Translog Cost Function Estimation: Banking Efficiency

Toby Daglish, Oliver Robertson, David Tripe, and Laurent Weill

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Abstract

This paper examines the selection of data source and econometric technique for studies of banking efficiency using translog cost functions. We examine the use of Seemingly Unrelated Regression estimation for a cost function, as against estimation using Ordinary Least Squares. Choice of cost data to feed to the estimation is also important, and we find that use of wage and interest data may sometimes be superior to cost data inferred from bank accounting information. Lastly, we discuss filtering of data, where some observations may contain erroneous or noisy data.

1 Introduction

There are a number of methods used by economists and econometricians to examine the production process. Theoretical models of a firm's production function, such as the Cobb-Douglas or translog functional forms, allow estimation of the various factors of production (Berndt and Wood, 1975). From a production function, we can derive the cost function, which describes the quantities of inputs needed, along with the cost, to produce a set level of output (Greene, 2008a). The translog cost function is frequently used in the banking literature, providing an estimation for the marginal cost of production for banks (Clark and Speaker, 1994; Weill, 2013). The literature on banking efficiency and competition uses estimates of marginal costs to investigate how banking efficiency differs over countries or time, and how the level of competition evolves with changes in regulation. The Lerner index is a measure of a firms market power, using a firm's estimated markup as a measure of the competition within a particular market (Carbó et al., 2009; De Guevara and Maudos, 2007).

The translog is a flexible generalisation of the Cobb-Douglas production function (Coelli et al., 2005). This increased flexibility allows it to more accurately represent empirical production functions. The Cobb-Douglas production function has universally smooth and convex isoquants for example, but also requires the estimation of more parameters. The generality of the translog introduces a potential problem, however, as it is not necessarily monotonic or globally convex, unlike the Cobb-Douglas (Greene, 2008b). This is one of the challenges of using the translog, and in this paper we explore ways to deal with these issues.

A further problem is the difficulty, especially in the banking literature, of identifying the inputs and outputs used in the cost function. Even once one has identified the variables of interest, it can be very hard to find data on the prices faced by the banks. Various authors have proposed using different bundles of inputs and outputs, and different ways of estimating their prices (Das and Drine, 2011; Sherman and Gold, 1985; Fries and Taci, 2005). Accounting data is frequently used in this estimation. In this case, we don't observe the prices of the inputs, but we do observe how total costs are split up between different categories. The price proxies created from accounting data mean that each bank faces a different set of prices, violating any assumptions made about perfect input markets, and potentially leading to significant measurement error (Koetter, 2006).

In this article, we explore different methodologies that can be used in estimating a translog cost function. Working with data from Weill (2013), we estimate a translog for European banking covering twenty countries and nine years. We compare the results of estimation when using a Seemingly Unrelated Regression (SUR) model of the cost function plus the cost share equations, versus estimating the cost function alone. We also introduce new proxy prices for labour and borrowing. These prices are not based on accounting data, so each bank in a particular country will face the same prices in a given year. Our results illustrate the potential gains to be had from exploring data sources beyond the available accounting data. By comparing the results of the various models we estimate, and exploring if these models obey the regularity conditions of a cost function, we can also gauge the effectiveness of the SUR methodology versus the single cost function estimation.

The remainder of this paper is organised as follows: Section 2 contains the methodology, While Section 3 discusses the empirical data. In Section 4 we present the results, and, lastly, Section 5 concludes.

2 Methodology

The translog is a frequently used production function formulation that allows examination of production, cost, and efficiency, in a range of areas (Martín and Voltes-Dorta, 2007; Henningsen et al., 2009; Gilligan et al., 1984). It is a second order flexible functional form, that is linear in the parameters (Coelli et al., 2005). A generalised example of a translog production function, where y is the output produced, and x_n is the quantity of input n used in the production process, takes the form:

$$\ln y = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n + \frac{1}{2} \sum_{n=1}^{N} \sum_{m=1}^{M} \beta_{nm} \ln x_n \ln x_m. \tag{2.1}$$

From the translog production function, we can derive the translog cost function, which is often used in the banking and finance literature to estimate the marginal costs of production, and the elasticities of input demand for banks or other financial institutions (Weill, 2013; Fries and Taci, 2005; Lang and Welzel, 1996). The general form of the translog cost function is:

$$\ln TC = \alpha_0 + \alpha_y \ln y + \frac{1}{2}\alpha_y y(\ln y)^2 + \alpha \sum_{n=1}^{N} \alpha_n \ln P_n + \frac{1}{2}\alpha_{nm} \sum_{n=1}^{N}\sum_{m=1}^{M} \ln(P_n)\ln(P_m) + \alpha_{ny} \sum_{n=1}^{N} \ln(P_n)\ln(y), \tag{2.2}$$

where P_n is the price of input n, y is output, and TC denotes total cost.

2.1 Data Sources

Estimation of a translog cost function requires a range of data on the firm (or firms) in the market. The first step we have to take is in deciding the inputs used by the bank, and the resulting output(s) produced. We then need to know the prices of the inputs used, total costs, output, and the cost shares of the inputs used. When we are estimating the cost function for a bank, there are a number of sources we can use for this data. Balance sheets contain a wide range of accounting data that can be useful, including total costs, revenue, and a break down of spending. While useful, this data does *not* include information on the prices of the inputs used in production, and so we have to create proxy prices based on what information is available. We can also draw on bank specific data, such as number of workers employed; or country specific data, such as average wages and interest rates, in order to construct different proxies for the input prices.

Defining what exactly constitutes a bank's output is problematic (Clark and Siems, 2002). Arguments can be made in favour of different measures of output. If we specify a model with multiple outputs, all banks within the sample must produce each product, as the translog requires non-zero variables (Clark and Speaker, 1994). Sherman and Gold (1985) suggest total transactions processed as a proxy for output. This measure may be problematic in studies using large samples of banks, as data on the number of transactions may not be available for all observations. Also, the number of transactions processed ignores off-book output that may be quite significant to a bank (Clark and Siems, 2002). A bank produces services (such as processing transactions), which it provides to its customers, so number of customers is also a potential proxy for output. On the other hand, customers are not homogeneous. This could be especially problematic when comparing banks of different sizes, or banks in different countries, making the assumption of equal output associated with each customer, invalid. Fries and Taci (2005) suggest using two outputs: loans to customers, and deposits with the bank. Another potential variable that can be used as a proxy for output is total assets (Weill, 2013).

Identifying inputs, while less complicated than identifying outputs, is not trouble free. Fries and Taci (2005) use physical capital and labour as inputs into banking production. Sherman and Gold (1985) use Data Envelopment Analysis (DEA) to examine banking efficiency, and include labour, rent paid, and supply costs as their inputs, with rent acting as a measure of physical capital. Others have also included borrowing as an input into the banking production function (Das and Drine, 2011; Weill, 2013). After selecting the inputs of interest, we also need to identify appropriate prices for them. Balance sheet data can be used to create proxy prices. If we have data on the number of workers employed by a bank, for example, we can estimate the price of labour as the ratio of labour costs to number of employees. When working with large multi-country data sets, we may not have information on the number of workers, and we will have to find other ways to use the available data to create a proxy estimate for the price of labour. This problem continues with the prices of other inputs we may be interested in. We have to find proxy prices that can be estimated from the accounting data that is available. This can also be problematic in that it leads to different banks in the same country facing different estimated prices for inputs, when under a perfect input market we would expect identical prices (Mountain and Thomas, 1999).

We can also draw on non-balance sheet data as sources for input prices. If we are carrying out a large study spanning multiple countries, we could use average wages in each country as a proxy for the price of labour. This would rely on the assumption that banks within a country would have similar wages, and that the relationship between the average wage and the price of labour for a bank would be consistent over the countries in the study area. We could also use the interest rate in each country as a proxy for the cost of borrowing in that country. This would rely on the assumption that banks within the same country would face equal costs of borrowing, which ignores different levels of debt, equity, and profit among banks, and may well not be realistic. We could create a proxy price of capital based on the average rental or purchase price of property. Again, this would give us a constant price level for banks facing the same market for physical capital, but would require us to define each market, and then find a data source that included prices for each of these markets.

2.2 Data Cleaning

There are a number of factors we must be wary of when preparing data for cost function estimation. Balance sheets contain accounting data, and manipulation that may make sense for accounting purposes could lead to distorted economic data, and thus mis-estimation of prices. For example, when we are estimating the price of an input based on balance sheet data, we have to carefully check the raw data and the results they produce: if our chosen proxy produces strange results, these could disrupt our translog estimation. This is especially pertinent as (for example) Weill (2013) creates a proxy for the price of physical capital that is the ratio of non-interest and personnel expenses to fixed assets. While this seems logical, in some cases it leads to zero or negative prices for capital. A negative price not only seems counter-intuitive, but it is also unusable when estimating a translog cost function. Hence cutting observations that have a negative estimated price is necessary. Likewise, if a method of creating a proxy price leads to large outliers, they should first be investigated individually, to see if there are problems with the observation (or our price creation rule). If their presence biases the estimators through excessive leverage, then they should be cut or new proxy prices found.

Alternatively, we could use the entire data set, sans prices that are less than or equal to zero, and then cut observations that break the regularity or concavity assumptions made with a cost function. We will explore these, and the tests for them, in Section 2.4.

2.3 Estimation

The translog cost function can be estimated in a number of ways. We can estimate the total cost function, (2.2), using Ordinary Least Squares (OLS) as it is linear in the parameters, or by using Maximum Likelihood Estimation (MLE) (see Coelli et al. (2005)). If the standard assumptions are correct, then these estimators will generate asymptotically equivalent results. Shephard's Lemma can also be used in to derive the cost-share equations for each input (Greene, 2008a). The cost share for input j is given by (2.3). By taking the derivative of the cost function with respect to the price of each input, we obtain a system of N optimal cost share equations, one for each of the inputs used in the production function. If the errors of the cost share equations are correlated, then this provides information that can be used to produce more efficient estimates than those achieved by OLS or MLE on the single cost equation. By estimating the system of equations, the cost function along with $N-1$ of the cost share equations, either through MLE or some kind of iterative least squares, we can use a SUR approach to obtain a more efficient estimator (see Coelli et al. (2005) and Greene (2008b)).

$$s_j = \frac{\partial \ln c}{\partial \ln P_j} = \alpha_j + \alpha_{j,1} \ln P_1 + \cdots + \alpha_{j,N} \ln P_N + \alpha_{j,y} \ln y. \tag{2.3}$$

The cost shares must sum to one, as each is the proportion of the total costs spent on that input. This requirement forces us to impose several restrictions on the system of equations. The intercepts of the cost share equations must sum to one, while both the row and column coefficients must sum to zero:

$$\sum_{n=1}^{N} \alpha_n = 1$$
$$\sum_{i=1}^{M} \alpha_{i,j} = 0 \tag{2.4}$$
$$\sum_{j=1}^{M} \alpha_{i,j} = 0.$$

These restrictions are imposed by dividing the first $M - 1$ prices (along with total cost), by the Mth price (Greene, 2008a). We operationalize the equations by removing the Mth share equation, leaving us with a non-singular system. This removes some of the coefficients of interest, but they can be recovered using the estimated coefficients, along with the assumptions in 2.4 (See Greene (2008a)). In addition to this, we assume/impose symmetry, so $\alpha_{i,j} = \alpha_{j,i}$.

2.4 Regularity Conditions

There are a number of tests that we can (and should) perform to establish if our estimated translog fulfils the criteria of a cost function (Fried et al., 2008). We can derive the translog's cost flexibilities using (2.5). We would expect a cost function to be increasing in the output quantity, and we can check this condition by examining the cost flexibility at each observation. A positive value indicates that our cost function predicts an increase in total costs when output is increased, while a negative value would indicate a cost function that decreases with increasing output:

$$\frac{\partial \ln c(w,y)}{\partial \ln y} = \alpha_y + \sum_{i=1}^{N} \alpha_{iy} \ln p_i + \alpha_{yy} \ln y. \tag{2.5}$$

Using the coefficients from our estimated translog function, we can estimate cost shares. This is the estimated share of total cost that is spent on each of the inputs. For each observation, the cost shares will sum to one, as we have already imposed the restriction that the cost function is linearly homogeneous in all input prices. The sign of the derived optimal cost share is the same as the sign of the first derivative of the cost function with respect to input prices. Thus, by examining the estimated optimal cost shares, we can check if the cost function is non-decreasing in input prices at each observation, as we would expect.

For our translog to be consistent with the microeconomic definition of a cost function, we require concavity in input prices, which in turn requires that the Hessian of the translog with respect to the input prices be negative semi-definite. The elements of the Hessian have the same sign as the corresponding elasticities; thus we can estimate the input demand elasticities and use these to check for concavity using 2.6. This will give us a three dimensional array with dimensions i by $i+k$ by n, where i is the number of inputs, k is the number of outputs, and n is the number of observations. Thus we have one matrix of input demand elasticities for each observation. For our estimated translog to be a concave cost function, we require each input's elasticity with respect to its own price to be negative. The symmetry condition for the estimated elasticities also requires that the cross-price elasticities of each input pair should have identical signs.

$$\epsilon_{ij} = \frac{\partial x_i(p, y)}{\partial p_j} \frac{w_j}{x_i(w, y)} \tag{2.6}$$

3 Data

In analysing the different methodologies that may be used in estimating a translog cost function, we have worked with the data set used by Weill (2013). These data are drawn from the Bankscope database, and are an unbalanced panel data set that includes unconsolidated accounting data on 4295 banks, over (a maximum of) 9 years, and twenty-seven European Union (EU) countries. It includes information on a number of variables including fixed, personnel, and loan expenses, total assets, equity, revenue, country of operation, and profit.

There are a total of 26201 bank/year observations in the complete data set. A subset of the data is used in this project, with the selection process explained in Section 3.2.

In his paper, Weill assumes that there are three inputs used in a bank's production function: labour, capital, and borrowing, and one output: total assets (Weill, 2013). Although the prices of the inputs and output are not directly observed in the data, we observe each bank's spending in different categories (but not the quantity purchased). For example, we see total spending on labour, but not the quantity of workers. We have estimated the prices of these inputs in two ways: first, following Weill's stated method of price estimation (outlined in Section 3.1), and second, replacing two of his estimated prices (those of labour and borrowing), with our own proxies. This allows us to explore how different ways of estimating input price affect the results of our translog estimation.

The data for the additional price proxies is sourced from the Organisation for Economic Co-operation and Development (OECD) and the United Nations (UN). We use interest rates from the OECD's Monthly Monetary and Financial Statistics data library. We use the published annual interest rates for the EU countries of interest. The average wage data is accessed through the UN Economic Commission for Europe statistical database. The wages are average monthly wages in US dollars for the countries of interest, and we convert them into average annual wages in terms of Euros, in order to match the data used by Weill.

3.1 Price Estimation

In the absence of direct observations of input prices, Weill creates proxy prices based on the available accounting data. He uses the ratio of personnel expenses to total assets as the price of labour, the ratio of non-interest, non-personnel expenses to fixed assets as the price of physical capital, and the ratio of paid interest to all funding as the price of borrowing. Proxies such as these can introduce noise, potentially leading to distorted estimation of parameters of interest (Koetter, 2006). In the cases of the price of capital and borrowing, we are estimating a ratio of the cost paid (in production) relative to a stock (total borrowing in one case, and the existing physical capital in the other). The price of labour, on the other hand, is the ratio of spending on labour relative to total assets, used as a proxy for output. In the first case, we are looking at the ratio of cost of a good to stock of that good, and in the last case we are comparing cost to total assets. Ideally we would be treating each variable in the same manner, but this requires knowledge of the number of workers employed by each firm, which is not available in the data.

The price of capital in this case is the ratio of the cost of capital to the total quantity of capital owned. This would be the number of dollars spent on capital per dollar of existing capital. There are some flaws in the estimator. Primarily, it assumes ownership of all physical capital, so spending is upkeep or new purchases (over the existing capital). However, many banks do not own their own buildings, renting much of their physical capital. This can lead to situations where their spending on capital is large, due to rental costs, but their fixed assets are very small, and thus we observe very large costs of capital in the data. There is also the potential for large discrepancies in the price of capital for different firms based on different levels of capital ownership. Basing the price of capital on how a bank balances its portfolio, and the renting/buying decisions, seems potentially dangerous and could lead to very different prices for otherwise similar banks. In this paper, we have not explored alternative proxies for the price of capital, but in the future it may be wise to investigate using rental prices for the area a bank is in (Clark and Speaker, 1994), although this is significantly more difficult in large, multi-country studies where banks face very different local environments.

The price of borrowing is estimated by taking the ratio of interest paid to total borrowing, as is common in the literature (Mountain and Thomas, 1999; Altunbas and Molyneux, 1996). This is essentially looking at the number of dollars spent per dollar of borrowing. If we assume that the market for loans takes place in perfect competition, and banks have similar levels of credit risk, then the fact that each bank has a different price of borrowing is quite problematic. Even if we assume that perfect competition in the market for loans only occurs within a country, and not over the entire EU, we still see quite large differences in the prices experienced by firms in each country. This measure of the price of borrowing also doesn't take into account each bank's level of equity, and over the entire data sample there may well be a large degree of heterogeneity with regards to equity. An alternative that we test in this paper is using interest rates as a proxy for the cost of borrowing for a bank. Thus each country will have a price of borrowing associated with the banks operating within its borders for each time period. While this does result in constant prices for banks within the same geographic region, it also ignores that the price of borrowing may differ based on a banks size, equity, or profit levels.

The price of labour is potentially the most problematic of the proxied prices. Estimated by taking the ratio of labour expenses to total assets, this is telling us the number of dollars spent on personnel per dollar of total assets (the proxy for output). As mentioned previously, this formulation is relatively different to that used to estimate the other prices. Ideally, we would use a proxy for average wage per worker as the price of labour, but this would require the data to contain information on the number of workers employed by each bank. It might be feasible to locate this in other data sources with a smaller and more focused study, but as this data set examines a range of EU countries, this is not possible. A potential proxy that we investigate in this paper is using the average wage for each country as the price of labour. If we wish to assume perfect competition in the labour market, then this is attractive as it means each bank in a given country, at a given time would face the same price of labour. For this proxy price to be accurate, we are assuming that the relationship between average wages in general, and average wages for bank employees is constant. We are also implicitly assuming that regardless of a bank's size and location, the structure of its workforce will be constant.

3.2 Data Selection

As mentioned previously in Section 2.2, it is important to check our estimated input prices for extreme numbers that might distort our estimation of the cost function. Weill's original data set included 26,201 observations, but after removing outlier prices, there are 26,016 data points used in the cost function estimation in his paper (Weill, 2013). The criteria for cutting these observations matches the broad suggestions made in Section 2.2: cutting observations that had extreme prices for capital or for the price of borrowing. In this case, we cut observations that have prices for capital that are zero, negative, or greater than 10,000, cost of borrowing of over 60, and observations that had a negative revenue, which is presumed to be the result of using accounting data.

The alternative prices of labour and borrowing that we implement required outside data (see Section 3). These data are limited in the countries that are covered, so while Weill's original paper looked at twenty seven EU countries, we only have alternative price data for twenty of these. Applying the rules listed above to this sub-set of the data with the original prices gives us 25,262 observations. If we instead apply these rules to the data sub-set but with our new proxy for the price of borrowing, we get 25,288 observations. Our new estimate for the price of borrowing has actually increased the number of observations available in the estimation process. This is one of the advantages of finding alternative proxies for the input prices. Table 1 shows the sample statistics of the data sub-set used. This is the sub-set that includes 25,262 observations.

4 Results

We have examined eight models in detail. We have estimated four models from the single cost equation, and four using a SUR. Our SUR estimation was carried out in r using the systemfit package (Henningsen and Hamann, 2007). In each case, we have estimated the model once using Weill's original prices, once using both of our new proxy prices, and once

Table 1: *Table of sample statistics for the sub-set of Weill's data found using our stated rules and his prices. TA is total assets, TC total costs, TR total revenue, P_i is the price of input i using Weill's data, and P_{ia} is our alternative price for input i.*

Countries	Obs	TA	TC	TR	P_l	P_b	P_k	P_{la}	P_{ba}
Austria	1,740	1,342.255	51.446	56.659	1,375.739	2.527	172.248	2,766.264	2.715
Belgium	347	19,327.250	683.002	704.198	1,174.778	3.148	441.151	2,953.604	2.747
Czech Rep.	132	4,275.592	167.554	235.100	945.395	4.066	299.099	750.742	2.630
Germany	13,785	2,705.629	106.777	112.751	1,529.194	2.726	138.126	2,599.731	2.704
Denmark	724	4,489.178	163.885	195.229	1,986.601	2.831	383.546	3,792.812	3.145
Estonia	38	1,002.665	41.522	61.614	1,451.923	2.588	175.263	565.288	3.725
Spain	772	10,950.630	400.863	495.966	1,030.566	2.407	176.568	1,951.418	2.834
Finland	36	25,511.410	762.253	982.717	940.587	4.500	957.771	2,699.892	3.092
France	1,572	16,960.900	753.096	813.588	1,449.846	3.834	472.220	2,491.506	2.925
UK	434	6,175.577	128.761	161.730	1,661.109	3.683	714.943	3,151.796	4.072
Greece	80	11,575.750	503.374	600.222	1,195.463	3.057	126.329	1,627.891	3.074
Ireland	75	7,968.507	269.650	322.104	530.057	6.971	949.360	3,575.902	3.058
Italy	3,663	2,829.681	116.121	138.759	1,409.482	3.277	208.250	2,199.043	2.805
Luxembourg	618	6,598.318	333.004	372.566	792.828	4.075	680.409	3,842.843	2.805
Netherlands	76	7,227.799	281.214	307.296	1,519.304	6.826	1,039.074	3,017.125	2.779
Poland	190	3,053.260	176.981	224.453	1,563.207	4.293	579.408	696.166	5.439
Portugal	118	9,875.765	510.225	563.619	1,043.455	4.733	313.519	1,239.586	2.895
Sweden	711	3,668.055	131.258	163.180	1,423.728	1.754	341.690	2,661.773	2.498
Slovenia	84	1,924.593	89.832	108.824	1,058.407	3.265	152.770	1,517.477	4.080
Slovakia	67	1,419.306	67.542	79.222	985.816	3.376	298.195	722.631	3.861

for each combination of one of our proxies with one of Weill's prices. For each of these eight model specifications, we estimate a translog cost function for each year of the study, use this to derive the marginal cost of banking, and follow Weill in using this to calculate the mean Lerner index for each country/year (Weill, 2013; Saving, 1970). The Lerner index is a measure of the market power of a firm. We estimate it using (4.1), by taking the difference between price of the output and the marginal cost of producing that output, and then divide by the price. The idea is that a competitive firm will have no mark up, resulting in a Lerner index of 0. As we are interested in which of the model specifications performs best, we then use the methods outlined in Section 2.4 to investigate how these models perform, as well as comparing the estimated mean Lerner values.

$$Lerner = \frac{Price - MC}{Price} \tag{4.1}$$

Table 2 shows the coefficients estimated for each year using Weill's original prices and the single cost function. Implicitly we are assuming that each country has a common production function for banking, and any differences between countries are captured by a series of country specific dummies, which we have removed from the table for ease of comprehension. The cost function estimated is shown in (4.2):

$$\begin{aligned}\ln(\frac{TC}{w_3}) &= \alpha_0 + \alpha_1 \ln y + \frac{1}{2}\alpha_2(\ln y)^2 + \alpha_3 \ln(\frac{w_1}{w_3}) + \alpha_4 \ln(\frac{w_2}{w_3}) + \\ &+ \alpha_5 \ln(\frac{w_1}{w_3}) \ln(\frac{w_2}{_3}) + \frac{1}{2}\alpha_6(\ln(\frac{w_1}{w_3}))^2 + \frac{1}{2}\alpha_7(\ln(\frac{w_2}{w_3}))^2 + \\ &+ \alpha_8 \ln y \ln(\frac{w_1}{w_3}) + \alpha_9 \ln y \ln(\frac{w_2}{w_3}) + \sum_{i=1}^{26} Country_i,\end{aligned} \tag{4.2}$$

where y is output and w_i indicates the price of input i. We have normalised prices by dividing TC, w_1, and w_2 by w_3, as outlined in Weill (2013). Some coefficients of interest are not directly estimated, and are recovered by imposing the symmetry and homogeneity restrictions, as explained in Section 2.3. Interpretation of the coefficients themselves is not simple, thus we will focus our analysis on comparing the results generated from each model, and each models regularity conditions. Table 3 shows the mean Lerner indices calculated using the marginal costs derived from this version of the translog.

Table 2: *Cost function coefficient estimates, estimated with original prices used by Weill.* w_i *is price of input* i.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	−7.243	−5.462	−5.773	−6.483	−6.850	−7.688	−7.692	−5.517	−4.841
w_l	0.167	0.002	−0.099	0.026	0.141	0.320	0.332	−0.128	−0.338
w_k	0.176	−0.168	−0.004	0.131	0.153	0.163	0.140	−0.00004	0.044
w_b	0.656	1.166	1.103	0.843	0.706	0.516	0.528	1.128	1.294
Y	1.219	1.052	1.109	1.097	1.099	1.204	1.227	1.026	0.974
ll	0.082	0.072	0.107	0.096	0.078	0.054	0.056	0.114	0.143
kk	−0.013	0.017	0.012	0.011	0.012	−0.002	−0.001	0.014	−0.0001
yy	−0.008	−0.004	−0.004	−0.003	−0.004	−0.008	−0.011	0.005	0.007
lk	−0.006	0.021	0.004	−0.010	−0.014	−0.006	−0.007	−0.0003	0.0003
kl	−0.006	0.021	0.004	−0.010	−0.014	−0.006	−0.007	−0.0003	0.0003
lb	−0.076	−0.093	−0.111	−0.086	−0.064	−0.048	−0.049	−0.114	−0.143
bl	−0.076	−0.093	−0.111	−0.086	−0.064	−0.048	−0.049	−0.114	−0.143
kb	0.019	−0.038	−0.016	−0.001	0.003	0.007	0.008	−0.014	−0.0002
bk	0.019	−0.038	−0.016	−0.001	0.003	0.007	0.008	−0.014	−0.0002
bb	0.057	0.130	0.128	0.087	0.061	0.041	0.041	0.128	0.143
ly	−0.024	−0.008	−0.011	−0.007	−0.008	−0.019	−0.023	−0.008	−0.002
ky	−0.004	0.005	−0.003	−0.009	−0.007	−0.008	−0.004	−0.0002	0.001
by	0.028	0.003	0.014	0.015	0.015	0.028	0.027	0.008	0.001

It is interesting to note some of the values observed in Table 3. Most of the mean Lerner

Table 3: *Mean Lerner indices, estimated from single cost function using original prices.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.086	0.126	0.133	0.155	0.130	0.105	0.008	-0.518	0.077
BE	-0.045	0.038	0.109	0.168	0.105	0.125	-0.582	0.131	0.133
CZ	0.107	0.121	0.156	0.202	0.207	0.221	0.186	-0.386	-0.042
DE	0.053	0.085	0.087	0.106	0.092	0.073	0.048	0.094	0.116
DK	0.176	0.217	0.289	0.334	0.327	0.220	-2.611	-0.059	-0.176
EE	0.209	0.261	0.228	0.218	0.308	0.312	0.119		
ES	-1.076	-0.700	0.106	0.215	0.223	0.178	0.110	0.035	0.089
FI	0.184	-1.574	0.081	0.154	0.178	0.163	0.044	0.193	0.168
FR	0.096	0.051	0.159	0.149	0.183	0.160	0.105	-2.573	0.166
GB	0.067	0.150	0.052	0.057	0.121	-0.058	0.044	0.026	0.002
GR	0.173	0.294	0.122	0.180	0.122	0.148	-0.026	-0.098	-0.245
IE	0.038	0.189	0.173	0.177	0.131	-0.008	0.049	0.301	0.362
IT	-0.938	-0.005	0.085	0.149	0.197	0.141	0.105	0.083	0.035
LU	0.111	0.137	0.174	0.176	0.035	0.115	0.025	0.160	0.247
NL	-0.057	0.055	0.110	0.162	0.130	0.108	0.077	0.083	0.345
PL	0.047	-0.083	-0.084	0.129	0.227	0.216	-0.614	-0.219	0.180
PT	0.199	0.162	-1.476	0.130	0.166	0.093	-0.207	0.035	0.027
SE	0.166	0.203	0.267	0.402	0.324	0.253	-0.063	0.277	0.227
SI	0.182	0.208	0.248	-0.015	0.139	0.173	0.096	0.066	-0.387
SK	0.058	0.156	0.082	0.123	0.155	0.179	0.100	0.046	-0.397

	Cost Flex	Cost Shares			Demand Elas		
Model		Labour	Borrowing	Capital	Labour	Borrowing	Capital
SUR_{orig}	0	583	12	5	1384	302	44
$SUR_{l,b}$	0	1	0	0	2	0	0
SUR_l	0	0	17	4	3	104	43
SUR_b	0	524	2	0	1579	230	0
$COST_{orig}$	0	26	32	44	125	169	81
$COST_{l,b}$	0	5792	3096	5233	16453	17741	2266
$COST_l$	0	0	21	4762	23	124	1421
$COST_b$	0	0	0	0	678	8799	3902

Table 4: *Regularity results: SUR_{orig} indicates SUR using Weill's prices, while SUR_l would indicate a SUR model using our new proxy for the price of labour. Cost flexibility tells us the number of observations at which there are negative cost flexibilities, implying costs would decrease as output increases. Cost shares are the predicted share of costs spend on each input, and the table returns the number that are negative for a model/input combination. Demand elasticity tells us the number of observations which have a positive demand elasticity for an input in its own price, implying that an increase in the price of an input would result in higher demand.*

values look quite plausible, but there are some negative values, and more noteworthy, some of them are quite large. A negative Lerner index would imply that a firm has marginal cost exceeding the price of their output. France in 2009 has an estimated Lerner index of -2.573, implying that French banks in that period have marginal costs of production much greater than the price they charge for their output. This could be a result of using accounting data to estimate the unobserved prices.

In order to judge the effectiveness of single equation estimation versus the SUR methodology, as well as the ability of our new price proxies to model the real underlying prices, we investigate the various regularity conditions mentioned previously. Table 4 lists the results of these tests.

There are no negative cost flexibilities for any of the models at any observation. This is good, as a negative cost flexibility implies that costs would decrease in output. The cost equation for which we have already shown results, the single equation estimation using Weill's original prices, actually performs quite well. While there are observations with negative predicted optimal cost shares, implying that costs are decreasing in the price of that output at that observation, this occurs at relatively few points. Certainly, if compared to the SUR estimation that also uses Weill's original prices, we have only 26 predicted negative cost shares for labour, versus the 583 predicted with the SUR model. It does have more observations with negative predicted cost shares for borrowing and capital, but compared to the size of the data set, they are still relatively small. It also has a much smaller set of positive input demand elasticities, where a positive input demand elasticity with regards to that input's price implies increasing demand as price rises.

The best results we see in Table 4 are for a SUR estimation made using both of our new proxy prices. In this case, we have only a single observation with an estimated negative cost share, and only two observations with positive input demand elasticities. Only the single cost estimation with our price of borrowing has fewer negative cost shares, and that model has a large number of positive demand elasticities. For example, it has $8,799$ observations where the demand for borrowing increases with the price of borrowing. It is interesting that the best result involves using our two new proxies for price, while the worst result also uses them. The single cost function estimation using our new price proxies breaks the regularity conditions more than any other model. There are $5,792$ observations with negative predicted cost shares for labour, and $17,741$ observations with positive demand elasticities for borrowing.

The coefficients of the cost function estimated using a SUR methodology and our new proxy prices can be seen in Table 5, and the resulting Lerner indices can be seen in Table 6. The Lerner indices we estimate based on this new translog's derived marginal costs are relatively similar to those seen previously. It does have a smaller number of negative mean Lerner indices, but the large negatives have not been eliminated, as can still be seen in France, during 2009.

We have also taken the overall mean Lerner value for each model and compared them with a t-test. The resulting test statistics can be seen in Table 7. We can see from this table that our best performing model, the SUR with our new prices, is significantly different from

Table 5: *Coefficient estimates for the translog cost function for each year. This model estimated using a SUR and our new price proxies.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-5.840	-6.094	-6.258	-6.244	-6.244	-6.200	-6.169	-6.078	-6.608
Pl	0.426	0.438	0.466	0.429	0.460	0.475	0.450	0.421	0.457
Pk	0.246	0.274	0.302	0.287	0.303	0.291	0.272	0.206	0.246
Pb	0.328	0.288	0.233	0.284	0.237	0.233	0.278	0.373	0.296
Y	1.059	1.116	1.134	1.137	1.107	1.109	1.137	1.202	1.279
ll	0.022	0.029	0.032	0.037	0.031	0.012	0.014	0.035	0.033
kk	0.031	0.032	0.030	0.033	0.027	0.024	0.020	0.038	0.034
yy	0.003	-0.002	-0.003	-0.005	-0.002	-0.004	-0.009	-0.015	-0.023
lk	-0.017	-0.017	-0.017	-0.014	-0.016	-0.015	-0.015	-0.012	-0.011
kl	-0.017	-0.017	-0.017	-0.014	-0.016	-0.015	-0.015	-0.012	-0.011
lb	-0.006	-0.012	-0.015	-0.023	-0.016	0.004	0.001	-0.023	-0.021
bl	-0.006	-0.012	-0.015	-0.023	-0.016	0.004	0.001	-0.023	-0.021
kb	-0.014	-0.014	-0.013	-0.019	-0.011	-0.008	-0.005	-0.025	-0.023
bk	-0.014	-0.014	-0.013	-0.019	-0.011	-0.008	-0.005	-0.025	-0.023
bb	0.019	0.026	0.028	0.041	0.027	0.005	0.004	0.048	0.044
ly	-0.025	-0.026	-0.029	-0.025	-0.027	-0.028	-0.027	-0.026	-0.028
ky	-0.019	-0.022	-0.024	-0.023	-0.023	-0.022	-0.019	-0.018	-0.019
by	0.044	0.048	0.053	0.048	0.050	0.050	0.046	0.044	0.047

Table 6: *Mean Lerner values for each country for each year. This model estimated using a SUR and our new price proxies.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.123	0.155	0.172	0.190	0.167	0.147	0.006	-0.477	0.129
BE	0.016	0.096	0.175	0.227	0.167	0.189	-0.448	0.242	0.253
CZ	0.127	0.145	0.178	0.231	0.241	0.253	0.223	-0.363	-0.007
DE	0.092	0.116	0.132	0.147	0.130	0.111	0.083	0.150	0.173
DK	0.213	0.257	0.330	0.369	0.369	0.269	-2.316	-0.016	-0.132
EE	0.199	0.246	0.221	0.223	0.320	0.325	0.131		
ES	-0.992	-0.620	0.143	0.238	0.244	0.201	0.142	0.086	0.115
FI	0.268	-1.365	0.158	0.231	0.250	0.235	0.135	0.264	0.224
FR	0.134	0.104	0.217	0.207	0.232	0.208	0.164	-2.121	0.273
GB	0.126	0.193	0.094	0.101	0.175	0.003	0.110	0.118	0.092
GR	0.182	0.300	0.155	0.214	0.148	0.172	0.013	-0.0002	-0.126
IE	0.150	0.275	0.275	0.269	0.224	0.136	0.204	0.451	0.511
IT	-0.826	0.057	0.144	0.187	0.233	0.183	0.147	0.133	0.082
LU	0.185	0.210	0.253	0.250	0.123	0.204	0.128	0.269	0.358
NL	0.020	0.121	0.200	0.245	0.205	0.208	0.191	0.230	0.435
PL	0.031	-0.110	-0.127	0.125	0.239	0.234	-0.673	-0.221	0.191
PT	0.213	0.176	-1.376	0.177	0.205	0.141	-0.143	0.099	0.104
SE	0.215	0.244	0.310	0.436	0.368	0.302	0.004	0.353	0.292
SI	0.169	0.173	0.234	-0.015	0.160	0.205	0.138	0.144	-0.259
SK	0.061	0.140	0.079	0.139	0.161	0.202	0.139	0.113	-0.310

	$SUR_{o,b}$	$SUR_{l,o}$	$SUR_{l,b}$	$COST_{o,o}$	$COST_{o,b}$	$COST_{l,o}$	$COST_{l,b}$
$SUR_{o,o}$	1.877546	-2.71	-0.42	2.27	2.79	-0.86	0.07
$SUR_{o,b}$		-4.6	-2.29	0.44	0.96	-2.78	-1.84
$SUR_{l,o}$			2.28	4.91	5.42	1.93	2.83
$SUR_{l,b}$				2.67	3.18	-0.42	0.49
$COST_{o,o}$					0.51	-3.15	-2.24
$COST_{o,b}$						-3.68	-2.76
$COST_{l,o}$							0.94

Table 7: *Test statistics from comparing mean Lerner indices for each model. COST is the single cost equation estimation, SUR uses the cost equation in conjunction with the cost share equations. Subscript* (o, o) *indicates both original prices used,* l *indicates new price of labour was used,* b *indicates new price of borrowing was used.*

four of the models, and not significantly different from the other three. Interestingly, it is not significantly different from the single cost function that uses both prices. So these models result in similar Lerner indices, even when one of them breaches many of the cost function regularity conditions. It is possible that this indicates that the errors for the various cost share equations are correlated, and the SUR model takes this into account while the single equation estimation does not.

5 Conclusion

In this paper, we examine the use of the translog cost function banking efficiency and competition studies. The translog cost function is a flexible functional form that allows us to model the empirical cost function. It is more flexible than the Cobb-Douglas production function, but this increase in flexibility also means that the function is not globally convex. Even after we impose homogeneity of prices, it is important to check regularity conditions at each observation. It can also be problematic to identify the inputs and outputs of a translog, especially in the case of banking. The translog is often used in the finance literature to estimate marginal costs for banks.

Weill (2013) uses estimated marginal costs in calculating Lerner indices for countries in the EU from 2002 - 20010, where the Lerner index is a measure of a firm's market power based on the markup over marginal cost. Weill assumes that banks have three inputs: labour, capital, and borrowing; and one output: total assets. As the prices of both inputs and the output are not directly observable, Weill creates proxy prices from the available accounting data. This data is potentially noisy, as accounting manipulations may create economic irregularities. In an attempt to counter this, we have used alternative data to generate new proxy prices for labour and borrowing.

We re-create Weill's results, and also explore different ways of estimating the translog using his data. We estimate eight models in total, four using a SUR methodology, which takes advantage of potential correlations between the cost share equation errors, and four using the single cost function. For each model, we use Weill's original prices, our new prices, and each combination of his original prices with our new estimates. From examining the regularity conditions, the SUR model that uses our new prices for labour and borrowing seems to perform best. There are only three observations (out of $25,288$) that do not obey the regularity conditions of a cost function. Interestingly, while the estimated Lerner indices are significantly different from some of the other models, they are not significantly different from the worst performing model. As that model uses the same input prices, it is quite possible that there is correlation between the cost share equations, and the SUR estimation takes this into account. Replacing the original prices means that, at least for labour and borrowing, there may be perfect competition in the markets for inputs. The use of accounting data also leads to some extreme values, and replacing these prices with our new proxies allows us to make use of more observation.

While our new proxy prices seem to perform well, further investigation may yield even better data to use. It would also be useful to find a new proxy price of capital, as this variable displays many of the problems discussed previously in this article. Rental prices might form a good basis, but in a large, multi-country study such as this, getting that level of data may be difficult. It could also be useful to explore other methods of estimating a banks output level, and the price of that output.

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A Supplemental Tables

Table 8: *Coefficient estimates for the translog cost function for each year. This model estimated using a SUR and Weill's prices.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-4.413	-4.542	-4.663	-4.905	-4.957	-4.899	-4.872	-4.639	-4.521
Pl	-0.495	-0.455	-0.440	-0.405	-0.369	-0.335	-0.329	-0.498	-0.616
Pk	0.302	0.275	0.277	0.379	0.362	0.335	0.312	0.455	0.575
Pb	1.193	1.180	1.163	1.026	1.008	0.999	1.017	1.043	1.041
Y	1.023	1.038	1.052	1.039	1.039	1.019	1.026	0.985	0.980
ll	0.146	0.139	0.136	0.131	0.124	0.114	0.112	0.152	0.175
kk	0.046	0.059	0.059	0.045	0.039	0.033	0.029	0.031	0.025
yy	0.001	-0.002	-0.003	-0.002	-0.002	0.001	-0.0001	0.0004	-0.002
lk	-0.032	-0.031	-0.029	-0.031	-0.026	-0.021	-0.018	-0.044	-0.055
kl	-0.032	-0.031	-0.029	-0.031	-0.026	-0.021	-0.018	-0.044	-0.055
lb	-0.114	-0.108	-0.107	-0.100	-0.098	-0.094	-0.094	-0.108	-0.120
bl	-0.114	-0.108	-0.107	-0.100	-0.098	-0.094	-0.094	-0.108	-0.120
kb	-0.015	-0.029	-0.029	-0.014	-0.013	-0.013	-0.011	0.013	0.030
bk	-0.015	-0.029	-0.029	-0.014	-0.013	-0.013	-0.011	0.013	0.030
bb	0.129	0.137	0.136	0.114	0.111	0.106	0.105	0.096	0.090
ly	0.001	0.002	0.002	0.003	0.002	0.001	0.00005	0.006	0.009
ky	-0.015	-0.019	-0.020	-0.023	-0.022	-0.022	-0.020	-0.016	-0.016
by	0.014	0.017	0.018	0.020	0.020	0.021	0.020	0.011	0.007

Table 9: *Mean Lerner values for each country for each year. This model estimated using a SUR and Weill's prices.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.106	0.145	0.153	0.186	0.164	0.153	0.061	-0.450	0.117
BE	-0.008	0.077	0.145	0.215	0.157	0.184	-0.507	0.206	0.211
CZ	0.146	0.165	0.192	0.245	0.253	0.270	0.236	-0.318	0.017
DE	0.073	0.101	0.107	0.138	0.127	0.120	0.094	0.132	0.155
DK	0.194	0.243	0.311	0.365	0.362	0.267	-2.316	-0.005	-0.124
EE	0.225	0.279	0.249	0.256	0.346	0.360	0.185		
ES	-1.025	-0.631	0.133	0.243	0.253	0.204	0.146	0.080	0.119
FI	0.251	-1.368	0.136	0.220	0.237	0.227	0.117	0.247	0.205
FR	0.116	0.090	0.190	0.193	0.227	0.205	0.151	-2.222	0.229
GB	0.107	0.196	0.098	0.113	0.176	0.017	0.121	0.098	0.071
GR	0.184	0.301	0.147	0.213	0.155	0.178	0.009	-0.025	-0.160
IE	0.130	0.258	0.240	0.248	0.203	0.108	0.175	0.393	0.454
IT	-0.866	0.047	0.125	0.185	0.233	0.191	0.155	0.122	0.073
LU	0.158	0.187	0.219	0.230	0.105	0.188	0.107	0.232	0.319
NL	-0.007	0.097	0.161	0.221	0.195	0.188	0.169	0.184	0.401
PL	0.075	-0.047	-0.047	0.175	0.272	0.266	-0.550	-0.152	0.241
PT	0.218	0.179	-1.393	0.176	0.211	0.152	-0.129	0.091	0.091
SE	0.203	0.243	0.296	0.435	0.364	0.306	0.013	0.319	0.272
SI	0.197	0.212	0.260	0.033	0.176	0.219	0.144	0.125	-0.282
SK	0.103	0.191	0.122	0.170	0.199	0.229	0.158	0.112	-0.298

Table 10: *Coefficient estimates for the translog cost function for each year. This model estimated using a SUR and new labour price proxy, original price of borrowing.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-5.372	-5.263	-5.326	-5.508	-5.559	-5.596	-5.532	-5.256	-5.407
Pl	0.329	0.262	0.271	0.310	0.330	0.339	0.342	0.331	0.307
Pk	0.130	0.085	0.124	0.156	0.168	0.198	0.184	0.134	0.158
Pb	0.541	0.653	0.605	0.534	0.503	0.464	0.474	0.535	0.535
Y	1.054	1.055	1.056	1.077	1.088	1.108	1.112	1.002	1.014
ll	0.034	0.049	0.059	0.048	0.046	0.042	0.036	0.049	0.058
kk	0.047	0.055	0.051	0.048	0.042	0.035	0.032	0.046	0.042
yy	-0.003	-0.003	-0.002	-0.006	-0.007	-0.011	-0.012	0.006	0.005
lk	0.001	0.011	0.010	0.005	0.003	-0.00005	0.001	0.004	0.006
kl	0.001	0.011	0.010	0.005	0.003	-0.00005	0.001	0.004	0.006
lb	-0.035	-0.060	-0.069	-0.054	-0.049	-0.042	-0.037	-0.053	-0.064
bl	-0.035	-0.060	-0.069	-0.054	-0.049	-0.042	-0.037	-0.053	-0.064
kb	-0.049	-0.066	-0.061	-0.054	-0.046	-0.035	-0.033	-0.050	-0.049
bk	-0.049	-0.066	-0.061	-0.054	-0.046	-0.035	-0.033	-0.050	-0.049
bb	0.084	0.126	0.130	0.107	0.094	0.076	0.070	0.103	0.113
ly	-0.024	-0.022	-0.025	-0.022	-0.024	-0.025	-0.026	-0.025	-0.025
ky	-0.016	-0.016	-0.019	-0.019	-0.018	-0.019	-0.017	-0.016	-0.016
by	0.039	0.037	0.044	0.041	0.041	0.044	0.044	0.041	0.041

Table 11: *Mean Lerner values for each country for each year. This model estimated using a SUR and our new price for labour, with the original price of borrowing.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.156	0.190	0.215	0.228	0.200	0.183	0.096	-0.247	0.188
BE	0.052	0.123	0.204	0.254	0.192	0.229	-0.387	0.244	0.245
CZ	0.163	0.177	0.220	0.258	0.268	0.287	0.259	-0.280	0.029
DE	0.120	0.143	0.164	0.179	0.162	0.154	0.130	0.179	0.203
DK	0.245	0.289	0.372	0.406	0.396	0.301	-2.185	0.068	-0.033
EE	0.233	0.289	0.275	0.263	0.345	0.358	0.181		
ES	-0.931	-0.562	0.192	0.284	0.286	0.251	0.184	0.127	0.168
FI	0.296	-1.205	0.206	0.255	0.263	0.261	0.165	0.296	0.260
FR	0.163	0.132	0.240	0.231	0.261	0.249	0.200	-2.040	0.268
GB	0.164	0.240	0.167	0.146	0.201	0.053	0.152	0.156	0.149
GR	0.221	0.326	0.195	0.248	0.189	0.221	0.058	0.012	-0.132
IE	0.181	0.294	0.285	0.276	0.231	0.148	0.220	0.386	0.464
IT	-0.773	0.086	0.186	0.219	0.257	0.211	0.174	0.164	0.125
LU	0.207	0.228	0.275	0.268	0.144	0.230	0.158	0.280	0.366
NL	0.046	0.135	0.206	0.242	0.218	0.217	0.209	0.209	0.414
PL	0.081	-0.040	-0.011	0.177	0.272	0.274	-0.521	-0.148	0.241
PT	0.247	0.200	-1.276	0.195	0.224	0.170	-0.108	0.111	0.115
SE	0.246	0.281	0.357	0.469	0.394	0.329	0.043	0.382	0.346
SI	0.218	0.233	0.296	0.077	0.199	0.246	0.172	0.152	-0.238
SK	0.105	0.196	0.146	0.184	0.206	0.237	0.168	0.131	-0.259

Table 12: *Coefficient estimates for the translog cost function for each year. This model estimated using a SUR and new price of borrowing proxy, original price of labour.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-4.996	-5.194	-5.423	-5.294	-5.486	-5.419	-5.389	-4.245	-4.036
Pl	-0.426	-0.430	-0.401	-0.433	-0.381	-0.354	-0.335	-0.587	-0.730
Pk	0.388	0.467	0.527	0.558	0.482	0.395	0.352	0.511	0.690
Pb	1.038	0.963	0.874	0.876	0.899	0.959	0.983	1.076	1.040
Y	1.087	1.137	1.134	1.083	1.084	1.064	1.076	1.060	1.052
ll	0.137	0.139	0.137	0.141	0.135	0.128	0.122	0.157	0.178
kk	0.016	0.011	0.007	-0.0002	0.002	0.007	0.008	0.017	0.006
yy	0.002	-0.001	0.001	0.002	0.002	0.005	0.001	0.0001	-0.003
lk	-0.025	-0.030	-0.032	-0.034	-0.027	-0.018	-0.016	-0.039	-0.050
kl	-0.025	-0.030	-0.032	-0.034	-0.027	-0.018	-0.016	-0.039	-0.050
lb	-0.112	-0.109	-0.105	-0.108	-0.109	-0.110	-0.106	-0.118	-0.128
bl	-0.112	-0.109	-0.105	-0.108	-0.109	-0.110	-0.106	-0.118	-0.128
kb	0.009	0.018	0.025	0.034	0.024	0.011	0.008	0.022	0.044
bk	0.009	0.018	0.025	0.034	0.024	0.011	0.008	0.022	0.044
bb	0.103	0.091	0.080	0.074	0.084	0.099	0.099	0.095	0.084
ly	-0.006	-0.007	-0.007	-0.003	-0.005	-0.005	-0.005	0.0001	0.005
ky	-0.018	-0.020	-0.023	-0.021	-0.021	-0.021	-0.018	-0.018	-0.019
by	0.023	0.028	0.030	0.024	0.025	0.026	0.024	0.018	0.015

Table 13: *Mean Lerner values for each country for each year. This model estimated using a SUR and our new price for borrowing, with the original price of labour.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.081	0.106	0.121	0.156	0.129	0.113	-0.025	-0.515	0.102
BE	-0.037	0.036	0.112	0.179	0.116	0.134	-0.579	0.187	0.203
CZ	0.117	0.125	0.159	0.213	0.220	0.230	0.199	-0.364	0.001
DE	0.049	0.066	0.078	0.110	0.092	0.077	0.054	0.113	0.144
DK	0.171	0.209	0.282	0.335	0.332	0.230	-2.469	-0.037	-0.143
EE	0.202	0.244	0.222	0.228	0.319	0.326	0.141		
ES	-1.063	-0.691	0.097	0.207	0.213	0.156	0.109	0.057	0.104
FI	0.223	-1.507	0.094	0.179	0.198	0.184	0.075	0.226	0.190
FR	0.094	0.051	0.162	0.159	0.188	0.159	0.112	-2.301	0.222
GB	0.078	0.148	0.047	0.070	0.136	-0.039	0.078	0.074	0.060
GR	0.157	0.271	0.113	0.178	0.113	0.131	-0.033	-0.049	-0.169
IE	0.090	0.207	0.197	0.206	0.157	0.054	0.129	0.381	0.449
IT	-0.905	0.007	0.097	0.157	0.203	0.156	0.125	0.103	0.061
LU	0.133	0.147	0.186	0.194	0.061	0.142	0.063	0.208	0.309
NL	-0.035	0.061	0.135	0.194	0.149	0.149	0.130	0.165	0.395
PL	0.040	-0.107	-0.111	0.132	0.235	0.224	-0.648	-0.192	0.219
PT	0.191	0.144	-1.456	0.144	0.176	0.110	-0.174	0.075	0.084
SE	0.179	0.205	0.270	0.410	0.335	0.272	-0.028	0.311	0.263
SI	0.163	0.162	0.216	-0.030	0.136	0.175	0.108	0.106	-0.296
SK	0.068	0.141	0.079	0.131	0.155	0.190	0.124	0.091	-0.310

Table 14: *Translog cost function coefficient estimates, estimated using both of our new proxies for price and using a single equation.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-5.022	-5.188	-4.674	-1.534	-5.976	-5.467	-4.404	-2.094	-1.588
Pl	-0.268	-0.276	-0.500	-4.141	0.498	-0.142	-0.642	-0.599	-0.552
Pk	0.149	0.191	0.260	0.299	0.396	0.383	0.176	0.006	-0.062
Pb	1.119	1.085	1.240	4.842	0.106	0.759	1.466	1.593	1.615
Y	1.023	1.070	0.999	1.025	1.084	1.086	1.053	0.923	0.981
ll	0.507	0.452	0.417	2.197	0.001	0.371	0.341	0.072	-0.020
kk	0.012	0.007	0.013	0.001	0.014	0.010	0.024	0.053	0.024
yy	0.006	0.002	0.006	0.0003	0.004	0.003	0.001	0.014	0.010
lk	-0.017	-0.013	-0.017	-0.023	-0.082	-0.085	0.004	0.010	0.059
kl	-0.017	-0.013	-0.017	-0.023	-0.082	-0.085	0.004	0.010	0.059
lb	-0.489	-0.439	-0.400	-2.174	0.081	-0.287	-0.345	-0.082	-0.038
bl	-0.489	-0.439	-0.400	-2.174	0.081	-0.287	-0.345	-0.082	-0.038
kb	0.006	0.006	0.004	0.022	0.069	0.074	-0.028	-0.063	-0.083
bk	0.006	0.006	0.004	0.022	0.069	0.074	-0.028	-0.063	-0.083
bb	0.484	0.433	0.397	2.152	-0.150	0.212	0.374	0.145	0.121
ly	-0.017	-0.015	0.018	0.020	-0.017	-0.021	0.009	0.042	0.029
ky	-0.017	-0.023	-0.035	-0.030	-0.031	-0.029	-0.032	-0.042	-0.041
by	0.034	0.037	0.017	0.009	0.048	0.050	0.024	0.0005	0.011

Table 15: *Mean Lerner indices, estimated based on non-SUR cost function estiamted using our new proxies for price.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.121	0.150	0.167	0.175	0.156	0.137	-0.005	-0.457	0.116
BE	0.010	0.086	0.163	0.207	0.156	0.174	-0.517	0.214	0.218
CZ	0.133	0.154	0.231	0.262	0.240	0.248	0.237	-0.266	0.053
DE	0.089	0.110	0.124	0.132	0.119	0.100	0.073	0.126	0.156
DK	0.210	0.251	0.321	0.350	0.362	0.261	-2.312	0.014	-0.101
EE	0.210	0.260	0.293	0.277	0.330	0.330	0.182		
ES	-0.995	-0.621	0.152	0.231	0.230	0.174	0.125	0.084	0.116
FI	0.255	-1.365	0.159	0.222	0.241	0.226	0.123	0.253	0.186
FR	0.127	0.095	0.210	0.190	0.220	0.192	0.146	-2.039	0.235
GB	0.121	0.192	0.119	0.113	0.173	-0.001	0.118	0.120	0.100
GR	0.185	0.298	0.166	0.211	0.130	0.151	-0.002	-0.006	-0.129
IE	0.140	0.263	0.259	0.243	0.211	0.121	0.195	0.392	0.453
IT	-0.822	0.057	0.164	0.183	0.228	0.177	0.146	0.129	0.081
LU	0.176	0.199	0.236	0.222	0.117	0.192	0.107	0.220	0.316
NL	0.015	0.113	0.197	0.229	0.194	0.196	0.177	0.206	0.397
PL	0.046	-0.089	0.002	0.199	0.245	0.233	-0.589	-0.049	0.275
PT	0.213	0.175	-1.266	0.189	0.199	0.133	-0.119	0.135	0.131
SE	0.216	0.247	0.321	0.427	0.367	0.302	0.005	0.332	0.289
SI	0.178	0.182	0.266	0.021	0.152	0.193	0.134	0.144	-0.236
SK	0.077	0.159	0.174	0.187	0.163	0.199	0.165	0.165	-0.205

Table 16: *Coefficient estimates for linear cost function, estimated using original price of borrowing and new proxy for the price of labour*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-6.432	-5.730	-6.094	-5.954	-6.042	-6.432	-6.746	-6.202	-6.403
Pl	0.938	0.546	0.623	0.549	0.411	0.673	0.863	0.688	0.707
Pk	0.154	0.036	0.119	0.128	0.273	0.275	0.258	0.156	0.139
Pb	-0.092	0.419	0.258	0.323	0.316	0.052	-0.121	0.156	0.154
Y	1.101	1.044	1.069	1.011	0.984	1.032	1.117	1.020	1.051
ll	-0.054	0.010	0.017	-0.035	0.102	0.023	-0.027	0.017	-0.020
kk	0.005	0.006	0.013	0.003	0.007	0.005	0.007	0.035	0.012
yy	-0.004	-0.004	0.002	-0.002	0.002	0.001	-0.004	0.014	0.007
lk	-0.004	0.037	0.027	0.034	-0.023	-0.017	-0.010	-0.009	0.022
kl	-0.004	0.037	0.027	0.034	-0.023	-0.017	-0.010	-0.009	0.022
lb	0.058	-0.048	-0.044	0.001	-0.079	-0.006	0.037	-0.009	-0.002
bl	0.058	-0.048	-0.044	0.001	-0.079	-0.006	0.037	-0.009	-0.002
kb	-0.002	-0.043	-0.039	-0.037	0.016	0.012	0.004	-0.027	-0.034
bk	-0.002	-0.043	-0.039	-0.037	0.016	0.012	0.004	-0.027	-0.034
bb	-0.056	0.091	0.083	0.036	0.062	-0.006	-0.041	0.036	0.035
ly	-0.028	-0.003	-0.011	0.022	0.028	0.012	-0.015	-0.004	-0.004
ky	-0.019	-0.018	-0.031	-0.027	-0.029	-0.030	-0.031	-0.038	-0.035
by	0.047	0.021	0.042	0.006	0.001	0.019	0.046	0.042	0.039

Table 17: *Mean Lerner indices for each country, estimated from single cost function using original price of borrowing, and new proxy for the price of labour.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.140	0.166	0.189	0.187	0.159	0.146	0.059	-0.288	0.146
BE	0.038	0.100	0.182	0.218	0.158	0.185	-0.481	0.227	0.227
CZ	0.145	0.182	0.217	0.274	0.277	0.281	0.237	-0.306	0.018
DE	0.102	0.123	0.137	0.144	0.126	0.115	0.095	0.140	0.167
DK	0.233	0.263	0.354	0.362	0.356	0.264	-2.248	0.043	-0.073
EE	0.213	0.293	0.276	0.288	0.380	0.374	0.175		
ES	-0.961	-0.589	0.173	0.246	0.250	0.197	0.139	0.092	0.126
FI	0.292	-1.299	0.194	0.231	0.249	0.236	0.133	0.277	0.215
FR	0.149	0.115	0.221	0.202	0.230	0.208	0.162	-1.992	0.247
GB	0.154	0.217	0.154	0.127	0.186	0.020	0.134	0.144	0.129
GR	0.204	0.317	0.176	0.226	0.161	0.179	0.008	-0.013	-0.152
IE	0.171	0.276	0.270	0.251	0.206	0.114	0.200	0.375	0.461
IT	-0.806	0.069	0.178	0.194	0.240	0.191	0.146	0.130	0.088
LU	0.196	0.207	0.256	0.232	0.105	0.190	0.125	0.256	0.346
NL	0.029	0.118	0.194	0.235	0.205	0.194	0.178	0.206	0.396
PL	0.058	-0.026	-0.005	0.216	0.310	0.283	-0.539	-0.138	0.248
PT	0.231	0.197	-1.292	0.201	0.236	0.164	-0.136	0.100	0.107
SE	0.233	0.261	0.347	0.434	0.360	0.306	0.021	0.370	0.322
SI	0.198	0.229	0.276	0.045	0.188	0.220	0.136	0.130	-0.251
SK	0.081	0.205	0.151	0.202	0.231	0.241	0.150	0.130	-0.247

Table 18: *Coefficient estimates from single equation translog, estimated using new proxy for the price of borrowing, and the original price of labour.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Intercept	-7.718	-3.673	-4.918	-5.606	-4.738	-5.695	-3.177	-1.916	-1.990
Pl	0.363	-0.506	-0.341	-0.224	-0.405	-0.172	-0.712	-0.715	-0.689
Pk	0.052	-0.257	-0.112	-0.045	-0.208	-0.196	-0.343	-0.394	-0.367
Pb	0.585	1.763	1.453	1.269	1.613	1.368	2.055	2.109	2.056
Y	1.325	1.161	1.261	1.281	1.224	1.280	1.044	1.070	1.082
ll	0.052	0.131	0.131	0.124	0.138	0.105	0.156	0.149	0.144
kk	0.007	0.011	0.010	0.008	0.021	0.014	0.028	0.035	0.020
yy	-0.003	-0.003	-0.005	-0.007	-0.008	-0.011	-0.006	-0.0001	0.001
lk	0.001	0.042	0.026	0.017	0.034	0.039	0.051	0.037	0.040
kl	0.001	0.042	0.026	0.017	0.034	0.039	0.051	0.037	0.040
lb	-0.053	-0.174	-0.157	-0.141	-0.172	-0.143	-0.207	-0.186	-0.183
bl	-0.053	-0.174	-0.157	-0.141	-0.172	-0.143	-0.207	-0.186	-0.183
kb	-0.008	-0.053	-0.036	-0.025	-0.055	-0.053	-0.079	-0.072	-0.060
bk	-0.008	-0.053	-0.036	-0.025	-0.055	-0.053	-0.079	-0.072	-0.060
bb	0.060	0.227	0.193	0.165	0.227	0.196	0.287	0.258	0.243
ly	-0.047	-0.021	-0.030	-0.031	-0.025	-0.031	0.003	-0.008	-0.010
ky	-0.004	-0.001	-0.007	-0.007	-0.003	-0.003	0.001	-0.0004	-0.001
by	0.051	0.022	0.037	0.038	0.028	0.034	-0.004	0.008	0.010

Table 19: *Mean Lerner indices for each country, estimated from single equation translog cost function, which used our new proxy for the price of borrowing, and the original price of labour used by Weill.*

	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	0.078	0.116	0.123	0.141	0.116	0.094	-0.050	-0.563	0.068
BE	-0.060	0.028	0.098	0.151	0.086	0.110	-0.583	0.133	0.128
CZ	0.084	0.109	0.144	0.191	0.200	0.213	0.179	-0.399	-0.055
DE	0.051	0.076	0.083	0.101	0.082	0.062	0.032	0.090	0.110
DK	0.171	0.212	0.280	0.321	0.315	0.210	-2.662	-0.075	-0.194
EE	0.201	0.251	0.217	0.204	0.295	0.297	0.111		
ES	-1.049	-0.694	0.098	0.200	0.209	0.175	0.110	0.028	0.076
FI	0.136	-1.578	0.063	0.139	0.166	0.154	0.046	0.188	0.160
FR	0.088	0.044	0.158	0.146	0.175	0.153	0.091	-2.582	0.167
GB	0.044	0.136	0.019	0.024	0.097	-0.083	0.036	0.020	-0.007
GR	0.160	0.283	0.117	0.176	0.120	0.147	-0.042	-0.098	-0.251
IE	-0.030	0.157	0.134	0.126	0.094	-0.030	0.095	0.317	0.360
IT	-0.936	-0.009	0.081	0.140	0.186	0.134	0.101	0.078	0.026
LU	0.089	0.122	0.158	0.152	0.011	0.102	0.034	0.159	0.242
NL	-0.073	0.044	0.099	0.141	0.104	0.104	0.109	0.091	0.339
PL	0.017	-0.107	-0.121	0.099	0.211	0.203	-0.710	-0.230	0.165
PT	0.176	0.148	-1.480	0.123	0.157	0.090	-0.214	0.034	0.022
SE	0.156	0.196	0.257	0.391	0.310	0.239	-0.077	0.272	0.221
SI	0.149	0.182	0.223	-0.064	0.123	0.163	0.099	0.066	-0.399
SK	0.023	0.134	0.051	0.101	0.135	0.169	0.095	0.045	-0.408