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# The stability of efficiency rankings when risk-preferences and objectives are different

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# Abstract

We analyze the stability of efficiency rankings of German universal banks between 1993 and 2004. First, we estimate traditional efficiency scores with stochastic cost and alternative profit frontier analysis. Then, we explicitly allow for different risk preferences and measure efficiency with a structural model based on utility maximization. Using the almost ideal demand system, we estimate input and profit demand functions to obtain proxies for expected return and risk. Efficiency is then measured in this risk-return space. Mean risk-return efficiency is somewhat higher than cost and considerably higher than profit efficiency. More importantly, rank-order correlation between these measures are low or even negative. This suggests that best-practice institutes should not be identified on the basis of traditional efficiency measures alone. Apparently, low cost and/or profit efficiency may merely result from alternative yet efficiently chosen risk-return trade-offs.



**Keywords:** Risk, efficiency, banks, Germany

**JEL:**D21, G21, G33, L21

# Non-technical summary

Managing risk is at the very heart of banking business. But most bank efficiency comparisons account only indirectly for the risk associated with chosen production plans. Usually, efficiency measurement assumes cost minimizing or profit maximizing behavior. Risk is only accounted for by including equity capital as a catch-all control in the technology constraint of banks that choose production plans in pursuit of these objectives. Such measures may thus fail to fully capture the risk associated with banks' objectives and chosen production plans. This is because potentially heterogenous risk preferences and profit expectations as well as possibly alternative objectives are neglected.

In this study, we suggest as an alternative a structural model of bank behavior that accounts for risk more directly. Bank managers maximize utility, which depends on (i) the production plan and (ii) the associated riskiness of that plan. Utility maximization is general enough to also allow for non-value maximizing objectives. Subject to different risk-preferences, managers choose most preferred production sets and associated after-tax profit. We use the Almost Ideal Demand System to estimate a system of demand equations for input factors and after-tax profit. From the latter, we derive measures of expected risk and return to measure risk-return efficiency (RRE). RRE quantifies the ability of banks to realize risk-return trade-offs.

First, we find in line with basic financial theory that increasing risk influences expected returns significantly positive at a decreasing rate. Specification tests support the use of a stochastic risk-return frontier based on utility maximization.

Second, we find that risk-return efficiency (RRE) among German universal banks is around 84%. This is considerably higher compared to cost and profit efficiency (CE and PE) of 77% and 55%, respectively. Apparently, some banks identified as inefficient in terms of costs and profits may just have followed different objectives or obey their preferences for lower risk.

Third, we control for bank characteristics other than prediction risk that may influence expected returns. Our result that (i) RRE is higher than CE, and especially PE, and that (ii) higher risk taking is associated with higher expected returns remains robust after controlling for banking sector membership, macroeconomic conditions and size.

Fourth, closer inspection of extreme performers shows that especially RRE and PE rankings differ drastically. We conclude that PE can be high if banks are just lucky to book relatively large profits at high risk that is neglected in traditional efficiency analysis. Likewise, banks considered potentially problematic on the basis of PE alone may in fact just pursue more risk-averse or other non-value maximizing strategies when choosing their production plan.

In sum, traditional efficiency measures seem not to account sufficiently well for risk associated with chosen production plans. An alternative model of bank behavior that incorporates risk-preferences more explicitly and allows for different objectives yields higher efficiency among German universal banks compared to CE and PE. In fact, rankings are also substantially affected, suggesting that studies relating efficiency to the stability of the banking system should also consider risk-return efficiency.

# Nichttechnische Zusammenfassung

Das Beurteilen des Risikos alternativer Produkte und Dienstleistungen ist zentraler Bestandteil der Tätigkeit einer Bank. Traditionelle Effizienzvergleiche berücksichtigen Risiko jedoch nur indirekt. Effizienz wird üblicherweise unter der Annahme kostenminimierenden oder gewinnmaximierenden Verhaltens gemessen. Das Risiko gewählter Produktionspläne geht lediglich durch die Spezifikation von Eigenkapital in der Produktionsfunktion in die Analyse ein. Traditionelle Effizienzmaße können deshalb nur bedingt das Risiko einer Bank in Verbindung mit deren Zielfunktion und Produktionsentscheidungen berücksichtigen, weil unterschiedliche Risikopräferenzen, Gewinnerwartungen und Zielfunktionen vernachlässigt werden.

In dieser Studie schlagen wir ein strukturelles Nutzenmaximierungsmodell vor, welches eine direktere Berücksichtigung von Risiko ermöglicht. Banken maximieren Nutzen und können alternative Zielen verfolgen. Nutzen hängt von Produktionsentscheidungen und den damit verbundenen Gewinnerwartungen ab. Unter der Berücksichtigung von Risikopräferenzen, welche zwischen den Banken unterschiedlich sein können, wählen Banken bevorzugte Produkt- und Dienstleistungskombinationen. Mit Hilfe des *Almost Ideal Demand System* schätzen wir optimale Input- und Gewinnfunktionen. Hiermit generieren wir erwarteten Gewinn und dazugehöriges Risiko, um schließlich Risiko-Ertrags Effizienz (RRE) zu quantifizieren. Diese bemisst die Fähigkeit einer Bank, Ertrag und Risiko effizient zu wählen.

Unser erstes Ergebnis ist, dass höhere Risiken mit einer abnehmenden Rate zu höheren Erträgen führen. Dieser Effekt ist statistisch signifikant und weitere Tests unterstützen die Formulierung einer stochastischen Frontier.

Zweitens zeigt sich, dass die RRE deutscher Universalbanken deutlich höher ausfällt (84%) als traditionelle Kosten- und Gewinneffizienz (CE und PE), welche im Mittel 77% und 55% betragen. Anscheinend haben einige traditionell als ineffizient identifizierte Institute unterschiedliche Risikopräferenzen und Ziele.

Drittens kontrollieren wir hinsichtlich möglicher weiterer Einflußfaktoren erwarteter Gewinne: Bankengruppenzugehörigkeit, Region und Größe. Unsere Ergebnisse hinsichtlich höherer RRE im Vergleich zu CE, und insbesondere PE, sowie der positive Zusammenhang zwischen Ertrag und Risiko sind robust.

Die nähere Untersuchung von extrem (in)effizienten Instituten zeigt schließlich, dass sich insbesondere RRE und PE Rangfolgen stark unterscheiden. Gewinneffiziente Banken sind unter Umständen lediglich solche, welche einen relativ hohen Gewinn mit geringem Faktoreinsatz und hohem Risiko verbuchen konnten, weil das Risiko dieses Produktionsplans in dieser Analyse nicht berücksichtigt wird. Entsprechend sind gemäß PE als problematisch identifizierte Banken gegebenenfalls jene mit einer höheren Risikoaversion.

Insgesamt halten wir fest, dass traditionelle Effizienzmaße nur bedingt die Risiken berücksichtigen, die mit gewählten Produktionsplänen verbunden sind. Ein alternatives Nutzenmaximierungsmodell, welches unterschiedliche Risikopräferenzen explizit in Betracht zieht und alternative Zielfunktion zulässt, führt im Durchschnitt zu deutlich höheren Effizienzwerten als CE und PE. Weil Rangfolgen gemäß RRE ebenfalls stark beeinflußt sind, sollten Studien zur Effizienz und Stabilität des Bankensystems deshalb auch Risiko-Ertrags Effizienz berücksichtigen.

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# The stability of efficiency rankings when risk-preferences and objectives are different[1]

## 1 Introduction

In the wake of the creation of a single European market for financial services, mounting competitive pressure forces banks to streamline the efficiency of their operations (Berger, 2003). Consequently, performance comparisons of financial institutions are of increasing importance. For example, regulators use performance benchmarks to identify worst-practice banks that could jeopardize the stability of financial systems (Deutsche Bundesbank, 2005). Furthermore, the identification of best-practice institutions may aid practitioners and the public to learn which banks could serve as role models (The Economist, 2004).

To benchmark bank performance many academics and practitioners measure cost and (alternative) profit efficiency (CE and PE) as a bank's position relative to an optimum cost or profit frontier (Kumbhakar and Lovell, 2000). Stochastic frontier analysis (SFA) allows to estimate such a benchmark frontier and the (lacking) ability of banks to convert inputs as efficient as possible into outputs and has been applied widely in the financial economics literature.[2]

An important drawback of the vast majority of studies is, however, the neglect of risk when measuring efficiency.[3] If agents are risk-neutral the result obtained by Modigliani and Miller (1958) states that cost minimization and profit maximization are equivalent to value maximization. However, if risk preferences differ, efficiency rankings obtained under the traditional assumption might be misleading. A bank earning lower profits than a peer is *ceteris paribus* considered inefficient. However, lower profits earned at lower risk might just reflect a higher degree of risk adversity. Hence, compared to the peer group the bank is just as efficient when efficiency measurement is adjusted for different risk preferences. Likewise, a bank that economizes excessively on labor cost by reducing the number of risk managers and loan officers may be relatively cost efficient. But it may well be located below the locus of optimal risk-return trade-offs. As a consequence of too few risk managers, such a bank may for example price itself out of business (too low returns given risk) or systematically underprice risky loans (too high risk given returns).

In this paper we therefore address the role of risk in efficiency measurement more directly. To this end we compare to our knowledge for the first time standard efficiency measures to risk-return efficiency. We derive the latter from a model

[1]e-mail: m.koetter@rug.nl. Substantial parts of this paper result from research conducted at the Utrecht School of Economics. I thank participants of the $2^{nd}$ Deloitte conference on risk management in Antwerp for helpful comments. I am furthermore indebted to Jaap Bos, Clemens Kool, Jim Kolari, Christoph Memmel, Daniel Porath and two anonymous referees for most valuable input. I thank the Deutsche Bundesbank for providing me with the data. The opinions expressed here, however, are personal and do not necessarily reflect those of the Deutsche Bundesbank. All remaining errors are, of course, my own.

[2]Review studies are, for example, Berger and Humphrey (1997) and Amel et al. (2004).

[3]Most studies follow an early suggestion by Hughes and Mester (1993) and account for risk by specifying an additional netput in the production constraint of banks, namely equity capital.

developed by Hughes and Moon (1995) and Hughes et al. (1996). In contrast to the usual assumption of cost minimization, bank managers maximize utility subject to their respective preferences associated with alternative production plans. These preferences are, among other things, influenced by the manager's attitude towards risk-taking and are recovered from production data using the Almost Ideal Demand system (Deaton and Muehlbauer, 1980). The optimal demand for profits is then used to estimate risk-return efficiency.

Some US studies use this structural model of bank behavior to examine the enforcement of regulatory corrective actions, agency problems at banks (Hughes et al., 2003), risk-taking and bank default (DeYoung et al., 2001) or the effects of deregulation (Hughes et al., 1996). This way of modeling efficiency measurement is a new direction of research and this paper is the first application to a banking market outside the US, namely Germany. We estimate firm-specific efficiency relative to a cost, an alternative profit and a risk-return frontier as to learn if different efficiency measures identify similar best- and worst-practice banks. The stability of rankings is especially important in German banking since efficiency is an important indicator to predict, for example, bank distress and, hence, the stability of the banking system (Koetter et al., 2005). We hypothesize that risk-return efficiency contains important additional information and thus identifies different best-practice banks. An efficiency measure incorporating risk explicitly into a framework of bank behavior can be of interest to practitioners, consumers and regulators alike.

The remainder of this paper is structured as follows. In section 2 we first review the evidence from previous efficiency studies with a particular focus on the available evidence on German bank efficiency. Second, we relate our study to previous risk-return efficiency analyses for the US. In section 3 we first introduce the theoretical cost, alternative profit and the utility maximization models, respectively. Second, we discuss the empirical implementation. In section 4 we describe the data used in this study. We employ confidential data provided by the Deutsche Bundesbank on virtually all universal banks that operated in Germany between 1993 and 2004. We discuss our main findings in section 5. In particular, we focus on the differences between the three measures in terms of identified best- and worst-performers. We also provide robustness checks to illustrate the usefulness of our approach to proxy bank risk if market price data is unavailable for non-listed banks. We conclude in section 6.

# 2 Bank Efficiency and Risk

Bank-specific inefficiency is most often measured as the deviation from an estimated optimum industry cost frontier. The economic theory behind is to assume that banks operate on perfect markets and seek to minimize costs when demanding input factor quantities to provide a given amount of financial services. In this model, suboptimal costs or profits are due to the X-efficiency idea of Leibenstein (1966): banks demand too much of an input to produce the output vector and/ or they demand input factors in suboptimal proportions given relative factor prices. Taken together, CE quantifies how much a bank could reduce cost and still provide the same output.

Despite numerous alternatives to empirically specify optimum cost or profit frontiers, review studies on US banking yield by and large fairly stable results.[4] During the last two decades, mean CE and PE was around 20 and 40 percent, respectively (Berger and Humphrey, 1997; Amel et al., 2004).[5] While not as abundant, the European evidence confirms the dominance of profit over cost inefficiency. The magnitude of foregone cost savings and profit realizations mimics that reported for US banking.

In the light of this study two issues deserve attention. First, recent evidence of German bank efficiency is scarce. This is surprising given the important role of Germany's banking industry in the European landscape (ECB, 2005). Among the few country studies, only Altunbas et al. (2001) examine both CE and PE of private, cooperative and savings banks between 1989 and 1998.[6] They study the differences between sectors and size classes with stochastic frontier and distribution free analysis. Cost inefficiencies are highest for commercial institutes and amount to 17 percent for the industry as a whole. The authors find furthermore that the ability of banks to realize potential profits is worse, as mean alternative profit inefficiency amounts to 20 percent. Another study by Lang and Welzel (1996) examines only cost efficiency of 757 cooperative banks located in the state of Bavaria over the period in 1989-1992. They report evidence of improving CE but also find that the average bank deviates considerably from the best practise frontier. In line with Altunbas et al. (2001), larger institutes are performing worse than the smaller ones. However, they restrict their findings explicitly to the sample and caution to draw inference for the entire banking population.[7]

Apart from the sheer limitation of available evidence on German bank efficiency, the second issue that deserves attention is the treatment of risk in these analyses. In fact, only Altunbas et al. (2001) follow the early suggestion of Hughes and Mester (1993) and adjust the technology constraint of banks to also depend on the level of equity. They include equity capital as an additional netput for two reasons. First, equity can be an alternative source of funds for investments. Second, it accounts for the riskiness of the bank. Hughes and Mester (1998) argue that higher capitalization serves as a cushion against losses due to, for example, a sudden decline of asset prices and also as a signal to outsiders about the solvency of the bank. Consequently, neglecting the capital structure of a bank may yield biased efficiency scores. This is because observed input demands are deemed inefficient although they are in fact the result of different constraints or risk preferences. The approach to account for risk by including the level of equity capital in the technology constraint is by now

[4]Specification choices of parametric methods, such as SFA, are discussed in Kumbhakar and Lovell (2000). Non-parametric methods, such as Data Envelopment Analysis, avoid any distributional assumptions (Coelli et al., 1998), but are more sensitive to measurement error. Because the latter is a well-known problem in banking data we opt here for SFA (Mountain and Thomas, 1999).

[5]Due to well-known problems to measure output prices in banking, most PE studies are in fact so-called *alternative* PE analyses. Humphrey and Pulley (1997) suggest to allow banks some output market power. Thus, banks choose prices subject to an additional pricing opportunity constraint.

[6]A number of European cross-country studies also include German banks, for example Maudos et al. (2002) or Cavallo and Rossi (2001). By and large, reported CE is around 20 percent in the early 1990s. But most studies cover only a very small fraction of German banking. For example, Cavallo and Rossi (2001) sample 442 banks from 6 countries while already in Germany alone around 3,500 banks were in operation at the time under investigation.

[7]Some studies use efficiency to determine bank mergers and failures (Koetter et al., 2005) or to analyze the effects of German bank consolidation (Lang and Welzel, 1999). Since efficiency measurement itself is of subordinated interest there, we do not review these studies here.

standard in the efficiency literature.

Incorporating risk into efficiency analysis is important to avoid potentially misleading CE and PE measures. For example, if banks choose consciously riskier production plans, this could imply high spending on risk management. Higher operational cost compared to peers would then lead to lower CE. This suggests that not only the constraints of a bank manager's optimization problem need to be adjusted but that in fact objective functions are fundamentally different.

Ideally, we would therefore control for market-priced risk in bank efficiency analyses. But studies on German bank risk (Memmel and Wehn, 2005) highlight the fact that most banks are not publicly traded. Hence, market prices for bank risk are not available for the vast majority of banks.[8] Alternatively, if data on bank failures is available, supervisory authorities use rating models, such as the CAMEL model of the Federal Reserve Bank, to assess bank risk. These models estimate individual probabilities of bank default conditional on bank-specific risk and further characteristics (King et al., 2005).[9] However, bank default data is usually also confidential and not available. Finally, risk measurement alone would not allow us to evaluate the ability of managers to trade risk for the returns expected from choosing a particular production plan subject to their potentially different risk preferences. In fact, Hughes et al. (2000) show that if firms are not risk-neutral, the "*comparative statics differ from those of the profit maximizing [cost minimizing] firm*".

As an alternative, Hughes and Moon (1995) and Hughes et al. (1996) developed a structural model of bank production on the basis of utility maximization to derive estimates of expected profit and risk per bank. These and companion studies (Hughes, 1999b; DeYoung et al., 2001; Hughes et al., 2000, 2003) use the standard error of the predicted return as a proxy for market-priced risk. Hughes (1999a,b) demonstrates that for traded banks this proxy for risk is significantly and positively correlated with the market price of publicly traded banks. Further, the standard error of predicted return is regressed on traditional risk proxies capturing capitalization, market and credit risk and confirm a high correlation between this alternative risk proxy and traditional measures of risk, too.

The starting point in the model is that managers do not only care about profit maximization or cost minimization, respectively. More specifically, they may have different risk preferences and pursue alternative objectives. First, when choosing a production plan the riskiness of the production plan is evaluated, too. Risk matters if managers maximize value instead of profits. Intuitively, riskier plans require a higher rate of return. Subject to their individual preferences, managers may therefore choose different production plans and still be equally efficient. Second, further objectives can influence the decision making process of the manager. Examples include alternative spending preferences or tax optimizing behavior (Hughes et al., 2003). Hughes and Moon (1995) show that a general utility function allows to model preferences general enough to accommodate different objectives beyond value maximization. This is of particular interest in German banking, where a third of the banking market

[8]Out of 3,907 that operated between 1993 and 2004, only 4.7 % were stock incorporated banks. Out of these 187 banks even fewer were also listed and traded on stock exchanges.

[9]For example Porath (2006) estimates probabilities of cooperative and savings bank default in this way and specifies proxies for solvency, market, and credit risk.

is accounted for by publicly owned savings banks, which may pursue additional objectives other than pure profit maximization.

The utility maximization model used here is adapted from Hughes et al. (1996). Utility is maximized by choosing optimal profit and input demand. After-tax profit is depicted by $\pi$. Technology stipulates the production plan represented by output quantities $y$, input quantities $x$ and equity capital $z$. The price demanded for output is denoted by $p$. Bank managers form a subjective, conditional probability distribution of profit to be realized $f(\pi|y, x, p, z, s)$, where $s$ denotes future states of the world. Expectations are subjective because beliefs about $s$ differ and depend on individual production plans and their interaction with the expected state of the world. *Generalized managerial preferences* are then represented by a utility function of the form $U(\pi, y, x, p, z)$. Banks maximize utility by choosing the highest ranked production plan. The solution to this maximization problem yields most preferred demand functions for inputs and after tax profit, respectively. This system of demand equations reflect managers' preferences regarding risk and their expectations of profit conditional on the production plan and the state of the world.

Note that in this model risk is not measured by volatility as usual. Instead, the elements of the production plan represent particular risk and other managerial preferences. Therefore, Hughes et al. (1996) point carefully out that this risk proxy depends on the specification of utility and thus on the determinants of the profit demand equation. Efficiency is then measured in the risk-return space: combinations of predicted profits and the standard error of the predicted profit are the benchmark.

Some examples why utility $U(\pi, y, x, p, z)$ captures different aspects of bank risk are as follows. Regarding outputs $y$, banks with a higher appetite for risk may decide to produce less fixed interest bearing loans and engage more in security or derivatives trading. The output vector $y$ then captures market risk. Regarding inputs $x$, a preference for representative office buildings results in higher expenditure on fixed assets. Alternatively, the desire to signal managerial power by commanding large numbers of employees may result in "over-employing" labor. Higher output prices $p$ may increase expected profits. At the same time, higher loan rates are likely to attract the lemons in the credit market, thereby increasing the uncertainty of expected profit. Finally, for a given output portfolio, lower ratios of equity capital $z$ increase the risk of insolvency due to credit losses or sudden security price deterioration.

In sum, in this model managers can maximize either profit or value and they are also allowed to trade profit or value for other preferences. Hughes et al. (1996) call this modeling of utility a *generalized managerial objective function.* The solution to the manager's maximization problem leads to the *most preferred production plan* regarding in- and outputs and their *most preferred profit function.* To our knowledge this approach to generalize bank objectives rather than constraints has not been applied to any banking market outside the US. Therefore, we turn next to the methodology used here to measure risk-return efficiency in German banking.

# 3 Methodology

First, we introduce the models used to measure CE, PE and risk-return efficiency (RRE). Since we consider the former two approaches standard, we just briefly recall the underlying assumptions and variables before discussing risk-return efficiency. Second, we present the empirical implementation of the utility maximization model.

## 3.1 Bank Production Choices

*Cost minimization* We follow the majority of efficiency studies and use the intermediation approach to model bank production. The main function of a bank is to channel savings from surplus units to investors in need for funds. Banks operate in perfect markets when demanding input quantities $x_i$ at given factor prices $w_i$ to produce outputs $y_m$. The objective of a bank is to minimize cost $C$. In addition to in- and output quantities, we specify the technology of bank production to depend on equity capital $z$. The technology constraint is thus given as $T(y, x, z)$. Solving this cost minimization problem yields optimum input demand functions, which in turn yield the optimum cost function $C_k^* = f(y_k, w_k, z_k)$.

*Alternative profit maximization* Humphrey and Pulley (1997) argue that cost minimization may fall short to evaluate the ability of a bank to generate profits and therefore emphasize the necessity to study profit efficiency, too. One important problem with profits is according to Mountain and Thomas (1999), however, that bank output prices are subject to substantial measurement problems. First, they are hardly ever available at the bank, let alone at the product level for European banks. Second, even if they were available, it is conceptually not trivial to disentangle different price components, such as for example fees and commissions from interest. Finally, German banks in particular may possess some output market power due to the regional demarcation of markets, implying degrees of freedom to set prices.[10]

In fact, most banking studies follow the suggestion of Humphrey and Pulley (1997) and estimate alternative profit functions. Banks maximize profit before tax, $PBT = py - wx$, subject to the above depicted technology constraint and, in addition, a pricing opportunity constraint $H(p, y, w, z)$. This implies that banks choose optimal input quantities $x$ and output prices. Put differently, we allow banks to possess some price setting discretion within the bounds of the pricing opportunity set. We compare profit efficiency here as well to RRE because this model received considerable attention in the literature to assess the output efficiency of banks. Moreover, we are interested if profit efficient banks are also choosing efficient risk-return trade-offs. Alternatively, realizations of high returns with low input may merely be the result of risky bets.

Importantly, both the cost and the profit approach incorporate risk only by amending the technology constraint with equity as a catch-all indicator of risk. Let us therefore turn next to the more direct alternative to assume a different objective function: utility maximization.

*Utility Maximization* Managers maximize utility $U(\pi, y, x, p, z)$ and face two constraints. The first is the transformation function $T(y, x, z)$., the second is the profit identity. Let $m$ denote income from sources other than output $y$. In addition, let $t$ equal the tax rate on profits so that $p_\pi = 1/(1 - t)$ depicts the price of after-tax profit in terms of before-tax profit. Then, nominal before-tax accounting profit is

[10]Evidence on market power among German banks is provided by Hempell (2004).

given by the profit identity $p_\pi \pi = py + m - wx$. We write the utility maximization problem (UMP) as

$$\begin{aligned} &\max_{\pi,x} U(\pi, y, x, p, z) \\ &\text{s.t. } p_\pi \pi + wx = py + m, \\ &\text{s.t. } T(y, x, z) \leq 0. \end{aligned} \tag{1}$$

Solving this maximization problem for $\pi$ and $x_i$ yields the most preferred profit function and the most preferred input demand functions, respectively:

$$\pi^* = \pi^*(y, v, m, z), \tag{2}$$

$$x_i^* = x_i^*(y, v, m, z), \tag{3}$$

where $v$ is a vector of the form $v = (w, p, p_\pi)$ depicting the price environment of the bank. A number of points are worthwhile mentioning with regard to the solution of the UMP. The profit function $\pi^*$ need not be the profit maximizing one from the standard approach.[11] It reflects the possibility that managers have different preferences and depicts the trade-off managers make. Risk-preferences are recovered from observed choices of production plans the bank has made. As the most preferred profit demand function is conditional on risk preferences we use it to estimate the benchmark frontier and to derive efficiency estimates.

## 3.2 Empirical Specification

Since the estimation of cost and alternative profit frontiers is fairly standard, we focus here on the empirical measurement of the risk-return frontier.[12]

Direct estimation of the structural model in equation (1) is not possible because the functional form is unknown and utility is, of course, not observable. But we are not directly interested in managers' utility levels. Instead we are more concerned with the ranking managers assign to a family of available production plans and profit functions given their general preferences depicted by the utility function. We can therefore use standard techniques from consumer theory that analyze consumers' preferences for goods on the basis of their expenditure behavior and budget data. In the context of the banking firm, we estimate most preferred profit and most preferred input demand functions to gain insight into the preferences of bank managers. We employ the AID and thus rely on two relations. First, the dual relation between the UMP and the expenditure minimization problem (EMP). Second, the inverse relation of indirect utility and the expenditure function. Duality allows us to restate the maximization problem in equation (1) as a minimization problem of the form

[11] That is to say, $x_i^U(y, v, m, z) \neq x_i^\pi(y, w, z) = x_i^C(y, w, z)$ , where superscripts indicate utility maximization, profit maximization and cost minimization, respectively.

[12] We use for both the cost and alternative profit frontier the translog functional form and a fixed effect panel estimator described below. For details regarding CE and PE estimation with German bank data see Koetter (2006).

$$\begin{aligned}&\min_{\pi,x} \; wx + p_\pi \pi \\ &\text{s.t. } U^0 - U(\pi, y, x, p, z) = 0, \\ &\text{s.t. } T(y, x, z) \leq 0.\end{aligned} \tag{4}$$

$U^0$ is the fixed level of utility. The solution to this problem are the expenditure minimizing amounts of the goods in question, which are here the most-preferred profit $\pi^u(y, v, z, U^0)$ and input demand functions $x^u(y, v, z, U^0)$. Substituting these into the EMP yields the minimum expenditure function $E(y, v, z, U^0)$. Deaton and Muehlbauer (1980) then substitute the indirect utility function $V(y, v, m, k)$ for $U^0$ and write the optimal demand functions as

$$\pi^u(y, v, z, V(y, v, m, z)) = \pi^*(y, v, m, z), \tag{5}$$

$$x^u(y, v, z, V(y, v, m, z)) = x^*(y, v, m, z), \tag{6}$$

where $x^*(\cdot)$ and $\pi^*(\cdot)$ are the demand functions given in equations (2) and (3) and $V(\cdot)$ depicts the indirect utility function. Since utility levels are not observable we use the inverse relationship between indirect utility and the expenditure function $E(y, v, k, U^0)$. Substituting the former into the expenditure function yields

$$py + m = E(y, v, k, V(y, v, m, z)). \tag{7}$$

All expenditure on profit and inputs to attain a given level of utility must equal total revenue, that is meet the budget constraint. As it is standard in the AID, we do not estimate demanded quantities directly. Instead, we rely on Sheppard's Lemma to derive budget shares from the expenditure function. The standard expenditure function of the AID system has been derived by Deaton and Muehlbauer (1980) and the adaptation of Hughes et al. (1996) is:

$$\ln E(\cdot) = \ln P + U * \beta_0 \left(\prod_i y_i^{\beta_i}\right) \left(\prod_j w_j^{\nu_j}\right) p_\pi^\mu z, \tag{8}$$

where $\ln P$ is the price index employed in the AID system. Following the initial suggestion of Deaton and Muehlbauer (1980) many applications in the consumer literature employ the functional form of a translog function for the price index (Tridimas, 2000). We follow this approach and write $\ln P$ as

$$
\begin{aligned}
\ln P &= \alpha_0 + \alpha_p \ln \tilde{p} + \sum_i \delta_i \ln y_i + \sum_j \omega_j \ln w_j \qquad (9)\\
&+\eta_\pi \ln p_\pi + \rho \ln z + \frac{1}{2}\alpha_{pp}(\ln \tilde{p})^2\\
&+\frac{1}{2}\sum_i \sum_j \delta_{ij} \ln y_i \ln y_j + \frac{1}{2}\sum_s \sum_t \omega^\star_{st} \ln w_s \ln w_t\\
&+\frac{1}{2}\eta_{\pi\pi}(\ln p_\pi)^2 + \frac{1}{2}\rho_{zz}(\ln z)^2 + \sum_j \theta_{pj} \ln \tilde{p} \ln y_j\\
&+\sum_s \phi_{ps} \ln \tilde{p} \ln w_s + \psi_{p\pi} \ln \tilde{p} \ln p_\pi + \psi_{pz} \ln \tilde{p} \ln z\\
&+\sum_j \sum_s \gamma_{js} \ln y_j \ln w_s + \sum_j \gamma_{j\pi} \ln y_j \ln p_\pi\\
&+\sum_j \gamma_{jz} \ln y_j \ln z + \sum_s \omega^\star_{s\pi} \ln w_s \ln p_\pi\\
&+\sum_s \omega_{sz} \ln w_s \ln z + \eta_{\pi z} \ln p_\pi \ln z.
\end{aligned}
$$

Note that not each output price is included. Instead, we use an average price $\tilde{p}$ for two reasons. First, Hughes et al. (1996) note that this approach helps to conserve on degrees of freedom in the estimation of the share equations. Second, income earned by output category is not available for German banks.

We derive share equations by applying Sheppard's Lemma to equation (8). Partial derivatives of the expenditure function with respect to goods' prices are equal to respective budget shares. To this end we substitute the indirect utility function for the given level of utility $U^0$ into the derivatives $\partial \ln E(\cdot)/\partial \ln w_i$ and $\partial \ln E(\cdot)/\partial \ln p_\pi$. Substituting (7) into (8) and solving for utility yields the indirect utility function as

$$
V(\cdot) = \frac{\ln(py+m) - \ln P}{\beta_0 \left(\prod_i y_i^{\beta_i}\right)\left(\prod_j w_j^{\nu_j}\right) p_\pi^\mu z}. \qquad (10)
$$

The share equations for input demand and profit are then given by[13]

$$
\begin{aligned}
\frac{\partial \ln E}{\partial \ln w_i} &= \frac{w_i x_i}{p*y+m} = \frac{\partial \ln P}{\partial \ln w_i} + \nu_i \left[\ln(p*y+m) - \ln P\right] \qquad (11)\\
&= \omega_i + \sum_s \omega_{si} \ln \omega_s + \phi_{pi} \ln \tilde{p} + \sum_j \gamma_{ji} \ln y_i + \omega_{\pi i} \ln p_\pi\\
&+\omega_{iz} \ln z + \nu_i \left[\ln(p*y+m) - \ln P\right] + \varepsilon_{w_i}
\end{aligned}
$$

[13]According to Deaton and Muehlbauer (1980) the parameters on the consumed goods' prices are defined as $\omega_{si} = \frac{1}{2}(\omega^*_{si} + \omega^*_{is}) = \omega_{is}$ and $\omega_{s\pi} = \frac{1}{2}(\omega^*_{s\pi} + \omega^*_{\pi s}) = \omega_{\pi s}$.

and

$$\frac{\partial \ln E}{\partial \ln p_\pi} = \frac{p_\pi \pi}{p * y + m} = \frac{\partial \ln P}{\partial \ln p_\pi} + \mu \left[\ln(p * y + m) - \ln P\right] \tag{12}$$

$$= \eta_\pi + \eta_{\pi\pi} \ln p_\pi + \psi_{p\pi} \ln \tilde{p} + \sum_j \gamma_{j\pi} \ln y_j + \sum_s \omega_{s\pi} \ln w_s$$

$$+\eta_{\pi z} \ln z + \mu \left[\ln(p * y + m) - \ln P\right] + \varepsilon_{p_\pi}.$$

In contrast to the application in Hughes et al. (1996), we treat the amount of equity employed in the production process as exogenous and include it in the transformation constraint. This way it enters the demand shares for inputs and profit and we ensure that the technology constraint is identical in the two standard and the utility maximization approach, respectively. We assume that equity is exogenous because the vast majority of banks are rather small. Limited access to capital markets may thus render it difficult to choose capital ratios freely.[14]

We impose the required symmetry and homogeneity restrictions on the model. They are depicted in the appendix and for a more detailed discussion we refer to Hughes et al. (2000) and Deaton and Muehlbauer (1980). Furthermore, we impose the adding up restrictions by dropping the share equation of demand for physical capital from the system. After substituting the price index $\ln P$ from equation (9) into the share equations (11) and (12) and collecting terms, the final system results. We estimate the system with seemingly unrelated regression equation (SURE) techniques and allow for heteroscedasticity. As noted earlier, the latter is important since the definition of risk as the standard error of predicted returns derived from equation (12) implies that the production plan specification determines our risk proxy, which in turn prohibits to impose homoscedasticity. Moreover, we allow risk preferences to change over time and estimate the system for each year separately.[15] Let us therefore turn next to the measurement of expected return, risk and RRE.

## 3.3 Risk-Return Efficiency

As outlined earlier, a direct approach to measure the efficiency of banks to trade risk against return is to rely on financial market data (Hughes, 1999a). But since the vast majority of German banks are not listed publicly, proxies for market priced risk (and return) are not available. Therefore, we follow Hughes et al. (1996) and use equation (12) to measure expected return and risk. Expected return on equity, $ER$, is the predicted profit divided by financial capital, $ER = E(p_\pi \pi)/z$. We measure expected risk, $RK$, by the standard error of predicted profit, $S(E(p_\pi \pi)/z)$. It is bank specific and results from the uncertainty of predicted profit in equation (12). In this model, managers know expected profits when making choices subject to their expectations and preferences, however with an imperfect degree of certainty. Since risk preferences may be different, the optimal trade-off between expected return and risk differs across banks. Financial theory entails that higher returns require higher

[14]For example Diamond and Rajan (2000) discuss the endogeneity of equity capital.

[15]In fact, we also estimated the system pooled over all years and with alternative estimation techniques such as three-stage least squares with virtually no changes in terms of economic implications for RRE and the relation to CE and PE reported below.

risk-taking. Hence, we expect that the locus of optimal risk-return trade-offs slopes upward: risk is positively related to return, albeit at a decreasing rate. We therefore estimate an upper envelope of expected returns given its prediction risk as:

$$ER_{kt} = \alpha_k + \Gamma_1 RK_{kt} + \Gamma_2 RK_{kt}^2 + \Gamma_3 h_{kt} + \epsilon_{kt}, \quad (13)$$

where $\epsilon_{kt}$ is a total error term composed of random noise and inefficiency. Before turning to the estimation details of this risk-return frontier, it is important to note that both measures $ER$ and $RK$ are dependent on the production plan of the bank. Therefore, both are functions of exogenous variables. In this model all variables that explain profit also explain its prediction risk. We thus assume that observed most preferred production plans adequately reflect the choices of managers subject to their risk preferences. In fact, this is consistent with the standard assumption in traditional efficiency analyses that observed cost and profit combinations with production plans reflect cost minimizing and profit maximizing choices, respectively. This is necessary in light of our focus on the stability of RRE rankings relative to standard efficiency measures. In addition, we check below whether the prediction risk is an appropriate proxy for bank risk. We do so by regressing traditional risk proxies used in bank failure analyses on our suggested measure $RK$. More specifically, we select measures for capitalization, market and credit risk for each bank along the lines of failure studies for German banks by Porath (2006) and Koetter et al. (2005).

Furthermore, it is important to control for additional sources $h$ that may influence the expected profits of a bank.[16] Bos et al. (2005) suggest to control for systematic differences, i.e. heterogeneity, across banks that are not due to expected risk, inefficiency or random noise by adding a vector of control variables $h$ to the deterministic kernel of the frontier.

First, we account for Germany's fragmented banking market structure of commercial, savings and cooperative banks, the so-called three-pillar system. Koetter et al. (2006) discuss that business mix, regional scope of activities and income structures differ considerably within and across pillars.[17] This requires to control for heterogeneity in efficiency analysis.[18] Intuitively and in the context of risk-return efficiency, internationally active banks are likely to have more degrees of freedom to manage their risk-return trade-off more actively, for example by means of more complex financial products paired with better access to international financial markets. Our first group therefore comprises the largest commercial banks, central cooperative banks and so-called *Landesbanken*. These banks exhibit similar investment, funding and income structures and are internationally active (Hackethal, 2004). As a second group we distinguish local commercial banks. These banks are frequently incorporated as limited partnerships and are more specialized both in terms of production plans as well as regional scope. Third, we classify local savings banks as a group.

[16] Results for CE and PE reported below also include this control vector $h$ for heterogeneity in the deterministic kernel of the respective frontiers.

[17] Altunbas et al. (2001) also report differing standard CE and PE measures across groups.

[18] Alternatively, one may argue to estimate separate frontiers for these banking groups. However, Coelli et al. (1998) point out that efficiency scores are relative measures. Therefore, a comparison of efficiency scores derived from different benchmarks is not possible. Since we focus here on (rank) stability across CE, PE and RRE for Germany's banking system as a whole, we directly account for systematic differences in the specification of the cost, profit and risk-return frontiers, respectively.

These banks are ultimately owned by the government and operate on regionally confined markets (Frankenberger, 2004). Given their public ownership, especially these banks may not pursue pure profit maximization but exhibit fundamentally different preferences for return and risk compared to privately owned banks. As a final group, we specify local cooperative banks, which are by far most numerous. While also offering the entire product scope of a universal bank, these mutually owned banks operate on regionally demarcated markets, too. They provide financial services especially in the rural areas of Germany. Often owners are simultaneously customers and lending occurs at arm's length. In short, asset portfolios and funding structures are likely to differ systematically across banking groups in Germany.

Second, given that all savings and cooperatives as well as most commercial banks operate in regionally confined markets, we control for systematically different macroeconomic conditions in East and West Germany. In fact, Koetter and Wedow (2006) show that regional differences in bank efficiency and credit provision affect economic growth significantly different in German economic agglomeration areas. Therefore, we distinguish by means of an East-West dummy banks that operate in economically weaker areas of the Republic.

Third, bank profitability and risk may depend on the sheer size of the banking firm. In the most extreme case, the too-big-to-fail (TBTF) doctrine entails that very large banks are *de facto* 100% insured. In fact, Black et al. (1997) provide statistical evidence that financial markets extent a perceived TBTF insurance also to other banks. Ennis and Malek (2005) provide a formal model to assess the cost of TBTF insurance and show that the potential costs can be large due to excessive risk-taking. While the empirical evidence regarding these costs is mixed, their findings highlight that bank size is related to bank profits and risk-taking. The importance to account for size when predicting bank profits is further underpinned by profit efficiency studies that report PE difference across banks of different size, for example Altunbas et al. (2001). Therefore, we assign each bank in each year into one out of four size classes based on gross total assets and include this indicator variable in the risk-return frontier in equation (13), too.[19]

Obviously, the range of further bank-specific characteristics that may influence expected bank profit is not completely exhausted by this choice. We therefore follow Greene (2005) and account for additionally important factors through bank-specific fixed effects. We estimate the parameters in equation (13) with a panel estimator where non-random differences of banks' returns that are not due to inefficiency are captured by the bank-specific fixed effect, $\alpha_k$. Importantly, this estimator allows the $\alpha_k$'s to be correlated with the $RK$'s (Greene, 2005). In any year $t$, a bank $k$ can deviate from optimal risk-return trade-offs due to random noise, $v_{kt}$, or inefficient use of in- and outputs, $u_{kt}$. An important difference to alternative panel frontier estimators, for example in Lang and Welzel (1999), is that inefficiency can vary over time but is not further specified to follow a particular trend.[20]

To distinguish between random noise and inefficiency, we specify a composed total error, $\epsilon_{kt}$. For given risk, inefficiency leads to below frontier returns. Therefore,

[19]More specifically, in each year we create quartiles. Respective mean total assets in millions of €for size classes I through IV are, respectively: 5500, 339, 131 and 46.

[20]We avoid to assume a priori any (linear) development of an individual bank's RRE but rather allow it to develop unrestrictedly over time.

the total error is $\epsilon_{kt} = v_{kt} - u_{kt}$. The random error term $v_{kt}$ is assumed *iid* with $v_{kt} \sim N(0, \sigma_v^2)$ and independent of the explanatory variables. The inefficiency term is *iid* with $u_{kt} \sim N|(0, \sigma_u^2)|$ and independent of the $v_{kt}$. It is drawn from a non-negative distribution truncated at zero. After controlling through $h$ and fixed effects $\alpha_k$, RRE is derived as deviations from optimal risk-return trade-offs. For a given production plan and associated profits, a bank may simply incur too high risks compared to it's peers. We obtain bank-specific efficiency measures as the conditional distribution of $u$ given $\epsilon$ (Kumbhakar and Lovell, 2000). A point estimator of efficiency is given by $E(u_{kt}|\epsilon_{kt})$, i.e. the mean of $u_{kt}$ given $\epsilon_{kt}$. RRE is calculated as $[\exp(-u_{kt})]$ and equals one for a fully efficient bank. Likewise, RRE of 0.9 implies that a bank only realized 90 percent of potential return at given risk.

# 4 Data

Our data is obtained from the Deutsche Bundesbank. The sample covers virtually all universal banks from the three pillars in German banking: commercial, cooperative and savings banks between 1993 and 2004. Summary statistics for the cost and alternative profit frontier are depicted in the upper panel of table 1. In line with the intermediation approach, we specify four bank outputs, all measured in volumes of Euros. First, we account for the growing importance of interbank loans, $y_1$.[21] Second, we specify customer loans as $y_2$. Third, because of the increasing importance of non-lending business, we include investments in stocks and bonds as securities, $y_3$. Finally, we follow Clark and Siems (2002) and include off-balance sheet activities (OBS) as a fourth output.[22] To produce outputs, banks employ fixed assets, such as office buildings and ATM's, $x_1$, labor, $x_2$, and other borrowed financial funds, $x_3$, which includes customer deposits, bonds and other interest-bearing liabilities.[23] We follow the literature and obtain the respective input prices as depreciation and leasing expenses relative to fixed assets, $w_1$, personnel expenses over full-time equivalents, $w_2$, and total interest expenses over total borrowed funds, $w_3$.[24]

In the lower panel of table 1 we depict additionally required variables to estimate the AID. The mean tax rate equals paid taxes according to the profit and loss account divided by profit before tax. Mean output interest rates reflect interest revenue divided by total interest bearing assets. The shares for inputs and profit add up to a hundred percent.

[21] Koetter et al. (2006) report an interbank loan share of total assets for large banks of one third in 2003. Smaller banks also expanded this share on average by 7.4 percent each year since 2002.

[22] Including latent liabilities from discounted commercial paper (*"Wechsel"*), guarantees, collateral for third party debt, irrevocable credit commitments and other OBS.

[23] Note that our data does not allow to distinguish different sources of funding, for example saving deposits versus marketable funds. While different funding sources most likely influence a bank's risk profile, we thus have to follow the majority of efficiency studies and leave such risk-return determinants unspecified.

[24] As pointed out by a referee, the common approach in the literature to use imputed input prices can be problematic since prices should be strictly exogenous. Mountain and Thomas (1999) suggest therefore to drop input prices entirely from estimation. Instead, Koetter (2006) calculates a bank's input prices as the average of all other banks operating in it's regional market. He reports that only CE levels are around five percentage points lower but that rankings are fairly stable. Since we are here especially interested in the latter and to ease comparability with other studies we therefore follow here the standard approach followed in the majority of efficiency analyses.

Table 1: Summary statistics on German bank production 1993-2004

| **Variable** | **Description** | **Mean** | **SD** | **Min** | **Max** |
|---|---|---|---|---|---|
| $y_1$ | Interbank loans [1)] | 349.23 | 3,829.9 | 0.001 | 130,902 |
| $y_2$ | Customer loans [1)] | 721.76 | 5,612.4 | 0.035 | 214,536 |
| $y_3$ | Bonds and stocks [1)] | 2 328.69 | 2,717.6 | 0.003 | 102,994 |
| $y_4$ | Off-balance sheet items [1)] | 200.31 | 2,686.0 | 0.001 | 108,681 |
| $w_1$ | Price of fixed assets [2)] | 20.99 | 468.8 | 0.219 | 73,847 |
| $w_2$ | Price of labor [3)] | 51.54 | 161.6 | 0.377 | 20,692 |
| $w_3$ | Price of borrowed funds [2)] | 3.82 | 26.7 | 0.000 | 4,586 |
| $z$ | Equity [1)] | 55.49 | 426.1 | 0.223 | 18,207 |
| $C$ | Total operating cost [1)] | 70.28 | 569.1 | 0.035 | 16,932 |
| $PBT$ | Profit before tax [1)] | 17.67 | 110.6 | 0.040 | 4,198 |
| $t$ | Tax rate [2)] | 0.21 | 0.1 | 0.000 | 1 |
| $\tilde{p}$ | Mean output interest [2)] | 6.65 | 1.2 | 0.613 | 37 |
| $p_\pi$ | Price of after tax profit | 1.54 | 37.5 | 1.000 | 6,443 |
| $SW_{w_1}$ | Input share FA [2)] | 3.36 | 2.0 | 0.003 | 30 |
| $SW_{w_2}$ | Input share labor [2)] | 21.89 | 5.4 | 0.406 | 73 |
| $SW_{w_3}$ | Input share borrowed funds [2)] | 47.97 | 8.9 | 0.016 | 96 |
| $SW_{p_\pi \pi}$ | Input share PBT [2)] | 26.78 | 5.9 | 1.100 | 100 |
| $py + m$ | Total revenue [2)] | 87.95 | 667.8 | 0.191 | 20,280 |
| $TA$ | Total assets [2)] | 1,504 | 12,571.7 | 3.416 | 395,012 |

Notes: N: 29,960; [1)] in millions of Euros; [2)] in percentages; [3)] in thousands of Euros.

The data and results reported here follow the suggestion to also include extreme observations exhibited by minima and maxima, which appear odd at first sight. Consider, for example, the maximum price for borrowed funds of 4,586 percentage points. One option is to exclude observations which such "implausible values": paying more than a hundred percent interest for external finance does not seem plausible. However, any such exclusion policy is ultimately based on an arbitrary definition of "implausible". We checked here for the robustness of our results by following an approach suggested by Maudos et al. (2002) and excluded outliers according to the $1^{st}$, $5^{th}$ and $10^{th}$ deciles for each variable, respectively. We also applied this filter to obtained efficiency estimates for the full sample and then re-estimated CE, PE and RRE with the reduced samples, respectively. Since the results reported below did not change qualitatively, we decide here to rely on the stochastic element in SFA to account for random measurement error (Coelli et al., 1998).

# 5 Empirical Findings

In the discussion of our results we focus on the results from estimating the risk-return frontier and the comparison of efficiency measures.

## 5.1 Risk Return Frontier

To conserve on space we only depict parameter estimates of the risk return estimation in table 2.[25] In the first column we depict coefficients for a risk-return frontier that accounts for other factors only through the fixed effect. Both the direct and the squared risk term are significantly different from zero. In line with expectations and earlier findings for U.S. banking markets, an increase in risk taking increases expected profits at a decreasing rate (Hughes et al., 1996).

To test if the specification of a frontier as opposed to an average response function is appropriate, we follow Kumbhakar and Lovell (2000). In the maximum likelihood estimation, $\lambda$ is parameterized as the ratio of variation due to inefficiency relative to random noise. It provides a mean to test whether the assumption of deviations from optimal profits given risk due to inefficiency is supported. We reject the null hypothesis that $\lambda$ equals zero and thus find support for a stochastic risk-return frontier.[26]

In the bottom panel of table 2 we depict mean efficiency scores and standard deviations from this risk-return frontier and compare them to results from the cost and profit frontiers, respectively. Mean RRE is around 78%, signifying that banks could have realized considerably higher returns at given production plans and associated risk. While the difference between RRE and CE is small, the efficiency differential between RRE and PE amounts to 28 percentage points. Consequently, the neglect of potentially different risk preferences in traditional PE analysis may overstate potential inefficiencies since higher RRE indicates that lower profits may merely result from less appetite for risk associated with these returns. In fact, a dispersion of PE measures around twice as high as for RRE measures indicates that some banks may be identified either as very profit efficient or inefficient as a result of "bets", which either materialized in favor of the bank or against it. Obviously, we need to analyze rank stability more carefully and will do so below.

Beforehand, it is worthwhile to note that this result is robust also after accounting more explicitly for different business strategies of banking groups, regional location and sheer bank size. The three subsequent columns in table 2 depict coefficients for the respective dummy variables included in $h$.[27]

While the direction and magnitude of the effect of risk on return is largely unaffected, the fit of the frontier improves as exhibited by higher log-likelihood values. In line with the idea of potentially excessive risk taking of very large banks, the indicator variable for the group of (inter)nationally active institutes indicates lower expected returns compared to local banks from the savings and cooperative bank pillar. Together with the negative coefficient for local commercial banks, this result is in line with previous findings for European bank efficiency, which also report worse performance compared to local savings and cooperative banks (Altunbas et al., 2001). In the same vein, and independent of pillar membership, larger bank size is

[25]Parameter estimates of cost and alternative profit frontier estimates are available upon request. To control for fixed time effects all reported results are estimated with yearly indicator variables.

[26]In addition, we conducted for all specifications log-likelihood ratio tests if OLS is preferable compared to SFA and reject these hypotheses, too (Kumbhakar and Lovell, 2000).

[27]Reported CE and PE estimates result accordingly from cost and profit frontiers where $h$ is specified in the deterministic kernel, too.

Table 2: Risk-return frontiers for universal German banks 1993-2004

| **Parameter estimates** | | | | | |
|---|---|---|---|---|---|
| | | **Groups** | **Region** | **Size** | **All** |
| | $\Gamma$ | $\Gamma$ | $\Gamma$ | $\Gamma$ | $\Gamma$ |
| $RK$ | 11.444*** | 11.581*** | 11.136*** | 11.384*** | 10.680*** |
| $RK^2$ | -4.853*** | -5.701*** | -3.756*** | -4.952*** | -2.588** |
| National banks | | -0.148*** | | | -0.146*** |
| Local commercial | | -0.147*** | | | -0.143*** |
| Local savings | | 0.035*** | | | 0.031*** |
| East | | | 0.099*** | | 0.090*** |
| Size class I | | | | -0.036*** | -0.035*** |
| Size class II | | | | -0.006*** | -0.009*** |
| Size class III | | | | 0.004*** | 0.001 |
| $\sigma$ | 1.243*** | 1.088*** | 1.045*** | 1.194*** | 1.031*** |
| $\lambda$ | 15.779*** | 18.569*** | 13.160*** | 15.491*** | 17.916*** |
| LL | -13,881 | -9,742 | -8,992 | -12,722 | -8,200 |

| **Efficiency estimates** | | | | | | |
|---|---|---|---|---|---|---|
| **RRE** | *Mean* | 78.7 | 80.1 | 79.4 | 79.1 | 83.8 |
| | *SD* | 4.94 | 5.21 | 4.94 | 4.93 | 3.82 |
| **CE** | *Mean* | 75.6 | 75.8 | 76.4 | 75.5 | 77.1 |
| | *SD* | 5.30 | 5.29 | 5.26 | 5.33 | 5.27 |
| **PE** | *Mean* | 50.5 | 50.6 | 52.6 | 53.0 | 55.0 |
| | *SD* | 8.9 | 8.9 | 9.0 | 9.1 | 8.7 |

Notes: All estimations with time dummies (not reported); N:29,620; K:3,567; $\sigma^2 = \sigma_u^2 + \sigma_v^2$; $\lambda = \sigma_u/\sigma_v$; National banks: Commerzbank, Deutsche Bank, Dresdner Bank Hypovereinsbank, Postbank, Central cooperative banks and *Landbanks*; Mean total assets size in millions of €: I: 5,500; II: 339; III: 131; IV: 46; Efficiency measures in percentages.

associated as well with lower expected returns. Apart from such extreme too-big-to-fail scenarios it may simply be more difficult to manage risk-return trade-offs in larger, more complex organizations as opposed to running a compact universal bank of smaller size. Finally, the positive coefficient for expected profits of banks located in East Germany is in line with earlier PE findings per state reported in Koetter (2006). Less buoyant macroeconomic conditions may in fact foster a more careful approach of bankers to assess return and risk associated with choosing a particular production plan.

In sum, differences in mean CE, PE and RRE are not due to the neglect of banking group membership, location or sheer size. In fact, the risk-return frontier including all control variables for heterogeneity depicted in the last column of table 2 exhibits the best fit while yielding at the same time even larger efficiency differentials. We therefore use this specification to assess next the rank stability of CE, PE and RRE, respectively.

## 5.2 Efficiency rank stability

In the upper panel of table 3 we compare the mean level of CE and PE to mean RRE in table 2 of 84%. After controlling for banking group, location and size effects, cost efficiency differs already by 7% from risk-return efficiency. The difference between RRE and PE is substantially larger with 29%. While CE and PE estimates are fairly in line with earlier European and US studies, especially the latter seems to suffer from a failure to account for the possibility that banks may have chosen consciously less return in exchange for less risky production plans.

Table 3: Extreme performers according to CE, PE and RRE

| | CE | | PE | |
|---|---|---|---|---|
| **Mean** | 0.771 | | 0.550 | |
| $\rho^{1)}$ | 0.227*** | | -0.430*** | |
| **Wilcoxon**$^{2)}$ | -142.7*** | | -148.8*** | |
| **RRE decile** | **CE** | | **PE** | |
| | *Top* | *Flop* | *Top* | *Flop* |
| **1 (Flop)** | 8.4 | 31.2 | 32.0 | 8.4 |
| **2** | 7.7 | 14.1 | 22.3 | 5.3 |
| **3** | 7.1 | 10.3 | 15.4 | 5.5 |
| **4** | 8.3 | 7.8 | 9.6 | 4.8 |
| **5** | 8.1 | 7.4 | 6.4 | 5.6 |
| **6** | 8.0 | 6.8 | 5.2 | 7.2 |
| **7** | 9.7 | 5.5 | 4.1 | 7.9 |
| **8** | 10.7 | 5.3 | 2.4 | 10.3 |
| **9** | 11.9 | 5.4 | 1.6 | 14.6 |
| **10 (Top)** | 20.1 | 6.3 | 1.2 | 30.4 |
| **N** | 2,962 | 2,962 | 2,962 | 2,962 |

Notes: $^{1)}$ Spearman's rho; $^{2)}$ Wilcoxon rank-sum test for equality of means; $^{***)}$ significant at the 1%-level; Frequencies per decile in percent.

Apart from mean efficiency differentials, however, especially extreme performers are of interest in a benchmarking exercise. Consider therefore rank-order correlations between RRE and the two traditional measures. Despite relatively similar mean RRE and CE measures, Spearman's $\rho$ reveals that the composition of best- and worst performers are significantly different after allowing banks to choose production plans subject to different risk preferences. Apparently, some cost efficient banks, for example due to relatively low spending on risk management, score poorly if we allow more explicitly for risk in the analysis of efficiency.

A substantial negative correlation between profit efficiency and risk-return ranks supports this finding even clearer. This is an important result since it indicates that some banks appear in traditional benchmarking exercises as role models while in fact they may have merely been lucky. Consider for example a bank that chooses a very risky production plan, for example lending to low quality borrowers at high interest premia. If such risky lenders do not default, the bank is identified as very efficient since it achieved above average returns for given nominal values of output volumes compared to it's peers. However, those peers may not be inefficient but rather have consciously chosen different production plans that reflect less risk-inclined strategies as such a hypothetical lemon-lender: namely to lend at lower rates to less risky debtors.

To test if CE and PE scores differ significantly from RRE, we use a Wilcoxon rank test depicted in table (3), too.[28] Results confirm that both CE and PE distributions are different from that of RRE and thus support our earlier conclusion on the basis of first moments alone.

Given the particular importance of extreme performing banks, for example for regulatory purposes, we focus in the lower panel of table 3 on the re-distribution of the top and bottom deciles of the RRE rank distribution, so-called top and flop performers, respectively. We do so because correlation coefficients alone may be the result of a few outliers that are drastically re-classified.

Consider to this end first re-rankings of the most and least cost efficient banks in terms of their ability to balance risk and return. In the first column of table 3 we depict the distribution of the top ten percent banks in terms of CE across RRE deciles. Around 42% of the most cost efficient banks are simultaneously identified in one of the top three deciles according to RRE (deciles 8 through 10). In turn, almost a quarter of all top cost performers are among the least efficient in the risk-return space (deciles 1 through 3). Consequently, CE does not yield diametrically different rankings for the majority of extremely cost efficient banks. But there exists a considerable portion of banks that appear to achieve high cost efficiency by combining less spending on resources with higher risk-taking, thus leading to markedly poorer performance according to RRE.

In terms of identifying worst performers, CE and RRE yield somewhat more consistent results in the second column of table 3. More than half of those banks identified in the lowest cost efficiency decile (55%) are also to be found in one of the three least performing RRE deciles (deciles 1 through 3). Nonetheless, there are still 16% of worst CE performers that may be identified mistakenly as potentially troublesome banks (deciles 8 through 10). Since these banks are in fact located among the best RRE performers it appears that some banks deliberately decide to spent more resources on a given production plan as to manage the associated risk more efficiently.

As already indicated by a negative correlation coefficient, PE rankings are much less consistent with those resulting from a model of utility maximization. In the third and fourth column of table 3 we report that almost 70% of the most (deciles 1 through 3) and around 55% of the least profit efficient banks (deciles 8 through 10) are reclassified according to RRE as least and best performing institutes, respectively. Only 5% of banks are simultaneously identified as top performers according to both PE and RRE. This result underpins that high returns are per se no sign of role model banking conduct. More specifically, even the relative ability to maximize profits when converting inputs into financial services and products, i.e. profit efficiency, can be misleading if the associated riskiness of that production plan is not modeled more explicitly.

[28] Since efficiency measures are not normally distributed we do not use t-tests.

In sum, despite similar levels of RRE and CE, both measures yield different rankings of best and worst performers, respectively. Differences between PE and RRE are even stronger. Markedly different rankings signal to us that the identification of top performers on the basis of PE is problematic if risk is neglected. Fundamentally different rankings, especially of top PE performers, indicate that extremely high PE may in fact be not risk-return efficient at all. These results suggest to use risk-return efficiency as a complementary measure when assessing the stability of the banking system.

As a word of caution, however, we need to realize that the "true" efficiency of a bank remains, of course, unobservable. In fact, one may object that this non-standard approach to measure bank risk cannot capture the financial soundness of a bank appropriately. We therefore analyze next the relation between prediction risk and traditional proxies of bank risk.

## 5.3 Robustness of prediction risk

To check the robustness of prediction risk we follow suggestions by Hughes (1999b) and DeYoung et al. (2001) and regress traditional risk proxies on this measure. In line with these studies and in the vein of previous failure studies for German banking (Porath, 2006; Koetter et al., 2005), we analyze the relation between prediction risk and traditional measures for capitalization, credit and market risk as well as a simple measure of market power.[29]

We depict parameter estimates alongside with descriptive statistics in table 4. To assess the capitalization of banks we specify the equity ratio as total bank equity and reserves to gross total assets. Higher equity ratios reflect a better ability of the bank to absorb sudden losses in asset values, for example due to asset price deteriorations. A negative and significant coefficient is in line with the expectation that *ceteris paribus* higher capitalization reduces bank risk.[30]

We specify next three measures of credit risk. First, banks with relatively high share of customers loans in their business mix are more exposed to credit risk (King et al., 2005). We find that an increase in the share of customer loans is significantly and positively related to the risk proxy suggested here. Second, higher provisions against loan losses relative to the total amount of claims on non-banks reduce risk. As with capitalization, a larger buffer against unexpected credit losses fosters the stability of the bank. In turn, our third proxy for credit risk captures is the share of bad loans written off relative to total non-bank claims. It exhibits a positive relation to our risk proxy. Unexpected higher credit defaults not covered by provisions thus increase the riskiness of the bank, which is also in line with expectations.

[29]We applied a selection procedure along the lines of Hosmer and Lemshow (2000). Out of an initial total of around 150 candidate covariates for banks' risk profiles we select the reported vector on the basis of stepwise regression. More details on choosing a financial profile to predict the risk of bank default can be found in the aforementioned studies.

[30]Note that we neglect what follows any potential interdependencies. One may argue that higher risk induces increasing capital ratios. While our specification here follows the majority of hazard models, it should be noted that modeling dynamic interdependencies of risk, performance and stability proxies is an interesting question in it's own right. In our view, this may be accomplished with (panel) VAR techniques but we deem the issue out of the present paper's scope.

Table 4: Relation between traditional risk proxies and expected risk from the AID

| **Risk proxy** | **Estimation results**[1] | | **Descriptive Statistics**[2] | |
|---|---|---|---|---|
| | $\beta$ | *p-value* | *Mean* | *SD* |
| Equity ratio | -0.652 | 0.000 | 6.16 | 2.76 |
| Customer loan share | 0.136 | 0.000 | 58.08 | 12.77 |
| Loan loss provisions | -0.255 | 0.071 | 0.69 | 2.41 |
| Credit write off's | 2.827 | 0.000 | 0.77 | 1.00 |
| Security share | 0.329 | 0.000 | 22.67 | 10.25 |
| OBS business share | 0.109 | 0.000 | 10.23 | 10.94 |
| Market share per state | 0.466 | 0.000 | 0.63 | 3.48 |

[1] OLS estimates with robust standard errors and time dummies (not reported); N: 29,620; $R^2$: 72.28%;

[2] All risk proxies measured in percent; SD: Standard deviation.

Notes: Total equity including reserves to gross total assets (GTA); customer loans to GTA; Loan loss provisions relative to total claims on non-banks; Loan write offs to total claims on non-banks; Stocks and bonds to GTA; Off-balance sheet activities to GTA.

We approximate the exposure of banks to market risk, first, with the share of stocks and bonds as well as, second, the ratio of off balance sheet activities to gross total assets. Increasing exposures in either asset class are positively related to our risk measure, too. Finally, we also find that higher market share increase the riskiness of a bank as measured by prediction error.

In sum, these traditional proxies for different categories of banking risk explain 72% of the variation of the suggested risk proxy derived from the utility maximization model. While this selection is clearly not exhaustive, we conclude that this alternative measure of bank risk is well suited to capture most of the effects of important risk variables. Hence, the efficiency to trade expected returns for predicted risk appears an important and meaningful measure that takes different risk preferences of bank managers more explicitly into account compared to standard CE and PE.

# 6 Conclusion

In this study, we use a structural model based on utility maximization to study the stability of efficiency rankings among German universal banks between 1993 and 2004. More specifically, we hypothesize that bank risk needs to be measured more explicitly in bank efficiency analyses as to avoid confounding alternative objectives and preferences with excessive cost-cutting and/or risk-taking when minimizing cost and/or maximizing profits. To this end we estimate the ability of bank managers to choose risk-return alternatives subject to heterogeneous risk preferences. Production choices result in predicted return and the associated prediction risk. The latter two constitute the space in which we estimate risk-return efficiency (RRE).

Our comparison to standard efficiency measures yields two results on the basis of first moments of efficiency distributions alone. First, mean cost efficiency (CE) is somewhat lower than RRE and, second, mean profit efficiency (PE) is substantially lower than RRE: the former differential accounting for 7 percentage points and the latter for 27 percentage points.

Specification tests support the formulation of risk-return trade-offs as a stochastic frontier. Furthermore, we conclude in line with previous studies (Hughes and Mester, 1993; Bos et al., 2005) that accounting for systematic differences across banks other than inefficiency is necessary. We control for banking group membership to account for systematically different business mixes across and within Germany's banking pillars, location in less buoyant economic areas and bank size. Qualitatively, the effect of predicted risk on expected returns is robust: higher risk-taking increases expected returns at a decreasing rate. Moreover, efficiency differentials to traditional CE and PE measures even increase.

We investigate resulting rankings in more depth and find that especially RRE and PE rankings differ significantly. A considerable number of banks identified as top performers in terms of PE are simultaneously poor risk-return optimizers. This result suggests that benchmarking exercises should consider RRE measures as well as to ensure that high PE does not merely result from excessive risk-taking paired with luck. While less drastic, CE rankings also differ substantially for a considerable portion of Germany's banking landscape, too. This result suggests that some very cost efficient banks combine cost-cutting, for example on risk management capacities, with higher risk-taking, thus leading to high CE but low RRE.

Finally, we check whether our proxy of bank risk is related sensibly to more traditional measures of bank capitalization, credit and market risk. In line with previous risk-return efficiency studies for the US (Hughes, 1999b; DeYoung et al., 2001) and German bank default studies, our results highlight two conclusions. First, already a reduced vector of traditional risk measures explains around 73% of the variation of prediction risk. Hence, prediction risk derived from a structural model of bank behavior is closely related to more traditional risk proxies. Second, with respect to the direction of effects, estimated coefficients are in line with expectations. We conclude that the risk measure used in this study is also suited for banking markets outside the US and contains important additional information to consumers, professionals and regulators active in the banking industry.

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# 7 Appendix: Restrictions

Partial differentiation of the expenditure function to arrive at the input and profit demand functions implies the following symmetry restrictions:

$$\delta_{ij} = \delta_{ji} \quad \text{and} \quad \omega_{si} = \omega_{is} \quad \text{and} \quad \omega_{s\pi} = \omega_{\pi s} \quad \text{for all } i, j, s \text{ and } \pi. \tag{14}$$

The expenditure function is homogenous of degree one and the share equations are thus of degree zero (Coelli et al., 1998). The bank alters its demand for inputs and profit only if *relative* prices change. Therefore, the following restrictions apply:

$$\sum\nolimits_j v_j + \mu = 0, \tag{15a}$$
$$\alpha_p + \sum\nolimits_j \omega_j + \eta_\pi = 1, \tag{15b}$$
$$\alpha_{pp} + \sum\nolimits_t \phi_{jt} + \psi_{j\pi} = 0, \tag{15c}$$
$$\phi_{pt} + \sum\nolimits_s \omega_{st} + \omega_{t\pi} = 0, \tag{15d}$$
$$\theta_{pj} + \sum\nolimits_t \gamma_{jt} + \gamma_{j\pi} = 0, \tag{15e}$$
$$\eta_{\pi\pi} + \psi_{p\pi} + \sum\nolimits_s \omega_{s\pi} = 0, \tag{15f}$$
$$\psi_{pz} + \sum\nolimits_s \omega_{sz} + \eta_{\pi z} = 0, \tag{15g}$$
$$\frac{1}{2}\alpha_{pp} + \frac{1}{2}\sum\nolimits_s \sum\nolimits_t \omega_{st} + \sum\nolimits_t \phi_{pt} + \frac{1}{2}\eta_{\pi\pi} + \psi_{p\pi} + \sum\nolimits_s \omega_{s\pi} = 0. \tag{15h}$$

To impose homogeneity we divide all prices, i.e. $w, p_\pi$ and $\tilde{p}$, by the price of physical capital. The adding-up restrictions are

$$\sum\nolimits_i \omega_i + \eta_\pi = 1, \tag{16a}$$
$$\sum\nolimits_i \omega_{si} + \omega_{s\pi} = 0, \tag{16b}$$
$$\sum\nolimits_i \phi_{pi} + \psi_{p\pi} = 0, \tag{16c}$$
$$\sum\nolimits_i \gamma_{ji} + \gamma_{j\pi} = 0, \tag{16d}$$
$$\sum\nolimits_i \omega_{\pi i} + \eta_{\pi\pi} = 0, \tag{16e}$$
$$\sum\nolimits_i \omega_{iz} + \eta_{\pi z} = 0, \tag{16f}$$
$$\sum v_j + \mu = 0. \tag{16g}$$

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