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THE INTEGRATION OF SLOVENE BANKS INTO THE EUROPEAN BANKING AREA – ASSESSMENT OF TRENDS IN THE NEAR FUTURE

Božo Jašovič and Tomaž Košak*

SUMMARY

The future structural changes in the Slovene banking sector will mainly be the consequence of integration into the euro area. Prior to the introduction of the euro as the domestic currency, the continued nominal convergence of interest rates will have the greatest effect on the future development of events. In addition, Slovene banking will be affected by regulatory changes in the EU and general trends on the largest European financial markets. The process of the integration of Slovene banks into European financial markets began a few years before Slovenia joined the EU in May 2005. This article provides an assessment of the degree of integration in the banking business. It is based on a set of financial integration indicators, separated into two groups. The quantity-based indicators measure the level to which the banks have managed to internationalise their assets and liabilities. Meanwhile the price-based indicators are less reliable at the moment due to the still different currencies used in the Slovene and EU financial markets. The available evidence for the Slovene banking system suggests that the degree of banking integration varies depending on the segment of banking activities: from the lowest degree in retail banking to the highest degree in wholesale lending.

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1 INTRODUCTION

The topic stated in the title requires extensive and convincing empirical analysis in order to uphold the credibility of the paper. Otherwise it would more resemble futurism than a serious professional assessment. However, there is a pragmatic intermediate approach: since we are increasingly becoming a part of our wider environment, the findings which refer to that environment are therefore relevant for us. We will use such an approach in this paper, and will add some findings that are characteristic for Slovenia, and on that basis form conclusions about the kinds of structural changes that our banks will encounter. The relevant findings from the wider environment come mainly from professional articles of the ECB, which give a detailed analysis of various business trends in banking and the new regulatory features that will create the structural changes.

The paper will then deal with the particularities of the Slovene banking environment. The coming structural changes in banking will mainly be the consequence of our integration into the euro area. In addition to the nominal convergence of interest rates, the cashing in of accumulated tolar bills, which are the consequence of an excessive structural position on our money market, will also affect the behaviour of the banks. Besides our particularities, domestic banks will also be affected by the general trends characteristic of the wider European area. These include especially the growing importance of syndicated loans, mortgage banking and consumer financing. Changes to regulations and recently the frequently discussed process of financial integration will also affect the behaviour of banks in the European area. The sections below will follow the above-stated sequence of topics.

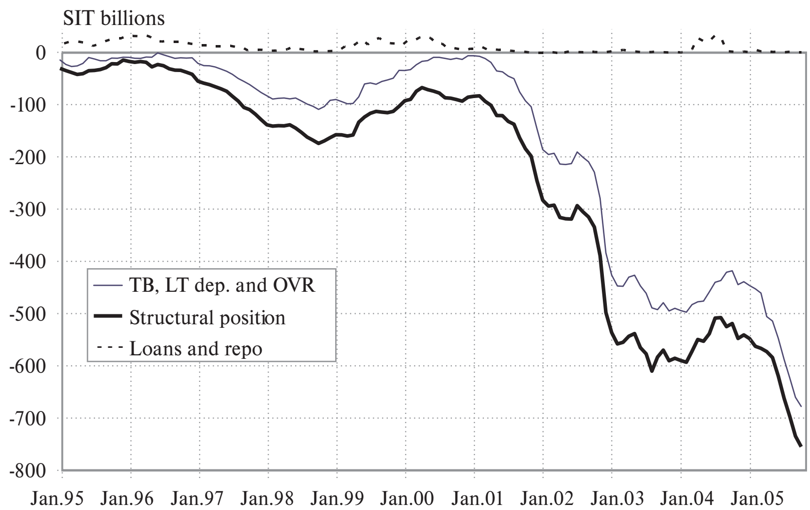
2 REASONS FOR STRUCTURAL CHANGES DUE TO INTEGRATION INTO THE EURO AREA

2.1 Structural position of the Slovene money market

The liquidity management framework is composed of a series of instruments and rules with which the central bank regulates the liquidity of the banking system. The direct goal of liquidity management is to use the range of instruments of monetary policy to offer the banking system sufficient liquidity that it will be able to meet the demands for mandatory reserves without systematically resorting to the use of marginal standing facilities (marginal lending or overnight deposits). There are no major differences in the range of instruments used for liquidity management in different monetary areas. However, there are major differences in the instruments that are most often used to implement monetary policy, depending mainly on the liquidity characteristics of the money market. For Slovenia it is characteristic that the money market is in structural surplus, due to which it is necessary to intensively apply instruments for withdrawing the liquidity that appears as a consequence of autonomous foreign currency transactions between commercial banks and the central bank. For this purpose the Bank of Slovenia issues 60-day tolar bills (TB), through which it sterilises the liquidity that appears in the above-described manner, and also has to offer them regularly due to current maturity of accumulated TBs.

The bold line in Figure 1 shows the movement of the surplus structural position of the money market in Slovenia. The surplus structural position of the money market refers to the amount by which the additional liquidity that appears as a consequence of autonomic foreign currency transactions (swaps) between commercial banks and the central bank exceeds the demand for primary money arising from autonomic items (cash in circulation, state deposits etc.). If we subtract from this surplus the mandatory reserves of commercial banks at the central bank and add the net liquidity offered via the instruments of monetary policy, we obtain the total amount of surplus liquidity that the central bank must withdraw by issuing TBs and other instruments (e.g. long-term deposits). In Figure 1 this category is denoted with a thin line. Recently it has amounted to nearly 700 billion tolars, which represents the entire amount of issued TBs and long-term tolar deposits in the balance sheets of commercial banks. In the structure of the overall portfolio of commercial banks, TBs have approximately a 10-percent share, but if we add foreign currency bills, which in the past banks had to enter in the amount of the prescribed share of short-term foreign currency liabilities, then that share amounts to over 15% of the combined total assets of the banks.

Figure 1: Structural position of the money market



Source: Bank of Slovenia

In terms of the share of short-term securities, Slovene banks stand out from average medium-sized banks in the euro area, where that share is only just over 2% of their investments. From this comparative data we can conclude that upon joining the euro area, our banks will begin to adjust to the other banks, since the Bank of Slovenia will no longer issue securities, owing to which upon their maturity the liquidity will begin to be released, which the banks will earmark for other investments. Here the question arises of the consequences for Slovene banks. We can risk the assumption that it is entirely likely that the banks will not maintain their present above-average share of short-term securities. Part of the released liquidity will be earmarked for investments in long-term securities, which are considered secondary liquidity, a second part will be invested in the interbank market in the euro area in the form of deposits in other banks, and the rest will be earmarked for higher-risk credit and other investments. The described restructuring of bank portfolios will not occur without consequences for the banks' capital requirements in relation to their investments. When calculating the risk-adjusted assets from the perspective of credit risk, the current investments in Bank of Slovenia short-term securities are calculated with a weight of

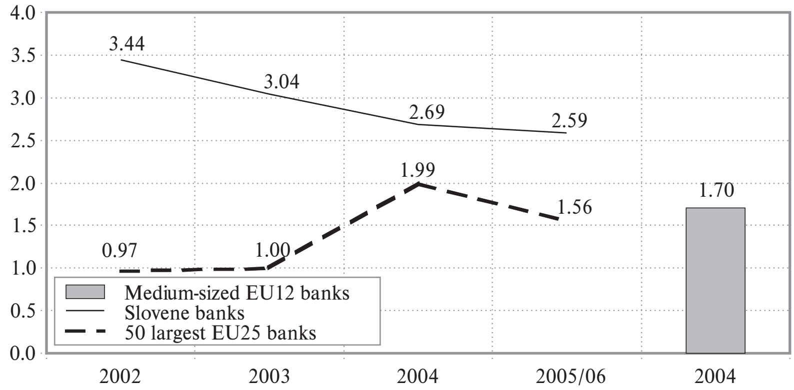
0%, which means that no capital is necessary for such investments. This however is not the case for other, riskier investments, which are weighted differently from 0% (20%, 50% and 100%) and then require additional capital in comparison with the present situation. In this connection we can conclude that Slovene banks, which upon their entry into the euro area will be presented with the dilemma of how to invest the surplus liquidity which will be released because of the cashing in of TBs, foreign currency bills and long-term tolar deposits, will at the same time have to respond to the question of how to provide the additional capital which will be required due to the expected restructuring of bank portfolios.

2.2 Convergence of interest rates upon entry into the euro area

The process of nominal convergence of interest rates began before Slovenia joined the EU and the ERM 2 exchange rate mechanism in 2004. Since that time the Bank of Slovenia has not changed its interest rates, since it is attempting to maintain them at the highest possible level, which is in accordance with the stability of the exchange rate on the foreign currency market. The transmission of interest rate policy is stronger on the money market than in the other segments of the financial market, and therefore it is no surprise that the interest rates for certain financial products (e.g. consumer loans) are already nearly at a level comparable with the interest rates in the euro area. The development of interest rates in the field in question is definitely also a consequence of the competitive conditions on this market. The time series of interest rates in various segments of the financial market in countries which have already introduced the euro shows that the convergence of nominal interest rates just before the introduction of the euro (in the second half of 1998) was most pronounced on the most short-term markets, which are characterised by a high degree of financial integration (market of interbank overnight deposits and uninsured interbank loans with maturity up to one month). The convergence of the nominal interest rates on longer-term markets (uninsured interbank loans with 12 month maturity, national bond market) occurred a bit earlier and over a longer period of time. On financial markets where the degree of integration is low, local and other factors predominate in setting the level of market interest rates (e.g. the consumer loans market).

A similar process of convergence of nominal interest rates to that which occurred in the EU twelve can be expected to take place in Slovenia. The convergence of interest rates on the bond market has more or less already occurred, since the yield on our 10-year bonds is only about 20 basis points higher than the yield of comparable German bonds. The expected convergence of nominal interest rates among short-term money market instruments will occur just before entry into the euro area, if the pattern that held for the countries that first introduced the euro is upheld. More important than trying to guess exactly when the convergence of interest rates will occur is the fact that the convergence trend will be unavoidable and that this will cause a reduction of the banks' interest margins.

Figure 2: Movement of net interest rates of banks in Slovenia and the EU in percentages



Source: Bank of Slovenia and ECB

Due to the reduction of interest margins the banks will begin to search for alternative non-interest revenues in order to compensate for the loss of income. Undoubtedly the bank mangers will also be under a great deal of pressure to streamline their operations and will lower their operating costs (including forming provisions for credit risk) in order to partially compensate for the loss of income due to lower interest margins. Another possible response is to increase the scope of business (e.g. loan activity). The latter scenario is all the more likely if convergence moves in the direction of the present interest rate levels predominating in the euro area. All of the described structural adjustments will undoubtedly also change the capital requirements.

3 REGULATORY CHANGES IN THE EU

The most significant regulatory changes which have occurred in the past year and will be implemented in the near future are the introduction of the International Accounting Standards (IAS) and the adoption of the Basel II revised international capital framework, which are implemented in the European area through the amended Codified Banking Directive 2000/12/EC.

The main reason for the introduction of the IAS is, simply stated, to ensure correct, accurate and internationally comparable accounting statements. In addition to these obvious benefits, the IAS also entail certain negative side-effects for banking operations in comparison with previous accounting practice. The appraisal of the majority of items according to market value and credit claims according to replacement value, where attrition due to credit risk is possible only if there is unambiguous proof of the justification for the attrition, will undoubtedly encourage increased fluctuation of business results and items in bank balance sheets. Since ex ante provisions for credit risk and thus safe reserves for future losses are not justified according to IAS, the behaviour of banks will be even more cyclical: in times of recession due to increased credit risk and provisions, they will be extremely cautious in approving loans to their clients and vice versa, and in times of conjuncture new rules upon the lower perception of credit risk will contribute to increased lending.

The amended codified banking directive introduces new rules with regard to capital with respect to the risks which banks assume in their operations. It must be admitted that the new rules discuss and measure the risks to which banks are exposed more accurately than Basel I. The most obvious consequence of the introduction of the new rules will be the release of a part of regulatory capital through increased annual profits of the entire banking sector in the EU in the amount of 10 to 12 billion euros.[2]

In addition to more appropriate discussion of the risks connected with required capital, the codified banking directive also strives for the convergence of supervisory competences and practices among national supervisory bodies. The Financial Services Action Plan (FSAP) contributed even more than the directive to the creation of a uniform financial services market. It provided 39 measures adopted up to 2005, which included changes in the fields of accounting practice, business legislation, business management, supervision of conglomerates and similar. Since the FSAP expired in 2005, it has already been succeeded by a new initiative for continued convergence of supervisory practice called the Green Paper on Financial Services Policy (2005-2010). A detailed description of this initiative exceeds the purposes of this paper. What they have in common is an emphasis on the need for a unified financial services market and its increased integration, and equal opportunities for the participation of providers of financial services from various geographical areas.

4 GENERAL TRENDS IN THE EU BANKING SECTOR

4.1 Growth of syndicated loans

Data on the extent of syndicated loans indicate that this segment of the financial market has undergone above-average growth in the last 10 years. Borrowers from the EU have a 40-percent share of the global market for syndicated loans. The total amount of syndicated loans in the EU is approximately 500 billion euros, the average maturity of approved loans varies from five to six years, and the average amount of the loans grew from 135 million euros in the period before 1995 to 320 million euros in the last ten years. What are the characteristics that make syndicated loans attractive for banks?

Syndicated loans provide banks with sectoral and regional diversification of their portfolios, and thus a reduction of the risks associated with excessive exposure to individual branches or regions. Syndicated loans enable participant banks to spread credit risk and to participate in the financing of large borrowers who would otherwise be inaccessible to small banks. A banking syndicate that approves a syndicated loan to an important borrower is also a stronger partner in negotiations and debt recovery than an individual bank, since the risk of unpaid principal is reduced. The syndicated loans market also maintains a relatively liquid secondary market of participation in such loans, which gives banks greater flexibility in balancing their portfolios. Last but not least, such loans are characterised by favourable margins, especially with higher-risk borrowers, owing to which there is a clear trend towards increasing the share of high-risk loans throughout this credit market.[3] Increased exposure to the highest-risk borrowers is not surprising

2 EU Banking Structures (2005).

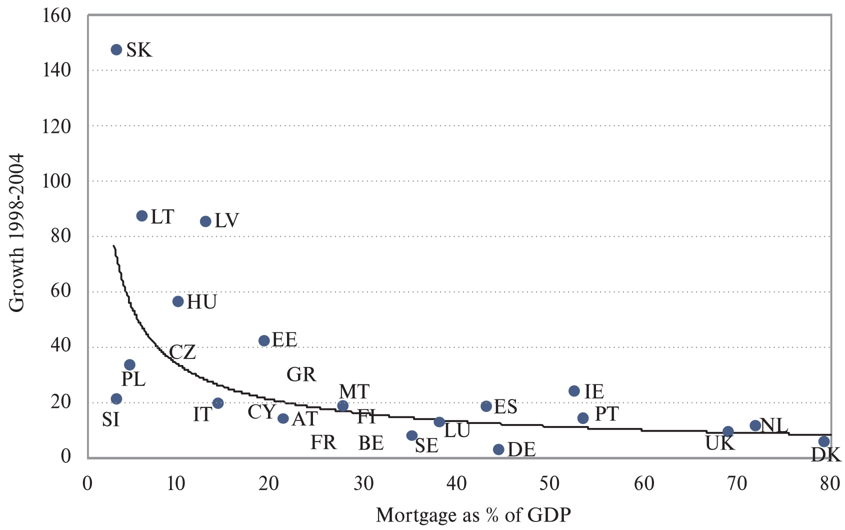
3 A high-risk borrower is one who has high debts, or is financing an LBO or MBO with a loan, or has not received “investment grade” ratings from international ratings agencies.

given the characteristics of the typical loan arrangement: spreading risk among the participants in the bank syndicate and their relative strength in comparison with the debtor. The syndicated loans market is one of the possibilities for our banks to consider when they face the question of where to invest the liquidity that will be released when the TBs and long-term deposits mature after the introduction of the euro.

4.2 Growth of mortgage banking

Mortgage loans are one of the more important bank loan segments in EU countries: they comprise 35% of loans to the non-banking sectors and a full two thirds of loans to households. The mortgage market is one of the less integrated markets, and therefore local particularities are highly significant. The dispersion of interest margins among local markets is still high despite a tendency towards reducing the differences.

Figure 3: Growth rate and proportion of mortgage loans in GDP of EU countries in percentages



Source: ECB

Figure 3 shows very clearly that these types of loans are among the least developed in Slovenia. Slovenia is one of the few countries which has not yet regulated this field, and therefore it is no surprise that we lag behind the majority of European countries. The not up-to-date land register, especially in urban areas, is another obstacle to the development of mortgage banking in Slovenia.

For banks in the EU, mortgage banking is a stable and secure source of interest income. When approving long-term loans secured with a mortgage, banks establish long-term relationships with their clients, which can be the basis for offering other banking products and services (cross selling). Mortgage loans rank among lower-risk products and are therefore also favourable from the viewpoint of required capital. At the same time, this characteristic makes it possible for banks to securitize claims on mortgage loans. Securitization allows banks additional flexibility, since it provides them with additional, cheaper sources for loan expansion, allows them to release capital for new investments and enables them to manage interest risk through the issuing of fixed yield bonds. Mortgage bonds are also appropriate instruments from the point of view of the development of the securities market, since owing to their low level of risk they represent an alternative form of investment for the widest spectrum of investors. One of the priority tasks in connection with the continued development of the financial system in Slovenia is to adopt legislation regulating the field of financial operations as soon as possible.

4.3 Growth of consumer financing

Consumer financing (loans) is another field that has recently experienced a high rate of growth: in the period from 1998 to 2004 it was 36% in the countries in the euro area. For comparison we can add that deposits, the most important source of financing of these loan activities, did not achieve such high growth rates during this period; their growth rate was 29%, meaning that they lagged behind the growth of consumer loans.

What are the major reasons for the upswing in consumer financing? Undoubtedly the amount of consumer loans increased due to changes in the consumer habits of households in the past decade, as well as the increased income of households, and finally the low interest rates which have prevailed during this period. Other significant but not crucial reasons we can list are increased competition among providers of consumer loans, technological and financial innovations in this field (checking credit ratings following the principle of “credit scoring”, applying CRM principles when evaluating customers, simplification of administrative procedures for approving and concluding loan contracts) and the development of new distribution channels (the Internet, mobile telephones, etc.). Consumer financing in the EU has grown faster than GDP in the recent past and it is estimated that it will continue to grow in the future, since the share of this segment in certain countries is still relatively small.

The wide range of products offered by various providers of consumer financing additionally increases competitiveness and the range of choices. Financial innovations have brought a series of new products, including payment in instalments, consumer hire, personal loans, revolving loans, the principle of current accounts and credit cards. The overall look of consumer financing has been changed most of all by credit cards, since they give consumers added flexibility and autonomy when making purchasing and borrowing decisions. There are several methods, for instance approving higher spending limits or payment of debts in instalments. Competition and the expected increase in consumer lending pose the question of financing this segment of the financial market. The main source for consumer loans which are approved by the banks are deposits, but owing to their slower growth rates the banks have to search for alternative sources on the interbank (syndicated loans) or capital markets. The securitizing of claims, which offers banks the possibility of additional sources of financing for these activities, is also becoming established in this field.

Consumer loans are an attractive and profitable banking activity, since they provide relatively stable interest and other incomes. The interest rates for such financing are even slightly higher than the interest rates for mortgages. Consumer financing is fairly dependent on general economic circumstances and the general levels of interest rates. The expected increase in interest rates could impede the dynamic growth of these activities in the future. Consumer financing markets are also typically poorly integrated, owing to which there are few international providers of such services. Continued harmonisation in this field will enable increased international activity and thus increased geographic diversification, but the entire process is also highly dependent on changes in the habits of consumers, who prefer to conduct such business with local service providers.

5 MEASURING THE INTEGRATION OF SLOVENE BANKS IN THE EU BANKING AREA

The process of integration of financial systems lowers the costs of capital and thus encourages increased economic growth. Economic studies (London Economics 2002) have assessed the contribution of the integration of financial systems in the EU to a level of growth of one percent over a period of ten years. The integration of national financial systems also has a significant effect on the transmission mechanism for monetary policy as well as the stability of the financial system.

We speak of an integrated financial system when there are no barriers to or discriminatory relations with economic actors with regard to access to funding or capital investment opportunities, regardless of the actors' origins (Hartmann 2003). A financial system defined in this way has the following consequences:
1. that uniform prices are formed for financial instruments with equal monetary flows;
2. that after individual characteristics are isolated, there are no systematic differences in investment portfolio structures and structures of sources for actors within an integrated financial system.

On the basis of the consequences listed above, two groups of indicators of the degree of integration of the financial system are gradually formed in practice: indicators based on a comparison of the prices for the same types of financial products, and quantity-based indicators. Below we shall discuss some of the quantity-based and price-based indicators of the financial integration of the Slovene banking system into the banking system of the euro area.

5.1 Some structural characteristics of the Slovene banking system

Owing to the multi-product operations of banks, i.e. marketing various financial products in different segments of the financial market, establishing the degree of integration of banking systems is relatively complicated. In principle their complete integration is already ensured with the absence of barriers to entry for new providers of banking services and simply with the possibility for new providers to appear in the banking system. However, despite efforts at standardising legal regulations in the field of marketing banking services in the EU and introducing standard bank licences, which began with the adoption of the second banking directive, and continued with the adoption of the Financial Services Action Plan (FSAP) and the introduction of the common currency, the euro, there are still some "objective" barriers which prevent the achievement of ideal integration of the national banking systems. Professional analyses of the development of the financial sector (1999) point to the fundamental fragmentariness of the financial markets of the EU, which on the supply side is reflected in loyalty on the part of household savers to domestic banks and on the demand side in companies' heavy dependence on financing through bank loans. In addition to this factor, which precludes the ideal integration of banking systems despite the removal of legal and formal barriers, cultural and language differences, different tax systems, etc. are also significant. The FSAP, the purpose of which was to form a unified financial market by 2005, led to different degrees of integration of the banking sector in different segments of operations. A relatively high degree of integration is achieved among the countries in the euro area in the field of wholesale lending (especially the interbank market), while integration in the consumer segment ("relationship banking") is lower, and the lowest degree is achieved in the field of retail banking. Findings similar to those given by the analyses for the euro area also hold for the most part for the Slovene banking system.

5.2 Quantity-based indicators of integration of the Slovene banking system

With the fulfilment of the Maastricht convergence criteria for the introduction of the euro and the implementation of the European directives in Slovene legislation, the convergence process is also being reflected in the structure of the banking sector and the structure of bank balance sheets. However, these integration processes did not begin with Slovenia's accession to the EU and joining ERM2, but have been operating for a long period of time and have only become intensified in the last two years.

At the end of 2004 there were 18 banks and two branches of foreign banks operating in Slovenia. No major changes have occurred since Slovenia joined the EU in May 2004 and the introduction of a standard passport for the operation of banks from the EU. As of the end of August 2005 only two new branches of foreign banks had been established, while the banks which are majority foreign owned remained independent legal entities. The foreign banks which operate in Austria, Italy and France probably did not decide to reform their subsidiary companies mainly because of the differences in the legal and institutional structures of the Slovene banking market. On the other hand, interest among European banks for a relatively passive presence in the Slovene financial market increased, which is demonstrated by numerous notifications of temporary performance of banking activities in Slovenia. Up to the end of March 2005, 82 European banks had notified the Bank of Slovenia of temporary direct performance of banking services.

A comparison of the movement of the indicator of the number of bank branches and the number of employees per thousand inhabitants in Slovenia and the EU shows that Slovenia stands out more for its relatively high density of bank branches than for the number of employees. Analyses of the movement of both of these indicators for the EU, however, show the opposite picture, with a relatively high degree of convergence in the density of bank branches in the countries in the euro area compared with the relative number of employees in banking. But it is worth mentioning that the convergence of these relatively specific indicators of banking integration are dependent on various non-economic indicators, such as population density, geographic variation, etc., which will prevent complete integration. It is significant that the density of bank branches in the EU is decreasing, while in Slovenia, despite the reduction of the number of banks, it is increasing, but nevertheless remains below average.

Table 1: Density of bank branches and number of employees per 1000 inhabitants in Slovenia and the EU

	Number of bank branches per 1000 inhabitants				No. of employees in banks per 1000 inhabitants			
	1997	2000	2003	2004	1997	2000	2003	2004
Slovenia	0.29	0.29	0.32	0.37	5.26	5.49	5.71	5.70
Euro area (average)	0.51	0.50	0.45		5.78	5.75	5.56	
EU (average)	0.48	0.48	0.43		6.51	6.68	6.47	

Source: Barros et al. 2005 and authors' calculations

The integration of the Slovene banking system with the banking system of the euro area will also reduce the differences in the average size of the banks. The opportunities for taking advantage of the effects of economies of scale on the segmented national financial markets are different, which causes relatively major differences in the average size of the banks in the euro area. With the forming of a unified financial market the opportunities for all participants in the market will become equal, which should gradually lead to a reduction in the differences of the average size of banks. Alongside the growth of the average size of the credit institutions in the EU12, due to the consolidation of the Slovene banking market in recent years the average size of credit institutions in Slovenia has increased even faster, and achieved 31.9% of the average size of credit institutions in the EU12. From 2001 to the end of 2004 the average total assets of credit institutions in Slovenia increased by a factor of four, to 1019 million euros, while in the EU in the same period it increased by 30%, to 3190 million euros (Table 3).

Mergers and acquisitions in the banking system

The changing size of banks in the EU and Slovenia is among other things a consequence of takeovers and mergers in the banking sector. According to Barros (2005), with increased financial integration the manner and rationale for expanding banking operations into other national banking markets within the EU will also change. The evolution of the process is as follows: in completely segmented markets with numerous legal and regulatory barriers to access for foreign banks, the rationale for cross-border associations of banks is negligible. However, with increased integration, banks have a stronger rationale for expanding their operations especially to neighbouring national financial markets through the acquisition of foreign banks and cross-border associations. Furthermore, in conditions of complete integration of financial markets, the "*de novo*" entry of banks onto other national markets supersedes cross-border mergers and acquisitions.

Mergers and acquisitions of banks are the result of several other factors besides the degree of market integration. The majority of bank mergers and acquisitions in the second half of the nineties, when the EU's largest bank mergers in terms of number and size took place, are explained in terms of their surplus capacities. Of the 30 largest European banks, over half were formed through mergers and acquisitions. According to estimates by Morgan Stanley and Oliver Wyman (European Banking Consolidation, 2005), by 2006 surplus capital in the European banking system will have risen to 74 billion euros. Despite the trend towards a reduction in the number and size of mergers and acquisitions in the EU banking system, the proportion of cross-border M & A is gradually increasing, as they amount to 30% of the number and 24% of the value of all mergers and acquisitions. Thus from the introduction of the common currency in 1999 to 2004 the number of credit institutions in the euro area has decreased by 19.5% (from 7955 to 6403).

In Slovenia the process of consolidation of the banking system was most intensive in the second half of the nineties,[4] when the number of banks fell from 33 in 1996 to 20 at the end of 2004 (39.4%), in which the majority were mergers and acquisitions among domestic banks. Larger acquisitions of Slovene banks in terms of number and value by banks from the euro area were conducted only after the end of the decade.

Table 2: Ratio of mergers and acquisitions among banks in the EEA to the number of all domestic and foreign mergers and acquisitions

	Number of domestic and foreign M & A among banks					Proportion of M & A among EEA banks in all M&A				
	2001	2002	2003	2004	2005 p1	2001	2002	2003	2004	2005 p1
Slovenia	4	3	1	0	0	25%	100%	0%	0%	0%
EU12	82	77	68	52	22	22%	26%	10%	17%	27%

Source: ECB, 2005

We should remember not to confuse the degree of integration of the banking system with its competitiveness. One of the aspects of bank integration is international consolidation – cross-border associations and mergers. The increased concentration of the European banking system, which is a consequence mainly of domestic and only in the last few years of more intensive international consolidation, does not however guarantee increased competitiveness. The coefficient of concentration, measured as the shares of the total assets of the five largest banks in the system, increased from 38.8% in 2001 to 40% in the euro area in 2003. In Slovenia the level of concentration fell from 67.6% in 2001 to 64.1% in 2004, which is comparable with the banking markets in Portugal (66.5%), Greece (65%), the Czech Rep. (64%), Slovakia (66.5%), etc.

Barros (2005) explains why the integration of the banking market does not ensure increased competitiveness as follows: interest rates for the same types of financial instruments can be similar among banks in different geographical areas, which is a consequence of a high degree of market integration, but are still high from the point of view of ensuring competitiveness. As an example of such behaviour we could present the entry of foreign banks into the Slovene banking system in the nineties, which did not fundamentally contribute to a change in the price of handling money, since the foreign banks generally followed the interest rate policies of the leading domestic banks. In the last few years the behaviour of foreign banks has changed markedly, since they generally achieve the fastest market share growth on the Slovene banking market. Of course a higher degree of integration of the banking system with a more open market is a condition for ensuring the increased competitiveness and efficiency of banks. In the opinion of the authors of a European Commission study (Financial Market Integration and Economic Growth, 2002), the degree of financial integration is the main incentive towards faster development of the domestic financial sector and increased efficiency of financial mediators in financially less developed areas, through ensuring greater competitiveness and improved (standardised) national regulations.

The level of development of Slovenia‘s banking system measured as the share of the total assets of credit institutions in GDP is still far behind that of the EU12. In the last four years this share has increased in Slovenia by just under 9 percentage points, to 92%, while in the same period in the EU12 it increased by 13 percentage points to 266%. However it should be taken into account that the Slovene non-banking sectors annually took out from 1.9% to 2.7% of GDP in loans

[4] Not including the consolidation of savings and loan associations and the Združena kmetijska banka into the new Deželna banka Slovenije in 2003.

abroad, which in the four years from 2001 to 2004 represented an 8.7% GDP growth in loans to the non-banking sectors, the mediation of which did not include the Slovene banking system. With the integration of the banking system and the convergence of Slovene interest rates to a level comparable with that of those in the euro area, the amount of the loans presently taken out by the non-banking sectors which Slovene banks will be able to win back and thus ensure faster growth of their total assets will depend on the competitive ability of the Slovene banks.

Table 3: Number of credit institutions, their average total assets and share of total assets in GDP

	2001	2002	2003	2004
Slovenia				
Number of credit institutions (number of banks)	69 (23)	50 (22)	33 (21)	24 (20)
Average size of CI in EUR millions	258	400	653	1019
Total assets of CI in GDP	83.0%	87.0%	89.1%	91.9%
EU12				
Number of credit institutions	7213	6899	6590	6403
Average size of CI in EUR millions	2442	2625	2866	3190
Total assets of CI in GDP	253%	252%	255%	266%

Source: Bank of Slovenia and ECB

Structure of the loan market

The growth structure of the loan market indicates that the share of loans taken out abroad is relatively stable and since 1999 has amounted to approximately a quarter of the annual growth of loans to the non-banking sectors, which also indicates a relatively high degree of integration of the Slovene non-banking sectors in international credit flows.

With the approach of Slovenia's accession to the EU, in the last ten years the currency structure of the annual growth of loans taken out at Slovene banks has changed markedly. Despite cyclical fluctuations in the growth of the loan market, there was a decreasing trend in the share of the annual growth of tolar loans and an increasing trend in the annual growth of foreign currency loans taken out at Slovene banks. Since 1995, when there was a 78% increase in tolar loans to the non-banking sectors, the share of the former fell to only 27% in 2004. On the other hand, the share of foreign currency loans (net) taken out at Slovene banks underwent an increase, its share of the annual growth of the loan market moving from 4% to 49%. These proportions bear out a steady decrease in the relative share of the tolar loan market and a growing share of foreign currency loans to the non-banking sectors through domestic banks or foreign currency loans abroad.

Table 4: Annual growth of loans to the non-banking sectors in percentage of GDP

	1995	1999	2000	2001	2002	2003	2004
Foreign and domestic loans to the non-banking sectors	9.8	9.6	9.4	7.8	7.2	8.1	11.3
Loans by Slovene banks in tolars	7.6	5.8	4.2	4.3	1.8	2.7	3.1
Loans by Slovene banks in foreign currency	0.4	1.4	1.6	1.5	3.2	3.5	5.5
Loans from abroad	1.2	2.3	3.5	1.9	2.2	1.9	2.7

Source: Bank of Slovenia

5.3 Structure of bank balance sheets and the integration process

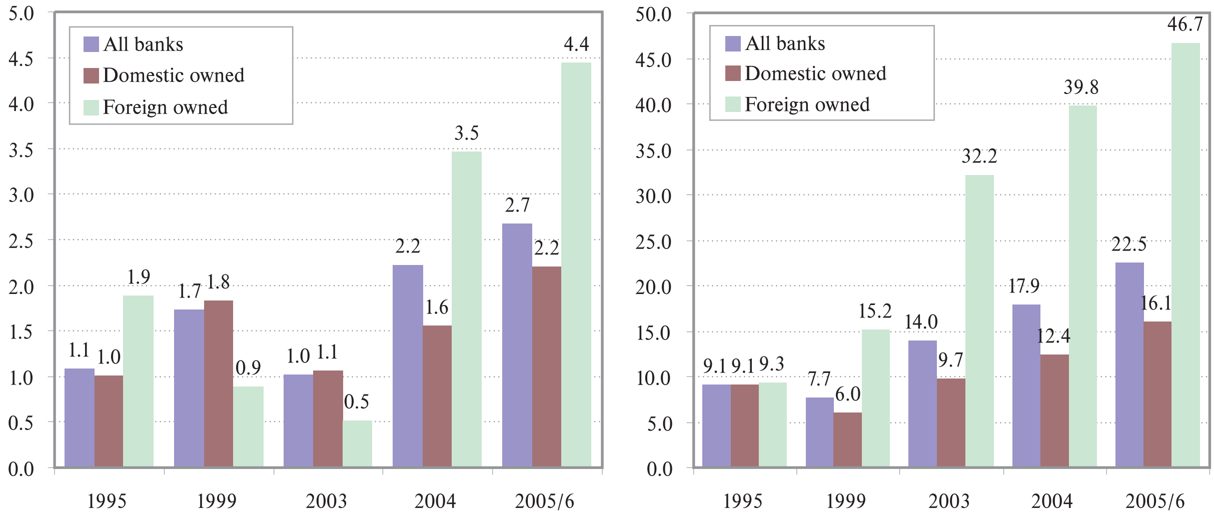
Changes on the Slovene loan market are reflected in changes in the structure of bank balance sheets. In addition to the process of integration of the banking sector, in the last three years there has also been an intensive process of convergence of interest rates to the level of the interest rates in the euro area, which together with the fixed euro/tolar exchange rate since Slovenia's entry into ERM2, increased economic growth and higher domestic consumption have created favourable conditions for the fast growth of bank loans, and along with this changes in the structure of bank balance sheets. Both processes, the integration of the banking market and the convergence of economic variables, encourage the increased involvement of Slovene banks in the European financial market and increased annual levels of growth of the amount of loans to the non-banking sectors, and consequently changed structure of bank balance sheets, which are increasingly similar to the structures of the balance sheets of banks in the euro area. Despite this fact, the degree of integration of the banks is indicated at different levels with respect to the segment of bank operations: it is relatively high in wholesale lending (interbank market) and lower for retail banking, but at the same time varies considerably with respect to the predominant foreign or domestic ownership of the banks. The shares of foreign liabilities and foreign claims vary widely among the individual groups of banks – majority domestic owned or majority foreign owned – with respect to the segment of operations.

Degree of integration of Slovene banks

In the euro area, the degree of integration in all segments of bank operations measured using both price-based and quantity-based indicators is relatively the highest in the wholesale lending segment. The strongest motivator was the introduction of the common currency, which encouraged the harmonisation of short-term interest rates for uninsured loans and increased liquidity of operations on the unified money market.

Despite maintaining our own currency, we find Slovene banks engaging in cross-border operations in this segment to be extremely highly integrated in European financial flows, especially banks which are majority foreign owned. The reason for this is the significance of the share of foreign interbank financing for financing the growing loan activities of banks in Slovenia. Ten years ago the liabilities of Slovene banks to foreign banks, regardless of whether they were majority foreign or domestic owned, were less than 10% of total assets. In the middle of this year this share among banks which are majority foreign owned rose to 46.7%, and for majority domestic-owned banks to over 16% of total assets.

Figure 4: Share of claims on (left) and liabilities to (right) foreign banks in the total assets of all Slovene banks, majority domestic-owned banks and majority foreign-owned banks



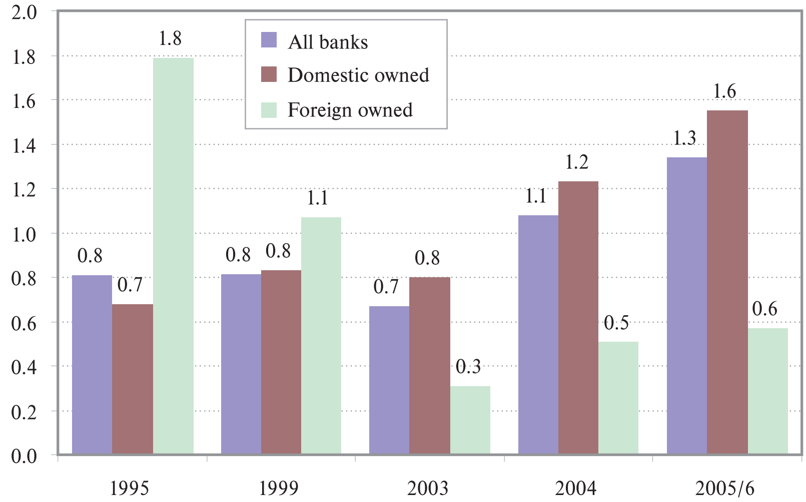
Source: Bank of Slovenia

Similar to liabilities to foreign banks, claims on foreign banks are also growing, but do not exceed 5% of total assets for any group of Slovene banks. The share of claims on foreign banks more than doubled in the last ten years for majority foreign owned banks, but remains on the modest level of 4.4% of total assets, while for majority domestic owned banks this share rose to just 2.2%. Despite the low percentage of interbank loans in total assets, the degree of integration of Slovene banks in the wholesale lending segment is relatively the most comparable with the integration of banks in the euro area, since in both markets approved loans to foreign banks make up 22% of all interbank loans.

Integration of Slovene banks in the investments in securities segment

Slovene banks achieve a significantly lower degree of integration in the field of investments in securities. The share of investments in foreign securities, despite moderate growth in the last three years, is only 1.3% of total assets, or just 4.5% of all bank investments in securities. In the banking system of the EU12 in 2004 the share of investments in securities by other countries in the euro area among all securities was at an incomparably higher level, at 35%.

Figure 5: Share of investments in foreign securities in total assets of banks with respect to predominantly domestic or foreign ownership



Source: Bank of Slovenia

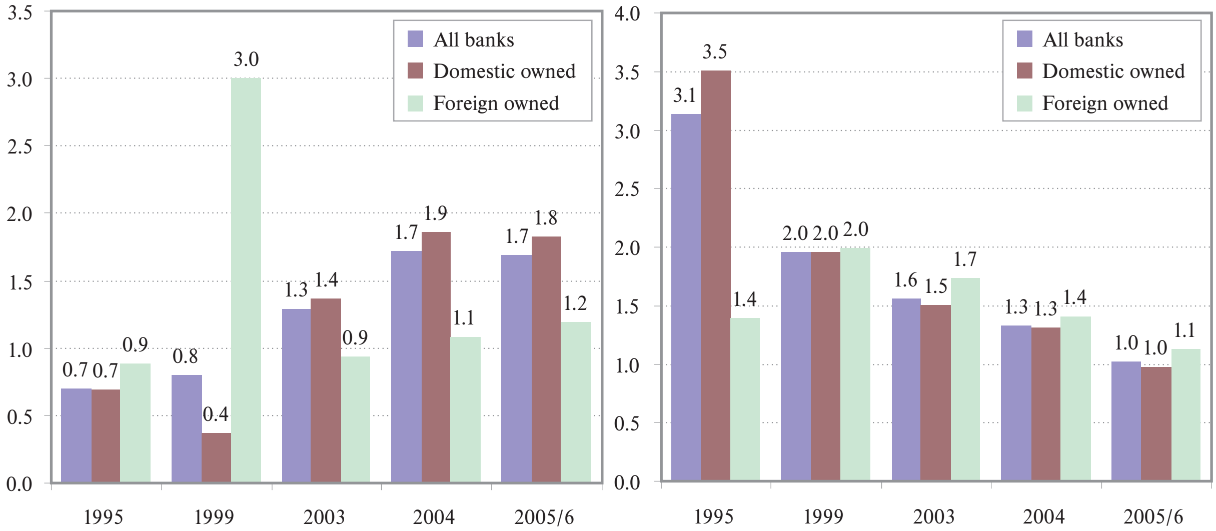
The low level of integration of Slovene banks in the field of securities trading can be explained through the monetary policy, which especially in the second half of the nineties and the first few years of this decade was based on the active sterilisation of foreign currency inflows. This is also the reason that the share of all investments in securities by Slovene banks in 2003 amounted to 34% of total assets against otherwise modest investments in foreign securities. The share of such investments by banks in the euro area in 2004 amounted to only 22.3% of total assets, thus over ten percentage points lower. The difference is even greater if we compare these percentages with medium-sized banks in the euro area, which are more comparable with our banking system, and which in the previous year achieved only half as large a share of investments in securities as Slovene banks (17.5%). Thus upon the introduction of the euro we expect a relatively fast increase especially in investments in short-term foreign securities by Slovene banks, which the banks will have to gradually replace with loans.

Integration of Slovene banks in the field of retail banking

The degree of integration of the European banking market in the retail banking segment, measured as the proportion of loans to the non-banking sectors of other Member States in the euro area, remains relatively low, not exceeding 3.5%. The authors of analyses of the integration of the financial markets of the EU (Barros et al. 2005; Giannetti et al. 2002) give the following reasons for the relatively low degree of integration of the European banking market in this segment: information barriers, the importance of the proximity of clients, the importance of access to “soft” information which is hard to predict for non-local lenders, and the role of long-term relationships with clients for banks which deal especially in making loans to small and medium-sized companies.

In the Slovene banking system the level of the quantity-based indicator in question is not far behind, since loans approved to the foreign non-banking sectors is 3.1% of all non-bank loans, and the level of this indicator has doubled in the last ten years. At the same time this share is comparable with the level of the indicator for the banking system in the euro area before the introduction of the common currency in 1999, so we can expect a gradual increase in the integration of Slovene banks in this segment of operations after the introduction of the euro. Despite the comparability of Slovene banks with European banks, we find that lending to foreign non-bank clients remains relatively modest, as majority domestic owned banks do not exceed 1.8% of total assets, and this share is predictably lower for majority foreign owned banks and amounts to 1.2% of total assets.

Figure 6: Share of claims on and liabilities to the foreign non-banking sectors in the total assets of all Slovene banks, majority domestic owned banks and majority foreign owned banks



Source: Bank of Slovenia

Opposite movements to those for operations with foreign borrowers (growth) can be found for the share of deposits by foreigners among all non-banking sectors deposits (decreasing). Thus the share of deposits by foreigners in all non-bank deposits of Slovene banks in the last ten years has decreased from 4.7% to 1.7%. This fall is even more pronounced in banks which are majority domestic owned, since from 1995 to 2005 they decreased by nearly four percentage points, to 1.6%. In the structure of sources of bank financing, non-bank deposits by non-residents are negligible, as they do not exceed 1% of total assets, and their share is shrinking.

In comparison with banks from the euro area, Slovene banks are not an exception with respect to the degree of integration into the common banking market of the EU in the retail banking segment. Despite the introduction of the common currency and the removal of regulatory barriers, retail operations among banks in the euro area remain highly fragmented, while this is not true of wholesale lending.

5.4 Changing structure of bank balance sheets

The process of the integration of Slovene banks into the EU banking area is, however, not the most significant factor in the changing structure of bank balance sheets, with the exception of majority foreign owned banks, for which liabilities to foreign banks is already 47% of total assets. Although the degree of integration of Slovene banks in the field of interbank operations and in the retail banking segment is comparable with the degree of integration of banks in the euro area, especially if we take into consideration the fact that Slovenia does not yet have the euro, the share of claims on foreign clients and the share of liabilities to foreign depositors in total assets is relatively small in comparison with claims and liabilities denominated in foreign currency. This indicates a high degree of integration of the Slovene economy in the European area, to which the banks are forced to adapt.

Table 5: Quantity-based indicator of the degree of integration of bank balance sheets and share of foreign currency assets and liabilities in the total assets of Slovene banks with respect to majority domestic or foreign ownership in percentages

	1995	1999	2003	2004	2005/6
			All banks		
Investments abroad	3.0	3.7	3.1	5.2	5.8
Foreign currency assets	36.0	30.8	33.4	35.9	38.4
Liabilities abroad	12.3	9.7	15.5	19.2	23.5
Foreign currency liabilities	40.4	31.9	34.6	38.3	40.7
			Domestic owned banks		
Investments abroad	2.9	3.4	3.4	4.8	5.8
Foreign currency assets	35.4	29.1	33.3	35.3	38.4
Liabilities abroad	12.6	8.0	11.3	13.7	17.0
Foreign currency liabilities	40.0	30.1	33.2	36.7	39.4
			Foreign owned banks		
Investments abroad	4.6	5.0	1.8	5.1	6.2
Foreign currency assets	37.6	38.2	35.2	36.9	38.5
Liabilities abroad	10.7	17.2	33.9	41.2	47.8
Foreign currency liabilities	42.6	39.9	40.3	44.6	45.6

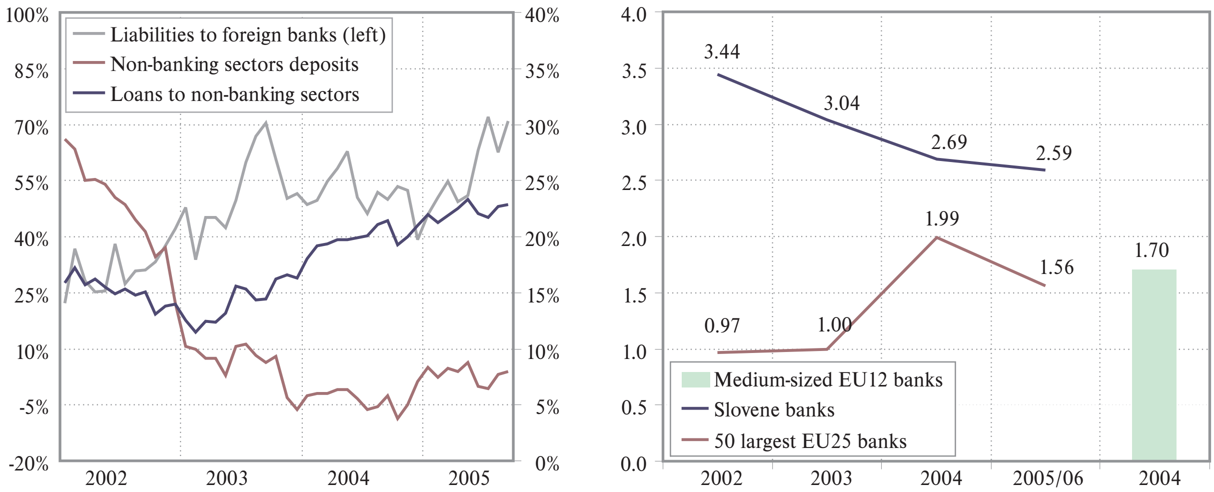
Source: Bank of Slovenia, authors' calculations

The high rate of growth of loans to the non-banking sectors, which reached 22.9% in September 2005, is mainly the consequence of the fast growth of foreign currency lending to both companies and the population, where half-year growth rates are over 51% or 476%, respectively. The convergence of nominal interest rates to the level of interest rates in the euro area, the maintaining of a relatively high level of GDP growth, increasing domestic consumption, the stability of the euro/tolar exchange rate after joining ERM2 and the increasing competition in the banking sector are in our view more important factors in the changing of the structure of bank balance sheets than the process of financial integration itself, with the exception of changes among the sources of bank financing (removal of regulatory barriers, increased foreign financial flows).

Although the process of financial integration is the first condition for faster development, especially of relatively less developed fields in national financial sectors (Giannetti et al. 2002), in Slovenia the latter is reflected mainly in increased foreign sources of bank financing. Although credit growth is fast, deposits from the non-banking sectors are increasing only at an eight-percent half-year level of growth, which is stimulated by an increased share of loans to the non-banking sectors in total assets (June 2005: 54.7%) and on the other hand a reduction of the share of deposits from the non-banking sectors in total assets (58.2%). The banks obtain the necessary additional sources for satisfying credit demands by taking loans from foreign banks and only to a small extent by reducing their investments in securities. The share of such foreign financing of Slovene banks increased in the last ten years from 9.1% of total assets in 1995 to 22.5% of total assets in the middle of this year, and is increasing rapidly. This changing structure of balance sheets is even more pronounced in majority foreign owned banks, where the share of loans to the non-banking sectors is an above-average 64% of total assets against merely 42% of total assets for total deposits from the non-banking sectors, while deposits by foreign banks at 47% of total assets is far above average.

Slovene banks are forced into this behaviour by relatively fast convergence of domestic interest rates, i.e. steadily approaching the levels of the interest rates of banks in the euro area, which has lowered net interest margins. This circumstance, which arises from the convergence of interest rates and net interest margins, is additionally exacerbated by historically low interest rates on key world financial markets and a nearly level curve of the time structure of interest rates, i.e. yield curve of debt securities, which reduce bank revenues from the time transformation of accepted deposits.

Figure 7: Level of growth of loans to the non-banking sectors and deposits by the non-banking sectors and comparable movement of net interest margins, calculated on total assets for Slovene banks and EU25 banks



Source: Bank of Slovenia, ECB

Comparative structure of balance sheets of Slovene banks and medium-sized banks in the euro area

Through a comparison of the structures of the balance sheets of Slovene banks and medium-sized banks in the euro area[5] we can establish the key changes in the structures of the balance sheets in the continued process of financial integration.

The share of loans to the non-banking sectors by Slovene banks will, with the expected increase, be equal to the corresponding shares of medium-sized banks in the euro area already in 2007, although they are currently four percentage points behind. While the share of securities in the total assets of Slovene banks is still nearly twice as much as the share of the same investments in comparable European banks, we can expect the largest fall in interest income revenues precisely in this area of operations of Slovene banks, since the effect of the integration of the banks into the common financial market will be relatively strongest in this segment (levelling of interest rates).

[5] Medium-sized banks from the euro area are relatively more comparable with the size of Slovene banks, since their total assets amount to from 0.005 to 0.5% of the consolidated total assets of the entire banking system of the EU, i.e. from 1.19 to 119.0 billion euros.

Table 6: Comparative structure of assets in the balance sheets of Slovene banks and medium-sized banks in the euro area in percentages

	Slovenia all banks					Euro area all banks	Euro area medium-sized banks
	1995	1999	2003	2004	2005/6	2004	2004
Assets	100	100	100	100	100	100	100
Cash	4.0	3.4	2.8	2.5	1.7	1.3	1.4
Loans to banks	17.4	9.6	6.8	8.9	9.2	16.5	14.0
Loans to non-banking sectors	40.3	52.8	50.2	54.1	54.7	48.4	58.7
Loans to companies	26.5	30.8	33.6	36.3	36.8		
Loans to households	10.7	16.5	12.5	13.5	13.8		
Loans to the state	2.4	4.7	2.8	2.5	2.4		
Loans abroad	0.7	0.8	1.3	1.7	1.7		
Securities	28.9	27.0	34.0	28.9	28.9	22.3	15.8
Short-term	7.6	12.5	20.9	14.1	15.0	1.8	2.2
Long-term	21.3	14.4	13.2	14.8	14.0	20.5	13.6
Capital investments	1.8	2.3	1.6	1.5	1.6	3.4	4.1
Other assets	7.7	5.0	4.6	4.1	3.9	8.1	6.0

Sources: Bank of Slovenia, ECB, authors' calculations

On the other hand we can see among the sources of funding in the balance sheets of Slovene banks a relatively fast decrease in the share of deposits from the non-banking sectors, which currently amounts to 58.2% of total assets. According to our estimates, by the end of 2007 this share will approach the one percentage point exceeding of the current level of the share of the same types of sources of funding at European banks, while the use, especially by foreign banks, of interbank loans as sources of financing already exceeds the share of the use of such sources by medium-sized European banks by 6.8 percentage points, and according to estimates will continue to rise in the next two years. At the same time, Slovene banks use securities as a way of obtaining sources of funding to a negligible extent in comparison with European banks.

On the basis of a comparison of the quantity-based indicators of the degree of integration of Slovene banks in the common banking area we can conclude that in the future Slovene banks will have to pay more attention to their methods of gathering sources of funding if they want to compete on the common market with comparably-sized banks in the euro area.

Table 7: Comparative structure of liabilities in the balance sheets of Slovene banks and medium-sized banks in the euro area in percentages

	Slovenia all banks					Euro area all banks	Euro area medium-sized banks
	1995	1999	2003	2004	2005/6	2004	2004
Liabilities	100	100	100	100	100	100.0	100.0
Deposits by domestic banks	4.3	3.2	2.6	1.8	1.8	22.2	17.5
Deposits by foreign banks	9.1	7.7	14.0	17.9	22.5		
Deposits from non-banking sectors	65.3	71.5	65.1	62.1	58.2	48.5	50.9
Deposits by companies	17.5	20.5	17.4	16.4	15.7		
Deposits by households	35.2	40.3	43.1	42.0	39.4		
State deposits	6.6	7.9	3.1	2.4	2.1		
Liabilities to BS	3.0	0.8	0.0	0.0	0.0		
Depoists by foreigners (non-bank)	3.1	2.0	1.6	1.3	1.0		
Securities	2.7	1.7	4.3	4.0	3.8	21.4	22.0
Provisions	2.3	2.0	2.0	2.1	2.1	1.5	2.0
Subordinated liabilties	0.0	1.0	1.9	2.5	2.2	1.9	2.0
Capital	11.5	10.6	8.3	8.1	7.2	3.7	4.7
Other liabilties	4.7	2.2	1.8	1.5	2.2	0.9	1.0

Source: Bank of Slovenia, ECB, authors' calculations

5.5 Price-based indicators of the degree of integration of the Slovene banking system in the common European banking market

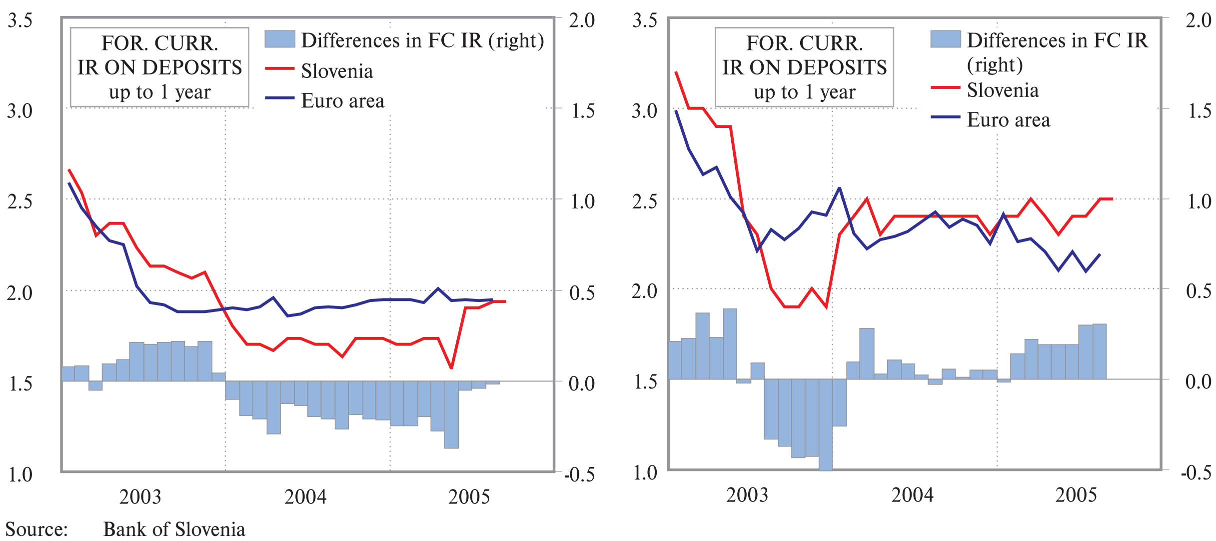
Although national financial systems can have relatively homogenous legal arrangements with similar legal regulations and a similar framework for implementing monetary policy, they can form different prices for the financing of assets. Numerous microeconomic factors such as the level of development of financial markets, competitiveness in the banking system and among various financial mediators, restrictions to the movement of capital etc. are the reasons for the formation of different levels of risk premiums for the same financial forms in individual financial systems. Market actors thus bear the direct costs of non-integrated financial markets (Barros et al. 2005).

In practice there are no widely accepted measurements of the degree of integration of banking systems that are based on the formation of the prices of individual financial instruments. The analyses which deal with this problem are conducted using the principle of the law of standard prices, which means that with complete integration a standard price would be formed for similar financial products among various national markets. This principle requires the comparison of similar products in the same segments of an integrated financial market, which in practice is difficult if not impossible to satisfy completely, especially when measuring the degree of integration of a banking system like Slovenia's, which uses its own currency.

Comparison of interest rates in the retail banking segment

In order to satisfy the condition of the same type of financial instruments, we performed a comparison of interest rates for relatively similar financial products which are offered to clients by both Slovene banks and banks in the euro area: interest rates for housing loans, interest rates for loans to companies in amounts up to one million euros and interest rates for foreign currency time deposits with maturity up to one year and deposits with maturity over one year. In the range of financial instruments of Slovene banks we took into consideration interest rates for instruments denominated in foreign currency.

Figure 8: Comparison of Slovene interest rates for foreign currency time deposits with maturity up to and over one year with comparable interest rates of banks in the euro area



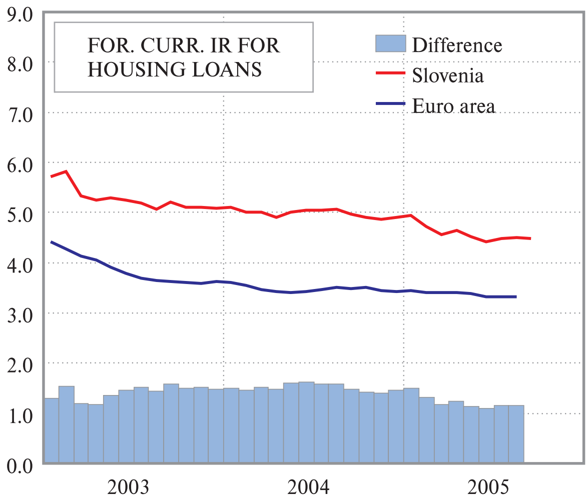
Source: Bank of Slovenia

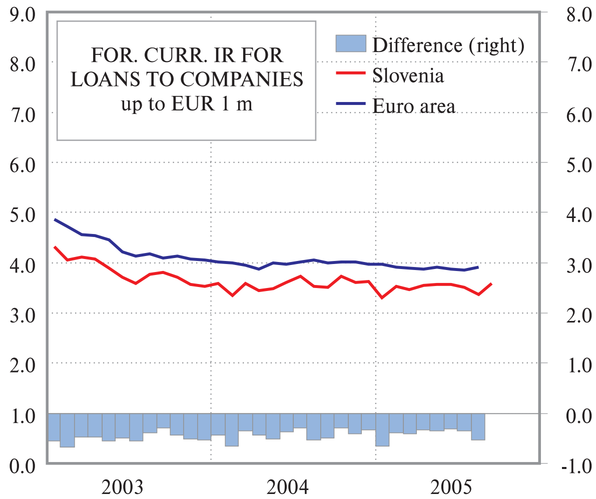
In no segment of the loan or deposit market in the last three years was it possible to detect any pronounced trend towards a reduction or increase in the differences between interest rates offered to clients by Slovene banks and those offered by banks in the euro area. The differences between deposit interest rates in the Slovene and European banking markets never even exceeded 0.5 percentage points, which can be partially explained by the relatively modest share of non-banking deposits by foreigners among all non-banking deposits. In addition, bank time deposits are a relatively standard banking product, which additionally contributes to the high degree of integration of this segment of bank operations. The relatively minor differences between the interest rates for time deposits up to one year and over one year confirm the relatively high degree of integration in interest rates on foreign currency savings.

The difference between domestic and foreign interest rates for housing loans denominated in foreign currency (euros) is somewhat higher, where the interest rates for Slovene banks are from one to 1.5 percentage points higher. In comparison with time deposits, housing loans to the population on the local market are an adjusted product, since they are also sensitive to national property legislation and thus to the effectiveness of insurance claims for housing loans. The difference between the interest rates of foreign and domestic foreign currency loans are also a reflection of institutional differences and thus the lower degree of integration in this segment of banking operations.

Similar to other banking products, the difference between (variable) foreign currency interest rates for loans to companies up to one million euros is relatively stable and since 2003 has not exceeded 0.75 percentage points. However, in this case the interest rates of Slovene banks are lower than those for the same types of loans at banks in the euro area. We can at least partially attribute this difference to the relatively competitive environment which Slovene banks have to take into consideration when approving loans to companies. Slovene companies are relatively flexible when taking out loans and when searching for the best offer they force Slovene banks to set competitive interest rates for foreign currency loans. With regard to the small difference between domestic and foreign interest rates for foreign currency loans to companies, we can also explain this price-based indicator as a reflection of the relatively high degree of integration of Slovene banks in the common European banking area in the retail banking segment.

Figure 9: Comparison of Slovene interest rates for foreign currency housing loans and foreign currency loans to companies up to one million euros with interest rates of banks in the euro area





Source: Bank of Slovenia

Upon the introduction of the euro, Slovene banks will also be forced into increased levelling of interest rates in other areas of operations, where owing to the present use of the national currency they are taking advantage of "barriers" to the competitive offers of the same types of loans by foreign banks. A more realistic picture of the degree of integration of Slovene banks in the common European banking area could also be obtained through a direct comparison of the prices of other banking services, e.g. costs of payment transactions, prices of investment banking services, etc.

6 CONSEQUENCES FOR THE FUTURE OPERATIONS OF SLOVENE BANKS

Slovene banks are no exception in achieving integration in the retail banking segment in comparison with banks in the euro area. Despite the introduction of the common currency and the removal of regulatory barriers in the euro area, retail operations among banks remain highly fragmented, while this is not true of wholesale lending. Owing to this fact, Slovene banks will have to pay a greater amount of attention to the movements of domestic savings and not just to loans to the non-banking sectors. With the increasing of the share of foreign sources in the wholesale lending sector and with the maintenance of a large share of investments in (domestic) securities, after the introduction of the euro we can expect relatively fast and more consistent levelling of our interest rates with interest rates in the euro area in both segments in question, and thus also a decrease in bank revenues.

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DETERMINANTS OF BANK EFFICIENCY DIFFERENCES IN THE NEW EU MEMBER COUNTRIES

Marko Košak and Peter Zajc*

SUMMARY

The article focuses on the cost efficiency of banks as an indicator of progress within the banking sectors of the new EU member-states. Analysis of bank cost efficiency is based on a sample of 100 banks from the five new EU member-states in central and eastern Europe (Czech Republic, Hungary, Poland, Slovakia and Slovenia), and the three Baltic states of Estonia, Latvia and Lithuania, which joined the EU in 2004. The authors used standard methodology for measuring efficiency to estimate average cost efficiency in the selected countries and regions, viz. a stochastic boundary approach, and the Battese and Coelli (1992) specification of the technical efficiency model with truncated normal distribution of efficiency effects and a time-variant decay model.

The estimates of bank cost efficiency revealed some noticeable differences in average cost efficiency. The highest average efficiency score was achieved by banks in Slovakia (91%), followed by banks in Poland (87%), Slovenia (84%), Hungary (84%) and Latvia (83.6%). The lowest average efficiency scores were recorded by banks in the Czech Republic (71%), Estonia (78%) and Lithuania (79%). It was found that national banking sectors with lower cost efficiency usually have greater variation in the cost efficiency scores of individual banks. The analysis showed mixed results in connection with the correlation between the specifics of the banking sector with cost efficiency: the depth of intermediation and the density of demand are negatively correlated with cost efficiency, while deposits per inhabitant and the number of inhabitants per banks are positively correlated with cost efficiency. As expected, market concentration was negatively correlated. Analysis of the relationship between foreign ownership and cost efficiency showed that the majority of banks under foreign ownership were on average less efficient than banks with different ownership structures.

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1 INTRODUCTION

The first decade of transition was a very dramatic process, which changed the landscape of banking sectors considerably. Central and Eastern European countries recognised that one of the key prerequisites for economic recovery and prosperity was a well-designed and functioning financial system in which banks play a particularly important role. Prior to transition, banking sectors in most of the Central and Eastern European countries were virtually non-existent in terms of performing standard banking functions. They were merely an extended arm of the state, allocating funds according to the central plan and its political preferences. Central and Eastern European countries, with the exception of the former Yugoslavia, introduced a two-tiered banking system only in the late 1980s when commercial banks were carved out of the former mono banks. Although in the early 1990s many new privately owned banks emerged, Central and Eastern European countries struggled to set up sound foundations for their new banking systems and the banking sector transformation in Central and Eastern Europe has not been an outright success story. There were failures in recapitalising banks and solving the inherited problem of non-performing loans, which in some countries led to a series of bailouts. Some countries left major banks in state ownership for too long, which prolonged too-close ties and unhealthy relations with ailing industrial conglomerates.

Nevertheless, banking sectors in the new EU member countries in Central and Eastern Europe have undergone a remarkable transformation, particularly in the process of the EU accession. They adopted the common EU legislation and regulation, undertook extensive structural and institutional reforms, and integrated their banking systems, at least to some extent, into the EU banking sector. Also, banks in Central and Eastern Europe benefited from the extensive privatisation, in which foreign banks played a key role. The entry of foreign banks in the banking systems of Central and Eastern Europe has been very important and has contributed significantly to the development of efficient banking sectors, the introduction of sound supervision practices and the instalment of confidence. Overall, the conventional wisdom is that the benefits of foreign bank entry have exceeded the costs. Although it is important to acknowledge the contribution of foreign banks, it is equally important to recognise that foreign banks have not been a panacea for all existing problems and have not always provided the right answer to problems.

An increasingly important perspective or segment of banking sector studies has been bank efficiency. In recent years, bank efficiency research has received wide attention. Studies have been undertaken for several countries and regions, including Central and Eastern Europe. Researchers have developed an extensive array of sophisticated methods and tools to estimate efficiency. In general, bank efficiency studies, which are not only of interest to academics, but also to policymakers, bank creditors, owners and managers, address two major questions. They estimate cost (and profit) efficiency of banks, and try to identify variables (also called correlates) that could explain some of the differences in efficiencies across banks.

The main objective of our study is to examine the issue of bank efficiency for five new EU member countries from Central and Eastern European countries (the Czech Republic, Hungary, Poland, Slovakia and Slovenia) and the three Baltic countries (Estonia, Latvia and Lithuania) for the period 1996-2003. The departure point of our analysis is the fact that despite extensive reforms and progress in banking sectors one needs to keep in mind the starting point in the late

1980s, and hence it remains unclear how successful banks from the new EU member countries have been in closing the efficiency gap to the old EU states. To address this issue we focus on comparing efficiency estimates across countries, and identifying explanatory variables for differences in efficiency.

The study is structured as follows. First, we give a short literature overview, which highlights the development of the efficiency framework and discusses the body of literature on bank efficiency. The next two sections sketch the methodology and estimation techniques. This is followed by a presentation and discussion of the cost efficiency model used in our analysis. Section six presents the data. Finally, estimation results for cost efficiency as well as for an extensive set of efficiency correlates are presented. The study concludes with comments on results.

2 LITERATURE REVIEW

Earlier studies on the performance of banks focus on the presentation of financial ratios and the analysis of scale and scope economies. Molyneux, Altunbas and Gardener (1996) note that there are other aspects of efficiency such as technical and allocative efficiency. These two components of efficiency were first identified by Farrell (1957). The concept of X-efficiency encompasses both allocative and technical efficiency.[1] X-efficiency was introduced by Leibenstein (1966) and basically reflects the differences in managerial ability to control costs or maximise profits (Molyneux, Altunbas and Gardener, 1996).

The dominance of X-inefficiency over scale and scope inefficiency in banking has been recognised for quite some time, but researchers have only recently turned their focus to studying X-inefficiency. This new area or direction of research has brought about several approaches and methods of analysis. Molyneux, Altunbas and Gardener (1996) indicate that there is no agreement on how to measure and model X-inefficiency. The key issue is how to measure or determine the efficiency frontier. Farrell (1957) proposed that the efficiency frontier could be estimated from the sample data applying either a non-parametric or a parametric approach. The most widely used non-parametric estimation technique is the data envelopment analysis (DEA), while the stochastic frontier approach (SFA) and the distribution-free approach (DFA) are the most frequently used parametric techniques.

Berger and Mester (1997) in their article Inside the black box: What explains differences in the efficiencies of financial institutions? give a very informative synopsis of the elements of efficiency measurement (efficiency concept, measurement technique and functional form) and analyse the sources of differences in efficiencies across banks. They find that in general the choice of the measurement technique and functional form does not make a substantial difference in determining the average efficiency for the banking sector or the ranking of individual banks.

Although the body of literature on bank efficiency is substantial, it is heavily geared towards studies of U.S. banks, followed by European banks as a distant second. There are some studies on bank efficiency in less developed countries but their number is relatively small. Berger and

[1] Terms X-efficiency and simply efficiency are not used consistently in the literature. They both refer to frontier efficiency.

Humphrey (1997) in their survey list only eight efficiency studies for developing countries, of which none deals with the transition countries of Central and Eastern Europe. Hence, extant research on bank efficiency in Central and Eastern European countries is relatively limited, especially when compared to studies of mature markets or other developing markets.

Another area of bank efficiency research that has not been intensively explored yet is bank efficiency across countries. In their survey, Berger and Humphrey (1997) list merely five inter-country comparisons at the time of their study. They note that cross-country studies are difficult to perform and interpret because (i) the regulatory and economic environments are different across countries, and (ii) there are differences in the quality of banking services across countries that are difficult to account for. The first cross-country study was the 1993 comparative analysis of bank efficiency in Finland, Norway and Sweden by Berg, Forsund, Hjalmarsson and Suominen (1993). They found Swedish banks to be the most efficient in the pooled sample.

Most cross-country studies analyse developed countries, and only few focus on banking efficiency in Central and Eastern European economies. The 2002 working paper Determinants of Commercial Bank Performance in Transition: An Application of Data Envelopment Analysis by Grigorian and Manole (2002) estimates bank efficiency using the DEA (Data Envelopment Analysis) technique and also includes a dummy variable for foreign ownership. They divide the countries included in the study into three groups: Central Europe, South-Eastern Europe and the Commonwealth of Independent States. Overall, banks from Central Europe are found to be more efficient. Another study on transition economies is the working paper Efficiency of banks: Recent evidence from the transition economies of Europe 1993-2000 by Yildirim and Philippatos (2002). They use the SFA (Stochastic Frontier Analysis) as well as the DFA approach to estimate bank efficiency for 12 Central and Eastern European countries. On average, they find cost efficiency to be higher than profit efficiency in Central and Eastern European countries.

In recent years the role of foreign ownership in the banking industry has received increasing attention. Hasan and Hunter (1996) study cost and profit efficiency of Japanese and domestic banks in the US. For the 1984-1989 period they find that Japanese banks operating in the US were less cost and profit efficient that their US-owned counterparts. Chang, Hasan and Hunter (1998) perform a comparative study of efficiency of foreign and US-owned commercial banks operating in the United States. Their results indicate that in the US foreign banks are less cost efficient than domestic ones. In their extensive study Berger, DeYoung, Genay and Udell (2000) undertake an efficiency analysis of foreign and domestic banks in 13 countries. The average cost and profit efficiency of domestic banks is higher compared to that of foreign banks. The latter are found to be less efficient. This is one of the few studies analysing the role of foreign ownership in a cross-country comparison.

Again, the body of literature on the effects of bank ownership on efficiency for Central and Eastern European countries is quite limited. Nikiel and Opiela (2002) analyse the performance of domestic and foreign banks in Poland. Domestic private and state owned banks have on average higher profit and lower cost efficiency than foreign banks. This may seem unusual at first glance, but the authors explain it by the fact that many domestic banks operate in niche markets in which they may enjoy some market power. Hasan and Marton (2000) study bank efficiency in Hungary and the performance of foreign banks based on the extent of foreign involvement.

Banks with a higher percentage of foreign ownership turn out to be more efficient than those with a lower percentage.

A study by Weill (2003) represents an attempt of a direct comparison of the banking efficiency in Western and Eastern European countries. Weill's research provides evidence on the existence of an efficiency gap between Western and Eastern banks, which is mainly caused by differences in managerial performance, while environmental and risk preference effects did not turn out to be important. As indicated by the author, further research in this area is needed, not only on the existence of the efficiency gap but also on the evolution of efficiency and its explanations.

A recent paper by Bonin et al. (2005) focuses on evaluating bank efficiency and identifying relevant efficiency correlates in transition countries, with focus on the efficiency-ownership relationship. The authors applied stochastic frontier estimation procedures to banks in eleven transition countries. The results provided by Bonin et al. (2005) indicate that private ownership is, by itself, insufficient to ensure bank efficiency in transition countries because no statistically significant evidence of an adverse effect of government ownership relative to private domestic ownership was found. Foreign-owned banks turn out to be more cost efficient than other banks and they also provide better services, particularly if they have a strategic foreign owner.

The recent study on bank efficiency by Fries and Taci (2005) was performed on a sample 289 banks from 15 East European countries for the period 1994-2001. The authors focused on cost efficiency of banks and investigated an extensive set of correlating factors that could be associated with costs of banking operations. They confirmed that greater macroeconomic stability and competition resulting from foreign bank entry, as well as development of the supportive institutions, promoted cost efficiency. However, they emphasized that for most Eastern European countries the major challenge after their accession to the European Union and the common market for financial services would be the increased competitive pressure. As they used only data up to 2001, this effect could not have been examined empirically.

3 METHODOLOGY

The concept of efficiency measurement assumes that the production function of the fully efficient firm or firms is known. Since this is not the case in practice, one has to estimate the production function. A number of different techniques are used to estimate efficiency. Farrell (1957) proposed that the production function can be estimated from sample data applying either a non-parametric (mathematical programming) or a parametric (econometric) approach.[2]

The two most commonly used non-parametric efficiency estimation techniques are the data envelopment analysis (DEA) and the free disposable hull (FDH), the latter being a special case of DEA. DEA is a linear programming technique where the DEA frontier is constructed as piecewise linear combinations connecting a set of best-practice observations (Berger and Humphrey, 1997). Non-parametric techniques have some drawbacks. They focus on technological optimisation rather than economic optimisation. Since they ignore prices, they only provide

[2] See Bauer et al. (1998) for a discussion of parametric and non-parametric estimation techniques.

information on technical efficiency and ignore allocative efficiency. Non-parametric techniques generally do not allow for random error in the data, i.e. they do not consider measurement error and luck as factors affecting efficiency estimates (Berger and Mester, 1997). Thus, any deviation from the frontier is assumed to reflect inefficiency. If there were any measurement errors, they would be reflected in a change of measured efficiency. Moreover, as pointed out by Berger and Humphrey (1997) any of these errors in one of the banks on the efficient frontier may change the measured efficiency of all banks. On the other hand, DEA does not require an explicit specification of the functional form of the underlying production function and thus imposes less structure on the frontier.

The three main parametric techniques are the stochastic frontier approach (SFA), the distribution-free approach (DFA) and the thick frontier approach (TFA). These methods focus on the difference or distance from the best-practice bank (efficient frontier), i.e. this distance reflects the inefficiency effect u_i. For example, if costs are higher than those of the best-practice bank, then the bank is cost inefficient. The key characteristic of parametric techniques is that they a priori impose a rule (assumption) for how random errors can be separated from inefficiency. Thus, they make an arbitrary distinction between randomness and inefficiency, which is the main drawback and criticism of parametric techniques (Schure and Wagenvoort, 1999). Estimation techniques differ in the way they handle the composite error term $v_i + u_i$, i.e. in the way they disentangle the inefficiency term u_i from the random error term v_i. In our analysis we apply the SFA technique, which is based on the assumption that the random error v_i is symmetrically distributed (normal distribution) and that the inefficiency term u_i follows an asymmetric (one-sided) distribution (truncated normal distribution).

4 STOCHASTIC FRONTIER ESTIMATION TECHNIQUE

There is a general distinction between deterministic and stochastic frontier production functions (Kaparakis, Miller and Noulas, 1994). The main drawback of the deterministic frontier is that it does not account for measurement errors and statistical noise problems, thus all deviations from the frontier are assumed to reflect inefficiency (Coelli, Rao and Battese, 1998). This can seriously distort the measurement of efficiency. The stochastic frontier production function avoids some of the problems associated with the deterministic frontier. Aigner, Lovell and Schmidt (1977), and Meeusen and van den Broeck (1977) independently proposed a stochastic frontier function with a composite error term, which allows the production function to vary stochastically:

$$y_i = x_i \beta + e_i \qquad i = 1..\mathrm{N}$$

where y_i is the logarithm of the maximum output obtainable from x_i
x_i is a vector of logarithms of inputs used by the i-th firm
β is the unknown parameter vector to be estimated
e_i is the error term.

The error term e_i is composed of two parts:

$$e_i = v_i - u_i \qquad i = 1..\mathrm{N}$$

where v_i is the measurement error and other random factors
u_i is the inefficiency component.

The v_i component captures the statistical noise, i.e. measurement error and other random or uncontrollable factors. Aigner, Lovell and Schmidt (1977) assumed that v_is are independently and identically distributed normal random variables with mean zero and a constant variance, i.e. v_i ~ iid N(0, σ_v^2). The u_i component is a non-negative random variable accounting for technical inefficiency in the production of firms. It measures technical inefficiency in the sense that it measures the shortfall of output from its maximal possible value given by the stochastic frontier $x_i\beta + v_i$ (Jondrow et al., 1982). This shortfall or, more generally, deviations from the frontier are due to factors that are under the control of management, as opposed to v_is, which are not under management control (Chang, Hasan and Hunter, 1998). u_is are distributed either iid exponential or half-normal.

The main shortcoming of the SFA is the a priori distributional assumption of u_is. This assumption is necessary in order to use the maximum likelihood method to solve for the parameters. In general, the stochastic frontier model can be estimated by using corrected ordinary least squares (OLS), but maximum likelihood is asymptotically more efficient. In our estimation, we apply the maximum likelihood method.

The mean of the distribution of the u_i (the mean technical inefficiency) is easy to compute. One simply calculates the average of e_i estimates, and the statistical noise component v_i averages out. Computing technical inefficiency for individual firms is more demanding. The decomposition of the error term into its two components, v_i and u_i, remained unresolved until Jondrow et al. (1982) proposed how to calculate the observation (bank) specific estimates of inefficiency conditional on the estimate of the error term $e_{i.}$. The best predictor for u_i is the conditional expectation of u_i given the value of $e_i = v_i - u_i$. The predictor for efficiency is obtained by subtracting the inefficiency from one.

Battese and Coelli (1988) showed that the best predictor of technical efficiency, exp(-u_i), is obtained by using

$$E\left[\exp\left(-u_i\right)|\,\varepsilon_i\right] = \frac{1-\Phi(\sigma_A + \frac{\gamma\varepsilon_i}{\sigma_A})}{1-\Phi(\frac{\gamma\varepsilon_i}{\sigma_A})}\exp(\gamma\varepsilon_i + \frac{\sigma_A^2}{2}),$$

where

$\Phi(.)$ is the cummulative density function of a standard normal random variable,

$\sigma_A = \sqrt{\gamma\left(1-\gamma\right)\sigma_S^2}$

$\gamma \equiv \frac{\sigma^2}{\sigma_S^2}\ ,\quad \sigma_S^2 \equiv \sigma^2 + \sigma_V^2$

σ^2 – is the variance of u_i,s.

σ_V^2 – is the variance of v_i s.

5 COST EFFICIENCY MODEL

The technical efficiency concept based on a production function is easily modified and extended to measure bank cost efficiency. Cost efficiency is derived from the cost function. It provides information on how close (or far) a bank's costs are from a best-practice bank's costs, producing the same output in the same conditions. In other words, cost efficiency reflects the position of a particular bank relative to the cost frontier. A stochastic cost frontier is presented below, where C(.) is a suitable functional form.

$$\ln c_i = C(y_i, w_i; \beta) + v_i + u_i \qquad i=1,2,...,N$$

where
c_i – is the observed cost of production for the i-th firm
y_i – is the logarithm of the output quantity
w_i – is a vector of logarithms of input prices
β – is a vector of unknown parameters to be estimated
v_i – is the random error
u_i – is the non-negative cost inefficiency effect.

Note that the inefficiency factor u_i is added because the cost frontier represents minimum costs (Coelli, Rao and Battese, 1998).[3] The random error v_i accounts for measurement errors and other random factors. The inefficiency factor incorporates both technical inefficiency (i.e. employing too many of the inputs) and allocative inefficiency (i.e. failures to react optimally to changes in relative prices of inputs) (Berger and Mester, 1997). The random error and the inefficiency term are assumed to be multiplicatively separable from the cost frontier. Efficiency measurement techniques differ in how they separate the composite error term $v_i + u_i$, i.e. how they distinguish the inefficiency term from the random error.

Battese and Coelli (1992) proposed a stochastic frontier model with time-varying inefficiency effects. The model can be written as

$$\ln(y_{it}) = x_{it}\beta + v_{it} + u_{it} \qquad i=1,2,...,N \qquad t=1,2,...,T$$

where
y_{it} – is the output of i-th firm in the t-th time period
x_{it} – is a K-vector of values of logarithms of inputs and other appropriate variables associated with the suitable functional form
β – is a K-vector of unknown parameters to be estimated
v_{it} – are random errors assumed to be iid $N(0, \sigma_V^2)$ independent of s u_{it}
u_{it} – are technical inefficiency effects.

Different distributions of u_{it}s have been assumed for this panel data model (see Coelli, Rao and Battese, 1998, for a short overview of the evolution of this model). The model permits unbalanced panel data and u_{it}s are assumed to be an exponential function of time, involving only one unknown parameter,

$$u_{it} = \{\exp[-\eta(t-T)]\}u_i \qquad i=1,2,...,N \qquad t=1,2,...,T$$

3 The production frontier represents maximum output and ui is subtracted from it.

where u_i are assumed to be *iid* generalised truncated normal random variables η eta is an unknown scalar parameter to be estimated.

In period T (i.e. t=T), the exponential function $\exp\left[-\eta(t-T)\right]$ has a value of one and thus the u_i is the technical inefficiency for the i-th firm in the last period of the panel. Inefficiency effects in all previous periods of the panel are the product of the technical inefficiency for the i-th firm in the last period of the panel and the value of the exponential function $\exp\left[-\eta(t-T)\right]$. The value of the exponential function is determined by the parameter eta (η) and the number of periods in the panel. Inefficiency effects can decrease, remain constant or increase as time increases, i.e. $\eta > 0$, $\eta = 0$ and $\eta < 0$, respectively. This specification of inefficiency effects implies that the ranking of firms according to the magnitude of their technical inefficiency effects is the same in all time periods. Thus, this model cannot accommodate the situation where an initially relatively inefficient firm becomes relatively more efficient (a change in relative ranking) in subsequent periods (Coelli, Rao and Battese, 1998).

This model gives estimates of efficiency but does not allow for the exploration of potential correlates, i.e. factors or variables that might explain some of the differences in predicted efficiencies among banks.[4] To include efficiency correlates into the analysis, one can perform a two-stage estimation procedure in which efficiency estimates from the first stage are regressed on a vector of potential correlates (stage two). The two-stage approach to introduce correlates into the analysis has been used in several bank efficiency studies, for example Allen and Rai (1996), Berger and Hannan (1998), Berger and Mester (1997), Chang, Hasan and Hunter (1998) and Mester (1993 and 1994). Hasan and Marton (2000) performed a two-stage efficiency analysis for Hungary, and Nikiel and Opiela (2002) for Poland. Among the most recent studies a two stage approach was used in Bonin et al. (2005).

6 DATA

The analysis includes eight new EU member countries, five from Central and Eastern Europe (Czech Republic, Hungary, Poland, Slovakia and Slovenia), and three Baltic countries (Latvia, Lithuania and Estonia). Although there are differences among the banking sectors of these countries, they nevertheless form a relatively homogeneous group. In particular, preparations for EU membership and the membership itself brought about the introduction of the common EU legislative framework and the common regulation standards. This allows us to compare estimated bank efficiencies across countries.

To construct the sample, we used information drawn from the financial statements of individual banks provided by the Fitch IBCA's BankScope database. Fitch IBCA collects data from balance sheets, income statements and other relevant notes in audited annual reports. To ensure consistency, only data for commercial banks in the unconsolidated format were used. Data, expressed in euros, were collected for the 1996-2003 period and corrected for inflation in order to ensure comparability (see the Table 2 for descriptive statistics of the data).

[4] There is no theoretical model on which correlates to include in the analysis. Maudos et al. (2002, p. 53) note that "...in the absence of a theoretical model, we will speak of potential correlates of efficiency rather than explanatory variables".

Mathieson and Roldos (2001) indicated three important characteristics of the BankScope database. First, its comprehensive coverage as BankScope has data on banks accounting for around 90% of total bank assets in each country. Second, comparability – the data-collection process is based on separate data templates for each country to accommodate different reporting and accounting standards. Fitch IBCA adjusts the collected data for country specificities and presents them in a so-called global format, i.e. a globally standardised form for presenting bank data. Thus, BankScope data is comparable across banks and across countries, i.e. it allows cross-country comparisons (Claessens, Demirguc-Kunt and Huizinga, 2001). Third, BankScope provides balance sheet data for individual banks, which are usually not available from other sources.

In specifying input prices and outputs of the cost function, we follow the intermediation approach as suggested by Sealey and Lindley (1977). Three inputs (labour, funds and physical capital) are used to produce three outputs (loans, other earning assets and deposits) (Table 1). The three inputs reflect the three key groups of inputs in the bank production process: bank personnel and the management expertise necessary for the provision of bank services (labour), funds collected on the liabilities side (funds), and offices, branches and computer hardware (physical capital).

Table 1: Input and output variables

	Variable	Name	Description
Dependent Variables	C	Total cost	Sum of labour, interest, physical capital and other costs
Input Prices	w_1	Price of labour	Personnel expenses over total assets
	w_2	Price of funds	Interest expenses over the sum of deposits, other funding
	w_3	Price of physical capital	Depreciation over fixed assets
Output quantities	y_1	Total loans	Sum of short- and long-term loans, mortgages and other
	y_2	Other earning assets	Sum of total securities, deposits with banks and equity inv.
	y_3	Total deposits	Sum of demand and savings deposits, deposited by bank and non-bank depositors
Other variables	z	Equity capital	Total amount of equity capital

Source: Authors

BankScope does not provide data on the price of labour (w_1) directly, i.e. there is no information on the number of employees to enable the construction of the ratio of personnel expenses to the number of employees as the unit price of labour. Instead, we use the ratio of personnel expenses over total assets, which is a common approach in bank efficiency studies based on BankScope (Yildirim and Philippatos, 2002). Price of funds (w_2) was constructed as the ratio of interest expenses over funding. Price of physical capital (w_3) also cannot be directly taken from BankScope and was constructed as depreciation over fixed assets. The three outputs, loans, other earning assets and deposits are proxies for banking services provided. Total loans (y_1) is the total customer loans item from BankScope. Other earning assets (y_2) is the sum of total securities, deposits with banks and equity investments. Total deposits (y_3) is the sum of demand and savings deposits held by bank and non-bank depositors. The dependent variable, total cost (C), is the sum of total operating expenses and interest expenses. Equity capital (Z) is the amount of bank equity that reflects both the size and riskiness of banking operations.

Following Berger and Mester (1997), cost, and input prices were normalised by the price of physical capital in order to impose homogeneity. Cost and output quantities were normalised by equity to control for potential heteroscedasticity. Large banks have much larger costs (and profits) than smaller banks, thus their random errors would have substantially larger variances if no normalisation were performed. However, ratios of costs to equity vary much less across banks of different sizes. As the inefficiency terms are derived from the (composite) random error, the variance of the inefficiency term might be strongly influenced by bank size if it were not for the normalisation by equity. Normalisation also allows the model a more economic interpretation.

Table 2: Descriptive statistics of dependent variables, inputs and outputs for cost

Variable	Units	Mean	Std. Dev.	CV
Total assets	EUR millions	3.063	4.129	1.35
Total loans	EUR millions	1.377	1.732	1.26
Total other earning assets	EUR millions	1.304	2.051	1.57
Total deposits	EUR millions	2.499	3.421	1.37
Price of labour	%	1.78%	0.93%	0.52
Price of funds	%	9.84%	83.85%	8.51
Price of physical capital	%	110.02%	243.92%	2.22
Total cost	EUR millions	307	434	1.42
Total equity	EUR millions	239	301	1.26

Source: Authors' calculations

The sample of banks is not constant, i.e. we do not require a bank to have existed throughout the sample period to be included in the sample. Thus, in the unbalanced panel the number of banks across years varies for all countries. In Table 3 we summarize the number of banks included in the sample in specific years and across countries. Following Bonin et al. (2005) we decided to use only data for banking firms with consolidated financial statements, and prior to the estimation of the cost function we exclude all the observations containing variables with non-positive values (necessary because of the logarithmic form of the cost function). As a result not all of the active banks in individual countries were included in our sample.

Table 3: Number of banks included in the study by country and year

Country	1996	1997	1998	1999	2000	2001	2002	2003
Czech Republic	11	12	12	12	10	11	12	11
Estonia	9	9	9	9	8	9	8	9
Hungary	22	22	22	21	22	21	21	21
Lithuania	8	8	8	8	8	8	8	8
Latvia	10	10	10	10	9	10	10	10
Poland	18	18	18	18	18	18	18	18
Slovenia	14	13	14	14	14	14	14	14
Slovakia	9	8	7	9	9	9	9	9
Total	101	100	100	101	98	100	100	100

Source: Authors' calculations

7 ESTIMATION OF THE COST FUNCTION

In order to perform a cross-country comparison of cost efficiency, we construct a pooled data set for the 1996-2003 period, and employ a common frontier function in the form of a translog function.

The translog functional form is specified as follows:

$$\ln(C/w_3 z) = \alpha_0 + \sum_{i=1}^{2}\alpha_i \ln(w_i/w_3) + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}\alpha_{ij}\ln(w_i/w_3)\ln(w_j/w_3) +$$

$$+\sum_{k=1}^{3}\beta_k \ln(y_k z) + \frac{1}{2}\sum_{k=1}^{3}\sum_{m=1}^{3}\beta_{km}\ln(y_k/\mathrm{z})\ln(y_m/z) +$$

$$+\sum_{k=1}^{3}\sum_{i=1}^{2}\delta_{ki}\ln(y_k/z)\ln(w_i/w_3) + \kappa_1 \ln z + \frac{1}{2}\kappa_2(\ln z^2) +$$

$$+\sum_{i=1}^{2}\rho_{\mathrm{i}}\ln(w_i/w_3)\ln z + \sum_{k=1}^{3}\tau_k \ln(y_k/z)\ln z + \ln v + \ln u$$

where C – is total cost,
y_k – is the *k*-th output,
w_i – is the *i*-th input price,
z – is the equity capital,
v – is measurement error term,
u – is the inefficiency term.

The duality theorem requires the cost function to be linearly homogeneous in input prices and for the second-order parameters to be symmetric (Altunbas et al., 2001).[5] Therefore, the following restrictions apply to the parameters of the cost function:

$$\sum_i \alpha_i = 1 \qquad \sum_i \alpha_{ij} = 0,\ \text{for all } i \qquad \sum_k \delta_{ki} = 0,\ \text{for all } k$$

$$\alpha_{ij} = \alpha_{ji},\ \text{for all } i, j \qquad \beta_{km} = \beta_{mk},\ \text{for all } k, m$$

The maximum likelihood method was applied for estimation. The inefficiency effects are incorporated in the error term. The error term in a stochastic cost frontier model is assumed to have two components. One component is assumed to have a symmetric distribution (measurement error, v_{it}) and the other is assumed to have a strictly non-negative distribution (inefficiency term, u_{it}). The estimation technique we use is based on the Battese-Coelli (1992) parameterisation of time effects in the inefficiency term and accordingly the inefficiency term is modelled as a

5 The duality theorem states that any concept defined in terms of the properties of the production function has a dual definition in terms of the properties of the cost function and vice versa. See Varian (1992) for more details.

truncated-normal random variable multiplied by a specific function of time. The idiosyncratic error term is assumed to have a normal distribution. As is always the case when implementing frontier estimation techniques, the efficiency score acquired from the frontier function measures the efficiency of a specific bank relative to the best-practice or most efficient bank.[6]

In the process of constructing the cost function we tried different normalisations of cost and input prices (normalisation with personnel costs vs. normalisation with price of physical capital) and different specifications of the function (three vs. four product variables). Ultimately, we identified a three-product cost frontier function (loans, other earning assets, deposits), normalised with price of physical capital, as a preferred cost function. The inclusion of off-balance-sheet items as a fourth product variable turned out to significantly reduce the total number of observations, whereas the normalisations with personnel costs decreased the number of statistically significant coefficients. Following some other studies (e.g. Berger and Mester, 1997), we employ also a normalisation of cost and output variables in order to control for heteroskedasticity and avoid the skewness of the variables for large banks.

We report the estimation results of our preferred translog model specification in the Appendix and selected summary statistics in Table 4. The parameters μ and σ_u^2 represent the distributions parameters of the inefficiency effects, parameter η is the decay parameter in modelling the inefficiency effects $u_{it} = \exp\{-\eta[t-T_i]\}u_i$ as in Battese and Coelli (1992) and indicates the time dynamics of measured inefficiencies. Parameter γ indicates the proportion of the variance in disturbance that is due to inefficiency, $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$, i.e. the γ value shows the contribution of the u efficiency term to the dichotomous term $v + u$. The γ value is always between 0 and 1. Since the estimated γ value in our case is 0.59 we conclude that the variation of inefficiency is more important than any other stochastic variation in the frontier.

Table 4: Selected estimation results for the translog cost function specification

	Coefficient	Std. Err.
$\mathrm{Ln}(\sigma^2)$	-2.6098	0.1947
η	0.1000	0.0260
Log likelihood	80.7607	
σ_u^2	0.0434	0.0149
σ_v^2	0.0301	0.0024
$\gamma = \sigma_u^2/(\sigma_v^2+\sigma_u^2)$	0.5903	0.0905

Source: Authors' calculations.

As the objective of our study is not to investigate the reasons for cost (in)efficiencies within individual banks, the results presented in Table 5 and Figure 1 explain average cost efficiency levels in individual countries. The variability of bank efficiency within each country can be observed, which sheds light on cost efficiency differentials in the new EU member countries.

The average efficiency scores calculated for the entire sample of countries/banks and for individual countries are reported in Table 5. The average efficiency score for every country is obtained as a weighted average of individual banks' efficiency scores as predicted by the estimated translog

6 Cost efficiency can take values between zero and one. For example, a bank with cost efficiency of 0.80 is 80% efficient. In other words, the bank could improve its cost efficiency, i.e. reduce its costs, by 25%. The bank's cost inefficiency is 1-0.80=0.20.

cost function. The relative importance of the total equity of specific banks is used as a weight for the bank when calculating average efficiency score. We consider the weighting approach to be essential for the correct interpretation of the average efficiency results for specific sub-regions.

Table 5: Weighted average efficiency scores for the sample and by individual countries (mean value, standard deviation, coefficient of variation, 25th, 50th and 75th percentile)

	Mean	Sd	Cv	P25	p50	p75
Czech Republic	0.7078	0.0946	0.1336	0.6347	0.7046	0.7706
Estonia	0.7830	0.0907	0.1159	0.7121	0.8206	0.8508
Hungary	0.8420	0.0608	0.0722	0.8185	0.8513	0.8739
Lithuania	0.7910	0.0753	0.0951	0.7513	0.8105	0.8422
Latvia	0.8366	0.0916	0.1095	0.7683	0.8460	0.9265
Poland	0.8730	0.0397	0.0454	0.8499	0.8793	0.9014
Slovenia	0.8429	0.0655	0.0777	0.8063	0.8595	0.8876
Slovakia	0.9125	0.1160	0.1271	0.9020	0.9515	0.9842
Sample	0.8202	0.0977	0.1191	0.7706	0.8499	0.8885

Source: Authors' calculations

As presented in Table 5, the average cost efficiency of banks included in the sample was 82%, indicating that on average banks could reduce their cost by 22% if compared with the most cost efficient bank in the sample. The median cost efficiency score for the entire sample was 85% and the cost efficiency score for the 75th percentile was 89%, suggesting that the distribution of efficiency scores is skewed to the right from the centre. The standard deviation and the coefficient of variation of the cost efficiency score indicate a moderate variability in efficiency score among banks in the sample.

Presentation of data by individual countries reveals some noticeable differences in average cost efficiency. The highest average efficiency score was achieved by banks in Slovakia (91%), followed by banks in Poland (87%), Slovenia (84%), Hungary (84%) and Latvia (83,6%). The lowest average efficiency score had banks in the Czech Republic (71%), Estonia (78%) and Lithuania (79%). Comparing mean and median values of average efficiency scores we can observe that most of the countries experienced an asymmetric distribution of efficiency scores, mostly skewed to the right with the exception of the Czech Republic, where mean and median efficiency score were almost identical.

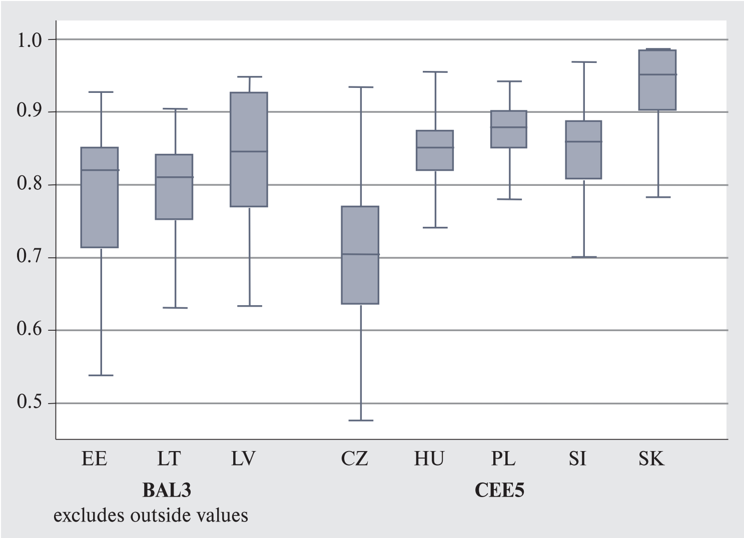
Variability of the measured average efficiency score by country also differed significantly. The lowest variability was measured with Polish (CV = 4.5) and Hungarian banks (CV = 7.2), while in four out of eight countries the coefficient of variation exceeded value of 10.

Graphical representation of efficiency scores by country clearly reveals the discrepancies in average efficiency among countries and even more importantly also the variability of efficiency scores across countries. Particularly for the most efficient banking sectors (Slovakia, Poland, Slovenia and Hungary) it is typical that their interquartile ranges[7], as denoted by the height of the box, are relatively narrow and their “whiskers”[8] relatively short. Both characteristics are a sign of lower variability of individual banks’ cost efficiency score.

7 Interquartile range is confined to the central 50% of the sample in each country, bounded by the 25th and 75th percentile.

8 Vertical lines, denoting the lower and the upper adjacent value.

Figure 1: Boxplot of individual banks' efficiency scores by country (median, 25th percentile, 75th percentile and lower and upper adjacent value)



Source: Authors' calculations

Another important aspect of bank efficiency studies that needs to be addressed is the time dynamics of bank efficiency. The time varying decay model developed by Battese and Coelli (1992) models inefficiency effects as: $u_{it} = exp\{-\eta(t - T_i)\}u_i$. The estimated η coefficient provides information on the time dynamics of inefficiency effects. When $\eta > 0$, the degree of inefficiency is decreasing over time and when $\eta > 0$, the degree of inefficiency is increasing over time. The η coefficients for the entire sample, turned out to be significant at p>1%, with the value of 0.10. A positive value of the coefficient indicated an increase of average efficiency of banks in the period under observation.

8 WHAT EXPLAINS DIFFERENCES IN BANK EFFICIENCY ACROSS COUNTRIES?

Measuring bank cost efficiency per se does not usually provide very informative answers to bank owners, bank regulators or even bank customers on the causes for efficiency differences among banks. Hence, studies on bank efficiency also investigate factors (correlates) that could, at least partly, explain some of the differences in predicted efficiencies among banks and across countries. Potential correlates have been tested in various studies, for example Allen and Rai (1996), Berger and Mester (1997), Casu and Molyneux (2000), Dietsch and Lozano-Vivas (2000) and very recently Fries and Taci (2005) and Bonin et al. (2005).

To select efficiency correlates we draw particularly on three recently published studies: Fries and Taci (2005), Bonin et al. (2005), and Dietsch and Lozano-Vivas (2000). Dietsch and Lozano-Vivas (2000) was one of the first papers investigating closely the factors that could explain cross-country differences in measured efficiency scores. The authors isolated three groups of environmental variables: main conditions, bank structur, and regulation, and accessibility of banking services. Fries and Taci (2005) employed two categories of variables: country-level factors and correlates with bank inefficiencies. Bonin et al. (2005) focus on ownership characteristics affecting efficiency score variability. They also control for some environmental variables.

Following the above-mentioned studies we formed three groups of variables that are assumed to be associated with changes in efficiency across banks. The first group are country level variables explaining macroeconomic conditions (population density, financial deepening ratio). The second group consists of variables describing the structure of the banking industry in specific countries (intermediation ratio, density of demand, HH index of market concentration, EBRD index of banking sector development, market share of state owned banks, proportion of foreign owned banks, population per bank, banking deposits per capita). Finally, variables in the third group describe the individual bank characteristics that could determine differences in the achieved efficiency levels (ownership status, return on average equity, return on average assets, net interest margin).

Altogether fourteen variables have been employed as potential correlates for testing. Table 6 gives an overview and description of these correlates, Table 7 provides their descriptive statistics, and Table 8 presents the estimations results. Variables were obtained from different sources, including central bank publications, IMF's International Financial Statistics and from various issues of the EBRD Transition Reports.

Table 6: Description of the efficiency correlates included in the model

Symbol	Name of the variable	Description of the variable
Country level variables		
POPULKM	Population density	Number of inhabitants per square kilometre
TAGDP	Financial deepening ratio	Total-assets-to-GDP ratio indicating the level of financial intermediation through the banking sector
Structure of banking industry		
INTERMED	Intermediation ratio	Ratio of total banking sector loans to total deposits of the banking sector
DENSITY	Density of demand	Density of demand measured as total deposits per square kilometre (in million EUR)
HHI	Hirschman – Herfindahl index of market concentration	HHI index measured by total assets of banking firms in each national market separately
EBRD	EBRD index of banking sector development	Banking sector development index as defined by EBRD and taking values on a 1 to 4 scale
STATE	Market share of state owned banks in each national banking market	Market share measured as a share of the total assets of the state owned banks in total assets of the banking sector
FOREIGN	Proportion of foreign owned banks	Proportion of foreign owned banks in total number of banks in each national banking market
POPULBANK	Population per bank in 1000s	Number of inhabitants per bank
DEPOSITPC	Total banking deposits per capita	Total banking deposits per inhabitant (in million EUR per 1000 inhabitants)
Individual bank characteristics		
OWNERSHIP	Ownership status of the individual bank	Dummy variable identifying the ownership of the individual bank (value 1 if bank is in foreign ownership, value 0 if not)
ROAE	Return on average equity	
ROAA	Return on average assets	
NIM	Net interest margin	Net interest income over total assets

Source: Authors

Special attention was paid to composing the OWNERSHIP variable, which contains information on the ownership structure of each individual banking firm included in the sample. The BankScope database provides information on bank ownership. There are, however, two problems with this information. First, no ownership information is available for some banks, especially banks that ceased to exist, or were merged with or taken over by other banks. Second, BankScope classifies banks as foreign or domestic at the time the database was last updated. Many authors use the built-in filter to separate domestic from foreign banks, but we believe that this is not an optimal procedure. Although it is a very time consuming and difficult procedure, one should gather ownership data for every bank for every year. We used a wide array of sources, e.g. annual reports, home pages, daily and weekly financial publications, as well as direct contact with banks to compile precise and up-to-date ownership data on individual banks (Bol, de Haan, de Haas and Scholtens, 2002, apply a similar approach to construct their database).

Table 7: Descriptive statistics of the correlate variables

Variable	Mean	Std. Dev	CV	Min	Max
OWNERSHIP				0.00	1.00
ROAE	0.089	0.314	3.542	-1.75	4.14
ROAA	0.008	0.025	3.182	-0.33	0.05
NIM	0.043	0.018	0.430	-0.01	0.13
POPULKM	0.094	0.034	0.358	0.03	0.13
INTERMED	0.558	0.124	0.222	0.24	0.96
DENSITY	0.508	0.429	0.843	0.01	1.91
HHI	0.270	0.153	0.565	0.00	0.81
EBRD	3.356	0.395	0.118	2.67	4.00
STATE	0.209	0.186	0.888	0.00	0.70
FOREIGN	0.532	0.254	0.478	0.09	1.25
POPULBANK	251.505	153.498	0.610	55.19	660.34
TAGDP	10.447	8.633	0.826	0.26	29.64
DEPOSITPC	5.057	3.996	0.790	0.12	19.33

Source: Authors' calculations

Among the macroeconomic variables authors usually use variables that reflect the income differences and general characteristics of the market. The most commonly used macroeconomic indicator is GDP per capita, which is expected to have a negative sign (Dietsch and Lozano-Vivas, 2000). The more developed the economy, the higher the operating and financial costs banks incur when supplying a given level of services, causing a lower cost efficiency. However, actual empirical results regarding this variable are mixed. Grigorian and Manole (2002) found a significantly positive association between GDP per capita and cost, while Fries and Taci (2005) did not find a statistically significant relationship. Similarly, in our analysis GDP per capita always proved to be highly statistically insignificant (Table 8), so we decided to drop this variable from the final version of the model.

In contrast, the total-banking-assets-to-GDP ratio proved to be highly statistically significant with a negative sign, indicating that banks in financially more developed countries (i.e. countries with higher levels of financial intermediation through banking sector) on average operate at somewhat lower efficiency levels. This result is in line with the results of Dietsch and Lozano-Vivas (2000). In our opinion total-assets-to-GDP ratio is a better indicator then the GDP per capita because it reflects directly how much companies and individuals in a specific country are actually using banking services, whereas the GDP per capita ratio measures this potential only indirectly.

To capture the potential for retail banking services and its correlation with the bank cost efficiency, we follow Dietsch and Lozano-Vivas (2000) and include a population density variable. According to the explanation by Dietsch and Lozano-Vivas, higher density contributes to an increase in banking costs (i.e. decrease in cost efficiency) due to characteristics of banking competition. In particular, if banks compete by opening more branches for strategic reasons, this creates excessive bank operating costs. In our analysis population density variable proved to be statistically insignificant, although its sign was positive.

Table 8: Estimated regression coefficients of the efficiency correlates

	Coeficient	Std. Err.	z	P>z	[95% Conf. interval]	
OWNERSHIP	-0.0240	0.0112	-2.14	0.03	-0.0459	-0.0021
ROAE	0.0004	0.0002	1.93	0.05	0.0000	0.0008
ROAA	0.0066	0.0025	2.65	0.01	0.0017	0.0115
NIM	-0.0047	0.0028	-1.69	0.09	-0.0102	0.0007
POPULKM	0.0007	0.0005	1.55	0.12	-0.0002	0.0017
INTERMED	-0.1020	0.0550	-1.85	0.06	-0.2098	0.0058
DENSITY	-0.2790	0.0911	-3.06	0.00	-0.4574	-0.1005
HHI	-0.2750	0.0619	-4.45	0.00	-0.3962	-0.1538
EBRD	0.0184	0.0201	0.91	0.36	-0.0211	0.0579
STATE	-0.0005	0.0004	-1.42	0.16	-0.0013	0.0002
FOREIGN	-0.0551	0.0260	-2.12	0.03	-0.1060	-0.0042
POPULBANK	0.0003	0.0000	4.69	0.00	0.0000	0.0000
TAGDP	-0.0047	0.0014	-3.24	0.00	-0.0075	-0.0018
DEPOSITPC	0.0301	8.6100	3.50	0.00	13.2340	46.9844
Constant	0.8247	0.0797	10.34	0.00	0.6684	0.9809

Depended variable: efficiency scores obtained in the estimation of the cost function. Estimation method: FGLS.
Source: Authors' calculations

The second set of variables was used to capture the structure of banking industry in specific countries. Since in our opinion these parameters are of crucial importance for the identification of efficiency differences among countries, this set of variables was the largest one.

The intermediation ratio, defined as a loans-to-deposit ratio, reveals the intermediation activity of banks and is therefore expected to be associated with the cost efficiency of banking firms. According to some previous studies (e.g. Dietsch and Lozano-Vivas, 2000; Fries and Taci, 2005) there should be a positive relationship between the ratio and bank efficiency. This may reflect developments in the legal and regulatory framework that support both the financial intermediation process and lower costs to banks (Fries and Taci, 2005). The sample used by Fries and Taci (2005) consisted of 15 Eastern European countries, among them some at early stages of their development, so positive effects of the developments in the legal and regulatory framework might be detected easier, since any changes represented a relatively large progress. In our study we include only eight Central and Eastern European and Baltic countries, which became EU members in 2004 and therefore have already achieved much higher levels of harmonisation with the EU legal and regulatory framework, which means that any changes in this area are only minor. On the other hand, banks in these countries had to adopt much higher credit risk measurement and prudential control standards, which resulted in additional costs. Our results show a negative sign of this coefficient, although the coefficient happened to be significant at only 6% confidence level.

The density of demand may affect cost efficiency of banking firms. Banks operating in an economic environment with a lower level of deposits per square kilometre may incur higher costs in mobilising deposits and making loans through their branches (Fries and Taci, 2005). In our analysis this particular variable fails to deliver results as predicted by Fries and Taci. Namely, the estimated parameter (DENSITY) turned out to have a negative sign, which was contrary to some prior expectations. In our opinion the reason for that is that the variable does not really reflect the actual density of demand. That is because generally countries are not populated evenly, i.e. people tend to concentrate in certain areas, which are consequently also targeted by banking firms. As a result it is more likely to expect the density of demand to be measured more precisely by a variable, which reflects the size of deposits per inhabitant. Therefore, we decided to employ a variable deposit-per-capita and expected a positive relationship between this variable and cost efficiency of banking firms. In fact, estimation results confirmed our expectations, since the deposit-per-capita (DEPOSITPC) parameter proved to have a positive sign and was statistically significant. The estimated parameter indicates that on average any increase in DEPOSITPC by one million per one thousand inhabitants is associated with a raise in bank cost efficiency by three percentage points.

As a corollary to the information provided by the density of demand variable, we generated a variable reflecting an average number of population per bank. The higher the population per bank ratio, the more efficient banks can be in approaching their customers, hence they can generate cost savings. The expected sing on this parameter (POPULBANK) is positive. Estimation results confirmed our expectations. It seems that on average banks in countries with higher population per bank ratio managed to operate at higher cost efficiency than their counterparts in countries in with lower ratio. However, the intensity of the effect appears to relatively small, since on average an increase of the population per bank ratio by one thousands inhabitants per bank produces merely an 0.035 percentage points increase in cost efficiency.

Market concentration – efficiency relationship has already been widely investigated in developed banking markets in the past. Usually, two main hypothesises have been tested. The first is the structure-conduct-performance hypothesis, SCP, (e.g. Heffernan, 1996 or Molyneux et al., 1996), according to which the banking market structure is predominantly changing due to changing market power of individual banks. As a result banks tend to increase market power and lower competitiveness level in the market. According to this scenario the market is dominated by few banks, which are typically not superior in terms of their efficiency. The efficiency – concentration relationship is expected to have a negative sign. The second hypothesis is the efficient structure hypothesis (e.g. Berger, 1995; Goldberg and Rai, 1996), which advocates a different relationship between market structure and efficiency of individual banks. Namely, according to this hypothesis banks with superior cost efficiency turn their cost savings into stronger market positions, which leads to a market dominance of more efficient banks. The efficiency – concentration relationship is expected to have a positive sign. Although our study is not focused on the thorough investigation of the "efficiency – market structure" relationship, we included in the explanatory model also a market structure variable, reflecting market concentration in individual banking markets. Following Fries and Taci (2005) we employed Hirschman-Herfindahl index of market concentration (HHI variable) based on total assets. In line with our expectations the HHI parameter turned out to be statistically significant with a negative sign, meaning that on average higher market concentration can be associated to deteriorating cost efficiency in banking sector.

We also included in the EBRD index of banking sector development, which contains information on the overall progress of banking sectors in individual transition economies of Central and Eastern Europe[9]. Countries with larger EBRD index should on average have higher efficiency of banking operations and vice versa. Although, in our analysis the estimated parameter (EBRD) had the expected positive sign, the parameter itself was not statistically significant.

In several bank efficiency studies the authors examined the relationship between ownership characteristics of banking firms and their efficiency. A detailed analysis of ownership characteristics and efficiency was published recently by Bonin, Hasan and Wachtel (2005). The authors investigate ownership-efficiency relationship on a sample of 225 banks from transition economies in the 1996 – 2000 period. The ownership characteristics of transition economies' banking were also examined by Fries and Taci (2005), although their study did not focus solely on the ownership characteristics but rather on a broader set of variables covering different aspects of banking operations.

In our study we try to capture the ownership dimension of banking operations by a set of three variables: OWNERSHIP, STATE and FOREIGN.

The first variable, OWNERSHIP, is a dummy variable taking the value of 1 if a bank is foreign owned bank, and 0 if a bank is domestically owned. We classify a bank as foreign when non-residents hold more than 50% of its equity. If foreigners acquire a majority share during a year, the bank remains classified as domestic until the end of the respective year and becomes foreign at the beginning of the next year. Thus, we allow bank ownership to change during the sample period.

The second variable, STATE, represents a market share of state owned banks in specific countries. As in the countries included in our sample many banks used to be or still are owned by the government, it makes sense to control for this effect, since state ownership is usually being associated with lower efficiency levels, not only in banking but also in other industries. The third variable, FOREIGN, is complementary to the OWNERSHIP variable. While the variable OWNERSHIP identifies foreign ownership at the firm level, the variable FOREIGN identifies the share of foreign owned banks in total number of banks in each country, i.e. it controls for the foreign ownership impact at the aggregate level.

The estimation results reveal that only two of three estimated parameters, which describe the ownership characteristics, turned out to be statistically significant. The STATE parameter was not significant, although it had the expected negative sign, indicating that state ownership could be associated with inferior cost efficiency in banking firms.

Somewhat surprisingly similar results were obtained when controlling for foreign ownership. The parameter of the OWNERSHIP dummy variable also had a negative sign, indicating that on average banks in foreign ownership achieved somewhat lower efficiency scores than banks with different ownership structures. The difference in results, as compared to some other studies (Bonin et al., 2005; Fries and Taci, 2005), might be explained by more complex structure of the

[9] This measure of reform progress ranges in value from 1 (little progress in reforming the socialist banking systems) to 4.0 (reforms consistent with a well functioning market economy). The index essentially partitions the reform of the banking sector into three broad steps. The first is the separation of commercial banking activities from the central bank and partial liberalisation of interest rates and credit allocation. The second is establishment of framework for prudential regulation and supervision, full liberalisation of interest rates and credit allocation, while the third is significant progress towards implementation of Basle Committee core principles on banking regulation and supervision. The index also allows for no change from the previous regime, an index value of 1 (Fries and Taci, 2005, p. 63).

OWNERSHIP variable in our study, by a different, much more homogeneous sample of countries included in our study, and possibly also because some methodological differences. Namely, in the OWNERSHIP variable the information on ownership of each specific bank included in the sample varies throughout the period under observation, whereas for example Bonin et al. (2005) did not account for the time variability of this information and kept the ownership fixed throughout the investigated period. Likewise, we consider the structure of our sample (although it is smaller) more reliable, since we concentrated on the group of the new EU member countries, which have become - during the process of preparation for the EU membership - significantly more homogenous in terms of the institutional setting, regulatory measures and professional standards.

Similar findings that confirmed a negative relationship between foreign ownership and cost efficiency are known from the literature in the past. Berger et al. (2000) found that in developed countries foreign banks had lower cost and alternative profit efficiency than domestic banks. Hasan and Hunter (1996) analysed Japanese banks operating in the USA and concluded that they were less cost and profit efficient than the domestic banks. Chang, Hasan and Hunter (1998) confirmed that in the USA foreign-owned banks are less cost efficient than the US banks.

Similarly to the OWNERSHIP variable also the FOREIGN variable parameter proved to be negative and therefore indicated the existence of a negative relationship between foreign ownership and efficiency.

There may be a plausible explanation for the lower cost efficiency of foreign banks in Central and Eastern European banking markets. Foreign banks that entered the market as greenfield investments had to set up their operations from scratch. Establishing a branch network, recruiting and training staff, and building up reputation and recognition are very expensive undertakings, the costs of which are spread over several years. Also, in the initial years of existence, concentrating on gaining market share may have resulted in cost control being relegated to a position of secondary importance. Banks that entered through acquisition did not only acquire the better domestic banks but frequently acquired troubled banks that were put on sale at attractive discounts. At first glance, this approach to entry may appear to entail lower cost, but foreign parent banks had to invest substantial sums into dismantling the old and setting up a new organisational structure. In some cases, they also had to deal with non-performing loans. All these efforts could have lead to relatively high costs, which were reflected in low cost efficiency compared to domestic banks. Domestic banks either continued with their old practices and eventually went bankrupt or were taken over by other banks – or they refocused and concentrated on their comparative advantages, like serving small and mid-sized businesses. In some cases they were assisted by foreigners holding a minority share or by foreign advisors (consultants) and twinning arrangements with foreign banks. Another potential explanation may be the fact that some foreign banks in some countries adapted their approach to operating their business to local market conditions. In banking markets in which there is a low degree of competition, banks are inclined not to pay much attention to the cost side.

The OWNERSHIP variable was actually a part of the third set of variables representing individual bank characteristics. In this group there were three more variables: return on average equity (ROAE), return on average assets (ROAA) and net interest margin (NIM). The first two variables were highly significant and both had the expected positive sign of the estimated parameters, i.e.

on average individual bank returns happened to be positively associated with the individual banks' efficiency scores.

Similarly, we obtained the expected result when testing the NIM variable. Net interest margin (NIM) is typically considered as a rough measure of bank efficiency, where a lower NIM indicates better performance of a bank and vice versa. Our estimated NIM parameter proved to be in line with this interpretation, although it is statistically significant only at the 10% confidence level.

9 CONCLUSIONS

Banking sectors in the new EU member countries in Central and Eastern Europe have undergone a remarkable transformation over the last 15 years. They adopted the common EU legislation and regulation, undertook extensive structural and institutional reforms, and integrated their banking systems, at least to some extent, into the EU banking sector. Banks in Central and Eastern Europe benefited from the extensive privatisation and restructuring process. Nevertheless, keeping in mind the starting point in the late 1980s, it remains unclear how successful banks from the new EU member countries have been in closing the efficiency gap to the old EU states, and which factors have been driving the banking sector efficiency.

In our study we focus on cost efficiency of banks as an indication of progress in the banking industry. The cost efficiency study is performed on a sample of about 100 banks from five Central and European new EU member countries (Czech Republic, Hungary, Poland, Slovakia, Slovenia), and the three Baltic countries (Estonia, Latvia, Lithuania), which became EU members in 2004.

We applied the standard efficiency measurement methodology to estimate the average cost efficiency for selected countries and geographical regions. We used the stochastic frontier approach, and the Battese and Coelli (1992) specification of the technical efficiency model with truncated normal distribution of efficiency effects and time varying decay model. The effect of the selected correlates on bank efficiency was tested using a two stage approach, where the cost efficiency scores obtained in the first estimation stage were used as the input for the second estimation stage (correlates). Most of the data for the cost function estimation were obtained from the BankScope database, whereas the sources for correlates were central bank publications, IMF's International Financial Statistics and EBRD Transition Reports. The unbalanced data panel covers the period 1996-2003.

The average bank cost efficiency estimates reveal some noticeable differences in average cost efficiency. The highest average efficiency score was achieved by banks in Slovakia (91%), followed by banks in Poland (87%), Slovenia (84%), Hungary (84%) and Latvia (83,6%). The lowest average efficiency score had banks in the Czech Republic (71%), Estonia (78%) and Lithuania (79%). Typically, national banking sectors with lower cost efficiency turned out to have larger differences in cost efficiency scores of individual banks.

The second stage estimation results explain the association of cost efficiency with country level macroeconomic variables, structure of the banking industry, and some individual bank characteristics. As to the first set of variables, we identified a connection between the level of the development of the financial system and the cost efficiency. The analysis showed mixed results for the correlation of the banking industry characteristics and the cost efficiency. We found a negative relationship of the intermediation ratio and density of demand on the one side, and cost efficiency on the other. The deposit per capita parameter turned out to be positively associated with cost efficiency, and the same result was found for the population per bank indicator. In line with our expectations was the negative sign of the market concentration parameter. The EBRD index of banking sector development was not significant.

As to the relationship between foreign ownership and cost efficiency, the majority of foreign owned banks turned out to be on average less efficient than banks with different ownership structures. Bank profitability indicators ROA and ROE were found to be positively related to bank efficiency, but the result was – in line with our expectations – the opposite for the net interest margin.

Our results provide an interesting insight into the efficiency of banking operations in eight new EU member states. Nevertheless, there is still ample scope for further research. The robustness of the results could be checked by applying the alternative methodologies. The set of correlating variables could be extended in order to capture a wider array of characteristics relevant for the banking industry, and the analysis could be extended to different aspects of bank efficiency (e.g. profit efficiency). An interesting research topic will be the impact of the integration of Eastern European banking industries in the EU single market for financial services. However, it will take some time before sufficient data are available to empirically investigate this effect.

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APPENDIX

Table 9: Estimation results of the estimated translog cost function.

	Coef.	Std. Err.	Z	P>z	[95% Conf. interval]	
alfa01	1.1663	0.0609	19.14	0.00	1.0468	1.2857
alfa02	-0.1663	0.0609	-2.73	0.01	-0.2857	-0.0468
alfa11	0.0252	0.0147	1.71	0.09	-0.0036	0.0540
alfa22	-0.1374	0.0152	-9.03	0.00	-0.1672	-0.1076
alfa1221	0.1122	0.0131	8.54	0.00	0.0865	0.1379
beta01	-0.4504	0.1571	-2.87	0.00	-0.7583	-0.1425
beta02	-0.5598	0.0705	-7.94	0.00	-0.6980	-0.4216
beta03	1.8949	0.1129	16.78	0.00	1.6737	2.1162
beta11	0.0479	0.0553	0.87	0.39	-0.0604	0.1562
beta22	-0.0403	0.0151	-2.67	0.01	-0.0699	-0.0107
beta33	-0.2195	0.0765	-2.87	0.00	-0.3694	-0.0697
beta1221	0.0101	0.0231	0.44	0.66	-0.0351	0.0554
beta1331	0.1334	0.0536	2.49	0.01	0.0283	0.2384
beta2332	0.1244	0.0272	4.57	0.00	0.0711	0.1778
gama01	0.0944	0.0348	2.71	0.01	0.0262	0.1626
gama02	0.0404	0.0158	2.56	0.01	0.0095	0.0714
gama03	-0.1113	0.0321	-3.47	0.00	-0.1741	-0.0485
gama04	-0.1212	0.0387	-3.13	0.00	-0.1971	-0.0453
gama05	-0.1160	0.0169	-6.86	0.00	-0.1491	-0.0828
gama06	0.2136	0.0388	5.50	0.00	0.1375	0.2897
delta01	0.0222	0.0091	2.43	0.02	0.0043	0.0401
delta02	-0.0220	0.0135	-1.64	0.10	-0.0484	0.0043
delta03	0.0051	0.0150	0.34	0.73	-0.0242	0.0345
delta04	-0.0434	0.0248	-1.75	0.08	-0.0921	0.0052
delta05	-0.0083	0.0091	-0.90	0.37	-0.0262	0.0097
delta06	-0.0348	0.0253	-1.38	0.17	-0.0845	0.0148
/eta	0.1000	0.0260	3.85	0.00	0.0491	0.1508
/lnsigma2	-2.6098	0.1947	-13.41	0.00	-2.9914	-2.2283
/ilgtgamma	0.3651	0.3743	0.98	0.33	-0.3684	1.0987
sigma2	0.0735	0.0143			0.0502	0.1077
gamma	0.5903	0.0905			0.4089	0.7500
sigma_u2	0.0434	0.0149			0.0143	0.0725
sigma_v2	0.0301	0.0024			0.0254	0.0349
Number of observations:			429			
Log likelihood:			80.7607			
Prob > chi^2:			0.0000			

Note: Dependant variable is total cost (TC).
Source: Author's calculations

THE DEVELOPMENT OF THE SLOVENIAN GOVERNMENT DEBT MARKET AND ESTIMATION OF THE YIELD CURVE

Andraž Grum*

SUMMARY

Despite of the importance of term structure estimation for business and monetary purposes, Slovenian term structure has not yet been estimated. Partly the blame goes to underdeveloped bond market, characterized by high portion of foreign currency issues in Slovenian government bond outstanding, the lack of long term instruments and low liquidity on the secondary market. The liquidity improved with parallel OTC-DVP market introduction in September 2005 and consequently the information value of fixed income asset prices for term structure estimation purposes has improved significantly.

In this paper we will present theoretical methods of static term structure estimation. The goals are to obtain initial estimates of Slovenian term structure, to identify the most suitable estimation method and to analyze the volatility movements of zero coupon yields and forward interest rates for different maturities in analyzed time period.

Among applied models of term structure estimation, namely Nelson-Siegel model, Svensson model, B-splines model, smoothing B-splines model and Merrill Lynch exponential splines model, Nelson-Siegel model proved to be superior in terms of goodness of fit measured as root mean square error (RMSE), mean absolute error (MAE), mean percentage error (MPE) and hit ratio. The resulted estimates are to the knowledge of the author initial estimates of Slovenian term structure.

With OTC-DVP bond market introduction (as parallel bond market) the volatility of spot and forward rates for mid and long remind maturities has fallen. Volatility reduction is important, as 10 year benchmark bond yield is closely observed as one of Maastricht's criteria which have to be fullfield before joining the EMU.

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1 INTRODUCTION

The term structure of interest rates shows a connection between the yield to maturity of zero-coupon bonds and their remaining maturity, and the yield curve is the graphical representation of this connection. From the function of zero-coupon yields to maturity it is possible to algebraically deduce the discount function and/or the forward interest rates function. The three possible functional forms of term structure representation are also known as the basic elements of the term structure of interest rates.

The data implicitly included in the yield curve are among the most important data that can be obtained on the financial market. The informational value of the term structure of interest rates is dependent upon the purpose of its use; that is, it is important for the decision-making process of leaders in economic policy and from the financial analysis perspective. Defining forward interest rates as a function of the remaining maturity includes information on future movement of the spot interest rates that have direct impact on real economic activity. The zero-coupon yield curve represents a market measure for evaluating current conditions and expected developments on the government debt market which affect business decisions. An understanding of term structure is important for conducting monetary policy and public debt management, as well as for forming expectations about future commercial activity and inflation. On the basis of comparing nominal and real term structure it is possible to evaluate inflation term structure, and on the basis of comparing the term structure of interest rates between countries it is possible to evaluate the expected movement of foreign exchange rates.

In the business world, the term structure of interest rates is used as a financial analysis tool in estimating theoretical coupon bond prices, in discounting future cash flows and evaluating companies, in risk management of financial instruments that are linked to interest rates, in evaluating derivatives, in forming forward interest rates and in determining the risk premium for bonds with different remaining maturities. Term structure therefore plays an important role in fund management, risk management, financial engineering, company finances, and in investment projects appraisals and visibility studies.

Due to the role of the term structure of interest rates in the business world and its importance from the economic policy viewpoint, this paper will present methods for its estimation. Term structure will be estimated on the basis of continously compounded interest rates. Presented methods will be applied to the Slovenian government debt maket data to obtain initial estimates of the Slovenian term structure of interest rates. The purpose of this paper is to select the best methods for estimating and analysing the movements of interest rates with special emphasis on their volatility.

2 AN OVERVIEW OF METHODS FOR STATIC TERM STRUCTURE ESTIMATION

Static methods for term structure estimation are, with regard to the methodology used, divided into spline methods and parametric methods. Due to the good numerical features of spline methods, B-splines are most commonly applied. The most mathematically challenging method is the smoothing spline method.

The central role of parametric methods is held by the Nelson-Siegel (1987) model and the Svensson (1994) model. Due to the robustness of these models, the world's central banks with developed financial markets use them for estimating term structure for the needs of conducting monetary policy.

Selection of estimation method is especially dependent upon the intended use of estimated term structure. The major advantage of the spline methods is their flexibility, which is the reason why it is especially appropriate when term structure is used for evaluating bonds. On the other hand, the major advantage of the parametric models is that they provide an economically sound functional form of the forward interest rate function that can also be extrapolated. Parametric models are, due to their features, mainly used for monetary analysis (see Table 1). From the monetary analysis viewpoint they are also important for estimating real and, consequentially, inflation term structure, which is subject to the existence of a liquid index-linked bond market.

Table 1: Term structure methods used by the central banks of selected countries[1]

Central bank	Estimation method	Targeted function of minimising errors	Adaptation for tax considerations	Evaluated term interval
Belgium	Svensson or Nelson-Siegel	Weighted prices	No	From a few days to 16 years
Finland	Nelson-Siegel	Weighted prices	No	From 1 to 10 years
France	Svensson or Nelson-Siegel	Weighted prices	No	Up to 10 years
Italy	Nelson-Siegel	Weighted prices	No	Up to 10 years
Japan	Smoothing splines	Prices	With price adaptation of treasury bills	From 1 to 10 years
Canada	Svensson	Weighted prices	With bond exclusion from the analysis	From 1 to 30 years
Germany	Svensson	Yield	No	From 1 to 10 years
Norway	Svensson	Yield	No	Up to 10 years
Spain	Svensson	Weighted prices	Yes	Up to 10 years
	Nelson-Siegel before 1995	Prices	No	Up to 10 years
Sweden	Svensson	Yield	No	Up to 10 years
Switzerland	Svensson or Nelson-Siegel	Yield	No	Up to 10 years
Great Britain	Svensson	Yield	From 1996 for taxes adapted estimation method	From 2 to 10 years
USA	Smoothing splines	Weighted prices	No	From 1 to 10 years

Source: BIS (1999, page v), Meier (1999, pages 16–20)

2.1. The use of splines in term structure estimation

A spline is a segmented polynomial function composed of individual *k*-degree polynomials, defined in a sequence of knots (De Boor, 2003, page 2-15). The major feature of spline models is dividing the whole remaining maturity segment into sub-intervals and evaluating the selected

[1] Meire (1999) states that the Swiss and Austrian central banks also use Nelson-Siegel or Svensson models to at estimate term structure . Further information on the estimation of the Austrian term structure may be found in Brandeer and Jaeger (1992).

segment function parameters (splines) on the sub-interval in order to achieve the best adaptation of the function to actual observations. McCulloch (1971 and 1975) suggested the use of squared or cubic splines. McCulloch (1975), Litzenberg and Rolfo (1984), and Jordan (1984) explicitly analysed the influence of tax on the shape of the yield curve. Schaefer (1973 and 1981) suggested the use of Bernstein splines instead of ordinary polynomial splines, while Shea (1984) proposed B-splines, the use of which in modern practice is most widespread.

Vasicek and Fong (1982) used exponential splines in evaluating the discount function. Fisher, Nychka and Zervos (1994) used cubic B-splines. Their contribution is shown in the inclusion of the penalisation function for smoothness into a target function, which ensures smoothness in term structure estimation. Waggoner (1997) complemented their model by allowing variability in the penalisation function value for different remaining maturities. Anderson and Sleath (2001) applied the model to the British government debt market, which has a developed index-linked bond segment so that it enables estimation of nominal and real term structure.

For term structure estimation, cubic splines ($k = 4$) are most commonly used. The cubic spline is defined as a segmented cubic polynomial with the individual cubic polynomials joined at knots. An estimation of such a composite function is based on the following conditions (Bolder and Gusba, 2002, page 8)[2]:

- neighbouring segmented polynomial functions must have the same functional value and the same first and second derivative value at the knots;
- all analysed values must lie on one of the segmented polynomial functions;
- the value of the second derivative is fixed at zero at the first and second knot.

Due to numerical stability and other positive numerical features, in practice the most commonly used methods for term structure estimation are B-splines in a cubic spline space (Ioannides, 2003, page 6). The use of B-splines in term structure estimation was first suggested by Shea (1984) and generalised by Steeley (1991).

2.1.1. Recursive spline method

The recursive spline method can be used in estimating the term structure of interest rates represented by an arbitrary basic function. As indicated by the name itself, the technique is based on the assumption that the theoretical bond price equation is linear in unknown parameters. If the zero-coupon yield curve function or the instantaneous forward interest rate function are used as the basic term structure function, then the equation of bond prices is not linear in the unknown parameters. In this case the result can be obtained with linear approximation, which requires the application of an iterative procedure. If the term structure is estimated on the basis of discount function, then the equation of bond prices is linear in the unknown parameters, and parameters can in this case be estimated with a simple least squares method.

[2] Further information on the method of evaluating the splines parameters can be found in Houweling et al. (2001, page 301).

Let us define **P** = (p_1, p_2, ..., p_N) as the vector of actual prices of N securities included in the analysis and $\hat{P}(a)$ as the vector of their evaluated theoretical values. The evaluated theoretical values are obtained on the basis of term structure function represented with B-splines:

$$\hat{p}_i(a) \equiv c_i^T \tilde{d}_s(t_i, a) = c_i^T \tilde{g}(h_s(\cdot, a), t_i) = c_i^T \tilde{g}(\varphi(\cdot)a, t_i) \qquad (1)$$

The theoretical bond price is the same as the current value of all bond cash flows until maturity, whereas the discount factors are obtained on the basis of the estimated term structure function. As the term structure function is presented with the forward rate function and/or zero-coupon yield curve, the function g represents the transformational function that transforms the arbitrary basic function applied in the estimation in discount function. The term structure function is estimated with B-splines and is therefore defined as the scalar product of B-spline base $\varphi(\cdot)$ and parameter vector **a.**

The optimal value of the elements of parameter vector (**a***) of the recursive spline $h_s(t, \mathbf{a}^*)$ can be obtained as a solution of the following optimisation problem:

$$\min_a \left(\left(P - \hat{P}(a) \right)^T \left(P - \hat{P}(a) \right) \right) \qquad (2)$$

In general, the above optimisation problem cannot be solved with the use of linear least squares. When the zero-coupon yield function or instantaneous forward interest rate function are used as the basic term structure function, the transformational function g is not linear in parameters **a**. In this case the problem becomes a non-linear optimisation problem, which can be solved by applying a non-linear optimisation algorithm. Further information on the iterative method can be found in Fisher, Nychka and Zervos (1994, page 5) and Chow (1983).

With the recursive spline method the estimated term structure function is dependent on the number and positioning of the spline knots. Further information on determining the number and the positioning of the spline knots can be found in McCulloch (1971, page 31, and 1975 page 828), Bekdache and Baum (1997, page 13), Bolder and Gusba (2002, page 42), and Litzenberger and Rolfo (1984, page 11).

2.1.2. Smoothing spline method

Application of the smoothing spline method in the term structure estimation was presented in theory by Fisher, Nycka and Zervos (1994), and updated by Waggoner (1997), Tanggaard (1997), and Anderson and Sleath (2001). Their main goal was to find a term structure estimation model that would accurately evaluate bonds while at the same time ensuring relatively stable forward interest rates, especially for longer maturities. The key deficiency of the smoothing spline model is that it leads to high volatility in the estimated instantaneous forward interest rates. Volatility is increased by the number of knots used in the term structure estimation. Waggoner (1997, page 1) stresses that there is no theoretical basis that would imply that the forward interest rate function values are not permitted to oscillate; however, volatility is less desirable from a practical point of view. This is especially true with regard to the long-term segment of the yield curve. Oscillation in the long-term segment is not practical from the viewpoint of economic interpretation. As the shape of the zero coupon yield curve is dependent on the expected future movements of interest rates (subject to the assumption that there is no risk and that the forward premium is zero), then the volatility of rates on the long remaining maturity segment would mean that the expected short term interest rates in the distant future strongly oscillate - an assumption that has no basis.

Bekdache and Baum (1997, page 8) state that the smoothing spline method for term structure estimation, when compared with McCulloch's recursive spline method, adds two new fundamental features, namely:

- term structure estimation is based on the use of the smoothing spline method and not on the use of the recursive spline method;
- a spline is directly applied for estimating the instantaneous forward interest rate function, whereas the McCulloch term structure estimation is based on the discount function.

Prior assignment of the number of knots in the recursive spline method strongly affects the results and the estimated term structure function. Consideration of too many knots leads to excessive function flexibility and thereby to a high volatility of interest rates. With the smoothing spline method a compromise between goodness of fit (the sum of squares deviations) and the smoothness of the term structure function (penalty function for smoothness) is achieved in the process of parameter estimation. With the smoothing spline method, the number of knots used is significantly higher, since the use of the penalty function substantially reduces the effective number of knots. The number of used knots determined in advance becomes of secondary importance. Waggoner (1997, page 254) stresses that determining the smoothing parameter value λ is of key importance.

Fisher, Nychka and Zervos (1994), and Fisher and Zervos (1996) have suggested two alternative approaches to determining the number of knots. The first approach is based on prior fixing of the number of knots, which is equal to one-third of the fixed income instruments included in the term structure estimation. In such an instance, the smoothness of the term structure is determined by the penalty function value. Similarly, Anderson and Sleath (2001, page 17) conclude that inclusion of a greater number of knots does not substantially contribute to improving the quality of goodness of fit; on the contrary, only the calculation of the parameters becomes more complex.

The second approach is based on an endogenously adaptable specification of the effective number and the location of knots, where these are determined with the use of the GCV method (Generalised Cross Validation). In this instance, the effective number of knots is dependent on the data, or is endogenously determined in the estimation procedure in accordance with the determination of the penalisation parameter for smoothness. As the main advantage of the method, Fisher, Nychka and Zervos (1994, page 9) point out that the complete spline function parameterisation is dependent upon this parameter value, which at the same time represents a trade-off between the goodness of fit and smoothness. With the inclusion of the penalisation parameter, the function becomes more rigid but the quality of adaptation is also reduced.

On the assumption that the term structure approximation function is presented by cubic B-splines the optimal parameter values can be obtained as a solution to the following optimisation problem (Fisher, Nychka in Zervos, 1994, pages 5–8):

$$\begin{aligned}
&\min_{a}\left(\sum_{i=1}^{N}\left(P_i-\hat{P}_i(a)\right)^2+\lambda\int_0^T h''(t,a)^2\,dt\right)= \\
&=\min_{a}\left(\left(P-\hat{P}(a)\right)^T\left(P-\hat{P}(a)\right)\right)+\lambda\int_0^T\left(\frac{\partial^2}{\partial t^2}h(t,a)\right)^2 dt= \\
&=\min_{a}\left(\left(P-\hat{P}(a)\right)^T\left(P-\hat{P}(a)\right)\right)+\lambda\, a^T\left(\int_0^T \varphi''(t)\varphi''(t)^T dt\right)a= \\
&=\min_{a}\left(\left(P-\hat{P}(a)\right)^T\left(P-\hat{P}(a)\right)\right)+\lambda\, a^T H a
\end{aligned} \tag{3}$$

$h(t, \mathbf{a})$ – the term structure represented by an arbitrary basic function (discount function, instantaneous forward curve or zero-coupon yield function) which can be transformed into the discount function used in calculating theoretical bond prices $\hat{P}$;
N – number of fixed-income securities in a sample;
T – highest t_{ji} for all i and j – the highest remaining maturity until cash payout (coupon or principal) for all securities included in the analysis;
λ – parameter that determines the significance or weight of the penalty function for smoothness

Within the penalty function, the parameter λ has an important role, as it determines the relative significance of the penalty function within the objective function. If $\lambda = 0$, then the smoothing spline method changes to the recursive spline method, whereas with an increased value of parameter λ the estimated term structure approaches the linear function. The Bank of Japan (1999, page 19) stresses that with an increasing of value λ, the evaluated instantaneous forward interest rate function becomes smoother.

2.2. Parametric models for term structure estimation

Parametric models for term structure estimation fall into the second group of models, otherwise known as parsimonious term structure estimation models. They are based on simplified parameterisation of a arbitrary form basic term structure function. Parametric models aim to model the term structure of interest rates as a linear combination of chosen basic functions that are not segmented and that are defined over the whole estimation interval. The optimal parameter values are usually obtained with the objective function minimisation, where the objective function can be defined on the basis of the least squares of the bonds' theoretical price deviation or on the basis of the least squares of bonds' yield deviation from actual observed values. Among the authors who are regarded as the founders of the development of such methods are Nelson and Siegel (1987), Svensson (1994), and Li et al. (2001). Even in such an instance, different models consider various forms of basic term structure functions , namely the discount function and the instantaneous forward rate function.

2.2.1 Merrill Lynch exponential model

The Merrill Lynch exponential model (MLES[3]), defined in Li et al. (2001), considers the discount function as the basic form for term structure estimation; it is modelled as a linear combination of basic exponential functions, which are, in comparison with the spline method, defined over the whole estimation interval:

$$d(m) = \sum_{k=1}^{D} \zeta_k e^{-k\alpha m} \tag{4}$$

$d(m)$ – discount function as a remaining maturity m function,
ξ_k – unknown parameters for $k = 1, \ldots, D$,
α – long-term instantaneous forward interest rate

As stressed by Bolder and Gusba (2002, page 45), it is possible to use the MLES for modelling the discount function as a linear combination of arbitrary functions. The selection of exponential functions has certain theoretical advantages – theoretically and in accordance with Vasicek and Fonga (1982) it may be expected that the discount function has the form of an exponential function. With an increase in the number of basic exponential functions (D), the godness of fit of estimated term structure is also improving. However, this can lead to complications in the matrix calculations and thereby to unreliable results. Bolder, Grahame and Metzler (2004, page 3) concluded that increasing the number of basic functions above 9 does not contribute to a reduction of errors.

2.2.2 Nelson-Siegel and Svensson Models

Among the parametric models, the model suggested by Nelson and Siegel (1987) and expanded by Svensson (1994) are most commonly used in practice.

The basic concept of the model is in the parsimonious estimation of the instantaneous forward rate function. Algebraically the function is derived as the solution to the second degree differential equation with equal real roots. The shape of the function provides several advantages:

- it can be used in different market environments with different term structure shapes, humped, monotone and/or S shaped;
- the model is parsimonious[4] as only four parameters need to be estimated;
- the estimated forward curve has the desired theoretical characteristics – it is smooth and asymptotical[5];
- the estimated function can be extrapolated.

[3] MLES represents an abbreviation for *Merrill Lynch Exponential Spline* model. Even though the name of the model includes splines, the method for estimation is not based on a splines method as represented elsewhere in this article.

[4] Dahlquist and Svensson (1994) compared the functional form of Nelson-Siegel model as it was used on the Swedish data with a significantly more complex form suggested by Longstaff and Schwartz (1992) and concluded that the use of the latter is much more difficult; the added flexibility given by the latter was generally not needed. In rare samples where the Nelson-Siegel model was not sufficiently flexible, the Svensson model or the adopted Nelson-Siegel model were sufficiently flexible, both of which are much easier to evaluate than the Longstaff and Schwartz form.

[5] As concluded by Fisher, Nychka and Zervos (1994, page 1), the mere fact that as the term increases the interest rate function moves closer to an asymptote does not ensure a positive value of term interest rates.

Nelson and Siegel (1985, page 8) suggested the forward curve to be estimated as:

$$f(m,\beta)=\beta_0+\beta_1 e^{\left(\frac{-m}{\tau_1}\right)}+\beta_2\frac{m}{\tau_1}e^{\left(\frac{-m}{\tau_1}\right)} \tag{5}$$

Besides being parsimonious the model has another advantage, namely interesting economic interpretation of parameters and good asymptotical characteristics (Seppälä and Viertiö, 1996, page 17). It holds $\lim_{m\to\infty} f(m,\beta)=\beta_0$ and $\lim_{m\to 0} f(m,\beta)=\beta_0+\beta_1$. The value of parameter β_0 represents the asymptote of the zero coupon yield curve function and at the same time the asymptote of the forward curve as remaining maturity approaches infinity, and can be interpreted as the long-term interest rate. The sum of parameters $\beta_0 + \beta_1$ represent the initial value of the forward curve ($f(0) = \beta_0 + \beta_1$), which can be interpreted as the instantaneous spot interest rate. The value of parameter β_1 represents the deviation of the function values from the asymptote, and can intuitively be explained as the curvature of the function or as the difference between the long-term and short-term forward interest rates. The parameters β_0 and ($\beta_0 + \beta_1$) must be positively valued.

The value and the sign of parameter β_2 define the magnitude and the direction of the hump. If the value of the parameter is negative, then the term structure is U-shaped. If the parameter has a positive sign, the term structure is humped. The value of parameter τ_1 must be positive and it defines the location of the hump on the maturity spectrum. The parameters of instantaneous forward rate function that have to be estimated are $\beta = (\beta_0, \beta_1, \beta_2, \tau_1)$. The facilitating fact is that the model is linear in β_0, β_1 in β_2 for the chosen value of parameter τ_1 and that the parameters have the same value in the entire maturity interval. Applied functionality guarantees that term structure function isbe smooth and at the same time sufficiently flexible.

Svensson (1994, page 6) extended the Nelson-Siegel model by introducing additional parameters that allow term structure function to have an additional hump. Schich (1997, page 15) and Ricart and Sicsic (1995, page 52) find the application of Svensson model to be desirable in the highly uncertain environment of financial markets. The Svensson model is more demanding in computing terms. In most cases in practice the application of the model does not significantly improve the results obtained with the Nelson-Siegel model, and is therefore questionable. Svensson (1994, page 7) suggested the forward curve to be estimated as:

$$f(m,\beta)=\beta_0+\beta_1 e^{\left(\frac{-m}{\tau_1}\right)}+\beta_2\frac{m}{\tau_1}e^{\left(\frac{-m}{\tau_1}\right)}+\beta_3\frac{m}{\tau_2}e^{\left(\frac{-m}{\tau_2}\right)} \tag{6}$$

The interpretation of the parameters is identical for the Svensson and Nelson-Siegel models, where the additional parameters τ_2 and β_3 have the same properties as τ_1 and β_2.

2.2.2.1. An evaluation of model parameters

The Nelson-Siegel model is based on the instantaneous forward rate function. For the purpose of parameter estimation for the Nelson-Siegel model , we have to derive the discount function from the zero-coupon yield function (z(m, β)), viz.:

$$d(m,\beta)=e^{\left(-\frac{z(m,\beta)}{100}m\right)} \tag{7}$$

The parameters of the discount function are estimated as a sum of square residuals optimisation between the theoretical and actually observed bond prices, where the estimated discount function for given parameter (τ_1, β_0, β_1 and β_2) values serves as an input in the theoretical bond price calculation:

$$\hat{P}_j\left(m_j,\beta\right)=\sum_{k=1}^{K_j} C_{jk} * \hat{d}\left(\tau_{jk},\beta\right)+V_j * \hat{d}\left(\tau_{jK_j},\beta\right);\ j = 1, \ldots, N \qquad (8)$$

The above equation is nonlinear in unknown parameters (τ_1, β_0, β_1 and β_2) and as a consequence the parameters cannot be estimated with simple regression. Svensson (1994, page 7) suggests that the parameters can be estimated with the maximum likelihood method, with nonlinear least squares or with a generalised method of moments.

In the optimisation process the value of the parameters (τ_1, β_0, β_1 and β_2) is set under the condition of objective function value minimisation, where the objective function is defined as the difference between the theoretical and observed bond prices:

$$\min_{\beta_0,\beta_1,\beta_2,\tau_1,\tau_2} \sum_{j=1}^{N}\left(P_j\left(m_j\right)-\hat{P}_j\left(m_j,\beta\right)\right)^2 \qquad (9)$$

The use of price difference in the objective function is common in practice, as the method is numerically relatively undemanding. The shortcoming of the method is that it can lead to relatively large errors in estimated yields to maturity in the short maturity segment[6] (Schich, 1997, page 18). The relative price change of a fixed-income instrument is equal to the product of the modified duration and the change in yield to maturity. For instruments with short remaining maturity, the modified duration is small. High relative price volatility is therefore inevitably reflected in even higher yield to maturity volatility. As a result, price errors are more than proportionally reflected in yield errors. Price differential is not a suitable objective function in the short maturity segment. The problem can be solved by applying a weighted price errors method or by applying a yield errors method. If the weighted price errors method is applied, then the objective function can be written as (Bolder and Gusba, 2002, page 47; Dombrecht and Wouters, 1999, page 1):

$$\min_{\beta} \sum_{j=1}^{N}\left(\frac{\left(P_j\left(m_j\right)-\hat{P}_j\left(m_j,\beta\right)_i\right)}{\Phi_j}\right)^2 \qquad (10)$$

where[7] $\Phi_j = D_j * \dfrac{P_j}{1+y_j} = MD_j * P_j$ (11)

P_j – observed price of *j*-th financial instrument
$\hat{P}$ – theoretical price of *j*-th financial instrument, calculated on the basis of estimated term structure (discount function)
D_j – duration of *j*-th financial instrument
MD_j – modified duration of *j*-th financial instrument
y_j – yield to maturity of *j*-th financial instrument

6 From the modified duration definition $\frac{dP}{P} = -D * \Delta y$ it follows that the relative price change of the bond is a product of modified duration and yield to maturity. With short-term bonds the modified duration is small (for treasury bills and zero-coupon bonds it is the same as the remaining maturity). Big price changes therefore necessarily result in even bigger yield changes.

7 Modigliani and Fabozzi (1996, page 217) determine the connection between price change and the return as $\Delta P \approx -\frac{D}{(1+y)} * P * \Delta y$. The parameter Φ represents the sensitivity to bond price changes in connection with the changes on yield to maturity $\Phi = \frac{\Delta P}{\Delta y}$.

3 DATA AND SLOVENIAN TERM STRUCTURE ESTIMATION

Slovenian government bonds are not very liquid on the Ljubljana Stock Exchange. An attempt to solve the problem of the low liquidity of the secondary bond market is the introduction of an external organised market for immediate payment, or OTC-DVP ("over the counter – delivery versus payment"), which began successfully trading treasury bills in 2001. The external market began trading parallel to the Stock Exchange, or the organised government bond market, in September 2005. As Mohanty's (2001) research has shown, competition between different trading systems may bring higher liquidity. The experiences of introducing the OTC-DVP market for treasury bills are positive, as the market has substantially improved the volume of trading among market participants. The introduction of official market-makers should ensure a higher volume of trading in long-term government securities and improve the liquidity of government bonds as well as the daily trading prices that enter into the estimation of the term structure of interest rates.

3.1. Defining instruments entered and their prices

Term structure estimation on the Slovenian financial market will be based on government fixed-income securities, that is, treasury bills and government bonds. Index linked government bonds, government bonds with a recall option and government bonds denominated in foreign currencies will be excluded from the pool of all government bonds. For analysis, ordinary tolar-denominated government bonds with a fixed nominal interest rate will be used. Among the bonds with a fixed nominal interest rate the bonds included were RS51, RS54, RS55, RS56, RS57, RS58, RS59 and RS60, up until 24 January 2006 (the trading date is the day after issue), and after this date RS61 and RS62. These are bonds that are traded on the TUVL, and it can be expected that their prices appropriately reflect market conditions and represent quality data for estimating the yield curve. Apart from prices, the data in the term structure estimation includes the amortisation schedules of individual fixed income instruments that are included in the analysis. Prospectuses with the amortisation schedules are available on the Ministry of Finance website (www.gov.si/mf). In the last period, the RS51 bond was excluded from estimation due to its absurd returns. The reason is that the bond falls due for payment on 24 February 2006 and because of a short remaining maturity, the equal relative price change of the bond requires a large absolute change of yield to maturity. It was found out that the yield to maturity of bond RS51 systematically lags behind the yield to maturity of other instruments with similar remaining maturity.

Owing to the characteristics of the issuing schedule of Slovenian treasury bills, 16 different non-expired treasury bills with different remind maturity included in the analysis were being circulated at any given time by the end of 2005. At the end of November 2005, the Ministry of Finance ceased issuing monthly treasury bills, and thus the number of active treasury bills was reduced to 12.

In the analysis, the trading of treasury bills at 11 am on each date of estimation on the OTC-DVP market will be considered. The stated hour is the most appropriate, as it was found in practice that the banks that function as market-makers usually have traded all the instruments that they have in the portfolio by this time, whereas after this time trading does not change or it subsides. Apart from this, in accordance with the agreement on forming Slovenian interbank interest rates (TBS-GIS, 2003, page 2) for calculating the SITBOR, the basis of the calculations are the trading interbank interest rates of the eight largest Slovenian banks that trade until 11 a.m.

The market-makers trade the bid price and ask price for each individual instrument. As a representative price for an individual instrument traded by an individual market-maker, the mean between its bid price and ask price will be considered. Since various market-makers trade the same instrument series at different prices, the final price of an individual instrument on the particular day that will enter the term structure estimation will be the same as the average of the representative prices of the individual market-makers.

For bonds, the OTC-DVP market opened on 1 September 2005. Prior to this, the bonds were traded on the Ljubljana Stock Exchange; therefore, for dates prior to September, the closing stock exchange price on the date of term structure estimation will be considered as data. In Appendix 1 the data for the term structure estimation are two days (1 April 2005 and 26 August 2005) prior to the opening of the TUVL bond market and three days (14 December 2005, 24 January 2006 and 31 January 2006) after the opening of the TUVL bond market. Presentation of the entry database and the result for all the remaining days would be too extensive, since the estimation period includes approximately 8,000 trades. These data are obtainable from the author.

3.2. Selection of the best method for term structure estimation

In accordance with the methodology described in point 2 and by considering the data defined in point 3.1, the term structure function was evaluated for the period from 1 January 2005 until 31 January 2006. For choosing the best model, the following goodness of fit criteria were used: root mean square error (RMSE), mean average error (MAE), mean percentage error (MPE) and hit ratio. The latter is defined as the share of accurately evaluated bonds among all bonds.

A bond is accurately evaluated if its theoretical value estimation as calculated on the basis of the term structure estimation is within a range between the actual bid price and the real ask price on the day of estimation. Apart from quality adjustments, other criteria have been considered in the model selection, namely model stability for estimating interest rate terms at different terms.

The estimation period spans from 1 January 2005 to 31 December 2005; however for the analysis the period had to be divided into two sub-periods. The first sub-period runs from 1 January 2005 until the opening of the TUVL market, that is, until 1 September 2005.

3.2.1 The period prior to the opening of the TUVL bond market

Prior to the opening of the TUVL, the Ljubljana Stock Exchange quotes were used as input data for bonds and the TUVL market quotes for treasury bills. In this sub-period the quality of the bond rate on the Ljubljana Stock Exchange was low due to poor liquidity: therefore, only the Nelson-Siegel method proved to be sufficiently robust. With its use it was possible to systematically obtain sensible forward rate estimation, but the instability of the evaluated interest rates was too high. Apart from this, there were too few securities available on the market for the estimation to be sufficiently robust if other more flexible methods were employed. The use of the Svensson model improved quality adjustments by a small amount, but the parametric calculations demanded significantly more computing time than with the Nelson-Siegel model, and the algorithm frequently did not achieve convergence. In this period the market conditions were such that the use of a double-hump term structure did not prove to be sensible.

The recursive spline and smoothing spline methods proved to be significantly more flexible. The smoothing spline method proved to be the more flexible of the two, as it was possible to obtain sensible economic term structure estimation by using high values of the penalisation function for smoothness. However, these results were obtained at the expense of a poorer adjustment in the short-term segment. McCulloch's placing of knots did not yield good results due to the high frequency of observations in the short-term segment. Condensing knots in a one-year term segment resulted in high inconsistency for short-term interest rates. Good results were obtainable by placing the second knot for a term around one year or by considering McCulloch's knot placing and high values for the penalisation function for smoothness.

The parametric MLES model proved to be too flexible. If the number of basic exponential functions was above 5, the obtained zero-coupon yields and term interest rates were too inconsistent. With such a small number of basic exponential functions, the evaluated term structure was rigid, and the adjustment on all the remaining maturity segments was not satisfactory. The comparison of estimation obtained with the use of various methods on the two chosen estimation days prior to the opening of TUVL bond market (1 April 2005 and 26 August 2005) is shown in Appendices 2 and 3.

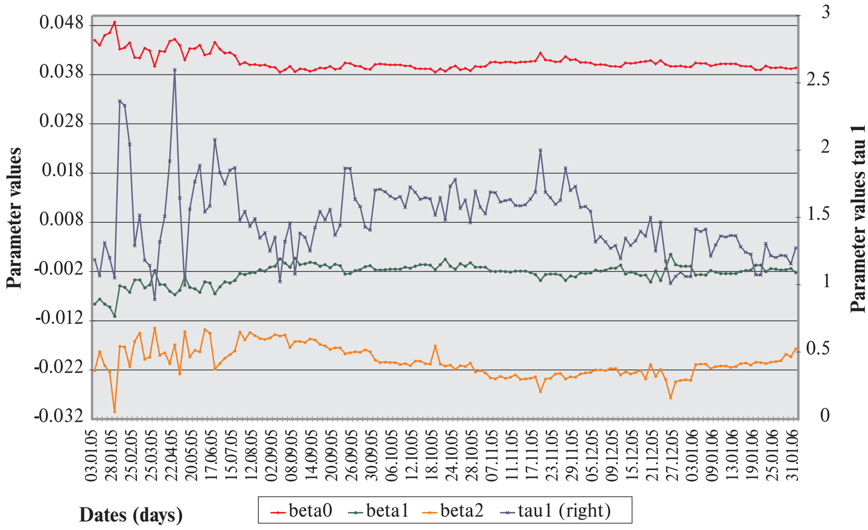
3.2.2 The period after the opening of the TUVL bond market

The second sub-period refers to the period from the opening of the TUVL market until the end of the estimation period. As will be shown further on, after the launch of the TUVL market the informational value of bond prices increased significantly for the needs of term structure estimation and, consequently, the volatility of the evaluated interest rates decreased. Despite this, in the second sub-period the methods founded on B-splines and MLES models proved to be too complex to systematically obtain economically sensible estimation of the term structure of interest rates. It was often the case that with their use the evaluated values of the forward curve for different terms oscillated too much. The comparison of the estimation obtained with the use of various methods on the two chosen estimation days after the opening of the TUVL bond market (14 December 2005, 24 January 2006 and 31 January 2006) is shown in Appendices 2 and 4.

In practice it was found that on a particular estimation day the MLES method and the smoothing spline method proved to be marginally better for the used adjustment measure values than the Nelson-Siegel model; however, the use of the same methods proved to be less appropriate when evaluating a different day. Apart from its systematics, a preference for the Nelson-Siegel model is also supported by the stability of the term interest rate for various terms, which was poorer with the other two models.

Among all the methods, the Nelson-Siegel model proved to be the most robust in the second sub-period. Among the various possibilities that the method offers, the procedure that evaluates the parameters on the basis of minimised weighted error prices of the instruments included in the analysis was used, while non-linear least squares was used as the optimisation method. In general, the use of the Svensson model did not improve the estimation results; however, the required computing time to obtain the convergence improved significantly. The two-hump term structure assumed by the Svensson model offers too much flexibility when considering the Slovenian debt market, and therefore the algorithm frequently did not achieve convergence in evaluating the parameters.

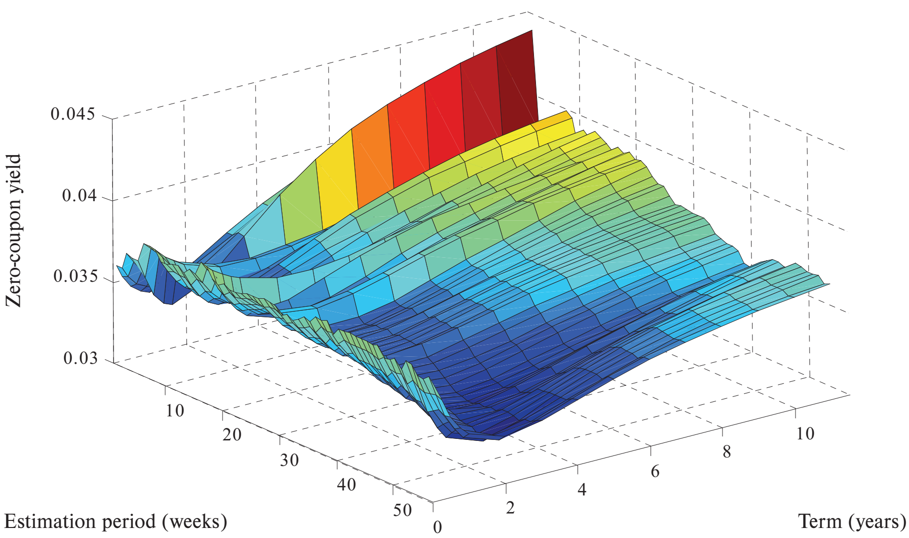
Figure 1: Movement of the parameter values in the Nelson-Siegel models in the estimation period



Source: own calculations

The B-spline method and MLES method did not prove to be sufficiently robust, as they are highly sensitive to a number of instruments included in the term structure estimation. This is especially true for the instruments in the medium-term and in the long-term segments of the remaining maturity, both of which are lacking in Slovenia. From 24 January 2006 onwards, when two new bonds (RS61 and RS62) were included in the estimation, the estimation quality obtained with the MLES model and the B-spline model improved (Appendix 5), and the number of the basic exponential functions that were used in the evaluation of the MLES model increased. Despite this, it is possible to conclude that, when considering the instability of long-term interest rates, the estimation quality obtained with the aforementioned models would significantly improve if a distinctive long-term bond were to exist on the Slovenian market. The significant advantage of the Nelson-Siegel model is the possibility of extrapolating it and obtaining sensible long-term interest rates for terms that are longer than the bond with the longest remaining maturity included in the analyses. It can be expected that the more flexible methods will gain in importance with the development of the loan market in Slovenia, and with it the issue of new instruments.

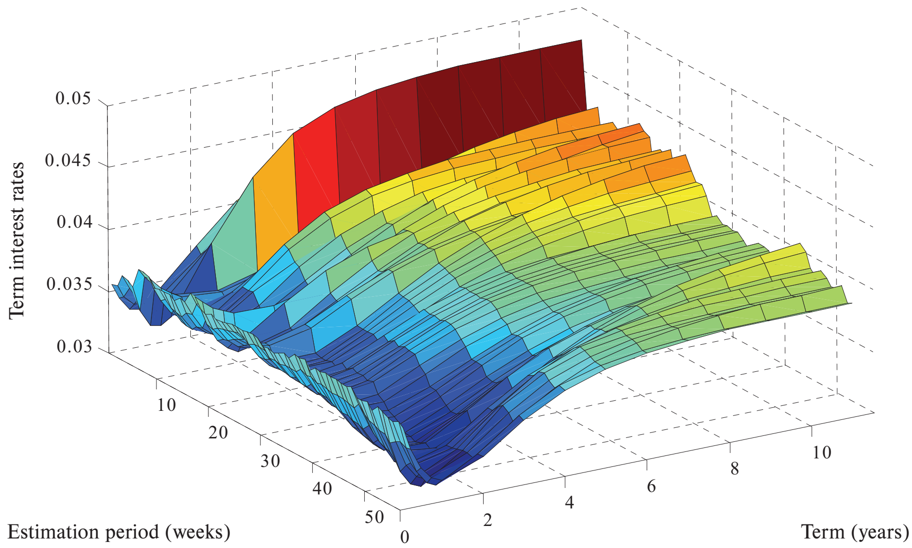
Figure 2: Three-dimensional graph of weekly estimation of the zero-coupon yield function in the period from 1 January 2005 and 31 January 2006



Source: own calculations, Matlab 7.0

In Figures 2 and 3, the estimations for the zero-coupon yield function and forward curve are shown for the estimation period. The functions are evaluated with the Nelson-Siegel model. From an economic analysis standpoint, the form of the forward curve is interesting because it allows easier interpretation of the expected movements of short-, medium- and long-term interest rates than the use of the zero-coupon yield function does. From the profile of the Slovenian forward curve on 31 January 2006 it can be concluded that the market is anticipating an additional lowering of short-term interest rates. The forward curve achieves its minimum at 1.2 years. From then on, the expected short-term interest rates increase until a 7-year term, where expectations stabilise at a short-term interest rate significantly higher than the spot rate, i.e. at 4%. On the basis of the term interest rate it is possible to analyse expectations more effectively. Of course, it is important to be prudent with the interpretation, as the term interest rate includes a time-variable risk premium.

Figure 3: Three-dimensional graph of weekly estimation of the forward curve in the period from 1 January 2005 and 31 January 2006



Source: own calculations, Matlab 7.0

The results of the term structure of the interest rate estimation performed with the Nelson-Siegel model for both periods are shown in Table 2. The estimation of the model parameters, the adjustment measurements and the level of spot (**z**) and term (**f**) interest rates for the standardised terms (from 1 month to 11 years) are shown. The average parameter values and the adjustment values, their standard deviations and the minimum and maximum values are calculated.

The introduction of the TUVL market significantly improved the adaptation of the term structure of interest rates to actual data. The estimation error was reduced by approximately 50%. At the same time, the instability of the interest rates significantly decreased.

Table 2: Estimation results for the Nelson-Siegel parameter models and the evaluated values of zero-coupon yields and term interest rates with associated statistics

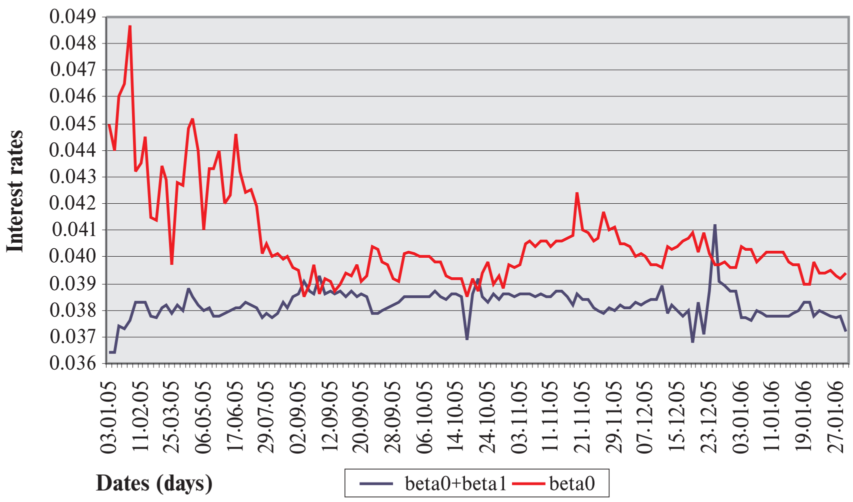
	Prior to TUVL market introduction (1 Jan 2005 – 1 Sep 2005)					After TUVL market introduction (1 Sep 2005 – 31 Jan 2006)				
	Mean	Standard deviation	Min	Max	KV	Mean	Standard deviation	Min	Max	KV
1	2	3	4	5	6	7	8	9	10	11
beta 0	0.04288	0.00208	0.0397	0.0487	4.86%	0.03989	0.00069	0.0385	0.0424	1.73%
beta 1	-0.00496	0.00223	-0.0111	-0.0016	-44.89%	-0.00157	0.00097	-0.0041	0.0015	-61.51%
beta 2	-0.01828	0.00346	-0.0305	-0.0135	-18.93%	-0.02093	0.00258	-0.0277	-0.0148	-12.35%
tau 1	1.57019	0.40442	0.8898	2.5991	25.76%	1.45589	0.21775	1.0090	2.0014	14.96%
RMSE	51.65485	34.53156	14.5428	152.9435	66.85%	25.69371	20.24347	5.4172	107.1674	78.79%
MAE	27.39231	16.57603	9.7586	71.6042	60.51%	13.22113	7.89695	3.5949	47.0397	59.73%
MPE	-0.00004	0.00700	-0.0002	0.0001	-183.91%	0.00001	0.00400	-0.0001	0.0002	401.40%
CR	67.39%	5.80300	42.11%	76.19%	8.61%	97.56%	6.18900	43.48%	100.00%	6.34%
z										
1M	3.76%	0.052	3.60%	3.85%	1.39%	3.78%	0.049	3.64%	4.01%	1.29%
3M	3.69%	0.061	3.52%	3.80%	1.64%	3.68%	0.048	3.56%	3.81%	1.31%
6M	3.62%	0.069	3.44%	3.77%	1.90%	3.57%	0.054	3.46%	3.66%	1.51%
9M	3.57%	0.071	3.39%	3.74%	1.98%	3.48%	0.059	3.36%	3.60%	1.71%
1Y	3.54%	0.068	3.36%	3.71%	1.93%	3.41%	0.062	3.28%	3.55%	1.82%
2Y	3.50%	0.052	3.42%	3.66%	1.47%	3.30%	0.058	3.20%	3.47%	1.76%
3Y	3.54%	0.069	3.45%	3.67%	1.95%	3.31%	0.054	3.25%	3.48%	1.64%
4Y	3.61%	0.096	3.50%	3.87%	2.67%	3.36%	0.055	3.28%	3.53%	1.64%
5Y	3.68%	0.117	3.55%	4.03%	3.18%	3.43%	0.056	3.33%	3.58%	1.62%
6Y	3.75%	0.131	3.61%	4.15%	3.49%	3.49%	0.054	3.38%	3.63%	1.55%
7Y	3.80%	0.140	3.66%	4.25%	3.67%	3.54%	0.051	3.44%	3.67%	1.44%
8Y	3.85%	0.146	3.70%	4.33%	3.78%	3.59%	0.048	3.49%	3.70%	1.33%
9Y	3.90%	0.150	3.73%	4.39%	3.85%	3.63%	0.045	3.53%	3.73%	1.24%
10Y	3.93%	0.154	3.76%	4.43%	3.91%	3.66%	0.043	3.57%	3.75%	1.17%
11Y	3.96%	0.156	3.78%	4.47%	3.95%	3.69%	0.041	3.59%	3.77%	1.12%
f										
1M	3.72%	0.057	3.55%	3.82%	1.54%	3.72%	0.048	3.59%	3.90%	1.28%
3M	3.61%	0.074	3.42%	3.76%	2.04%	3.55%	0.057	3.44%	3.65%	1.61%
6M	3.50%	0.081	3.28%	3.70%	2.32%	3.36%	0.073	3.19%	3.51%	2.16%
9M	3.44%	0.074	3.26%	3.65%	2.15%	3.25%	0.077	3.06%	3.43%	2.36%
1Y	3.42%	0.064	3.32%	3.62%	1.88%	3.19%	0.074	3.01%	3.38%	2.31%
2Y	3.53%	0.120	3.39%	3.84%	3.41%	3.23%	0.073	3.12%	3.44%	2.26%
3Y	3.73%	0.186	3.53%	4.31%	4.99%	3.43%	0.090	3.27%	3.62%	2.64%
4Y	3.90%	0.210	3.69%	4.59%	5.39%	3.61%	0.088	3.44%	3.76%	2.43%
5Y	4.03%	0.212	3.82%	4.74%	5.26%	3.75%	0.074	3.60%	3.87%	1.97%
6Y	4.12%	0.207	3.90%	4.81%	5.02%	3.84%	0.061	3.71%	3.94%	1.60%
7Y	4.18%	0.202	3.94%	4.84%	4.84%	3.90%	0.056	3.77%	4.00%	1.43%
8Y	4.21%	0.200	3.97%	4.86%	4.75%	3.93%	0.056	3.80%	4.04%	1.42%
9Y	4.24%	0.200	3.97%	4.86%	4.72%	3.96%	0.058	3.82%	4.10%	1.48%
10Y	4.26%	0.201	3.97%	4.87%	4.72%	3.97%	0.061	3.83%	4.15%	1.55%
11Y	4.27%	0.202	3.97%	4.87%	4.74%	3.98%	0.064	3.84%	4.18%	1.61%

Source: own calculations

From Table 2 it is evident that in 2005 a trend towards lowering long-term zero-coupon yield is noticeable, and therefore the yield curve becomes flatter. In the evaluated period the yield curve has an ordinary form. The same holds true for term interest rates. The interest rates reached their minimum at the end of October and at the beginning of November. From then on, a tendency towards an increase in long-term interest rates is noticeable. The last rise can be explained as the result of the then expected changes towards higher restrictions in the monetary policy management of the European Central Bank, which in fact did happen.

On the basis of the parameter value development of the Nelson-Siegel model (Figure 1) it can be concluded that the long-term interest rates represented by the parameter β_0 did not significantly change during the estimation period. In the period analysed, the 11-year interest rate fluctuated between 3.59% and 4.47%, and the long-term interest rate, calculated as a limit when the remaining maturity approaches infinity, fluctuated between 3.85% and 4.87%. In the period analysed, short-term interest rates, calculated as the sum of parameters β_0 and β_1, increased and mainly fluctuated within a narrow range (Figure 4). If the outlier (4.12% on 26 December 2005) is ignored, then the short-term interest rates fluctuated between 3.64% and 3.93%.

Figure 4: Movement of short- and long-term interest rates in the evaluated period



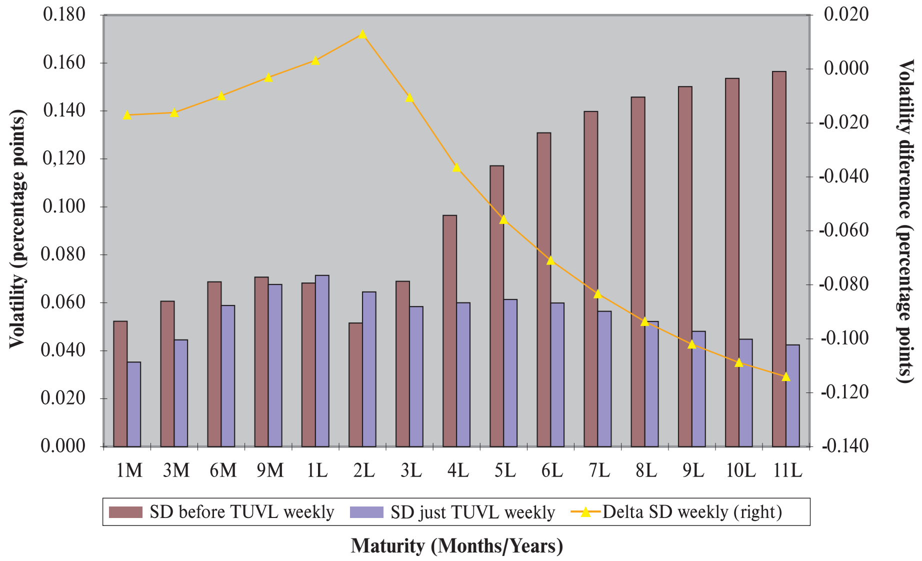
Source: own calculations

The parameter β_1 represents the deviation of the term structure of interest rates or extras for the term. In the period analysed, the parameter mostly assumed a negative value, meaning that the yield curve was growing somewhat. The value of β_1 became so low that it could be said that the term structure had become flat. Throughout the estimation period, the absolute value of β_1 was lower than the absolute value of β_2, and β_2 was always negative. This means that the yield curve always assumed a concave form. The parameter β_1 fluctuated between a somewhat positive and negative value, which means that the concavity was under the long-term interest rate or ran through the long-term interest rate. No other possible forms of the term structure of interest rates that are offered by the flexibility of the Nelson-Siegel model were observed in the period evaluated. The value of τ_1 shows the curve positioning (in the present case the positioning of the concavity) at term intervals. A higher parameter value means that the highest curve is achieved at a higher term.

3.3 Use of term structure estimation for analysing interest rate volatility

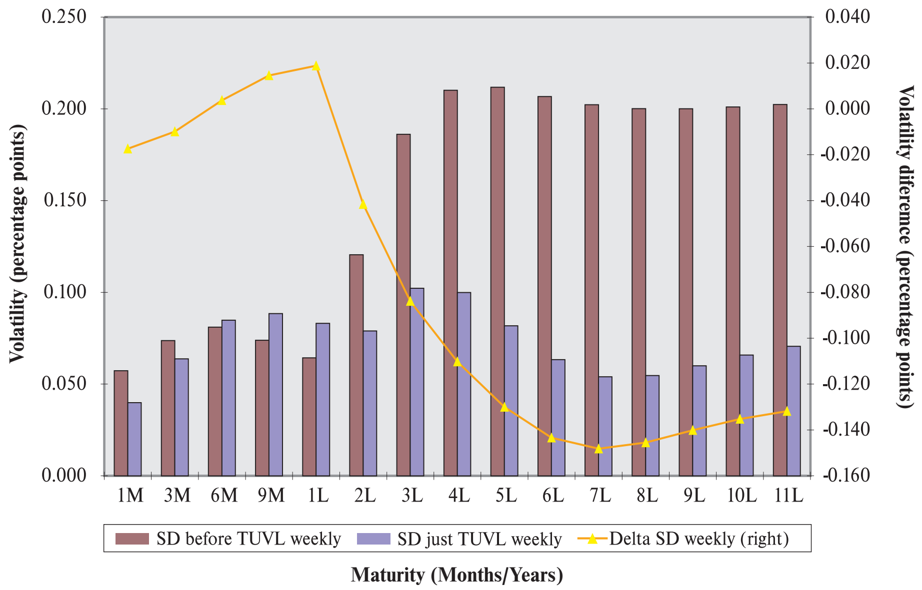
The opening of the TUVL market significantly contributed to reducing the volatility of spot and term interest rates. Figures 5 and 6 show the weekly instability for zero-return yield and for term interest rates prior to the opening of the OTC-DVP bond market and after its opening. Volatility is shown as the standard deviation (SD) of the weekly estimation. It can be concluded that, due to the introduction of the parallel bond market, the instability of interest rates was significantly reduced for the medium-term and the long-term interval of the remaining maturity. For the 10-year remaining maturity, the volatility of zero-coupon yield was reduced from 0.154% to 0.043%.

Figure 5: Volatility of weekly estimation of zero-coupon yield for a standardised term prior to the opening of the TUVL and after its opening



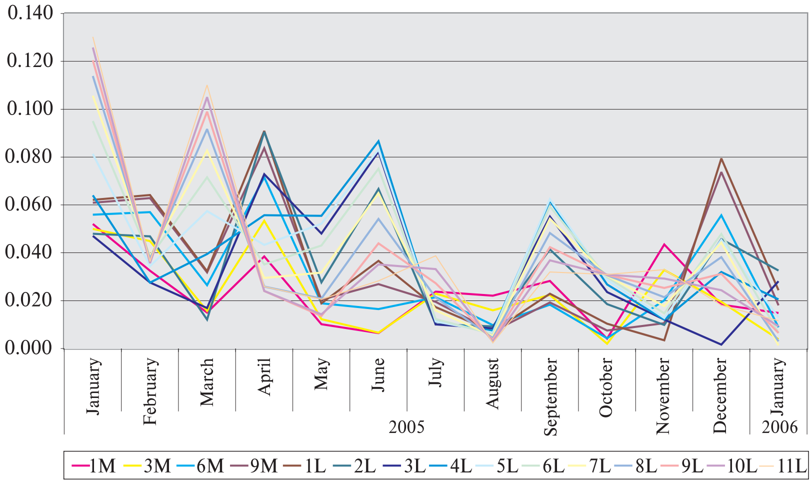
Source: own calculations

Figure 6: Volatility of weekly estimation of term interest rates for a standardised term prior to the opening of the TUVL and after its opening



Source: own calculations

Figure 7: Monthly movements of volatility of zero coupon yield (weekly data) for a standardised term in the period analysed



Source: own calculations

Figure 7 shows the movement of the volatility of the spot interest rate per month for the estimation period. Monthly volatility values are calculated on the basis of weekly estimation of the zero-coupon yield curve. From the graph, a trend towards decreasing volatility can be seen. After notably low volatility in August, volatility increased in September, even though September interest rates were evaluated on the basis of data obtained from the TUVL market. Irrespective of the level of the volatility, the graphs show the important finding that the change in volatility during the months after the opening of the TUVL market is significantly less than prior to its opening, which is especially true for long-term interest rates. Due to greater liquidity on this market and consequently more informational values of traded prices for the needs of term structure estimation, these results were expected. The reduction in the volatility of long-term interest rates is important in connection with the fulfilment of the Maastricht criterion for interest rates on 10-year bonds.

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APPENDICES

Appendix 1: Data for the days chosen prior to the opening of the TUVL market (1 Apr 2005 and 26 Aug 2005) and after its opening (14 Dec 2005, 24 Jan 2006 and 31 Jan 2006)

Security designation	Market making	Trading day	Days to maturity	Ask price	Ask yield	Bid price	Bid yield	Single price
EZ 202	BA CA d.d.	1 Apr 05	13	99.862	3.84	99.867	3.7	99.8645
TZ 81	BA CA d.d.	1 Apr 05	27	99.714	3.83	99.726	3.67	99.72
SZ 32	BA CA d.d.	1 Apr 05	90	99.064	3.78	99.113	3.58	99.0885
DZ 26	BA CA d.d.	1 Apr 05	118	98.779	3.77	98.834	3.6	98.8065
EZ 201	Abanka Vipa	1 Apr 05	6	99.936	3.82	99.94	3.63	99.938
DZ 28	BA CA d.d.	1 Apr 05	237	97.603	3.73	97.748	3.5	97.6755
DZ 29	BA CA d.d.	1 Apr 05	300	97.017	3.69	97.182	3.48	97.0995
EZ 204	Abanka Vipa	1 Apr 05	27	99.714	3.83	99.727	3.65	99.7205
DZ 30	BA CA d.d.	1 Apr 05	363	96.403	3.7	96.61	3.48	96.5065
TZ 81	Abanka Vipa	1 Apr 05	27	99.715	3.81	99.727	3.65	99.721
TZ 82	Abanka Vipa	1 Apr 05	55	99.423	3.8	99.447	3.64	99.435
TZ 83	Abanka Vipa	1 Apr 05	90	99.059	3.8	99.11	3.59	99.0845
SZ 31	Abanka Vipa	1 Apr 05	27	99.715	3.81	99.727	3.65	99.721
SZ 32	Abanka Vipa	1 Apr 05	90	99.059	3.8	99.11	3.59	99.0845
SZ 33	Abanka Vipa	1 Apr 05	146	98.498	3.76	98.569	3.58	98.5335
DZ 25	Abanka Vipa	1 Apr 05	55	99.423	3.8	99.447	3.64	99.435
DZ 26	Abanka Vipa	1 Apr 05	118	98.773	3.79	98.837	3.59	98.805
DZ 27	Abanka Vipa	1 Apr 05	181	98.145	3.76	98.261	3.52	98.203
DZ 28	Abanka Vipa	1 Apr 05	237	97.597	3.74	97.748	3.5	97.6725
DZ 29	Abanka Vipa	1 Apr 05	300	97.001	3.71	97.19	3.47	97.0955
DZ 30	Abanka Vipa	1 Apr 05	363	96.394	3.71	96.648	3.44	96.521
TZ 81	SKB banka	1 Apr 05	27	99.712	3.85	99.731	3.6	99.7215
TZ 82	SKB banka	1 Apr 05	55	99.423	3.8	99.453	3.6	99.438
SZ 32	SKB banka	1 Apr 05	90	99.071	3.75	99.13	3.51	99.1005
DZ 26	SKB banka	1 Apr 05	118	98.786	3.75	98.834	3.6	98.81
SZ 33	SKB banka	1 Apr 05	146	98.502	3.75	98.561	3.6	98.5315
DZ 29	SKB banka	1 Apr 05	300	97.009	3.7	97.19	3.47	97.0995
DZ 30	SKB banka	1 Apr 05	363	96.403	3.7	96.619	3.47	96.511
EZ 201	NLB d.d.	1 Apr 05	6	99.936	3.82	99.939	3.69	99.9375
EZ 202	NLB d.d.	1 Apr 05	13	99.861	3.85	99.867	3.7	99.864
EZ 204	NLB d.d.	1 Apr 05	27	99.712	3.85	99.726	3.66	99.719
SZ 31	NLB d.d.	1 Apr 05	27	99.712	3.85	99.726	3.66	99.719
TZ 81	NLB d.d.	1 Apr 05	27	99.713	3.84	99.727	3.65	99.72
TZ 82	NLB d.d.	1 Apr 05	55	99.42	3.82	99.45	3.62	99.435
TZ 83	NLB d.d.	1 Apr 05	90	99.059	3.8	99.108	3.6	99.0835
DZ 26	NLB d.d.	1 Apr 05	118	98.77	3.8	98.834	3.6	98.802
SZ 33	NLB d.d.	1 Apr 05	146	98.482	3.8	98.561	3.6	98.5215
DZ 29	NLB d.d.	1 Apr 05	300	97.009	3.7	97.19	3.47	97.0995
EZ 201	Probanka	1 Apr 05	6	99.936	3.83	99.94	3.63	99.938
EZ 202	Probanka	1 Apr 05	13	99.86	3.87	99.867	3.69	99.8635
EZ 203	Probanka	1 Apr 05	20	99.787	3.85	99.798	3.64	99.7925
EZ 204	Probanka	1 Apr 05	27	99.714	3.83	99.728	3.63	99.721
TZ 81	Probanka	1 Apr 05	27	99.712	3.85	99.726	3.66	99.719
TZ 83	Probanka	1 Apr 05	90	99.059	3.8	99.108	3.6	99.0835
SZ 32	Probanka	1 Apr 05	90	99.071	3.75	99.13	3.51	99.1005
SZ 33	Probanka	1 Apr 05	146	98.486	3.79	98.565	3.59	98.5255
DZ 30	Probanka	1 Apr 05	363	96.403	3.7	96.619	3.47	96.511
SZ 32	BA CA d.d.	1 Apr 05	90	99.069	3.76	99.123	3.54	99.096
RS52	LJSE	1 Apr 05						107
RS54	LJSE	1 Apr 05						110.7
RS55	LJSE	1 Apr 05						102.44
RS56	LJSE	1 Apr 05						104.55
RS57	LJSE	1 Apr 05						107.6
RS58	LJSE	1 Apr 05						99.28
RS59	LJSE	1 Apr 05						100.2

Source: TUVL market, Ljubljana Stock Exchange

Security designation	Market making	Trading day	Days to maturity	Ask price	Ask yield	Bid price	Bid yield	Medium price
EZ224	SKB banka	26 Aug 05	20	99.789	3.8	99.799	3.63	99.794
DZ27	SKB banka	26 Aug 05	34	99.642	3.8	99.658	3.63	99.65
SZ34	SKB banka	26 Aug 05	62	99.353	3.78	99.384	3.6	99.3685
TZ88	SKB banka	26 Aug 05	90	99.064	3.78	99.108	3.6	99.086
SZ35	SKB banka	26 Aug 05	125	98.705	3.78	98.779	3.56	98.742
DZ29	SKB banka	26 Aug 05	153	98.431	3.75	98.563	3.43	98.497
SZ36	SKB banka	26 Aug 05	188	98.079	3.75	98.23	3.45	98.1545
DZ30	SKB banka	26 Aug 05	216	97.828	3.7	97.972	3.45	97.9
DZ31	SKB banka	26 Aug 05	272	97.28	3.7	97.46	3.45	97.37
EZ223	Abanka Vipa	26 Aug 05	13	99.863	3.79	99.87	3.61	99.8665
TZ87	Abanka Vipa	26 Aug 05	62	99.346	3.82	99.38	3.62	99.363
TZ88	Abanka Vipa	26 Aug 05	90	99.069	3.76	99.11	3.59	99.0895
SZ34	Abanka Vipa	26 Aug 05	62	99.346	3.82	99.38	3.62	99.363
SZ35	Abanka Vipa	26 Aug 05	125	98.705	3.78	98.776	3.57	98.7405
SZ36	Abanka Vipa	26 Aug 05	188	98.079	3.75	98.175	3.56	98.127
DZ27	Abanka Vipa	26 Aug 05	34	99.644	3.78	99.656	3.65	99.65
DZ28	Abanka Vipa	26 Aug 05	90	99.069	3.76	99.128	3.52	99.0985
DZ30	Abanka Vipa	26 Aug 05	216	97.828	3.7	97.937	3.51	97.8825
DZ31	Abanka Vipa	26 Aug 05	272	97.28	3.7	97.417	3.51	97.3485
DZ32	Abanka Vipa	26 Aug 05	335	96.689	3.68	96.837	3.51	96.763
EZ225	BA CA d.d.	26 Aug 05	27	99.712	3.85	99.727	3.65	99.7195
TZ87	BA CA d.d.	26 Aug 05	62	99.352	3.79	99.384	3.6	99.368
TZ88	BA CA d.d.	26 Aug 05	90	99.064	3.78	99.093	3.66	99.0785
SZ34	BA CA d.d.	26 Aug 05	62	99.353	3.78	99.384	3.6	99.3685
SZ36	BA CA d.d.	26 Aug 05	188	98.104	3.7	98.195	3.52	98.1495
DZ28	BA CA d.d.	26 Aug 05	90	99.064	3.78	99.093	3.66	99.0785
DZ29	BA CA d.d.	26 Aug 05	153	98.46	3.68	98.534	3.5	98.497
DZ30	BA CA d.d.	26 Aug 05	216	97.84	3.68	97.966	3.46	97.903
DZ32	BA CA d.d.	26 Aug 05	335	96.698	3.67	96.889	3.45	96.7935
EZ222	Probanka	26 Aug 05	6	99.936	3.86	99.939	3.64	99.9375
EZ223	Probanka	26 Aug 05	13	99.862	3.84	99.868	3.66	99.865
EZ224	Probanka	26 Aug 05	20	99.787	3.84	99.797	3.66	99.792
EZ225	Probanka	26 Aug 05	27	99.713	3.84	99.726	3.66	99.7195
TZ86	Probanka	26 Aug 05	34	99.641	3.81	99.654	3.68	99.6475
TZ87	Probanka	26 Aug 05	62	99.346	3.82	99.379	3.63	99.3625
TZ88	Probanka	26 Aug 05	90	99.054	3.82	99.108	3.6	99.081
SZ35	Probanka	26 Aug 05	125	98.705	3.78	98.772	3.58	98.7385
SZ36	Probanka	26 Aug 05	188	98.064	3.78	98.175	3.56	98.1195
DZ28	Probanka	26 Aug 05	90	99.064	3.78	99.113	3.58	99.0885
DZ29	Probanka	26 Aug 05	153	98.444	3.72	98.514	3.55	98.479
DZ31	Probanka	26 Aug 05	272	97.28	3.7	97.388	3.55	97.334
EZ222	NLB d.d.	26 Aug 05	6	99.936	3.86	99.94	3.63	99.938
EZ223	NLB d.d.	26 Aug 05	13	99.861	3.85	99.868	3.65	99.8645
EZ224	NLB d.d.	26 Aug 05	20	99.787	3.85	99.798	3.65	99.7925
TZ86	NLB d.d.	26 Aug 05	34	99.64	3.83	99.656	3.65	99.648
SZ34	NLB d.d.	26 Aug 05	62	99.346	3.82	99.38	3.62	99.363
TZ87	NLB d.d.	26 Aug 05	62	99.346	3.82	99.38	3.62	99.363
TZ88	NLB d.d.	26 Aug 05	90	99.056	3.81	99.108	3.6	99.082
SZ35	NLB d.d.	26 Aug 05	125	98.698	3.8	98.782	3.55	98.74
DZ29	NLB d.d.	26 Aug 05	153	98.411	3.8	98.563	3.43	98.487
SZ36	NLB d.d.	26 Aug 05	188	98.054	3.8	98.205	3.5	98.1295
DZ31	NLB d.d.	26 Aug 05	272	97.28	3.7	97.424	3.5	97.352
DZ32	NLB d.d.	26 Aug 05	335	96.689	3.68	96.846	3.5	96.7675
RS52	LJSE	26 Aug 05						107
RS54	LJSE	26 Aug 05						113.7
RS55	LJSE	26 Aug 05						101.8
RS56	LJSE	26 Aug 05						104
RS57	LJSE	26 Aug 05						108.1
RS58	LJSE	26 Aug 05						99.47
RS59	LJSE	26 Aug 05						101.68
RS60	LJSE	26 Aug 05						99.25

Source: TUVL market, Ljubljana Stock Exchange

Security designation	Market making	Trading day	Days to maturity	Ask price	Ask yield	Bid price	Bid yield	Single price
DZ30	BA CA d.d.	14 Dec 05	106	98.9223	3.7	98.98	3.5	98.95115
DZ32	BA CA d.d.	14 Dec 05	225	97.7804	3.632	97.9313	3.3798	97.85585
RS51	BA CA d.d.	14 Dec 05	72	100.73	3.8443	100.81	3.4514	100.77
RS58	BA CA d.d.	14 Dec 05	855	99.35	3.5314	99.67	3.3867	99.51
RS59	BA CA d.d.	14 Dec 05	3717	101.6	3.806	102	3.7584	101.8
RS60	BA CA d.d.	14 Dec 05	1568	99.88	3.5273	100.52	3.3648	100.2
SZ36	BA CA d.d.	14 Dec 05	78	99.1727	3.85	99.226	3.6	99.19935
DZ29	Probanka	14 Dec 05	43	99.5422	3.85	99.5801	3.53	99.56115
EZ238	Probanka	14 Dec 05	8	99.9134	3.9	99.9201	3.6	99.91675
EZ239	Probanka	14 Dec 05	15	99.8378	3.9	99.8502	3.6	99.844
RS56	Probanka	14 Dec 05	1155	104	3.5123	104.5	3.3477	104.25
RS57	Probanka	14 Dec 05	3227	108.2	3.7651	109.49	3.6004	108.845
RS58	Probanka	14 Dec 05	855	99.35	3.5314	99.9	3.2831	99.625
RS59	Probanka	14 Dec 05	3717	101	3.8777	102.2	3.7348	101.6
RS60	Probanka	14 Dec 05	1568	99.5	3.6245	100.4	3.3952	99.95
SZ35	Probanka	14 Dec 05	15	99.8378	3.9	99.8502	3.6	99.844
SZ36	Probanka	14 Dec 05	78	99.1727	3.85	99.2367	3.55	99.2047
TZ91	Probanka	14 Dec 05	78	99.1727	3.85	99.2367	3.55	99.2047
DZ29	SKB banka	14 Dec 05	43	99.5422	3.85	99.6074	3.3	99.5748
DZ30	SKB banka	14 Dec 05	106	98.9079	3.75	98.9944	3.45	98.95115
EZ238	SKB banka	14 Dec 05	8	99.9134	3.9	99.9194	3.63	99.9164
EZ239	SKB banka	14 Dec 05	15	99.8378	3.9	99.8498	3.61	99.8438
RS52	SKB banka	14 Dec 05	846	106.1	3.4498	107.21	2.9697	106.655
RS55	SKB banka	14 Dec 05	424	101.4	3.7349	102.71	2.5939	102.055
RS56	SKB banka	14 Dec 05	1155	104.01	3.509	104.9	3.2167	104.455
RS57	SKB banka	14 Dec 05	3227	108.3	3.7523	109.7	3.5738	109
RS58	SKB banka	14 Dec 05	855	99.38	3.5178	99.9	3.2831	99.64
RS59	SKB banka	14 Dec 05	3717	101.3	3.8418	102.3	3.7229	101.8
RS60	SKB banka	14 Dec 05	1568	99.6	3.5989	100.5	3.3698	100.05
SZ35	SKB banka	14 Dec 05	15	99.8378	3.8991	99.8544	3.4995	99.8461
SZ36	SKB banka	14 Dec 05	78	99.1727	3.85	99.258	3.45	99.21535
TZ89	SKB banka	14 Dec 05	15	99.8398	3.85	99.8565	3.45	99.84815
DZ30	NLB d.d.	14 Dec 05	106	98.9108	3.74	98.9742	3.52	98.9425
DZ31	NLB d.d.	14 Dec 05	162	98.371	3.68	98.4843	3.42	98.42765
DZ32	NLB d.d.	14 Dec 05	225	97.7696	3.65	97.9192	3.4	97.8444
DZ33	NLB d.d.	14 Dec 05	288	97.2006	3.6	97.3672	3.38	97.2839
DZ34	NLB d.d.	14 Dec 05	351	96.6545	3.55	96.8371	3.35	96.7458
EZ238	NLB d.d.	14 Dec 05	8	99.9134	3.9	99.9196	3.62	99.9165
RS51	NLB d.d.	14 Dec 05	72	100.7	3.9921	100.87	3.1579	100.785
RS52	NLB d.d.	14 Dec 05	846	106	3.4934	106.8	3.1462	106.4
RS54	NLB d.d.	14 Dec 05	2862	113	3.7985	114.2	3.633	113.6
RS55	NLB d.d.	14 Dec 05	424	101.55	3.6029	101.95	3.2526	101.75
RS56	NLB d.d.	14 Dec 05	1155	104	3.5123	104.49	3.351	104.245
RS57	NLB d.d.	14 Dec 05	3227	108.41	3.7381	109.48	3.6017	108.945
RS58	NLB d.d.	14 Dec 05	855	99.35	3.5314	99.78	3.3371	99.565
RS59	NLB d.d.	14 Dec 05	3717	101.55	3.8119	102.9	3.6523	102.225
RS60	NLB d.d.	14 Dec 05	1568	99.95	3.5095	100.65	3.3319	100.3
SZ35	NLB d.d.	14 Dec 05	15	99.8407	3.83	99.8502	3.6	99.84545
SZ36	NLB d.d.	14 Dec 05	78	99.1877	3.78	99.2367	3.55	99.2122
SZ37	NLB d.d.	14 Dec 05	135	98.6315	3.7	98.7155	3.47	98.6735
DZ31	Abanka Vipa	14 Dec 05	162	98.3318	3.77	98.4712	3.45	98.4015
DZ32	Abanka Vipa	14 Dec 05	225	97.7278	3.72	97.9492	3.35	97.8385
DZ33	Abanka Vipa	14 Dec 05	288	97.1251	3.7	97.3899	3.35	97.2575
DZ34	Abanka Vipa	14 Dec 05	351	96.5181	3.7	96.8371	3.35	96.6776
EZ238	Abanka Vipa	14 Dec 05	8	99.9154	3.81	99.9205	3.58	99.91795
RS52	Abanka Vipa	14 Dec 05	846	106.17	3.4193	106.82	3.1376	106.495
RS56	Abanka Vipa	14 Dec 05	1155	104.1	3.4793	104.7	3.2821	104.4
RS57	Abanka Vipa	14 Dec 05	3227	108.3	3.7523	109.55	3.5928	108.925
RS58	Abanka Vipa	14 Dec 05	855	99.4	3.5088	99.75	3.3506	99.575
RS59	Abanka Vipa	14 Dec 05	3717	101.7	3.7941	102.35	3.717	102.025
RS60	Abanka Vipa	14 Dec 05	1568	99.95	3.5095	100.52	3.3648	100.235
SZ35	Abanka Vipa	14 Dec 05	15	99.8415	3.81	99.8506	3.59	99.84605
SZ36	Abanka Vipa	14 Dec 05	78	99.1855	3.79	99.2388	3.54	99.21215
TZ89	Abanka Vipa	14 Dec 05	15	99.8419	3.8	99.8506	3.59	99.84625
TZ91	Abanka Vipa	14 Dec 05	78	99.1855	3.79	99.2388	3.54	99.21215

DZ33	Perspektiva	14 Dec 05	288	97.19	3.6141	97.37	3.3763	97.28
DZ34	Perspektiva	14 Dec 05	351	96.64	3.566	96.84	3.3468	96.74
EZ239	Perspektiva	14 Dec 05	15	99.83	4.0869	99.86	3.3647	99.845
RS52	Perspektiva	14 Dec 05	846	106.1	3.4498	107.2	2.974	106.65
RS55	Perspektiva	14 Dec 05	424	101.4	3.7349	102.7	2.6025	102.05
RS57	Perspektiva	14 Dec 05	3227	108.4	3.7394	109.8	3.5612	109.1
RS58	Perspektiva	14 Dec 05	855	99.39	3.5133	99.95	3.2607	99.67
RS59	Perspektiva	14 Dec 05	3717	101	3.8777	102.9	3.6523	101.95
RS60	Perspektiva	14 Dec 05	1568	100	3.4968	100.54	3.3597	100.27
SZ36	Perspektiva	14 Dec 05	78	99.18	3.8159	99.23	3.5814	99.205
TZ89	Perspektiva	14 Dec 05	15	99.83	4.0869	99.86	3.3647	99.845
TZ91	Perspektiva	14 Dec 05	78	99.18	3.8159	99.24	3.5346	99.21

Source: TUVL market

Security designation	Market making	Trading day	Days to maturity	Ask price	Ask yield	Bid price	Bid yield	Medium price
DZ30	BA CA d.d.	24 Jan 06	65	99.3275	3.75	99.3899	3.4	99.3587
DZ32	BA CA d.d.	24 Jan 06	184	98.208	3.57	98.3166	3.35	98.2623
DZ33	BA CA d.d.	24 Jan 06	247	97.6091	3.57	97.7532	3.35	97.68115
RS55	BA CA d.d.	24 Jan 06	383	101.5	3.515	101.66	3.3597	101.58
RS58	BA CA d.d.	24 Jan 06	814	99.45	3.5003	99.9	3.2873	99.675
RS59	BA CA d.d.	24 Jan 06	3676	101.9	3.7692	102.5	3.6975	102.2
RS60	BA CA d.d.	24 Jan 06	1527	99.9	3.5237	100.25	3.4324	100.075
SZ36	BA CA d.d.	24 Jan 06	37	99.6161	3.75	99.6416	3.5	99.62885
TZ91	BA CA d.d.	24 Jan 06	37	99.611	3.8	99.6416	3.5	99.6263
DZ30	Probanka	24 Jan 06	65	99.3328	3.72	99.3792	3.46	99.356
RS56	Probanka	24 Jan 06	1114	103.95	3.4858	104.42	3.3255	104.185
RS57	Probanka	24 Jan 06	3186	108.1	3.7659	109.27	3.6147	108.685
RS58	Probanka	24 Jan 06	814	99.47	3.4908	99.94	3.2684	99.705
RS59	Probanka	24 Jan 06	3676	101.9	3.7691	102.59	3.6868	102.245
RS60	Probanka	24 Jan 06	1527	99.65	3.5892	100.3	3.4194	99.975
RS61	Probanka	24 Jan 06	1825	98.6	3.5607	98.89	3.4959	98.745
RS62	Probanka	24 Jan 06	4076	97.71	3.7536	97.97	3.7243	97.84
SZ36	Probanka	24 Jan 06	37	99.6161	3.75	99.6416	3.5	99.62885
SZ38	Probanka	24 Jan 06	156	98.4304	3.68	98.5144	3.48	98.4724
TZ92	Probanka	24 Jan 06	65	99.3328	3.72	99.3792	3.46	99.356
DZ30	SKB banka	24 Jan 06	65	99.3328	3.72	99.3738	3.49	99.3533
DZ31	SKB banka	24 Jan 06	121	98.7786	3.679	98.8701	3.4	98.82435
DZ33	SKB banka	24 Jan 06	247	97.6105	3.568	97.786	3.3	97.69825
DZ34	SKB banka	24 Jan 06	310	96.9932	3.6	97.2043	3.34	97.09875
RS54	SKB banka	24 Jan 06	2821	113.17	3.751	114.5	3.566	113.835
RS57	SKB banka	24 Jan 06	3186	108.21	3.7516	109.25	3.6173	108.73
RS58	SKB banka	24 Jan 06	814	99.45	3.5003	99.95	3.2637	99.7
RS59	SKB banka	24 Jan 06	3676	102.06	3.75	102.65	3.6797	102.355
RS60	SKB banka	24 Jan 06	1527	99.6	3.6023	100.34	3.409	99.97
RS61	SKB banka	24 Jan 06	1825	98.6	3.5607	99	3.4714	98.8
RS62	SKB banka	24 Jan 06	4076	97.69	3.7558	98.15	3.704	97.92
SZ37	SKB banka	24 Jan 06	94	99.0431	3.7	99.0995	3.48	99.0713
SZ38	SKB banka	24 Jan 06	156	98.4346	3.67	98.514	3.481	98.4743
TZ91	SKB banka	24 Jan 06	37	99.613	3.78	99.6405	3.51	99.62675
TZ92	SKB banka	24 Jan 06	65	99.3328	3.72	99.3774	3.47	99.3551
DZ30	NLB d.d.	24 Jan 06	65	99.331	3.73	99.3756	3.48	99.3533
DZ31	NLB d.d.	24 Jan 06	121	98.7717	3.7	98.8701	3.4	98.8209
DZ32	NLB d.d.	24 Jan 06	184	98.1686	3.65	98.3166	3.35	98.2426
DZ33	NLB d.d.	24 Jan 06	247	97.5895	3.6	97.7532	3.35	97.67135
DZ34	NLB d.d.	24 Jan 06	310	97.0337	3.55	97.2369	3.3	97.1353
RS51	NLB d.d.	24 Jan 06	31	100.3	3.9986	100.4	2.8651	100.35
RS52	NLB d.d.	24 Jan 06	805	105.75	3.4815	106.45	3.1621	106.1
RS54	NLB d.d.	24 Jan 06	2821	113.15	3.7539	114.3	3.5937	113.725
RS55	NLB d.d.	24 Jan 06	383	101.45	3.5636	101.68	3.3404	101.565
RS56	NLB d.d.	24 Jan 06	1114	103.9	3.5029	104.45	3.3153	104.175
RS57	NLB d.d.	24 Jan 06	3186	108.15	3.7594	109.19	3.625	108.67
RS58	NLB d.d.	24 Jan 06	814	99.4	3.5241	99.83	3.3204	99.615
RS60	NLB d.d.	24 Jan 06	1527	99.6	3.6023	102.9	2.7543	101.25
RS61	NLB d.d.	24 Jan 06	1825	98.61	3.5585	98.92	3.4892	98.765
RS62	NLB d.d.	24 Jan 06	4076	97.7	3.7547	98.1	3.7097	97.9

SZ36	NLB d.d.	24 Jan 06	37	99.6161	3.75	99.6416	3.5	99.62885
SZ37	NLB d.d.	24 Jan 06	94	99.038	3.72	99.1021	3.47	99.07005
SZ38	NLB d.d.	24 Jan 06	156	98.4388	3.66	98.5481	3.4	98.49345
TZ91	NLB d.d.	24 Jan 06	37	99.6161	3.75	99.6416	3.5	99.62885
DZ30	Abanka Vipa	24 Jan 06	65	99.3346	3.71	99.3845	3.43	99.35955
DZ31	Abanka Vipa	24 Jan 06	121	98.7749	3.69	98.8668	3.41	98.82085
DZ32	Abanka Vipa	24 Jan 06	184	98.1588	3.67	98.3265	3.33	98.24265
DZ33	Abanka Vipa	24 Jan 06	247	97.5438	3.67	97.7663	3.33	97.65505
DZ34	Abanka Vipa	24 Jan 06	310	96.9365	3.67	97.2124	3.33	97.07445
RS52	Abanka Vipa	24 Jan 06	805	105.76	3.4769	106.72	3.0398	106.24
RS56	Abanka Vipa	24 Jan 06	1114	103.88	3.5097	104.3	3.3663	104.09
RS57	Abanka Vipa	24 Jan 06	3186	108.2	3.7529	109.2	3.6237	108.7
RS58	Abanka Vipa	24 Jan 06	814	99.48	3.4861	99.84	3.3156	99.66
RS59	Abanka Vipa	24 Jan 06	3676	101.95	3.7632	102.55	3.6916	102.25
RS60	Abanka Vipa	24 Jan 06	1527	99.93	3.5159	100.24	3.4351	100.085
SZ37	Abanka Vipa	24 Jan 06	94	99.0431	3.7	99.1149	3.42	99.079
SZ38	Abanka Vipa	24 Jan 06	156	98.4304	3.68	98.5481	3.4	98.48925
TZ92	Abanka Vipa	24 Jan 06	65	99.3346	3.71	99.3845	3.43	99.35955
DZ30	Perspektiva	24 Jan 06	65	99.328	3.747	99.39	3.3992	99.359
DZ34	Perspektiva	24 Jan 06	310	96.937	3.6694	97.237	3.2998	97.087
RS51	Perspektiva	24 Jan 06	31	100.3	3.9986	100.42	2.64	100.36
RS55	Perspektiva	24 Jan 06	383	101.4	3.6123	101.75	3.2726	101.575
RS57	Perspektiva	24 Jan 06	3186	108	3.7789	109.3	3.6108	108.65
RS58	Perspektiva	24 Jan 06	814	99.4	3.5241	99.95	3.2637	99.675
RS59	Perspektiva	24 Jan 06	3676	101.75	3.7871	102.25	3.7273	102
RS60	Perspektiva	24 Jan 06	1527	99.65	3.5892	100.4	3.3935	100.025
RS61	Perspektiva	24 Jan 06	1825	98.5	3.5831	98.9	3.4937	98.7
RS62	Perspektiva	24 Jan 06	4076	97.55	3.7716	97.98	3.7231	97.765
SZ36	Perspektiva	24 Jan 06	37	99.616	3.7506	99.642	3.4958	99.629
SZ37	Perspektiva	24 Jan 06	94	99.038	3.72	99.115	3.4196	99.0765
TZ91	Perspektiva	24 Jan 06	37	99.611	3.7996	99.642	3.4958	99.6265
TZ92	Perspektiva	24 Jan 06	65	99.333	3.719	99.385	3.4272	99.359

Source: TUVL market

Security designation	Market making	Trading day	Days to maturity	Ask price	Ask yield	Bid price	Bid yield	Single price
DZ30	BA CA d.d.	31 Jan 06	58	99.3995	3.75	99.4552	3.4	99.42735
DZ32	BA CA d.d.	31 Jan 06	177	98.2608	3.6	98.3796	3.35	98.3202
DZ33	BA CA d.d.	31 Jan 06	240	97.6563	3.6	97.8155	3.35	97.7359
DZ35	BA CA d.d.	31 Jan 06	359	96.5344	3.6	96.814	3.3	96.6742
RS55	BA CA d.d.	31 Jan 06	376	101.5	3.4898	101.65	3.3415	101.575
RS58	BA CA d.d.	31 Jan 06	807	99.45	3.5029	99.9	3.2881	99.675
RS59	BA CA d.d.	31 Jan 06	3669	101.65	3.799	102.15	3.739	101.9
RS60	BA CA d.d.	31 Jan 06	1520	99.9	3.524	100.25	3.4324	100.075
SZ36	BA CA d.d.	31 Jan 06	30	99.6885	3.75	99.7175	3.4	99.703
TZ91	BA CA d.d.	31 Jan 06	30	99.6843	3.8	99.7175	3.4	99.7009
TZ93	BA CA d.d.	31 Jan 06	87	99.1019	3.75	99.1898	3.38	99.14585
DZ30	Probanka	31 Jan 06	58	99.3995	3.75	99.4488	3.44	99.42415
DZ35	Probanka	31 Jan 06	359	96.5809	3.55	96.8047	3.31	96.6928
RS56	Probanka	31 Jan 06	1107	103.88	3.5023	104.29	3.3614	104.085
RS57	Probanka	31 Jan 06	3179	108.1	3.7638	109.18	3.6239	108.64
RS58	Probanka	31 Jan 06	807	99.49	3.4838	99.9	3.2881	99.695
RS59	Probanka	31 Jan 06	3669	101.7	3.793	102.23	3.7294	101.965
RS60	Probanka	31 Jan 06	1520	99.8	3.5503	100.3	3.4193	100.05
RS61	Probanka	31 Jan 06	1818	98.5	3.5841	98.78	3.5212	98.64
RS62	Probanka	31 Jan 06	4069	97.65	3.7606	97.93	3.729	97.79
SZ36	Probanka	31 Jan 06	30	99.6926	3.7	99.7175	3.4	99.70505
SZ37	Probanka	31 Jan 06	87	99.1256	3.65	99.1827	3.41	99.15415
SZ38	Probanka	31 Jan 06	149	98.5198	3.63	98.6002	3.43	98.56
TZ92	Probanka	31 Jan 06	58	99.3995	3.75	99.4488	3.44	99.42415
TZ93	Probanka	31 Jan 06	87	99.1256	3.65	99.1827	3.41	99.15415
DZ30	SKB banka	31 Jan 06	58	99.4061	3.708	99.4552	3.4	99.43065
DZ31	SKB banka	31 Jan 06	114	98.858	3.648	98.9348	3.4	98.8964
DZ33	SKB banka	31 Jan 06	240	97.6575	3.598	97.8474	3.3	97.75245
DZ34	SKB banka	31 Jan 06	303	97.0591	3.6	97.2649	3.341	97.162
RS54	SKB banka	31 Jan 06	2814	113.05	3.7638	114.5	3.5616	113.775

RS57	SKB banka	31 Jan 06	3179	108.15	3.7573	109.25	3.6149	108.7
RS58	SKB banka	31 Jan 06	807	99.4	3.5269	99.91	3.2833	99.655
RS59	SKB banka	31 Jan 06	3669	101.7	3.793	102.09	3.7462	101.895
RS60	SKB banka	31 Jan 06	1520	99.8	3.5503	100.33	3.4115	100.065
RS61	SKB banka	31 Jan 06	1818	98.54	3.5751	98.79	3.519	98.665
RS62	SKB banka	31 Jan 06	4069	97.65	3.7606	97.92	3.7301	97.785
SZ37	SKB banka	31 Jan 06	87	99.1261	3.648	99.185	3.4	99.15555
SZ38	SKB banka	31 Jan 06	149	98.5206	3.628	98.5962	3.44	98.5584
TZ92	SKB banka	31 Jan 06	58	99.3998	3.748	99.4504	3.43	99.4251
RS51	NLB d.d.	31 Jan 06	24	100.22	4.178	100.3	3.0056	100.26
RS52	NLB d.d.	31 Jan 06	798	105.65	3.506	106	3.3444	105.825
RS54	NLB d.d.	31 Jan 06	2814	113.1	3.7568	114.3	3.5893	113.7
RS55	NLB d.d.	31 Jan 06	376	101.3	3.6881	101.65	3.3415	101.475
RS56	NLB d.d.	31 Jan 06	1107	103.8	3.5298	104.25	3.3751	104.025
RS57	NLB d.d.	31 Jan 06	3179	108.21	3.7495	109.14	3.6291	108.675
RS58	NLB d.d.	31 Jan 06	807	99.4	3.5269	99.77	3.35	99.585
RS59	NLB d.d.	31 Jan 06	3669	101.6	3.805	102.5	3.6972	102.05
RS60	NLB d.d.	31 Jan 06	1520	99.8	3.5503	100.4	3.3932	100.1
RS61	NLB d.d.	31 Jan 06	1818	98.59	3.5639	98.79	3.519	98.69
RS62	NLB d.d.	31 Jan 06	4069	97.7	3.7549	97.92	3.7301	97.81
DZ30	Abanka Vipa	31 Jan 06	58	99.4058	3.71	99.4504	3.43	99.4281
DZ31	Abanka Vipa	31 Jan 06	114	98.845	3.69	98.9317	3.41	98.88835
DZ32	Abanka Vipa	31 Jan 06	177	98.2276	3.67	98.3891	3.33	98.30835
DZ33	Abanka Vipa	31 Jan 06	240	97.6118	3.67	97.8282	3.33	97.72
DZ34	Abanka Vipa	31 Jan 06	303	97.0036	3.67	97.2737	3.33	97.13865
RS52	Abanka Vipa	31 Jan 06	798	105.68	3.4921	106.05	3.3214	105.865
RS56	Abanka Vipa	31 Jan 06	1107	103.89	3.4988	104.27	3.3683	104.08
RS57	Abanka Vipa	31 Jan 06	3179	108.2	3.7508	109.15	3.6278	108.675
RS58	Abanka Vipa	31 Jan 06	807	99.5	3.479	99.78	3.3452	99.64
RS59	Abanka Vipa	31 Jan 06	3669	101.85	3.775	102.1	3.745	101.975
RS60	Abanka Vipa	31 Jan 06	1520	99.93	3.5162	100.2	3.4454	100.065
RS61	Abanka Vipa	31 Jan 06	1818	98.58	3.5661	98.84	3.5078	98.71
RS62	Abanka Vipa	31 Jan 06	4069	97.68	3.7572	97.95	3.7267	97.815
SZ38	Abanka Vipa	31 Jan 06	149	98.4997	3.68	98.6123	3.4	98.556
TZ92	Abanka Vipa	31 Jan 06	58	99.3995	3.75	99.4488	3.44	99.42415
TZ93	Abanka Vipa	31 Jan 06	87	99.1138	3.7	99.1779	3.43	99.14585
DZ33	Perspektiva	31 Jan 06	240	97.55	3.7673	97.9	3.2176	97.725
DZ34	Perspektiva	31 Jan 06	303	97	3.6746	97.35	3.2342	97.175
DZ35	Perspektiva	31 Jan 06	359	96.5	3.637	96.87	3.2401	96.685
RS55	Perspektiva	31 Jan 06	376	101.2	3.7876	102.7	2.3157	101.95
RS58	Perspektiva	31 Jan 06	807	99.4	3.5269	99.9	3.2881	99.65
RS59	Perspektiva	31 Jan 06	3669	101.6	3.805	102.15	3.739	101.875
RS60	Perspektiva	31 Jan 06	1520	99.87	3.5319	100.35	3.4062	100.11
RS61	Perspektiva	31 Jan 06	1818	98.55	3.5728	98.87	3.501	98.71
RS62	Perspektiva	31 Jan 06	4069	97.65	3.7606	97.97	3.7245	97.81
SZ37	Perspektiva	31 Jan 06	87	99.05	3.9687	99.25	3.1269	99.15

Source: TUVL market

Appendix 2: Comparison of estimation obtained with various models for term structure estimation prior to the introduction of TUVL bond market on the chosen day of estimation (1 Apr 2005)

Nelson-Siegel Model		Svensson Model		MLES (m = 4)		Smoothing splines on term function	
beta 0	0.0428	beta 0	0.0423	Alfa	0.0401	Lambda	1,900,000,000
beta 1	-0.0046	beta 1	-0.0042	zeta 1	-2.67	Eta	2
beta 2	-0.019	beta 2	-0.4986	zeta 2	12.65	GCV	258.2000
tau 1	1.3166	beta 3	0.4804	zeta 3	-14.25	RMSE	56.8437
RMSE	51.1989	tau 1	0.7556	zeta 4	5.27	MAE	33.4357
MAE	27.4089	tau 2	0.7376	RMSE	78.45	MPE	-0.0011
MPE	-0.0001	RMSE	50.9964	MAE	36.1232	HR	56.52%
HR	73.91%	MAE	27.191	MPE	0.0003	Knots after McCulloch	Years
		MPE	-0.0001	HR	73.91%	1	0
		HR	73.91%			2	0.07
						3	0.35
						4	1.97
						5	10.89

Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates
0.1	3.77%	0.1	3.79%	0.1	3.78%	0.1	3.78%
0.2	3.73%	0.2	3.76%	0.2	3.76%	0.2	3.77%
0.3	3.69%	0.3	3.73%	0.3	3.74%	0.3	3.76%
0.4	3.65%	0.4	3.70%	0.4	3.72%	0.4	3.75%
0.5	3.62%	0.5	3.67%	0.5	3.70%	0.5	3.74%
0.6	3.59%	0.6	3.64%	0.6	3.68%	0.6	3.73%
0.7	3.57%	0.7	3.61%	0.7	3.66%	0.7	3.73%
0.8	3.55%	0.8	3.59%	0.8	3.64%	0.8	3.72%
0.9	3.53%	0.9	3.56%	0.9	3.62%	0.9	3.71%
1	3.52%	1	3.54%	1	3.61%	1	3.71%
1.5	3.48%	1.5	3.47%	1.5	3.53%	1.5	3.71%
2	3.49%	2	3.46%	2	3.48%	2	3.72%
2.5	3.51%	2.5	3.48%	2.5	3.44%	2.5	3.74%
3	3.55%	3	3.53%	3	3.42%	3	3.77%
3.5	3.59%	3.5	3.58%	3.5	3.41%	3.5	3.81%
4	3.63%	4	3.64%	4	3.41%	4	3.85%
4.5	3.68%	4.5	3.69%	4.5	3.42%	4.5	3.90%
5	3.72%	5	3.73%	5	3.45%	5	3.95%
5.5	3.76%	5.5	3.77%	5.5	3.48%	5.5	3.99%
6	3.79%	6	3.81%	6	3.52%	6	4.04%
6.5	3.82%	6.5	3.84%	6.5	3.56%	6.5	4.08%
7	3.85%	7	3.86%	7	3.62%	7	4.11%
7.5	3.88%	7.5	3.89%	7.5	3.68%	7.5	4.14%
8	3.90%	8	3.91%	8	3.74%	8	4.15%
8.5	3.92%	8.5	3.93%	8.5	3.81%	8.5	4.16%
9	3.94%	9	3.94%	9	3.89%	9	4.15%
9.5	3.96%	9.5	3.96%	9.5	3.97%	9.5	4.12%
10	3.97%	10	3.97%	10	4.05%	10	4.08%
10.5	3.99%	10.5	3.98%	10.5	4.14%	10.5	4.02%

Source: TUVL market

Appendix 3: Comparison of estimation obtained with various models for term structure estimation prior to the introduction of the TUVL bond market on the chosen day of estimation (26 Aug 05)

Nelson-Siegel Model		Svensson Model		MLES (m = 5)		Smoothing splines on term function	
beta 0	0.0400	beta 0	0.0392	Alfa	0.0379	Lambda	2,473,200
beta 1	-0.0019	beta 1	-0.0014	zeta 1	-0.46	Eta	2
beta 2	-0.0158	beta 2	-0.4964	zeta 2	4.62	GCV	1.6199
tau 1	1.3850	beta 3	0.4836	zeta 3	-4.18	RMSE	20.1565
RMSE	14.5428	tau 1	0.6724	zeta 4	0.34	MAE	12.5311
MAE	9.7586	tau 2	0.6564	zeta 5	0.68	MPE	0.0000
MPE	0.0000	RMSE	10.475	RMSE	23.744	HR	65.22%
HR	65.22%	MAE	6.6704	MAE	14.2616	Knots after McCulloch	Years
		MPE	0.0000	MPE	-0.0006	1	0
		HR	65.22%	HR	52.17%	2	0.15
						3	0.45
						4	2.4
						5	10.48

Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates
0.1	3.76%	0.1	3.78%	0.1	3.78%	0.1	3.78%
0.2	3.72%	0.2	3.76%	0.2	3.76%	0.2	3.77%
0.3	3.68%	0.3	3.74%	0.3	3.75%	0.3	3.74%
0.4	3.64%	0.4	3.71%	0.4	3.74%	0.4	3.71%
0.5	3.61%	0.5	3.67%	0.5	3.73%	0.5	3.67%
0.6	3.59%	0.6	3.64%	0.6	3.72%	0.6	3.63%
0.7	3.56%	0.7	3.61%	0.7	3.71%	0.7	3.59%
0.8	3.54%	0.8	3.58%	0.8	3.70%	0.8	3.56%
0.9	3.52%	0.9	3.55%	0.9	3.69%	0.9	3.52%
1	3.50%	1	3.52%	1	3.68%	1	3.49%
1.5	3.45%	1.5	3.43%	1.5	3.64%	1.5	3.40%
2	3.43%	2	3.40%	2	3.60%	2	3.37%
2.5	3.44%	2.5	3.41%	2.5	3.58%	2.5	3.39%
3	3.46%	3	3.44%	3	3.56%	3	3.44%
3.5	3.48%	3.5	3.48%	3.5	3.55%	3.5	3.48%
4	3.51%	4	3.52%	4	3.54%	4	3.53%
4.5	3.54%	4.5	3.55%	4.5	3.54%	4.5	3.58%
5	3.57%	5	3.58%	5	3.54%	5	3.61%
5.5	3.59%	5.5	3.61%	5.5	3.55%	5.5	3.65%
6	3.62%	6	3.64%	6	3.57%	6	3.67%
6.5	3.64%	6.5	3.66%	6.5	3.58%	6.5	3.69%
7	3.66%	7	3.68%	7	3.60%	7	3.71%
7.5	3.68%	7.5	3.69%	7.5	3.62%	7.5	3.72%
8	3.70%	8	3.71%	8	3.65%	8	3.72%
8.5	3.72%	8.5	3.72%	8.5	3.67%	8.5	3.73%
9	3.73%	9	3.73%	9	3.70%	9	3.73%
9.5	3.74%	9.5	3.74%	9.5	3.73%	9.5	3.73%
10	3.76%	10	3.75%	10	3.77%	10	3.73%
10.5	3.77%	10.5	3.76%	10.5	3.80%	10.5	-

Source: own calculations

Appendix 4: Comparison of estimation obtained with various models for term structure estimation after the introduction of TUVL bond market on the chosen day of estimation (14 Dec 05)

Nelson-Siegel Model		Svensson Model		MLES (m = 5)		Smoothing splines on term function	
beta 0	0.0403	beta 0	0.0396	Alfa	0.0376	Lambda	1,866,500
beta 1	-0.0021	beta 1	-0.0015	zeta 1	5.00	Eta	1
beta 2	-0.0228	beta 2	-0.5028	zeta 2	-22.29	GCV	1.5700
tau 1	1.2914	beta 3	0.4819	zeta 3	44.98	RMSE	19.6109
RMSE	15.1684	tau 1	0.8097	zeta 4	-39.11	MAE	12.0598
MAE	10.331	tau 2	0.7934	zeta 5	12.42	MPE	0.0000
MPE	0.0000	RMSE	14.487	RMSE	23.0188	HR	95.24%
HR	100.00%	MAE	9.8399	MAE	13.8884	Knots after McCulloch	Years
		MPE	0.0000	MPE	-0.0007	1	0
		HR	95.24%	HR	85.71%	2	0.14
						3	0.51
						4	2.15
						5	10.18

Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates
0.1	3.74%	0.1	3.75%	0.1	3.77%	0.1	3.77%
0.2	3.68%	0.2	3.70%	0.2	3.74%	0.2	3.72%
0.3	3.62%	0.3	3.64%	0.3	3.72%	0.3	3.67%
0.4	3.56%	0.4	3.59%	0.4	3.69%	0.4	3.62%
0.5	3.51%	0.5	3.54%	0.5	3.67%	0.5	3.56%
0.6	3.47%	0.6	3.50%	0.6	3.64%	0.6	3.51%
0.7	3.43%	0.7	3.46%	0.7	3.62%	0.7	3.46%
0.8	3.40%	0.8	3.42%	0.8	3.60%	0.8	3.42%
0.9	3.37%	0.9	3.39%	0.9	3.58%	0.9	3.38%
1	3.35%	1	3.36%	1	3.56%	1	3.35%
1.5	3.27%	1.5	3.26%	1.5	3.48%	1.5	3.24%
2	3.25%	2	3.23%	2	3.42%	2	3.22%
2.5	3.26%	2.5	3.24%	2.5	3.38%	2.5	3.24%
3	3.29%	3	3.28%	3	3.36%	3	3.29%
3.5	3.32%	3.5	3.32%	3.5	3.35%	3.5	3.34%
4	3.37%	4	3.37%	4	3.36%	4	3.39%
4.5	3.41%	4.5	3.42%	4.5	3.37%	4.5	3.44%
5	3.45%	5	3.46%	5	3.39%	5	3.48%
5.5	3.49%	5.5	3.50%	5.5	3.42%	5.5	3.51%
6	3.52%	6	3.54%	6	3.45%	6	3.55%
6.5	3.55%	6.5	3.57%	6.5	3.48%	6.5	3.57%
7	3.58%	7	3.59%	7	3.52%	7	3.59%
7.5	3.61%	7.5	3.62%	7.5	3.55%	7.5	3.61%
8	3.63%	8	3.64%	8	3.59%	8	3.63%
8.5	3.66%	8.5	3.66%	8.5	3.63%	8.5	3.65%
9	3.67%	9	3.67%	9	3.67%	9	3.66%
9.5	3.69%	9.5	3.69%	9.5	3.70%	9.5	3.68%
10	3.71%	10	3.70%	10	3.74%	10	3.70%
10.5	3.72%	10.5	3.72%	10.5	3.77%	10.5	3.72%
11	3.74%	11	3.73%	11	3.80%	11	3.73%

Source: own calculations

Appendix 5: Comparison of estimation obtained with various methods for term structure estimation after the introduction of the TUVL bond market on the chosen day of estimation (24 Jan 06)

Nelson-Siegel Model		Svensson Model		MLES (m = 7)		Smoothing splines on term function	
beta 0	0.0394	beta 0	0.039	Alfa	0.0373	Lambda	215,260
beta 1	-0.0014	beta 1	-0.0019	zeta 1	117.62	Eta	1.00
beta 2	-0.0204	beta 2	-0.5008	zeta 2	-875.39	GCV	2.7208
tau 1	1.2147	beta 3	0.4833	zeta 3	2733.52	RMSE	5.5313
RMSE	6.6891	tau 1	0.7942	zeta 4	-4544.6	MAE	3.7305
MAE	4.7685	tau 2	0.7783	zeta 5	4241.85	MPE	0.0000
MPE	0.0000	RMSE	6.2388	zeta 6	-2106.72	HR	100.00%
HR	100.00%	MAE	4.2891	zeta 7	434.73		
		MPE	0.0000	RMSE	5.5597	Knots after McCulloch	Years
		HR	100.00%	MAE	3.6878	1	0
				MPE	0.0000	2	0.38
				HR	100.00%	3	2.28
						4	11.17

Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates
0.1	3.73%	0.1	3.67%	0.1	3.70%	0.1	3.67%
0.2	3.66%	0.2	3.64%	0.2	3.64%	0.2	3.63%
0.3	3.60%	0.3	3.60%	0.3	3.59%	0.3	3.59%
0.4	3.55%	0.4	3.56%	0.4	3.55%	0.4	3.55%
0.5	3.50%	0.5	3.52%	0.5	3.51%	0.5	3.51%
0.6	3.46%	0.6	3.48%	0.6	3.47%	0.6	3.47%
0.7	3.43%	0.7	3.45%	0.7	3.44%	0.7	3.44%
0.8	3.40%	0.8	3.42%	0.8	3.41%	0.8	3.41%
0.9	3.37%	0.9	3.39%	0.9	3.38%	0.9	3.38%
1	3.35%	1	3.37%	1	3.36%	1	3.36%
1.5	3.28%	1.5	3.28%	1.5	3.29%	1.5	3.28%
2	3.26%	2	3.25%	2	3.26%	2	3.26%
2.5	3.28%	2.5	3.26%	2.5	3.27%	2.5	3.27%
3	3.30%	3	3.29%	3	3.29%	3	3.30%
3.5	3.34%	3.5	3.34%	3.5	3.33%	3.5	3.33%
4	3.38%	4	3.38%	4	3.37%	4	3.37%
4.5	3.42%	4.5	3.42%	4.5	3.41%	4.5	3.41%
5	3.45%	5	3.46%	5	3.45%	5	3.45%
5.5	3.48%	5.5	3.49%	5.5	3.49%	5.5	3.49%
6	3.52%	6	3.52%	6	3.52%	6	3.52%
6.5	3.54%	6.5	3.55%	6.5	3.55%	6.5	3.55%
7	3.57%	7	3.58%	7	3.58%	7	3.58%
7.5	3.59%	7.5	3.60%	7.5	3.60%	7.5	3.60%
8	3.61%	8	3.62%	8	3.62%	8	3.62%
8.5	3.63%	8.5	3.63%	8.5	3.64%	8.5	3.64%
9	3.65%	9	3.65%	9	3.66%	9	3.66%
9.5	3.66%	9.5	3.66%	9.5	3.67%	9.5	3.67%
10	3.67%	10	3.67%	10	3.68%	10	3.68%
10.5	3.69%	10.5	3.68%	10.5	3.68%	10.5	3.68%
11	3.70%	11	3.69%	11	3.69%	11	3.69%

Source: own calculations

Appendix 6: Comparison of estimation obtained with various methods for term structure estimation after the introduction of TUVL bond market on the chosen day of estimation (31 Jan 06)

Nelson-Siegel Model		Svensson Model		MLES (m = 6)		Smoothing splines on term function	
beta 0	0.0394	beta 0	0.0393	Alfa	0.0378	Lambda	702,540
beta 1	-0.0022	beta 1	-0.0021	zeta 1	-25.76	Eta	1
beta 2	-0.0177	beta 2	-0.5014	zeta 2	169.5	GCV	3.9782
tau 1	1.2742	beta 3	0.4836	zeta 3	-426.89	RMSE	8.144
RMSE	7.8047	tau 1	1.1709	zeta 4	534.18	MAE	4.7491
MAE	4.5820	tau 2	1.1673	zeta 5	-331.85	MPE	0.0001
MPE	0.0000	RMSE	7.8016	zeta 6	81.82	HR	100.00%
HR	100.00%	MAE	4.5829	RMSE	8.3301	Knots after McCulloch	Years
		MPE	0.0000	MAE	4.7807	1	0
		HR	100.00%	MPE	0.0000	2	0.23
				HR	100.00%	3	0.8
						4	3.19
						5	11.15
Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates	Term (years)	Interest rates
0.1	3.66%	0.1	3.66%	0.1	3.61%	0.1	3.55%
0.2	3.61%	0.2	3.61%	0.2	3.58%	0.2	3.52%
0.3	3.56%	0.3	3.56%	0.3	3.55%	0.3	3.49%
0.4	3.52%	0.4	3.52%	0.4	3.52%	0.4	3.46%
0.5	3.49%	0.5	3.49%	0.5	3.49%	0.5	3.44%
0.6	3.46%	0.6	3.46%	0.6	3.46%	0.6	3.42%
0.7	3.43%	0.7	3.43%	0.7	3.44%	0.7	3.41%
0.8	3.41%	0.8	3.41%	0.8	3.42%	0.8	3.39%
0.9	3.39%	0.9	3.39%	0.9	3.40%	0.9	3.38%
1	3.37%	1	3.37%	1	3.39%	1	3.37%
1.5	3.31%	1.5	3.31%	1.5	3.33%	1.5	3.34%
2	3.30%	2	3.30%	2	3.31%	2	3.33%
2.5	3.31%	2.5	3.31%	2.5	3.31%	2.5	3.33%
3	3.34%	3	3.34%	3	3.33%	3	3.35%
3.5	3.37%	3.5	3.37%	3.5	3.36%	3.5	3.37%
4	3.41%	4	3.41%	4	3.39%	4	3.40%
4.5	3.44%	4.5	3.44%	4.5	3.43%	4.5	3.43%
5	3.47%	5	3.47%	5	3.47%	5	3.46%
5.5	3.51%	5.5	3.51%	5.5	3.51%	5.5	3.49%
6	3.53%	6	3.53%	6	3.54%	6	3.52%
6.5	3.56%	6.5	3.56%	6.5	3.57%	6.5	3.55%
7	3.58%	7	3.58%	7	3.59%	7	3.58%
7.5	3.60%	7.5	3.60%	7.5	3.62%	7.5	3.61%
8	3.62%	8	3.62%	8	3.63%	8	3.63%
8.5	3.64%	8.5	3.64%	8.5	3.65%	8.5	3.65%
9	3.66%	9	3.66%	9	3.66%	9	3.67%
9.5	3.67%	9.5	3.67%	9.5	3.67%	9.5	3.68%
10	3.68%	10	3.68%	10	3.68%	10	3.69%
10.5	3.70%	10.5	3.69%	10.5	3.69%	10.5	3.70%
11	3.71%	11	3.71%	11	3.70%	11	3.70%

Source: own calculations