Financial intermediation in Austria and comparisons of value at risk methods with implications for regulators

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1. Introduction

Over the last decade, Austrian banks have experienced significant changes in their economic and legal environment. Increasing competitive pressure from non-bank financial intermediaries and foreign financial institutions have led to declining income from the traditional "core" business (lending and deposit taking) of Austrian banks. As a result, they are forced to substitute interest income with non-interest income to sustain certain levels of profitability. In addition, EMU will have a significant impact on the banking industry since Austrian banks will have to operate in a large and highly liquid euro financial market.

Another important issue for Austrian banks as well as for regulators is the new capital adequacy directive (CAD) which is part of the Austrian Banking Act since 1st January 1998. The intention of the CAD is to provide an international "level-playing field" for financial institutions and to ensure national and global financial stability. According to the CAD, banks have, in addition to the so-called "standard approach", the option to use Value at Risk (*VaR*) models to determine their capital requirements for market risk that arise from their trading books. These rather advanced methods already have an important impact on risk measurement, risk management and capital requirements of major Austrian banks and will be even more important in the future.

Both topics are of major importance for the Austrian banking industry and for the regulatory authorities as well. However, they cover rather different areas and are hard to present in an integrated manner. To get around these problems we have divided the paper into two parts.

Section 2 reviews the main driving forces behind the changes in Austrian banking during the last decade and their significance for bank profitability. It assesses the impact of these developments on the structure, strategy and profitability of Austrian banks and their competitiveness vis-à-vis other financial intermediaries. It further analyses how lending and deposit taking by banks have changed and will be further affected by EMU. It concludes that for the Austrian banking system, the consequences of EMU are comparable to those of the single market for the real economy.

Section 3 deals with particular issues concerning *VaR* models. We analyse variance-covariance methods and historical simulation approaches to estimate daily *VaR* numbers for one equally weighted and nineteen randomly chosen linear fx-portfolios over a period of one thousand trading days. In addition, we apply a new method based on mixtures of normal distributions that deals with fat-tailed distributions of risk factors. We ask whether *VaR* estimates generated by the different methods can easily be used for comparisons among financial institutions. Although the same parameters (confidence level, holding period) are used for all models, our results indicate that comparisons of *VaR* numbers among different financial institutions can be misleading. We also analyse how accurately the *VaR* estimates of the various models match specified confidence intervals. For our portfolios we find that the new methodology performs best.

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2. Financial intermediation in Austria

2.1 Introduction

Austria's banking and financial system experienced considerable shifts on both the supply and the demand side during the past decade. Rising volumes of assets and liabilities of households and enterprises required new forms of finance which deregulation and financial innovations made available. As demand for financial services became less "bank-specific" these new forms of finance increasingly competed with intermediation by banks and eroded the core function of banking, lending and deposit taking.[2] Thus the role of banking, which had dominated the Austrian financial system for all of Austria's post-war history, increasingly came under pressure. These developments will most likely be aggravated by monetary union which can be viewed as another major deregulation measure rendering all regulation tied to national currencies obsolete and thereby fostering disintermediation.

The aim of this part of the paper is first to analyse the significance of these changes for the core functions of the banking industry and the resulting effects on competitiveness of banking vis-à-vis other financial intermediaries.

The remainder of this part is organised as follows: Section 2.2 reviews the structure and the main driving forces for change of Austria's banking and financial system in the last decade and analyses the reasons for the shrinking market shares of banks in the financial assets and liabilities of households and enterprises. Section 2.3 discusses the strategies pursued by the banks to make up for the resulting losses of business and revenues. Section 2.4 examines the effects on banks' profitability. Section 2.5 assesses the consequences of EMU for the Austrian banking system

2.2 Financial intermediation in Austria

Disintermediation arrived later in Austria than in many other countries. Lack of private capital pervaded most of Austria's post-war history and foreign direct investments in Austrian corporations have been high for decades. For historical reasons, Austria has one of the largest shares of state ownership of all industrial countries, although the share has much diminished in recent years. Therefore, small and medium-sized (largely self-financed family-owned) enterprises[3] prevail whereas large Austrian-owned corporations are almost absent. According to a survey,[4] foreign firms owned 30.3% of the 600 largest Austrian corporations, domestic firms 33.6%, and families 22.6% in 1996.

In the past, investment and business promotion schemes (including a more favourable tax treatment of debt than equity) were strongly biased towards credit financing so that demand for direct financing was to some extent crowded out by, now declining, subsidised credit. In the last few years, however, investment rules and tax treatment have been largely remodelled to encourage capital investments.[5]

Therefore, enterprises in Austria have relied heavily on bank credit for financing. The importance of bank lending is much higher for small businesses than for medium-sized and large companies.[6] Direct finance via organised capital markets, on the other hand, has played a minor role in Austria.[7] The Austrian capital market is smaller than those of most other small European countries; bonds and shares in circulation amounted to 82.5% of GDP in 1997. Assets of financial intermediaries in 1996 equalled

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2 For a survey of issues related to the role of financial intermediation see, for example, Becsi and Wang (1997).

3 In January 1998, only 429 companies (or 0.18% of all companies in Austria) had 500 or more employees, of which 149 had 1,000 or more employees (0.06% of the total).

4 Gugler (1998).

5 See, for example, Böheim (1998).

6 Quehenberger (1997), p. 66.

7 For 28 years, between 1956 and 1984, there had been no IPO on the Vienna Stock Exchange.

276% of GDP (see Appendix Table A.1). Financial intermediation is still dominated by banks; in 1996, their share, although declining, was still the highest of all EU countries.[8]

Rising levels of corporate debt, however, increased the attractiveness of other forms of finance. Additionally, privatisations in the past decade have lowered state ownership and increased private equity at the stock exchange. The surge in outward foreign investment since the beginning of the 1990s[9] may also have altered the financial requirements of enterprises. The share of bank lending in total external financing of the private non-bank sector[10] has decreased from 71% in 1988-90 to 58.9% in 1994-96.[11]

Table 1

Outside financing by private non-banks in Austria

Percentage shares, three-year averages

	1988-90	1991-93	1994-96
Bank loans	70.6	63.5	58.9
Loans by public sector incl. ERP	6.0	9.6	10.7
Loans by insurance companies	–0.1	1.4	–0.2
Bonds	1.3	5.8	7.5
Equity and of near-equity	13.7	12.9	10.1
Foreign	8.4	6.8	13.1
Total	100.0	100.0	100.0

Sources: Staatsschuldenausschuß (1998), Bericht über die Finanzschuld des Bundes 1997, Vienna and own calculations.

As wealth increased,[12] investors had more opportunities to diversify. Bank deposits are appropriate for small amounts of savings, whereas many non-bank financial instruments require a minimum investment. The share of banks in acquisition of financial assets fell by 16 percentage points between 1991-93 and 1994-96. Savings deposits, for decades the favourite savings vehicle in Austria, lost 19.5 percentage points; net of capitalised interest they have shrunk in absolute terms since 1995. Acquisition of financial assets outside banks, on the other hand, is continuously on the rise. Investment funds registered the most vigorous growth, but insurance policies gained shares, too.

As the financial requirements of households and enterprises became less bank-specific, the competitiveness of other intermediaries rose. Financial innovations, which in due course arrived in Austria, increased the alternatives to "traditional" bank lending and deposits and reduced the reliance of investors and corporations (and the public sector) on the intermediation by banks. Thus other financial intermediaries have gained ground in recent years. Investment funds' assets rose from 1.9 to 22.5% of GDP between 1987 and 1997, while the assets of insurance companies and pension funds rose from 13.5 to 24.9% (in 1996; see Appendix, Table A.1). However, in 1995, this was still below the EU average which in turn was lower than the US average.

8 For an international comparison of assets of financial intermediaries, see CEPS (1998).

9 Between 1989 and 1996, the nominal equity of foreign direct investments by Austrian companies rose from ATS 16.8 billion to ATS 83.2 billion (OeNB, Austrian Outward and Inward Direct Investment in 1996: Stocks at Year End, Focus on Austria 3/1998).

10 Separate data for business and private households are not available.

11 Another reason was an enhanced self-financing capacity (although it is still below the EU average) of Austrian manufacturing which has increased the ratio of equity to total assets (and therefore financial independence) over the past decade (see Peneder and Pfaffermayer (1998)).

12 Between 1998 and 1996, financial assets of Austrian non-banks rose by ATS 2,015 billion.

Table 2
Acquisition of financial assets in Austria
Percentage shares, three-year averages

	1988-90	1991-93	1994-96
Cash	3.36	4.06	3.78
Schilling financial assets	48.17	56.68	49.58
Of which: savings deposits	*35.01*	*44.91*	*25.39*
Foreign currency financial assets	7.16	11.06	4.19
Other	2.76	1.50	–2.75
Acquisition of financial assets at banks	56.71	68.49	52.40
Insurance	11.13	12.32	17.80
Investment certificates	8.64	3.84	23.55
Other domestic securities	14.02	4.34	0.47
Foreign investments	6.14	6.96	2.01
Acquisition of financial assets outside banks	39.93	27.46	43.83
Total	100.00	100.00	100.00

Source: OeNB.

The balance sheets of banks already reflect this changing environment: The expansion of loans and deposits has slowed down markedly whereas the growth of holdings and own issues of securities has accelerated: Between 1993 and 1997, holdings of domestic securities grew by 40% (or more than three times as fast as in 1989-93) whereas loans grew by 20% (which was somewhat less than in the four preceding years). Growth of deposits slowed from 31% in 1989-93 to 16% in 1993-97. But despite these profound changes in the behaviour of flows, the importance of lending and deposits remained high in terms of stocks. As a ratio of total domestic assets, loans to non-banks have even risen somewhat in recent years (from 57.4% in 1993 to 58.1% in 1997) and deposits have remained stable (50.2% in both 1993 and 1997).

Due to the universal banking system in Austria, however, the channels of disintermediation are controlled to a large extent by the banks. They play a substantial role in the capital markets and at the Vienna Stock Exchange; they own most of the non-bank financial intermediaries such as investment and pension fund companies; and interconnections between banks and insurance companies are rising, too. All major banks have established "strategic partnerships" with insurance companies in recent years to arrange for mutual cross-selling agreements. Income from participations which rose by some 40% between 1994 and 1997 is therefore partially offsetting "traditional" bank income. Recently, however, the numbers of foreign investment funds as well as insurance companies active in the Austrian market has increased.[13]

Therefore, at present a sizeable fraction of funds that are shifted away from bank deposits remain under the control of the banks as long as they are channelled into investment certificates. This enables the banks to earn commissions (or dividends on their participations in investment fund companies) instead of interest. But shifting revenues from interest to non-interest income reduces net income of banks. Fees usually are lower than net interest margins since they comprise fewer productivity components, and since prime borrowers are more likely to substitute other forms of finance for bank loans, loan portfolios are set to deteriorate.[14] Moreover, fees and commissions are more volatile than interest income, especially in an environment of relationship banking.

13 The number of foreign investment funds registered in Austria rose from 572 at end-1994 to 1,197 at end-1997 (Die Presse, 3rd March 1998, p. 19).

14 This poses no problem as long as higher risks are reflected by appropriate risk premia. Interest statistics in Austria do not indicate risk premia in bank lending, but given the tight competition in Austrian banking lending rates in Austria do probably not sufficiently account for risk. Provisions have not risen in recent years, however.

2.3 The responses of the banks

The first response of the banks to shrinking revenues was to expand their customer base by targeting other bank's customers. During the past two decades, the differences between the banks as well as the banking sectors[15] have become less distinctive which has intensified competition considerably. Apart from building societies[16] and special purpose banks, banks (or the sectors, respectively) now offer a comprehensive range of financial services and, for all purposes, are predominantly universal banks. As a consequence, Austria has one of the densest networks of bank branches in Europe.[17] The growth of banking outlets has only very recently started to abate as a result of the mergers within the banking sector.

A comparison of interest rates charged by banks in Austria and Germany could serve as one (admittedly crude) measure of competitive intensity. Since money market rates and bond yields are very similar in Austria and Germany due to Austrian monetary policy, other interest rates should be more or less equal for comparable customers, too. Owing to differences in the design of the statistics, interest rates are not completely comparable. Nevertheless, they show that loan rates are lower in Austria than in Germany.[18]

Table 3
Bank lending rates in Austria and Germany
1997 averages, in percent

Germany	
Long-term fixed-interest loans to enterprises and self-employed persons	
up to DM 1 million	6.68
up to DM 10 million	6.43
Advances on current account	
up to DM 200,000	10.01
DM 200,000 to DM 1 million	9.13
DM 1 million to DM 5 million	7.74
Austria	
Commercial loans	6.65

Sources: OeNB and Deutsche Bundesbank.

15 Nearly 85% of all banks are part of one of the three so-called multi-tier banking sectors ("dezentrale Sektoren"): the savings banks sector, the rural credit cooperatives (Raiffeisenkassen), and the industrial cooperatives (Volksbanken). Member banks of multi-tier sectors do not compete with each other, but co-operate in the fields of marketing, liquidity management, data processing, training etc. and are linked by a mutual assistance obligation. Each sector has a central institution that serves as a liquidity manager and does much of the international and investment banking business for their sector affiliates. Most of the sector members are relatively small savings and cooperative banks that focus primarily on retail banking with private customers and small and medium-sized companies. Large-scale business, such as lending to larger corporations, and wholesale operations, such as foreign exchange transactions, are handled by their central institutions.

16 Building societies are owned by the banks. For example, each of the multi-tier sectors has its own building society.

17 The scope of a bank branch in Austria might, however, be somewhat broader than in countries with clear distinctions between banking and other forms of finance. Due to the large extent of bank intermediation and the fact that much of the disintermediation is handled by the banks, their branches serve as points of sale for investment funds, insurance policies and the like. Therefore, a somewhat higher banking density than other countries could be expected in Austria.

18 Other components of the banks' income are lower in Austria than in other countries, too. A study by McKinsey (1995) showed that in 1994 the ratio of cost and revenues from payment services was 62% in Austria but 95% in Germany and 103% in Italy.

At the point when all major banks were universal banks with a branch network covering all or large parts of Austria (or a central institution of a multi-tier sector whose members covered all of Austria), new areas of business could only be found abroad. After trying (unsuccessfully) the euro-markets in the 1980s and retrenching subsequently, opportunities arose in Central and Eastern Europe.[19] The share of foreign assets in the balance sheet total climbed from 19.8% at end-1991 to 24.2% at end-1997. Austria's banks have established a strong position in Central and Eastern Europe and – according to BIS data – in 1997 were number one foreign lenders in Slovenia and Slovakia and number two in the Czech Republic, Hungary and Croatia.

Table 4
Foreign and domestic assets and liabilities
Shares, in percentages

	Foreign	**Domestic**	**Total**
Cash	0.34	1.70	1.37
Interbank claims	51.92	19.59	27.40
Securities and participations	19.88	16.95	17.66
Loans to non-banks	27.13	57.90	50.46
Other	0.73	3.86	3.10
Total assets	**100.00**	**100.00**	**100.00**
Interbank liabilities	54.48	21.30	30.42
Deposits of non-banks	18.22	50.20	41.41
Own securities	26.19	16.78	19.37
Other	1.11	11.72	8.80
Total liabilities	**100.00**	**100.00**	**100.00**
Net interest income as a percentage of the balance sheet volume	*0.57*	*1.84*	*1.49*

Source: OeNB.

The contribution to revenues, however, did not match the contribution to business volumes. In 1997, net interest income in international business was only 0.57% of foreign assets, compared with 1.84% in domestic business.[20] The main reason is that, internationally, interbank business (and to a much lesser extent securitised assets and liabilities), where interest margins are much slimmer, has a considerably higher share in assets and liabilities. Conversely, the shares of loans to and deposits from non-banks are much smaller than in the respective domestic balance sheet volumes.

Another option for at least the largest banks was to "play the markets", such as foreign exchange trading or derivatives, both proprietary and as intermediaries for corporate customers. Off-balance sheet items rose by more than 600% between 1987 and 1997 and thus much faster than the balance sheet; in terms of total assets they rose from one quarter in 1987 to more than 100% in 1997. By international standards, the volumes traded by Austrian banks are rather small, however. The share of net income from financial transactions in gross income has risen by approximately 1 percentage point to roughly 5½% between 1994 and 1997, its contribution to net income rose from 14 to 17½%. Although earnings from financial transactions have grown steadily over the past few years for which data are available, they are, of course, subject to a much higher degree of volatility.

19 Another important reason for Austrian banks to step up business with Central and Eastern Europe was, of course, to follow their corporate customers. Austrian enterprises have invested heavily in the region.

20 The total contribution of international business to interest income might be underestimated by income of subsidiaries, for which data are not available.

Table 5
Special off-balance sheet items of Austrian banks

	In billions of ATS	As a % of total assets
1987	842	24.62
1988	1,182	32.67
1989	2,019	52.71
1990	2,778	68.76
1991	2,996	70.06
1992	4,043	89.04
1993	3,510	72.73
1994	3,771	74.26
1995	4,786	88.90
1996	5,341	94.52
1997	6,200	103.34

Source: OeNB.

Banks sought to reduce competition by decreasing their numbers and hence the number of competitors. Between 1987 and 1997, the number of independent banks in Austria sank by 255 or approximately 20% to 995. Although by European standards the cutbacks in Austria were relatively strong, the number of banks is still comparatively high,[21] and market concentration has remained relatively low. The market share of the five largest banks is 44% which is considerably less than in most other small European countries.[22] Most of the reductions have taken place in the multi-tier banking sectors where smaller institutions were taken over by larger members of the sectors resulting in the establishment of regional institutions. Frequently these take-overs target banks that show weak earnings or a high risk exposure and therefore do not influence the banking infrastructure as a whole. Mergers have also taken place across banking sectors, whereby the acquiring bank almost always was a multi-tier sector member.[23]

Table 6
Change in the number of independent banks in Austria, 1988 to 1997

Joint-stock banks	8
Savings banks	–56
Mortgage banks	–1
Rural cooperative banks	–189
Industrial cooperative banks	–31
Building societies	1
Special purpose banks	13
Total	**–255**

Source: OeNB.

21 In part, this is attributable to the sectoral structure of the banking system. In Switzerland, there are 892 legally independent Raiffeisenkassen, which in Swiss banking statistics are counted as one bank. (Schweizerische Nationalbank, Die Banken in der Schweiz, Zürich (1998), p. 21). If their number were added to the total of Swiss banks, it would exceed the corresponding number for Austria.

22 The international comparability of market concentration is somewhat limited, however, as, due to rising international business volumes, an increasing fraction of balance sheet volumes concerns foreign business and hence does not reflect the size of the home market.

23 The sectoral structure makes it almost impossible for outsiders to purchase (stakes in) banks within one of the sectors.

Table 7
Corporate restructurings at the ten largest banks (1988)

Creditanstalt	1996	Acquisition of majority by Bank Austria
Girozentrale	1992	Merger with Österreichisches Credit-Institut to form GiroCredit
	1992	Acquisition by Erste österreichisches Spar-Casse and merger to Erste Bank
Länderbank	1991	Merger with Zentralsparkasse to Bank Austria
Zentralsparkasse	1991	Merger with Länderbank to Bank Austria
Postsparkasse	1997	Reorganisation as joint-stock company, 49% are to be sold to strategic partner
BAWAG	1994	Acquisition of minority stake by Bayrische Landesbank
RZB	–	
Erste österreichische Spar-Casse	1992	Merger with GiroCredit to Erste Bank
ÖVAG	1996	Acquisition of minority stake by DG Bank
Oberbank	–	

In the course of these mergers, the ownership of Austrian banks has undergone considerable changes over the past decade. Beginning in 1991, most major banks have seen changes in their ownership, up to fully-fledged mergers. Of the ten largest Austrian banks in 1988, the first three have completely changed hands. State ownership in banking, which had long been an important feature of the Austrian banking system, has been reduced over the past years. From nearly a quarter in 1992, public ownership of the seven largest Austrian banks fell to 7% in 1998.

2.4 The effects of disintermediation on banks' earnings

According to OECD Bank Profitability Data, the income of banks in Austria was still below the European average in 1995 (the last year for which data are available) but its relative performance had improved since the late 1980s. In 1987,[24] net income in terms of the average balance sheet total in Austria was 47% of the average of 12 EU countries, in 1995 it was 85%. Net income improved considerably until 1993 but, since then, has fallen back to (and even below) its end-1980s levels.

In terms of the respective year-end balance-sheet items, lending and deposit-taking by non-bank customers still yield by far the highest returns: in 1997, the margin between income and expenses equalled 2.8%; on the balance sheet as a whole, the margin was 1.7%.

Table 8
Income and expenses by type of assets and liabilities[1]

	Assets		**Liabilities**		
	Income million of ATS	"Interest rate" %	Expenses million of ATS	"Interest rate" %	"Margin"[2] %
Interbank	76,368	4.5	74,204	4.1	0.4
Non-banks	184,478	6.0	80,886	3.3	2.8
Securities	41,418	6.1	57,760	5.5	0.6
Shares	5,500	4.6			
Participations	7,469	4.6			
Other	2,098	0.8	2,051	0.3	0.4
Total	317,331	5.3	214,901	3.6	1.7

[1] Net interest income and earnings from securities and participations. [2] The margin for the different types of assets and liabilities is purely hypothetical since their respective volumes differ markedly.
Source: OeNB.

[24] Comprehensive data on banks' income and profitability in Austria are available from 1987. Due to changes in the reporting requirements for banks, however, time series for many items are available only from 1994 or 1996.

The rising competitive pressures from other forms of finance and the resulting losses of market shares and/or possible price concessions to stay in business begin to show in the income statement of the banks. Substitution of (on aggregate) lesser-yielding securities for loans and deposits as well as the expansion of foreign business have exerted pressure on banks' interest earnings, too. Net interest income in terms of total assets has declined by 0.23 percentage points to 1.49% since 1993 (see the Appendix, Table A.5). The largest reduction was registered in the multi-tier sectors,[25] but joint-stock banks recorded a fall, too. Non-interest income as a percentage of total assets, however, has shown very little fluctuations over the past decade and could not compensate for falling net interest ratios. So, up to now, disintermediation has led to an increased ratio of non interest income mainly by decreasing interest revenues.

The data do not allow a breakdown of activities that do not show up in the balance sheet. So profitability of off-balance sheet activities cannot be registered directly. Apart from a few specialised investment banks and investment banking activities by the large commercial banks in Austria (which, however, do "traditional" banking business as well), it is the so-called "central institutions" of the multi-tier sectors which most of all are comparable to investment banks. Including the regional institutions of the three-tier rural cooperative sector (Raiffeisen-Landesbanken) there are ten[26] such central institutions. They differ considerably from commercial banks in aim and scope of business. In a sense, they might serve to show what the average (at least medium-sized) Austrian banks could be like in the future: less direct lending and deposit taking but more brokerage and counselling services. In order to get an idea of what this future could look like, we compared their performance in 1997 with that of other large and medium-sized banks. By the end of 1997, there were 65 banks with a balance sheet total of more than ATS 5 billion.[27] We grouped them according to size and the medium-sized banks (with a balance sheet volume of ATS 20 billion to ATS 100 billion) according to their affiliation to a multi-tier sector as data show that multi-tier sectors are consistently more profitable than joint-stock banks.

Net income of banks with a balance sheet total of between ATS 5 billion and ATS 20 billion in terms of total assets was twice as high as that of the five largest banks – irrespective of sector affiliation (see the Appendix, Table A.4). Apart from lower net interest income, the larger banks and central institutions also have significantly lower non-interest income in terms of total assets. Disregarding the item "other"[28] and net results of financial operations there is no large difference in the shares of interest and non-interest income across the respective sub-groups of the panel with the exception of the central institutions. The relation between interest and non-interest income is roughly 2:1.

The reason might be that much of the non-interest income is generated via lending or deposit taking or even tied to it (e.g. commissions for loans). Credit is still to a large extent the cornerstone of a banking relationship. This could in part explain the low levels of both interest and non-interest income at the central institutions which do much less business with domestic non-banks.[29] On the other hand, the central institution fulfil some non-interest-bearing functions for the sector affiliates. Prima facie these findings would imply that by growing, Austrian banks may not expect their share in non-interest

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25 Due to reclassifications following cross-sector mergers, data are not perfectly comparable, however. Especially noteworthy in this respect are the two major takeovers in the early 1990s of joint-stock banks by members of the savings banks sector. Moreover, since 1994 income statements of building societies have been reported separately.

26 Erste Bank, the central institution of the savings bank sector, has for the purpose of this analysis been excluded from the "central institutions", since it has an extensive branch network and is therefore not exclusively a "central institution".

27 With the exception of mortgage banks, building societies and special purpose banks.

28 These consist mainly of one-off measures and activities that are not related to the usual banking business.

29 In parts, the lower income ratios can be explained by their large share of international business which yields considerably lower margins for Austrian banks than domestic business. Within the sample, there are seven medium-sized banks with a share of foreign assets of more than 50% of the balance sheet. Both interest and non-interest income are lower than in the domestically-oriented peers. But again, the ratio between interest and non-interest income is about 2:1.

income to rise. Furthermore, substituting interest income for fees would not be so easy to achieve to the extent they are interconnected.[30]

2.5 Outlook: financial intermediation in EMU

Austrian banks are going to enter into monetary union with their core business already under considerable pressure. Monetary union is almost certain to intensify these pressures. It will mean for the banks one more major deregulation measure stepping up disintermediation. For the Austrian banking system, the effects of EMU are comparable to those of the single market for the real economy, since a host of financial regulation is tied to national currencies, such as investment regulations, restrictions of foreign currency positions or national legislation concerning securities issues. The euro will reduce the number of existing barriers to cross-border investment and eliminate some restrictions on currency exposure of various pools of capital (pension funds, insurance companies etc.). Monetary union therefore abolishes the non-tariff trade barrier "different currencies" that up to now has segregated the national financial markets.

All banks in the euro area will have access to primary funds in the same currency. At the moment, foreign banks are severely disadvantaged in extending loans to Austrian customers, as without a branch network in Austria they have only limited access to schilling primary funds and therefore have to buy schilling in the interbank market. This reduces the interest margin to such an extent that foreign banks at present play a relatively minor role in Austria – their overall share in the balance sheet total did not exceed 3% in 1995.[31] Foreign banks tend to focus on special market segments and primarily engage in the lending and deposit business on a large-scale basis.[32] In monetary union, however, all banks in all EMU countries have access to euro deposits which they can lend in the entire euro area and – at least in this respect – will be able to compete with domestic banks on a level playing field. Not all customers, of course, will be equally attractive targets. Along with possible regional peculiarities, the high costs associated with lending (e. g., acquisition, risk assessment) will be an obstacle to exhaustive market penetration by foreign competitors. They will focus instead on those market segments that can be serviced without full presence in Austria, mainly on lending to larger corporates.[33] In the light of the probable imperfect reflection of risk in interest rates in Austria it can be expected that foreign competitors will especially target enterprises with the highest standing, since the interest rates those customers are charged in any case reflect risk appropriately. Austrian banks are therefore expected to lose business volume and at the same time see their average loan portfolio deteriorate. Pressure on interest income of Austrian banks is therefore expected to keep on.

In addition to enhanced competition from foreign banks, monetary union will further erode the core function of banks (lending and deposit taking) that in recent years already has waned. Austrian banks will no longer operate within the small and often rather illiquid Austrian financial market, but in the large and highly liquid euro financial market. With the much higher number of market participants, the role and importance of fungibility of financial assets will increase. This will reduce the cost of financing via capital markets and increase the relative cost of bank loans which will lead either to increased pressure on banks' margins or to a loss of volume (or both). Additionally, non-interest

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30 However, the falling share of gross that is spent on funding points to rising efficiency of intermediation. Between 1990 and 1997, the ratio of interest income and interest expenses fell from 80 to 71%.

31 One obstacle to foreign ownership of Austrian banks is that it is almost impossible to buy into one of the sectors. Therefore the by far largest share of foreign participation is joint-stock banks. The relatively high share in the industrial credit cooperatives sector is due to a participation in the sector's central institution. High branch density also had the effect of deterring entry by foreign banks into retail banking.

32 In recent years, however, foreign banks acquired substantial shares in major Austrian banks for the first time which means that foreign influence is spreading from the formerly rather specialised business segments (the foreign and interbank business) to the retail market (see Mooslechner (1997)).

33 Of some relevance for Austrian banks due to the high degree of foreign direct investments is that multinational companies are expected to concentrate their euro cash management at their respective headquarters. This could lead to additional losses of business for banks which now do business with Austrian subsidiaries of multinational companies.

income banks now earn due to their dominant role in the Austrian capital markets could decrease. For example, underwriting fees might diminish since monetary union will facilitate underwriting of Austrian securities by foreign investment banks.[34]

Within the banks' balance sheets, securitised assets will therefore be likely to continue to gain volume from non-securitised assets. This will reduce banks' income as margins on direct lending and deposit taking are higher than for securitised business. Moreover, given that the changes in attitudes of investors and enterprises seen over the last decade mean that bank customers are now more prepared to reap the benefits of this large euro market today than in the past, the effects for banks will be even more striking.

So, even if Austria's banks succeed in maintaining their business volumes in the face of continuing disintermediation the pressure on their margins is likely to continue. Banks are already faced with slimmer margins, higher volatility and a shift of demand towards products and services that employ fewer resources than traditional banking services. In the past few years they began – albeit slowly – to reduce their capacities, such as their number of employees (which has been falling since 1995) or their branch network (mostly redundancies as a result of mergers). Operating expenses have accordingly come down somewhat in recent years. The overall pattern of earnings and expenditures which moved very much in line over the past decade as well as the very strong correlation between earnings and expenses in the cross-sectional analysis (see the Appendix, Table A.4), however, imply the existence of at least some form of X-inefficiency in the Austrian banking sector which would give banks some leeway to improve profitability if earnings continued to deteriorate.[35]

3. Comparisons of value at risk methods with implications for regulators

3.1 Introduction

Over the last decades many financial institutions have significantly increased their trading activities in general and in derivatives markets in particular. Jorion (1997) identifies increased volatility, technological change in physical equipment, advances in finance theory and political developments (like more market-oriented policies and deregulation of financial markets) as the driving forces behind this process. In addition, many new financial products have been developed, sometimes as a response to regulation. Although these products can have certain advantages in hedging financial risks or provide speculative opportunities, they can also create large losses in certain instances. Indeed, spectacular financial disasters related to derivatives trading have been observed during the last decade. The 233-year-old British bank Barings went bankrupt on 26th February 1995 when Nick Leeson lost \$1.3 billion from derivatives positions. Another well-known case is the \$1.3 billion loss by the German firm Metallgesellschaft. Most of these (and other) financial disasters could probably have been avoided if properly functioning internal controls and adequate risk management had been in place.

With the aim of assuring financial stability the need for accurate measurement of financial risks and sound risk management has clearly been recognised by the financial industry and regulatory authorities. In particular, the concept of Value at Risk (*VaR*) has gained much attention and is now widely accepted as a useful measure of financial risk. In short, *VaR* is the expected maximum loss over a target horizon for a given confidence interval. To be more precise, let P be the price of a portfolio that contains m contracts C_j $(j = 1,...,m)$ where the changes in value of the contracts ΔC_j depend on n risk factors r_i $(i = 1,...,n)$. These risk factors are stochastic and might be specific equity

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[34] In this market segment, market penetration of foreign competitors is already rather high. For example, the share of foreign institutions at all privatisations in Austria between 1987 and 1996 was 38% (Walter Springer, Kapitalmarkt Österreich, Vienna (1998), p. 153).

[35] On the other hand, the fact that profitability of banks is to a large extent determined by expenses possibly indicates a tight price competition in the Austrian banking sector (see Mooslechner (1995), p. 107).

prices, interest rates, exchange rates, etc. The portfolio profit/loss ΔP over a given horizon is a function of the changes in the value of the contracts. Thus the change in the value of a portfolio $\Delta P(r_1,...,r_n) = \Sigma_j \Delta C_j(r_1,...,r_n)$ can be expressed as a function of the underlying risk factors.[36] Let $F(\Delta P)$ be the cumulative probability distribution of the changes in the market value of a portfolio, then *VaR* can formally be defined as:

$$(1) \qquad VaR = F^{-1}(p)$$

where p is a specified probability (for example 0.05 or 0.01) and $F^{-1}(p)$ denotes the inverse of $F(.)$. Thus losses greater than the estimated *VaR* should only occur with probability p. For example, if a *VaR* calculated at the 95% confidence level is accurate, then losses greater than the *VaR* measure (so called "tail events") should occur on average only five times in every hundred trading days.

VaR is attractive because it is easy to understand (the measure is units of money) and it provides an estimate of the amount of capital that is needed to support a certain level of risk. Another advantage of this measure is the ability to incorporate the effects of portfolio diversification. Many banks (and other financial institutions) now base their assessment of financial risk and risk management practices on *VaR* or plan to do so in the future.

According to the Basle Committee proposals, many countries' banks have an option to use *VaR* models (after approval by their regulatory authorities) to determine their capital requirements for market risk. For capital requirement purposes the model parameters are standardised and require banks to use a one-sided confidence interval of 99%, an assumed holding period of 10 days and at least one year of historical data for the market risk factors underlying their trading books. Although the model parameters are standardised, no particular approach to estimate *VaR* has to be used by all banks. Thus banks can choose their individual approach to *VaR*. This liberal view makes sense because there is no single "best" approach to *VaR*, and the ongoing research in this area is far from being completed.

While financial institutions use their *VaR* models in their daily business, reported *VaR* numbers can also provide useful information for regulators. From a regulator's point of view it would be important if reported *VaR* numbers could be utilized to compare risk-taking across different banks at a given point in time and to track market risk exposures over time. For example Hendricks and Hirtle (1997) argue that:[37]

"...the information generated by the models will allow supervisors and financial market participants to compare risk exposures over time and across institutions."

And that:[38] "...a capital charge based on internal models may provide supervisors and the financial markets with a consistent framework for making comparisons across institutions".

We think that this view is unduly optimistic since different approaches and assumptions might produce systematically different *VaR* estimates. The purpose of this section is twofold. First, we investigate whether it makes sense to compare *VaR* numbers generated by different models. We analyse variance-covariance methods and historical simulation approaches to estimate *VaR* numbers for one equally weighted and nineteen randomly chosen linear foreign exchange portfolios over a period of one thousand trading days. In addition, we apply a new method recently proposed in Hull and White (1998) that deals with fat-tailed distributions which are typical for foreign exchange returns but also for many other financial returns. The second goal is to compare the performance of the various models over the simulation period with a simple "backtesting" procedure to see how accurately the models match the specified confidence intervals.

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[36] The risk factors r_i are typically measured as logarithmic returns $r_{it} = ln(p_{it}/p_{it-1})$ or as arithmetic returns $r_{it}=(p_{it}-p_{it-1})/p_{it-1}$. Using a Taylor series expansion it can be shown that for small r_i both expressions are approximately equal. In all our calculations we use arithmetic returns.

[37] Hendricks and Hirtle (1997), p. 1.

[38] Hendricks and Hirtle (1997), p. 8.

The remainder of this part is organised as follows: in Section 3.2 we briefly describe the *VaR* approaches on which our calculations are based. Section 3.3 provides a description of our data. Section 3.4 describes the application of the various methods, Section 3.5 presents and explains the results. Finally, Section 3.6 contains some concluding remarks.

3.2 *VaR* methods

To generate our *VaR* estimates we use variants of the variance-covariance approach, historical simulations and Monte Carlo methods based on mixtures of normal distributions as proposed in Hull and White (1998).[39] The variance-covariance approach assumes that the risk factors that determine the value of the portfolio are multivariate normally distributed which implies that the changes in the value of a linear portfolio are also normally distributed. Since the normal distribution is completely described by its first two moments, the *VaR* of a portfolio is essentially a multiple of the standard deviation and is given by:

$$(2) \qquad VaR = -\alpha\sqrt{w'\Sigma w}$$

where w is a vector of absolute portfolio weights, w' its transpose, Σ a variance-covariance matrix and α a scaling factor which is 1.65 for a 95% confidence interval and 2.33 for a 99% confidence interval. Equation (2) implies that an estimate of the covariance matrix of the risk factors is needed, and it is usually estimated from daily historical time series of the returns of the relevant risk factors using equally weighted moving averages such as:

$$(3) \qquad \sigma_{ijT}^2 = \sum_{t=T-n}^{T-1} r_{it} r_{jt} / n$$

where the mean is often assumed to be zero.[40] $\sigma_{ijT}{}^2$ denotes a variance (or covariance) at time T, r_{it} and r_{jt} are returns and n is the number of observations (i.e. the window length) used to calculate the variances and covariances.

Another frequently used estimator is the exponentially weighted moving average (*EWMA*). In contrast to equally weighted moving averages, the *EWMA* weights current observations more than past observations to calculate conditional variances (covariances). The *EWMA* estimator in its recursive form is given by:

$$(4) \qquad \sigma_{ij/t}^2 = \lambda\sigma_{ij/t-1}^2 + (1-\lambda) r_{i/t-1} r_{jt-1}$$

where the parameter λ (sometimes called the "decay factor") determines the exponentially declining weighting scheme of the observations.[41] One difference between the two estimators is that the equally weighted moving average does not account for time dependent variances whereas the exponentially weighted moving average does.[42] From equation (4) it can be seen that an *EWMA* model is equivalent to an *IGARCH* (1,1) model without intercept.[43]

The second approach that we use is historical simulation. In contrast to variance-covariance methods, no specific distributional assumptions about the individual market risk factors (i.e. returns) are made,

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[39] For a comprehensive discussion of variance-covariance-approaches and historical simulation methods, see, for example, Dowd (1998) or Jorion (1997).

[40] The assumption of zero means is quite common since the means of most daily financial return series are very close to zero and are hard to estimate precisely. For more details and a comprehensive study of this issue, see Figlewski (1994).

[41] The allowed range of λ is between zero and one.

[42] A variance-covariance approach in conjunction with variances (covariances) based on exponentially weighted moving averages assumes conditional normality.

[43] For this and other issues concerning the estimation of variance-covariance matrices, see Alexander (1996) or Kroner (1996).

and no variances or covariances have to be estimated. Instead it is only assumed that the distribution of the relevant market returns is constant over the sample period. To calculate *VaR* numbers, the returns of the risk factors for each day within the historical sample period are viewed as a possible scenario for future returns. The portfolio is evaluated under each of the scenarios and the resulting profits/losses are ordered in ascending order with respect to their size. The resulting empirical distribution is then viewed as the probability distribution of future profits and losses. The *VaR* is then determined as the quantile of the empirical profit/loss distribution that is implied by the chosen confidence level.

The approaches described above have their particular advantages and disadvantages. For example, the variance-covariance approach is relatively easy to implement and *VaR* numbers can be calculated quickly. On the other hand, the method is problematic if the portfolio contains a significant amount of nonlinear financial instruments (such as options) because then the resulting profit/loss distribution is typically not normally distributed. Another problem arises if the distributions of the underlying risk factors are not normal. Then the joint distribution of the risk factors cannot be derived analytically in most cases. Finally the resulting *VaR* depends crucially on the method used to estimate the variance-covariance matrix. Historical simulation methods avoid many of the problems of the variance-covariance approach because the underlying risk factors need not be normally distributed and the method can deal with nonlinear portfolios. In addition no variance-covariance matrices have to be estimated. On the other hand, the method is data intensive and requires more computer power. What is more, the resulting *VaR* depends heavily on the chosen window length of historical data.

The main idea of the third approach is to transform the original data in such a way that the transformed data are normally distributed. Then the convenient properties of the normal distribution can be exploited. Let e_{it} be the return of risk factor i on day t and let G_{it} be the assumed probability distribution for e_{it}. The goal is to transform e_{it} into a new variable f_{it} that is normally distributed using the transformation:

(5) $$f_{it} = N^{-1}[G_{it}(e_{it})]$$

where N is the cumulative probability function of a standard normal distribution and N^{-1} is its inverse. Thus the original variables e_{it} are mapped into variables f_{it} that are standard normally distributed on a "fractile to fractile" basis. To make this method operational the functional form of the G-distributions of the risk factors must be chosen and the parameters of these distributions have to be estimated using historical data. The choice of the G-functions obviously depends on the characteristics of the distributions of the risk factors that drive the value of the portfolio (our specific choice will be presented in a later section). Given the parameters of the G-functions, the f_{it} variables can be mapped back into actual outcomes using the relationship:

(6) $$e_{it} = G_{it}^{-1}[N(f_{it})]$$

This methodology has the advantage that it can deal with risk factors that are not normally distributed which is important when we want to calculate *VaR* numbers using financial returns which are typically fat tailed. Fat tailed distributions imply that extreme observations are more likely to occur than in a normal distribution. In addition, the method can easily deal with nonlinear portfolios.

We exploit the methodology by running Monte Carlo simulations to generate a large number of f_{it} variables from standard normal distributions. To simulate the joint distribution of market risk factors, we incorporate the correlation between the risk factors via Cholesky factorisation. The generated f_{it} variables are mapped into actual outcomes using relationship (6). Individual portfolios can then be evaluated under each simulation trial. From the resulting profit/loss distribution (under the mapped outcomes e_{it}) *VaR* numbers can be calculated using the appropriate quantile of this distribution.[44]

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[44] For other possible ways of implementing this methodology, see Hull and White (1998).

3.3 Data

We apply the methods described above to one equally weighted portfolio and nineteen randomly chosen foreign exchange portfolios. We assume that an investor holds a certain amount of dollars in foreign currencies. Thus changes in the value of these portfolios depend solely on changes in exchange rates. In our calculations we assume that the amount invested in each portfolio is US$ 100 million. The reason for the choice of simple linear portfolio structures is that we do not want to complicate matters by issues concerning the valuation and mapping of complicated financial instruments. These complications would only add additional noise to our comparisons.

All of our portfolios contain the Australian dollar (AUD), Belgian franc (BEF), Swiss franc (CHF), Deutsche mark (DEM), Danish krone (DKK), Spanish peseta (ESP), French franc (FRF), British pound (GBP), Italian lira (ITL), Japanese yen (JPY), Dutch guilder (NGL), Swedish krone (SEK) and Austrian schilling (ATS). We use daily exchange rates over the period from 16th June 1986 to 15th June 1998 which gives a total of 3,131 observations for each individual time series.[45] All distributions of the returns of the individual currencies display excess kurtosis (see Table 9).[46]

Table 9
Excess kurtosis of exchange rate distributions

Currency	Excess kurtosis	Currency	Excess kurtosis
AUD	4.84	GBP	3.44
BEF	2.91	ITL	8.49
CHF	2.04	JPY	4.81
DEM	2.30	NLG	3.50
DKK	4.18	SEK	6.07
ESP	5.69	ATS	2.87
FRF	3.04		

As mentioned above, the fat tails of the distributions imply that extreme market shocks are more frequently observed than under normal distributions.[47] For example, if we wanted to calculate the *VaR* for a position in a single currency at the 99% level of confidence we would use 2.33 times the standard deviation if we assume a normal distribution. If the true distribution has fat tails, we would

Table 10
Multiples of standard deviations

Currency	5% quantile	1% quantile	Currency	5% quantile	1% quantile
AUD	1.49	2.46	GBP	1.60	2.60
BEF	1.64	2.61	ITL	1.57	2.54
CHF	1.66	2.80	JPY	1.64	2.80
DEM	1.68	2.66	NLG	1.62	2.64
DKK	1.63	2.56	SEK	1.53	2.53
ESP	1.56	2.49	ATS	1.66	2.60
FRF	1.62	2.75	Average	1.61	2.62

45 The data were retrieved from Datastream.

46 The return distributions (for various frequencies) of major exchange rates are studied in Müller, Dacorogna and Pictet (1996).

47 Fat-tailed distributions can, for example, arise from jump diffusion processes, stochastic volatility or Markov-switching. Further discussion can be found in Duffie and Pan (1997).

underestimate the *VaR* because of the higher probability mass of the distribution on the left tail. Table 10 demonstrates this problem for the 1% and 5% quantiles of the empirical distributions.

For each currency the 1% quantile exceeds the 2.33 multiples implied by a normal distribution. On average the 1% quantile is located 2.62 standard deviations below the mean. At the 5% quantile some multiples are above the 1.65 as implied by the normal distribution but the majority are below, indicating a tendency for slightly too conservative *VaR* estimates.

3.4 Application of the various *VaR* models

In this section we describe the specific applications and variants of the *VaR* models that we use in our comparisons. With each model we generate daily *VaR* estimates of the overnight risk (i.e. we assume a one-day holding period) for the last thousand trading days of our sample for each of the twenty portfolios at the 99% and 95% confidence intervals. In all calculations we assume that the means of the daily return series are zero.

The first model used in our calculations is the variance-covariance approach. The first variant of this model is based on daily variances and covariances estimated with equally weighted moving averages with a window length of 250 actual trading days. The equal weighting scheme implies that the *VaR*s generated by this model do not account for time dependent variances.[48] Since there is much empirical evidence that variances of financial returns are predictable, equally weighted moving averages do not seem to be very attractive estimators.[49]

The next model is the variance-covariance-approach with exponentially weighted moving averages. In contrast to the first model, the resulting *VaR* estimates incorporate effects (for example the well known volatility clustering) of time dependent variances. It follows from equation (4) that the persistence of the estimated variances (and covariances) depend on the chosen lambda. Following J.P. Morgan we set λ to 0.94 when we estimate the daily variances and covariances.[50]

The third and the fourth model are based on historical simulation with a time window of 250 and 1,250 historical scenarios, respectively. To obtain our *VaR*-numbers we interpolate linearly between the neighboring observations that are implied by the 1% and 5% quantiles of the ordered changes of portfolio values. Due to the equal weighting of each historical scenario these models do not discriminate between recent scenarios and scenarios further away in the past. All scenarios (implicitly) carry the same probability of occurrence. Let us assume that markets would not be very volatile at the moment and consider that the sample to simulate *VaR* still contains a significant fraction of scenarios from a highly volatile period. In such a case we would overestimate our *VaR* numbers. On the other hand, if we were in a highly volatile period we would underestimate the *VaR* if the scenarios are based on a low volatility period. We will return to this point later when we present the results.

To implement the Monte Carlo Methods based on Hull and White we have to assume a particular form of the distributions of the risk factors that determine the values of our portfolios. Following Hull and White (1998) we assume that the empirical distribution of an individual risk factor i at time t is generated by a mixture of two normal distributions according to:

$$(7) \qquad G_{it}(e_{it}) = p_i N\left(\frac{e_{it}}{u_i \sigma_{it}}\right) + (1 - p_i) N\left(\frac{e_{it}}{v_i \sigma_{it}}\right)$$

where $G_{it}(e_{it})$ denotes the value of the cumulative probability distribution function for observation e_{it}, p_i and $(1-p_i)$ are probabilities, N denotes the cumulative probability distribution function of a standard

[48] This is obvious because this estimator produces the same variances and covariances for every possible ordering of the observations contained in the time window.

[49] See Campbell, Lo and MacKinlay (1997), Chapter 12.

[50] This is of course not the best λ for each individual time series since the lambdas can be estimated separately for each time series. For an empirical justification of the choice of 0.94 see RiskMetricsTM Technical document (1996).

normal distribution and u_i and v_i are parameters that scale the standard deviation σ_{it}.[51] The parameters of the distribution must satisfy the restriction:

$$(8) \qquad p_i u_i^2 + (1 - p_i) v_i^2 = 1$$

since the variance of the mixed distribution must be the same as the variance of the observed empirical distribution.[52]

The p, u, v and σ parameters have to be estimated for each individual risk factor. For technical reasons we do not maximize the implied likelihood functions directly. Instead we group our data for each risk factor i into four categories: less than one standard deviation ($|e_{it}| \leq \sigma_{it}$); one to two standard deviations ($\sigma_{it} < |e_{it}| \leq 2\sigma_{it}$); two to three standard deviations ($2\sigma_{it} < |e_{it}| \leq 3\sigma_{it}$); and more than three standard deviations ($|e_{it}| > 3\sigma_{it}$). We than maximise the log-likelihood function:

$$(9) \qquad \sum_{j=1}^{4} \alpha_{ij} \log(\beta_{ij})$$

that results when we compare the predicted fraction of data β_{ij} implied for particular values of p, u and v with the proportion α_{ij} of the data actually observed in each category (i.e. we search for the values of p, u and v that provide the best fit for the empirical distributions of the individual risk factors).

We estimate two different versions of the model for each risk factor using 1,880 historical observations. In the first version we categorise our data using equally weighted moving averages according to equation (3) with a window length of 250 trading days. In the second version we estimate the standard deviations using exponentially weighted moving averages according to (4) with a weighting parameter of 0.94. The estimated parameters for both versions of the model are summarised in Table 11.

Table 11
Parameter estimates for mixture of normal distributions

Currency	**Equal weights**			***EWMA***		
	u	***p***	***v***	***u***	***p***	***v***
AUD	0.68	0.71	1.52	0.64	0.36	1.15
BEF	0.71	0.68	1.43	0.45	0.21	1.10
CHF	0.74	0.63	1.33	0.45	0.15	1.07
DEM	0.73	0.74	1.53	0.44	0.19	1.09
DKK	0.77	0.81	1.65	0.45	0.18	1.08
ESP	0.70	0.72	1.52	0.49	0.25	1.12
FRF	0.74	0.77	1.59	0.47	0.14	1.06
GBP	0.64	0.68	1.50	0.45	0.24	1.12
ITL	0.69	0.71	1.51	0.48	0.22	1.10
JPY	0.71	0.73	1.53	0.67	0.49	1.24
NLG	0.72	0.73	1.52	0.45	0.18	1.08
SEK	0.78	0.81	1.63	0.49	0.20	1.09
ATS	0.69	0.71	1.51	0.47	0.23	1.11

51 It can be shown that a mixture of normal distributions model like equation (7) produces distributions with fatter tails than a normal distribution. For a discussion, see, for example, Duffie and Pan (1997), Hull and White (1998) or Campbell, Lo and MacKinlay (1997).

52 The variance of the mixture of normals distribution is given by $pu^2\sigma^2 + (1-p)v^2\sigma^2$.

Under both sets of parameters we run 10,000 Monte Carlo trials for each of the thousand trading days to simulate the joint distributions of the market risk factors for each of our twenty portfolios. In our simulations we use the estimated correlation matrices according to equation (3) and (4) that correspond to each individual trading day. Thus for day t we simulate the joint distribution of the risk factors using the Choleski-factorisation that is implied by the estimated variances and correlations for day t for both versions of the model.

Since there is no closed form solution for the transformations of the simulated values into the "actual" outcomes implied by the mixture of normal distributions, we iterate these values using the Newton-scheme. Having obtained the transformed values for day t we evaluate the portfolios under each of the 10,000 scenario vectors for day t and calculate the *VaR* numbers as the corresponding quantiles from the resulting profit and loss distributions.

3.5 Results

In this section we report and discuss the results of the daily *VaR* estimates at the 99% and 95% confidence level. In all calculations we assume a holding period of one day. In addition, we present the results from the "backtesting" of each method. The backtesting results should provide information on how accurately the various methods perform.

We start our discussion with an inspection of the plots of *VaR* numbers generated by the different models. Graph 1 shows the daily *VaR* at the 99% confidence interval for the hypothetical portfolio with equal portfolio weights for each of the six methods.[53] The patterns are clearly quite different for the different methods, although all methods measure the *VaR* for the same portfolio. The historical simulation with 1,250 days of historical data produces the highest *VaR* on average. It is also easily seen that the plots for both historical simulation methods look rather different from the plots for all other methods. The *VaR* computed by historical simulation often does not change for rather long periods of time, but if they change, they do so in an abrupt fashion. These changes are more drastic in the case where only 250 historical observations are used. These patterns are driven by extreme events that influence the *VaR* numbers over long time periods.

The *VaR* numbers computed with variance-covariance approaches are driven by the methods for estimating the daily variance-covarianc matrices. The equally weighted moving average estimator produces a much smoother *VaR* series than the *EWMA*-estimator. The *VaR* obtained with the *EWMA* reflects to some extent the kind of "volatility clustering" that is typical for most financial return series. If we compare the *VaR* series computed with unweighted and weighted moving averages more closely, we see that the unweighted *VaR* reacts more slowly to changes in market volatility. For example, although market volatility falls sharply over the period from the 300th to the 500th day of our simulations according to the *EWMA* based *VaR* series, it stays high and approximately constant until around the 400th day and than falls only gradually for the equally weighted *VaR* series. Over this period, the *VaR* is always above the *EWMA* based *VaR*.

Next we examine the differences between the different methods with the *EWMA* based variance-covariance approach as a benchmark for the 99% confidence interval. We decided to take this approach as a benchmark because it is frequently used and the variance-covariance matrices are freely available on the Internet (provided by J.P. Morgan/Reuters). Table 12 reports the results of the comparisons. As can be seen, the differences can be extremely large, as large as 276% as observed for the historical simulation method with a window length of 250 trading days.

Consider a regulator who would compare the *VaR* numbers of two banks in that period, when bank A uses the parametric approach with *EWMA* and bank B a 250-day historical simulation. Relying solely on the reported numbers, he would conclude that bank B's trading book is nearly three times as risky as that of bank A, although both banks hold identical portfolios. It is obvious from Table 12 that similar conclusions hold for all other comparisons with the exception of the *EWMA* based mixtures of

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[53] The plots for the other portfolios are quite similar and do not change the conclusions.

normal distributions model.[54] The results in Table 12 clearly demonstrate that comparisons of risk exposures across financial institutions with *VaR* measures generated by different methods can lead to serious misinterpretations.

Table 12

Differences between *VaR* methods with 99% confidence interval in percent

Benchmark model: variance/covariance model with *EWMA*

Model	Min	Max	Mean
Vcunw	0.0	133.7	25.7
HS1250	0.0	243.1	59.1
HS250	0.0	276.5	53.0
MNunw	0.0	167.6	31.0
MNewma	0.0	11.2	4.1

Legend: Vcunw: variance-covariance approach with equally weighted moving averages.
HS250: historical simulation with 250 days of historical data.
HS1250: historical simulation with 1250 days of historical data.
Mnunw: mixtures of normal distribution approach with equally weighted moving averages.
Mnewma: mixtures of normal distribution approach with exponentially weighted moving averages.
Min (max) denotes the minimal (maximal) difference observed over all portfolios, while mean denotes the average difference over all portfolios.

Although the differences between the methods can be very large, one should not conclude that the Value at Risk concept itself is flawed. First, on average the differences range from 25 to 59%, which is not negligible but far below the observed maximum differences. Second, comparisons of risk exposures within institutions (e.g. among trading desks or different risk categories etc.) are useful if the calculations are based on the same methodology and *VaR* numbers are not only interpreted in an absolute sense but also in a relative context.

It is interesting to compare the *VaR* estimates from the mixture of normal distribution methods and the variance-covariance approaches. From Graph 2 it can be seen that at the 99% confidence interval the mixtures of normal distribution model with variances based on equally weighted estimators always produces higher *VaR* numbers than the corresponding variance-covariance approach. This result reflects the fact that the mixture of normal distributions method incorporates the excess kurtosis of the underlying market risk factors. On the other hand, the differences are small for both methods if the variances are estimated with exponentially weighted moving averages, although in this case the mixture of normal distributions *VaR*s provide a kind of upper boundary (see Graph 3). This finding indicates that the *EWMA* based variances reduce the effects of excess kurtosis of the distributions of the risk factors but do not eliminate it.

Graph 4 shows the *VaR* numbers at the 95% confidence level for the mixtures of normal distributions model and the variance-covariance approaches. In the case of equally weighted estimators the mixture of normal distributions method generates *VaR* numbers that most of the time are slightly below the numbers of the corresponding variance covariance approach. The reverse pattern occurs in the case of *EWMA*-based *VaR* calculations.

Having discussed the *VaR* patterns of the various approaches, it is interesting to compare the methods via "backtesting" to evaluate their accuracy with respect to the specified confidence interval. We test our models by comparing the estimated *VaR* of each portfolio for day *t* with the profits/losses of the portfolios realized at day *t*. We count the cases in which the realized losses exceed the estimated *VaR* for each portfolio and method. Table 13 presents the percentages of observed "outliers" or "tail

[54] The results for the 95% level are quite similar and therefore not reported.

events" for each method averaged over the twenty portfolios. We also report the minimum and maximum number of tail events in percentages. The average percentage of tail events provides information about how accurate a method matches a specified confidence interval (i.e. the implied quantile of the profit/loss distribution).

Table 13
Backtesting results

		99% confidence interval		
Method	**Min**	**Max**	**Mean**	**Std**
VCunw	1.3	2.1	1.790	0.20494
VCewma	0.9	1.6	1.305	0.17614
HS250	1.3	2.1	1.790	0.20494
HS1250	0.9	1.6	1.305	0.17614
MNunw	0.8	1.6	1.170	0.23864
MNewma	0.7	1.7	1.010	0.22455
		95% confidence interval		
Method	**Min**	**Max**	**Mean**	**Std**
VCunw	4.3	5.3	4.780	0.28023
VCewma	3.8	4.8	4.250	0.23508
HS250	4.3	5.3	4.250	0.28023
HS1250	3.8	4.8	4.250	0.23508
MNunw	4.6	5.6	5.030	0.28488
MNewma	3.7	4.6	4.160	0.25215

Legend: Vcewma: variance-covariance approach with exponentially weighted moving averages. Otherwise, see Table 12.

For example, a "perfect" model would produce 1 and 5% tail events at the 99 and 95% confidence interval, respectively. At the 99% level the variance-covariance method with equally weighted moving averages and the historical simulation with 250 historical scenarios show the weakest performance. Both methods tend to produce the greatest fraction of outliers on average. Note that even the minima are above 1% in both cases. If we interpret the average percentages of tail events as tail probabilities, we see that for both methods the probability of losses greater than the estimated *VaR* is 1.8% and not 1% as implied by a 99% confidence interval. The historical simulation with 1,250 days of data and the *EWMA* based variance-covariance approach produce somewhat better results. Not unexpectedly, the Monte Carlo methods based on a mixture of normal distributions are the most accurate ones. Both methods come very close to the specified probability of 1%. The Monte Carlo simulation with the *EWMA* updating scheme matches the 99% confidence interval almost precisely. Generally, models that do not account for fat tails tend to underestimate *VaR* numbers at the 99% confidence interval. At the 95% confidence interval five of the six methods generate somewhat too conservative *VaR* estimates. The Monte Carlo simulations based on the equal weighting scheme come closest to the 5% fraction implied by a 95% confidence interval. Note that the Monte Carlo approach based on the mixture distributions with *EWMA* produces the lowest fraction of tail events in this case.

3.6 Conclusions

In this part of the paper we have analysed six different approaches to estimate Value at Risk. Two methods were based on the variance-covariance approach with equally and exponentially weighted moving averages, and two methods on historical simulation with different period lengths. Both types of models are commonly used in financial institutions to compute Value at Risk. Since many financial return distributions display excess kurtosis, we also applied a new method based on mixture of normal distributions to incorporate fat tails in our *VaR* estimates.

A comparison of the various methods revealed that for identical portfolios differences in the resulting *VaR* numbers can be extremely large. For linear fx portfolios we found differences sometimes larger than 200% when we compared the methods with the *EWMA* based variance-covariance approach as the benchmark. Even the average differences between the methods range from 25 to 59%. Hence, it can be very misleading to compare *VaR* numbers across financial institutions if the reported numbers are based on different methods. However, it has to be pointed out that the Value at Risk concept itself is extremely useful for risk management inside financial institutions. If *VaR* calculations are based on a single methodology then comparisons across trading desks, risk categories etc. provide valuable information for risk management purposes.

We also investigated the performance of the various methods with respect to specified confidence intervals via backtesting. The results are consistent with the conjecture that methods that do not incorporate excess kurtosis tend to underestimate *VaR* at the 99% confidence interval. On the other hand, the same methods tend to overestimate *VaR* at the 95% confidence interval. For both confidence intervals one particular version of the Monte Carlo simulations based on mixtures of normal distributions incorporateing fat tails performed best.

Appendix

Table A.1
Assets of financial intermediaries and volumes on the capital market in Austria

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	In million of ATS										
Banks' assets	3,419,130	3,617,329	3,830,858	4,040,476	4,276,192	4,540,454	4,826,676	5,078,727	5,382,997	5,650,976	5,999,832
Insurance companies' assets	202,217	226,388	250,704	285,691	318,461	365,372	417,488	458,979	519,013	573,650	
Investment funds' assets under management	68,427	119,713	150,648	152,829	161,380	171,341	222,112	255,732	332,827	431,600	567,441
Pension funds' assets under management					8,985	11,025	13,821	16,313	22,670	29,832	43,655
Total	3,689,774	3,963,430	4,232,210	4,478,996	4,765,018	5,088,192	5,480,097	5,809,751	6,257,507	6,686,058	6,610,928
Shares at the Vienna Stock Exchange	83,220	110,498	263,017	281,016	259,126	230,105	330,003	321,341	314,389	357,491	451,948
Bonds outstanding	699,179	763,469	823,685	881,465	944,453	1,009,501	1,152,734	1,277,086	1,401,007	1,494,881	1,623,810
	In percent of GDP										
Banks' assets	228.8	231.0	228.5	222.8	219.8	220.7	227.1	226.8	230.6	233.4	238.4
Insurance companies' assets	13.5	14.5	15.0	15.8	16.4	17.8	19.6	20.5	22.2	23.7	
Investment funds' assets under management	4.6	7.6	9.0	8.4	8.3	8.3	10.5	11.4	14.3	17.8	22.5
Pension funds' assets under management					0.5	0.5	0.7	0.7	1.0	1.2	1.7
Total	247.0	253.1	252.4	247.0	244.9	247.3	257.8	259.4	268.1	276.1	
Shares at the Vienna Stock Exchange	2.3	2.8	6.2	6.3	5.4	4.5	6.0	5.5	5.0	5.3	6.8
Bonds outstanding	18.9	19.3	19.5	19.7	19.8	19.8	21.0	22.0	22.4	22.4	24.6
	In percent of total financial intermediation										
Banks' assets	92.7	91.3	90.5	90.2	89.7	89.2	88.1	87.4	86.0	84.5	
Insurance companies' assets	5.5	5.7	5.9	6.4	6.7	7.2	7.6	7.9	8.3	8.6	
Investment funds' assets under management	1.9	3.0	3.6	3.4	3.4	3.4	4.1	4.4	5.3	6.5	
Pension funds' assets under management					0.2	0.2	0.3	0.3	0.4	0.4	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

Table A.2
Banks and banking outlets in Austria, end-1997

	Headquarters	Branches	Banking outlets	Inhabitants per outlet
Vienna	145	600	745	2,141
Lower Austria	162	1,081	1,243	1,226
Styria	121	615	736	1,640
Upper Austria	201	805	1,006	1,372
Salzburg	87	317	404	1,261
Tyrol	122	461	583	1,132
Carinthia	72	343	415	1,356
Vorarlberg	37	219	256	1,344
Burgenland	50	232	282	976
Austria	997	4,673	5,670	1,421

Source: OeNB.

Table A.3
Foreign capital in Austrian banking (1995; in percentages)

Joint-stock banks	30.5
Savings banks	3.2
Regional mortgage banks	0.0
Rural credit cooperatives	0.1
Industrial credit cooperatives	7.1
Building societies	1.3
Special purpose banks	7.2
Total	10.6

Source: Mooslechner (1997), p. 25.

Table A.4

Profitability of banking groups

As a percentage of total assets

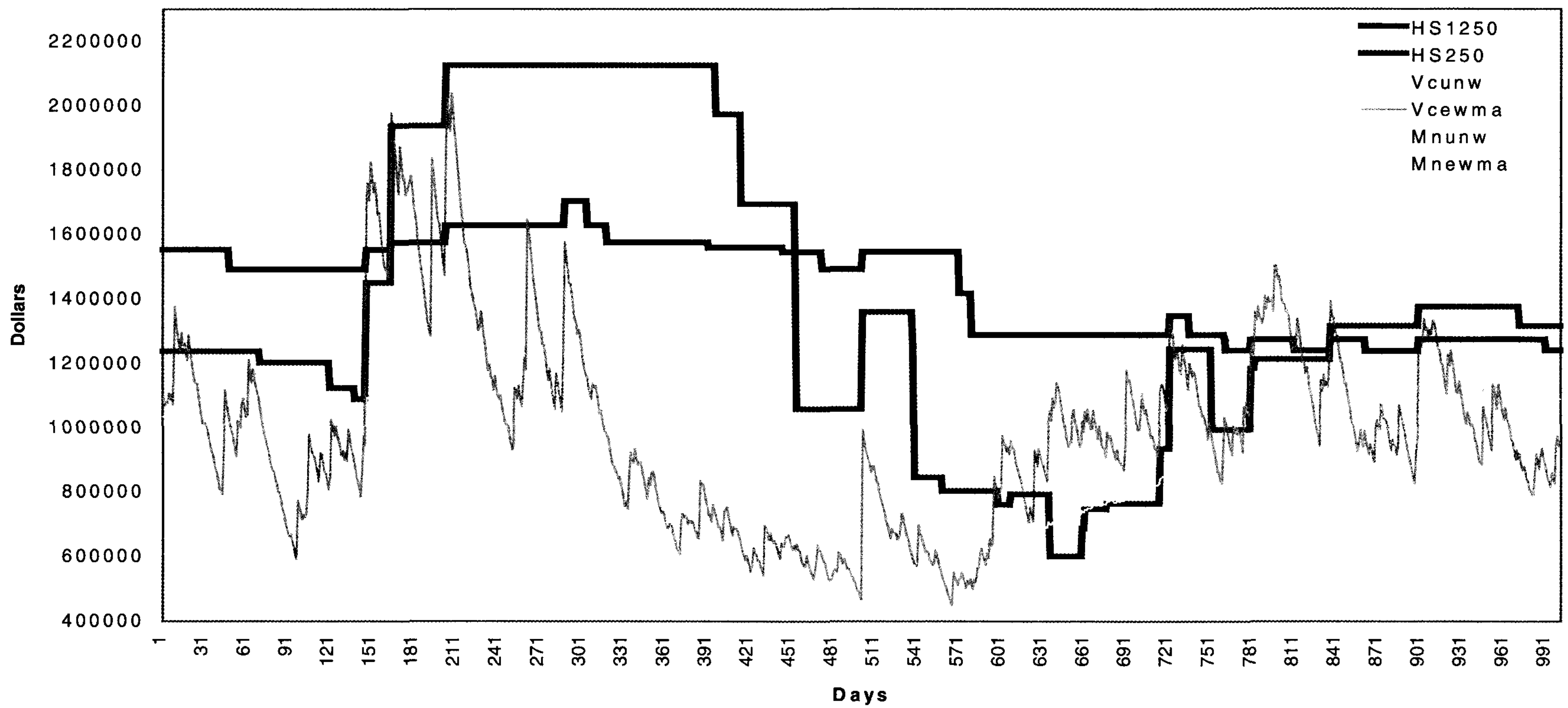
	Non-sector members			Sector members		
	Total assets above ATS 100 bn	**Total assets between ATS 20 bn and ATS 100 bn**	**Total assets between ATS 5 bn and ATS 20 bn**	**Total assets between ATS 20 bn and ATS 100 bn**	**Total assets between ATS 5 bn and ATS 20 bn**	**Central institutions**
Number of members	5	6	13	5	26	10
Average balance sheet total (ATS mn)	519,956	42,530	9,314	46,682	7,876	71,820
Interest income	5.07	4.90	5.31	5.19	5.37	4.36
Interest expenses	3.83	3.05	3.40	3.02	2.94	3.52
Net interest income	1.24	1.86	1.91	2.17	2.43	0.85
Earnings from securities and participations	0.18	0.12	0.14	0.32	0.27	0.30
Net fees and commissions	0.40	0.76	0.91	0.62	0.84	0.40
Net profits or loss on financial operations	0.18	0.11	0.19	0.19	0.11	0.15
Other	0.07	0.10	2.31	0.09	0.19	0.25
Non-interest income	0.76	1.00	1.23	1.13	1.22	0.85
Gross income	2.08	2.95	5.45	3.38	3.84	1.95
Staff expenditures	0.80	1.23	1.35	1.62	1.49	0.63
Other administrative expenditures	0.50	0.57	0.70	0.60	0.63	0.41
Provisions	0.09	0.17	0.18	0.23	0.26	0.11
Other	0.03	0.04	1.83	0.02	0.13	0.07
Operating expenses	1.42	2.00	4.06	2.48	2.51	1.21
Net income	0.65	0.95	1.39	0.90	1.33	0.73
	As a percentage of net income					
Non-interest income without items "other" and "financial operations"	35.7	35.2	39.6	31.5	32.6	49.8
Net interest income	64.3	64.8	60.4	68.5	67.4	50.2

Table A.5
Profitability of Austrian banks

	1989	1990	1991	1992	1993	1994	1995	1996	1997
	As a percentage of total assets								
Net interest income	**1.55**	**1.58**	**1.58**	**1.60**	**1.72**	**1.68**	**1.68**	**1.63**	**1.49**
Joint-stock banks	1.24	1.23	1.26	1.31	1.43	1.32	1.26	1.28	1.35
Multi-tier sectors	2.03	2.08	1.94	1.93	2.08	1.97	1.97	1.88	1.69
Other	0.90	0.96	1.00	1.02	1.05	1.34	1.42	1.38	1.05
Non interest income	**1.36**	**1.14**	**1.01**	**1.09**	**1.14**	**1.10**	**1.06**	**1.12**	**1.13**
Joint-stock banks	0.98	1.02	1.06	1.11	1.28	1.17	1.10	1.10	1.21
Multi-tier sectors	0.86	0.90	0.94	1.05	1.00	0.93	0.90	0.97	1.01
Other	3.56	2.09	1.13	1.22	1.34	1.55	1.55	1.68	1.38
Gross income	**2.91**	**2.72**	**2.58**	**2.69**	**2.86**	**2.78**	**2.74**	**2.75**	**2.62**
Joint-stock banks	2.22	2.25	2.32	2.42	2.71	2.49	2.37	2.38	2.56
Multi-tier sectors	2.89	2.97	2.88	2.98	3.09	2.90	2.87	2.85	2.70
Other	4.46	3.05	2.14	2.24	2.40	2.88	2.97	3.06	2.43
Operating expenses	**2.06**	**1.90**	**1.81**	**1.86**	**1.83**	**1.90**	**1.90**	**1.89**	**1.81**
Joint-stock banks	1.42	1.55	1.64	1.69	1.71	1.70	1.66	1.65	1.77
Multi-tier sectors	1.91	2.01	2.03	2.04	1.97	1.96	1.95	1.92	1.84
Other	3.07	1.62	0.77	0.84	0.87	1.10	1.11	1.21	0.99
Net income	**0.86**	**0.82**	**0.77**	**0.84**	**1.04**	**0.88**	**0.84**	**0.86**	**0.81**
Joint-stock banks	0.81	0.70	0.68	0.73	1.00	0.79	0.71	0.73	0.79
Multi-tier sectors	0.98	0.96	0.85	0.94	1.12	0.94	0.91	0.93	0.86
Other	0.62	0.68	0.69	0.69	0.84	0.84	0.84	0.85	0.69
Non-interest income in % of net income	**46.81**	**41.92**	**38.99**	**40.68**	**39.83**	**39.49**	**38.79**	**40.79**	**43.04**
Joint-stock banks	44.17	45.43	45.55	45.99	47.24	46.94	46.64	46.05	47.40
Multi-tier sectors	45.19	44.58	46.31	51.42	50.93	47.35	46.03	50.78	54.70
Other	92.81	88.16	78.39	78.85	86.47	75.56	72.53	75.97	79.30

Source: OeNB.

Graph 1: VaR Approaches over 1000 Trading Days (99% Confidence Interval)



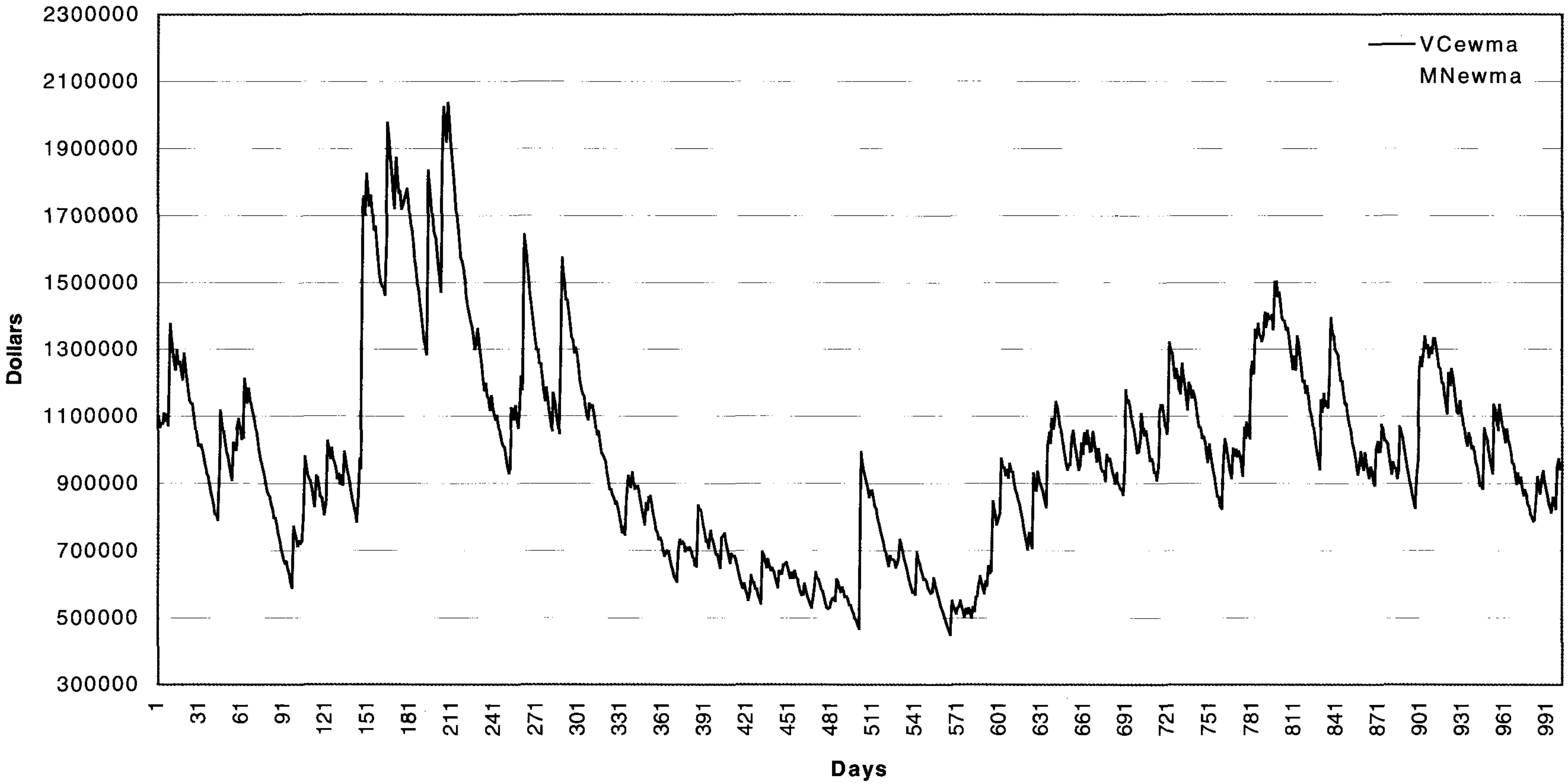
Legend: HS1250	historical simulation with 1,250 days of historical data
HS250	historical simulation with 250 days of historical data
VCunw	variance-covariance approach with equally weighted moving averages
VCewma	variance-covariance approach with exponentially weighted moving averages
MNunw	mixture of normal distribution approach with equally weighted moving averages
MNewma	mixture of normal distribution approach with exponentially weighted moving averages

Graph 2: Mixture Of Normal Distribution Approach Vs. Variance-Covariance Approach (Equally Weighted Moving Averages, 99% Confidence Interval)

Legend: VCunw variance-covariance approach with equally weighted moving averages

Mnunw mixture of normal distributions approach with equally weighted moving averages

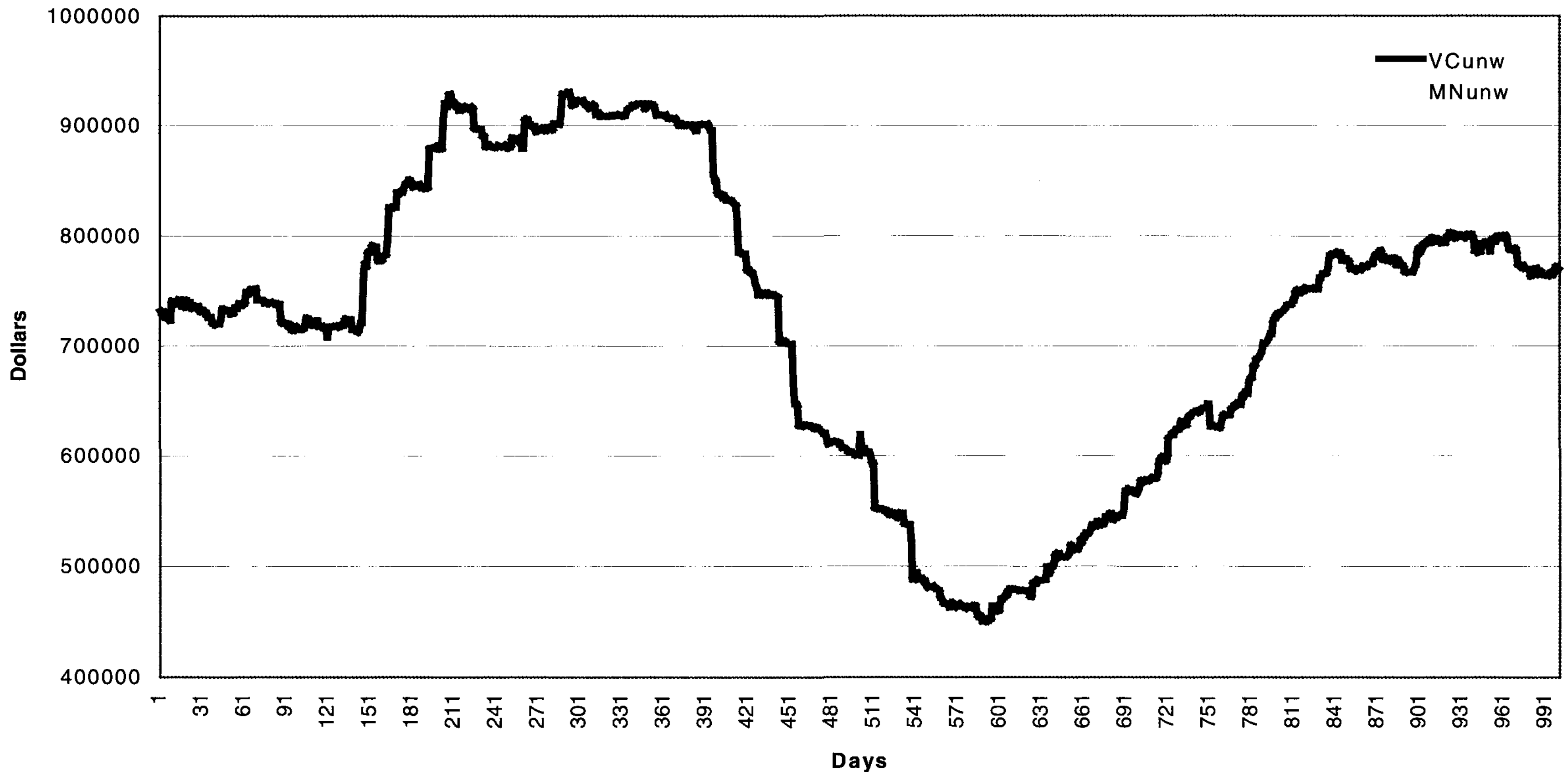
Graph 3: Mixture Of Normal Distribution Approach Vs. Variance-Covariance Approach (Exponentially Weighted Moving Averages, 99% Confidence Interval)



Legend: VCewma variance-covariance approach with exponentially weighted moving averages

MNewma mixture of normal distribution approach with exponentially weighted moving averages

Graph 4: Mixture Of Normal Distribution Approach Vs. Variance-Covariance Approach (Equally Weighted Moving Averages, 95% Confidence Interval)



Legend: VCunw variance-covariance approach with equally weighted moving averages

MNunw mixture of normal distribution approach with equally weighted moving averages

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