Measuring financial stability: applying the MfRisk model to the Netherlands
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Jan Willem van den End and Mostafa Tabbae *

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Abstract
Models which integrate various financial stability risks are still in an early stage of development. In this paper we use the Macrofinancial Risk model (MfRisk) to construct a measure for financial stability. MfRisk applies the Merton option model in a multi-sector framework. We argue that this method satisfies the macro-prudential approach. On the basis of the MfRisk model we construct a system-wide financial stability measure for the Netherlands, which builds on the put options of the banking, insurance and pension sectors. This measure approximates the probability and the potential loss of stress in the financial system. The measure is tested against various indicators of default risk, from which we conclude that it is a reliable proxy. Finally, it is shown how the measure can be used for stress testing.

Key words: financial stability, default risk, option model

JEL Codes: G12, G13, G28, G32, G33

* Jan Willem van den End (w.a.van.den.end@dnb.nl) and Mostafa Tabbae (m.tabbae@dnb.nl) are in the Financial Stability Division of De Nederlandsche Bank. The views expressed in this paper are those of the authors and do not necessarily reflect those of De Nederlandsche Bank. The authors would like to thank the participants of the DNB Research Group on Financial Stability for their valuable comments on an earlier version.
1 INTRODUCTION

Despite the increasing focus on financial stability over the past few years, there is (as yet) no standard framework for policy. This is due not least to the fact that financial stability is a multi-faceted concept, making it hard to measure (Houben et al., 2004). Financial stability relates to the functioning of financial markets, institutions and infrastructure and to the interaction between the financial sector and the real economy. As a result of its diffuse nature, financial stability cannot easily be summarised in a single measure, like the inflation index for price stability. However, a measure summarising various elements of financial stability could make an important contribution to macro-prudential policy by signalling to what extent the various risks pose systemic threats, how stable the system is and how systemic stability evolves over time. The resulting insights would help policy in terms of both timing and effectiveness.

In the literature, various methods are described for measuring financial stability. A distinction can be made between indicators at the micro and the macro level, between measures which quantify risks within a certain sector and those which do so system-wide, and between measures which are confined to the financial system and those which also allow for the interaction with the real economy. Macro-prudential analysis traditionally relies on micro indicators (for instance indicators of the solvency, liquidity or mismatch risks of individual institutions), which are aggregated and used for a judgement at the macro level. A basic set of such macro-prudential indicators is contained in the IMF’s Financial Soundness Indicators. In addition to aggregated micro data, macro-economic variables (such as interest rates, GDP growth and credit expansion) are also used as financial stability indicators. They may signal imbalances which predate shocks within the financial sector. Various studies have shown the (leading indicator) relationship between macro-economic factors and financial crises.\(^1\) In macro-economic credit risk models, macro-economic factors explain default probabilities, mostly in regard of banks’ corporate exposures. For this, single equation models are used, which are also suited for macro stress testing (see, for instance, Virolainen, 2004). Default risk can also be measured on the basis of market prices, such as equity prices in Merton models. These can be applied to both banks’ exposures (Tudela and Young, 2003) and the soundness of the banks themselves (Gropp et al., 2002). These models do not make allowance for risks of contagion within the banking sector, which are mostly modelled separately in contagion models (as in Van Lelyveld and Liedorp, 2004). Models which integrate such systemic risks into a broader financial stability framework are still in a stage of development. A case in point is the Systemic Risk Monitor project of the Austrian central bank, which models both exogenous shocks to the banks and potential domino
effects within the banking system.\textsuperscript{2} This model does not cover other financial sectors, such as the pension and insurance sectors. Macro-prudential risks within non-bank institutions are sometimes quantified by means of sector-specific \textit{stress tests} (Jones, 2004). In most cases, these separate sectoral analyses are not embedded in systemic models. \textbf{General equilibrium models} incorporate both the financial sector and the real economy. These models may be used to describe the transmission of shocks from the financial sector to the economy and vice versa. One example is the financial accelerator model of Bernanke and Gertler (1989), which shows how capital market imperfections may give rise to a credit crunch (for an overview, see Bank of England, 2004).

In this paper, we present an approach for a financial stability measure, based on the Macrofinancial Risk model (MfRisk) of Moody’s KMV (Gray \textit{et al}, 2003, and Gapen \textit{et al}, 2004). MfRisk is a multi-sector model, which integrates the default risks of various sectors into a systemic model. This comprises all the different sectoral balance sheets; financial markets and infrastructure - which cannot be depicted by balance sheets - are not modelled as independent segments. MfRisk is based on the option pricing model of Merton (1974), in which default risk is derived from equity prices and debt ratios. The combination of market prices and balance sheet data makes for an efficient measurement of default risk and contributes to the leading properties of the Merton model (Gropp \textit{et al}, 2002). Furthermore, conclusions in the literature are that the model is reliable, as it correctly reflects the risks, and that the results meet the information needs of supervisory authorities.\textsuperscript{3} MfRisk adds a systemic dimension to the Merton model, by which it fits in the macro-prudential approach (Borio, 2003) and makes it useful for measuring financial stability.

The MfRisk model is set out in section 2, with a description of the way in which it can be applied to the various sectors of the economy and the financial system. The properties which make the MfRisk model useful for measuring financial stability are stated in section 3, which also highlights the model’s weaknesses. Subsequently, section 4 presents an application to financial stability in the Netherlands, with an evaluation of the measure’s reliability and a discussion of the possibilities for stress testing. The paper concludes with some policy-relevant observations.

\textsuperscript{1} See, for instance, Dermirguc-Kunt and Detragiache (1998), Kaminsky and Reinhart (2000), and Borio and Lowe (2002).
\textsuperscript{2} See the website of the Oesterreichische Nationalbank (www.oenb.at)
\textsuperscript{3} Tudela and Young (2003), and Gropp \textit{et al} (2002).
2 MODEL

MfRisk is based on the models of Black-Scholes and Merton, which describe a corporate balance sheet in terms of the option pricing theory (Contingent Claims Analysis (CCA); see also Annex 1). In this framework, the corporation’s equity (equity market capitalisation) constitutes an implicit call option on the corporation’s assets. If the market value of assets (A) exceeds nominal debt (DB), the call option is at the money; see equation 1. A corporation defaults when the value of its equity decreases and the market value of assets falls to below the nominal debt level. The default risk is represented by the probability of the corporation exercising a put option, written by the lenders on the assets. In the event of default, the assets accrue to them, while they are faced with the unredeemed proportion of the debt. This (potential) loss is equal to the value of the put option (P) in equation 2. The market value of the debt (D in equation 3) is equal to nominal debt less the value of the put option. Using the two option equations, the balance sheet position at market value can be determined in equation 4 (for a detailed description of the call and put option formulas, see Annex 1).

\[
E = \max[A - DB, 0] \quad (1)
\]
\[
P = \max[DB - A, 0] \quad (2)
\]
\[
D = DB - \max[DB - A, 0] \quad (3)
\]
\[
A = D + E \quad (4)
\]

In the CCA, default risk is summarised in a single measure, the distance to distress:

\[
d_1 = \frac{\ln\left(\frac{A}{DB}\right) + \left(r + \frac{1}{2}\sigma_A^2\right)T}{\sigma_A\sqrt{T}} \quad (5)
\]
\[
d_2 = d_1 - \sigma_A\sqrt{T} \quad (6)
\]

where \(d\) indicates how many standard deviations the market value of assets (A) is removed from the default point (the nominal debt level, DB), with T being the risk horizon (usually set at 1 year to calculate the default risk over a 1 year’s horizon\(^4\)) and \(r\) the risk-free 12-month interest rate. The default risk increases when the corporation’s market value decreases, its leverage increases or the

\(^4\) This is in line with (point-in-time) credit risk models that are used by banks.
volatility of the market value of assets \((s_A)\) goes up. The distance to distress can subsequently be expressed as the probability of default \((PD)\):

\[
PD = N \left(-d_1\right)
\]  

(7)

for which the Merton model assumes a standard normal distribution \(N(\cdot)\). However, empirical default distributions usually have fatter tails than the standard normal. Therefore, we have based the probability measures in this paper on an empirical distribution of default risk as established by KMV (2001); see Annex 1.

The contingent claims concept was developed by KMV into the ‘expected default frequency’ (EDF) in the 1990s. Meanwhile, this measure of credit risk is commonly used, also in financial stability analyses conducted by central banks. In addition to its application to individual corporations, the EDF is also used to assess risks at the level of sectors or countries. This is how MfRisk applies the KMV concept to the balance sheets of the corporate, financial and public sectors. In this respect, it is an extension of the IMF’s Balance Sheet Approach, which analyses a country’s default risk on the basis of sectoral balance sheets (Allen et al, 2002). Sectoral analysis offers a number of advantages over the analysis of macro-economic data. First, sectoral balance sheets may reveal risks which remain hidden at the macro level. Second, imbalances may be identified which are related to maturity or currency mismatches, balance sheet structures or capital inadequacy at the sectoral level. Concentration risks may also become evident, since sectoral balance sheet analysis may reveal common exposures of different sectors. Third, sectoral balance sheets offer an insight into the potential channels of contagion among sectors. Through their balance sheet positions, sectors are interlinked, so that problems in one sector have – by definition – an impact on other sectors.

In the MfRisk model, the relations between the sectors are embodied in option contracts, by which the corporate sector has implicitly concluded a put option contract with the banks and bond holders (see Annex 2). In the event of default on bank loans, the put option is exercised and the corporate assets accrue to the banks, which have to shoulder the residual debt. The banks in turn have in effect a put option contract with the central bank or the government, since they guarantee the stability of the banking system. The risk of this guarantee (the banks’ put option) being called upon increases when the banks’ market value falls relative to their liabilities. The guarantee takes the form of a lender of last resort facility or deposit insurance. In the latter case, residual losses have to be borne by the central bank or the government as third-party guarantor of the liabilities to deposit holders. In several studies, the value of the deposit insurance has been described as a put option with the Merton model (Merton, 1977, Marcus and Shaked, 1984). Pension funds and insurance companies may also, as it were, rely on a guarantor/guarantee through a put option. Underfunding problems at pension
funds may be shifted to the household sector, or more specifically to pensioners by way of lower benefits (the so-called pension put, Siegelaer, 2003) or to future generations if the problems are not resolved in the short term. Through reinsurance, insurance companies buy, as it were, a put option from their reinsurers, which is exercised in the event of a claim. The reinsurance put lessens the probability that the primary insurers will exercise their put option in respect of policy holders. If this happens nonetheless - because the claim of the insurer is not honoured by the reinsurer - the burden has to be shouldered by the household sector, in the form of lower claim payments and/or stricter insurance conditions.

3 FINANCIAL STABILITY

3.1 Probability and loss measures

By way of the option approach, default risk can be expressed in a probability and a loss measure. The former reflects the risk of a sector calling upon its ‘guarantee’, being the probability of the put option being exercised (PD in equation 7). Considering the balance sheet linkages, the probability measure also depends on the risks in other sectors. The loss measure is equal to the value of the put option (P in equation 2), being the amount of (potential) losses. This depends on the probabilities of default (probability of financial stress), the collateral and the size of the sectoral balance sheets. The latter indicates a sector’s importance within the system and determines the loss given stress. For as long as the put option is not exercised, its value may be viewed as the shadow costs for the guarantor. These costs translate into capital held (by the banks, (re)insurers or central banks) to absorb residual losses. Using the probability and loss measures of the banking, insurance and pension sectors, the various risks within the financial system can be reduced to the same denominator and thus be assessed in relation to each other. Moreover, the loss measures of the different financial sectors (the put options) can be aggregated into a single measure for the financial system as a whole. This represents a possible approach for a financial stability measure, based on the (shadow) costs of preserving financial stability. The lower the degree of systemic stability, the higher these costs, expressed as the aggregate value of the (implicit) guarantees.

3.2 Risks

The probability and the loss measures basically reflect the default risks of the various sectors, over a 1 years’ horizon. Because the measures are determined by market prices (equity market capitalisation (E), volatility of stock prices (s_E) and interest rates), they also reflect other stability risks, apart from default risk. This is because, in principle, stock prices reflect the full range of available market
information (about credit, currency, interest rate, liquidity and operational risks, etc.). Interest rate risks, related to balance sheet maturity mismatches, are also reflected in the measures by way of the relative sensitivity of the assets and liabilities to changes in interest rates. One thing which the measures do not explicitly reflect is the relative importance of the stability of the various financial sectors, which is – by nature – greater for banks than for other financial institutions, owing to the risk of interbank contagion and the banks’ vulnerability to confidence effects. To some extent this shortcoming is offset by the fact that the maturity structure is taken into account in the level of debt (DB). The measures thus make allowance for funding risks and, hence, for the vulnerability to a confidence crisis.

Apart from the sector-specific risks, the probability and the loss measures also reflect systemic risks, since probabilities of default are driven by the economic and financial cycles (Vassalou and Xing, 2004). Upswings and downturns may be reinforced by the interaction between the real and the financial sector (Borio, 2003, and Borio and White, 2004). In the MfRisk-model, this becomes evident in pass-through effects between the sectors. For example, if the market value of the corporate sector falls due to a shock, its collateral value goes down and the expected loss on bank loans (value of the put contract with the corporate sector) increases. If the loans are written down, the banks’ equity decreases and their default risk increases. The funding position of the pension funds will also worsen, since they invest in the corporate sector. These developments the banking and pension sectors could lead to second-round effects on the economy. As a consequence of the banks’ deteriorating solvency, the supply of credit may be curtailed. Besides, if the pension funds shift their burden of adjustment by raising pension premiums, corporate profits and equity will be impaired. These pass-through effects intensify the downswing. A number of systemic aspects are not (directly or completely) taken into account in the probability and the loss measures. Risks relating to the payments and securities settlement infrastructure and the institutional side of the financial system are only coming to the fore if they are reflected in market prices or in the balance sheet positions of the institutions. Likewise, the efficiency component of financial stability, the allocation of capital and risks within the system, is not measured directly. It is, however, discernible in the underlying sectoral balance sheets, which show the cross-sector exposures and the distribution of risks among the sectors.

3.3 Market prices

The use of market prices in the probability and the loss measures contributes to the transparency of the risks measured. It is in line with the tendency towards fair value accounting. Given the dynamic nature

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5 In the MfRisk model, short-term liabilities are weighted at 100% and long-term liabilities at 50% in the calculation of DB. Because default risk also depends on the debt level, shortening the maturity structure gives...
of the measures, they also fit in with the concept of financial stability as a continuum in between stability and instability (Houben et al., 2004). Movements within this continuum are mostly non-linear, as it is within the measures, due to the fact that default risk increases more rapidly when the market value approaches the debt level. The use of market prices for measuring financial stability is open to criticism in that market prices may emit misleading signals about the underlying risks (Borio, 2003). This is related to the procyclicality described above. During the cycle, market prices give incentives which may fuel an upswing or a downturns and be conducive to imbalances. The use of a short risk horizon is allegedly another contributory factor in this regard. For a number of reasons, this criticism is less apt in the case of the probability and the loss measures:

- The measures are forward-looking. Gropp et al. (2002) demonstrate that the distance to default predicts payment problems at banks 6 to 18 months ahead. Consequently, the use of the distance to default (from which the probability and the loss measures have been derived) in rating and provisioning models lessens the procyclicality of risk assessment at banks. Research has shown that such risk models lead to an increase of capital buffers during economic booms, which is in line with the macro-prudential approach (Lowe, 2002). Boom-bust cycles are characterised by imbalanced price movements in financial markets, which usually come up in high volatility (Chart 1). Through this, the volatility variable ($s_E$) in the probability and the loss measures contributes to their forward looking nature, as they will indicate increasing financial stability risks during a stock market boom when volatility is high (as in the late 1990s).

- Sometimes, rising equity prices go in tandem with low equity volatility, as in the most recent 2004-2005q1 period. Market prices may then give potentially misleading signals about risks to financial stability, which may arise under the surface. Imbalances which may threat financial stability frequently relate to increasing leverage. Debts usually increase in periods of excessive market developments, owing to the procyclical interaction between real and financial factors. Since the probability and the loss measures include sectoral indebtedness (DB), this helps to offset potentially misleading signals emitted by market prices.
4 APPLICATION TO THE NETHERLANDS

4.1 Data

The probability and the loss measures have been applied to the Netherlands. To this end, five sectors were distinguished: banks, pension funds, insurance companies, non-financial corporations and households. The measures were calculated for each sector at the aggregated level. The market value of the unknown value of assets (A) and volatility of assets ($s_A$) of the corporate, banking and insurance sectors were calculated using equity (E) and the volatility of equity ($s_E$) by an iterative procedure (see Annex 1). For the Dutch pension and household sectors, E and $s_E$ are not available; hence, A and $s_A$ can not be calculated iteratively. Gray (2004) suggests three methods for determining the ‘best performance to cost’ market value. First, the market value can be read from the market prices of balance sheet items. Second, comparable measures can be used, such as the present value of underlying cash flows. Third, implied market values may be used, such as option prices. For the household sector, the first method was used and for the pension funds a combination of the first and the second method (see Annex 1).

The calculations are based on quarterly data of equity value (E), the stock price index (to derive $s_E$) and indebtedness (DB) at the sectoral level. In those cases where no quarterly data were available (DB of non-financial corporations), annual data were interpolated using the method of Boot-Feibes-Lisman (1967). For the financial sectors, nominal debt (DB) was based on the (assumed) term to maturity of liabilities (see Annex 3 for a more detailed description of data, assumptions and sources).
$s_E$ was determined as the standard deviation of the log equity returns of the sectors on a daily basis, calculated in one-year moving periods. This is the historical volatility, as in Hull (2000). Alternatively, the implied volatility extracted from option prices could be used. That would however, not fit in the risk-neutral nature of the Merton model. Moreover, implied volatilities are not available at the sectoral level. The quarterly data for $s_A$ have also been smoothed by using one-year moving periods in order to reduce noise in the volatility, assuming that investors are not guided by short-run fluctuations in volatility but by averages (Gropp et al., 2002). The measures’ sensitivity to changes in volatility is a disadvantage. This is remedied by smoothing, but this involves a trade-off with the measures’ timeliness.

4.2 Results

Chart 2 shows the probability measures for the Dutch banking, pension and insurance sectors. It appears from the Chart that since 2003 the stability risks have decreased in all three financial sectors, after having increased during the 2002-2003 downturn, with a notable peak for the pension sector. The stock market crisis of that time caused a major contraction of the Dutch pension funds’ solvency margin, to approximately nil in the first quarter of 2003. As a result, the probability measure in the pension sector was temporarily at a much higher level than in the banking sector. This is striking, since default risk is typically higher for banks than for institutional investors, given the higher leverage in the banks’ balance sheets$^7$ (owing to their funding with borrowed funds, such as deposits and interbank loans, which have relatively short maturities). The movements in the probability measure indicate that the relative risk profiles among the sectors have changed in recent years, underlining the increasing focus on the pension and insurance sectors in DNB’s financial stability policies. The relatively high probability measure for the banking sector in 1998-1999 was related to the tensions in the global financial system (LTCM, emerging market crisis) and their impact on the banks (in late 1998, ABN-AMRO’s rating, for instance, was downgraded). During the recession of the early 1990s, the probability measure for the banks was substantially lower than in the late 1990s and in 2002-2003. One reason was that the recession at the time had just limited effects on the banks, as measured by their market prices.

$^7$ The average probability measure in the 1990-2004 period was 0.54 for the banks and 0.18, resp. 0.37 for the insurance and pension sectors.
Chart 3 indicates that the aggregated financial stability risk, as reflected in the loss measure, increased considerably between 2001 and 2003. This was only to a limited extent due to the pension sector, despite the peak in its probability measure. Although the probability of exercising the put option was very high in 2003 (it was in effect partially exercised since many pension funds, in order to restore their stability, had to call upon their guarantee by limiting indexation and cutting back on pension rights), the systemic costs involved remained relatively limited, as is indicated by the loss measure. Compared to that, the shadow costs of financial stability in the banking sector had risen considerably more until 2003. This was due not so much to an increased risk profile of the banks (in 2003 their probability measure was not much higher than in 1998, see Chart 2), as to the expansion of the banks’ balance sheets.8 As a consequence, the underlying value of the put option has gone up and so have the shadow costs for safeguarding stability. It appears that the loss measure is structurally higher for the banking sector than for the insurance and pension sectors, as the balance sheet total of the Dutch banks is almost double that of the two other sectors combined.

Owing to sectoral balance sheet linkages, the probability and the loss measures of financial stability also depend on the non-financial companies and households, since their financial conditions affect the credit quality of the financial sector exposures. The default risks of the corporate and household sectors can also be quantified by means of the probability measure (Chart 4). This shows that default risk of Dutch companies is much higher than that of households (as is reflected in a higher capital requirement for banks’ corporate lending). According to the probability measure, the default risk of households is on average less than 1 basis point, owing to their very healthy net asset position. Between 1998 and 2001, driven by the sharp increase in the value of houses, the default risk
decreased, but it has risen again over the last years. The default risk in the corporate sector jumped from the late 1990s onwards, owing to the lower equity value (due to the decline of equity prices) and higher leverage. It peaked in 2003 at a considerably higher level than during the recession of the early 1990s. Since 2003, the probability measure has shown a renewed decrease, as the equity value of the corporate sector has risen and stock price volatility has come down, being a reflection of the recovery of profits and the balance sheet restructuring in the corporate sector.

4.3 Evaluation

The reliability of the loss measure can be tested against credit spreads, being the risk remuneration for creditors to offset expected losses (the latter can expressed as the value of the put option, see Annex 1). For emerging markets, Gray (2004) finds a strong relationship between credit spreads and the MFRisk indicator for defaults. Simple correlation shows that there is a rather close relationship – expected to be positive – between our loss measures of the Dutch corporate and banking sectors and the relevant credit spreads (Table 1).

The reliability of the probability measure can be tested against default data. First, as a benchmark for defaults we used credit ratings, as in Gropp et al (2002). They find that the distance to default (the key variable in MFRisk and the measures) is a leading indicator for the default risk of European banks (read from changes in credit ratings) with a lead time up to 18 months. Our probability measure, too, appears to be closely related to changes in the credit ratings of Dutch firms, banks and insurance companies (Table 1). As expected, this relationship is negative: when credit ratings go up, the measure goes down (with risk decreasing). The correlation coefficients are highest

\[8\] The balance sheet total of the Dutch banks doubled between 1997 and 2003, with the assets side showing a
when the measure leads by 3 to 4 quarters, confirming its forward-looking nature. Secondly, the probability measure has been correlated with data on failures in the Dutch financial and non-financial sectors (Table 1). This test also brings out the (4 quarter) leading nature of the probability measure, which, in line with expectations, proves to be positively related to the bankruptcy rates in both sectors. Chart 5 shows the forward-looking nature of the probability measure. While in the second half of the 1990s the probability measure for Dutch firms already showed an increase, banks’ provisions for bad loans as well as the bankruptcy rate in the corporate sector still continued to decline.

Table 1  Reliability of the measures

<table>
<thead>
<tr>
<th>Sector</th>
<th>Spreads(^1)</th>
<th>Credit ratings(^2)</th>
<th>Failures(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporations</td>
<td>+ 0.48 (1)</td>
<td>- 0.84 (3)</td>
<td>+ 0.56 (4)</td>
</tr>
<tr>
<td>Banks</td>
<td>+ 0.44 (0)</td>
<td>- 0.92 (4)</td>
<td>+ 0.40 (4)</td>
</tr>
<tr>
<td>Insurance companies</td>
<td>+ 0.33 (0)</td>
<td>- 0.84 (3)</td>
<td>+ 0.65 (4)</td>
</tr>
</tbody>
</table>

Based on quarterly data.
\(^2\) Correlation with probability measure. Credit ratings for long-term debt of Dutch corporations, banks and insurance companies (1996-2004, source: Moody’s).
\(^3\) Correlation with probability measure. Bankruptcy rate for non-financial and financial sectors (1993-2003, source: Statistics Netherlands). A breakdown of financial institutions’ failures into banks and insurance companies is not available. Therefore, the bankruptcy rate of the financial sector has been correlated with the probability measure for banks and insurance companies.

4.4 Stress tests

The MfRisk model can also be used for stress tests, by either direct or indirect methods. Under the former approach, sensitivity analyses are conducted by shocking the model’s variables (such as the equity value), as in Gray (2004), with the shock in a certain sector being transmitted to other sectors’ balance sheets. In indirect methods, regression analysis is used to relate the model variables to certain macro-economic factors in order to perform scenario analyses. An example is the multi-factor model of Drehmann et al (2004), which explains stock prices as a variable in the Merton model from macro-

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rapid expansion of notably interbank lending and lending to the private sector.
economic factors, whose distributions are simulated.\(^9\) In this paper, the first approach has been used; more extensive scenario analysis is a suitable subject for further research.

As an example of a stress test, a simulation has been conducted in which the equity of Dutch non-financial corporations falls by 30% (owing to a stock market crisis or plummeting operating results). In such a situation, the default risk increases by a factor two (Chart 6). Consequently, the credit quality of corporate loans deteriorates and banks will have to raise provisioning levels, leading to decreases in their equity. Since this raises the risk that the banking sector will exercise its put option vis-à-vis the authorities, the financial stability risk goes up. However, the measures suggest that this systemic risk remains limited (Chart 7). While the deteriorated corporate credit quality shows up in an increase of the put option which the firms have bought from their lenders, the change of this put value (from 0.6 bn to 1.3 bn) remains limited compared to the banks’ equity (\(E\) equals EUR 53 bn in 2003). Besides, the fact that more than half of the corporate debts is outstanding outside the banking sector, also limits the banks’ vulnerability to adverse developments in the corporate sector. It means that more than half of the increase in the put value is shouldered by non-banks. As a result, due to the corporate sector shock the banks’ probability measure goes up by a mere 2 basis points, while the loss measure increases by only EUR 0.06 billion to EUR 15.1 billion. In addition, a liquidity shock has been simulated, which impacts the banking sector directly. In this simulation, it has been assumed that Dutch bank deposits with an agreed maturity and those redeemable at notice become withdrawable on demand. The resultant shorter maturity structure raises the default risk and, hence, the risk of financial instability. The liquidity shock leads to a considerably sharper increase in the loss measure than the shock in respect of corporate exposures (Chart 7). This is due to the fact that the DB of the banking sector increases by more than 30%, by which the value of the put which has been concluded between the banks and the authorities increases from EUR 15 bn to EUR 22.3 bn.

\(^9\) The introduction of expectations through the simulations of macro-economic factors means that the risk-neutral property of the Merton model is abandoned.
The presented measure for financial stability (broken down in a probability and a loss measure) offers a number of insights which may prove useful for policy purposes. First, it contributes to measuring financial stability, thus facilitating the identification of risks and providing a guideline for policy efforts. This function would be enhanced if the measure were applied to sub-sectors instead of sectors as in this paper, since this may help to map vulnerabilities more precisely. This is especially relevant for sectors marked by a high degree of diversity (such as households).

Second, the methodology shows that financial stability policy may be considered as the management of the (implicit or explicit) guarantee given by the authorities to the financial sector. Current policy initiatives (aimed at more risk-based capital requirements, marked-to-market valuation of balance sheets and transparency of risk transfers between institutions) are improving the conditions for this risk management. In all this, the risk that the guarantee will be called upon should be adequately priced. For the pension funds, this means that current generations should pay cost-effective premiums in exchange for the possibility to cut back on pensioners’ benefits or having any underfunding offset by future generations (the possibility to exercise the put option). Banks would have to pay a risk-based price for the put option, in the form of adequate fees for supervision and the capital held by the central bank to cover the guarantee. This also holds for the banks’ deposit insurance, with risk-sensitive premiums being notably relevant for funded systems. It is probable, however, that the true value of the banks’ guarantee cannot be charged from the institutions in a market-based manner, because stability and confidence in the banking system can be viewed as a public good. Therefore, passing the full costs to the financial sector may be undesirable.

Third, the measure shows that mismatches between assets and liabilities and sectoral concentrations of exposures may affect financial stability. This means that such imbalances should be
addressed by policy measures, for instance by encouraging risk transfers to sectors having comparative advantages for bearing certain risks. A case in point could be the transfer through credit derivatives of bank loans to life insurance companies, which thereby reduce their balance sheet mismatch (IMF, 2004). Risk transfers may be encouraged by improving the relevant infrastructure, for instance by developing regulation and enhancing transparency. Risk transfers to sectors marked by low asset volatility may also be conducive to systemic stability, given the smaller risk of failure of these sectors. Viewed from this angle, transferring risks from financial institutions to households, for example by means of unit-linked policies and defined contribution pension schemes, would have favourable effects. Still, this might not always be efficient, since financial intermediaries are better capable of bearing certain (complex) risks.
References


Annex 1 Option approach

The probability measure in this paper is based on an empirical distribution of the probabilities of default for corporations as established by KMV (2001). Such empirical default distributions have fatter tails than the standard normal. On the basis of the KMV distribution, a lognormal distribution, \( N(\cdot) \), has been calibrated, as in Chart A, representing an approximation of the relationship between the distance to distress and default risk.\(^{10}\)

![Chart A Probability distribution of the distance to distress](image)

According to the properties of the Black-Scholes model, the probability of default is risk-neutral, because none of the variables depends on investors’ risk preferences. The Black-Scholes formulas for the value of the call option (\( E \)) and the put option (\( P \)) are:

\[
E = A \cdot N(d_1) - DB \cdot e^{-rt} N(d_2) \tag{2.1}
\]

\[
P = DB \cdot e^{-rt} N(-d_2) - A \cdot N(-d_1) \tag{2.2}
\]

The put option is equal to the risk premium, or the credit spread, as follows:

\[
Spread = -\frac{1}{T} \cdot \ln \left[ N(d_2) + \frac{A}{DB} e^{-rt} N(-d_1) \right] \tag{2.3}
\]

\(^{10}\) If the distance to distress is calculated using a large data set of individual corporations and institutions, a corresponding empirical default distribution may be derived from historic default data (as in Tudela and Young, 2003). This approach has not been adopted in this paper because the distance to distress has been calculated at the aggregated sectoral level. Given the dominance of a few large institutions within the Dutch financial system,
P in (2.2) is the difference between the present value of nominal debt and the market value of assets in the event of default. The Black-Scholes formulas (2.1) and (2.2) include two unknowns: the market value of assets (A) and the volatility of assets ($s_A$). The relationship between the volatility of $E$ ($s_E$) and $s_A$, which follows from Ito’s lemma, also includes A and $s_A$ (Hull, 2000):

$$E = \frac{\sigma_A}{\sigma_E} * A * N(d_1)$$  \hspace{1cm} (2.4)

$E$ and $s_E$ are both known. By numerically solving equations (2.1) and (2.3), $A$ and $s_A$ can be derived. For this purpose, an iterative procedure has been applied, with $s_E$ being used as the initial value of $s_A$ and the initial value of $A$ being guessed. Using these initial values, $A$ and $s_A$ have been calculated for each quarter from equations (2.1) and (2.3). The values thus calculated have been used in the next iteration. The procedure has been repeated until the values of both $A$ and $s_A$ converged in the successive iterations. The tolerance level for the convergence has been set at $10^{-9}$.

no sufficiently large and representative data set of defaults is available for constructing an empirical distribution that is specific to the Netherlands.
### Annex 2 Sectoral balance sheets (source: Gray et al, 2003)

#### Non-financial Corporate Sector

<table>
<thead>
<tr>
<th>ASSETS</th>
<th>LIABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corporate Sector Assets</strong></td>
<td><strong>Debt</strong></td>
</tr>
<tr>
<td>(default-free value minus put option)</td>
<td>(default-free value minus put option)</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td>(call option on corporate assets)</td>
</tr>
</tbody>
</table>

#### Financial Sector

<table>
<thead>
<tr>
<th>ASSETS</th>
<th>LIABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loans and other Assets</strong></td>
<td><strong>Debt / Deposits / Liabilities</strong></td>
</tr>
<tr>
<td>(including loans to corporate sector and public sector)</td>
<td>(default-free value)</td>
</tr>
<tr>
<td><strong>Financial Guarantees</strong></td>
<td><strong>Equity</strong></td>
</tr>
<tr>
<td>(modelled as put option)</td>
<td>(call option on financial sector total assets)</td>
</tr>
</tbody>
</table>

#### Combined Government and Monetary Authorities

<table>
<thead>
<tr>
<th>ASSETS</th>
<th>LIABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foreign Currency</strong></td>
<td><strong>Foreign-currency Debt</strong></td>
</tr>
<tr>
<td><strong>Net Fiscal Asset</strong></td>
<td>(default-free value minus put option)</td>
</tr>
<tr>
<td><strong>Value of Monopoly on Issue of Money</strong></td>
<td><strong>Financial Guarantees</strong></td>
</tr>
<tr>
<td><strong>Other Public Assets</strong></td>
<td>(put options related to financial sector)</td>
</tr>
<tr>
<td><strong>Base Money and Local-currency Debt</strong></td>
<td>(call options on public sector assets)</td>
</tr>
</tbody>
</table>

* Banknotes and domestically issued public debt (which, in the case of emerging countries, has junior status relative to foreign-currency debt) are to be viewed as potential claims of residents on their national government’s assets, comparable to shares issued by a corporation.
Annex 3 Data, assumptions and sources

Market value of assets and equity
For the Dutch pension and household sectors, no equity market capitalisation (E) and sectoral stock price index (to calculate $s_E$ and thereby $s_A$) are available. For the pension funds, the market value of assets (A) is shown in the balance sheet. For the calculation of the market value of equity (E), the market value of the technical provision for pension liabilities (VPV, which is equal to DB in the model) is needed. This has been approximated by adjusting the VPV against book value (based on a fixed actuarial rate of interest) for the market interest rate (see equation 4.1). Thereby, future cash flows are implicitly discounted to present values by means of market interest rates, to derive a market value of liabilities (market value VPV).

$$\text{Market value VPV} = \left( \frac{\text{book value VPV}}{((1 + \text{market rate})/\text{actuarial rate})^{\text{Duration}/\text{PV}}} \right)$$

(4.1)

The volatility of assets ($s_A$) of the pension sector has been calculated on the basis of a ‘theoretical’ volatility of investment returns. To that end, the volatilities of bond and equity returns have been weighted to reflect the pension funds’ average investment mix, assuming no correlation between the two (as in Van Rooij et al., 2004).

For the household sector, E and $s_E$ have been based on the net assets from the aggregated Dutch household sector’s balance sheet. Net assets are influenced by price changes in the asset markets, as the assets are (partially) based on market value. Since no quarterly series of the household sector balance sheet are available, a constant volatility of assets ($s_A$) has been assumed, equal to the average standard deviation of the balance sheet total.

Maturity structure of liabilities
For the financial sectors, nominal debt (DB) is based on the (assumed) maturity of liabilities. For the banks, it has been assumed that deposits with agreed maturity and those redeemable at notice fall due in year 1 by 10% and 20%, respectively. Within DNB’s liquidity reporting system, these percentages apply on a monthly basis in a stress situation. With regard to debt securities, it has been assumed that 50% falls due in year 1 (in the same way as long-term debt is treated by Gray and Bodie, 2003). In

11 With the introduction of the Financial Assessment Framework (FTK) of DNB, Dutch pension funds’ balance sheets will be based on market value from 2006 onwards.
12 See DNB’s Credit System Supervision Manual, Memorandum on the liquidity reporting and testing of the liquidity requirements (section 6101).
respect of the remaining liabilities, such as interbank balances, we assume that they fall due in full in
year 1. It should be noted that DB does not include off-balance-sheet positions.

For the purposes of determining DB, the technical provisions on the balance sheets of the
pension and insurance sectors, which are traditionally based on a fixed actuarial rate of interest\textsuperscript{13},
have been converted to market values, as in equation 4.1. Furthermore, for the pension funds it has
been assumed that, at an average duration of 15.3 years of the provision for pension liabilities, 1/15.3
falls due in year 1. Similarly, for the insurance companies, at an average duration of 8.3 years, 1/8.3 of
the provisions falls due in year 1. The durations used are estimates of the average duration of the
provisions of Dutch pension funds and insurance companies in 2002. For other years no estimates are
available, so that the duration has been assumed to be constant over the years.

For non-financial companies and households, it has been assumed that short-term debt falls due
in full in year 1 and long-term debt to the extent of one-half (as in Gray and Bodie, 2003).

\textbf{Table A  Definitions} (data sources in brackets)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity (E)</td>
<td>Equity market capitalisation per sector on a quarterly basis (Statistics Netherlands, DNB)</td>
</tr>
<tr>
<td>Volatility of equity (s\textsubscript{E})</td>
<td>Standard deviation of log return of stock price index per sector on a daily basis (Datastream)</td>
</tr>
<tr>
<td>Assets (A)</td>
<td>Asset value on balance sheets of pension funds (DNB, quarterly data) and households (Netherlands Bureau for Economic Policy Analysis, annual data)</td>
</tr>
<tr>
<td>Debt (DB)</td>
<td>Aggregate debt level (financial institutions: DNB, non-financial companies: Statistics Netherlands, households: Netherlands Bureau for Economic Policy Analysis); adjusted for maturity structure, quarterly data interpolated</td>
</tr>
<tr>
<td>Interest rate (r)</td>
<td>Risk-free 12-month interest rate euro area (DNB)</td>
</tr>
</tbody>
</table>

\textsuperscript{13} For pension funds the actuarial interest rate is 4%, for insurance companies it was 4% until 1999 and has been 3% from that year onwards.
Previous DNB Working Papers in 2005

No. 27  Jan Marc Berk and Beata K. Bierut, On the optimality of decisions made by hub-and-spokes monetary policy committees
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