Tjalling C. Koopmans Research Institute

Discussion Paper Series nr: 04-08

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The Stability of Efficiency Rankings when Risk-Preferences are different

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January 2004

Abstract
In this paper we analyse bank efficiency in Germany for four cross-sections of data during the period 1995-2001. Under the assumption of cost minimisation we obtain firm-specific efficiency estimates using stochastic frontier analysis. To explicitly allow for different risk preferences when measuring efficiency we then develop a model based on utility maximisation. Using the almost ideal demand system, input- and profit demand functions are estimated and risk-preferences recovered. Efficiency is then measured in the risk-return space. Efficiency scores improve substantially and the dispersion of performance across sectors and size classes vanishes. Rank-order correlation between the two measures is low or insignificant. This suggests that best-practice institutes should not be identified only on the basis of cost efficiency. However, in terms of magnitude risk-return efficiency seems to be of less importance than cost efficiency.

JEL classification: G21, D12, L21

Acknowledgements
I like to thank the attendants of the Tjalling C. Koopmans Institute seminar series for helpful comments. In addition, the input provided by Rob Alessi, Jaap Bos, Wolter Hassink and Clemens Kool is gratefully acknowledged.

1 Introduction

To measure the performance of financial institutions Stochastic Frontier Analysis (SFA) enjoyed considerable popularity since it's introduction by Aigner et al. (1977), Battese and Corra (1977) and Meeusen and Broeck (1977). The production process is at the core of the analysis. Under behavioural assumptions like cost minimisation or profit maximisation banks' success (or failure) to convert inputs as efficient as possible into outputs is evaluated. In identifying what "as efficient as possible" exactly means one needs an appropriate benchmark. SFA is a methodology to estimate such a benchmark and measure firm-specific efficiency. While many applications exist for banking markets in the US the number of analyses for Europe is still limited. Perhaps more importantly, the vast majority of studies ignores the role of risk when measuring efficiency. This paper aims at extending the literature by adressing the role of risk directly.

To this end we bridge the SFA literature with insights from the risk literature. If agents are risk-neutral the result obtained by Modigliani and Miller (1958) states that cost minimisation and profit maximisation are equivalent to value maximisation. However, if risk preferences differ, efficiency rankings obtained under the traditional assumption might be misleading. A bank earning lower profits than a peer is cet. par. considered inefficient. However, lower profits earned at lower risk might just reflect a higher degree of risk aversity. Hence, the bank is just as efficient as it's peer when efficiency measurement is adjusted for different risk preferences. Two alternative models how to incorporate risk into the formulation of the efficient benchmark have been used to account for different risk preferences. The first has been introduced by Hughes and Mester (1993) and accounts for risk differences by conditioning production technology on equity capital. Put differently, alternative capital structures of banks are considered when formulating the benchmark because the source of funding causes differences in performance. Efficiency is measured relative to a cost frontier. A range of empirical research employed this theoretical framework to benchmark financial institutions in the US and, to a lesser extent, in Europe. It is the current standard approach to incorporate risk into the analysis. Berger et al. (1993) and Berger and Humphrey (1997) provide extensive reviews of studies for the US. European studies have been reviewed in Goddard et al. (2001) and Molyneux et al. (1997).

The second model has been developed by Hughes and Moon (1995) and Hughes et al. (1996). It incorporates risk-preferences on behalf of managers by departing substantially from the assumption of cost minimising behaviour. Instead, managers are expected to maximise utility while having particular preferences about available production plans. These preferences are, among other things, influenced by the manager's attitude towards risk-taking and can be recovered from production data using the Almost Ideal Demand system developed by Deaton and Muehlbauer 1980. The optimal demand for profits is then used to calculate risk-return efficiency. A number of studies for the US applied this model to examine the enforcement of regulatory corrective actions (DeYoung et al. 2001), agency problems at banks (Hughes et al. 2003), scale economies (Hughes et al. 2001) and the recovery of risk preferences(Hughes et al. 2000). Of particular interest is whether accounting for risk changes not only the level of efficiency but especially the ranking of efficient and inefficient firms. This way of modelling efficiency measurement is a new direction of research. So far, it has only been applied to the US banking market and this paper, to our knowledge, represents its introduction to German banking.

This paper contributes to the literature on efficiency analyses by examining banks in Germany. According to the ECB (2002) the importance of banks in Germany's financial system remains substantially higher compared to other European countries. As a role model of a bank-based system German banks are an interesting subject of investigation. Performance measurement is of special interest because of the sectors' prominent role in the financing process.[1] This stronger involvement might entail a higher risk with respect to the economys' stability if banks are performing poorly (see for example Goddard et al. (2001), p.100). At the same time a number of practioners repeatedly raised the point that German banks are suffering from inefficiency (see for example The Economist (2003a) and The Economist (2003c)). We investigate this claim by determining firm-specific performance under alternative behavioural assumptions. Firm-specific estimates of bank efficiency are expected to yield insights into which are "best-practice" banks. Measuring firm-specific performance against a risk-adjusted benchmark might result in different best-practice banks than under cost minimisation. We are interested in the differences between the two efficiency measures with respect to

1. average efficiency levels,
2. ranking of banking firms,
3. the development of mean efficiency over time and
4. differences between banks of alternative size and sector classes.

To summarise, the goal of this paper is to compare firm and industry efficiency rankings when accounting for risk according to alternative methodologies to analyse efficiency.

To this end the paper is organised as follows. Section two introduces the reader to that portion of the existing efficiency literature for Germany which is using compareable measures. Section three describes how the production technology of the banking firm is modeled. Based on the assumption of cost minimisation a baseline model is provided. Thereafter, the assumption of utility maximisation is used in order to include risk preferences when modeling a way to measure bank performance. In the fourth section the empirical models to test the alternative theoretical models and to derive efficiency estimates are devised. The fifth section introduces the reader to the data and discusses the construction of the variables used. The following section discusses and interprets the empirical findings. Ultimately, the results are compared regarding the order of rankings and the mean level of efficiency in the examined periods. Section seven concludes.

[1] For an early reference about the structure of european financial markets consider Mayer (1988). More recent contributions about the particularities of German banks are Agarwal and Elston (2001), Lehman and Neuberger (2001) and Gorton and Schmid (2000).

2 Efficiency literature

The concept of efficiency employed in this research, originally introduced by Leibenstein (1966), is referred to as X-efficiency.[2] In the context of the banking firm it evaluates not only the ability to formulate a production plan but also how well the bank performs in attaining it. Principally, this concept requires some best-practice benchmark against which actual performance can be measured. Depending on whether this benchmark is formulated as a production, cost or profit function the literature uses terms which range from productive efficiency to cost efficiency or other alternative labels.

The number of applications to German Banking is surprisingly smal. Available results frequently find that gains from unexhausted scale economies are low compared to cost inefficiencies Berger and Mester (1997). This is in line with results from the US and other European countries (see for example Berger and Humphrey 1997 and ?)). Thus, efficiency apparently has a stronger influence over scale economies on bank performance. We therefore focus on efficiency instead of scale economies. We start by reviewing analyses concerning only the German banking market. Then we continue by considering a number of recent European studies, in which German banks are examined as well. To illustrate the magnitudes of scale economies and efficiency both kind of results will be presented where available.

The most recent study by Altunbas et al. (2001) examines profit and cost efficiency next to scale economies for the time period from 1989 until 1998. They focus on the three major banking sectors of private, cooperative and savings banks and study the differences between sectors and size classes. Applying a stochastic frontier and a distribution free methodology they find considerable scale economies for all of the three sectors of around 9 percent. Cost inefficiencies are found to be higher for commercial institutes and amount to 17 percent for the banking sector as a whole. The authors find furthermore that the ability of banks to realise potential profits is even worse, as average profit inefficiency amounts to 20 percent.[3] Thus, they are underpinning the idea that the actual size of banking operations is too small compared to the optimal size. In a cross-sectional study with data from 1992 Lang and Welzel (1998b) examine almost half of the entire German banking market with a thick frontier approach. While they do not find any evidence for economies of scope they identify increasing returns to scale for banks up to a size of about 5 billion DM in total assets. Their sample of 1490 banks thereafter supports the commonly held view of a U-shaped cost curve. Another study by the same authors (Lang and Welzel 1996) examines an alternative data set of 757 cooperative banks over the period in 1989-1992. Here, they find evidence of moderate scale economies. In particular, smaller banks seem to enjoy more than their larger counterparts potential gains from increasing the size of their operations. This also holds for their findings of cost efficiency. The average bank in their sample deviate considerably from the best practise frontier for all size classes. The larger institutes are performing worse than the smaller

[2] For a more detailed discussion of the concept of X-efficiency refer to Leibenstein (1978).

[3] Profit efficiency resembles the frontier logic but differs from cost efficiency by specifying the dual as a profit function. Under perfect competition the two approaches are equivalent (see for example chapter 3 in Beattie and Taylor (1985)).

classes. However, they restrict their findings explicitly to the sample and mention that conclusions for the entire banking population cannot be made. In a study of the 283 Bavarian Cooperative bank mergers Lang and Welzel (1998a) employ stochastic frontier analysis for panel data. They find average cost inefficiency to be around 8 percent before the merger took place. They also find evidence by comparing the performance of observed and hypothetical merged banks that concentration leads to improvements in terms of cost efficiency and scale. Again, they note that their study is restricted to the cooperative sector in general and the Bavarian state in particular.

A study by Carbo et al. (2002) investigates the European savings bank sector for the period between 1989 and 1996. By applying stochastic frontier analysis to a cost function they find scale economies between 7 and 10 percent for the whole sample. Again, cost inefficiency is considerably higher, amounting to approximately 22 percent. Another study by Maudos et al. (2002) compares banking industries of ten European countries with a sample of 832 banks over the period 1993 to 1996. Using a stochastic frontier and a distribution free approach they find cost inefficiencies to range around 13 percent for Germany, while average inefficiency amounts to approximately 19 percent. Regarding scale economies Cavallo and Rossi (2001) compare an unbalanced panel of 442 banking firms from six European countries over the period 1992 to 1997. They find economies of scale for all specified banking sectors. According to them German banks exhibit economies of scale of around 9 percent, while the lion share of potential gains lies with smaller banks and the result for large banks indicates constant returns to scale. In additon, they provide estimates of cost inefficiency measured with a stochastic frontier analysis. German banks perform in the international comparison best with an inefficiency of 14 percent. Altunbas et al. (2001) employ a Fourier Flexible form to analyse cost efficiency and scale economies in European banking. For the latter they report scale economies of around 6 percent. However, most of the potential gains are again confined to the group of small banks, amounting to 17 percent at total assets below 100 mil ECU. Cost inefficiencies decline over time from 22 percent in 1989 to 14 percent in 1996. In contrast to scale economies their findings suggest that cost efficiency is equally distributed across size classes.

Summing up, four points are noteworthy. Firstly, the number of studies for Germany is not matching the abundance of analysis for the US banking market. Secondly, various methodologies have been employed, including stochastic, distribution free and thick frontier analysis, translog and Fourier flexible forms, cost and profit efficiency. Results tend to be fairly stable: cost inefficiencies clearly dominate scale economies. The former being around 15 to 20 percent and independent of asset size, the latter tend to be around 5 to 10 percent on average. Importantly, scale economies seem to apply in particular to smaller asset size classes below 3 bn Euro of total assets. Thirdly, and perhaps surprisingly, in international comparison the German banking sector seems to perform rather well. Fourth, none of the studies at hand explicitly put risk at the core of its research. This is the main motivation to compare results from traditional SFA with risk-adjusted efficiency results to learn about the stability of rankings.

3 Managing Bank Production

In this section the theoretical models to specify appropriate benchmarks are developed. We start by discussing characteristics of bank production. Subsequently, we introduce a cost minimisation model. It will serve as the fundament to derive a cost frontier in the next section. Finally, we introduce a utility maximisation model which allows us to derive optimal profit demand conditional on risk preferences. This profit demand function will then serve in the following section to formulate a risk-return frontier.

3.1 Production Technology

As laid out in section **??** the measurement of X-efficiency requires the specification of an adequate frontier. Duality implies that we have to have some knowledge about the primal, that is the underlying production technology. According to the theory of the banking firm two conceptually different ways can be chosen to model bank production (Freixas and Rochet 1997).

On the one hand the production approach considers banks to provide depositors and borrowers with services such as processing withdrawls. This view was initially put forward by Benston (1965). It regards banks as consisting of a main branch conducting all management decisions such as lending and investment decisions. In addition, fully transparent branches are merely collecting funds and executing head quarters' orders. Hence, bank production is best described as using the inputs physical capital and labour to produce services, proxied for example by the number of orders processed. This approach has been mostly used when analysing the efficiency of branching networks.

The alternative approach is known as the intermediation approach and was advocated by Benston et al. (1982). Here, in addition to physical capital and labour, funds available for lending are considered inputs. This adds deposits and funds borrowed in financial markets to the production technology. According to this theory the central task of the banking firm is the intermediation of funds collected from alternative sources into output, specified as the volume of loans and investment outstanding. As the subject of investigation is not a branching network of a single banking firm but the efficiency of the German banking system as a whole the intermediation approach is chosen to model bank production.

To this end let a banking technology be denoted by the transformation function $T(y,x)$ where y is a vector of outputs including loans, securities and off-balance sheet activities (OBS). The input vector is denoted by x and contains labour, physical capital and deposits. Input prices are depicted by w. Regarding the role of deposits some authors do not agree on their role as inputs. Some argue, they should be considered instead as output because their nature as demandable debt causes the bank to provide transaction services, which in turn cause cost. Others argue that deposits earn interest and should therefore be considered as output. Two arguments can be raised why to include deposits as inputs. Firstly, the assumption of the intermediation approach emphasises the ability of banks to transform assets of different maturity, liquidity, divisibility and risk. Rather than the aspect of physically serving clients of the bank in handling their transactions it is this matching process which characterises production in the intermediation approach. The fact that deposits cause costs and carry interest is secondary to its role as source of funding. If the interest earned by deposits is the argument to include deposits as output it would rather be appropriate to regard the earnings generated through deposits as output. However, interest income is already a performance measure in itself. Hence, it is hardly suited to serve as an output. The second argument has been raised by Hughes and Mester (1993) for the first time. Their point rests in the specification of the cost function. They define operating cost as being incurred by the production factors physical assets and labour to produce a given output. In addition to these variable inputs they assume the level of deposits to be given, hence the operating cost function depends on the level of deposits. They argue if deposits are inputs an increase in its level should cet. par. allow a reduction in the expenditure on other variable inputs, thereby decreasing costs. In a number of studies they test this hypothesis and find deposits to be treated as inputs.

Two issues should be noted about the specification of bank production. First, we consider the long run which implies that we are dealing with variable cost functions. This is to ensure that our concepts defined in section ?? apply. Geometrically, this can be seen in figure ?? where the primal eminates from the origin. Thus, its dual should also start from the origin which is the case in the long run. Secondly, the specification of OBS acitivities as output is the result of the growing importance as a source of earnings and an activity to spend costs on for banks. The importance to include OBS started to enter the literature in contributions by Jagtiani et al. (1995), Hunter and Timme (1995) and Jagtiani and Khanthavit (1996). In a more recent study Clark and Siems (2002) perform an extensive comparison of different specifications to test the importance to include OBS. They find across alternative functional forms that the inclusion of OBS as an output is significant. This result is also obtained for different methodologies. They conclude that neglecting OBS as inputs affects efficiency estimates considerably. Hence, we will include OBS as well.

3.2 Cost minimisation

For the case of cost minimisation the problem requires us to solve for the level of inputs demanded at given factor prices and output quantities to incur the least cost. Following the standard approach in the microeconomics literature (see e.g. Mas-Colell et al. 1995) and using the variables defined in 3.1 we can write

$$\begin{aligned} C(y, w_i) &= \min_x \, (w_i * x_i) \\ \text{s.t.} T(y, x) &\leq 0 \end{aligned} \tag{1}$$

to solve for the factor demand functions conditional on the output produced, y. As we are dealing with a long-run cost function all quantities and prices are considered variable. Writing the Lagrangean of this minmisation as

$$L = \sum_i w_i * x_i - \lambda T(y, x) \tag{2}$$

and taking the partial derivatives with respect to x_i yields

$$\frac{\partial L}{\partial x_i} = w_i - \lambda \frac{\partial T(y,x)}{\partial x_i}. \tag{3}$$

Setting these expressions equal to zero and solving for x_i yields the conditional factor demand as

$$x_i^* = x_i^*(y,w). \tag{4}$$

The minimum cost level is then obtained by substituting equation (4) into equation (1) resulting in

$$C^* = \sum_i w_i * x_i^*(y,w) = C^*(y,w). \tag{5}$$

In this model banks are assumed to be price takers in both input and output markets. Hence, output and input prices are exogenous to the model. This is in line with examining variable costs.

Until the early 1990's the above mentioned approach has been the dominant one in the literature. However, Hughes and Mester (1993) point out that excluding the capital structure leads to a mispecified form and will yield misleading efficiency estimates. Firstly, this is because equity capital can be used by the bank as an alternative to deposits or other borrowed funds to finance loans and engage in security operations. Put differently, it can be used as an additional input to produce output. Therefore, disregarding the equity level and its price when minimising costs requires one of the two following assumptions. Either there is reason to believe that banks do not fund loans with equity at all. Or, alternatively, we must assume that the price of equity is identical for all banks and each bank is using the cost minimising level. Both assumptions do not seem plausible. How does then the capital structure relate to risk considerations? And how to account for it?

If we assume that a bank chooses its level of equity freely given the prevailing price to minimise its cost than the capital structure does not relate to risk. In this case its allocative efficiency depends solely on the *relative* price of inputs, which are deposits, other borrowed funds and equity. Implicitly, we assume that the bank, or more precisely, the bank manager is risk-neutral. In this case the indeterminacy result obtained by Modigliani and Miller (1958) implies that the market value of the bank is independent of its source of funding or alternatively its' capital structure. In this case cost minimisation is a sufficient behavioural assumption to describe the choices of the bank.

At least two lines of argumentation suggest to believe this does not hold. Firstly, banks are subject to regulatory constraints. One constraint refers to minimum capital requirements. Therefore, the observed capital structure might indeed fall short of being cost minimising if required equity levels are higher than cost minimising ones. Another regulation possibly causing distortions of efficient equity levels refers to deposit insurance schemes. Rochet (1992) introduces bankruptcy costs into the Modigliani-Miller model. Then, market discipline ensures that banks hold efficient portfolios and adhere to an appropriate capital structure. Because of perfectly informed depositors and complete financial markets, higher risk-taking by the bank will lead the creditors to require a higher rate of return. In this model higher risk is signalled in terms of riskier asset portfolios on the asset side of the balance sheet or too low capital ratios on the liability side.[4] Introducing now a deposit scheme distorts this market discipline. Depositors know they are insured and fail to monitor the bank appropriately. Thus, the required return on equity will be too low given the incurred risk. This can lead to inadequate capital ratios. Secondly, bank managers might be risk-averse. DeYoung et al. (2001) identify four major sources for costs of financial distress. These include imposed constraints when debt covenants become binding, increased costs of borrowing, disrupted customer relationships and required asset sales at too low prices. Ultimately and beyond financial distress glooms the threat of failure and the loss of a valuable banking license. When making her production decision a risk-averse manager probably chooses a higher capital ratio to reduce the risk of incurring these costs of distress or even failure. In addition, Hughes and Mester (1998) point out that bank capitalisation serves not only as a cushion in order to prevent these potential costs but also as a signal to outsiders about the solvency of the bank.

Both lines of argumentation indicate that efficiency estimates excluding the capital structure might result in distorted cost inefficiencies. This is because observed input demands are deemed inefficient although they are in reality the result of different constraints or risk preferences. The solution to account for these risk preferences can follow two alternative approaches. One, which has been used in the majority of cases, is to maintain the behavioural assumption of cost minimisation. The strategy is to re-formulate the constraint under which managers make production decisisions. By adding the level of equity capital to the transformation technology it is then depicted as $T(y, x, k)$, where k represents equity capital. The resulting conditional input demands now depend on the level of equity as well. The cost-minimising level is therefore given by

$$C^* = \sum_i w_i * x_i^*(y, w, k) = C^*(y, w, k). \quad (6)$$

This specification can be found in the majority of bank efficiency analyses in the past ten years. We estimate this model as benchmark model to obtain efficiency rankings and compare it to results of the new approach of utiliy maximisation described below. By estimating a cost frontier we also allow for a comparison of cost efficiency scores obtained in the existing literature. However, note that the inclusion of equity as a catch-all approach towards risk is an indirect method. Is it plausible to expect such different issues as asset portfolio risk, liquidity risk or credit risk to be adequately represented by conditioning cost minimising production plans simply on capital structure? It seems unlikely that adjusting the constraint of the managers problem is sufficient. Rather the behavioural assumptions need to be adjusted as cost minimisation falls short to describe the decision process undertaken by bank managers.

Therefore the second approach to account for risk preferences when measuring bank performance is preferable. It relates more directly to the presence of different risk preferences in the banking industry.

[4] We discuss the use of asset portfolios and capital structure as risk proxies further when specifying risk-return efficiency in section ??.

3.3 Utility maximisation

Modelling efficiency measurement of banks on the basis of utility maximisation is a new development in the literature. It was initiated by Hughes and Moon (1995) and Hughes et al. (1996). At the core of the analysis rests the belief that managers do not only care about profit maximisation or cost minimisation, respectively. Instead, when choosing a production plan the riskiness of the production plan is evaluated, too. The principal strategy is to derive optimal demand for inputs and profit conditional on managers preferences regarding risk and other influences. Optimal profit demand is then employed to estimate an efficient risk-return frontier. In this section we introduce the model. The specification of the frontier and efficiency estimation follows in the next section.

The main motivation of this paper is to analyse the impact of including risk into efficiency analysis. Why would risk matter anyway is then a natural question. An example is provided by managers maximising value instead of profits. The result obtained by Modigliani and Miller (1958) states that the two assumptions are equivalent if risk-preferences are neutral and identical for all managers. We challenge this assumtpion to hold in German banking. Consequently, value and profit maximisation are no longer equivalent. The reason is that riskier plans require a higher rate of return. This increases the discount rate and reduces the present value of future cash-flows. Depending on their particular preferences managers therefore might choose different production plans and still be equally efficient.

While value maximisation provides an illustrative example why different risk-preferences matter, there are additional objectives which can influence the decision making process of the manager. Examples include alternative spending preferences or tax optimising behaviour [Hughes et al. (2003)]. Hughes and Moon (1995) show that a general utility function allows to model manager preferences general enough to accomodate different objectives beyound value maximisation. We therefore model managers to maximise utility.

The model is adapted from Hughes et al. (1996). Utility is maximised by choosing optimal profit and input demand. After-tax profit is depicted by π. Technology stipulates the production plan represented by output quantities y, input quantities x and equity capital k. The price demanded for output is denoted by p. It would be desirable to include a measure of output quality, such as non-performing loans. However, this data is not available for German banks.[5] Conditional on future states of the world s managers form beliefs how s interacts with the production plan (y, x, p, k) to determine a realisation of profit $\pi = g(y, x, p, k \mid s)$. In addition, they form a subjective distribution, which state s will prevail. Together, these two form a subjective, conditional probability distribution of profit to be realised $f(\pi \mid y, x, p, k, s)$ It is subjective because each bank managers beliefs about s differs and it is conditional on the production plan and it's interaction with the state of the world expected to prevail.

One approach to consider risk would be to define utility now over expected profit and its standard deviation, i.e. $U(E(\pi), S(\pi))$. However, this way of mod-

[5] An attempt to employ loan loss reserves and their volatility instead did not improve the results and was therefore discarded. This shortcoming can be explained by the ambiguity how much of these reserves are actually used at what point in time to cover losses from what origin.

elling risk would not tell us something about the source of uncertainty which determines $S(\pi)$. If we assume instead that the variation of profits is explained by characteristics of production plan elements we might prefer to include these elements directly into the utility function. In fact,Hughes and Moon (1995) show that the definition of utility over $E(\pi)$ and $S(\pi)$ prohibits alternative objectives to influence utility. Therefore Hughes and Moon (1995) allow the production plan (y, x, p, k) to influence utility not only through it's effect on profit but also directly and independently. *Generalised managerial preferences* are then represented by a utility function of the form $U(\pi, y, x, p, k)$. Note that we do not measure risk in this model by it's volatility. Instead, the elements of the production plan represent particular risk and other managerial preferences.

An example of risk characteristics regarding outputs is that banks with a higher taste for risk might decide to produce less fixed interest bearing loans and engage more heavily in security or derivatives trading. The output vector y then captures asset portfolio risk. With regard to the input vector x a preference for representative office buildings results in "too high" expenditure on fixed assets. Another example is the desire to "overemploy" labour in order to signal managerial power because of commanding huge numbers of employees. Higher output prices p certainly increase expected profits. At the same time higher rates on e.g. loans 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 k increase the risk of insolvency due to credit losses or sudden securtiy price deterioration.

Instead of measuring risk directly the manager is simply modelled to identify her most preferred production plan and profit. Highest ranked production plans have as solutions most preferred demand functions for inputs and profit, respectively. They reflect managers' preferences regarding risk and their expectations of profit conditional on the production plan and the state of the world. As mentioned above efficiency is then measured in the risk-return space. We refer to it as risk-return efficiency (RRE). Expected profit and the associated risk constitute the benchmark. Banks are evaluated depending on their position relative to the risk-return frontiers (RRF).

To evaluate the impact of different risk preferences on efficiency measurement one needs a comparison. Results from estimating profit efficiency would allow such a comparison and it would be desirable to compare efficiency results from all three assumptions, i.e. profit maximisation, cost minimisation and utility maximisation. Unfortunately, Humphrey and Pulley (1997) point towards the problems associated with profit maximisation. Output prices are not available on the bank and product level. To circumvent this data problem we utilise the equivalence between profit maximisation and cost minimisation if perfect competiton prevails (see chapter 5 in Mas-Colell et al. (1995)). Instead of analysing profit efficiency explicitly, we assume that profit maximisation and cost minimisation are equivalent when illustrating the importance to include risk next to profit and cost into efficiency research.

In this model RRE is influenced by three different sources. The first influence refers to potential learning effects of managers when forming their subjective, conditional probability distributions. If the *ability to predict* future states of the world and their respective interaction with production plans improves over time banks might increasingly choose more efficient production plans. The second influence refers to learning effects regarding banks' *ability to attain* a certain profit associated with the preferred production plan to deliver an adequate return given risk. The last influence results from changing opportunity sets. The RRF might shift, for example due to technological change, and enable banks to produce more of all products with identical input and risk. We are not able to disentangle these effects. To reduce the ambiguity surrounding the influences on efficiency estimates we use cross-sections only. We assume that risk-preferences and opportunity sets are likely to change over time but that they are fairly stable within one period. We postpone the discussion how to specify a risk measure until sub-section **??**

In sum, defining utility as $U(\pi, y, x, p, k)$ is more general than defining it only over expected profit and some measure of profit uncertainty. As a special case it also allows for a risk-neutral manager who solely maximises profits. Then, utility only depends on π. Noting that under perfect competition profit maximisation entails cost minimisation this result would resemble the one obtained from the cost approach in section 3.2.[6] But when managers are pursuing additional objectives and/or are non-neutral towards risk-taking the model specifies utility general enough to allow for these generalised managerial objectives such as expense preferences or tax optimising behaviour. In these cases utility is influenced directly through the production plan and indirectly via the plan's impact on π. Managers can maximise either profit or value in this model and they are also allowed to trade profit or value for other preferences. Hughes et al. (1996) call this modelling of utility a *generalised managerial objective function*. The solution to the manager's maximisation problem leads to the *most preferred production plan* regarding in- and outputs and their *most preferred profit function*.

The first constraint of the utility maximisation problem (UMP) is the transformation function of the form $T(y, x, k)$. This conditions technology on the existing capital structure as in section 3.2. Again, k is not assumed to be the cost-minimising level and therefore we consider it as exogenous for the regulatory reasons mentioned there. The second constraint according to which managers rank their preferences refers to the profit identity. Let m denote income from sources other than output y. In addition, let t equal the tax rate on profit 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 given by the profit identity

$$p_\pi \pi = py + m - wx. \tag{7}$$

We assume here that the identity must hold as no excess returns are earned. Put differently, we are assuming perfect competition in in- and output markets which in turn ensures compareability with the case of cost efficiency. We write the UMP as

[6] This means that the conditional input demands resulting from utility maximisation (see later this section) would be identical to the ones resulting from cost minimisation, i.e. $x_i^*(y, v, m, k) = x_i^*(y, w, k)$. It does not necessarilly mean that efficiency scores are identical, for example because of the existence of market power, which we do not investigate.

$$
\begin{aligned}
&\max_{\pi,x}\ U(\pi, y, x, p, k) \qquad (8)\\
&\text{s.t. } p_\pi \pi + wx = py + m,\\
&\text{s.t. } T(y, x, k) \leq 0.
\end{aligned}
$$

Forming the Lagrangean

$$L = U(\pi, y, x, p, k) - \lambda(wx + p_\pi \pi - py - m) - \theta T(y, x, k) \qquad (9)$$

and taking partial derivatives with respect to after-tax profit and quantities of input yields

$$\frac{\partial L}{\partial \pi} = \frac{\partial U(\bullet)}{\partial \pi} - \lambda p_\pi - \theta \frac{\partial T(\bullet)}{\partial \pi}, \qquad (10)$$

$$\frac{\partial L}{\partial x_i} = \frac{\partial U(\bullet)}{\partial x_i} - \lambda w_i - \theta \frac{\partial T(\bullet)}{\partial x_i}. \qquad (11)$$

Solving simultaneously for π and x_i yields the solution values as the most preferred profit function and the most preferred input demand functions, respectively, as

$$\pi^* = \pi^*(y, v, m, k), \qquad (12)$$

$$x_i^* = x_i^*(y, v, m, k), \qquad (13)$$

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 π^* need not be the profit maximising one from the standard approach.[7] It reflects the possibility that managers have different preferences and depicts the trade-off managers make. Thus, 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. To this end we now turn to section 4.

4 Empirical Measurement

In this section the empirical models to implement the theoretical models are derived. Firstly, we introduce the cost function. It is specified as a frontier representing the best-practice costs when no inefficiencies prevail. Holding all exogenous factors constant, the cost frontier constitutes the benchmark relative to which the individual banking firms are examined. Secondly, the measurement of cost efficiency is shown. This is undertaken with respect to the positon of the banking firm relative to the frontier, thereby providing information on the firm's cost efficiency. Thirdly, we derive the empirical model assuming utility maximisation. Compared to the cost model the primal changes. Whereas the primal is the production function in the cost model, it is a utility function in the second model. As utility is unobservable we cannot estimate a utility frontier

[7] That is to say, $x_i^U(y, v, m, k) \neq x_i^\pi(y, w, k) = x_i^C(y, w, k)$, where superscripts indicate utility maximisation, profit maximisation and cost minimisation, respectively.

directly just as we were unable to estimate a production frontier directly in the cost minimising model. But equation (12) contains all the information about different risk-preferences that we need. Note that we are interested whether a bank's return given the risk associated with it is efficient or not. Therefore, we need to estimate the utility maximising demand for profit in a first step. To this end we employ the AID system developed by Deaton and Muellbauer (1980). We use duality to estimate share equations of the two "goods" consumed, namely profit and inputs. Fourthly, efficiency is then measured in the risk-return space. The frontier constituting fully efficient banks is measured as expected profit, predicted by the most preferred profit demand function, and the uncertainty associated with this prediction.

4.1 Cost minimisation

To estimate a minimum cost function a number of flexible functional forms can be used. The underlying trade-off is between ease and clarity of interpretation versus sufficient flexibility to accomodate the data at hand. While the Cobb-Douglas function is an example of the former, flexible forms such as the Fourier functional form exemplify the latter. The former allows the deduction of production technology via duality and exhibits clearly interpretable results. Unfortunately, at the same time it imposes substantial structure on the data, for example constant returns to scale. The latter abstains from imposing this structure and allows to approximate the data closer through ammended interaction terms. However, deduction of the underlying production technology is not possible. In addition, flexible forms might suffer from multicollinearity problems. The difference in results due to specifying alternative functional forms has been examined in Bauer et al. (1998) and Berger and Humphrey (1997). While there are differences between flexible forms and Cobb-Douglas the differences within the class of flexible forms seems to be of minor importance. In the literature the translog form has been used widely as a compromise between the respective advantages and disadvantages.

Therefore, we follow the majority of applications and use the multi-output translog cost function. For a bank k this cost function takes on the form

$$\begin{aligned}\ln C_k(w,y,k) = {} & \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln w_{ik} + \sum_{m=1}^{3} \beta_m \ln y_{mk} \\ & + \frac{1}{2} \sum_{i=1}^{3} \sum_{j=1}^{3} \alpha_{ij} \ln w_{ik} \ln w_{jk} + \sum_{i=1}^{3} \sum_{m=1}^{3} \zeta_{im} \ln w_{ik} \ln y_{mk} \\ & + \frac{1}{2} \sum_{m=1}^{3} \sum_{n=1}^{3} \beta_{mn} \ln y_{mk} \ln y_{nk} + \gamma_0 \ln k_k + \frac{1}{2} \gamma_1 (\ln k_k)^2 \\ & + \sum_{i=1}^{3} \delta_i \ln w_{ik} \ln k_k + \sum_{m=1}^{3} \tau_m \ln y_{mk} \ln k_k + \varepsilon_k . \end{aligned} \quad (14)$$

As outlined in the previous section w_i denote input prices and y_m denote outputs. As argued in section 3.2 we need to include the level of equity capital into the specification as well. Here, k depicts the level of equity capital. Because we are dealing with a cross-section of data no time trend variable is included.

As noted in Coelli et al. (1998) certain restrictions have to be imposed before estimation. The first requires linear homogeneity in input prices. This is demanded by the fact that an increase in input prices should result in proportionally increased total cost as can be seen from equation (1). The second restriction stems from the use of duality when estimating a cost function and refers to the symmetry of cross partial derivatives of the conditional factor demand functions. These restrictions are given by

$$\sum_{i=1}^{3} \alpha_i = 1, \sum_{i,j=1}^{3} \alpha_{ij} = 0 \text{ for all } i \text{ and } j, \sum_{i=1}^{3} \zeta_i = 0, \sum_{i=1}^{3} \delta_i = 0,$$

$$\alpha_{ij} = \alpha_{ji} \text{ and } \beta_{mn} = \beta_{nm} \text{ for all } i, j, m \text{ and } n.$$

We follow the standard approach in the efficiency literature and impose the homogeneity restrictions by normalising all factor price variables and the dependent variable by one factor price. As explained in the data section we choose here the price of fixed assets. Note that this ensures homogeneity of input prices only. To impose for example constant returns to scale one would have to scale output levels, too.

4.2 Cost efficiency

The distinctive assumption regarding SFA refers to the error term in equation (14) One assumes that the error term consists of two parts. The first reflects inefficiency and the second random noise. It is depicted as

$$\varepsilon_k = v_k + u_k.$$

The v and u are assumed to be independently distributed. Followig Battese and Coelli (1988) the random error term v_k is assumed to be i.i.d. with $v_k \sim N(0, \sigma_v^2)$ and independent of the explanatory variables. The inefficiency term is i.i.d. $u_k \sim |N(0, \sigma_u^2|$. Note that a number of alternatives to the normal distribution of the inefficiency term have been suggested. Examples include the standard normal with truncation at μ instead of 0 or the exponential model. Greene (1993b) presents a survey about most of the specifications of the error term employed in the literature.

The model is estimated using maximum likelihood methods. In a first step an OLS model is estimated. The parameter estimates obtained are biased with respect to the intercept and the error as OLS estimation does not employ the composed error term. Aigner et al. (1977) derived the likelihood function for the stochastic frontier model for first time and employed a re-parameterisation of $\lambda = \sigma_u/\sigma_v$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. Therefore, λ indicates the ratio of standard deviation attributable to inefficency relative to the standard deviation due to random noise. Using the OLS estimates to maximise the most-likelihood function for λ results in the adjusted values for the intercept and σ^2. Finally, the maximum-likelihood for the whole model is maximised using the updated and unbiased values obtained beforehand.

Next, we need a way to obtain firm-specific efficiency measures. Jondrow et al. (1982) use the conditional expectation of the u_k given ε_k. Following Battese and Coelli (1988) a measure of cost efficiency (CE) is calculated as

$$CE_k = E[\exp(-u_k)|\varepsilon_k]. \tag{15}$$

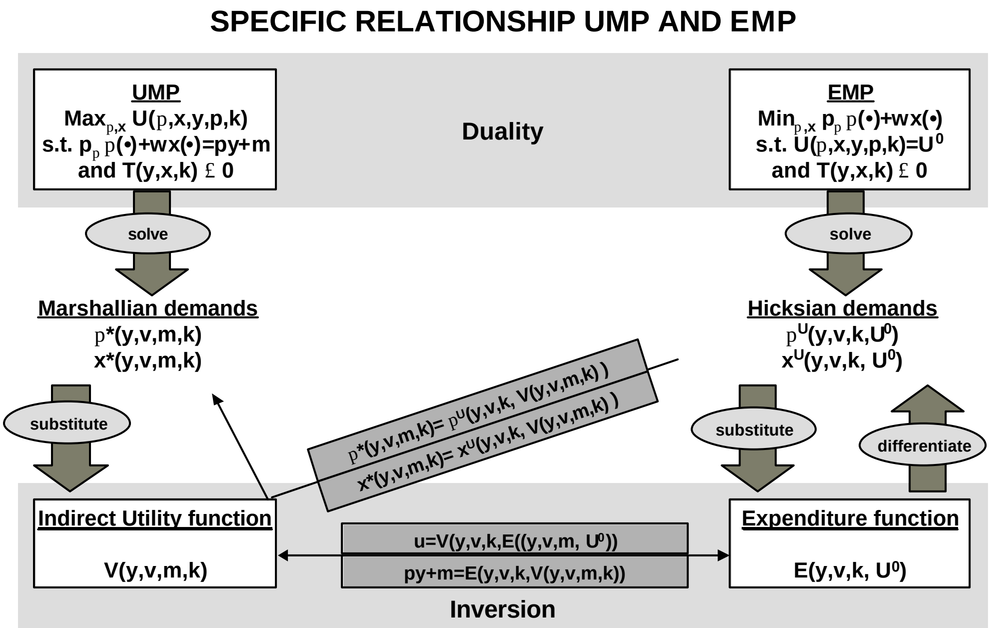
This measure takes a value between 0 and 1 where the latter indicates a fully efficient bank. Regarding its interpretation the value gives an indication which percentage of observed cost would have been enough to produce the observed output if the bank was fully efficient.

4.3 Utility maximisation

Estimating the structural form represented by the UMP formulated in equation (8) is not directly possible as the form of the utility function is unknown and utility is, of course, not observable. However, we are not directly interested in some managers' utility level derived from choosing a production plan. 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. To this end we use standard techniques from consumer theory. There, preferences of consumers for goods are analysed given their expenditure behaviour and budget data. In the context of the banking firm we estimate most preferred profit and most preferred input demand functions in order to gain insight into the preferences of bank managers. By employing the AID we rely rather intensively on the dual relation between the UMP and the expenditure minimisation problem (EMP) and the inverse relation of indirect utility and the expenditure function.[8] To ease understanding of the relations discussed here consider figure 1 below, which is an adaptation of representations in the consumer theory literature (Deaton and Muellbauer (1980), see chapter 3, and Mas-Colell et al. (1995), chapter 4).

[8] Duality of the UMP and EMP implies to look at the maximum utility attainable given wealth and prices while for the EMP we examine the minimum expenditure required to attain a given level of utility. An inverse relation, in contrast, is just the rewriting of a function.

Figure 1: Relation between UMP and EMP



In this figure the UMP described in section 3.3 and the relation to the EMP is depicted. Both are dual in employing identical functional forms to arrive at solutions for profit $\pi(\bullet)$ and input-demand functions $x(\bullet)$. They differ regarding the definition of the exogenous and endogenous variables and whether the functions used are specified as objective function or constraint. To illustrate which relationships allow us to go back and forth between the two problems the figure depicts those relations actually used.

The UMP is formulated in terms of a bank choosing inputs and profit subject to its budget constraint determined by total revenue and the technology available. $U(\bullet)$ depicts a utility function with an index number u as solution value. To maximise utility the bank solves for the utility-maximising profit- and input demand functions $\pi^*(y, v, m, k)$ and $x^*(y, v, m, k)$, which correspond to the solution values in section 3.3 given in equations (12) and (13). In terms of consumer theory these are uncompensated demand functions of a Marshallian type. In order to find the corresponding utility index we substitute the result into the appropriate value function, which is the indirect utility function depicted as $u = V(y, v, m, k)$ where $v = (p, w, p_\pi)$ denotes the price environment of the bank. To summarise, we obtain maximum utility when the bank chooses optimal levels of profit and inputs given an output bundle, prevailing prices and revenue available for spending on these two goods.[9] The problem when measuring the demand functions empirically is of course the unobservability of utility. To solve this problem consider the EMP.

The EMP solves for those profit- and input demands where costs are minimised

[9] In addition, the demand for the two goods is conditional on the level of equity k.

to attain a given level of utility U^0. Hence, the resulting demand schedules are of a Hicksian nature, that is, wealth compensated. What are the implications for the analysis at hand? The duality relation between the UMP and EMP allows us to restate the problem formulated in equation (8) as a minimisation problem of the form

$$\begin{aligned} &\min_{\pi,x} wx + p_\pi \pi \\ &\text{s.t. } U^\circ - U(\pi, y, x, p, k) = 0, \\ &\text{s.t. } T(y, x, k) \leq 0. \end{aligned} \tag{16}$$

where U° is the fixed level of utility. From figure 1 we know that the solution to this problem are the expenditure minimising amounts of the goods in question. In our specific application these are the most-preferred profit $\pi^u(y, v, k, U^\circ)$ and input demand functions $x^u(y, v, k, U^\circ)$. From figure 1 we see that these solution values will yield the expenditure function $E(y, v, k, U^\circ)$ when being substituted into the original minimisation problem represented in equation (16) of our analysis. Up to now, however, we only shifted the problem. Innitially, we had the unobservable level of utility as an argument in the objective function of the UMP. Now, we encounter utility again as an argument in the constraint of the EMP and its' solution values. Before tackling this question we have to make sure that the UMP and the EMP will indeed yield identical most preferred profit and input demand functions. The relation between Hicksian and Marshallian demand shows that this is the case if we substitute the indirect utility function into Hicksian demand functions. The indirect utility function is obtained by substituting the optimal solution values of the UMP defined in equation (8) into the objective function so that we obtain an indirect utility function $V(y, v, m, k)$ which has the same arguments as the solutions. Then, we can write

$$\pi^u(y, v, k, V(y, v, m, k)) = \pi^*(y, v, m, k), \tag{17}$$

$$x^u(y, v, k, V(y, v, m, k)) = x^*(y, v, m, k), \tag{18}$$

where $x^*(\cdot)$ and $\pi^*(\cdot)$ are the demand functions given in equations (12) and (13) and $V(\cdot)$ depicts the aforementioned indirect utility function. Turning now to the problem of having to circumvent the unobservability of the utility level we make use of the inverse relationship between indirect utility and the expenditure function $E(y, v, k, U^\circ)$. Microeconomic theory tells us that each of the two functions can be written in terms of the other. Thus, by substituting the indirect utility function into the expenditure function we can write

$$py + m = E(y, v, k, V(y, v, m, k)) \tag{19}$$

stating that all expenditure on profit and inputs to attain a given level of utility must equal total revenue, that is to meet the budget constraint. How do we progress from here?

The approach taken by the AID system is not to estimate demanded quantities directly. Instead, we rely on Sheppard's Lemma to derive budget shares from the expenditure function. The form of the expenditure function in the AID is chosen in such a way that these budget shares represent Hicksian demand curves. The standard expenditure function of the AID system has been derived by Deaton and Muehlbauer (1980). It has been adapted by Hughes et al. (1996) who define it as

$$\ln E(\cdot) = \ln P + U * \beta_0 \left(\prod_i y_i^{\beta_i}\right)\left(\prod_j w_j^{\nu_j}\right) p_\pi^{\mu} k \tag{20}$$

where $\ln P$ is the price index employed in the AID system. Following the innitial suggestion of Deaton and Muehlbauer (1980) many applications in the consumer literature employ the functional form of a translog function for the price index . Examples are Brox (2003), Tridimas (2000) and Hossain and Jensen (2000). Alternatively, Deaton and Muellbauer (1980) propose to use a Stone price index for $\ln P$. While this approach is well established for aggregate data it leads according to Pashardes (1993) and Moschini (1995) to biased and unit-sensitive estimates when measuring firm-level data as in our study. Therefore we follow the use of a translog functional form for the price index, which allows also a comparison with the cost minimising models. We write $\ln P$ as

$$\begin{aligned} \ln P \;=\; & \alpha_0 + \alpha_p \ln \tilde{p} + \sum_i \delta_i \ln y_i + \sum_j \omega_j \ln w_j \\ & + \eta_\pi \ln p_\pi + \rho \ln k + \frac{1}{2}\alpha_{pp}(\ln \tilde{p})^2 \\ & + \frac{1}{2}\sum_i \sum_j \delta_{ij} \ln y_i \ln y_j + \frac{1}{2}\sum_s \sum_t \omega^\star_{st} \ln w_s \ln w_t \\ & + \frac{1}{2}\eta_{\pi\pi}(\ln p_\pi)^2 + \frac{1}{2}\rho_{kk}(\ln k)^2 + \sum_j \theta_{pj} \ln \tilde{p} \ln y_j \\ & + \sum_s \phi_{ps} \ln \tilde{p} \ln w_s + \psi_{p\pi} \ln \tilde{p} \ln p_\pi + \psi_{pk} \ln \tilde{p} \ln k \\ & + \sum_j \sum_s \gamma_{js} \ln y_j \ln w_s + \sum_j \gamma_{j\pi} \ln y_j \ln p_\pi \\ & + \sum_j \gamma_{jk} \ln y_j \ln k + \sum_s \omega^\star_{s\pi} \ln w_s \ln p_\pi \\ & + \sum_s \omega_{sk} \ln w_s \ln k + \eta_{\pi k} \ln p_\pi \ln k. \end{aligned} \tag{21}$$

Note that not every price for each output is included. Instead we use an average price $\tilde{p}$. The reason is twofold. Firstly, as noted by Hughes et al. (1996), this helps to conserve on degrees of freedom in the estimation of the share equations. Secondly, income earned by output category is not readily available for German banks.

To derive the share equations for the two goods the bank consumes we apply Sheppard's Lemma to equation (20), which states that given utility the partial derivative of the expenditure function with respect to the good's price is equal to that good's budget share. To apply this relation we will have to substitute the indirect utility function for the given level of utility U°into the derivatives $\partial \ln E(\cdot)/\partial \ln w_i$ and $\partial \ln E(\cdot)/\partial \ln p_\pi$. Substituting (19) into (20) and solving for utility yields the indirect utility function as

$$V(\cdot) = \frac{\ln(py + m) - \ln P}{\beta_0 \left(\prod_i y_i^{\beta_i}\right) \left(\prod_j w_j^{\nu_j}\right) p_\pi^\mu k}. \tag{22}$$

The share equations for input demand and profit for a given level of utility are then depicted by

$$\begin{aligned} \frac{\partial \ln E}{\partial \ln w_i} &= \frac{w_i x_i}{p * y + m} = \frac{\partial \ln P}{\partial \ln w_i} + \nu_i \left[\ln(p * y + m) - \ln P\right] \\ &= \omega_i + \sum_s \omega_{si} \ln \omega_s + \phi_{pi} \ln \tilde{p} + \sum_j \gamma_{ji} \ln y_i + \omega_{\pi i} \ln p_\pi \\ &\quad + \omega_{ik} \ln k + \nu_i \left[\ln(p * y + m) - \ln P\right] + \varepsilon_{w_i} \end{aligned} \tag{23}$$

and

$$\begin{aligned} \frac{\partial \ln E}{\partial \ln p_\pi} &= \frac{p_\pi \pi}{p * y + m} = \frac{\partial \ln P}{\partial \ln p_\pi} + \mu \left[\ln(p * y + m) - \ln P\right] \\ &= \eta_\pi + \eta_{\pi\pi} \ln p_\pi + \psi_{p\pi} \ln \tilde{p} + \sum_j \gamma_{j\pi} \ln y_j + \sum_s \omega_{s\pi} \ln w_s \\ &\quad + \eta_{\pi k} \ln k + \mu \left[\ln(p * y + m) - \ln P\right] + \varepsilon_{p_\pi}. \end{aligned} \tag{24}$$

According to the model in 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

$$\omega_{s\pi} = \frac{1}{2}(\omega_{s\pi}^* + \omega_{\pi s}^*) = \omega_{\pi s}.$$

In contrast to the application in Hughes et al. (1996) we treat the amount of equity employed in the production process as exogenous. There are two main reasons to do so. The first one is related to estimation problems. An attempt to formulate an additional share equation to represent demand for equity capital did not succeed. Therefore we treat capital as exogenous and include it as conditioning argument 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 cost minimisation and the utility maximisation approach. We therefore assume that equity levels are not necessarily utility maximising. While banks can use equity as element of their technology to produce output they cannot choose their capital structure to maximise utility. The second reason is a matter of economic interpretation. We assume that equity levels are determined by the environment of the bank, for example by regulation. The underlying rationale to specify equity capital as exogenous results from the belief that the fragmented German banking market with numerous small banks in the sample is better described by a lack of power to choose capital ratios freely. Equity capital of very large banks might be endogenous to a certain extent because of liquid stock markets to raise equity and opportunities to structure debt and move it on and off the balance sheet, for example by means of asset backed securities.[10] We assume, however, that for the majority of firms in the sample such options exist only to a far lesser degree.[11]

The restrictions imposed on the model refer to the symmetry, homogeneity and adding-up conditions implied by the derivation of the share equations via duality. With respect to the symmetry conditions Chiang (1984) mentions that the second-order partial derivatives are invariant to the order of differentiation. The use of Sheppard's Lemma, i.e. partial differentiation of the expenditure function to arrive at the input and profit demand functions, implies the following restrictions on the parameters with regard to second-order derivatives.

$$\delta_{ij} = \delta_{ji} \quad \text{and} \quad \omega_{si} = \omega_{is} \quad \text{and} \quad \omega_{s\pi} = \omega_{\pi s} \quad \text{for all } i, j, s \text{ and } \pi. \tag{25}$$

As noted in the consumer literature the two last restrictions are used to obtain the share equations. Hence, they can be identified because they appear in separate equations. Hughes et al. (2000) refer to it as a judgement call as to impose these restrictions or not. We will follow the typical way in which the AID is implemented in the consumer literature and impose only the first restriction.

The share equations are derived from the expenditure function and thus one can infer homogeneity restrictions. The expenditure function consists of the nominal profit function $p_\pi \pi(\cdot)$ and the most preferred cost function $wx(\cdot)$. Both are homogenous of degree one in $v = (w, p, p_\pi)$. Hence, the expenditure function is homogenous of degree one, too. A doubling of all prices should under perfect competition result in doubling all expenditure. Consequently, the share equations will be of degree zero (see Coelli et al. (1998)). It is well known that the first derivative of a function of degree λ results in a function of degree $\lambda - 1$ (see e.g. Chiang 1984). This translates into the notion that the bank alters its demand for inputs and profit only if *relative* prices change. A proportional increase in prices on inputs and the tax rate[12] do not make the manager choose another production plan. Therefore, the following restrictions apply:

[10] This phenomena is related to regulatory bodies being perhaps more inclined to assist big banks. The foundation of a construction between the Kreditanstalt fuer Wiederaufbau, a government owned bank, and the five biggest banks in Germany to collect bad debt off the commercial banks' balance sheets and to sell structured products is only circumstantial evidence. However, as The Economist (2003b) puts it these cosmetic actions indicate more leeway for big banks compared to the majority of small institutes in the market.

[11] For a discussion about the endogeneity of equity capital refer to Neukomm and Büttler (1999), Zimmer and McCauley (1990), Diamond and Rajan (2000) and Clark 1996.

[12] Through p_π

$$\sum_j v_j + \mu = 0, \quad (26a)$$
$$\alpha_p + \sum_j \omega_j + \eta_\pi = 1, \quad (26b)$$
$$\alpha_{pp} + \sum_t \phi_{jt} + \psi_{j\pi} = 0, \quad (26c)$$
$$\phi_{pt} + \sum_s \omega_{st} + \omega_{t\pi} = 0, \quad (26d)$$
$$\theta_{pj} + \sum_t \gamma_{jt} + \gamma_{j\pi} = 0, \quad (26e)$$
$$\eta_{\pi\pi} + \psi_{p\pi} + \sum_s \omega_{s\pi} = 0, \quad (26f)$$
$$\psi_{pk} + \sum_s \omega_{sk} + \eta_{\pi k} = 0, \quad (26g)$$
$$\frac{1}{2}\alpha_{pp} + \frac{1}{2}\sum_s \sum_t \omega_{st} + \sum_t \phi_{pt} + \frac{1}{2}\eta_{\pi\pi} + \psi_{p\pi} + \sum_s \omega_{s\pi} = 0. \quad (26h)$$

To impose homogeneity we divide all prices, i.e. w, p_π and $\tilde{p}$, by one of the goods' prices. Here, we chose the price of physical capital. The last set of restrictions stems from the requirement that the shares derived from the dual function must sum to one. Hence, the resulting eight adding-up restrictions are

$$\sum_i \omega_i + \eta_\pi = 1, \quad (27a)$$
$$\sum_i \omega_{si} + \omega_{s\pi} = 0, \quad (27b)$$
$$\sum_i \phi_{pi} + \psi_{p\pi} = 0, \quad (27c)$$
$$\sum_i \gamma_{ji} + \gamma_{j\pi} = 0, \quad (27d)$$
$$\sum_i \omega_{\pi i} + \eta_{\pi\pi} = 0, \quad (27e)$$
$$\sum_i \omega_{ik} + \eta_{\pi k} = 0, \quad (27f)$$
$$\sum v_j + \mu = 0. \quad (27g)$$

To impose the adding up restrictions the share equation of demand for physical capital is dropped from the system. Thus, we are left with a system of three equations. After substituting the price index $\ln P$ from equation (21) into the share equations (23) and (24) and collecting terms, the final system results. In section (6) we will estimate the linear system with SURE[13] techniques.

4.4 Risk-Return efficiency

In this sub-section, we introduce our approach to assess the efficiency and, hence, the performance of German banks by employing the risk-amended specification derived from the UMP. Performance refers to the banks' ability to realise the efficient trade-off between return and risk. Efficiency measures locate banks relative to a risk-return frontier and rank the institutes relative to this benchmark. Using our production model given by (23) and (24) we measure expected return by predicted profits. The specification of risk is in contrast less straightforward. Principally, risk is understood as the uncertainty about an outcome, in our formulation profit. However, Saunders (2000) distinguishes no less than nine different

[13] SURE: seemingly unrelated regression equation

types of risk to which financial intermediaries are exposed.[14] Two major strategies to measure risk can be found in the literature.

Firstly, a certain risk type is singled out and investigated more in-depth. One frequently analysed risk type is credit risk. The notion to investigate credit risk as a major source of uncertainty of the banks' stability is for example reflected in Cebenoyan and Strahan (2001). Here, credit risk is reflected by capital structure variables, such as capital to asset and liquidity ratios, and capital budgeting variables, namely the share of commercial and industrial (C&I) loans and real estate loans relative to total loans and assets. The bank-specific activity in the secondary market for loans is then used to explain variations in risk as measured by these variables. The idea is that lower capital ratios and higher shares of C&I loans reflect higher riskiness which becomes affordable because of more sophisticated risk management, proxied by more loan sales activities.

While this approach explains differences in risk-proxies it is less suited to benchmark firms relative to an estimated best-practice frontier as we rely on absolute measures of risk. The risk proxies observed do not indicate what would have been optimal. In addition,the appropriatenes of using capital ratios as a proxy for risk is a matter of debate. For example Evanoff and Wall (2002) compare various capital ratio specifications with subordinated debt yield spreads regarding their explanatory power of triggering supervisory action. The underlying assumption is that supervisory corrective action, capital ratios and debt yield spreads all reflect bank risk. Using partly confidential central bank data the authors find that capital ratios are inferior measures of risk.

The relation between separate risk categories is stressed in Ieda and Ohba (1999). They develop a model to relate equity price risk and credit risk following a value-at-risk and option pricing approach. They point towards the fact that the risk associated with security portfolios held by banks is related to the lending relationships maintained in the loan portfolio. Using historical data on security and bond prices their results indicate that both types of risk are intimately related and should not be managed seperately. This relation between risk types leads to the alternative strand in the literature when analysing bank risk.

This second strand of the literature does not regard the various sources of risk as separate issues. The focus rests on bank risk as a whole, which reflects the ultimate threat for a bank to be forced out of business because of a lack in capital to compensate for a decline in the value of its' assets. This type of risk is sometimes also referred to as insolvency risk. Amihud et al. (2002) examine banks' risk of insolvency by distinguishing relative risk and systematic risk. Two respective measures are derived from stock market data. Firstly, the variance of a particular bank's stock return relative to a number of peer group indexes is used. Secondly, the change in the bank's beta relative to returns of three indexes is employed. Both approaches rely on variation of stock market prices over time. Thus, bank risk is assumed to be reflected by the bank's historical share price. While the appropriateness of historical performance as a good predictor of future performance remains a question in it's own right, the majority of banks

[14] These include interest rate risk, market risk, credit risk, off-balance-sheet risk, technology and operational risk, foreign exchange risk, country risk, liquidity risk, insolvency risk and ultimately the interaction of risks

investigated in our study are non-listed companies. Thus, stock price information is only available for a small fraction of the German banking market.

An early study examining risk of non-listed banking firms is Liang and Rhoades (1988). Solvency risk is assumed to be driven mostly by liquidity and credit risk. In addition, operational risk refers to the difficulties arising as firms grow larger and more complex to manage. A measure of risk including all three elements is calculated as an index. The index comprises the level of earnings, its' variability and capitalisation. Regarding the first measure we note that our production model already includes earnings through the profit identity constraint in equation (8). Capitalisation is included by conditioning the production technology on equity capital in the second constraint of the UMP. The remaining risk measure represented by the variance of earnings measures the uncertainty related to variation over time. As noted earlier we assume risk preferences to change over time. Therefore, we would not be able to distuingish if inefficiencies result from changed appetite for risk over time, changed abilities to realise most preferred production plans or changed opportunity sets. We try to reduce this source of ambiguity and apply the model to cross-sections only. Consequently, we have to abstain from including historical volatility of profits.

A number of points can be summarised regarding alternative specifications of risk. Firstly, the analysis of one type of risk does not conform with our goal to compare the overall performance of banks. The reason is that only fragments of the bank's operative business are reflected by single risk categories. Secondly, the interaction between risk types require us to find a sufficiently broad measure of risk. Thirdly, we assume that risk preferences can change over time. To reduce the ambiguity about the source of inefficiency we employ cross-sections in this study. This prevents the use of historical volatility as a risk approximation. Fourthly, traditionally employed risk proxies such as capital ratios are not without debate. In addition, the production model used already takes into consideration the level of equity capital.

We therefore have to find an alternative to model the uncertainty surrounding profits, that is risk. To do so we follow Hughes et al. (1996) and assume that managers care about expected profits and the risk associated with this expectation. We obtain expected return, ER, for each bank by using the predicted profit $E(p_\pi \pi)$ and divide it by the banks' respective financial capital k. Hence, $ER = E(p_\pi \pi)/k$. To obtain a measure of expected risk, RK, we employ two alternative specifications. This is because the uncertainty of predicted profits, i.e. the prediction error, consists of two elements (see chapter 6 in Woolridge (2000) or chapter 7 in Greene (1993a)).

The first is the *standard error of predicted profit* $S(E(p_\pi \pi))$. It is bank specific and results ultimately from the uncertainty surrounding the estimated coefficients in equation (24). The second specification is the *standard error of the prediction error*. In addition to the standard error of predicted profit it contains another source of uncertainty. This is due to the unknown population error ε_{p_π}. We use the estimated error term in the share equation, $\sigma^2_{p_\pi}$ to capture this source of risk. The error reflects how well our model explains profit in order to make predictions and it will be smaller the better the model fits the data. Of course, this source of variation is identical for all banks in the sample. The sum of the standard error of predicted profit and the error term constitute the standard error of the prediction error $S(PE)$.[15]

$$S(PE) = S(E(p_\pi \pi)) + \sigma_{p_\pi} \quad (28)$$

It is important to note that this specification of risk is debatable. Ultimately, risk in this form is inherent to the model. More precisely, we use the uncertainty of predictions of this model due to the presence of an error term to proxy risk. It might therefore be more appropriate to label this uncertainty *model risk*. An important question is if this risk specification appropriately reflects the risk-return trade-off the manager makes when choosing a production plan. Is it for example true that risk increases if a manager chooses to use inputs in such a way that relatively more risky assets are produced? In this model it does not. The estimated parameters of the profit share equation just tell us something about the profit which to expect given observed input prices and output and equity levels. Therefore, one might doubt whether this specification is useful in measuring risk-return efficiency. An argument could be that the manager knows the model when formulating most preferred production plans. In this case we assume that she knows expected profits when making her choices with an imperfect degree of certainty. In turn, we then assume that deviations in the realisation of this expectation are partly due to the error term of the model she uses to form her expectation[16] and partly due to inefficiency.

We leave the issue subject to discussion and continue with our first risk specification, the standard error of predicted profit. We also divide it by k, that is $RK_1 = S(E(p_\pi \pi)/k)$. Likewise, the second risk specification is depicted as $RK_2 = S(PE)/k$. Both measures ER and RK are dependent on the production plan of the bank and are therefore functions of exogenous variables determined by the environment of the bank.

Estimating a risk-return frontier is then the next step. We regress expected return ER on expected risk RK together with a combined error term. To my knowledge financial theory does not provide a theoretical model which suggests a particular functional form for the efficient risk-return frontier. What we do know from many finance textbooks is that efficient portfolio frontiers exhibit decreasing returns in the risk-return space. Therefore, I allow the frontier to be nonlinear. For the added squared risk term one would expect a negative sign if additional units of risk would increase expected profits at a decreasing rate.[17] The risk-return frontier is then given by

$$ER_k = \Gamma_0 + \Gamma_1 RK_{jk} + \Gamma_2 RK_{jk}^2 + \epsilon_k \qquad j = 1, 2 \quad (29)$$

where $\epsilon_k = \nu_k - u_k$, $\nu_k \sim iid\ N(0, \sigma_\nu^2)$ and $u_i \sim iid\ N(0, \sigma_\upsilon^2)$. The error term is composed of two parts. Firstly, the part representing white noise, ν_k, which

[15] Alternatively, the literature refers to the term as the standard error of the forecast error. Greene (1993) depicts it as $VAR[e^0] = \sigma^2 + VAR[(\beta - b)'x^0 = \sigma^2 + x^{0'}[\sigma^2(X'X))^{-1}]x^0$

[16] Which reflects the imperfection of the model to explain profits perfectly because of random noise and/or ommitted variables.

[17] An additional idea to pursue is to follow the use of Fourier-Flexible forms. Inclusion of sinus and cosinus terms allows to approximate the data more closely even though there is no theoretical foundation as why to include these terms. Another approach might be to amend terms that are outside the production model, e.g. state dummies, local market conditions, but still influence the risk-return trade-off.

can be either positive or negative. Secondly, a term, u_k, representing inefficiency. Note, that in contrast to the cost frontier the inefficiency term is *subtracted*. This resembles the idea that an inefficient bank could have realised a higher profit given risk whereas it incurs higher cost given a production bundle. Risk-return efficiency is then measured as the conditional expectiation of u_k given ϵ_k and equals the difference between a banks' expected ROE and the frontier value of ROE given a certain level of risk and adjusted for random noise. Therefore, the estimate of efficiency is given by the mean of the conditional distribution of u_k given ϵ_k and as in equation (15) is depicted as

$$RRE_k = E[\exp(-u_k)|\varepsilon_k]. \tag{30}$$

As noted above the difference between the two risk specifications amounts to the error term of equation (24), which is constant for all banks. Therefore, we expect the results between efficiency scores to differ in terms of absolute score only. In contrast, relative rankings should not be affected. Also, the development of industry mean efficiency over time should be identical.

5 Data

This study uses balance sheet and profit and loss account data on German banks obtained from the Bankscope database provided by Bureau van Dijk, London. Data for four years in the period between 1995 and 2001 is employed to compare efficiency rankings between cost and risk-return efficiency. The variables included are constructed in line with approaches exhibited in the literature, e.g. Altunbas et al. (2001). Variables expressed in millions of Euro are measured as annual averages and deflated by the consumer price index. The descriptive statistics employed in the estimation of the cost and AID model are depicted in tables (1) to (4).

Table 1: Descriptive Statistics 2001

Variable	Mean	Stdev	Skew	Kurtosis	Min	Max	N
y_1*	2014.3	10080.0	10.733	139.581	12.100	159781.0	1040
y_2*	478.2	4903.3	20.041	477.124	0.100	128842.0	1040
y_3*	937.6	5972.8	14.169	236.693	0.200	116554.0	1040
w_1**	0.043	0.047	11.952	172.097	0.022	0.930	1040
w_2**	0.013	0.005	4.138	62.951	0.000	0.084	1040
w_3**	0.199	0.114	2.877	14.177	0.054	0.978	1040
k*	133.4	710.6	12.571	180.469	1.900	12787.0	1040
$\tilde{p}$**	0.099	0.047	15.497	342.885	0.059	1.244	1040
p_π**	2.806	20.659	28.309	842.881	1.002	633.0	1040
$p * y + m$*	223.7	1297.7	11.731	162.441	1.300	22627.3	1040
TOC*	56.9	298.0	17.301	346.876	0.800	6902.0	1040
Sw_1**	0.617	0.086	1.132	6.939	0.256	0.989	1040
Sw_2**	0.246	0.067	-0.880	6.701	0.001	0.640	1040
Sw_3**	0.051	0.022	2.228	19.290	0.001	0.280	1040
$Sp_\pi\pi$**	0.085	0.044	1.218	7.159	0.002	0.376	1040
TA*	4178.4	24667.9	11.976	167.804	22.300	423218.0	1040

* measured in millions of Euro

** measured in percent

Table 2: Descriptive Statistics 1999

Variable	Mean	Stdev	Skew	Kurtosis	Min	Max	N
y_1*	1812.5	10613.8	11.407	156.751	7.600	193590.0	1372
y_2*	528.4	5175.3	15.469	263.677	0.100	107824.0	1372
y_3*	779.9	5195.4	13.160	214.873	0.200	112251.0	1372
w_1**	0.040	0.052	10.674	125.755	0.012	0.855	1372
w_2**	0.014	0.005	4.104	53.150	0.000	0.076	1372
w_3**	0.188	0.106	2.642	13.258	0.031	0.935	1372
k*	113.9	676.9	12.379	176.284	0.900	11934.5	1372
$\tilde{p}$**	0.099	0.046	14.540	310.612	0.037	1.229	1372
p_π**	2.357	1.003	5.639	63.799	1.003	18.0	1372
$p * y + m$*	189.0	1187.2	11.777	163.975	0.900	21709.1	1372
TOC*	47.8	278.3	14.555	238.813	0.600	5200.8	1372
Sw_1**	0.582	0.092	0.794	7.649	0.091	0.988	1372
Sw_2**	0.258	0.067	-0.751	7.032	0.002	0.639	1372
Sw_3**	0.052	0.023	1.346	7.549	0.001	0.197	1372
$Sp_\pi \pi$**	0.105	0.052	1.423	9.169	0.003	0.543	1372
TA*	3677.0	22953.6	11.223	146.553	11.000	399413.0	1372

* measured in millions of Euro

** measured in percent

Table 3: Descriptive Statistics 1997

Variable	Mean	Stdev	Skew	Kurtosis	Min	Max	N
y_1*	1896.3	10597.4	10.652	136.432	8.600	181050.0	1485
y_2*	471.5	3925.9	13.510	200.373	0.100	69794.0	1485
y_3*	603.0	3470.8	12.225	179.811	0.100	69840.1	1485
w_1**	0.046	0.054	9.692	104.407	0.007	0.753	1485
w_2**	0.014	0.006	10.024	228.163	0.000	0.155	1485
w_3**	0.197	0.123	2.428	11.205	0.022	0.923	1485
k*	109.5	611.2	12.336	178.979	1.200	11366.0	1485
$\tilde{p}$**	0.111	0.067	24.646	787.331	0.022	2.301	1485
p_π**	2.937	1.381	7.495	108.186	1.003	28.7	1485
$p * y + m$*	195.4	1125.8	10.694	132.251	1.400	18082.5	1485
TOC*	48.7	250.1	12.245	167.736	0.700	4121.3	1485
Sw_1**	0.585	0.090	0.860	8.080	0.119	0.980	1485
Sw_2**	0.235	0.064	-0.285	8.105	0.003	0.716	1485
Sw_3**	0.050	0.029	2.075	10.202	0.001	0.235	1485
$Sp_\pi \pi$**	0.129	0.055	0.914	7.670	0.007	0.565	1485
TA*	3425.8	19792.3	10.501	127.003	23.400	313169.0	1485

* measured in millions of Euro

** measured in percent

Table 4: Descriptive Statistics 1995

Variable	Mean	Stdev	Skew	Kurtosis	Min	Max	N
y_1*	1617.6	8649.4	10.717	135.666	19.600	136799.0	1341
y_2*	384.1	3174.4	13.649	211.544	0.100	62745.3	1341
y_3*	470.8	2537.3	12.586	188.501	0.200	49585.1	1341
w_1**	0.052	0.062	10.878	132.770	0.025	0.997	1341
w_2**	0.015	0.006	9.038	188.689	0.001	0.138	1341
w_3**	0.205	0.148	2.269	8.765	0.016	0.966	1341
k*	99.6	560.0	13.586	230.013	1.700	12291.0	1341
$\tilde{p}$**	0.121	0.038	6.067	62.142	0.026	0.611	1341
p_π**	2.997	1.346	5.601	63.930	1.002	24.0	1341
$p * y + m$*	175.5	937.9	10.849	137.579	2.100	15346.0	1341
TOC*	47.9	245.0	13.768	224.115	1.000	5163.3	1341
Sw_1**	0.603	0.080	1.008	8.658	0.150	0.960	1341
Sw_2**	0.220	0.056	-0.107	10.304	0.013	0.720	1341
Sw_3**	0.047	0.033	2.812	14.276	0.002	0.299	1341
$Sp_\pi\pi$**	0.130	0.051	0.915	11.898	0.004	0.667	1341
TA*	2807.1	15468.7	10.844	137.196	33.600	254724.0	1341

* measured in millions of Euro

** measured in percent

For the cost model the dependent variable is total operating cost. It contains the costs incurred for physical assets, personnel expense, other administrative expenses, all expenses from trading activities[18] and interest expenses. For the AID model the dependent variables are the input- and profit demand shares. The price of labour, w_1, is calculated as personnel expenses divided by total assets. The price of borrowed funds, w_2, is calculated as interest expense over total borrowed funds and is expressed as percentage. The same holds for the price of physical assets, w_3, which is calculated by dividing total depreciation and other operating expenses by fixed assets. Regarding the last two prices all observations with implausible values are excluded. The cut-off point chosen here are prices of funds and physical capital above 100%. We specify three outputs in line with the intermediation approach, total loans y_1, total off-balance sheet activities (OBS), y_2, and total securities, y_3. The level of equity is denoted by k. The price of after-tax profit is denoted by p_π. It is measured by $1/(1-t)$, where t is measured as total tax paid over profit before tax. The average output price is measured by $\tilde{p}$, calculated as total interest received over total interest bearing assets. Total revenue $py + m$ is also measured in millions of Euro and includes via m all nonvariable income from fees, commisions and other sources of operational income.

It should be noted that the current sample reflects the substantial diversity across German banks. Banks from all sectors are included. Sinn (1999) notes in this context that corporate objectives may therefore vary significantly. Also, banks differ considerably regarding the size of operations as measured by total assets.

[18] These include commision expenses, fee expenses and trading expenses

Table 5: Average Total Assets by size and sector

Sector	**Variable**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Total**
Commercial	N	26	48	42	60	39	4		16	235
	Mean TA	131	329	733	2,360	11,142	35,284		216,072	17,976
	% of Total	0.02%	0.09%	0.17%	0.78%	2.38%	0.77%		18.95%	23.15%
	% of Size	2.50%	2.91%	4.31%	6.56%	20.54%	8.29%		40.97%	
	% of Sector	0.08%	0.37%	0.73%	3.35%	10.29%	3.34%		81.84%	
Local Cooperative	N	1,011	1,309	412	188	11				2,931
	Mean TA	120	314	682	1,724	10,076				426
	% of Total	0.67%	2.25%	1.54%	1.78%	0.61%				6.85%
	% of Size	89.00%	75.68%	39.34%	15.02%	5.24%				
	% of Sector	9.75%	32.92%	22.50%	25.95%	8.87%				
Central Cooperative	N					2	6	3	2	13
	Mean TA					22,429	35,910	70,577	125,270	55,584
	% of Total					0.25%	1.18%	1.16%	1.37%	3.96%
	% of Size					2.12%	12.66%	8.68%	2.97%	
	% of Sector					6.21%	29.82%	29.30%	34.67%	
Local Saving	N	56	312	527	832	97	2			1,826
	Mean TA	168	348	735	1,952	8,089	29,509			1,628
	% of Total	0.05%	0.60%	2.12%	8.90%	4.30%	0.32%			16.29%
	% of Size	6.85%	19.99%	54.21%	75.24%	37.08%	3.47%			
	% of Sector	0.32%	3.65%	13.03%	54.62%	26.39%	1.99%			
Central Saving	N	3				4	8	11	13	39
	Mean TA	45				11,809	37,496	80,074	215,494	103,322
	% of Total	0.00%				0.26%	1.64%	4.83%	15.35%	22.08%
	% of Size	0.10%				2.23%	17.63%	36.12%	33.20%	
	% of Sector	0.00%				1.17%	7.44%	21.86%	69.52%	
Mortgage Credit	N		1		2	29	18	15		65
	Mean TA		334		3,965	14,996	35,540	72,528		33,397
	% of Total		0.00%		0.04%	2.38%	3.51%	5.96%		11.90%
	% of Size		0.06%		0.37%	20.55%	37.59%	44.62%		
	% of Sector		0.02%		0.37%	20.03%	29.47%	50.12%		
Building Societies	N			10	14	7				31
	Mean TA			753	2,959	10,221				3,887
	% of Total			0.04%	0.23%	0.39%				0.66%
	% of Size			1.05%	1.92%	3.38%				
	% of Sector			6.25%	34.38%	59.37%				
Other	N	20	24	11	9	13	9	4	9	99
	Mean TA	106	308	705	2,123	14,405	38,498	64,472	214,300	27,846
	% of Total	0.01%	0.04%	0.04%	0.10%	1.03%	1.90%	1.41%	10.57%	15.11%
	% of Size	1.55%	1.36%	1.09%	0.89%	8.85%	20.36%	10.58%	22.86%	
	% of Sector	0.08%	0.27%	0.28%	0.69%	6.79%	12.57%	9.35%	69.96%	
Banking Sector	N	1,116	1,694	1,002	1,105	202	47	33	40	**5,239**
	Mean TA	123	321	713	1,953	10,474	36,208	73,889	210,945	**3,483**
	Sum TA	137	543	714	2,158	2,116	1,702	2,438	8,438	**18,246**
	% of Total	0.75%	2.98%	3.92%	11.83%	11.60%	9.33%	13.36%	46.24%	

Notes:
All numbers on the basis of averages of employed cross sections 1995 to 2001
Mean total assets in millions of Euro
Sum of total assets measured in billions of Euro
Size classes I: < m200 €; II: m200 €-m500 €; III: m500 €-bn1 €; IV: bn1 €-bn5 €; V: bn5€-bn25 €; VI: bn25€-bn50€; VII: bn50€-bn100€;VIII: >bn100

Table 5 illustrates the low concentration of the German banking market in terms of total assets under management. Only 23 percent are accounted for by the commercial banking sector. Especially the savings bank sector and other institutes control more than half of the market. Hence, corporate objectives like cost minimisation might not apply to a substantial number of banks. Instead, political objectives most likely play a role in deciding on production plans, too. An example provides the "Kreditanstalt fuer Wiederaufbau", which states explicitly its' goals as the promotion of SMEs, Home Finance, Energy Conservation, Export and Project Finance, Development Cooperation, Tasks on Behalf of the State, Cross-Task Environmental Protection. Clearly, to compare efficiency of banking firms with so different objectives might require more angles than cost minimisation only. In addition to the variety of banking sectors active in the financing process in Germany the size aspect becomes apparent in table 5 as well. Despite the vast number of banks especially in the cooperative and savings bank sector almost half of all assets are controlled by a mere 40 institutes out of 5,239 included in the four cross-sections. It appears that commercial banks exert in this size class more influence but the role of central public banks and other insitutes is at least as important.

The described heterogeneity of firms raises the question if a single benchmark is appropriate. I maintain throughout the assumption that all banks in the sample have access to the same technology and therefore have the opportunity to compete in the same market.[19] The fragmented structure of the industry suggests that even for the case of a single frontier it should be borne in mind that substantial structure is imposed on the data in order to fit an all encompassing benchmark.

6 Empirical Findings

In this section we are going to present and discuss the estimation results of the cost and the utility model, respectively. In the following subsections parameter estimates of the respective models are presented, followed by efficiency estimates. We begin with estimates of the cost frontier and resulting cost efficiency scores. Next, we turn to the risk-return frontier. We provide estimates for four different specifications of risk and their respective efficiency scores and choose a preferred version. We then compare the rankings based on cost and risk-return efficiency with each other. To honour the nature of the data we investigate efficiency results according to size and sector.

6.1 Cost frontier

Table 6 presents parameter estimates of the standard cost model for the four annual cross-sections examined. As with the AID model the cost of physical assets w_3 has been employed to impose linear homogeneity in input prices. Noting that the ratio of the standard deviation of the inefficiency term σ_u to the standard deviation of random noise σ_v measured by λ is significantly different from zero provides evidence that inefficiency prevails in German banking. In other words, the deterministic cost function implied by OLS does not describe the data appropriately. The total standard deviation of the composed error measured by σ is also significantly different from zero but fairly low.

Parameter estimates are by and large significantly different from zero. However, interpretation of the individual coefficients is subject to considerable caution. The reason is that the interaction terms are also exerting their influence when considering, say, the change of loans by 1% holding everything else constant. Hence,

[19] I did not find a formal statistical test to see whether a single frontier is appropriate. To adress the question I estimated sector specific cost and risk-return frontiers to allow for distinct markets and, hence, different frontiers. As noted later, low numbers of iterations when maximising the log-likelihood, non-existence of a frontier because of wrong skew of the residuals and mostly insignificant parameter estimates led me to maintain the assumption of a single frontier.

Table 6: Cost Frontier Estimates 1995 - 2001

Dependent variable	LNTOC		LNTOC		LNTOC		LNTOC	
Year	2001		1999		1997		1995	
N	1040		1372		1485		1341	
Log likelihood	400.5628		453.4948		470.1453		647.2974	
σ_v^2	0.00927		0.01041		0.00775		0.00792	
σ_u^2	0.05342		0.05960		0.07386		0.04294	
Variable	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**
Intercept	3.211	0.000	2.857	0.000	2.296	0.000	2.759	0.000
$\ln w_1$	0.805	0.000	0.524	0.000	0.153	0.010	0.510	0.000
$\ln w_2$	0.708	0.000	0.752	0.000	0.785	0.000	0.654	0.000
$\ln y_1$	-0.362	0.007	-0.221	0.042	0.075	0.377	-0.285	0.017
$\ln y_2$	0.164	0.003	0.230	0.000	0.124	0.001	0.302	0.000
$\ln y_3$	0.167	0.002	0.260	0.000	0.249	0.000	0.338	0.000
$\ln k$	0.979	0.000	0.648	0.000	0.359	0.000	0.453	0.000
$\frac{1}{2} \ln w_1 \ln w_1$	0.078	0.001	0.075	0.000	0.046	0.001	0.100	0.000
$\frac{1}{2} \ln w_1 \ln w_2$	-0.070	0.042	-0.068	0.006	0.020	0.329	-0.058	0.019
$\frac{1}{2} \ln w_2 \ln w_2$	0.019	0.365	0.021	0.168	-0.004	0.738	0.022	0.141
$\frac{1}{2} \ln y_1 \ln y_1$	0.298	0.000	0.331	0.000	0.254	0.000	0.438	0.000
$\frac{1}{2} \ln y_1 \ln y_2$	-0.045	0.160	-0.114	0.000	-0.035	0.154	-0.194	0.000
$\frac{1}{2} \ln y_1 \ln y_3$	-0.104	0.003	-0.211	0.000	-0.158	0.000	-0.328	0.000
$\frac{1}{2} \ln y_2 \ln y_2$	0.028	0.000	0.015	0.012	0.007	0.286	0.052	0.000
$\frac{1}{2} \ln y_2 \ln y_3$	-0.026	0.106	0.036	0.004	-0.010	0.450	0.017	0.211
$\frac{1}{2} \ln y_3 \ln y_3$	0.075	0.000	0.086	0.000	0.085	0.000	0.096	0.000
$\ln y_1 \ln w_1$	-0.250	0.000	-0.140	0.000	-0.015	0.362	-0.160	0.000
$\ln y_1 \ln w_2$	0.039	0.020	0.047	0.005	0.066	0.000	0.150	0.000
$\ln y_2 \ln w_1$	0.009	0.586	0.035	0.004	0.011	0.247	0.056	0.000
$\ln y_2 \ln w_2$	0.017	0.196	0.005	0.600	-0.006	0.398	-0.030	0.009
$\ln y_3 \ln w_1$	-0.004	0.805	-0.007	0.494	0.002	0.754	-0.018	0.006
$\ln y_3 \ln w_1$	-0.007	0.599	-0.014	0.067	-0.007	0.340	-0.066	0.000
$\ln w_1 \ln k$	0.240	0.000	0.091	0.000	0.000	0.987	0.118	0.000
$\ln w_2 \ln k$	-0.044	0.045	-0.043	0.006	-0.069	0.000	-0.068	0.000
$\ln y_1 \ln k$	-0.230	0.000	-0.176	0.000	-0.115	0.000	-0.120	0.000
$\ln y_2 \ln k$	0.010	0.609	0.020	0.144	0.005	0.725	0.022	0.258
$\ln y_3 \ln k$	0.012	0.609	0.023	0.025	0.018	0.133	0.055	0.000
$\frac{1}{2} \ln k \ln k$	0.201	0.005	0.128	0.002	0.044	0.167	0.007	0.854
λ	2.401	0.000	2.392	0.000	3.146	0.000	2.328	0.000
σ	0.250	0.000	0.265	0.000	0.285	0.000	0.226	0.000

σ_u^2 the variance of inefficiency, σ_v^2 the variance of random noise, $\lambda = \frac{\sigma_u}{\sigma_v}$ the ratio of standard deviations due to inefficiency over random noise, σ total standard deviation, where $\sigma^2 = \sigma_u^2 + \sigma_v^2$

the traditional interpretation that for example costs should decrease by -0.32% in 2001 is misleading.

As we are focusing in this study more on the difference of efficiency as a result of alternative specifications we turn to the efficiency estimates instead of drawing inferences from single parameter estimates. The estimated mean firm efficiencies represent the percentage of total operating cost which would have been sufficient to provide that particular output mix in that particular year. However, note that estimation of a single frontier for every year prohibits conclusions about a *single banks' efficiency* across years. The benchmark in one year might be considerably different from the best-practice frontier in another year, for example because of the composition of the banking sector, technological change or some macroeconomic shock. While it is correct to infer that the efficiency of that bank relative to the sample stayed constant, that bank's efficiency need not have stayed constant over time. This is because we are comparing two measures relative to different frontiers. To make a statement on the development over time we would have to consider the performance of that bank relative to an *identical* frontier. The same bank would be represented in the sample twice, one observation in t and one in

$t + 1$ and the distance of the two points to the frontier can be compared.[20]

As noted above we restrict ourselves to cross-sections. This implies that I ignore distributional aspects of efficiency across time. Thus, we will compare single years and abstain from conclusions about *individual banks' performance* development over time. However, we might use *mean industry efficiency* as an indicator across years with regard to the ability of the industry as a whole how well it performed given a particular year. When comparing mean industry efficiencies in different years we only say something about the average performance of all banks in the respective samples to convert inputs as cost efficient as possible into outputs. We allow the efficient frontier to change in different years without analysing the source of change, e.g. technological change or changed economic conditions.

Table 7: Mean cost efficiency

Variable	**Mean**	**SD**	**Skew**	**Kurt.**	**Min**	**Max**	**N**
CE 2001	0.839	0.092	-1.221	4.515	0.474	0.974	1040
CE 1999	0.832	0.095	-1.406	6.089	0.278	0.972	1372
CE 1997	0.821	0.110	-1.549	6.348	0.213	0.981	1485
CE 1995	0.854	0.084	-1.369	5.478	0.396	0.977	1341

Bearing this caveat in mind table 7 reveals that German banks could have provided identical output bundles in respective years at around 15-18% lower cost. Given the low standard deviation and the observed skew we conclude that most of the German banks in the sample are located close to the frontier while only relatively few are situated farther away.[21] Our results are well in line with other findings of German bank efficiency as mentioned in section **??**. Over time one notes only a modest decline in mean CE by 1.5 percent. This result indicates that German banks might have managed the turmoils in the industry better than perceived by the public. Interestingly, the spread of the most and least efficient banks in the sample drastically increased throughout the 1990's from approximately 58% to 70% and returned to its old level in 2001. The marked differences between most and least efficient banks does not come as a surprise given the samples' diversity. Is it reasonable to assume that banks from the public and private sector all pursue the identical objective of cost minimisation? It might be possible that some cost inefficient banks simply have other risk preferences or pursue alternative objectives. This could lead them to "overemploy" inputs to insure themselves against adverse developments. Relative to a cost frontier this results in inefficiency. However, while in fact the bank only chooses a production plan which suits it's objectives. Therefore, we turn now to the results obtained from risk-return efficiency under utility maximisation.

[20] For an analysis of the development of firm-specific efficiency over time a number of models have been suggested. Examples include the inclusion of time trends like in Molyneux et al. (1997) or Lang and Welzel (1998a) and/or models with time-varying efficiency, such as in Coelli et al. (1998).

[21] Appendix B provides graphical evidence for both CE and RRE.

6.2 Risk-Return frontier

The estimates of the risk-return parameters are based on the frontier formulated in equation (29). Estimates of the SURE estimation of the system are reproduced in Appendix A. There, most coefficients are significantly different from zero with a fairly good explanatory fit. Using the estimated share equation for profit demand we obtain predicted return. As laid out in section **??** alternative risk specifications are employed to estimate risk-return frontiers. We begin with two risk specifications based on the whole sample. We then continue with two risk specifications considering sector and size specific risk.

First, consider two frontiers based on the assumption that no systematic risk-preferences between banks of different size or sector exist. The first frontier depicts the benchmark on the basis of risk specified as the standard error of predicted profits $S(E(p_\pi \pi))$. The second frontier is the benchmark specifying risk as the standard error of the prediction error $S(PE)$. Estimation results are given in table 8 below. The upper panel displays coefficient estimates for the first benchmark, the lower panel displays the estimates for the second risk specification.

Table 8: Risk-Return Frontier 1995 - 2001

Risk specification	$S(E(p_\pi \pi))$		$S(E(p_\pi \pi))$		$S(E(p_\pi \pi))$		$S(E(p_\pi \pi))$	
Year	2001		1999		1997		1995	
N	1040		1372		1485		1341	
Log likelihood	1898.057		2497.79		2591.125		2212.883	
σ_v^2	0.00011		0.00104		0.00085		0.00141	
σ_u^2	0.00526		0.00139		0.00274		0.0021	
Variable	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**
ONE	0.141	0.000	0.142	0.000	0.205	0.000	0.241	0.000
RK2001	0.090	0.259	1.084	0.000	1.016	0.000	-0.519	0.020
RKSQ2001	1.411	0.072	-2.284	0.000	-4.730	0.000	0.293	0.885
λ	6.931	0.000	1.155	0.000	1.793	0.000	1.221	0.000
σ	0.073	0.000	0.049	0.000	0.060	0.000	0.059	0.000
Risk specification	$S(PE)$		$S(PE)$		$S(PE)$		$S(PE)$	
Year	2001		1999		1997		1995	
N	1040		1372		1485		1341	
Log likelihood	1701.534		2461.84		2468.289		2215.539	
σ_v^2	0.00006		0.00052		0.00023		0.00024	
σ_u^2	0.00829		0.00338		0.00663		0.00678	
Variable	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**
ONE	0.159	0.000	0.139	0.000	0.185	0.000	0.157	0.000
RK2001	0.033	0.346	0.461	0.000	0.873	0.000	2.026	0.000
RKSQ2001	0.357	0.002	-0.517	0.000	-2.161	0.000	-7.691	0.000
λ	12.007	0.000	2.556	0.000	5.418	0.000	5.263	0.000
σ	0.091	0.000	0.062	0.000	0.083	0.000	0.084	0.000

σ_u^2 the variance of inefficiency, σ_v^2 the variance of random noise, $\lambda = \frac{\sigma_u}{\sigma_v}$ the ratio of standard deviations due to inefficiency over random noise, σ total standard deviation, where
$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

As can be seen from the number of observations the sample used is identical to the one applied to the stochastic cost frontier. The significance of λ in all years for both specifications indicates support for the formulation of a stochastic frontier spanning the expected return and expected risk space. The insignificant risk coefficients in 2001 indicates that neither of the two specifications describes the risk-return trade-off perfectly. But most of the other coefficient estimates are significant. With the exception of 1995 the sign of risk coefficients are identical and resemble the results obtained by Hughes et al. (1996). This holds especially for the case where we consider risk specified as the standard error of the prediction error. A positive coefficient of the direct risk term implies that higher risk increases expected profits. In addition, a negative coefficient of the squared risk term indicates decreasing returns in the risk-return space.

In general, the estimates indicate that risk and return can be formulated as a frontier and are not well described by standard OLS. Total variance is small compared to the case of the cost frontier for both risk specifications. This suggests that banks seem to be even closer to each other in terms of expected profit given risk. Note that the total standard deviation, σ, in case of the second risk specification exceeds σ of the first risk specification alone.

Put differently, when we measure model risk as the standard error of the prediction error, the explanatory power of risk with regard to predicted profits decreases and the error of the frontier increases. The question remains how much of this error is due to random noise and how much is due to inefficiency. The share of inefficiency is depicted by λ and it is higher for the risk-return frontier employing the standard error of the prediction error. This means while the second frontier has a larger error it also indicates a larger share of inefficiency contained in this error.

The inclusion of the the standard error of the profit share equation into the measurement of risk therefore seems to shift the frontier. In addition the shape of the frontiers is different, too, as can be seen from the chaged intercept and coefficients. To learn something about relative differences we turn to the efficiency estimates.

Table 9: Mean Risk-Return efficiency

Year	**RRE** $_{S(E(p_\pi \pi))}$	**SD**	**Min**	**Max**	**RRE** $_{S(PE)}$	**SD**	**Min**	**Max**	**N**
2001	0.953	0.021	0.701	0.999	0.934	0.022	0.686	0.999	1040
1999	0.971	0.014	0.795	0.996	0.959	0.024	0.713	0.998	1372
1997	0.960	0.024	0.750	0.993	0.942	0.034	0.686	0.999	1485
1995	0.964	0.017	0.859	0.995	0.943	0.036	0.736	0.999	1341

$\text{RRE}_{S(E(p_\pi \pi))}$: risk specified as the standard error of predicted profit
$\text{RRE}_{S(PE)}$: risk specified as the standard error of prediction error

Table 9 provides an overview of efficiency estimates based on the whole sample. Starting with the distribution of efficiency scores one notes that the higher density of efficiency estimates is confirmed. Performance measures move closer to each other as exhibited by the low standard deviation compared to cost efficiency. This result might indicate that the assumption of utility maximisation accomodates the heterogeneity of the data set more appropriately. The dense clustering of risk-return efficiency, especially in 2001 and 1999 can be seen graphically in Appendix B.

The range between the worst and best in class is only between 30 percent and 14 percent in the case of RRE $_{S(E(p_\pi \pi))}$ in the four respective years. For the risk frontier RRE $_{S(PE)}$ the spread is slightly larger, ranging between 31 percent and 26 percent. However, in the latter case this difference between best and worst in class is more stable over time. It exhibits only a slight decrease of five percent over time. In contrast, differences in $\text{RRE}_{S(E(p_\pi \pi))}$ increase more pronounced by 15 percent. Again, the difference between RRE scores of best and worst performing banks is substantially narrowed compared to cost efficiency.

Continuing with the differences between levels of mean $\text{RRE}_{S(E(p_\pi \pi))}$ and $\text{RRE}_{S(PE)}$ the shift of the frontier becomes even more apparent than in table 8. Efficiency scores according to the former measure are approximately 2 percent lower compared to the latter. But over time the development is fairly identical, exhibiting slight improvements until 1999 followed by a substantial drop towards 2001. Interestingly, the German stock market index rose from 2,091 points to 6,958 points between 1995 and 1999 while it plummeted back to 5,160 at year-end 2001. One might speculate that German banks, while having improved to assess their risk-return trade off's in bullish markets failed to assess the risks in bearish times. At the same time the compareably low impact of this drastic decline in stock prices and the high level of RRE in general might be the result of a low share of trading income for the banking population as a whole. As most of the income of German banks is generated by credit business the intense relations between borrower and lender could explain a high efficiency in choosing risk-return pairs.

With a second set of risk-return frontiers, we now examine whether the observed pattern differs for RRE measures specific to sector or size. We compare efficiency scores of two risk specifications relaxing the assumption of identical systematic risk between banks of different size and sector classes. Both frontiers consider the standard error of the prediction error $S(PE)$. However, the prediction error is based on SURE estimations for the respective asset size and sector classes. We therefore add a subscript to our risk measure of $S(PE)_{Size}$ and $S(PE)_{Sector}$, respectively. To this end we constructed three classes each. Regarding asset size the first class comprises banks below m200€, the second between m200€ and m5,000€ and the last class comprises banks with more assets than m5,000€. With respect to sector classes, we distinguish savings banks and cooperative banks, both including central and local institutes and a sector class comprising all other banks. Ideally, we would examine the identical eight asset size and nine sector classes as in section 5. However, to have sufficient degrees of freedom we had to choose this aggregation. Parameter estimates are produced in table 10 below.

Table 10: Size- and Sector-specific Risk-Return Frontier 1995 - 2001

Risk Specification	$S(PE)_{Sector}$		$S(PE)_{Sector}$		$S(PE)_{Sector}$		$S(PE)_{Sector}$	
Year	2001		1999		1997		1995	
N	1040		1372		1485		1341	
Log Likelihood	1979.638		2472.646		2273.064		2209.635	
σ_v^2	0.00013		0.00062		0.00014		0.00084	
σ_u^2	0.0045		0.00295		0.00952		0.00396	
Variable	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
ONE	0.135	0.000	0.146	0.000	0.221	0.000	0.230	0.000
RK2001	0.044	0.343	0.267	0.000	0.442	0.000	0.427	0.000
RKSQ2001	0.295	0.044	-0.223	0.000	-0.955	0.000	-1.791	0.000
λ	5.831	0.000	2.183	0.000	8.194	0.000	2.174	0.000
σ	0.068	0.000	0.060	0.000	0.098	0.000	0.069	0.000

Risk Specification	$S(PE)_{size}$		$S(PE)_{size}$		$S(PE)_{size}$		$S(PE)_{size}$	
Year	2001		1999		1997		1995	
N	1040		1372		1485		1341	
Log Likelihood	2222.565		2507.691		2753.421		1609.271	
σ_v^2	0.0002		0.00046		0.00034		0	
σ_u^2	0.00209		0.0033		0.00344		0.02509	
Variable	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
ONE	0.114	0.000	0.115	0.000	0.089	0.000	0.242	0.000
RK2001	0.216	0.040	1.009	0.000	2.435	0.000	1.523	0.000
RKSQ2001	1.101	0.051	-2.049	0.000	-6.533	0.000	-4.098	0.000
λ	3.195	0.000	2.669	0.000	3.177	0.000	71.434	0.000
σ	0.048	0.000	0.061	0.000	0.062	0.000	0.158	0.000

σ_u^2 the variance of inefficiency, σ_v^2 the variance of random noise, $\lambda = \frac{\sigma_u}{\sigma_v}$ the ratio of standard deviations due to inefficiency over random noise, σ total standard deviation, where $\sigma^2 = \sigma_u^2 + \sigma_v^2$

The rough aggragation, especially the inherent assumption that specialised banks and other institutes are exposed to the same systematic element of uncertainty regarding profits, is highly disputable. But our main interest is here whether results drastically differ from our two previous measures. Most of the parameter estimates are significantly different from zero. Also, in terms of sign they resemble the results obtained in table 8. It should be noted that the insignificant parameter on risk persists for the sector-specific frontier in 2001. Although it is significant for the asset size-specific frontier we infer that results for 2001 of any of the models should be considered with care. Estimates of σ and λ are significantly different from zero, too, thereby providing evidence that inefficiency prevails. The results indicate that total variation is similar across all four risk specifications. However, the share of inefficiency is considerably higher when allowing differences in risk between classes. This indicates that for more homogenous samples the amount of random noise in the error term of the risk-return frontier is less. But in sum, the efficiency estimates do not seem to differ dramatically. We turn next to the efficiency estimates in table 11 below.

Table 11: Mean Risk-Return efficiency

Year	$\text{RRE}_{\text{Sector}}$	SD	MIN	MAX	RRE_{Size}	SD	MIN	MAX	N
2001	0.957	0.021	0.707	0.999	0.968	0.018	0.727	0.999	1040
1999	0.961	0.022	0.727	0.998	0.960	0.024	0.719	0.998	1372
1997	0.930	0.036	0.684	0.999	0.957	0.032	0.672	0.996	1485
1995	0.953	0.028	0.790	0.997	0.882	0.039	0.714	1.043	1341

$\text{RRE}_{\text{Sector}}$: risk specified as the standard error of prediction error for banks of identical sectors
RRE_{Size}: risk specified as the standard error of prediction for banks of identical size classes

Compared to $\text{RRE}_{S(PE)}$ the average level of efficiency appears to be higher when adjusting for different size and sector classes. This suggests that part of inefficiencies might be explained by different most preferred profit demand functions depending on size and sector characteristics. However, differences are miniscule with the exception of size-specific risk in 1995. With respect to the time trend $\text{RRE}_{\text{Sector}}$ is compareable to the overall measure of $\text{RRE}_{S(PE)}$, exhibiting a stable development. When correcting for size-specific effects, however, we observe increasing RRE_{Size} with a substantial improvement between 1995 and 1997. Apart from this outlier the remaining years confirm the stability of RRE across years. [22]

In sum, similar results in magnitude and trend, rough aggregation of classes and low degrees of freedom for the class specific system estimation let us feel to continue with RRE results based on the entire sample. Therefore, we will henceforth report the bank-specific risk estimates only as it is the individual bank's risk which matters the most for a comparison of relative performance.

6.3 Comparing cost and risk-return efficiency

In this sub-section we compare CE and RRE. We start by examining rank-order correlations, continue with an analysis of the four annual cross-sections and sum up major trends over time, sector and size in the end.

Taking a closer look at the relation between the alternative efficiency models consider table 12 depicting the rank order correlation between $\text{RRE}_{S(E(p_\pi \pi))}$ and CE for the four analysed years.

[22] With respect to 1995 note that we tested a number of alternative maximisation algorithms and varied the intervalls to change intercept and slope of the function. Still, the number of iterations never exceeded two, that is some MLE estimates were equal to their OLS starting values. Also, the estimate for σ_v^2 is supposed to be zero. Put differently, all random noise is suggested to be due to inefficiency. We do not consider this a stable result and discard the efficiency estimate for 1995 as an outlier.

Table 12: Rank order correlation by Spearman's rho

		RRE01	CE01		RRE99	CE99
Corr.Coeff.	**RRE01**	1	-0.027	**RRE99**	1	0.043
Sig.(2-tailed)		.	0.376			0.111
N		1040	1040		1372	1372
		RRE97	**CE97**		**RRE95**	**CE95**
Corr.Coeff.	**RRE97**	1	.057*	**RRE95**	1	0.088**
Sig.(2-tailed)		.	0.029		.	0.001
N		1485	1485		1341	1341

* Correlation is significant at the 5% level
** Correlation is significant at the 1% level

Low but significant correlation coefficients in 1995 and 1997 indicate that the two measures move into the same direction only very loosely. Thus, there is at best little evidence that a cost efficient bank also tends to manage it's risk-return trade-off efficiently. The results suggest that the ranking of banks differs indeed depending on what behavioural assumptions are underlying the benchmark employed. Note the lack of significant rank order correlation between cost and risk-return efficiency in the more recent periods, in particular 2001. We cannot conclude that banks' ability to minimise cost efficiently correlates with its ability to attain as much return as possible given risk. In other words, those banks being cost efficient need not to be identical to risk-return efficient managements. This implies that the identification of best-practice banks depends on whether we allow for different risk-preferences or not.

The scatter plots in appendix B depict the distribution of RRE and CE for each year. We note that the dispersion of risk-return efficiency declines substantially with some outliers located increasingly far away from the frontier. This confirms the results from the preceeding section. A small share of banks became increasingly risk-return inefficient while the majority converged to each other. The higher risk-return density for the majority of banks is not mirrored by the distribution of cost efficiency. This might be the result of measuring efficiency adjusted for different preferences. Production plans deemed cost inefficient might just reflect different risk-preferences. One might argue that therefore both measures complement each other and in order to identify truly best-practice banks one should not only look at cost efficiency but also at the ability to make efficient risk-return trade-off's.

Given the heterogeneity of the sample in terms of banking sectors and size classes covered one might suspect that efficiency results exhibit a certain pattern when distinguished between asset size classes and type of bank. Measured relative to identical risk-return frontiers for the respective years tables 13 to 16 compare CE and RRE results per asset size class and sector.[23] We continue with summarising some main points per year.

[23]Note that contrary to the two measures RRE_{Sector} and RRE_{Size} this comparison is based on efficiency measures relative to frontiers based on the whole sample. The former are based on separately estimated systems for their respective class only.

Table 13: Cost and risk-return efficiency 2001

Sector	Size Class	I	II	III	IV	V	VI	VII	VIII	Total
Commercial	CE	0.802	0.848	0.813	0.816	0.744	0.868		0.821	0.810
	RRE	0.960	0.967	0.977	0.957	0.951	0.955		0.951	0.962
Local Cooperative	CE	0.848	0.845	0.826	0.804	0.795	0.939			0.837
	RRE	0.957	0.952	0.946	0.953	0.946	0.970			0.952
Central Cooperative	CE							0.677		0.677
	RRE							0.995		0.995
Local Savings	CE	0.902	0.877	0.839	0.849	0.843				0.851
	RRE	0.953	0.955	0.956	0.952	0.955				0.954
Central Savings	CE	0.836				0.860	0.961	0.693	0.887	0.809
	RRE	0.971				0.995	0.981	0.960	0.909	0.952
Mortgage Credit	CE					0.793	0.817	0.774		0.793
	RRE					0.985	0.938	0.903		0.939
Building Societies	CE			0.861	0.779	0.847				0.824
	RRE			0.984	0.941	0.939				0.953
Other Institutions	CE	0.818	0.891	0.727	0.740	0.607		0.919	0.696	0.786
	RRE	0.958	0.952	0.953	0.962	0.955		0.786	0.951	0.949
Banking Sector	CE	0.848	0.852	0.830	0.836	0.814	0.863	0.749	0.783	**0.839**
	RRE	0.957	0.953	0.952	0.953	0.956	0.952	0.922	0.935	**0.953**

Size classes I: < m200 €; II: m200 €-m500 €; III: m500 €-bn1 €; IV: bn1 €-bn5 €; V: bn5€-bn25 €; VI: bn25€-bn50€; VII: bn50€-bn100€;VIII: >bn100

In 2001 the most cost efficient banks are local savings banks while central cooperatives are most efficient in the risk-return space. Note also that central cooperative banks also exhibit the largest difference between the two measures. This difference is also pronounced for the group of other institutions. This suggests, that for a meaningful comparison of banks with objectives substantially deviating from cost minimisation the possibility of alternative objectives and preferences alters efficiency results most drastically. In terms of size CE appears to be fairly stable until total assets of bn50€ but then deteriorates considerably for the banking sector as a whole. Regarding specific bank sectors the development of CE over size indicates that the optimal size of operations differs depending on sector. While commercial banks appear to become more cost efficient beyound bn25€ in total assets local public banks, that is cooperative and savings, seem to be most cost efficient when operations remain below bn0.5€. For the low number of central public banks we note varying CE estimates. This mixed result holds equally for the remaining banking sectors. Regarding RRE across size classes we note high stability. Only for the largest size classes RRE declines. This indicates that with increasing size the ability to choose efficient risk-return trade-off's becomes increasingly difficult. Perhaps this reflects a higher degree of organisational complexity and resulting internal supervision problems. Alternatively, one can think of larger banks entering more business fields thereby increasing interdependencies of risk and the associated difficulties to assess these risks appropriately. But in sum it appears that RRE is a far less sensitive performance measure with respect to size differences. Thus, to compare banks with so different characteristics the usefulness of RRE as an additional measure is underlined.

Table 14: Cost and risk-return efficiency 1999

Sector	Size Class	I	II	III	IV	V	VI	VII	VIII	Total
Commercial	CE	0.721	0.769	0.740	0.801	0.762			0.848	0.768
	RRE	0.969	0.964	0.966	0.968	0.980			0.965	0.970
Local Cooperative	CE	0.848	0.826	0.818	0.750	0.759				0.829
	RRE	0.971	0.970	0.971	0.972	0.980				0.971
Central Cooperative	CE					0.578	0.701	0.714	0.795	0.698
	RRE					0.983	0.969	0.976	0.949	0.969
Local Savings	CE	0.930	0.899	0.832	0.850	0.862				0.856
	RRE	0.975	0.975	0.975	0.975	0.977				0.975
Central Savings	CE	0.811				0.839	0.840	0.694	0.860	0.819
	RRE	0.974				0.993	0.953	0.971	0.955	0.964
Mortgage Credit	CE					0.855	0.760	0.809		0.808
	RRE					0.974	0.920	0.941		0.946
Building Societies	CE			0.869	0.894	0.816				0.861
	RRE			0.968	0.965	0.949				0.962
Other Institutions	CE	0.807	0.799	0.827	0.721	0.577	0.847	0.923	0.714	0.780
	RRE	0.966	0.967	0.983	0.980	0.978	0.881	0.847	0.980	0.962
Banking Sector	CE	0.847	0.834	0.822	0.825	0.809	0.778	0.782	0.815	**0.832**
	RRE	0.971	0.970	0.973	0.974	0.976	0.927	0.941	0.963	**0.971**

Size classes I: < m200 €; II: m200 €-m500 €; III: m500 €-bn1 €; IV: bn1 €-bn5 €; V: bn5€-bn25 €; VI: bn25€-bn50€; VII: bn50€-bn100€;VIII: >bn100

In 1999 local saving banks are again among the top performers according to both measures. Interestingly, the commercial sector which one might expect to be most cost efficient is again performing poorly across all size classes. The difference between CE and RRE is once again most visible for central cooperative banks and, to a lesser extent, other institutions. For the banking sector as a whole the pattern of CE now exhibits more of a U-shape, that is CE declines until bn25€ in total assets and than start to rebounce for larger size classes. The results for RRE, in turn, mirror the one observed in 2001 and are constantly around 97 percent up and until bn50€. Thereafter, we again observe a dip in performance according to this measure.

With respect to central public banks we note that particular banks deviate substantially from the frontier. Especially in the case of central cooperatives the bank in the lowest size class achieves a mere 57.8 percent in cost efficiency. Similarily for central saving banks the bank in asset class VII strikes the eye with 69.4 percent at an sector average of 81.9 percent. These outliers in terms of CE should be considered with caution. The result in terms of CE might also follow from the fact that these banks are not well described by cost minimisation or are not perfectly compareable relative to an identical cost frontier. The fact that the respective RRE results are more in line with sector and size averages suggests that especially for those banks in Germany which fulfill special tasks a complementary efficiency measure yields an helpful additional perfomance perspective.

Some points are also noteworthy regarding specialised institutes. The differences between mortgage credit institutions, which are frequently owned by commercial banks, and building societies, which are frequently subsidiaries of the savings bank sector, become clearer in 1999. The former operate on a larger scale compared to their public counterparts, thereby reflecting the size of operations of their origins, that is commercial versus saving banks. Both measures of CE and RRE deteriorate the larger mortgage credit banks grow. In contrast, building societies perform among the best sectors in terms of keeping cost in check while their RRE follows the industry trend and stays fairly constant across size classes.

This reflects also the performance comparison between commercial and saving banks. A potential explanation for the seemingly stronger CE and RRE of public banks could rest in lower financing cost. Before considering this argument further we examine the remaining two years.

Table 15: Cost and risk-return efficiency 1997

Sector	Efficiency	I	II	III	IV	V	VI	VII	VIII	Total
Commercial	CE	0.732	0.707	0.708	0.717	0.787	0.919		0.864	0.741
	RRE	0.919	0.941	0.932	0.935	0.940	0.917		0.943	0.935
Local Cooperative	CE	0.825	0.833	0.807	0.768	0.671				0.824
	RRE	0.956	0.958	0.960	0.963	0.929				0.958
Central Cooperative	CE					0.419	0.654		0.709	0.609
	RRE					0.990	0.944		0.961	0.960
Local Savings	CE	0.893	0.859	0.815	0.835	0.838	0.785			0.835
	RRE	0.964	0.971	0.969	0.971	0.971	0.954			0.970
Central Savings	CE					0.750	0.817	0.775	0.797	0.788
	RRE					0.992	0.969	0.960	0.923	0.957
Mortgage Credit	CE		0.967			0.757	0.739	0.761		0.764
	RRE		0.891			0.938	0.890	0.895		0.918
Building Societies	CE			0.931	0.718	0.819				0.784
	RRE			0.923	0.952	0.918				0.941
Other Institutions	CE	0.812	0.810	0.799	0.738	0.568	0.888	0.945	0.590	0.777
	RRE	0.943	0.942	0.974	0.991	0.945	0.909	0.879	0.953	0.941
Banking Sector	CE	0.827	0.834	0.808	0.817	0.775	0.797	0.807	0.788	**0.821**
	RRE	0.955	0.960	0.964	0.968	0.953	0.921	0.913	0.943	**0.960**

Size classes I: < m200 €; II: m200 €-m500 €; III: m500 €-bn1 €; IV: bn1 €-bn5 €; V: bn5€-bn25 €; VI: bn25€-bn50€; VII: bn50€-bn100€;VIII: >bn100

In 1997 local saving banks continue to perform among the best sectors in both CE and RRE while commercial and mortgage credit banks are still on the lowest ranks. For the banking sector as a whole the general trend of CE declines as banks become larger. Perfomance only increases again for the largest institutes. In general the CE trend is less obvious then in previous years. Additional to occasional increases when moving from one size class to the next the difference between CE between the smallest and largest asset size class is smaller then in 1999 and 2001. Commercial banks are still the exception to the rule and seem to enjoy cost efficiency advantages already in medium size classes. In contrast to the two more recent periods RRE exhibits a dip for the size classes between bn25€ and bn100€. Especially other institutes contribute to this below average performance. The single outliers in terms of CE in the central public sectors already observed in 2001 and 1999 re-appear. These mixed CE results apply equally to the group of other institutes, underpinning the difficulties in measuring banks of so different characteristics against a common cost frontier.

Table 16: Cost and risk-return efficiency 1995

Sector	Size Class	I	II	III	IV	V	VI	VII	VIII	Total
Commercial	CE	0.844	0.836	0.756	0.772	0.839	0.851		0.871	0.808
	RRE	0.940	0.948	0.946	0.935	0.946	0.942		0.928	0.942
Local Cooperative	CE	0.859	0.858	0.839	0.798	0.690				0.853
	RRE	0.963	0.964	0.966	0.964	0.963				0.964
Central Cooperative	CE						0.737	0.906		0.793
	RRE						0.965	0.908		0.946
Local Savings	CE	0.910	0.873	0.855	0.865	0.842				0.864
	RRE	0.967	0.970	0.969	0.970	0.971				0.970
Central Savings	CE					0.740	0.912	0.862	0.898	0.877
	RRE					0.990	0.950	0.963	0.909	0.944
Mortgage Credit	CE				0.921	0.804	0.879	0.652		0.820
	RRE				0.967	0.947	0.947	0.949		0.950
Building Societies	CE			0.950	0.900					0.916
	RRE			0.946	0.968					0.961
Other Institutions	CE	0.927		0.825	0.894	0.697	0.804			0.789
	RRE	0.934		0.972	0.980	0.966	0.935			0.955
Banking Sector	CE	0.863	0.861	0.845	0.851	0.811	0.845	0.787	0.880	**0.854**
	RRE	0.962	0.965	0.967	0.967	0.962	0.947	0.947	0.921	**0.964**

Size classes I: < m200 €; II: m200 €-m500 €; III: m500 €-bn1 €; IV: bn1 €-bn5 €; V: bn5€-bn25 €; VI: bn25€-bn50€; VII: bn50€-bn100€;VIII: >bn100

With regard to 1995 local public banks remain best in class in both performance dimensions. The CE trend in turn is even more harmonised and largest banks across all sectors exhibit even higher CE than the smallest banks with a dip in the second but largest asset size class. The tendency regarding RRE again notes stable performance until bn50€ in assets and a slight deterioration thereafter.

While the results regarding the development over time and between different sector and size classes do not suggest one obvious pattern, a number of tendencies can be summarised.

Time-wise mean industry efficiencies stays roughly constant. Changes refer more to the spread of efficiency as was mentioned earlier for the whole sample.

Sector-wise, local saving banks are surprisingly efficient according to both measures, ranking among the top three in all years. With few exceptions, cooperative local banks are also among the top three in both dimensions. This result indicates that public banks might still benefit from their shareholder structure and the resulting ability to fund their business cheaper than private sector banks because of the federal governments guarantee obligation.[24] Also, the on average smaller size of operations might imply that operative cost are held in check more efficiently and risk-return trade off's can be made more succesfully. In contrast, commercial banks are surprisingly cost inefficient. Especially in asset size classes below bn25€ this sector performs frequently below the market average by a substantial percentage. This could be the result of squeezed margins because of competition with public sector banks and their lower funding cost. Regarding risk-return efficiency commercial banks experienced a turnaround in the last two years. While performing worst in 1995 and 1997 compared to all other sectors the marked best in class practice during 2001 and 1999. A reason might rest in the increased relative importance of investment banking business. Fierce competition in the traditional loan market caused commercial banks to expand their

[24] So-called "Gewaehrtraegerhaftung", stating that ultimately the respective state governments will guarantee for their saving bank sector. This guarntorship is to fase out in 2005

business into these activities more rapidly compared to the public sector. Little experience and limited engagement in this income source might have resulted in initially poor decision making. With increasing activity in this field knowledge was acquired and led to more sophisticated risk-return assessments in subsequent years. Thus, the improvement in risk-return efficiency might be the result of some learning effects. According to the estimates these improvements were insensitive to the size of operation and applied across asset size classes for the whole sector. Contrary to their local branching networks the central institutes of cooperatives and savings banks performed poorly in terms cost efficiency. Especially central cooperatives appear to have operated most cost inefficiently with potential savings ranging between 20 to 40 percent in the four years, respectively. Regarding the specialised institutes cost and return efficiency suggest a marked difference between mortgage institutes and building societies. While the former tend to operate on a scale beyound bn5€ in total assets the sector is ranked among the three worst performing sectors in both efficiency dimensions throughout all years. For the latter operations are usually between €500mn and €1bn and yield in particular superior cost efficiencies. As expected, the results of banks included in the other sector perform consistently poor. Given the special nature of numerous institutes in this group the cost efficiency result is hardly surprising. However, low risk-return efficiency scores indicate that those banks were also unable to choose risk-return trade-off's according to their particular risk-preferences efficiently.

Size-wise a slight tendency can be observed that cost efficiency tends to decline for larger banks up to €100bn in total assets. The commercial sector is an exception to this development and here cost efficiency increases already earlier. It should be noted that in this largest asset class, which accounts for almost have of total assets, public saving banks perform better than their commercial counterparts. For the risk-return efficiency measure we note a decline for the banking sector as a whole in asset size classes larger than €25bn. As in the case of cost efficiency the commercial sector follows this trend the least. Most pronounced risk-return efficiency reductions prevail for the sector of other banks and central public institutions. Thus, it appears that bigger institutes in sectors with potentially alternative objectives seem to be less apt to optimise their risk-return trade-off efficiently compared to their smaller counterparts.

7 Conlusion

In this paper I am examining the effect of risk on efficiency measures. I compare cost efficiency measures from stochastic cost frontier (SFA) analysis with results from a risk-return frontier derived from utility maximisation. The former represents the current standard approach to measure what percentage of incurred costs could have been avoided if management is fully efficient. One of the most important assumptions in the model is the believe that managers are minimising cost and are neutral towards risk. I relax these assumptions in the utility maximisation model. Managers can choose production plans satisfying potential alternative objectives and different risk preferences.

In four years from 1995 to 2001 there is evidence that cost inefficiency exists in German banking. Mean cost inefficiencies are around 18 percent. The findings are well in line with the results obtained by the few studies focusing on the German banking market. I provide a split of mean efficiency scores for different banking sectors and size classes. Especially public banks of the savings and, to a lesser extent, cooperative sector are superior in terms of converting inputs as cost efficient as possible into outputs. Commercial banks are in all four years among the worst performing banks. In terms of size no clear-cut pattern can be observed. While public local banks appear to operate better on a smaller scale, commercial banks seem to be more able to achieve cost efficiency in larger asset size classes. Over time, mean cost efficiency remained fairly stable.

The utility maximisation model employs the Almost Ideal Demand System (AID) from consumer theory to derive optimal demand shares for inputs and profit. I adopt the model from Hughes et al. who applied it to a variety of studies of the US banking market. The most important virtue lies in relaxing the cost minimising assumption underlying traditional SFA analysis. Thereby managers are allowed to pursue alternative objectives and choose production plans which reflect their (different) risk preferences. I use the optimal demand for profits resulting from the AID to examine the risk-return trade-off managers make. Risk-return efficiency (RRE) is measured against a frontier of predicted profits and the uncertainty associated with these predictions.

I examine four different risk specifications and report mean RRE for the same data set as for the cost frontier. The risk specifications are the standard error of profits predicted by the profit share equation, the standard error of the prediction error for the whole sample, the standard error of the prediction error for the profit share equation per sector and the standard error of the prediction error for the profit share equation per size class.

Results for RRE differ considerably from the results obtained for cost efficiency. First, mean RRE is generally lower, amounting to approximately four percent. Second, the distribution of RRE is more dense. For each year the vast majoristy of banks is located close to the frontier. Only a few outliers are relatively far away with lowest efficiency scores of around 70 percent. Third, the difference between best and worst in class is much smaller compared to the cost case, where the minimum scores are between 20 and 50 percent in the respective years. Fourth, rank-order correlation is low and in two years insignificant.

Thus, a model accounting for heterogenous objectives and risk-preferencesleads to substantially improved efficiency measures. In addition, banks which are good at minimising cost are rarely perfoming well with regard to choose an efficient risk-return trade-off. Therefore, when evaluating the efficiency of banks RRE provides important additional information and should be assessed, too.

Appendix A: SURE estimates

Table 17: SURE Estimates 2001

	Input demand SW1				**Input demand SW2**				**Demand for $p_\pi \pi$**			
N	1040				1040				1040			
Parms	45				45				45			
R^2	0.9137				0.9565				0.3500			
P-value	0.0000				0.0000				0.0000			
Variable	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**
lnp	0.319	0.101	3.160	0.002	-0.049	0.055	-0.880	0.381	-0.228	0.140	-1.630	0.103
lny1	0.122	0.079	1.550	0.122	0.002	0.043	0.050	0.963	-0.118	0.109	-1.090	0.276
lny2	-0.015	0.022	-0.670	0.504	-0.010	0.012	-0.870	0.386	0.022	0.030	0.720	0.473
lny3	0.015	0.027	0.580	0.565	0.013	0.015	0.860	0.388	-0.003	0.037	-0.080	0.935
lnw1	0.060	0.077	0.780	0.435	-0.145	0.042	-3.430	0.001	0.034	0.106	0.320	0.749
lnw2	-0.277	0.039	-7.030	0.000	0.305	0.022	14.050	0.000	0.011	0.055	0.210	0.837
lnppi	-0.046	0.039	-1.170	0.242	-0.068	0.021	-3.190	0.001	0.078	0.054	1.450	0.148
lnk	-0.040	0.065	-0.610	0.542	0.005	0.036	0.140	0.886	0.023	0.091	0.250	0.801
lnrev	-0.075	0.009	-8.100	0.000	0.007	0.005	1.350	0.177	0.044	0.013	3.410	0.001
ln5pp	-0.080	0.041	-1.930	0.054	-0.040	0.023	-1.770	0.077	0.043	0.057	0.740	0.457
ln5y1y1	0.059	0.023	2.510	0.012	-0.012	0.013	-0.920	0.357	-0.073	0.032	-2.240	0.025
ln5y1y2	-0.008	0.010	-0.840	0.400	0.009	0.006	1.550	0.122	0.007	0.014	0.530	0.599
ln5y1y3	-0.024	0.012	-1.960	0.049	-0.003	0.007	-0.430	0.667	0.027	0.017	1.640	0.101
ln5y2y2	-0.003	0.001	-2.110	0.034	0.000	0.001	0.650	0.519	0.003	0.002	1.750	0.081
ln5y2y3	-0.005	0.004	-1.260	0.209	0.000	0.002	-0.070	0.948	0.006	0.005	1.110	0.266
ln5y3y3	0.004	0.002	2.160	0.031	-0.002	0.001	-1.730	0.083	-0.001	0.002	-0.300	0.766
ln5w1w1	-0.077	0.019	-4.000	0.000	0.029	0.011	2.760	0.006	0.010	0.027	0.360	0.719
ln5w1w2	0.055	0.018	3.060	0.002	-0.031	0.010	-3.180	0.001	-0.010	0.025	-0.400	0.690
ln5w2w2	-0.043	0.006	-6.990	0.000	0.045	0.003	13.410	0.000	0.010	0.008	1.140	0.254
ln5pppp	0.023	0.006	3.700	0.000	-0.002	0.003	-0.450	0.650	-0.044	0.009	-5.120	0.000
ln5kk	0.019	0.021	0.910	0.361	-0.005	0.011	-0.480	0.632	-0.041	0.029	-1.430	0.154
lnplny1	-0.038	0.029	-1.290	0.198	-0.040	0.016	-2.490	0.013	0.019	0.040	0.480	0.633
lnplny2	-0.002	0.007	-0.300	0.763	0.003	0.004	0.650	0.517	0.009	0.010	0.860	0.390
lnplny3	0.002	0.009	0.200	0.841	0.005	0.005	1.070	0.285	0.001	0.013	0.040	0.968
lnplnw1	0.067	0.028	2.420	0.016	0.009	0.015	0.620	0.536	-0.036	0.038	-0.940	0.348
lnplnw2	0.017	0.010	1.750	0.081	-0.015	0.005	-2.760	0.006	-0.009	0.013	-0.650	0.518
lnplnppi	-0.026	0.016	-1.660	0.097	0.030	0.009	3.510	0.000	0.037	0.022	1.700	0.089
lnplnk	0.036	0.023	1.550	0.121	0.030	0.013	2.360	0.018	-0.028	0.032	-0.880	0.381
lny1lnw1	0.024	0.022	1.100	0.270	0.019	0.012	1.540	0.124	-0.013	0.031	-0.410	0.681
lny1lnw2	0.023	0.007	3.140	0.002	-0.003	0.004	-0.820	0.410	-0.016	0.010	-1.520	0.129
lny2lnw1	0.001	0.006	0.190	0.847	0.004	0.003	1.170	0.241	-0.009	0.009	-1.080	0.281
lny2lnw2	-0.004	0.003	-1.580	0.114	-0.005	0.001	-3.210	0.001	0.008	0.004	2.230	0.026
lny3lnw1	0.012	0.008	1.420	0.155	-0.008	0.005	-1.790	0.074	-0.006	0.011	-0.510	0.610
lny3lnw2	-0.014	0.003	-3.950	0.000	0.005	0.002	2.620	0.009	0.013	0.005	2.630	0.009
lny1k	-0.042	0.020	-2.120	0.034	0.006	0.011	0.560	0.576	0.063	0.028	2.300	0.022
lny2k	0.013	0.005	2.610	0.009	-0.005	0.003	-1.860	0.063	-0.013	0.007	-1.870	0.061
lny3k	0.009	0.007	1.260	0.207	0.004	0.004	1.020	0.308	-0.014	0.009	-1.500	0.133
lny1ppi	-0.019	0.013	-1.490	0.136	0.014	0.007	2.050	0.040	0.039	0.017	2.270	0.023
lny2ppi	0.002	0.004	0.490	0.627	-0.001	0.002	-0.460	0.644	-0.006	0.005	-1.210	0.228
lny3ppi	0.006	0.006	1.070	0.284	-0.001	0.003	-0.170	0.867	-0.011	0.008	-1.430	0.154
lnw1k	-0.039	0.019	-2.070	0.039	-0.006	0.010	-0.550	0.585	0.022	0.026	0.840	0.401
lnw2k	-0.002	0.007	-0.310	0.759	-0.004	0.004	-1.150	0.249	-0.001	0.010	-0.160	0.876
lnw1ppi	-0.001	0.008	-0.170	0.863	-0.013	0.005	-2.740	0.006	0.007	0.012	0.640	0.525
lnw2ppi	0.004	0.006	0.780	0.433	-0.012	0.003	-3.790	0.000	-0.006	0.008	-0.760	0.445
lnppilnk	0.011	0.011	0.950	0.342	-0.014	0.006	-2.320	0.020	-0.022	0.016	-1.390	0.163
Constant	0.046	0.171	0.270	0.789	0.683	0.094	7.290	0.000	0.252	0.236	1.070	0.286

Table 18: SURE Estimates 1999

	Input demand SW1				Input demand SW2				Demand for PBT			
N	1372				1372				1372			
Parms	45				45				45			
R2	0.8991				0.9499				0.3994			
Parms	0.0000				0.0000				0.0000			
Variable	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**
lnp	0.356	0.090	3.970	0.000	0.274	0.046	5.970	0.000	-0.733	0.123	-5.970	0.000
lny1	0.275	0.079	3.480	0.000	0.196	0.040	4.840	0.000	-0.581	0.108	-5.370	0.000
lny2	-0.031	0.021	-1.460	0.143	0.008	0.011	0.770	0.444	0.056	0.029	1.960	0.050
lny3	-0.030	0.024	-1.240	0.216	-0.077	0.012	-6.270	0.000	0.150	0.033	4.540	0.000
lnw1	0.015	0.075	0.200	0.842	-0.373	0.039	-9.670	0.000	0.396	0.103	3.840	0.000
lnw2	-0.242	0.044	-5.560	0.000	0.211	0.022	9.460	0.000	0.031	0.060	0.520	0.601
lnppi	-0.067	0.044	-1.510	0.130	-0.041	0.023	-1.800	0.071	0.175	0.060	2.910	0.004
lnk	-0.143	0.064	-2.250	0.025	-0.098	0.033	-3.020	0.003	0.290	0.087	3.330	0.001
lnrev	-0.060	0.008	-7.530	0.000	-0.006	0.004	-1.430	0.152	0.054	0.011	4.960	0.000
ln5pp	0.006	0.031	0.180	0.858	-0.051	0.016	-3.180	0.001	0.082	0.043	1.920	0.055
ln5y1y1	0.055	0.019	2.900	0.004	-0.022	0.010	-2.240	0.025	0.000	0.026	0.000	0.997
ln5y1y2	0.007	0.007	1.010	0.310	-0.005	0.003	-1.320	0.186	-0.007	0.009	-0.810	0.421
ln5y1y3	-0.045	0.010	-4.720	0.000	0.011	0.005	2.270	0.023	0.007	0.013	0.540	0.588
ln5y2y2	0.001	0.001	0.390	0.693	0.000	0.001	-0.710	0.480	0.001	0.002	0.800	0.425
ln5y2y3	-0.015	0.003	-5.700	0.000	-0.002	0.001	-1.690	0.091	0.023	0.004	6.300	0.000
ln5y3y3	0.009	0.002	5.130	0.000	0.005	0.001	5.140	0.000	-0.012	0.003	-4.850	0.000
ln5w1w1	-0.081	0.015	-5.220	0.000	-0.020	0.008	-2.470	0.013	0.093	0.021	4.380	0.000
ln5w1w2	0.060	0.017	3.470	0.001	-0.084	0.009	-9.440	0.000	0.047	0.024	1.990	0.046
ln5w2w2	-0.029	0.006	-4.460	0.000	0.036	0.003	10.890	0.000	-0.009	0.009	-0.980	0.328
ln5pppp	0.056	0.008	7.090	0.000	0.019	0.004	4.640	0.000	-0.090	0.011	-8.390	0.000
ln5kk	0.000	0.011	0.030	0.976	-0.006	0.006	-1.090	0.274	0.024	0.015	1.560	0.119
lnplny1	0.014	0.021	0.680	0.496	-0.045	0.011	-4.210	0.000	0.060	0.029	2.110	0.035
lnplny2	0.018	0.005	3.510	0.000	-0.004	0.003	-1.600	0.109	-0.014	0.007	-2.000	0.046
lnplny3	-0.015	0.008	-1.940	0.052	0.014	0.004	3.610	0.000	-0.013	0.010	-1.290	0.197
lnplnw1	0.037	0.021	1.770	0.076	0.052	0.011	4.810	0.000	-0.112	0.029	-3.900	0.000
lnplnw2	0.015	0.010	1.500	0.132	0.022	0.005	4.090	0.000	-0.051	0.014	-3.650	0.000
lnplnppi	-0.088	0.013	-6.530	0.000	-0.035	0.007	-5.020	0.000	0.119	0.018	6.460	0.000
lnplnk	-0.025	0.014	-1.770	0.077	0.032	0.007	4.490	0.000	-0.025	0.019	-1.300	0.193
lny1lnw1	0.027	0.017	1.570	0.115	0.040	0.009	4.570	0.000	-0.085	0.023	-3.640	0.000
lny1lnw2	0.028	0.008	3.370	0.001	0.017	0.004	4.000	0.000	-0.057	0.011	-5.100	0.000
lny2lnw1	-0.008	0.005	-1.670	0.095	0.001	0.003	0.340	0.734	0.010	0.007	1.440	0.151
lny2lnw2	-0.013	0.003	-4.300	0.000	0.000	0.002	0.240	0.809	0.014	0.004	3.530	0.000
lny3lnw1	0.005	0.006	0.860	0.393	-0.018	0.003	-6.190	0.000	0.024	0.008	3.180	0.001
lny3lnw2	-0.006	0.004	-1.620	0.105	-0.006	0.002	-3.230	0.001	0.013	0.005	2.470	0.013
lny1k	-0.036	0.013	-2.700	0.007	0.013	0.007	1.950	0.051	0.003	0.018	0.190	0.849
lny2k	0.006	0.003	1.950	0.051	0.004	0.002	2.730	0.006	-0.012	0.004	-2.710	0.007
lny3k	0.023	0.004	5.320	0.000	-0.009	0.002	-4.220	0.000	-0.008	0.006	-1.360	0.175
lny1ppi	-0.069	0.010	-6.870	0.000	-0.020	0.005	-3.910	0.000	0.091	0.014	6.660	0.000
lny2ppi	-0.003	0.004	-0.840	0.399	-0.001	0.002	-0.290	0.770	-0.005	0.006	-0.980	0.329
lny3ppi	0.027	0.005	5.250	0.000	0.012	0.003	4.640	0.000	-0.036	0.007	-5.100	0.000
lnw1k	-0.022	0.014	-1.540	0.124	-0.012	0.007	-1.710	0.087	0.040	0.019	2.060	0.039
lnw2k	-0.003	0.006	-0.520	0.600	-0.018	0.003	-5.570	0.000	0.031	0.009	3.620	0.000
lnw1ppi	0.026	0.011	2.420	0.016	0.016	0.005	2.920	0.003	-0.029	0.014	-2.000	0.045
lnw2ppi	-0.002	0.007	-0.330	0.741	-0.006	0.003	-1.780	0.075	0.016	0.009	1.800	0.072
lnppilnk	0.045	0.009	4.990	0.000	0.008	0.005	1.660	0.096	-0.047	0.012	-3.740	0.000
Constant	0.037	0.187	0.200	0.843	0.260	0.096	2.710	0.007	0.660	0.257	2.570	0.010

Table 19: SURE Estimates 1997

	Input demand SW1				Input demand SW2				Demand for PBT			
N	1485				1485				1485			
Parms	45				45				45			
R2	0.8940				0.9504				0.3926			
Parms	0.0000				0.0000				0.0000			
Variable	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**
lnp	0.062	0.057	1.090	0.276	0.114	0.028	4.110	0.000	-0.219	0.083	-2.640	0.008
lny1	0.032	0.044	0.730	0.466	0.194	0.021	9.070	0.000	-0.254	0.064	-3.980	0.000
lny2	-0.042	0.018	-2.330	0.020	0.011	0.009	1.250	0.211	-0.024	0.027	-0.920	0.358
lny3	0.088	0.021	4.230	0.000	-0.075	0.010	-7.330	0.000	0.059	0.030	1.950	0.051
lnw1	0.327	0.048	6.740	0.000	-0.325	0.024	-13.700	0.000	0.008	0.071	0.110	0.909
lnw2	-0.161	0.025	-6.320	0.000	0.308	0.012	24.810	0.000	-0.099	0.037	-2.660	0.008
lnppi	-0.260	0.043	-5.990	0.000	-0.071	0.021	-3.350	0.001	0.265	0.063	4.190	0.000
lnk	-0.081	0.027	-2.960	0.003	-0.114	0.013	-8.470	0.000	0.250	0.040	6.250	0.000
lnrev	-0.033	0.009	-3.680	0.000	-0.006	0.004	-1.430	0.154	0.015	0.013	1.190	0.234
ln5pp	-0.020	0.029	-0.690	0.489	-0.005	0.014	-0.360	0.716	0.009	0.042	0.220	0.829
ln5y1y1	0.071	0.013	5.230	0.000	-0.020	0.007	-3.040	0.002	-0.043	0.020	-2.170	0.030
ln5y1y2	0.027	0.009	3.080	0.002	0.005	0.004	1.080	0.280	-0.016	0.013	-1.240	0.215
ln5y1y3	-0.037	0.010	-3.890	0.000	0.027	0.005	5.900	0.000	-0.030	0.014	-2.170	0.030
ln5y2y2	0.000	0.001	-0.090	0.930	0.001	0.001	1.450	0.147	0.000	0.002	0.070	0.947
ln5y2y3	-0.024	0.004	-5.700	0.000	-0.002	0.002	-1.090	0.275	0.013	0.006	2.210	0.027
ln5y3y3	0.004	0.002	2.320	0.020	-0.003	0.001	-4.130	0.000	0.004	0.002	1.830	0.067
ln5w1w1	-0.040	0.010	-3.990	0.000	-0.006	0.005	-1.150	0.248	0.016	0.015	1.060	0.289
ln5w1w2	0.058	0.009	6.550	0.000	-0.062	0.004	-14.190	0.000	0.022	0.013	1.690	0.091
ln5w2w2	-0.016	0.005	-3.330	0.001	0.055	0.002	22.970	0.000	-0.026	0.007	-3.700	0.000
ln5pppp	0.057	0.006	9.560	0.000	0.020	0.003	6.960	0.000	-0.081	0.009	-9.230	0.000
ln5kk	0.025	0.011	2.260	0.024	0.012	0.005	2.210	0.027	-0.062	0.016	-3.870	0.000
lnplny1	0.023	0.019	1.240	0.213	-0.020	0.009	-2.210	0.027	-0.018	0.027	-0.670	0.505
lnplny2	0.033	0.006	5.310	0.000	-0.001	0.003	-0.200	0.838	-0.009	0.009	-0.990	0.324
lnplny3	-0.012	0.007	-1.760	0.079	0.012	0.003	3.630	0.000	-0.023	0.010	-2.330	0.020
lnplnw1	0.028	0.016	1.770	0.077	0.020	0.008	2.650	0.008	-0.035	0.023	-1.540	0.123
lnplnw2	0.017	0.007	2.410	0.016	0.007	0.003	1.960	0.049	-0.032	0.010	-3.220	0.001
lnplnppi	-0.008	0.013	-0.670	0.500	-0.019	0.006	-3.130	0.002	0.060	0.018	3.270	0.001
lnplnk	-0.042	0.015	-2.870	0.004	0.006	0.007	0.860	0.389	0.047	0.021	2.190	0.029
lny1lnw1	-0.011	0.011	-0.980	0.326	0.032	0.005	5.930	0.000	-0.011	0.016	-0.650	0.513
lny1lnw2	0.032	0.005	6.310	0.000	0.018	0.002	7.200	0.000	-0.047	0.007	-6.520	0.000
lny2lnw1	-0.023	0.004	-6.000	0.000	0.000	0.002	0.200	0.844	0.009	0.006	1.520	0.128
lny2lnw2	-0.009	0.003	-3.670	0.000	0.002	0.001	1.590	0.112	-0.002	0.004	-0.640	0.522
lny3lnw1	0.011	0.004	2.940	0.003	-0.015	0.002	-8.830	0.000	0.022	0.005	4.140	0.000
lny3lnw2	0.004	0.003	1.490	0.137	-0.005	0.001	-4.230	0.000	0.006	0.004	1.610	0.108
lny1k	-0.060	0.009	-6.520	0.000	0.002	0.005	0.410	0.680	0.062	0.013	4.600	0.000
lny2k	0.001	0.004	0.200	0.838	-0.002	0.002	-0.900	0.370	0.000	0.006	0.080	0.939
lny3k	0.027	0.004	5.950	0.000	-0.010	0.002	-4.660	0.000	0.004	0.007	0.610	0.544
lny1ppi	-0.020	0.010	-1.890	0.058	-0.023	0.005	-4.490	0.000	0.060	0.015	3.980	0.000
lny2ppi	-0.007	0.004	-1.870	0.061	-0.003	0.002	-1.820	0.069	0.012	0.006	2.130	0.033
lny3ppi	-0.004	0.005	-0.920	0.360	0.008	0.002	3.640	0.000	-0.002	0.007	-0.290	0.770
lnw1k	0.017	0.008	2.050	0.040	-0.008	0.004	-1.980	0.047	-0.020	0.012	-1.630	0.102
lnw2k	-0.024	0.005	-5.060	0.000	-0.020	0.002	-8.450	0.000	0.050	0.007	7.140	0.000
lnw1ppi	-0.031	0.010	-3.090	0.002	0.016	0.005	3.290	0.001	0.004	0.015	0.240	0.810
lnw2ppi	-0.022	0.006	-3.910	0.000	-0.024	0.003	-8.450	0.000	0.032	0.008	3.820	0.000
lnppilnk	0.037	0.008	4.360	0.000	0.018	0.004	4.290	0.000	-0.078	0.012	-6.350	0.000
Constant	0.855	0.127	6.740	0.000	0.421	0.062	6.790	0.000	-0.208	0.185	-1.120	0.261

Table 20: SURE Estimates 1995

	Input demand SW1				Input demand SW2				Demand for PBT			
N	1341				1341				1341			
Parms	45				45				45			
R2	0.8714				0.9504				0.3911			
Parms	0.0000				0.0000				0.0000			
Variable	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**
lnp	-0.020	0.082	-0.240	0.808	-0.123	0.035	-3.470	0.001	0.074	0.114	0.640	0.519
lny1	-0.030	0.063	-0.480	0.630	-0.043	0.027	-1.580	0.113	0.026	0.087	0.300	0.764
lny2	0.003	0.024	0.110	0.911	0.051	0.011	4.810	0.000	-0.104	0.034	-3.070	0.002
lny3	0.095	0.036	2.670	0.008	0.031	0.015	2.030	0.043	-0.048	0.049	-0.980	0.330
lnw1	0.393	0.071	5.550	0.000	-0.122	0.031	-3.990	0.000	-0.246	0.098	-2.500	0.013
lnw2	-0.116	0.034	-3.390	0.001	0.315	0.015	21.330	0.000	-0.230	0.047	-4.840	0.000
lnppi	-0.320	0.049	-6.580	0.000	-0.085	0.021	-4.060	0.000	0.407	0.068	6.030	0.000
lnk	-0.001	0.037	-0.030	0.973	-0.027	0.016	-1.710	0.088	0.076	0.052	1.470	0.140
lnrev	-0.088	0.011	-7.940	0.000	-0.009	0.005	-1.930	0.053	0.063	0.015	4.090	0.000
ln5pp	-0.038	0.038	-1.010	0.311	0.058	0.016	3.580	0.000	0.007	0.052	0.140	0.891
ln5y1y1	0.107	0.020	5.280	0.000	0.040	0.009	4.580	0.000	-0.101	0.028	-3.580	0.000
ln5y1y2	-0.015	0.013	-1.130	0.257	-0.018	0.006	-3.170	0.002	0.042	0.018	2.320	0.020
ln5y1y3	-0.076	0.014	-5.480	0.000	-0.029	0.006	-4.810	0.000	0.052	0.019	2.690	0.007
ln5y2y2	0.005	0.002	2.560	0.010	0.004	0.001	4.540	0.000	-0.002	0.002	-0.870	0.387
ln5y2y3	0.011	0.005	2.060	0.039	0.015	0.002	6.450	0.000	-0.036	0.008	-4.830	0.000
ln5y3y3	0.009	0.003	3.010	0.003	0.005	0.001	3.920	0.000	-0.005	0.004	-1.210	0.225
ln5w1w1	-0.036	0.015	-2.330	0.020	0.033	0.007	4.940	0.000	-0.015	0.021	-0.690	0.488
ln5w1w2	0.049	0.015	3.240	0.001	-0.057	0.007	-8.640	0.000	0.008	0.021	0.380	0.702
ln5w2w2	-0.018	0.006	-2.980	0.003	0.059	0.003	22.540	0.000	-0.029	0.008	-3.430	0.001
ln5pppp	0.071	0.007	9.840	0.000	0.020	0.003	6.390	0.000	-0.094	0.010	-9.340	0.000
ln5kk	0.035	0.014	2.450	0.014	0.021	0.006	3.410	0.001	-0.054	0.020	-2.720	0.007
lnplny1	0.059	0.023	2.520	0.012	0.042	0.010	4.180	0.000	-0.087	0.033	-2.670	0.008
lnplny2	-0.008	0.009	-0.880	0.377	-0.014	0.004	-3.490	0.000	0.049	0.013	3.720	0.000
lnplny3	-0.010	0.010	-1.050	0.294	-0.008	0.004	-1.860	0.064	-0.020	0.013	-1.490	0.136
lnplnw1	0.035	0.022	1.600	0.110	-0.016	0.009	-1.710	0.087	-0.018	0.030	-0.600	0.547
lnplnw2	0.014	0.011	1.240	0.216	-0.017	0.005	-3.520	0.000	-0.013	0.015	-0.860	0.391
lnplnppi	-0.004	0.015	-0.290	0.768	-0.013	0.007	-1.960	0.049	0.030	0.021	1.440	0.151
lnplnk	-0.035	0.018	-1.940	0.053	-0.022	0.008	-2.840	0.004	0.053	0.025	2.090	0.036
lny1lnw1	-0.036	0.015	-2.320	0.020	-0.022	0.007	-3.320	0.001	0.061	0.022	2.850	0.004
lny1lnw2	0.013	0.007	1.890	0.058	0.003	0.003	1.100	0.271	-0.010	0.010	-0.980	0.327
lny2lnw1	0.004	0.006	0.660	0.507	0.018	0.003	6.500	0.000	-0.037	0.009	-4.310	0.000
lny2lnw2	0.007	0.004	2.130	0.033	0.003	0.002	2.070	0.038	-0.021	0.005	-4.400	0.000
lny3lnw1	0.009	0.007	1.390	0.166	0.005	0.003	1.730	0.084	0.011	0.009	1.190	0.234
lny3lnw2	-0.006	0.004	-1.360	0.173	-0.003	0.002	-1.600	0.109	0.013	0.006	2.210	0.027
lny1k	-0.066	0.014	-4.620	0.000	-0.018	0.006	-2.890	0.004	0.063	0.020	3.160	0.002
lny2k	0.007	0.006	1.170	0.243	-0.001	0.003	-0.450	0.656	-0.010	0.008	-1.180	0.240
lny3k	0.021	0.006	3.510	0.000	-0.001	0.003	-0.200	0.842	0.000	0.008	0.030	0.973
lny1ppi	-0.018	0.012	-1.520	0.128	-0.011	0.005	-2.160	0.031	0.027	0.017	1.600	0.109
lny2ppi	0.001	0.004	0.270	0.790	-0.005	0.002	-2.930	0.003	0.005	0.006	0.820	0.409
lny3ppi	0.001	0.006	0.140	0.885	0.003	0.003	0.980	0.327	0.004	0.009	0.510	0.612
lnw1k	0.015	0.012	1.270	0.203	0.004	0.005	0.880	0.377	-0.036	0.016	-2.190	0.029
lnw2k	-0.018	0.006	-2.910	0.004	-0.008	0.003	-2.980	0.003	0.030	0.008	3.490	0.000
lnw1ppi	-0.041	0.012	-3.360	0.001	0.003	0.005	0.580	0.561	0.027	0.017	1.590	0.113
lnw2ppi	-0.021	0.006	-3.450	0.001	-0.014	0.003	-5.520	0.000	0.039	0.008	4.630	0.000
lnppilnk	0.023	0.009	2.420	0.015	0.015	0.004	3.620	0.000	-0.042	0.013	-3.210	0.001
Constant	1.016	0.163	6.210	0.000	0.772	0.071	10.910	0.000	-0.849	0.227	-3.730	0.000

Appendix B: Cost versus Risk-Return Efficiency

Figure 2: Cost vs. Risk-Return Efficiency 2001

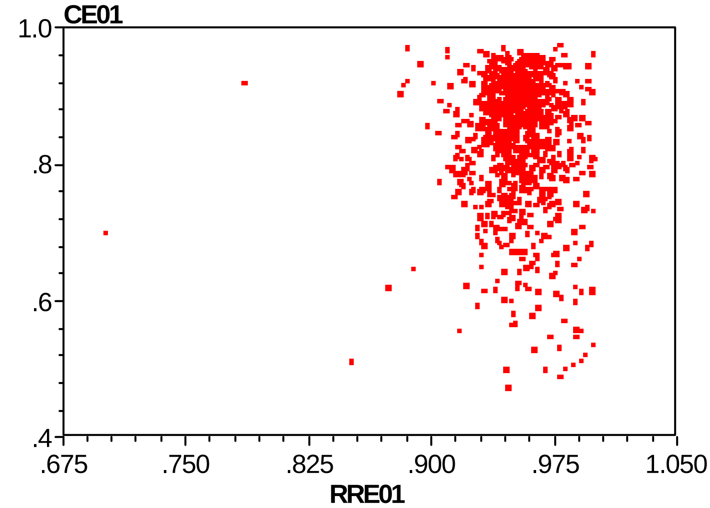


Figure 3: Cost vs. Risk-Return Efficiency 1999

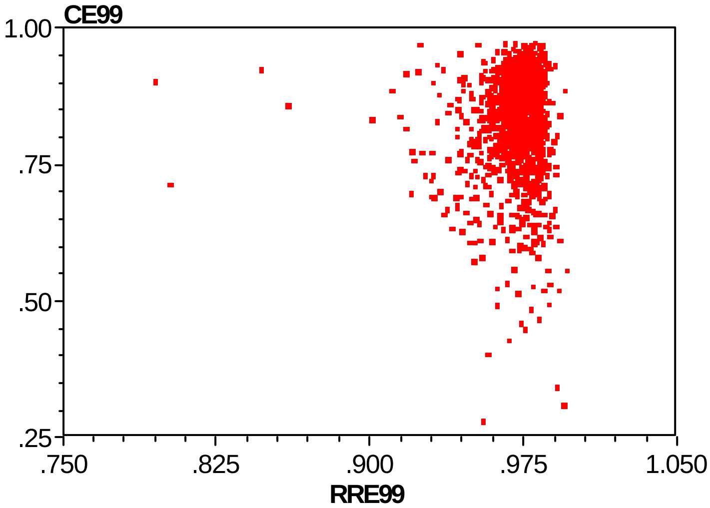


Figure 4: Cost vs. Risk-Return Efficiency 1997

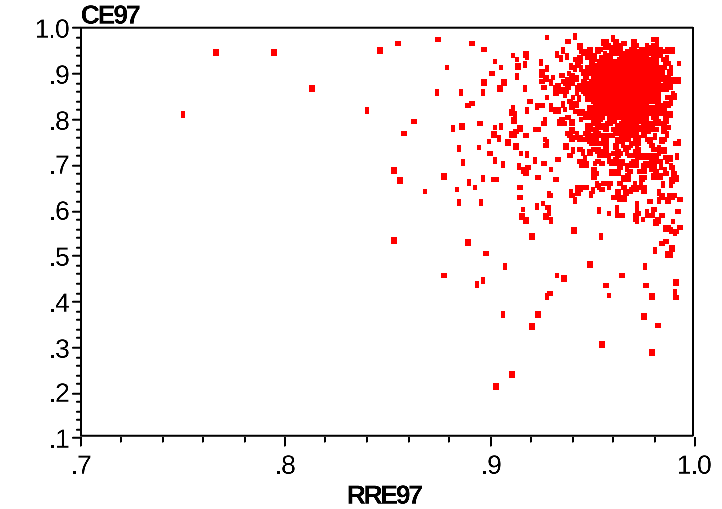
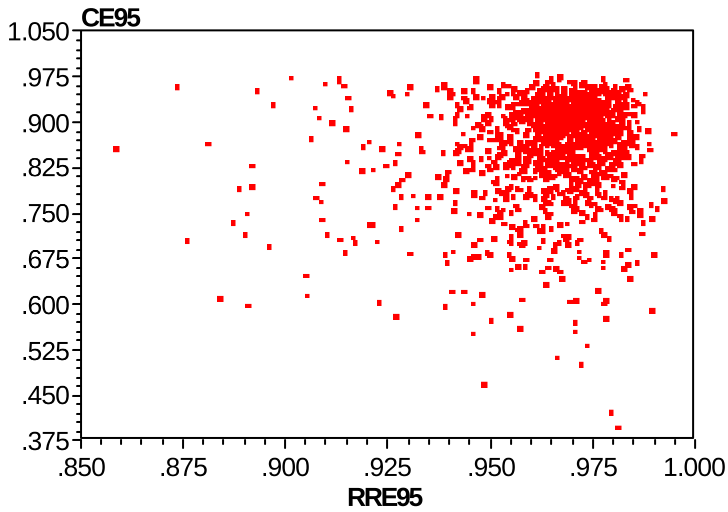


Figure 5: Cost vs. Risk-Return Efficiency 1995



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