Discussion Paper No. 07-067

# Price Discovery for Cross-Listed Securities from Emerging Eastern European Countries

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## Non-technical Summary


Cross-border capital flows have grown exponentially since the late 1970s. Having reached a peak of 4752 cross-listed companies worldwide in 1997, this figure has declined to 2787 at the end of 2006. A multitude of competing and complementing hypotheses tries to explain this tremendous growth and rapid decline. The scientific debate is far from having reached a definite conclusion, especially with regards to the effects of listing abroad on the domestic market environment as well as on non-cross-listing peers. More concretely, the question is whether the cross-listing behavior of enterprises from emerging markets affects and contributes to their transmission from opaqueness to transparency.

This study provides empirical evidence verifying the theory of price discovery for Eastern European enterprises based on their cross-listing on Western European exchanges. None of the companies in focus have more than 17 years of business experience, which provides knowledge about young economies. Moreover, they provide historical and political insights that were not available while the Iron Curtain still existed.

The empirical analysis has two dimensions: The evolution of the domestic stock price generates information about the change in the informational environment while the interdependence between different price quotes analyzes informational flows. First, the evolutionary perspective reveals that the stock price information increases by listing abroad since it stimulates competition between different trading locations. Competing market makers or trading systems have to decrease transaction costs in order to attract trading volume, and consequently generate more precise or accurate stock pricing. Second, despite the fact that most of the information is generated and redistributed from the domestic stock exchange, foreign markets contribute to information discovery by generating significant information flows as well.

Moreover, these results provide information on the design of corporate governance. It is interesting to note that the architecture of the market system generates effects on information efficiency. The bid-ask spread is reduced by cross-listings in Frankfurt; informational and liquidity frictions are reduced by listings in London. While Fernandes and Ferreira (2006) show that New York cross-listings have an asymmetric impact in stock price information for enterprises from different countries, my results reveal that different stock exchanges generate different impacts as well and reveal the relative importance of sound disclosure standards and superior information.

# Price Discovery for Cross-Listed Securities from Emerging Eastern European Countries

Marco Wölfle *

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**Abstract**

This study provides empirical evidence verifying the theory of price discovery for Eastern European enterprises based on their cross-listing on Western European exchanges. Despite the fact that the cross-listing behavior of companies has been analyzed very actively since the mid-70s, many competing hypotheses exist, and the debate is far from reaching an end. Cumulative average residuals (CARs) document increased information efficiency after the listing in Frankfurt or London. This result is supported by a stylized microstructure model. To be precise, competition for order flow alleviates informational frictions and reduces dealers' market power. These properties, however, are unevenly distributed among the auction system Frankfurt and the market maker system London. GARCH volatility spillovers strongly support these results and quantify a dominant role for home markets in information discovery. Moreover, they provide information on the relative functions of Frankfurt and London.

Keywords: Cross-Listing, Cumulative Average Residuals, Eastern Europe, Information Discovery, Time Series

JEL-Classification: C32, D53, F36, G14, G15, G30

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# 1 Introduction

Cross-border capital flows have grown exponentially since the late 1970s. In spite of the fact that more than 30 years have passed since Tinic and West (1974) determined lower bid-ask spreads for cross-listed Canadian enterprises, the scientific debate is far from having reached a definite conclusion. Quite the contrary; since then a multitude of competing and complementing hypotheses have emerged. The motivation for this study reaches back to Adler and Dumas (1983). The authors emphasize the analysis of market segmentation as "a key challenge for researchers in international finance." As for Eastern European enterprises, this gap has not yet been conclusively filled.

In the light of a transaction cost perspective or more generally, an informational perspective, cross-listed securities from Eastern Europe are of particular interest for a number of reasons. The analysis of enterprises from former socialist countries provides historical and political insights that were not available while the Iron Curtain still existed. None of the companies in focus have more than 17 years of business experience, which relates to the literature about venture capital. Admittedly, only a minority of Eastern European enterprises engage in high tech industries, but the majority are still very young, inexperienced and exhibit rapid economic growth. Most of the economic activity in these countries is opaque as a result of weak and seldom enforced disclosure standards. This leads to some central questions concerning my article: If and to what extent can a cross-listing contribute to corporate governance? What is the relative importance of external control for price information when foreign analysts, investors, and disclosure standards are involved? I will address these questions from two different angels. First, I will follow the evolutionary perspective (univariate implementation), and second, I will analyze interdependence (dynamic or multivariate implementation).

The first part begins with a replication of Alexander et al. (1988) and analyzes information efficiency relative to the foreign listing. An adequate introduction will be provided by tracking cumulative average residuals, like they did. Unfortunately, the shortcoming of this method lies in its bias to stock market covariation. One should keep in mind that in stock markets with higher covariation ex ante, less additional information is discovered through a cross-listing reflected in lower price effects ex post.

As already mentioned, the implementation of the stylized microstructure model by Domowitz et al. (1998) complements the event-study by analyzing competition for order flow after the cross-listing. The decomposition of variance gives deep insight into the information environment and its evolution, as soon as an enterprise starts to trade at a foreign exchange.

The second main component is devoted to the characteristics of information transmission from one market to the next. Univariate variance decompositions can neither reply questions for dynamic interdependence nor describe information channels between markets. A first step to overcome this disadvantage is made by Jung and Trost (2002), who perform Granger Causality and bivariate cointegration tests on a smaller sample of Eastern European cross-listings in Frankfurt. The aim of this methodology is to simultaneously characterize impacts to all trading prices for one stock. I will use their work as a starting point and extend the dataset to enterprises from all Eastern Europe with cross-listings in Frankfurt as well as in London.

These stocks, traded at three stock exchanges simultaneously, will improve our understanding of objectives for cross-listings in general and stock exchange characteristics in particular. The empirical analysis here is done based on GARCH volatility spillovers to quantify the interdependence appropriately.

All results are convincing and homonymous: Informational efficiency increases by listing abroad. This effect is robust to all empirical procedures, to the number, and to the sequence of foreign listings. In detail, the change in informational efficiency is positive and decreasing in the number of foreign listings. It is interesting to note that the architecture of the market system generates effects on information efficiency. The bid-ask spread is reduced by cross-listings in Frankfurt; liquidity and informational frictions are reduced by listings in London. Admittedly, home markets dominate interdependence among prices, but there is feed-back from foreign information as well. Finally, there is general consensus among all empirical methodologies about the learning effect. Managers who are seeking better price information should apply for a supplementary listing abroad.

Now the question arises: What value is added to the ongoing scientific debate about cross-listings? My results provide empirical evidence on the change in the information environment after listing abroad. Price information increases for enterprises from Eastern Europe that trade at Frankfurt and/or London stock exchange.

While Fernandes and Ferreira (2006) show that New York cross-listings have an asymmetric impact in stock price information for enterprises from different countries of origin, my results reveal that different stock exchanges generate different impacts as well. Fernandes and Ferreira (2006) stipulate that the gain in price information by listing in New York is dependent on the level of market development in the country of origin. Companies from countries with high levels of market development profit greatly while those from countries with lower levels of market development do not gain as much. Given the increased analyst coverage by listing in the U.S.,[1] collecting superior information on the home market becomes more expensive, and insiders are crowded out. For enterprises from less developed countries, the loss in private information collection is not compensated by the rise in marketwide information, leading to a decrease of idiosyncratic return variation for cross-listings in the U.S. From an efficiency perspective, European markets are often perceived as being inferior to American markets. This explains why European stock exchanges attract cross-listings from less developed countries, while high tech enterprises from industrialized countries leave for New York. Obviously, this explains the results of my analysis, which finds increased information efficiency by listing in Frankfurt, and surprisingly in London as well. Despite the fact that the U.K. and U.S. have comparable legal traditions, London cross-listings do not generate the same amount of marketwide information that reduces the incentive to collect inside information like a New York cross-listing would do.

Moreover, both results motivate debate on stock exchange policy. On one hand, they underscore the potential of sound disclosure standards and their enforcement as a way to mitigate insider trade. On the other hand, cross-listings reveal the relative importance of insider and analyst groups in the pricing of securities. In this sense, regulatory bodies may gain by analyzing this event in more detail. As an aspect of the general question of why companies list abroad, my paper follows a straight empirical approach and addresses informational effects on a sample of Eastern European enterprises.

As the two examples from the beginning illustrate, market segmentation was one of the first ideas to have been analyzed by means of cross-listed stock price data. On the empirical side, most of the studies calculate Cumulative Average Residuals (CARs) around the listing date, and determine a pre-listing run-up and a post-listing decline.[2] These empirical findings have

[1] See for example Bailey et al. (2005), Lang et al. (2003), or Lang et al. (2004).

[2] One of the most important event studies comes from Alexander et al. (1988) and is cited in more detail, later in this article. Other important empirical contributions come

motivated contributions from the theoretical side as well. Seminal papers have been written by Stapleton and Subrahmanyam (1977), Errunza and Losq (1985), Eun and Janakiramanan (1986), and Alexander et al. (1987), and explain share price reactions to cross-listing decisions. Merton (1987) and Stapleton and Subrahmanyam (1977) show that more than market segmentation and investment barriers are needed to explain the cross-listing phenomenon. Listing abroad reduces the cost of capital since it alleviates the premium, which has to be paid to local investors for their inability to diversify risk globally.

Another motivation for listing abroad is a higher expected liquidity and price efficiency. The seminal models of Kyle (1985) and Admati and Pfleiderer (1988) are introduced to the cross-listing world by Chowdhry and Nanda (1991), and are developed further by Foucault and Gehrig (2007). All these models assume asymmetric information between informed and liquidity traders. For informed traders it is easier to exploit informational advantages in more liquid markets. Foucault and Gehrig (2007) relate this aspect to the corporate governance literature and model how the enterprise management can learn about their investment decisions from the stock exchange. As Chen et al. (2007) show, more efficient information generates more efficient investment decisions.[3]

A different strand of the literature has evolved on this agency conflict. Clearly, investors profit from decreasing spreads, higher liquidity and information efficiency as well, but it is up to management to decide about the listing location. The seminal Stulz (1999) critique and contributions by Coffee (1999), and Coffee (2002) were the founding fathers of the "bonding" hypothesis and built another bridge to the corporate governance literature. As a starting point, each model uses management's ability to extract private benefits from the firm.[4]

In compliance with Foucault and Gehrig (2007), the central motivation for listing abroad is a specific growth opportunity that can only be pursued by raising capital. Listing abroad is one mechanism to "bond" managers in order to prevent them from expropriating investors since it imposes higher

from Miller (1999) and Foerster and Karolyi (1999).

[3] These results are supported by Doidge et al. (2004), Rajan and Zingales (2004), Lou (2005), Bakke and Whited (2006), among others.

[4] Merton (1987) followed a different idea and analyzed management's market timing for cross-listings.

disclosure standards, improved regulations and a better legal environment, and consequently attracts investors. After having raised capital by complying with higher listing standards, management is able to pursue the enterprise's growth opportunity and has a higher potential for private benefits. Doidge et al. (2004) offer empirical support for the bonding hypothesis and show that the cross-listing premium is higher for firms from countries with poorer investor protection and is positively correlated with future growth opportunities.

However, the bonding hypothesis is still disputed.[5] One reason, for example, is that the SEC pursues a "hands-off" policy for enterprises located outside the U.S. (Siegel (2005)). All things considered, legal enforcement varies significantly differently between domestic and foreign firms around the world and highlights the notion that effective legal bonding is rather difficult to achieve.

This weakness of the legal bonding hypothesis has produced a variety of further articles in which the effects of a cross-listing on the market for corporate control are shown. Evidently, the cross-listing decision is motivated by an increased access to capital in the foreign market. However, the pool of additional capital can only be achieved for enterprises that are able to bear the substantial costs which arise when listing abroad as a consequence of different disclosure standards and legal requirements. Those that remain with a local listing face a higher cost of capital since investors interpret the listing decision as an indication of quality.[6]

These arguments point to the notion that we still need better insight into information discovery since it affects price discovery and corporate governance considerably. Fuerst (1998) and Moel (1999) show that security prices increase with the level of information disclosure. Moreover Chemmanur and Fulghieri (2006) question the position Huddard et al. (1999) took of a "race for the top" among listing standards by determining a separating equilibrium of different exchanges with different listing standards. Assuming that enterprises behave rationally, only those with a net benefit from cross-listing will apply for a listing abroad.[7]

[5] See for example King and Segal (2003), Pinegar and Ravichandran (2003), Pinegar and Ravichandran (2004), or Burns (2004).

[6] For theoretical support see Akbel (2007), and for empirical support see Frost and Pownall (1994), Melvin and Valero-Tonone (2004), and Lee (2004).

[7] Litvak (2007a) and Litvak (2007b) offer empirical support for this line of argument, and analyze the impact of the Sarbanes-Oxley Act (SOX) on the cross-listing premium.

One part of this study is exclusively devoted to this competition aspect. Domowitz et al. (1998) analyze competition for order flow after the cross-listing and disaggregate price information to several sources. "Heightened intermarket competition may narrow domestic market spreads, but order flow migration may result in lower domestic market liquidity and may increase price volatility." Thus, price variation is decomposed into base-level volatility arising from imperfect competition and transitory volatility arising from trading frictions and information asymmetry. Thereupon, the authors test their microstructure model on a sample of Latin-American enterprises which cross-list in the U.S. However, as it is straightforward to generalize their empirical test to more than two markets, I will consequently do so in the remainder of this paper.

Other interesting articles and hypotheses could and should be presented to complete an adequate literature overview. However, Karolyi (1998) and Karolyi (2006) show that it is hard to do full justice to the academic literature on cross-listings. In his subsequent article he acknowledges that it was already challenging to summarize more than 70 contributions for his earlier survey. But, as the intention of this article does not lie in performing a complete survey, I will have to limit the literature discussion to this extent in order to focus on a straight empirical approach.

This paper proceeds as follows: Section 2 gives a brief overview of the dataset. All empirical analysis is performed in the following sections 3 and 4. First, an evolutionary perspective uses univariate approaches to analyze consequences of cross-listings for stock prices on home markets. Second, multivariate approaches are used to characterize interdependence for multiple price quotes after the cross-listing. Section 5 summarizes and concludes the paper.

## 2 Data

In order to analyze information discovery from Eastern European cross-listings, high frequency prices for a range of enterprises that are registered in a former socialist country and trade at multiple European stock exchanges are needed. The data for this exercise comes from *Thomson Financial Datastream*, which provides daily closing prices.

Table 1 reports a detailed overview on Eastern European stock exchanges and their trade. In general, Frankfurt and London close later, which may generate a favorable picture of information discovery in those foreign markets.[8] Lacking reliable tick data from Eastern European stock exchanges, which are necessary to control for this disadvantage, we will see that this bias is of minor importance. Most home markets remain dominant even after a long period of foreign trade.

As a starting point for my analysis, I chose a period that begins with the fall of the Iron Curtain on 01/01/1991 and ends 12/31/2006. Since data availability for Eastern European stock prices is moderate, sample selection is processed in a pragmatic way. I proceed by identifying stock quoted enterprises from these countries as a potential target group and then selecting those that are listed at home and either in Frankfurt, London or both foreign markets.

These trading places are especially well suited to provide evidence on information discovery by listing abroad. Both are among the world's leading stock exchanges, and attract many Eastern European enterprises, some of which even go public abroad. Furthermore, this setup allows for comparisons at the enterprise level and provides microstructure evidence about different trading systems as well: Frankfurt is organized as an auction system and in London order clearing is processed via market makers.

However, some enterprises require exclusion. Here, illiquidity is the main obstacle. Another disadvantage is irregular trading and delisting for a significant number of companies. Due to this fact, the dataset involves 34 enterprises from six countries: Croatia (1), Czech Republic (7), Estonia (3), Hungary (16), Poland (6), and Russia (1).

Table 2 presents listing activity for the full sample. In particular, I report trading places with the listing type and initial listing times for each enterprise. All but one stock are traded in Frankfurt, either by depository receipt or directly. 13 companies trade in London as well, and Bank BPH is exclusively cross-listed there.

If a cross-listing occurred earlier than one year after the IPO, the precise number of trading days before will be calculated in the remark column. On the one hand, fast orientation to foreign stock markets underscores the relevance of gaining insight on its reasons. On the other hand, this short period reduces potential for comparisons between ex ante and ex post. However,

[8] Schotman and Zalewska (2005) show that low frequency data on Central European stock markets leads to a significant loss of information. However, the highest frequency that is available for those enterprises are daily price quotes.

to get statistical insight into the evolution of price information a sufficient number of observations is essential.

Moreover, table 2 reveals secondary singularities of the sample: First, it reports an overrepresentation of Hungarian stocks. I cannot only relate this finding to a superior general economic environment. The Budapest Stock Exchange is connected to the Xetra system, which is designed as an electronic clearing platform for floor trade at Frankfurt stock exchange. Thus, Hungarian enterprises face only marginal additional fees for direct listing in Frankfurt, and do not involve a depository intermediary.

Second, the Czech Komercni Banka is dually listed in Frankfurt. GDRs are introduced on 07/02/1996 and followed by a complementary direct listing on 12/29/1998. As I will discuss later in this article, this adds an additional perspective to our view on cross-listings and again underlines their role.

Third, even though the most liquid stocks are selected, three Hungarian GDRs lose liquidity at the London Stock Exchange over time.

Before turning to methodological details, let me note that all collected price series are transformed to log differences. Let $r_{i,t} = log(p_{i,t}) - log(p_{i,t-1})$ denote the return on a security $i$ in period $t$, where $p_t$ is the stock price. By applying the Augmented Dickey Fuller tests[9] I am able to confirm stationarity, which represents a necessary condition to time series analysis. Descriptive statistics on the whole sample are available in table 3. For completeness, table 4 reports standard deviations relative to the foreign listing.

# 3 Univariate Approaches

The empirical implementation is separated into two complementary sections. First, stock price tracking on the home market provides an evolutionary perspective on listing activity. I apply two univariate time series implementations in order to characterize the impact of cross-listings. The second perspective is that of multiple price quotes on the same underlying. In the absence of arbitrage opportunities, relative prices are bounded by transaction costs. Interdependence among prices is of interest to this study as well, and analyzed on the basis of multivariate time series implementations, in the following section 4.

[9] For further discussion see Dickey and Fuller (1981), as well as Dickey and Fuller (1979).

## 3.1 Cumulative Average Residuals (CARs)

On the background of a market segmentation perspective, Alexander et al. (1988) stipulate that "as long as capital markets are not completely integrated, it is reasonable to expect that stock prices would react to international listings." An international cross-listing reduces market frictions by alleviating barriers to international investors, and causes a rise of the equilibrium price. This transaction cost effect is adequately exhibited in the seminal contribution of Stapleton and Subrahmanyam (1977).

Consequently, my first empirical test replicates their results on a sample of Eastern European enterprises. Alexander et al. (1988) apply the Mean Adjusted Returns technique to analyze the effects of international cross-listings. This methodology, which is commonly used in literature, is conducive to the comparison of my results for Eastern Europe with other international samples.

In detail, I will proceed as follows: Equation (1) defines the return-generating process on stock $i$ in period $t$. Projection of idiosyncratic returns $\tilde{r}_{i,t}$ on their long-run means $\mu_i$ yields the abnormal or unexpected returns $\tilde{\varepsilon}_{i,t}$.[10]

(1) $$\tilde{r}_{i,t} = \mu_i + \tilde{\varepsilon}_{i,t}$$

Each return series is conditioned on the cross-listing(s) and residuals are averaged cross-sectionally relative to those dates.

(2) $$AR_t = \left(\frac{1}{N}\right) \cdot \sum_{i=1}^{N} \tilde{\varepsilon}_{i,t}$$

Aggregation over different intervals from $a$ to $b$ yields the cumulative average residuals (CARs).

(3) $$CAR_{a,b} = \sum_{t=a}^{b} AR_t$$

[10] The long-run mean in equation (1) is used as a proxy for market expectations. There are good reasons to apply more sophisticated implementations; market or factor models for example. However, my study uses CARs on a replication argument and as an introduction for the more advanced microstructure analysis. Therefore I will limit this test to the basic version.

However, this method faces a deficiency in the analysis of Eastern European companies. 16 enterprises perform their cross-listing within the first year after going public at home. This reduces potential for fair comparisons of CARs before and after the cross-listing. As a cut-off for this procedure I chose a minimum of 30 trading days before listing abroad. This decision is justified since it guarantees a sufficient number of observations for regression analysis.

Evidently, such a fast orientation on foreign listings not only raises consequences for empirical implementation but is informative about Eastern European enterprises as well. Even when assuming informationally efficient markets, it is well understood that the return-generating process will need a specific period of time after the IPO to converge to equilibrium. For a number of stocks in the sample, I cannot separate this convergence effect from learning by cross-listing. However, in the case of a cross-listing contributing to information efficiency, it may even advance convergence. This learning perspective brings us back again to the academic discussion between the proponents of the learning and price discovery theory, and those who favor the capital constraints theory.[11]

Since I only analyze stocks with a minimum of 30 trading days before the cross-listing the sample is reduced to 25 enterprises. First insight to the regression results is given by Mean Squared Errors (MSE) in figure 1. Five outliers are excluded since their MSEs are beyond 0.0025. For the figure however, all numbers are multiplied by 100 to present daily percentages and better interpretability.

From left to right the three sections depict idiosyncratic MSEs before, after the first and the second cross-listing (if applicable). Increased information efficiency by cross-listing should cause more accurate stock pricing, and reduce abnormal returns over time. In other words, each function in the figure should be falling in the cross-listing. However, this is not the case here.

For the first cross-listing, MSEs decrease only for 11 out of 25 stocks. Those 10 securities with two foreign listings show five decreases relative to the non-cross-listed period and six decreases relative to the time after the first cross-listing.

It is straightforward to discover idiosyncratic dynamics in the figure, but

[11] See for example Kaplan and Zingales (1997), Rajan and Zingales (1998), Kaplan and Zingales (2000), or Baker and Wurgler (2002).

the general statement remains ambiguous. Consequently, I will present aggregate calculations corresponding to those of Alexander et al. (1988), in order to provide comparable statistics.[12]

Figure 2 exhibits CARs over 400 days before and 600 days after the first cross-listing, and on this aggregate level, it is easy to replicate the typical pre-listing run-up and the post-listing decline in prices that is found in Eun and Janakiramanan (1986), Alexander et al. (1988), Foerster and Karolyi (1993), Foerster and Karolyi (1999), Miller (1999), and Lee (2004). In detail, two years (400 trading days) before the cross-listing, CARs begin a slight decrease for one year. From that time on, we are able to recognize the announcement effect since most ARs are positive, and consequently their sum increases to become positive in the time surrounding the event. Once the stock is listed abroad, price quotes decrease.

Two corporate governance mechanisms lie behind these observations and shape the informational environment: Lang et al. (2003), Lang et al. (2004), and Bailey et al. (2005) analyze the role of cross-listings on analyst coverage and find differential increases in the number of analysts per enterprise for U.S. and U.K. cross-listings. One explanation for the decrease in abnormal returns after the cross-listing may be a higher level of marketwide information that is generated by a larger number of analysts, who are attracted by the trade in Frankfurt or London.

However, as Kyle (1985) and Admati and Pfleiderer (1988) show, deals are informative on the set of information of market participants and insiders can only exploit superior information to the extent that it is not revealed by trade. Thus, they have to hide their trade behind the orders of noise traders, whose information set is orthogonal, and this is the reason why insiders prefer liquid markets with a larger number of noise traders. Obviously, at least one of both mechanisms works, and if there is any innovation in the market, unexpected returns will go to the downside. Idiosyncratic return variation, which is often used as a proxy for price information efficiency, should increase, and as the figure clearly reveals, ARs turn negative in the subsequent period.

[12] I acknowledge that the comparison of both samples is only feasible with some restrictions. First, Alexander et al. (1988) apply this empirical test to a set of companies that operate in the world's leading economies compared to this emerging markets sample. Second, the stocks the authors use have a much longer trading history before applying for a listing abroad. Third, their article analyzes cross-listings in the U.S., which might produce different results. One possible reason is the different degree of market development of U.S. equity markets relative to the European ones.

Moreover, this pattern is still robust for second cross-listings. Again, cumulative average residuals decrease over time. In figure 3 the curve that represents the CARs for 600 observations after the second cross-listing seems smoother than after the first, which in effect is due to a different time scale. Three years after the first cross-listing CARs amount -0.7699, while they amount -0.5321 for the second one. Since the returns are log scaled, both figures are comparable and it is straightforward to see that the effect from the second cross-listing is only one-third lower.

Nevertheless, covariation is a critical point for the application of CARs and for the analysis of price discovery, in general. Let us now assume a two-stocks-two-country model, in which each stock comes from one country and is perfectly correlated with its market index, and in which both markets are also perfectly correlated. As long as we maintain the correlation assumption on the market side, it follows from a simple portfolio argument that it is not possible to diversify risk or to learn from listing in the foreign market. This is the main doubt in Alexander et al. (1988) and causes the authors to repeat their test methodology on subsamples of Canadian and Non-Canadian enterprises. They find that Canadian enterprises show the lowest impact from the U.S. cross-listing, and explain this result by comparatively high covariation between Canadian and U.S. equity markets.

Based on this example it is straightforward to sketch Roll's[13] argument which characterizes informational efficiency at the general level. As long as we maintain perfect correlation between the stock and the market index, each variation of the stock is a perfect replication of the variation in the market index, and there is nothing to learn from a specific stock price series on the company itself. Only if the relative change in the stock price deviates from the relative change in the market index will it be generated by firm specific information. Roll uses this "non-synchronicity" as a measure for price information.

Clearly, open points remain on the question of price discovery and interdependence. Before I come to the analysis of simultaneous trade on different locations that generates an interdependent pricing system and requires treatment on a dynamic level, I will apply a specific type of variance decomposition, which is the extension of the stylized microstructure model by Domowitz et al. (1998).

[13]See Roll (1988).

## 3.2 A cross-listing model with competition for order flow

Domowitz et al. (1998) propose a microstructure model that implements competition for order flow into the pricing framework. Their main pricing equation is as follows:

$$w = \left(s^2 + 2\lambda s\right) \cdot \sigma^2 \left(x_N\right) \tag{4}$$

$w$, the covariance between the fundamental value of an asset and idiosyncratic income, is increasing in the spread $s$ and decreasing in market liquidity $\lambda^{-1}$. In this context, $\lambda$ itself is often interpreted as the precision parameter and relates the model to the asset pricing universe. This covariance is shifted by the volatility parameter $\sigma^2$, which depends on total trading activity in the sense of Glosten and Milgrom (1985). Desired orders $x_k$ for each trader $k$ are normalized to unity; $+1$ (long position), -1 (short position), and 0 (hold), respectively. Partial market clearing for $N$ investors is calculated by aggregation of $x_k$ over all $k$. Consequently, the variance of successive changes in closing prices is understood as:

$$\sigma^2 \left(r\right) = \gamma + \lambda^2 \left(1 - \zeta\right) \cdot \left(\theta_d + \theta_f\right) \tag{5}$$

$\gamma$ (base-level volatility) is defined as $\gamma = w + \sigma_\epsilon^2$. It represents the volatility that arises from changes in the bid-ask spread and instantaneous public information. The second term in equation (5), transitory volatility, represents information asymmetry, or more generally microstructure frictions that are inversely related to market liquidity.

This implementation follows the idea that as long as markets are not perfectly integrated, a cross-listing raises competition for order flow. In a situation where information costs are comparable between two markets, an individual investor will direct his order to the market that offers him the lowest spread. This generates competitive pressure on market makers, who try to compensate losses from decreasing spreads by increasing volume.

Nevertheless, cross-listings may still increase base-level volatility $\gamma$ in the partial market fragmentation setup. According to Domowitz et al. (1998), the spread reducing effect on $w$ might be overcompensated by $\sigma_\epsilon^2$ through weak "intermarket information links or foreign noise traders with low quality information signals". However, when maintaining the Kyle assumption of noise traders whose trade is orthogonal to the information set of the insiders, it is sufficient to assume that the introduction of a stock to the foreign market attracts noise traders, who trade with stronger impact (higher $\sigma_\epsilon^2$). In other words, cross-listings generate adverse effects on base-level volatility since there is a trade-off between competition and world market risk, and it is an empirical exercise to analyze the relative size of both effects.

Domowitz et al. (1998) analyze the net effect for equation (5) on a sample of different stocks issued by 16 Mexican companies that are listing in the U.S. as ADR[14] and find that for most enterprises the effect of decreasing liquidity after the cross-listing is mitigated by a narrowing of the bid-ask spread. Before I can relate my results to their study, I have to modify their econometric test to allow for a second cross-listing, which is performed by ten enterprises in my sample.

$$r_t^2 = \gamma_t + \delta_t \cdot r_{t-1}^2 + \lambda_t \cdot V_t + \eta_t \tag{6}$$

$$\gamma_t = \gamma_0 + \gamma_{fr} \cdot x_{fr} + \gamma_{lo} \cdot x_{lo} \tag{7}$$

$$\delta_t = \delta_0 + \delta_{fr} \cdot x_{fr} + \delta_{lo} \cdot x_{lo} \tag{8}$$

$$\lambda_t = \lambda_0 + \lambda_{fr} \cdot x_{fr} + \lambda_{lo} \cdot x_{lo} \tag{9}$$

Equation (6) augments base-level volatility $\gamma_t$ and transitory volatility $\lambda_t$ by an autoregressive term to filter for volatility clustering. In the following lines, all time-varying estimation parameters are decomposed to a basic constant and the cross-listing effect with the dummies for Frankfurt ($x_{fr}$) and London ($x_{lo}$). After cross-listing, the corresponding dummy is set from zero to one.[15] $\eta_t$ represents the error term and should be white noise for accurate estimation.

In order to estimate equation (6), collection of additional data about trading volume is necessary. Since transaction volume from Eastern Europe is even more scarce than stock price quotes, I only take into consideration those 20 enterprises that exhibit less than 11% missing values in the volume series. Knowing that Eastern European stocks are less liquid than those used in Domowitz et al. (1998), $V_t$ is quantified in ten millions of shares to determine comparable coefficients.

The system outlined above requires estimation by a heteroskedasticity-robust Generalized Method of Moment (GMM) estimator. All regressions are

[14] Their study covers other aspects as well. They end with a sample of 25 time series since some of the 16 companies issue stock with ownership restrictions. The authors are able to isolate the effects of the cross-listing on different classes of assets.

[15] Mixed effects are not considered here since there is no theoretical prediction, if, how and why a network effect from several cross-listings should evolve.

calculated beginning from the time when the first volume data is registered; its results are shown in tables 5 to 7. In the tables, results for each enterprise call for two rows, of which parameter estimates are printed in the first, followed by their statistical significance in the second. Parameters with index $fr$ or $lo$ represent interaction with the corresponding cross-listing dummy.

Table 5 presents the effects after the first cross-listing and is directly comparable to the study by Domowitz et al. (1998). Their microstructure model is also appropriate for the majority of my sample since from 20 regressions, the natural or non-interacted parameters ($\gamma_0$, $\delta_0$, and $\lambda_0$) have significant coefficients in 12, 11, and 13 cases. In order to guarantee positive definiteness of volatility before the cross-listing, each significant $\gamma_0$ should take non-negative values, which is the case for my results. The $\gamma_0$ distribution is positively skewed with median 0.0005 and mean 0.0007. For the Mexican sample median and mean are definitively higher with 0.0070 and 0.0570. In this respect, Eastern European markets are more competitive (efficient) than those of Latin America since the bid-ask spread is substantially smaller. Natural market variation seems smoother in Europe.

Domowitz et al. (1998) determine positive values for their cross-listing parameter (the median increase is 0.0240 and the mean increase is 0.2860) and conclude "a dramatic increase in base-level volatility following the ADR listing" for those securities that are open to foreign investors. This result is in line with the foreign market perspective of Fernandes and Ferreira (2006), who show that price information decreases for enterprises from less developed countries when they list at New York stock exchange. Eastern European enterprises show a different effect; from five significant coefficients, four turn out negative, and base-level volatility increases only for Fotex after listing in Frankfurt. This atypical evolution might be caused by a very early introduction to Western European markets.

Fernandes and Ferreira (2006) find that cross-listings generate more marketwide information by increased analyst coverage. Thus it is more difficult and costly to acquire superior information which causes a crowding-out of insider trades after listing in New York. My results on Eastern European enterprises neither support these results for Frankfurt cross-listings nor do they for London cross-listings. Baker et al. (2002) offer supportive empirical evidence for this finding by comparing analyst and media coverage at London versus New York stock exchanges after the listing. They use hits in the *Wall Street Journal* and in *Financial Times* as a proxy for media coverage and show that U.S. listings are associated with better media and analyst coverage as well. Even though the U.S. and the U.K. share the same legal tradition, the informational environment at the New York Stock Exchange is superior to that at the London Stock Exchange. This explains why price information on Eastern European enterprises increases after the cross-listing at the Western European exchanges, while it decreases for Mexican enterprises listing in the U.S.

Comparing significant parameters from Latin America with my estimates, I am able to determine a more symmetric distribution with median -0.0004 and mean taking the same value. Unlike Domowitz et al. (1998), but in line with Foerster and Karolyi (1998), cross-listings from Eastern European countries strengthen the competition among market markers. Bid-ask spreads are reduced for a number of stocks and so are their base-level volatilities. It is noteworthy that these results still guarantee positive definiteness of the volatility after the cross-listing, due to the fact that neither interaction term $\gamma_{fr}$ or $\gamma_{lo}$ turns volatility negative.

Based on trading volume ($\lambda$ parameters) transitory volatility is analyzed. $\lambda_0$ is positive in 12 out of 13 significant cases, and eight significant $\lambda_{fr}$ and $\lambda_{lo}$ show mixed signs depending on the company. All told, listing abroad reduces volume dependence from 0.0193 to 0.0126. Median values for significant parameters are added under the exclusion of Softbank since its coefficients take absolute values of more than 2.5, which is far beyond the rest of the sample.

Even though market makers compete for order flow to attract additional volume, liquidity in the home market is not reduced to a critical extent. In other words, cross-listing reduces both base-level and transitory volatility.

Furthermore, listing abroad affects the structure of volatility clustering as well. With the exception of Lukoil, net autocorrelation ($\delta_0 + \delta_{fr}$) is reduced for all stocks (four cases) that have a significant non-cross-listed term $\delta_0$ (11 cases). Given the decreasing dependence on historical price variation, stock price volatility approaches random walk, which is synonymous to increased market efficiency.[16]

These estimates on first cross-listings indicate strong evidence in favor of competition for order flow. However, alternative hypotheses are able to

[16] Again, Fotex might be considered as an outlier in respect of increased autoregressive effects. Moreover, Unipetrol shows no significant parameter except interacted autoregression $\delta_{fr}$. Given the poor fit, this time series is not supported by the microstructure model applied.

justify managerial considerations about second cross-listings.

After the first cross-listing, base-level and transitory volatility decrease. Consequently, the enterprise management may recognize this and hope for further smoothing in price variation and transaction cost. This hypothesis is closely related to Subrahmanyam and Titman (1999), Foucault and Gehrig (2007), and Chen et al. (2007), who emphasize that managers learn (for investment decisions) from listing abroad. In particular, Chen et al. (2007) use idiosyncratic return variation (the (Roll (1988)) criteria of price non-syncronicity) to analyze an *active* role of the price. Enterprises focusing on German and British product markets especially might support this explanation, but it generalizes all enterprises from Eastern Europe which try to benefit from additional objective expertise from markets that are more advanced in the sense of market development.

This brings the discussion back to capital constraints arguments. Authors such as Baker et al. (2003) or Kaplan and Zingales (1997) argue for a complementary explanation. In their view, enterprises from less developed countries in particular seek additional financing by listing abroad.

Both hypotheses may govern decisions about second and third cross-listings. Moreover, the results in table 6 and 7 even present us with a third possible alternative. Different legal and listing standards at Frankfurt and London exchanges generate different consequences for the informational environment for enterprises that choose among both, and it is not surprising that the coefficients reveal separate properties for both exchanges.

All significant interaction terms for a Frankfurt cross-listing reduce the base-level volatility. This finding is still robust for the second direct cross-listing in Frankfurt from Komercni Banka.[17] A Frankfurt cross-listing strengthens competition and reduces the bid-ask spread.

However, the effects on transitory volatility are poor and ambiguous for a Frankfurt listing. Transitory volatility is increasing in the cross-listing for Telekomunikacja PL by 0.0360, and decreasing for Richter Gedeon by -0.1438. In contrast, results on the liquidity parameter $\lambda_{lo}$ in London are more consistent. It is also striking to note that all estimates reveal negative coefficients on significant parameters. I interpret this reduction as a consequence of at-

[17] Lukoil results do not converge to the rest of the sample. This time series exhibits probability for negative price volatility after the cross-listing. If $\gamma_0$ is interacted, $\gamma_{lo}$ with -0.0006 will require a minimum trading volume of 222000 to guarantee positive volatility. Liquidity, however, does not reach this number in 656 observations, which gives reason to exclude the time series from further analysis.

tracting foreign investors to Eastern European markets. Without a doubt, a cross-listing reduces liquidity constraints in the home market, therefore managers aiming at this effect should perform a cross-listing on LSE.

These new estimates indicate that both exchanges, Frankfurt and London, are shaped by a different informational environment: This may come from the different market architecture and different groups of market participants. Listings in Frankfurt with an auction based trading system generate competitive pressure, consequently drive spreads down, and market makers in London reduce informational frictions for cross-listed Eastern European enterprises.

Moreover, my results indicate increased information efficiency for cross-listed Eastern European enterprises. The spread effect is particularly negative for a number of enterprises and interestingly, the volume effect is negative as well. Despite the fact that the roles of foreign exchanges diverge, the results are robust to the second and third cross-listing. From a technical point of view, predictability to idiosyncratic return variation is reduced to the same degree as is volatility clustering. This can be interpreted as evidence of increased market efficiency.

# 4 Bivariate Approach

A second aim of this study is to get a better understanding of dynamic interdependence between trade prices. In order to analyze this system, contemporaneous price quotes of different exchanges and an empirical model without strict exogeneity restrictions are required. The class of GARCH models provides a useful formulation for that exercise.

Before turning to the technical side, some details on data require particular attention: Notably, while a number of Hungarian stocks trade very actively in Frankfurt, London price quotes lose liquidity in the later years of the sample. On this account, Borsodchem, Richter Gedeon, and Tiszai Vegyi are no longer considered.

To be sure, I took the possibility of structural breaks into consideration, and I came to the conclusion that after (each) cross-listing, the following two weeks (10 trading days) are excluded before (re)estimation.

It is straightforward to understand the idea of Engle (1982) and Bollerslev (1986) to model not only the return, but also the innovation on a mean-reverting process with autoregressive and moving-average terms as well, which leads to the variance equation:

$$\sigma_t^2 = a_0 + \sum_{i=1}^{q} a_i \cdot \varepsilon_{t-i}^2 + \sum_{j=1}^{p} b_j \cdot \sigma_{t-j}^2 \quad (10)$$

Since then, many variants have been introduced and I apply this basic formulation in addition to two asymmetric models (EGARCH and TGARCH) in order to allow for leverage effects in the dataset. While the exponential model of Nelson (1991) only restricts the asymmetric parameter between -1 and 0, TGARCH[18] is bound by the parameter restrictions of the basic model. In other words $a_0, a_i, b_j$ and the coefficient of the asymmetric parameter should be positive in order to guarantee non-negative values for $\sigma_t^2$. Bollerslev (1986) proves that the GARCH process is only stationary if $\sum_{i=1}^{q} a_i + \sum_{j=1}^{p} b_j < 1$.

For the mean equation I do not implement exogenous variables, but limit on autoregressive and moving-average coefficients as well as a component of the variance equation, which constitutes the GARCH-in-Mean (GARCH-M) approach. That is, either the conditional variance, its square root, or its log is implemented into the mean equation in the case of statistical significance.

In order to obtain parsimonious implementations I do not model more than two lags in the variance equation. My results acknowledge this convention, since repeated Lagrange multiplier tests do not reveal further ARCH effects.

To be sure, I investigate residuals' and squared residuals' autocorrelation and partial autocorrelation functions. Significant deviations in the squared residual sample would suggest misspecification, since they indicate additional ARCH effects in the time series.

I repeat this procedure for all symmetric and asymmetric ARCH implementations on a time series. Having eliminated unreasonable implementations, I choose the best performing model based on the Akaike Information Criterion (AIC).

All implementations generate a set of residuals that provides evidence of informational links in the dataset. For this reason, all collected residuals are squared and lagged by one period and introduced into the variance equation of a different price quote on the same underlying. This procedure describes the basic idea of the volatility spillover and was introduced by Engle et al. (1990), Engle et al. (1994), as well as Hamao et al. (1990). It was applied in a

[18]See Zakoian (1994) and Glosten et al. (1993).

wide range of studies, which mainly focused on stock[19] and money markets.[20] A simple formulation of volatility transmission is presented in the following:

$$\sigma_t^2 = a_0 + \sum_{i=1}^{q} a_i \cdot \varepsilon_{t-i}^2 + \sum_{j=1}^{p} b_j \cdot \sigma_{t-j}^2 + d \cdot \xi_{t-1}^2 \tag{11}$$

Equation (11) extends the basic GARCH setup from equation (10) by the spillover term. It represents a directional correlation in the variance equation, since the lagged, squared error term $\xi_{t-1}^2$ from one price quote is implemented to the variance equation of the next. If $\xi_{t-1}^2$ is significant, this will suggest informational interdependence among the trading locations. In this case, the spillover coefficient $d$ quantifies the extent of information transmission.

As reported in tables 8 through 11, this procedure generates 46 estimates on stocks after their first cross-listing, 89 estimates after the second, and 26 after the third. For multiple cross-listings a distinction must be made between the *full system*, which contemporaneously implements all spillover parameters, and the *reduced system*, which only implements a subset. In particular, each table provides detailed information on enterprises, number of cross-listings at the time, direction of the spillover, and its effect. Evidently, a number of time series are dropped for the reason that they do not convey ARCH effects according to the Lagrange multiplier test. In order to offer a more aggregate perspective on each of those detailed results, table 12 presents average and median coefficients. 38 out of 46 return series for the first cross-listing, and 57 out of 89 for the second show correlation in the variance equation. GARCH volatility spillovers provide strong support for interdependence and the learning hypothesis, and determine results that are in accordance with the findings on univariate test methodologies: Indeed, cross-listing is informative.

In detail, my estimates reveal an average spillover coefficient of 0.1355 (median 0.0460) for the first cross-listing. This means lagged, squared residuals for a price quote affect a different price quote on the same underlying by around 13.55% on average. This effect is even stronger than that of some estimated AR(1) coefficients of the variance equation. One cannot deny the existence of a dependence among markets. Relative to these models used to construct the interaction term, average AR(1) coefficients in the variance

[19] See e.g. Hahm (2004), Fabozzi et al. (2004), Booth et al. (1997), or Kim and Rogers (1995).

[20] See e.g. Hahm (2004), Black and McMillan (2004), or Booth and So (2003).

equation decrease by 3.00% on estimation with spillover parameters. Interestingly enough, marginal learning by the second listing abroad generates virtually half of the effect of the first one. AR(1)s decrease again by 1.60% and the average spillover accounts for 0.0967 (median 0.0463) here.

In spite of the fact that the results for the third cross-listing are shown for completeness, I will not pursue this discussion. Since Komercni Banka is the only enterprise in the sample, for which I could collect a fourth price quote, column (4) provides an idiosyncratic perspective. Moreover, the third cross-listing is a direct listing on the same market, where the company already trades with GDRs. However, this imposes a limit on general conclusions to a certain extent.

I proceed by disaggregating average dynamics from the home market toward foreign markets and vice versa for the first and second cross-listing. The results suggest a dominant role of the home market even after the second cross-listing. Here, average spillovers from the home market reach 14.22%. They are more than six times as large as the spillover back from foreign markets (2.20%). This relation is even more pronounced on the median figures, which are nearly twelve times as large. To be sure, only reasonable, non-negative and significant parameters are taken into consideration for these aggregates. Concerning the first cross-listing, a lack of significance or negative coefficients is only determined for spillovers from foreign markets (7 cases). After the second cross-listing, 51 out of 57 insignificant parameters come from Frankfurt and London. This again points to the notion that the majority of price discoveries concern the home market.

The second cross-listing allows for an analysis of information flows between foreign exchanges as well. On average, interdependence amounts to 0.0951, which is around two thirds of the spillover from the home market and considerably more than that back from the foreign markets. This aspect leads us back to the discussion on the level of the stock exchange. Results from the second cross-listing provide evidence on the relative importance of both foreign stock exchanges for the home markets. It is straightforward to compare spillovers between Frankfurt and London, as well as their specific impact on the home market. All in all, there is no distinct winner in this contest: While I am not able to determine an interdependence among these foreign exchanges for the Softbank price quotes, it can be understood that Frankfurt dominates in four enterprises and London dominates in five enterprises.

From an individual perspective, it is noteworthy that Fotex, Konzum, and Lukoil represent the only enterprises in which the spillover from abroad dominates the spillover from the home market. Yet this result is robust to the second cross-listing from Lukoil. The five strongest spillovers after the first cross-listing are on the enterprises Bank BPH, Komercni Banka, Synergon, Unipetrol, and Egis. Not surprisingly, all spillovers stem from home markets, but the fact that the Budapest stock exchange only appears twice in this list was unanticipated. As Hungarian enterprises represent nearly half of the sample, this finding attributes back to the conclusions made by Alexander et al. (1988), who suppose that marginal information discovery is weaker in markets that already have closer informational links. Since the Xetra platform is used for German and Hungarian stocks, higher informational covariation is likely. Nevertheless, I cannot exclude a different explanation for this result: Lacking high frequency data, this study uses daily price quotes. Consequently, I cannot analyze volatility transmissions during the day. This disadvantage generates a certain probability that yesterday's residuals, which are used to estimate the spillover parameter, lag behind the real information transmission, which is already comprised in the stock price quote.

# 5 Conclusion

As the surveys of Karolyi (1998) and Karolyi (2006) document, cross-listings are very actively debated in the academic literature. The number of contributions is still growing, and has identified several competing and complementing hypotheses in order to explain why companies list abroad. My paper contributes to this explanation by analyzing aspects of market segmentation, information discovery and corporate governance on a sample of Eastern European enterprises listed on a home stock exchange as well as in Frankfurt, London or both foreign exchanges. These enterprises are well-suited for this exercise due to the fact that they actively list on Western European stock exchanges. Large information differentials between Eastern and Western Europe help to isolate cross-listing effects on information discovery.

The first empirical part covers an evolutionary perspective and tracks the influence of foreign listings on the price at home. The second empirical part analyzes interdependence in the pricing system. In general, two major conclusions evolve: Listing on foreign stock exchanges is informative. However, home exchanges remain dominant.

The analysis of cumulative average residuals (CARs), which introduces the study, is of particular importance and suggests increased price efficiency by listing abroad. A second, more detailed analysis provides clear evidence on the relative size of two competing effects: On the one hand, competition for order flow reduces transaction costs that market makers can charge for their activity. On the other hand, if a substantial part of liquidity is withdrawn from the home market, frictions may arise. Interestingly, both effects turn out negative with special roles for the foreign stock exchanges and are robust to the number and sequence of foreign listings. It can be stated that listing in Frankfurt reduces the spread, and generates competitive pressure on market makers, while listings in London bring liquidity to the home market, instead of withdrawing it.

From an interdependence perspective, I determine strong informational links between stock price quotes. Admittedly, home markets are dominant, but information flows back from foreign exchanges as well. After the second cross-listing, spillovers from foreign markets are 2.20% on average. This is almost one sixth of the effect coefficient from home markets, for which I determined 14.22% on average. Even if one is not convinced by these results as evidence for increased information efficiency, the relevance of the decrease of auto-correlation in the variance equation cannot be disputed. AR(1) coefficients drop by 1.60% upon implementation of the second spillover, and point to a shift of historical information to the information that is generated at the other trading location.

What exactly can we learn from this empirical exercise? Due to the absence of alternative considerations such as financial constraints, it is advisable for Eastern European managers in search of more efficient stock pricing to apply for a listing abroad. Cross-listings in Frankfurt reduce base-level volatility (bid-ask spread), cross-listings in London reduce transitory volatility (informational and liquidity frictions). Moreover, there is still incentive to apply for multiple cross-listings, since marginal learning is decreasing but remains positive in the number of listings.

Do these results indicate a better corporate governance? Cross-listings in Frankfurt and London do not generate the same amount of market-wide information that reduces the incentive to collect inside information such as in New York. This study points to the need for further improvement on the informational environment. It is still possible to hide informed trade behind liquidity trade on both European exchanges, in spite of the fact that the

U.K. has the same legal tradition as the U.S., but also in Frankfurt which is perceived as being less efficient than London. Fernandes and Ferreira (2006), however, suggest that enterprises from less developed countries do not face the same disclosure standards when they list on the same foreign stock exchange as an enterprise from a developed country. They relate their thesis to the fact that approval of information or legal enforcement is difficult across the border.

Lacking additional reliable data, this study also points to the need for further research on the role of cross-listings for Russian enterprises. Even though several active exchanges operate in Russia, this study suffers from a lack of liquid price quotes for listings at home and abroad. If one overcame this dearth of data, the dominance of London as a foreign market over the home market Moscow could be tested. In particular, the role of political change on the amount of information discovery could be analyzed given the fact that the Russian government has been very actively engaged in exchange quoted companies in previous years. Moreover, a final note addresses general data frequency. It is very likely that further studies may try to collect intraday data from Eastern European enterprises in order to get a deeper understanding of informational dynamics. This would allow to relate their results to Hasbrouck (1995) or Grammig et al. (2005).

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Table 1: Trading Hours at European Stock Exchanges

| Country | Stock Exchange | Trading Hours | |
|---|---|---|---|
| **Croatia** | **Zagreb Stock Exchange (ZSE)** | | 10:00am - 2:00pm |
| | | 01/01/2003: | 10:00am - 4:00pm |
| **Czech Republic** | **Prague Stock Exchange (PSE)** | | 8:00am - 4:00pm |
| | | (17pm : Publication price quotations) | |
| **Estonia** | **Tallinn Stock Exchange (TSE)** | | 10:00am - 1:50pm |
| | | (2:05pm - 2:30pm after market trading) | |
| **Hungary** | **Budapest Stock Exchange (BSE)** | | 9:02am - 4:30pm |
| **Poland** | **Warsaw Stock Exchange (WSE)** | | 9:00am - 4:30pm |
| **Russia** | **Russian Trading System (RTS)** | | 9:00am - 4:00pm |
| | | 01/01/2005: | 9:00am - 4:00pm |
| **Germany** | **Frankfurter Wertpapierbörse (FWB)** | 01/01/1990: | 10:30am - 1:30pm |
| | | 07/01/1998: | 8:30am - 5:00pm |
| | | 09/20/1999: | 9:00am - 5:30pm |
| | | 06/02/2000: | 9:00am - 8:00pm |
| | **Floor** | 01/01/2003: | 9:00am - 8:00pm |
| | **Xetra** | 01/01/2003: | 9:00am - 5:30pm |
| **UK** | **London Stock Exchange (SEAQ)** | | 9:00am - 5:30pm |

This table presents the trading hours at European stock exchanges. All of the data has been collected from official web pages and verified by e-mail contact. The table indicates that some exchanges changed trading hours very actively.

Table 2: Listings

| Country | Firm | Listing in | Initial Listing | Listing in (as) | Initial Listing | Listing in (as) | Initial Listing | Remark |
|---|---|---|---|---|---|---|---|---|
| **Croatia** | Pliva | Zagreb | 01/25/1995 | Frankfurt (GDR) | 01/02/1997 | London (GDR) | 04/18/1997 | - |
| **Czech Republic** | Cez | Prague | 11/02/1993 | Frankfurt | 11/10/1994 | - | - | – |
| | Komercni Banka | Prague | 03/21/1994 | Frankfurt (GDR) | 07/02/1996 | London (GDR) | 08/05/1997 | Frankfurt (direct) 12/29/1998 |
| | RMS Holding | Prague | 11/09/1993 | Frankfurt | 07/08/1996 | - | - | – |
| | Setuza | Prague | 01/27/1994 | Frankfurt | 07/30/1996 | - | - | – |
| | SSZ | Prague | 11/18/1993 | Frankfurt | 06/25/1997 | - | - | – |
| | Telefonica O2 | Prague | 03/14/1995 | Frankfurt | 05/17/1996 | London (GDR) | 08/02/1999 | – |
| | Unipetrol | Prague | 09/01/1997 | Frankfurt | 09/10/1997 | - | - | 7 |
| **Estonia** | Eesti Telekomi | Tallinn | 02/11/1999 | Frankfurt | 05/27/1999 | London (GDR) | 07/29/1999 | 75 |
| | Merko Ehitus | Tallinn | 07/22/1997 | Frankfurt | 10/28/1997 | - | - | 70 |
| | Norma Aktsia | Tallinn | 08/12/1996 | Frankfurt | 09/30/1997 | - | - | – |
| **Hungary** | Borsodchem | Budapest | 03/21/1996 | Frankfurt | 07/17/1996 | London (GDR) | 07/22/1999 | 84 / London inactive 05/12/03-09/30/04 |
| | Danubius Hotel | Budapest | 12/23/1992 | Frankfurt | 07/01/1994 | - | - | – |
| | Egis | Budapest | 07/25/1994 | Frankfurt | 07/02/1996 | - | - | – |
| | Elmu | Budapest | 12/15/1998 | Frankfurt | 03/17/1999 | - | - | 66 |
| | Emasz | Budapest | 12/15/1998 | Frankfurt | 03/10/1999 | - | - | 61 |
| | Fotex | Budapest | 01/02/1991 | Frankfurt | 06/07/1994 | - | - | – |
| | Inter-Europa Bank | Budapest | 07/19/1994 | Frankfurt | 11/22/1996 | - | - | – |
| | Konzum | Budapest | 01/09/1991 | Frankfurt | 03/05/1991 | - | - | 82 |
| | Magyar TKom | Budapest | 11/14/1997 | Frankfurt | 12/15/1997 | London (ADS) | 08/02/1999 | 21 |
| | Mol Magyar | Budapest | 11/28/1995 | Frankfurt | 07/05/1996 | London (GDR) | 06/26/1997 | 158 |
| | OTP Bank | Budapest | 08/10/1995 | Frankfurt | 10/24/1996 | London (GDR) | 08/02/1999 | – |
| | Raba | Budapest | 12/17/1997 | Frankfurt | 01/07/1998 | - | - | 15 |
| | Richter Gedeon | Budapest | 11/09/1994 | Frankfurt | 10/15/1996 | London (GDR) | 11/16/1995 | London inactive from 1997 |
| | Synergon | Budapest | 05/05/1999 | Frankfurt | 05/11/1999 | - | - | 4 |
| | Tiszai Vegyi Kom | Budapest | 08/06/1996 | Frankfurt | 10/29/1996 | London (GDR) | 05/05/1998 | 60 / London inactive from 2001 |
| | Zwack Unicum | Budapest | 05/27/1993 | Frankfurt | 11/30/1993 | - | - | 133 |
| **Poland** | Bank BPH | Warsaw | 09/16/1996 | - | - | London (GDR) | 01/17/2002 | – |
| | Mostostal Export | Warsaw | 05/28/1992 | Frankfrut (ADR) | 07/03/1997 | - | - | – |
| | PKN Orlen | Warsaw | 11/26/1999 | Frankfurt (GDR) | 01/03/2000 | - | - | 26 |
| | Softbank | Warsaw | 07/20/1998 | Frankfurt (GDR) | 01/23/2001 | London (GDR) | 07/28/1998 | 6 |
| | Stalexport | Warsaw | 09/16/1996 | Frankfurt | 07/19/1999 | - | - | – |
| | Telekomunikacja PL | Warsaw | 11/18/1998 | Frankfurt (GDR) | 12/02/1998 | London (GDR) | 08/10/1999 | 10 |
| **Russia** | Lukoil | RTS | 09/01/1995 | Frankfurt (ADR) | 06/28/1996 | London (ADR) | 07/20/2001 | – |

This table presents all collected stock price time series from Eastern European enterprises that are cross-listed in Frankfurt, London or in both of the foreign markets. All enterprises are displayed with initial listing dates for corresponding stock markets. Since some stocks are traded indirectly (as depository receipts), the specific security type is indicated in case of necessity. For this table only stocks with liquid trading activity (daily price quotation) are considered. If stocks from an enterprise are introduced to a foreign market within one year after the IPO at home, the corresponding trading days before this event are calculated in the remark column.

Table 3: Descriptive Statistics

| Series | Mean | Max | Min | StdDev | Skew | Kurt | JarqueBera | Prob | Obs |
|---|---|---|---|---|---|---|---|---|---|
| DLBANKBPL | 0.0005 | 0.2075 | -0.2486 | 0.0250 | -0.08 | 11.60 | 8266 | (0.0000) | 2684 |
| DLBANKBXSQ | 0.0014 | 0.3058 | -0.2624 | 0.0307 | 1.26 | 33.12 | 49140 | (0.0000) | 1291 |
| DLBORSOHU | 0.0000 | 0.2101 | -1.5794 | 0.0399 | -22.37 | 881.33 | 905928778 | (0.0000) | 2811 |
| DLBORSOFR | 0.0000 | 0.3504 | -1.6029 | 0.0432 | -18.81 | 702.63 | 55777735 | (0.0000) | 2727 |
| DLBORSOXSQ | -0.0002 | 0.2703 | -1.3568 | 0.0390 | -21.70 | 764.50 | 47050733 | (0.0000) | 1941 |
| DLCEZCZ | 0.0000 | 0.3295 | -2.4015 | 0.0473 | -38.06 | 1939.09 | 53701136 | (0.0000) | 3433 |
| DLCEZFR | 0.0000 | 0.2228 | -2.3914 | 0.0496 | -35.48 | 1711.27 | 38562325 | (0.0000) | 3166 |
| DLDANUBHU | 0.0003 | 0.6730 | -0.2506 | 0.0310 | 3.19 | 79.35 | 894426 | (0.0000) | 3657 |
| DLDANUBFR | 0.0004 | 0.2943 | -0.4477 | 0.0268 | -1.49 | 42.92 | 217707 | (0.0000) | 3260 |
| DLEESTITA | 0.0001 | 0.1585 | -0.1051 | 0.0165 | 0.41 | 13.02 | 8650 | (0.0000) | 2056 |
| DLEESTIFR | 0.0002 | 0.1926 | -0.1317 | 0.0217 | 0.94 | 14.77 | 11736 | (0.0000) | 1981 |
| DLEESTIXSQD | 0.0002 | 0.2792 | -0.2624 | 0.0217 | -0.86 | 57.21 | 237327 | (0.0000) | 1936 |
| DLEGISHU | 0.0006 | 0.1889 | -0.3535 | 0.0264 | -1.01 | 20.51 | 41973 | (0.0000) | 3244 |
| DLEGISFR | 0.0003 | 0.1536 | -0.3136 | 0.0285 | -0.87 | 14.22 | 14714 | (0.0000) | 2738 |
| DLELMUHU | 0.0004 | 0.1737 | -0.1729 | 0.0247 | 0.14 | 12.04 | 7142 | (0.0000) | 2098 |
| DLELMUFR | 0.0003 | 0.1367 | -0.1639 | 0.0199 | -0.38 | 13.95 | 10204 | (0.0000) | 2032 |
| DLEMASZHU | 0.0004 | 0.1146 | -0.1683 | 0.0213 | -0.05 | 7.71 | 1944 | (0.0000) | 2098 |
| DLEMASZFR | 0.0006 | 0.1770 | -0.2017 | 0.0191 | -0.25 | 21.17 | 28037 | (0.0000) | 2037 |
| DLFOTEXHU | 0.0000 | 0.2381 | -0.3429 | 0.0310 | 0.30 | 14.12 | 21570 | (0.0000) | 4172 |
| DLFOTEXFR | 0.0000 | 0.3761 | -0.2744 | 0.0441 | 0.44 | 9.88 | 6538 | (0.0000) | 3257 |
| DLIEUBKHU | -0.0005 | 0.2238 | -2.2866 | 0.0498 | -30.60 | 1385.38 | 25912592 | (0.0000) | 3248 |
| DLIEUBKFR | -0.0009 | 0.2165 | -2.2581 | 0.0546 | -27.60 | 1122.11 | 13783938 | (0.0000) | 2635 |
| DLKOMBKCZ | 0.0000 | 0.1915 | -0.2372 | 0.0264 | -0.58 | 13.95 | 16854 | (0.0000) | 3334 |
| DLKOMBKFR | 0.0012 | 0.5614 | -0.3314 | 0.0274 | 5.04 | 126.10 | 1330322 | (0.0000) | 2093 |
| DLKOMBKFRG | 0.0002 | 0.3228 | -0.4090 | 0.0328 | -0.45 | 26.35 | 62271 | (0.0000) | 2738 |
| DLKOMBXSQ | 0.0004 | 0.2557 | -0.3567 | 0.0352 | -0.42 | 15.43 | 15852 | (0.0000) | 2453 |
| DLKONZUHU | -0.0015 | 1.1192 | -3.1585 | 0.0826 | -13.33 | 540.67 | 50317047 | (0.0000) | 4167 |
| DLKONZUFR | -0.0008 | 0.5921 | -0.5705 | 0.0572 | 0.57 | 24.66 | 80107 | (0.0000) | 4085 |
| DLLUKOIRS | 0.0009 | 0.2583 | -0.3912 | 0.0347 | -0.43 | 16.30 | 21865 | (0.0000) | 2955 |
| DLLUKOIFRA | 0.0008 | 0.2556 | -0.2627 | 0.0334 | -0.10 | 9.26 | 4486 | (0.0000) | 2740 |
| DLLUKOIXSQ | 0.0015 | 0.1114 | -0.1204 | 0.0220 | -0.26 | 5.25 | 316 | (0.0000) | 1420 |
| DLMAGTKHU | 0.0002 | 0.1174 | -0.1197 | 0.0219 | -0.14 | 6.09 | 954 | (0.0000) | 2380 |
| DLMAGTKFR | 0.0001 | 0.1690 | -0.1253 | 0.0263 | 0.20 | 6.89 | 1501 | (0.0000) | 2359 |
| DLMAGTKXSQ | -0.0001 | 0.1641 | -0.1606 | 0.0227 | 0.03 | 9.57 | 3484 | (0.0000) | 1934 |
| DLMERKOTA | 0.0005 | 0.2280 | -1.1628 | 0.0374 | -15.14 | 438.20 | 19531088 | (0.0000) | 2463 |
| DLMERKOFR | 0.0004 | 0.1780 | -0.7024 | 0.0356 | -9.29 | 179.93 | 3155680 | (0.0000) | 2393 |
| DLMOLHU | 0.0009 | 0.1524 | -0.2189 | 0.0239 | -0.36 | 10.31 | 6497 | (0.0000) | 2893 |
| DLMOLFR | 0.0008 | 0.1246 | -0.1643 | 0.0264 | -0.07 | 6.42 | 1336 | (0.0000) | 2735 |
| DLMOLXSQ | 0.0006 | 0.1513 | -0.2128 | 0.0237 | -0.41 | 9.57 | 4531 | (0.0000) | 2481 |
| DLMOSTOPL | -0.0007 | 1.9896 | -3.6984 | 0.0749 | -26.45 | 1693.53 | 45365570 | (0.0000) | 3806 |
| DLMOSTOFRA | -0.0005 | 0.5465 | -0.4520 | 0.0593 | 0.30 | 15.49 | 16121 | (0.0000) | 2476 |
| DLNORMATA | 0.0005 | 0.2412 | -0.2167 | 0.0257 | -0.29 | 18.35 | 26645 | (0.0000) | 2709 |
| DLNORMAFR | -0.0001 | 0.3028 | -0.3847 | 0.0301 | -1.48 | 31.76 | 84051 | (0.0000) | 2413 |
| DLOTPBKHU | 0.0005 | 0.1891 | -2.2957 | 0.0494 | -33.84 | 1573.19 | 30577489 | (0.0000) | 2971 |
| DLOTPBKFR | 0.0004 | 0.1873 | -2.2402 | 0.0520 | -30.47 | 1301.65 | 18705011 | (0.0000) | 2656 |
| DLOTPBKXSQ | 0.0000 | 0.1694 | -2.2331 | 0.0552 | -34.30 | 1389.05 | 15519083 | (0.0000) | 1934 |
| DLPKNORPL | 0.0006 | 0.0834 | -0.0880 | 0.0203 | 0.06 | 4.01 | 79 | (0.0000) | 1850 |
| DLPKNORFRG | 0.0005 | 0.1263 | -0.1859 | 0.0248 | 0.01 | 7.01 | 1219 | (0.0000) | 1824 |
| DLPLIVAZA | 0.0012 | 0.7895 | -0.2830 | 0.0310 | 7.04 | 171.29 | 3697844 | (0.0000) | 3112 |
| DLPLIVAFRG | 0.0003 | 0.3811 | -0.2775 | 0.0293 | 0.24 | 23.51 | 45721 | (0.0000) | 2606 |
| DLPLIVAXSQ | 0.0002 | 0.2252 | -0.1391 | 0.0239 | 0.40 | 10.98 | 6785 | (0.0000) | 2530 |
| DLRABAHU | -0.0004 | 0.2016 | -0.2459 | 0.0260 | -0.10 | 12.69 | 9232 | (0.0000) | 2357 |
| DLRABAFR | -0.0005 | 0.4414 | -0.6189 | 0.0314 | -2.14 | 94.14 | 812288 | (0.0000) | 2342 |
| DLRICHTHU | 0.0008 | 0.2168 | -0.2378 | 0.0267 | -0.54 | 15.76 | 21650 | (0.0000) | 3167 |
| DLRICHTFR | 0.0005 | 0.1631 | -0.3829 | 0.0284 | -1.13 | 21.40 | 38126 | (0.0000) | 2663 |
| DLRICHTXSQ | 0.0009 | 0.7926 | -0.1907 | 0.0290 | 6.95 | 199.52 | 4691550 | (0.0000) | 2901 |
| DLRMSHOCZ | 0.0000 | 0.2043 | -0.3045 | 0.0243 | -0.83 | 22.73 | 55982 | (0.0000) | 3428 |
| DLRMSHOFR | -0.0004 | 0.8666 | -0.4080 | 0.0347 | 6.22 | 189.11 | 3963561 | (0.0000) | 2734 |
| DLSETUZCZ | -0.0002 | 0.2836 | -0.3137 | 0.0265 | -0.29 | 29.10 | 95742 | (0.0000) | 3371 |
| DLSETUZFR | -0.0003 | 0.5887 | -0.8677 | 0.0323 | -6.69 | 287.26 | 9171510 | (0.0000) | 2718 |
| DLSOFTBPL | -0.0001 | 0.1392 | -0.7483 | 0.0354 | -4.62 | 96.51 | 810871 | (0.0000) | 2204 |
| DLSOFTBFRG | 0.0001 | 0.2167 | -0.3293 | 0.0425 | 0.05 | 10.22 | 3367 | (0.0000) | 1553 |
| DLSOFTBXSQ | 0.0000 | 0.5447 | -0.7470 | 0.0429 | -2.30 | 85.81 | 630014 | (0.0000) | 2198 |
| DLSSZCZ | 0.0005 | 0.2434 | -0.1431 | 0.0242 | 0.77 | 16.90 | 27894 | (0.0000) | 3421 |
| DLSSZFR | 0.0008 | 0.4640 | -0.6174 | 0.0233 | -4.64 | 287.00 | 8349843 | (0.0000) | 2482 |
| DLSTALEPL | -0.0009 | 0.2877 | -0.3023 | 0.0398 | 0.48 | 10.21 | 5907 | (0.0000) | 2684 |
| DLSTALEFR | -0.0010 | 0.6444 | -0.6568 | 0.0607 | 0.46 | 34.96 | 82814 | (0.0000) | 1944 |
| DLSYNERHU | -0.0003 | 0.1497 | -0.1666 | 0.0302 | 0.32 | 8.17 | 2262 | (0.0000) | 1997 |
| DLSYNERFR | -0.0003 | 0.4364 | -0.2540 | 0.0410 | 0.62 | 14.29 | 10714 | (0.0000) | 1993 |
| DLTELEPPL | 0.0003 | 0.1418 | -0.1172 | 0.0243 | 0.15 | 4.84 | 307 | (0.0000) | 2117 |
| DLTELEPFRG | 0.0003 | 0.1433 | -0.1492 | 0.0292 | 0.05 | 5.40 | 506 | (0.0000) | 2107 |
| DLTELEPXSQ | 0.0001 | 0.1082 | -0.0991 | 0.0244 | 0.12 | 4.23 | 126 | (0.0000) | 1928 |
| DLTELO2CZ | -0.0005 | 0.1175 | -2.2794 | 0.0462 | -38.90 | 1917.38 | 47079346 | (0.0000) | 3078 |
| DLTELO2FR | -0.0006 | 0.1551 | -2.3228 | 0.0513 | -33.47 | 1513.18 | 26374044 | (0.0000) | 2770 |
| DLTELO2XSQ | 0.0002 | 0.2479 | -0.2067 | 0.0268 | 0.38 | 16.60 | 14938 | (0.0000) | 1934 |
| DLTISZAHU | 0.0004 | 0.2083 | -0.2189 | 0.0285 | -0.09 | 11.77 | 8704 | (0.0000) | 2713 |
| DLTISZAFR | 0.0004 | 0.2717 | -0.3102 | 0.0282 | -0.26 | 18.92 | 28046 | (0.0000) | 2653 |
| DLTISZAXSQ | -0.0002 | 0.1574 | -0.1385 | 0.0208 | 0.52 | 19.14 | 24610 | (0.0000) | 2258 |
| DLUNIPECZ | 0.0004 | 0.1529 | -0.2239 | 0.0257 | -0.34 | 9.77 | 4694 | (0.0000) | 2434 |
| DLUNIPEFR | 0.0004 | 0.2076 | -0.3258 | 0.0333 | -0.50 | 13.72 | 11719 | (0.0000) | 2427 |
| DLZWACKHU | 0.0002 | 0.2815 | -0.2133 | 0.0252 | 0.47 | 22.19 | 54551 | (0.0000) | 3546 |
| DLZWACKFR | 0.0001 | 0.7496 | -0.1632 | 0.0261 | 6.93 | 205.60 | 5864440 | (0.0000) | 3413 |

Log differences (DL) from all time series are summarized in alphabetical order. Descripitve statistics for each enterprise are shown for home markets first (acronyms CZ=Czech Republic, TA=Tallinn (Estonia) HU=Hungary, PL=Poland, RS=Russia, ZA=Zagreb (Croatia)), and for Frankfurt and London in the following lines. The columns present mean, maximum, minimum, standard deviation, skewness, kurtosis, Jarque-Bera normality test including its significance, and the number of observations, over which these figures are calculated.

Table 4: Standard Deviation, relative to the Cross-Listing

| Foreign Listings | 0 | | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|---|---|
| Series | Std. Dev. | Obs. | Std. Dev. | Obs. | Std. Dev. | Obs. | Std. Dev. | Obs. |
| DLBANKBPL | 0.0286 | 1393 | 0.0205 | 1291 | | | | |
| DLBANKBXSQ | | | 0.0307 | 1291 | | | | |
| DLBORSOHU | 0.0244 | 84 | 0.0318 | 786 | 0.0432 | 1941 | | |
| DLBORSOFR | | | 0.0357 | 786 | 0.0458 | 1941 | | |
| DLBORSOXSQ | | | | | 0.0390 | 1941 | | |
| DLCEZCZ | 0.0365 | 267 | 0.0222 | 3166 | | | | |
| DLCEZFR | | | 0.0256 | 3166 | | | | |
| DLDANUBHU | 0.0841 | 130 | 0.0268 | 3260 | | | | |
| DLDANUBFR | | | 0.0268 | 3260 | | | | |
| DLEESTITA | 0.0224 | 75 | 0.0113 | 45 | 0.0164 | 1936 | | |
| DLEESTIFR | | | 0.0103 | 45 | 0.0219 | 1936 | | |
| DLEESTIXSQ | | | | | 0.0217 | 1936 | | |
| DLEGISHU | 0.0202 | 506 | 0.0274 | 2738 | | | | |
| DLEGISFR | | | 0.0285 | 2738 | | | | |
| DLELMUHU | 0.0191 | 66 | 0.0249 | 2032 | | | | |
| DLELMUFR | | | 0.0199 | 2032 | | | | |
| DLEMASZHU | 0.0329 | 61 | 0.0208 | 2037 | | | | |
| DLEMASZFR | | | 0.0191 | 2037 | | | | |
| DLFOTEXHU | 0.0170 | 915 | 0.0339 | 3257 | | | | |
| DLFOTEXFR | | | 0.0441 | 3257 | | | | |
| DLIEUBKHU | 0.0230 | 613 | 0.0541 | 2635 | | | | |
| DLIEUBKFR | | | 0.0546 | 2635 | | | | |
| DLKOMBKCZ | 0.0231 | 596 | 0.0220 | 285 | 0.0444 | 360 | 0.0234 | 2093 |
| DLKOMBKFRG | | | 0.0303 | 285 | 0.0460 | 360 | 0.0303 | 2093 |
| DLKOMBXSQ | | | | | 0.0481 | 360 | 0.0324 | 2093 |
| DLKOMBKFR | | | | | | | 0.0274 | 2093 |
| DLKONZUHU | 0.3515 | 82 | 0.0669 | 4085 | | | | |
| DLKONZUFR | | | 0.0572 | 4085 | | | | |
| DLLUKOIRS | 0.0327 | 215 | 0.0447 | 1320 | 0.0219 | 1420 | | |
| DLLUKOIFRA | | | 0.0420 | 1320 | 0.0228 | 1420 | | |
| DLLUKOIXSQ | | | | | 0.0220 | 1420 | | |
| DLMAGTKHU | 0.0293 | 21 | 0.0263 | 425 | 0.0207 | 1934 | | |
| DLMAGTKFR | | | 0.0286 | 425 | 0.0258 | 1934 | | |
| DLMAGTKXSQ | | | | | 0.0227 | 1934 | | |
| DLMERKOTA | 0.0237 | 70 | 0.0377 | 2393 | | | | |
| DLMERKOFR | | | 0.0356 | 2393 | | | | |
| DLMOLHU | 0.0330 | 158 | 0.0259 | 254 | 0.0230 | 2481 | | |
| DLMOLFR | | | 0.0269 | 254 | 0.0263 | 2481 | | |
| DLMOLXSQ | | | | | 0.0237 | 2481 | | |
| DLMOSTOPL | 0.1177 | 1330 | 0.0344 | 2476 | | | | |
| DLMOSTOFRA | | | 0.0593 | 2476 | | | | |
| DLNORMATA | 0.0237 | 296 | 0.0259 | 2413 | | | | |
| DLNORMAFR | | | 0.0301 | 2413 | | | | |
| DLOTPBKHU | 0.0292 | 315 | 0.0345 | 722 | 0.0209 | 1934 | | |
| DLOTPBKFR | | | 0.0383 | 722 | 0.0239 | 1934 | | |
| DLOTPBKXSQ | | | | | 0.0216 | 1934 | | |
| DLPKNORPL | 0.0211 | 26 | 0.0203 | 1824 | | | | |
| DLPKNORFRG | | | 0.0248 | 1824 | | | | |
| DLPLIVAZA | 0.0546 | 506 | 0.0243 | 76 | 0.0237 | 2530 | | |
| DLPLIVAFRG | | | 0.0278 | 76 | 0.0293 | 2530 | | |
| DLPLIVAXSQ | | | | | 0.0239 | 2530 | | |
| DLRABAHU | 0.0390 | 15 | 0.0259 | 2342 | | | | |
| DLRABAFR | | | 0.0314 | 2342 | | | | |
| DLRICHTHU | 0.0213 | 266 | 0.0265 | 238 | 0.0272 | 2663 | | |
| DLRICHTXSQ | | | 0.0249 | 238 | 0.0293 | 2663 | | |
| DLRICHTFR | | | | | 0.0284 | 2663 | | |
| DLRMSHOCZ | 0.0319 | 694 | 0.0219 | 2734 | | | | |
| DLRMSHOFR | | | 0.0347 | 2734 | | | | |
| DLSETUZCZ | 0.0280 | 653 | 0.0262 | 2718 | | | | |
| DLSETUZFR | | | 0.0323 | 2718 | | | | |
| DLSOFTBPL | 0.0332 | 6 | 0.0469 | 645 | 0.0294 | 1553 | | |
| DLSOFTBXSQ | | | 0.0452 | 645 | 0.0420 | 1553 | | |
| DLSOFTBFRG | | | | | 0.0425 | 1553 | | |
| DLSSZCZ | 0.0318 | 939 | 0.0206 | 2482 | | | | |
| DLSSZFR | | | 0.0233 | 2482 | | | | |
| DLSTALEPL | 0.0365 | 740 | 0.0410 | 1944 | | | | |
| DLSTALEFR | | | 0.0607 | 1944 | | | | |
| DLSYNERHU | 0.0160 | 4 | 0.0302 | 1993 | | | | |
| DLSYNERFR | | | 0.0410 | 1993 | | | | |
| DLTELEPPL | 0.0231 | 10 | 0.0296 | 179 | 0.0238 | 1928 | | |
| DLTELEPFRG | | | 0.0346 | 179 | 0.0286 | 1928 | | |
| DLTELEPXSQ | | | | | 0.0244 | 1928 | | |
| DLTELO2CZ | 0.0157 | 308 | 0.0814 | 836 | 0.0223 | 1934 | | |
| DLTELO2FR | | | 0.0841 | 836 | 0.0268 | 1934 | | |
| DLTELO2XSQ | | | | | 0.0268 | 1934 | | |
| DLTISZAHU | 0.0071 | 60 | 0.0329 | 395 | 0.0280 | 2258 | | |
| DLTISZAFR | | | 0.0319 | 395 | 0.0275 | 2258 | | |
| DLTISZAXSQ | | | | | 0.0208 | 2258 | | |
| DLUNIPECZ | 0.0193 | 7 | 0.0257 | 2427 | | | | |
| DLUNIPEFR | | | 0.0333 | 2427 | | | | |
| DLZWACKHU | 0.0261 | 133 | 0.0251 | 2413 | | | | |
| DLZWACKFR | | | 0.0261 | 2413 | | | | |

This table reports a comparison on standard deviations of log differences (DL). Each standard deviation is calculated relative to the cross-listing date. The number of observations is provided in the following columns.

Table 5: Estimates of cross-listing effects on price volatility

| **Frankfurt first** | $\gamma_0$ | $\gamma_{fr}$ | $\delta_0$ | $\delta_{fr}$ | $\lambda_0$ | $\lambda_{fr}$ |
|---:|---|---|---|---|---|---|
| Eesti Telekomi | 0.0002 | 0.0001 | 0.0777 | 0.0216 | 0.0293 | -0.0276 |
| | (0.0667) | (0.4671) | (0.5635) | (0.8800) | (0.2032) | (0.2318) |
| Egis | 0.0003 | -0.0004 | 0.2808 | -0.1861 | 0.0000 | 0.3216 |
| | (0.0000) | (0.3315) | (0.0000) | (0.1374) | (0.9759) | (0.0869) |
| Emasz | 0.0009 | -0.0006 | 0.0427 | 0.1450 | 0.5809 | -0.2896 |
| | (0.0079) | (0.0866) | (0.7256) | (0.3173) | (0.2275) | (0.5749) |
| Fotex | 0.0003 | 0.0004 | 0.0062 | 0.1682 | 0.0089 | 0.0061 |
| | (0.0000) | (0.0002) | (0.7155) | (0.0148) | (0.0838) | (0.3179) |
| Komercni Banka | 0.0005 | -0.0002 | 0.0697 | -0.0812 | 0.1845 | -0.1614 |
| | (0.0000) | (0.1297) | (0.0511) | (0.6353) | (0.0004) | (0.0023) |
| Lukoil | 0.0005 | -0.0004 | 0.1115 | 0.1657 | 0.0329 | -0.0058 |
| | (0.0004) | (0.0972) | (0.0002) | (0.0565) | (0.0048) | (0.6562) |
| Magyar Tkom | -0.0004 | 0.0002 | 0.0341 | -0.0171 | 0.0069 | -0.0033 |
| | (0.1618) | (0.4183) | (0.7998) | (0.9014) | (0.0025) | (0.1536) |
| Mol Magyar | 0.0012 | -0.0009 | 0.0785 | 0.1518 | -0.0001 | 0.0045 |
| | (0.0008) | (0.0084) | (0.3222) | (0.1102) | (0.0105) | (0.0005) |
| Norma Aktsia | 0.0004 | 0.0001 | 0.2291 | -0.0416 | 0.0195 | 0.0110 |
| | (0.0001) | (0.3400) | (0.0051) | (0.6825) | (0.1054) | (0.4903) |
| OTP Bank | 0.0005 | 0.0034 | 0.0681 | -0.0680 | 0.0136 | -0.0240 |
| | (0.0084) | (0.3508) | (0.4388) | (0.4396) | (0.0414) | (0.1349) |
| PKN Orlen | 0.0000 | 0.0000 | -0.0782 | 0.1179 | 0.0060 | -0.0022 |
| | (0.8897) | (0.9048) | (0.5402) | (0.3750) | (0.2088) | (0.6478) |
| Raba | 0.0001 | 0.0003 | -0.4742 | 0.7774 | 0.1908 | -0.1703 |
| | (0.8626) | (0.3663) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Stalexport | 0.0009 | 0.0000 | 0.1894 | 0.1204 | 0.1036 | -0.0988 |
| | (0.0000) | (0.8579) | (0.0050) | (0.3114) | (0.0042) | (0.0064) |
| Telefonica O2 | 0.0001 | 0.0032 | 0.1962 | -0.1968 | 0.0039 | -0.0134 |
| | (0.2010) | (0.2583) | (0.1293) | (0.1281) | (0.0163) | (0.2027) |
| Telekomunikacja PL | 0.0002 | 0.0003 | -0.8178 | 0.9186 | 0.0155 | -0.0151 |
| | (0.5273) | (0.1960) | (0.0118) | (0.0049) | (0.0152) | (0.0178) |
| Unipetrol | 0.0004 | -0.0004 | -0.2784 | 0.3632 | -0.0602 | 0.0705 |
| | (0.2752) | (0.2224) | (0.1585) | (0.0758) | (0.3606) | (0.2845) |
| **London first** | $\gamma_0$ | $\gamma_{lo}$ | $\delta_0$ | $\delta_{lo}$ | $\lambda_0$ | $\lambda_{lo}$ |
| Bank BPH | 0.0006 | -0.0003 | 0.3077 | -0.0995 | 0.3067 | -0.2608 |
| | (0.0000) | (0.0191) | (0.0524) | (0.6050) | (0.0131) | (0.0372) |
| Borsodchem | 0.0003 | 0.0014 | 0.1005 | -0.1000 | 0.0231 | -0.0051 |
| | (0.1115) | (0.4114) | (0.0480) | (0.0494) | (0.0004) | (0.8453) |
| Richter Gedeon | 0.0003 | 0.0000 | 0.4174 | -0.0434 | 0.0357 | -0.0049 |
| | (0.0002) | (0.9470) | (0.0043) | (0.8136) | (0.6721) | (0.9540) |
| Softbank | -0.0009 | 0.0018 | -3.3268 | 3.3409 | 2.6929 | -2.6328 |
| | (0.3777) | (0.1021) | (0.0000) | (0.0000) | (0.0006) | (0.0008) |

The table presents Generalized Method of Moment estimates with heteroskedasticity-consistent standard errors. The variables $\Delta P_t$ and $V_t$ are price change and volume (in ten millions of shares). All parameters with an index different from 0 present interaction with the respective cross-listing dummy. Cross-listing dummies are set from 0 to 1 after the cross-listing. The table only contains enterprises from our data set, from which we are able to obtain volume data with less than 11% of missing values. Each enterprise regression is printed in one double-row. In the first row parameter estimates are shown and followed by their statistical significance in the second.

Table 6: Estimates of cross-listing effects on price volatility (two cross-listings)

| **Frankfurt first** | $\gamma_0$ | $\gamma_{fr}$ | $\gamma_{lo}$ | $\delta_0$ | $\delta_{fr}$ | $\delta_{lo}$ | $\lambda_0$ | $\lambda_{fr}$ | $\lambda_{lo}$ |
|---|---|---|---|---|---|---|---|---|---|
| Eesti Telekomi | 0.0002 | -0.0001 | 0.0001 | 0.0777 | -0.0575 | 0.0789 | 0.0293 | -0.0076 | -0.0200 |
| | (0.0667) | (0.5088) | (0.0004) | (0.5635) | (0.7379) | (0.5029) | (0.2032) | (0.8081) | (0.3433) |
| Komercni Banka | 0.0005 | -0.0005 | 0.0001 | 0.0651 | 0.0582 | 0.4275 | 0.1759 | 0.6596 | -0.8216 |
| | (0.0000) | (0.0049) | (0.4454) | (0.0662) | (0.7852) | (0.0724) | (0.0007) | (0.1204) | (0.0513) |
| Lukoil | 0.0005 | 0.0001 | -0.0006 | 0.1115 | 0.1602 | -0.1148 | 0.0329 | -0.0089 | -0.0044 |
| | (0.0004) | (0.7490) | (0.0435) | (0.0002) | (0.0716) | (0.2645) | (0.0048) | (0.5152) | (0.5823) |
| Magyar Tkom | -0.0004 | -0.0002 | 0.0005 | 0.0341 | -0.0617 | 0.0557 | 0.0069 | -0.0009 | -0.0030 |
| | (0.1618) | (0.6167) | (0.0253) | (0.7998) | (0.6653) | (0.3818) | (0.0025) | (0.7347) | (0.0213) |
| Mol Magyar | 0.0012 | -0.0008 | -0.0002 | 0.0785 | 0.1005 | 0.0530 | -0.0001 | 0.0093 | -0.0046 |
| | (0.0008) | (0.0441) | (0.2298) | (0.3222) | (0.4038) | (0.6201) | (0.0105) | (0.1200) | (0.4526) |
| OTP Bank | 0.0005 | 0.0002 | 0.0045 | 0.0681 | 0.1119 | -0.1799 | 0.0136 | -0.0106 | -0.0210 |
| | (0.0084) | (0.4783) | (0.3756) | (0.4388) | (0.3887) | (0.0594) | (0.0414) | (0.1195) | (0.3378) |
| Telefonica O2 | 0.0001 | 0.0101 | -0.0098 | 0.1962 | -0.1982 | 0.1449 | 0.0039 | -0.1164 | 0.1130 |
| | (0.2010) | (0.3092) | (0.3250) | (0.1293) | (0.1256) | (0.0003) | (0.0163) | (0.3383) | (0.3525) |
| Telekomunikacja PL | 0.0002 | -0.0005 | 0.0007 | -0.8178 | 0.6792 | 0.2916 | 0.0155 | 0.0360 | -0.0510 |
| | (0.5273) | (0.2521) | (0.0190) | (0.0118) | (0.0424) | (0.0009) | (0.0152) | (0.0761) | (0.0082) |
| **London first** | | | | | | | | | |
| Richter Gedeon | 0.0003 | 0.0000 | 0.0000 | 0.4174 | -0.3277 | 0.2900 | 0.0357 | 0.1387 | -0.1438 |
| | (0.0002) | (0.9029) | (0.8526) | (0.0043) | (0.0751) | (0.0700) | (0.6721) | (0.2080) | (0.0453) |
| Softbank | -0.0009 | 0.0031 | -0.0022 | -3.3268 | 3.3261 | 0.2502 | 2.6929 | -2.6550 | 0.0415 |
| | (0.3775) | (0.0232) | (0.0169) | (0.0000) | (0.0000) | (0.0355) | (0.0006) | (0.0007) | (0.3570) |

The table presents Generalized Method of Moment estimates with heteroskedasticity-consistent standard errors. The variables $\Delta P_t$ and $V_t$ are price change and volume (in ten millions of shares). All parameters with an index different from 0 present interaction with the respective cross-listing dummy. Cross-listing dummies are set from 0 to 1 after the cross-listing. The table only contains enterprises from our data set, from which we are able to obtain volume data with less than 11% of missing values. Each enterprise regression is printed in one double-row. In the first row parameter estimates are shown and followed by their statistical significance in the second.

Table 7: Estimates of cross-listing effects on price volatility (multiple cross-listings)

| **Frankfurt first** | $\gamma_0$ | $\gamma_{fr}$ | $\gamma_{lo}$ | $\gamma_{fr2}$ | $\delta_0$ | $\delta_{fr}$ | $\delta_{lo}$ | $\delta_{fr2}$ | $\lambda_0$ | $\lambda_{fr}$ | $\lambda_{lo}$ | $\lambda_{fr2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Komercni Banka | 0.0005 | -0.0005 | 0.0004 | -0.0006 | 0.0651 | 0.0582 | 0.4743 | -0.3010 | 0.1759 | 0.6596 | -0.7222 | -0.0820 |
| | (0.0000) | (0.0049) | (0.1885) | (0.0453) | (0.0662) | (0.7852) | (0.0697) | (0.0836) | (0.0007) | (0.1204) | (0.0948) | (0.3934) |

The table presents Generalized Method of Moment estimates with heteroskedasticity-consistent standard errors. The variables $\Delta P_t$ and $V_t$ are price change and volume (in ten millions of shares). All parameters with an index different from 0 present interaction with the respective cross-listing dummy. Cross-listing dummies are set from 0 to 1 after the cross-listing. The table only contains enterprises from our data set, from which we are able to obtain volume data with less than 11% of missing values. Each enterprise regression is printed in one double-row. In the first row parameter estimates are shown and followed by their statistical significance in the second.

Table 8: Volatility Spillover (one cross-listing)

| Enterprise | For.List | from Market | to Market | Spill | Prob. | AR1-Share |
|---|---|---|---|---|---|---|
| Bank BPH | 1 | Warsaw | XSQ | 0.8387 | (0.0000) | 0.0048 |
| Bank BPH | 1 | XSQ | Warsaw | 0.0001 | (0.7091) | n/a |
| CEZ | 1 | Prag | FR | 0.0993 | (0.0000) | 0.0370 |
| CEZ | 1 | FR | Prag | 0.0186 | (0.0001) | 0.0125 |
| Eesti Telekomi | 1 | Tallinn | FR | 0.1503 | (0.0000) | 0.0390 |
| Eesti Telekomi | 1 | FR | Tallinn | 0.0013 | (0.0001) | 0.0159 |
| Egis | 1 | Budapest | FR | 0.4355 | (0.0000) | 0.0102 |
| Egis | 1 | FR | Budapest | 0.0021 | (0.0050) | 0.0204 |
| Elmu | 1 | Budapest | FR | 0.0177 | (0.0000) | -0.2603 |
| Elmu | 1 | FR | Budapest | -0.0003 | (0.0541) | n/a |
| Emasz | 1 | Budapest | FR | 0.0637 | (0.0000) | 0.0389 |
| Emasz | 1 | FR | Budapest | 0.0543 | (0.0000) | 0.2301 |
| Fotex | 1 | Budapest | FR | 0.1960 | (0.0000) | 0.0368 |
| Fotex | 1 | FR | Budapest | 0.2855 | (0.0000) | -0.2321 |
| Komercni Banka | 1 | Prag | FR | 0.5071 | (0.0000) | 0.0435 |
| Komercni Banka | 1 | FR | Prag | 0.0201 | (0.0000) | 0.0016 |
| Konzum | 1 | Budapest | FR | 0.0092 | (0.0000) | 0.0154 |
| Konzum | 1 | FR | Budapest | 0.2070 | (0.0000) | -0.1085 |
| Lukoil | 1 | Moscow | FR | 0.1091 | (0.0000) | 0.0782 |
| Lukoil | 1 | FR | Moscow | 0.1873 | (0.0000) | 0.1011 |
| Magyar TKom | 1 | Budapest | FR | 0.1183 | (0.0000) | 0.0138 |
| Magyar TKom | 1 | FR | Budapest | 0.0319 | (0.0000) | 0.0376 |
| Mol Magyar | 1 | Budapest | FR | 0.2619 | (0.0000) | 0.0187 |
| Mol Magyar | 1 | FR | Budapest | 0.0116 | (0.0960) | n/a |
| Mostostal Export | 1 | Warsaw | FR | 0.1573 | (0.0000) | -0.0144 |
| Mostostal Export | 1 | FR | Warsaw | 0.0003 | (0.0000) | 0.0056 |
| Norma | 1 | Tallinn | FR | 0.0070 | (0.0000) | -0.1172 |
| Norma | 1 | FR | Tallinn | 0.0037 | (0.0010) | -0.0078 |
| OTP Bank | 1 | Budapest | FR | 0.0114 | (0.0000) | 0.0986 |
| OTP Bank | 1 | FR | Budapest | 0.0260 | (0.0014) | 0.0153 |
| PKN Orlen | 1 | Warsaw | FR | 0.0376 | (0.0000) | 0.0490 |
| PKN Orlen | 1 | FR | Warsaw | 0.0002 | (0.9650) | n/a |
| Pliva | 1 | Zagreb | FR | 0.1014 | (0.0000) | 0.0380 |
| Pliva | 1 | FR | Zagreb | 0.0245 | (0.0000) | -0.0134 |
| Raba | 1 | Budapest | FR | 0.0324 | (0.0000) | -0.0440 |
| Raba | 1 | FR | Budapest | 0.0001 | (0.2033) | n/a |
| Softbank | 1 | Warsaw | FR | 0.0032 | (0.0000) | -0.1281 |
| Softbank | 1 | FR | Warsaw | -0.0001 | (0.0001) | n/a |
| Stalexport | 1 | Warsaw | FR | 0.0046 | (0.0000) | 0.0130 |
| Stalexport | 1 | FR | Warsaw | -0.0005 | (0.5208) | n/a |
| Synergon | 1 | Budapest | FR | 0.4979 | (0.0000) | 0.0332 |
| Synergon | 1 | FR | Budapest | 0.0007 | (0.0000) | 0.0085 |
| Telekomunikacja PL | 1 | Warsaw | FR | 0.1332 | (0.0000) | 0.0007 |
| Telekomunikacja PL | 1 | FR | Warsaw | 0.0005 | (0.8646) | n/a |
| Unipetrol | 1 | Prag | FR | 0.4899 | (0.0000) | 0.0133 |
| Unipetrol | 1 | FR | Prag | 0.0012 | (0.0027) | 0.0088 |

This table reports detailed estimates on GARCH volatility spillovers. Column 1 provides enterprise information. Column 2 gives the number of foreign listings on the period of estimate. Columns 3 and 4 present the direction of the spillover coefficient, which is presented in columns 5 and 6. In the last column, the AR(1)-parameter from the variance equation is calculated relative to its value without a cross-listing term.

Table 9: Volatility Spillover (two cross-listings, part 1)

| **Enterprise** | **For.List** | **from Market** | **to Market** | **Spill1** | **Prob.1** | **Spill2** | **Prob.2** | **AR1-Share** |
|---|---|---|---|---|---|---|---|---|
| Eesti Telekomi | 2 | Tallinn | FR | 0.1573 | (0.0000) | | | 0.0803 |
| Eesti Telekomi | 2 | Tallinn | XSQ | 0.0694 | (0.0000) | | | -0.0268 |
| Eesti Telekomi | 2 | FR | Tallinn | 0.0010 | (0.0000) | | | 0.0080 |
| Eesti Telekomi | 2 | FR | XSQ | 0.0382 | (0.0000) | | | -0.0100 |
| Eesti Telekomi | 2 | XSQ | Tallinn | -0.0001 | (0.5739) | | | n/a |
| Eesti Telekomi | 2 | XSQ | FR | -0.0015 | (0.0245) | | | n/a |
| Eesti Telekomi | 2 | Tallinn and FR | XSQ | 0.0571 | (0.0000) | -0.0241 | (0.0000) | -0.0022 |
| Eesti Telekomi | 2 | FR and XSQ | Tallinn | 0.0011 | (0.0000) | -0.0001 | (0.2745) | 0.0059 |
| Komercni Banka | 2 | Prag | FRG | 0.4733 | (0.0000) | | | 0.0475 |
| Komercni Banka | 2 | Prag | XSQ | 0.2071 | (0.0000) | | | -0.0012 |
| Komercni Banka | 2 | FRG | Prag | 0.0309 | (0.0000) | | | 0.0022 |
| Komercni Banka | 2 | FRG | XSQ | 0.1259 | (0.0000) | | | -0.0229 |
| Komercni Banka | 2 | XSQ | Prag | -0.0025 | (0.0002) | | | n/a |
| Komercni Banka | 2 | XSQ | FRG | 0.2492 | (0.0000) | | | -0.0209 |
| Komercni Banka | 2 | Prag and FRG | XSQ | 0.1951 | (0.0000) | 0.0159 | (0.0405) | -0.0038 |
| Komercni Banka | 2 | Prag and XSQ | FRG | 0.4739 | (0.0000) | 0.0026 | (0.2903) | 0.0482 |
| Komercni Banka | 2 | FRG and XSQ | Prag | 0.0302 | (0.0000) | -0.0032 | (0.0001) | 0.0072 |
| Lukoil | 2 | Moscow | FR | 0.0073 | (0.0041) | | | 0.0609 |
| Lukoil | 2 | Moscow | XSQ | 0.0047 | (0.0673) | | | n/a |
| Lukoil | 2 | FR | Moscow | 0.0812 | (0.0000) | | | 0.0536 |
| Lukoil | 2 | FR | XSQ | 0.0014 | (0.5950) | | | n/a |
| Lukoil | 2 | XSQ | Moscow | 0.0850 | (0.0000) | | | 0.0563 |
| Lukoil | 2 | XSQ | FR | 0.0040 | (0.1103) | | | n/a |
| Lukoil | 2 | Moscow and XSQ | FR | 0.0116 | (0.0024) | -0.0063 | (0.1048) | 0.0374 |
| Lukoil | 2 | Moscow and FR | XSQ | 0.0069 | (0.0394) | -0.0030 | (0.4005) | n/a |
| Lukoil | 2 | FR and XSQ | Moscow | 0.0541 | (0.0301) | 0.0436 | (0.0848) | n/a |
| Magyar TKom | 2 | Budapest | FR | 0.0067 | (0.0000) | | | 0.0506 |
| Magyar TKom | 2 | Budapest | XSQ | 0.1239 | (0.0000) | | | 0.0620 |
| Magyar TKom | 2 | FR | Budapest | 0.0023 | (0.0108) | | | n/a |
| Magyar TKom | 2 | FR | XSQ | 0.0680 | (0.0000) | | | 0.0305 |
| Magyar TKom | 2 | XSQ | Budapest | -0.0001 | (0.8074) | | | n/a |
| Magyar TKom | 2 | XSQ | FR | 0.0005 | (0.3451) | | | n/a |
| Magyar TKom | 2 | Budapest and XSQ | FR | 0.0076 | (0.0000) | -0.0011 | (0.0717) | 0.0482 |
| Magyar TKom | 2 | Budapest and FR | XSQ | 0.1044 | (0.0000) | 0.0526 | (0.0000) | 0.0589 |
| Magyar TKom | 2 | FR and XSQ | Budapest | 0.0023 | (0.0104) | -0.0003 | (0.6471) | n/a |
| Mol Magyar | 2 | Budapest | FR | 0.2632 | (0.0000) | | | 0.0045 |
| Mol Magyar | 2 | Budapest | XSQ | 0.0035 | (0.0026) | | | 0.0234 |
| Mol Magyar | 2 | FR | Budapest | 0.0022 | (0.0065) | | | 0.0129 |
| Mol Magyar | 2 | FR | XSQ | 0.0028 | (0.0070) | | | 0.0115 |
| Mol Magyar | 2 | XSQ | Budapest | 0.0018 | (0.0645) | | | n/a |
| Mol Magyar | 2 | XSQ | FR | 0.2081 | (0.0000) | | | 0.0236 |
| Mol Magyar | 2 | Budapest and XSQ | FR | 0.2052 | (0.0000) | 0.0825 | (0.0027) | 0.0150 |
| Mol Magyar | 2 | Budapest and FR | XSQ | 0.0031 | (0.0146) | 0.0020 | (0.0676) | n/a |
| Mol Magyar | 2 | FR and XSQ | Budapest | 0.0019 | (0.0253) | 0.0013 | (0.1713) | n/a |

This table reports detailed estimates on GARCH volatility spillovers. Column 1 provides enterprise information. Column 2 gives the number of foreign listings on the period of estimate. Columns 3 and 4 present the direction of the spillover coefficients, which is presented in columns 5 through 8. In the last column, the AR(1)-parameter from the variance equation is calculated relative to its value without a cross-listing term.

Table 10: Volatility Spillover (two cross-listings, part 2)

| Enterprise | For.List | from Market | to Market | Spill1 | Prob.1 | Spill2 | Prob.2 | AR1-Share |
|---|---|---|---|---|---|---|---|---|
| OTP Bank | 2 | Budapest | FR | 0.2085 | (0.0000) | | | 0.0109 |
| OTP Bank | 2 | Budapest | XSQ | 0.0471 | (0.0000) | | | 0.0102 |
| OTP Bank | 2 | FR | Budapest | 0.0039 | (0.0222) | | | n/a |
| OTP Bank | 2 | FR | XSQ | 0.0234 | (0.0000) | | | 0.0005 |
| OTP Bank | 2 | XSQ | Budapest | 0.0028 | (0.0261) | | | n/a |
| OTP Bank | 2 | XSQ | FR | 0.0963 | (0.0000) | | | -0.0123 |
| OTP Bank | 2 | Budapest and XSQ | FR | 0.1882 | (0.0000) | 0.0165 | (0.3371) | 0.0099 |
| OTP Bank | 2 | Budapest and FR | XSQ | 0.0462 | (0.0000) | 0.0012 | (0.8017) | 0.0534 |
| OTP Bank | 2 | FR and XSQ | Budapest | 0.0034 | (0.0311) | 0.0028 | (0.0324) | n/a |
| Pliva | 2 | Zagreb | FR | 0.3641 | (0.0000) | | | -0.0102 |
| Pliva | 2 | Zagreb | XSQ | 0.0010 | (0.0000) | | | -0.1300 |
| Pliva | 2 | FR | Zagreb | 0.0002 | (0.0000) | | | 0.0428 |
| Pliva | 2 | FR | XSQ | 0.0003 | (0.0000) | | | -0.0056 |
| Pliva | 2 | XSQ | Zagreb | 0.0166 | (0.0000) | | | 0.0229 |
| Pliva | 2 | XSQ | FR | 0.1730 | (0.0000) | | | 0.0286 |
| Pliva | 2 | Zagreb and XSQ | FR | 0.2680 | (0.0000) | 0.3171 | (0.0000) | -0.0033 |
| Pliva | 2 | Zagreb and FR | XSQ | 0.0004 | (0.0695) | 0.0008 | (0.0000) | -0.1276 |
| Pliva | 2 | FR and XSQ | Zagreb | 0.0027 | (0.0000) | 0.0166 | (0.0000) | 0.2408 |
| Softbank | 2 | Warsaw | XSQ | 0.3394 | (0.0000) | | | 0.0057 |
| Softbank | 2 | Warsaw | FR | 0.0105 | (0.0000) | | | 0.0110 |
| Softbank | 2 | XSQ | Warsaw | -0.0011 | (0.1223) | | | n/a |
| Softbank | 2 | XSQ | FR | 0.0002 | (0.0358) | | | n/a |
| Softbank | 2 | FR | Warsaw | 0.0025 | (0.4631) | | | n/a |
| Softbank | 2 | FR | XSQ | -0.0001 | (0.0000) | | | 0.0097 |
| Softbank | 2 | Warsaw and FR | XSQ | 0.2468 | (0.0000) | -0.0282 | (0.0000) | 0.0114 |
| Softbank | 2 | Warsaw and XSQ | FR | 0.0104 | (0.0000) | 0.0002 | (0.1074) | 0.0116 |
| Softbank | 2 | XSQ and FR | Warsaw | -0.0011 | (0.1244) | 0.0026 | (0.4577) | n/a |
| Telefonica O2 CR | 2 | Prag | FR | 0.0213 | (0.0000) | | | 0.0216 |
| Telefonica O2 CR | 2 | Prag | XSQ | 0.0397 | (0.0000) | | | 0.0173 |
| Telefonica O2 CR | 2 | FR | Prag | -0.0009 | (0.4005) | | | n/a |
| Telefonica O2 CR | 2 | FR | XSQ | 0.0261 | (0.0000) | | | 0.0127 |
| Telefonica O2 CR | 2 | XSQ | Prag | -0.0014 | (0.0028) | | | n/a |
| Telefonica O2 CR | 2 | XSQ | FR | 0.0002 | (0.3843) | | | n/a |
| Telefonica O2 CR | 2 | Prag and XSQ | FR | 0.0216 | (0.0000) | -0.0005 | (0.3374) | 0.0200 |
| Telefonica O2 CR | 2 | Prag and FR | XSQ | 0.1373 | (0.0000) | 0.0463 | (0.0000) | -0.0042 |
| Telefonica O2 CR | 2 | FR and XSQ | Prag | -0.0004 | (0.7199) | -0.0014 | (0.0036) | n/a |
| Telekomunikacja Polska | 2 | Warsaw | FR | 0.1776 | (0.0000) | | | 0.0054 |
| Telekomunikacja Polska | 2 | Warsaw | XSQ | 0.0108 | (0.1498) | | | n/a |
| Telekomunikacja Polska | 2 | FR | Warsaw | 0.0053 | (0.0906) | | | n/a |
| Telekomunikacja Polska | 2 | FR | XSQ | 0.0092 | (0.0158) | | | n/a |
| Telekomunikacja Polska | 2 | XSQ | Warsaw | 0.0080 | (0.2250) | | | n/a |
| Telekomunikacja Polska | 2 | XSQ | FR | 0.1305 | (0.0000) | | | -0.0045 |
| Telekomunikacja Polska | 2 | Warsaw and XSQ | FR | 0.1986 | (0.0000) | -0.0273 | (0.0983) | 0.0049 |
| Telekomunikacja Polska | 2 | Warsaw and FR | XSQ | 0.0070 | (0.3494) | 0.0085 | (0.0263) | n/a |
| Telekomunikacja Polska | 2 | FR and XSQ | Warsaw | 0.0046 | (0.1458) | 0.0052 | (0.4319) | n/a |

This table reports detailed estimates on GARCH volatility spillovers. Column 1 provides enterprise information. Column 2 gives the number of foreign listings on the period of estimate. Columns 3 and 4 present the direction of the spillover coefficients, which is presented in columns 5 through 8. In the last column, the AR(1)-parameter from the variance equation is calculated relative to its value without a cross-listing term.

Table 11: Volatility Spillover (three cross-listings)

| Enterprise | For.List | from Market | to Market | Spill1 | Prob1 | Spill2 | Prob2 | Spill3 | Prob3 | AR1-Share |
|---|---|---|---|---|---|---|---|---|---|---|
| Komercni Banka | 3 | Prag | FRG | 0.5151 | (0.0000) | | | | | 0.1034 |
| Komercni Banka | 3 | Prag | XSQ | 0.2239 | (0.0000) | | | | | -0.0013 |
| Komercni Banka | 3 | Prag | FR | 0.0292 | (0.0000) | | | | | -0.1497 |
| Komercni Banka | 3 | FRG | Prag | 0.0118 | (0.0346) | | | | | n/a |
| Komercni Banka | 3 | FRG | XSQ | 0.1232 | (0.0000) | | | | | -0.0268 |
| Komercni Banka | 3 | FRG | FR | 0.0027 | (0.0000) | | | | | 0.1752 |
| Komercni Banka | 3 | XSQ | Prag | -0.0027 | (0.0109) | | | | | n/a |
| Komercni Banka | 3 | XSQ | FRG | 0.2195 | (0.0000) | | | | | 0.0243 |
| Komercni Banka | 3 | XSQ | FR | 0.0073 | (0.0000) | | | | | -0.0412 |
| Komercni Banka | 3 | FR | Prag | -0.0018 | (0.4626) | | | | | n/a |
| Komercni Banka | 3 | FR | XSQ | -0.0035 | (0.3322) | | | | | n/a |
| Komercni Banka | 3 | FR | FRG | 0.0714 | (0.0000) | | | | | 0.0477 |
| Komercni Banka | 3 | Prag and FRG | XSQ | 0.2195 | (0.0000) | 0.0049 | (0.5174) | | | -0.0018 |
| Komercni Banka | 3 | Prag and FRG | FR | 0.0355 | (0.0000) | -0.0023 | (0.0000) | | | -0.1709 |
| Komercni Banka | 3 | Prag and XSQ | FRG | 0.5157 | (0.0000) | 0.0006 | (0.7530) | | | 0.1038 |
| Komercni Banka | 3 | Prag and XSQ | FR | 0.0284 | (0.0000) | -0.0020 | (0.0001) | | | -0.1230 |
| Komercni Banka | 3 | Prag and FR | FRG | 0.1529 | (0.0005) | -0.0046 | (0.6937) | | | 0.0333 |
| Komercni Banka | 3 | Prag and FR | XSQ | 0.2139 | (0.0000) | -0.0037 | (0.1637) | | | 0.0125 |
| Komercni Banka | 3 | FRG and XSQ | Prag | 0.0118 | (0.0383) | -0.0032 | (0.0121) | | | n/a |
| Komercni Banka | 3 | FRG and XSQ | FR | 0.0053 | (0.0000) | 0.0020 | (0.0000) | | | 0.1313 |
| Komercni Banka | 3 | XSQ and FR | Prag | 0.0049 | (0.2121) | -0.0022 | (0.3243) | | | n/a |
| Komercni Banka | 3 | XSQ and FR | FRG | 0.1582 | (0.0000) | 0.1678 | (0.0000) | | | 0.0034 |
| Komercni Banka | 3 | Prag, FRG, and XSQ | FR | 0.0380 | (0.0000) | -0.0023 | (0.0000) | -0.0027 | (0.0001) | -0.1718 |
| Komercni Banka | 3 | Prag, XSQ, and FR | FRG | 0.5230 | (0.0000) | 0.0008 | (0.6884) | 0.0116 | (0.1850) | 0.1022 |
| Komercni Banka | 3 | Prag, FRG, and FR | XSQ | 0.1949 | (0.0000) | -0.0013 | (0.8394) | -0.0038 | (0.0319) | 0.0202 |
| Komercni Banka | 3 | FRG. XSQ. FR | Prag | 0.0104 | (0.0868) | -0.0010 | (0.4281) | -0.0015 | (0.2199) | n/a |

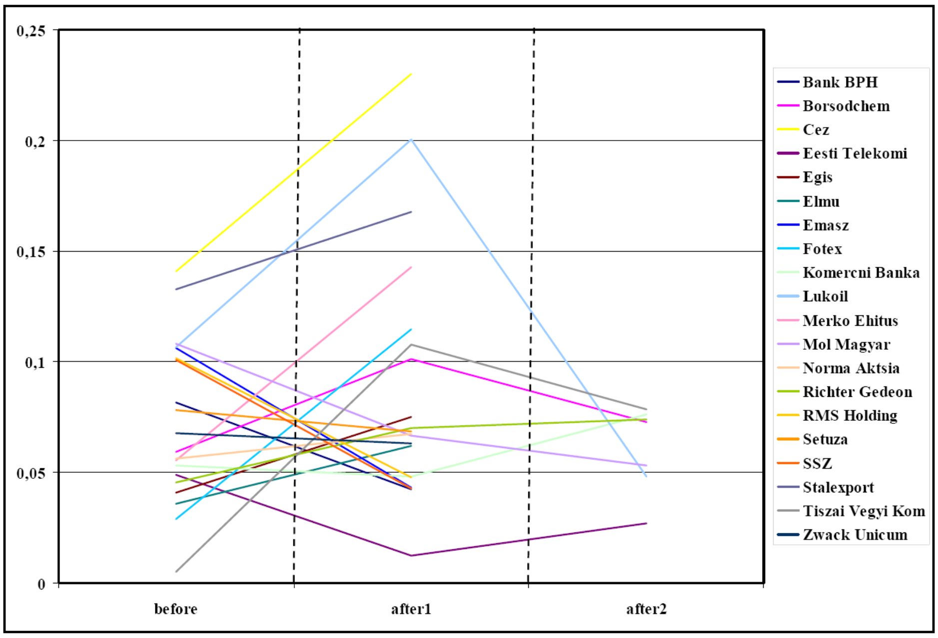
This table reports detailed estimates on GARCH volatility spillovers. Column 1 provides enterprise information. Column 2 gives the number of foreign listings on the period of estimate. Columns 3 and 4 present the direction of the spillover coefficients, which is presented in columns 5 through 10. In the last column, the AR(1)-parameter from the variance equation is calculated relative to its value without a cross-listing term.

Table 12: Overview on Spillover Estimates

| **Foreign Listing(s)** | **1** | **2** | **3** |
|---|---|---|---|
| Average Spillover | 0.1355 | 0.0976 | 0.1496 |
| Median Spillover | 0.0460 | 0.0463 | 0.0973 |
| Average from Home | 0.1862 | 0.1422 | 0.2242 |
| Median from Home | 0.1091 | 0.1239 | 0.2044 |
| Average from Foreign | 0.0576 | 0.0220 | -* |
| Median from Foreign | 0.0201 | 0.0096 | -* |
| Average between Foreign | - | 0.0951 | 0.0700 |
| Median between Foreign | - | 0.0812 | 0.0116 |
| Insig./neg. (reduced system) | - | 22/60 | 6/22 |
| Insig./neg. (full system) | 8/46 | 10/29 | 1/4 |

This table reports descriptive statistics on spillover estimates. Columns 2-4 provide aggregate information from the following tables 8, 9, 10, and 11. Average and median spillover coefficients are calculated on the total sample, spillovers from the home market, spillovers from foreign markets, and spillovers between foreign markets, respectively. The last double-row distinguishes the share of insignificant or negative estimates between the *full system*, which implements all spillover parameters contemporaneously, and *reduced system*, which only implements a subset. *=no significant spillovers

Figure 1: Estimates of Cross-Listing Mean Squared Errors




The figure is a graphical representation of mean squared errors from those 25 enterprises that have at least 30 trading days before listing abroad. It is separated into three sections. Mean squared errors before, and after the first and the second cross-listing (if applicable) are shown from the left to the right. In order to correct for outliers, 5 enterprises with more than 0.0025 of average daily return are excluded. All numbers are multiplied by 100 to represent daily percentages and guarantee better interpretability.

Figure 2: Cumulated Abnormal Returns over Time

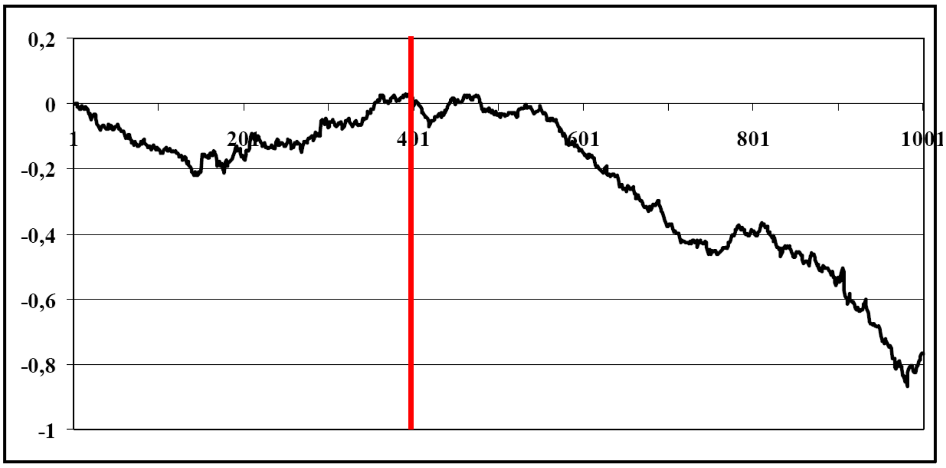



Figure 3: Cumulated Abnormal Returns over Time (continued)


The figures show cumulated abnormal returns (CAR) over time. For each enterprise that has at least 30 trading days before listing abroad, returns are regressed on their long run mean in the time dimension. Residuals taken therefrom are averaged for trading days relative to the cross-listing and cumulated over time. We calculate their sum (CAR) from 400 trading days before until 600 trading days after the first and the second cross-listing (if applicable), and plot it over time in the figures. Figure (2) shows the evolution of the CAR relative to the first cross-listing, figure (3) relative to the second.