analyze how the term structure of transactions has been affected by the levy introduction. Consequently, we present the regression results for transactions with different maturities of 1D, 1W and Term. We hypothesize that banks will try to avoid transactions that increase their tax burden. Thus, at the end of month – at Tax Day - we should see a decrease in any type of transaction.

Table 2 presents the results for the calendar effect. More specifically, we test whether we can see the effect that trading intensity has on the interbank market, whereby it is lower at the end of month due to increased tax burden. Consequently, we are interested in the λ coefficient for ON and TN at the last trading day in each month, for 1M at the last trading week of a month, while for transactions longer than one month it is assumed that all days in the data sample are affected, that is, there should be a lack of calendar effect.

In the further analysis we run the test of equality for coefficients, whether the number and volume of interbank transactions before and after the introduction of the bank levy have statistically changed. We also check how the term structure of transactions has changed. We hypothesize that the tax levy has shortened the nature of transactions, and thus the volume and number of transactions with longer term periods have decreased. Table 3 presents the results of this test. As stated in the Methodology section, we explicitly test the equality of coefficient

estimates when models are separately estimated for the period before and after bank levy introduction. We use a variant of the t-test of Moreno, Torres, and Casella (2005). The estimated models have an autoregressive (AR(1)) form with tax calendar effect for short maturities included in the form of dummy variables.

[Table 2]

[Table 3]

The results from Table 2 allow us to conclude that the introduction of a bank levy has a negative effect on the volume and the number of transactions. In particular, we find that the volume and number of transactions is statistically lower on the last day of the month when the tax is due. This result confirms the calendar effect in bank behavior, as we notice that interbank trading tends to especially reduce on the last working day of the month when the tax is due (Hamilton, 1996, Bartolini et al., 2001). Interestingly, this effect is especially observable for 1D and 1W. However, this effect could not be determined for longer maturities. This is because all longer-term transactions are tax affected, however short-term transactions are affected only when they correspond with the period of tax due. Interestingly, we can assign this effect to behavioral aspects. Banks seem to manage their liquidity in a way that the taxed asset is minimized at the end of the tax period. Thus, banks tend to reduce all transactions at the end of month.

Table 3 tends to confirm our hypothesis that the introduction of the bank levy has decreased the liquidity of the interbank market as compared to the periods before the introduction of bank levy. The number and the volume of transactions is statistically lower in the second sub-sample. This effect is clearly evident for 1D and 1W at the last working day of the month. So, this confirm that the bank levy increases the cyclicality of the short-term interbank market. For Term (longer maturity), we find that the volume is significantly lower after the introduction of the bank levy than it was before the introduction. More importantly, it is independent from the

calendar effect. Thus, we conclude that the introduction of a bank levy has shortened the term structure of interbank transactions.

5.2.Volatility of fixings after inclusion of bank levy - Hypothesis 3

In this sub-section, we show how bank levy affects the volatility of interbank rates. In line with our hypothesis, as well as existing studies, we expect that volatility after tax introduction should go down as banks will be more reluctant to use the interbank market for their liquidity management. Such an effect should be especially visible for long-term transactions.

Table 4 presents the results for equality of standard deviations in bank quoting between two sub-periods: before and after bank levy introduction. For the purposes of our study we use the Welch t- test for equality of variances.

[Table 4]

Based on the results in Table 4, we can conclude that the volatility of quotes has been statistically and significantly reduced after tax introduction. This effect is especially visible for all maturities above 2W. However, for terms up to 1W we cannot find such an effect. The presented results lead to two conclusions: (1) for short-term deposits (up to 2W) the volatility of rates is unaffected by tax implementation; (2) for long-term deposits (1M and more) the volatility of quotes is statistically different than before levy implementation. The results are very interesting, however, and seem to confirm the existing studies. The reduced demand for long-term funds decreases the volatility of prices (Michaud and Upper, 2008; Christensen et al, 2009). Yet, pricing of short-term transactions that are not tax affected has not significantly changed compared to the period before the bank levy was introduced.

5.3. Dispersion in quotations after inclusion of bank levy – Hypothesis 4

In this sub-section, we show how bank levy affects the dispersion of bank quotes for the interbank market. We test whether the dispersion has increased or decreased after the introduction of the bank levy. In line with the literature, we hypothesize that dispersion of quotes for short-term transactions should increase, while it should decrease for long-term transactions. Table 5 presents the test results for the equality of dispersions, that is, the difference between maximum and minimum panelist quotations in two subsamples before and after bank levy introduction. Similarly, as in the previous section, we estimate the AR(1) model with periodic dummies associated with parameter λ to control for calendar effects. For transactions with longer-maturities we again assume that all days in the data sample are affected, and therefore there is a lack of calendar effect. In order to verify the hypothesis under study, the Moreno, Torres, and Casella (2005) t-test on coefficient estimates is applied. In order to avoid bias in the results resulting from increased volatility for shorter periods, we exclude the final day of the reserve maintenance period, end of quarter, end of year, and fiscal payment days from our subsample before running the regressions. The last column presents the results of the equality test, which is our main interest.

[Table 5]

In general, our results indicate that there is a significantly higher dispersion of prices after the implementation of the bank levy for short-term transactions of ON, TN, 1W, and 2W maturities. We can especially observe that this dispersion increases on the last working day of the month, regardless of whether the requirement reserve is due or not.[2] In turn, for longer maturities of above 1M, we see that dispersion decreases. The results are in line with the calendar effect of

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[2] We control for reserve requirement day as it in may influence the value of quotation on interbank money market. For example: Furfine (2000) shows that specific liquidity needs on days with large payment volumes determine the intra maintenance period demand for reserves; Bech and Monnet (2013) find that as reserves expand, market volume decreases; Gaspar et al. (2004) shows an increase in volatility and dispersion of rates towards the end of the reserve maintenance period.

interbank rates (see Barrett et al. 1988 as well as Saunders and Urich 1988; Spindt and Hoffmeister 1988; Lasser 1992; Ayuso et al. 1997; Cassola et al, 2003; Alonso and Blanco, 2005; Nautz and Offermanns, 2008). Moreover, the results also confirm that in markets with tiny trading volume, the dispersion of prices is small as there is almost no trading on the market. Therefore, it is difficult to estimate the equilibrium price and true cost of borrowing (Kiu et al., 2014).

6. Conclusion

Efficient functioning of the interbank market is crucial for financial stability. Therefore, regulators should care about reducing frictions on the interbank market. Market structure or institutional features that intensify frictions on the interbank market should be carefully controlled and corrected, where possible.

With our study, we evaluate the effect of bank levy introduction on the functioning of the interbank market. More specifically, we test how bank levy introduction affects trading intensity, as well as the pricing of liquidity. To this end, we analyze the transactions and quotes of dealer banks in Poland between 2012 and 2017. Poland is a great testing ground for our research problem as regulators do not exclude the interbank transactions from tax burden. Consequently, this allows us to investigate how the institutional features might affect the functioning of the interbank market. This topic is new in academic literature, as the interbank market used to be as one of the least regulated market. Yet the new regulatory changes might impose a higher burden on its functioning. Thus, it is important to see how the market reacts to such changes. Moreover, it provides additional evidence on creditability of interbank rates as a benchmark for valuation of financial instruments – the debate which is new and extremely important, however difficult to empirically investigate.

Our results seem to be very promising. Firstly, we document that bank levy significantly affects the volume and the number of interbank transactions. More specifically, we show that trading on the interbank market becomes more cyclical and banks try to manage their liquidity in a way to minimize tax payment. Therefore, we see a statistical and significant reduction in trading volume at the end of the month, as compared to the period before tax introduction. For longer-term transactions, we see a significant reduction in trading intensity for the whole period. Our results also indicate that maturity of transactions significantly shortened, as compared to the period before the levy was introduced.

We also notice that bank levy negatively affects money market pricing. We see that, while volatility of quotes for short-term transactions has not significantly changed, it has decreased for long-term transactions. This is because trading for term transactions has almost disappeared. This further questions the credibility of IBOR as a benchmark rate for valuation of financial instruments. Furthermore, our results also indicate that price dispersion has increased for short-term transactions, while it has decreased for term ones. This is in line with the existing studies, which illustrate that, on markets and periods with increased demand for funds, the price dispersion increases, while on tiny markets, it is almost flat (Kiu et al., 2014).

Our regression results call for a re-thinking of the design of the bank levy and/or IBOR as benchmarks for financial transactions. The current frictions might especially "explode" in a period of greater uncertainty, decreased aggregate market liquidity, or in a crisis leading to the collapse of many institutions. Moreover, an intensification of short-term funding, leading to the collapse of many institutions during a crisis, is not in line with the regulatory changes imposed after the financial crisis. In fact, several efforts have been undertaken to decrease short-term

funding of banks (see for example, Claessens and Kodres, 2014). It seems to be the case that a bank levy might limit these efforts. Finally, the behavioral element in money market pricing raises a concern on the credibility of IBOR as a true cost of capital, and therefore endangers the stability of financial markets in countries where IBOR constitutes a benchmark for the majority of financial instruments.

Appendix

Table 1. Descriptive statistics for the dataset used in our study

	Vol. 1D	**Vol. 1W**	**Vol. Term**	**No.1D**	**No.1W**	**No. Term**
			Number and volume of Interbank transactions			
Minimum	5,28E+08	0	0	10	0	0
Maximum	8,04E+09	2,45E+09	1,66E+09	482	249	214
1. Quartile	3,68E+09	2,07E+08	3,70E+07	365	64	16
3. Quartile	5,07E+09	4,30E+08	1,44E+08	424	101	45
Mean	4,42E+09	4,18E+08	1,27E+08	364,6914	89,1703	37,9536
Median	4,38E+09	2,78E+08	6,71E+07	390	78	24
Stdev	1,03E+09	3,79E+08	1,66E+08	85,8534	40,7638	36,0717
Skewness	0,2570	2,4600	3,2800	-1,247713	1,45542	2,1065
Kurtosis	0,4990	6,0900	14,8000	0,736427	2,0196	4,5132
ADF stat.	-3,5315	-17,4535	-21,0225	-5,3389	-9,7411	-15,8659

	ON	**TN**	**1W**	**2W**	**1M**	**3M**	**6M**	**9M**	**1Y**
			Interbank interest rates fixings changes (results given in percentage points)						
Minimum	-0,8900	-	-0,2800	-0,2600	-0,2400	-0,1600	-0,1300	-0,1300	-0,1300
Maximum	0,7500	0,6500	0,1600	0,1100	0,1100	0,0800	0,0700	0,0700	0,0600
1. Quartile	-0,0100	-	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
3. Quartile	0,0100	0,0100	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Mean	-0,0011	-	-0,0010	-0,0010	-0,0010	-0,0009	-0,0009	-0,0009	-0,0009
Median	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Stdev	0,1184	0,0706	0,0164	0,0131	0,0116	0,0083	0,0076	0,0076	0,0074
Skewness	0,5621	0,5000	-8,7110	-	-15,3518	-11,7579	-9,8812	-8,9514	-8,8913
Kurtosis	13,967	19,272	174,5235	322,809	328,483	234,4231	179,7709	158,4640	148,3567
ADF stat	-	-	-26.9617	-	-29.2925	-25.5157	-23.6828	-23.9193	-22.4473

	ON	**TN**	**1W**	**2W**	**1M**	**3M**	**6M**	**9M**	**1Y**
			Daily ranges of panellist quotations						
Minimum	0,0200	0,0500	0,0200	0,0100	0,0000	0,0100	0,0100	0,0100	0,0100
Maximum	0,4900	1,1000	0,4900	0,1800	0,1300	0,1400	0,1600	0,1800	0,1800
1. Quartile	0,0500	0,1000	0,0500	0,0400	0,0200	0,0300	0,0200	0,0200	0,0200
3. Quartile	0,0900	0,1500	0,0900	0,0800	0,0600	0,0600	0,0600	0,0700	0,0700
Mean	0,0726	0,1353	0,0726	0,0574	0,0461	0,0454	0,0441	0,0455	0,0474
Median	0,0700	0,1200	0,0700	0,0500	0,0400	0,0400	0,0400	0,0400	0,0400
Stdev	0,0379	0,0856	0,0379	0,0271	0,0272	0,0252	0,0281	0,0282	0,0294
Skewness	3,8455	4,6124	3,8455	0,6828	0,6464	0,9626	0,7768	0,8873	0,8998
Kurtosis	27,666	33,663	27,6662	0,5325	-0,0714	0,0960	-0,1329	0,6431	0,3894
ADF stat.	-8,4659	-	-2,7473	-2,5433	-5,2710	-2,5680	-2,5680	-5,2710	-2,5830

Source: Own calculations.

Table 2. The results for calendar effect in trading intensity on interbank market after tax inclusion

	1D Volume				**1D No.**			
	Estimate	Std. error	t-Stat	p-value	Estimate	Std. error	t-Stat	p-value
β_0	2.80E+09	1.77E+08	15.8600	<0.0001	414.1977	18,0319	22.9700	<0.0001
β_1	4.27E-01	3.66E-02	11.6700	<0.0001	-0.0617	0.0458	-1.3490	0.1780
λ	-2.33E+09	1.79E+08	-12.9700	<0.0001	-118.1249	18.7348	-6.3050	<0.0001
	1W Volume				**1W No.**			
	Estimate	Std. error	t-Stat	p-value	Estimate	Std. error	t-Stat	p-value
β_0	3.39E+08	1.78E+07	19.0520	<0.0001	88.19283	4.0564	21.742	<0.0001
β_1	-6.29E-02	4.67E-02	-1.3480	0.1783	-0.07255	0.0463	-1.567	0.1177
λ	-1.08E+08	2.65E+07	-4.0580	0.0001	-21.92128	4.1499	-5.282	<0.0001
	Term Volume				**Term No.**			
	Estimate	Std. error	t-Stat	p-value	Estimate	Std. error	t-Stat	p-value
β_0	9.49E+07	8.17E+06	11.6060	<0.0001	2.91E+01	2.0500	14.2120	<0.0001
β_1	-6.36E-02	4.75E-02	-1.3390	0.1813	-0.0624	0.0475	-1.3140	0.1895

Source: Own calculations. t-stat. represents values of significance test for tax-affected variables. P-values are rounded up to four digits. "<0.0001" indicates machine precision because the value of computed test statistics lies in a very narrow probability area in a t-tail.

Table 3. The results for equality test of regression coefficients for volume and number of transactions for the period of before and after the introduction of bank levy

Var.	Estimate	Before Tax		After Tax		Diff. in parameter estimates	Test results	
		Estimate	Std. error	Estimate	Std. error		t-stat.	p-value
				Volume				
1D	β_0	2.06E+09	1.59E+08	2.80E+09	1.77E+08	7,46E+08	70.3000	<0.0001
	β_1	5.17E-01	3.72E-02	4.27E-01	3.66E-02	-9,02E-02	-40.3000	<0.0001
	λ	-7.17E+08	1.66E+08	-	1.79E+08	-1,61E+09	-137.0000	<0.0001
1W	β_0	6.10E+08	3.06E+07	3.39E+08	1.78E+07	-2,71E+08	-170.0000	<0.0001
	β_1	-1.61E-01	4.32E-02	-6.29E-	4.67E-02	9,82E-02	33.9000	<0.0001
	λ	-7.56E+07	5.20E+07	-	2.65E+07	-3,21E+07	-15.7000	<0.0001
Term	β_0	1.64E+08	1.04E+07	9.49E+07	8.17E+06	-6,87E+07	-115.0000	<0.0001
	β_1	-2.53E-02	4.37E-02	-6.36E-	4.75E-02	-3,83E-02	-12.9000	<0.0001
				No.				
1D	β_0	415.95609	14.9656	414.1977	18.0319	-1,76E+00	-0.0930	<0.0001
	β_1	-0.18486	0.04194	-0.0617	0.0458	1,23E-01	41.8000	<0.0001
	λ	-85.9517	15.8731	-	18.7348	-3,22E+01	-35.3000	<0.0001
1W	β_0	109.5878	4.7402	88.19283	4.0564	-2,14E+01	-74.5000	<0.0001
	β_1	-0.102	0.0434	-0.07255	0.0463	2,95E-02	10.4000	<0.0001
	λ	-10.5639	5.1285	-	4.1499	-1,14E+01	-45.1000	<0.0001
Term	β_0	39.18674	2.55177	2.91E+01	2.0500	-1,01E+01	-67.7000	<0.0001
	β_1	0.16268	0.04318	-0.0624	0.0475	-2,25E-01	-76.3000	<0.0001

Source: Own calculations. t-stat. represents values of significance test for tax-affected variables. P-values are rounded up to four digits. "<0.0001" indicates machine precision because the value of computed test statistics lies in a very narrow probability area in a t-tail.

Table 4. Test results for equality of standard deviations in subsamples for the period before and after the introduction of bank levy

Maturity	Before tax	After tax	Welch t-test	
	St.dev estimate	St.dev estimate	t-stat	p-value
ON	0.0443	0.0590	-2.1101	0.9824
TN	0.0247	0.0387	-3.3607	0.9996
1W	0.0037	0.0050	-1.3041	0.9037
2W	0.0018	0.0022	-2.0067	0.8843
1M	0.0026	0.0003	3.4192	0.0003
3M	0.0026	0.0002	5.0319	<0.0001
6M	0.0028	0.0002	5.9969	<0.0001
9M	0.0029	0.0002	6.1495	<0.0001
1Y	0.0030	0.0002	6.375	<0.0001

Source: Own calculations. The results are rounded up to four significant digits. t-stat. represents values of significance test for tax-affected variables. P-values are rounded up to four digits. "<0.0001" indicates machine precision because the value of computed test statistics lies in a very narrow probability area in a t-tail.

Table 5. Test results for equality of dispersion of panel bank quotations before and after tax introduction.

Var.	Estimates	before tax		after tax		Test results		
		Estimates	std. error	Estimates	std. error	**Diff. in parameter estimates**	test stat.	p-value
ON	β_0	0.0238	0.0025	0.0173	0.0027	-0.0065	-34.0766	<0.0001
	β_1	0.6577	0.0332	0.7765	0.0301	0.1188	46.8234	<0.0001
	λ	0.0022	0.0046	0.0071	0.0065	0.0049	-26.137	<0.0001
TN	β_0	0.0237	0.0026	0.0163	0.0027	-0.0074	-33.3961	<0.0001
	β_1	0.6541	0.0399	0.7755	0.0398	0.1214	46.9766	<0.0001
	λ	0.0024	0.0012	0.0073	0.0021	0.0049	-28.082	<0.0001
1W	β_0	0.0235	0.0025	0.0168	0.0027	-0.0067	39.8877	<0.0001
	β_1	0.6569	0.0332	0.772	0.0303	0.1151	-56.3229	<0.0001
	λ	0.0022	0.0026	0.0031	0.0038	0.0009	-4.1756	0.0002
2W	β_0	0.0058	0.0013	0.0022	0.0011	-0.0036	-46.0183	<0.0001
	β_1	0.8735	0.0229	0.9476	0.0142	0.0741	59.2015	<0.0001
	λ	0.0018	0.0011	0.0019	0.0008	0.0001	1.5913	0.0559
1M	β_0	0.0029	0.0008	0.0026	0.0008	-0.0003	-5.9003	<0.0001
	β_1	0.9084	0.0199	0.9546	0.0131	0.0462	41.7605	<0.0001
3M	β_0	0.0033	0.001	0.0028	0.0007	-0.0005	9.9184	<0.0001
	β_1	0.9391	0.0154	0.9145	0.0193	-0.0246	21.6529	<0.0001
6M	β_0	0.003	0.0009	0.0016	0.0006	-0.0014	28.5653	<0.0001
	β_1	0.9448	0.0144	0.9486	0.0151	0.0038	-4.0345	0.0003
9M	β_0	0.0059	0.0012	0.0014	0.0006	-0.0045	76.1971	<0.0001
	β_1	0.8897	0.0199	0.9615	0.0132	0.0718	-67.0956	<0.0001
1Y	β_0	0.0037	0.001	0.0019	0.0006	-0.0018	34.5579	<0.0001
	β_1	0.9331	0.0157	0.9499	0.0149	0.0168	-17.0093	<0.0001

Source: Own calculations. The results are rounded up to four significant digits. t-stat. represents values of significance test for tax-affected variables. P-values are rounded up to four digits. "<0.0001" indicates machine precision because the value of computed test statistics lies in a very narrow probability area in a t-tail.

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