Measuring multi-output banks' market power using a weighted-average Lerner index

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Abstract

Multi-output measures of market power have become increasingly important in banking, since banks have been broadening their business from interest-bearing activities to fee-based activities. For the analysis of a multi-output bank's market power, it is often attractive to calculate an average measure of market power over the various outputs. The contribution of this study's theoretical part is twofold. First, we propose a weighted-average Lerner index that has relatively mild data requirements. Second, we compare our weighted-average Lerner index to an alternative Lerner index that has recently gained popularity as a multi-output measure of market power in the banking literature. We show that this alternative Lerner index has no sensible economic interpretation in a multi-output setting and underestimates a multi-output firm's average degree of market power. The empirical part of this study illustrates the two Lerner indices using U.S. banking data covering the period 2000 – 2016.

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1. Introduction

According to Blair and Sokol (2014, p. 325), *"the standard measure of market power, at least by economists, has come to be the Lerner index"*. The theoretical and historical foundations of the Lerner index have been extensively discussed in the literature (Amoroso, 1933; Lerner, 1934; Amoroso, 1938, 1954; Landes and Posner, 1981; Elzinga and Mills, 2011; Giocoli, 2012). A firm's Lerner index compares the market output price with the firm's marginal costs of production, where marginal-cost pricing is referred to as the *'social optimum that is reached in perfect competition'* (Lerner, 1934, p.168). A positive Lerner index is generally associated with the presence of market power and reduced consumer welfare.

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The Lerner index was originally derived for a firm producing a single output. This raises the question how a multi-output Lerner index should be calculated. Intuitively, the multi-output analogue of the single-output Lerner index is obtained by calculating separate Lerner indices for each output. This intuition is indeed correct, since output-specific marginal-cost pricing characterizes the long-run competitive equilibrium of multi-output firms (Baumol et al., 1982) and of markets where both single-output and multi-output firms are active (MacDonald and Slivinski, 1987).

In the analysis of a multi-output firm's market power, it is often attractive to calculate a weighted-average Lerner index over the various outputs. This results in a single summary measure of a multi-output firm's market power, which may be conveniently used as an explanatory variable in a regression analysis to assess the impact of market power on any relevant economic variable.

Multi-output measures of market power have become increasingly important in banking, as banks have been broadening their focus from interest-bearing activities to fee-based activities (e.g., Lepetit et al., 2008). As a result, the alternative multi-output Lerner index of Koetter et al. (2012) has recently gained popularity in the banking literature.[1]

The contribution of this study's theoretical part is twofold. First, we show that the weighted-average Lerner index – based on the weights proposed by Encaua et al. (1986) – has relatively mild data requirements. Second, we compare the weighted-average Lerner index to the alternative Lerner index of Koetter et al. (2012) in the context of multi-output banks. We show that the latter Lerner index has no sensible economic and statistical interpretation and underestimates a multi-output firm's weighted-average degree of market power.

Because of the aforementioned relevance of multi-output technologies in the banking sector, the empirical part of this study focuses on U.S. commercial banks during the period 2000 – 2016. We show that the median of our weighted-average Lerner index is much larger than the median of the alternative Lerner index of Koetter et al. (2012). We also consider a simple Lerner index based on the assumption that total assets are the single aggregate output.[2] Surprisingly, this Lerner index closely resembles the weighted-average Lerner index.

Because the alternative Lerner index lacks a proper economic and statistical interpretation and underestimates a firm's weighted-average degree of market power, its use for policy decisions may have serious adverse welfare implications. We therefore recommend against its use. By contrast, the weighted-average Lerner index proposed in this study provides a sound way to summarize a multi-

[1]See e.g. Buch et al. (2012), Restrepo-Tobón and Kumbhakar (2014), Hakenes et al. (2015), Kick and Prieto (2015), Bolt and Humphrey (2015), Inklaar et al. (2015), Belke et al. (2016), Ahamed and Mallick (2017), Lapteacru (2017), and Degl'Innocenti et al. (2017).

[2]See e.g. Weill (2013), Mirzaei and Moore (2014), Fu et al. (2014), Delis et al. (2016), Calderon and Schaeck (2016), Dong et al. (2016), and Leroy and Lucotte (2017).

output firm's market power.

The setup of the remainder of this study is as follows. Section 2 shows that the weighted-average Lerner index imposes only mild data requirements. Subsequently, we compare the latter Lerner index to the aforementioned alternative Lerner index. An empirical application involving U.S. banking data during the 2000 – 2016 period is provided in Section 3. Finally, Section 4 concludes.

2. Theoretical framework

The standard framework for the Lerner index is a single-output production technology. The associated total cost function is written as $C(q, \mathbf{p})$, where q denotes a firm's output level and $\mathbf{p}$ a vector of exogenous input prices. The marginal cost (MC) function is denoted $MC(q, \mathbf{p}) = \partial C(q, \mathbf{p})/\partial q$. A firm's Lerner index is then defined as the firm's relative markup of the realized market output price (P^*) over MC, given the firm's output level $q > 0$:

$$L(q) = \frac{P^* - MC(q, \mathbf{p})}{P^*}. \tag{1}$$

For simplicity of notation, we write the Lerner index as a function of the output level only and ignore the dependence on $\mathbf{p}$ in our notation.

In case of a multi-output production technology, we assume a total cost function $C(\mathbf{q}; \mathbf{p})$, where $\mathbf{q} = (q_1, \ldots, q_n)$ and $\mathbf{p} = (p_1, \ldots, p_K)$. Here $q_j > 0$ denotes the level of firm's j-th output ($j = 1, \ldots, n$) and $p_k > 0$ a firm's k-th input price. The partial derivatives with respect to each output are denoted $MC_j(\mathbf{q}; \mathbf{p}) = \partial C(\mathbf{q}; \mathbf{p})/\partial q_j > 0$. The Lerner index can be calculated separately for the j-th output:

$$L_j(\mathbf{q}; \mathbf{p}) = \frac{P_j^* - MC_j(\mathbf{q}; \mathbf{p})}{P_j^*}. \tag{2}$$

As mentioned in the introduction, a formal economic proof of why this definition of output-specific Lerner indices makes sense in the multi-output case relies on Baumol et al. (1982) and MacDonald and Slivinski (1987).

Given $n \geq 2$ output-specific Lerner indices, a weighted-average Lerner index is easily derived as suggested by Encaua et al. (1986):

$$L_{WA}(\mathbf{q}; \mathbf{p}) = \sum_{j=1}^{n} L_j(q_j) w_j, \tag{3}$$

where the weights w_j represent revenue shares:

$$w_j = \frac{P_j^* q_j}{\sum_{i=1}^n P_i^* q_i} = \frac{TR_j}{TR}. \tag{4}$$

Hence, the weights w_j denote the ratio of the total revenues of the j-output divided by the total revenues over all outputs. The weighted-average Lerner index summarizes firm's overall market power over the various outputs. Taking the revenue shares as the weights ensures that the resulting average is not merely driven by one or more output-specific Lerner indices that correspond to minor activities of a firm. Yet there is another important reason to resort to this specific weighted-average measure of market power, as summarized in the proposition below.

Result 1 (calculation of L_{WA}) *The calculation of the weighted average Lerner index in (3) – using the weights proposed by Encaua et al. (1986) given in (4) – requires only total or average revenues, output quantities or shares, and output-specific MC. In particular, realized market output prices are not required. Hence, the weighted-average Lerner index can be calculated even if the output-specific Lerner indices cannot.*

Proof: By rewriting (3), we find

$$\begin{aligned} L_{WA}(\mathbf{q};\mathbf{p}) &= \sum_{j=1}^n L_j(q_j) w_j \\ &= \sum_{j=1}^n \Big(\frac{P_j^* - MC_j(\mathbf{q};\mathbf{p})}{P_j} \frac{P_j^* q_j}{\sum_{i=1}^n P_i^* q_i} \Big) \\ &= \frac{\sum_{j=1}^n P_j^* q_j - \sum_{j=1}^n MC_j(\mathbf{q};\mathbf{p}) q_j}{\sum_{j=1}^n P_j^* q_j}. \end{aligned} \tag{5}$$

Using short-hand notation, we can rewrite (5) as

$$L_{WA} = \frac{TR - \sum_{j=1}^n MC_j q_j}{TR} = \frac{AR - \sum_{j=1}^n MC_j \tilde{w}_j}{AR}. \tag{6}$$

Here $\tilde{w}_j = q_j / \sum_{i=1}^n q_i$ is the output share of the i-th output, while TR and $AR = TR/\sum_{i=1}^n q_i$ stand for total revenues and average revenues, respectively. From (6) it becomes immediately clear that the weighted average Lerner index can be calculated when output-specific prices not available. The only requirements are total or average revenues, output quantities and output-specific MC. □

Calculating L_{WA} by means of one of the expressions in (6) is particularly relevant if output-specific prices are not available or if the available price proxies are noisy. In the absence of output-specific Lerner indices, the weighted-average Lerner index still provides a summary measure of the a firm's market power over its various outputs. Such a summary measure may be conveniently used as an explanatory variable in regressions that aim to assess the impact of market power on any relevant economic variable.

The multi-output Lerner index in (6) differs from a popular index introduced by Koetter et al. (2012) and subsequently used in the banking literature as a multi-output measure of market power (e.g., Buch et al., 2012; Restrepo-Tobón and Kumbhakar, 2014; Hakenes et al., 2015; Kick and Prieto, 2015; Bolt and Humphrey, 2015; Inklaar et al., 2015; Ahamed and Mallick, 2017). In short-hand notation, this index is defined as

$$L_{KKS} = \frac{AR - \sum_{j=1}^{n} MC_j}{AR}. \tag{7}$$

Result 2 presents some useful properties of L_{KKS}:

Result 2 (properties of L_{KKS})

(i) ***(Statistical interpretation)*** *L_{KKS} cannot be written as a weighted-average of output-specific Lerner indices.*

(ii) ***(Economic interpretation)*** *In long-run competitive equilibrium, $L_{KKS} < 0$. Consequently, $L_{KKS} = 0$ corresponds to a multi-output firm with market power, but not to any fixed degree of market power. Furthermore, there is no unique value of L_{KKS} that corresponds to long-run competitive equilibrium for a multi-output firm.*

(iii) ***(Assumptions)*** *The definition of L_{KKS} assumes that the product-specific output values q_j are perfectly correlated for $j = 1, \ldots, n$.*

(iv) ***(Comparison)*** *$L_{KKS} < L_{WA}$.*

Proof:

(i) Without loss of generality, we consider the case $n = 2$. We can rewrite L_{KKS} as

$$\begin{aligned} L_{KKS} &= \frac{P_1^* - MC_1 \frac{q_1+q_2}{q_1}}{P_1^*} \frac{P_1^* q_1}{P_1^* q_1 + P_2^* q_2} + \frac{P_2^* - MC_2 \frac{q_1+q_2}{q_2}}{P_2^*} \frac{P_2^* q_2}{P_1^* q_1 + P_2^* q_2} \\ &= \frac{P_1^* - MC_1/\tilde{w}_1}{P_1^*} w_1 + \frac{P_2^* - MC_2/(1-\tilde{w}_1)}{P_2^*} (1 - w_1). \end{aligned} \tag{8}$$

This makes clear that we cannot write L_{KKS} as a weighted average of $L_1 = (P_1^* - MC_1)/P_1^*$ and $L_2 = (P_2^* - MC_2)/P_2^*$. □

(ii) We use the same short-hand notation as before. If $MC_j = AC_j$ for $j = 1, \ldots, n$, then

$$L_{KKS} = \frac{TR - \sum_{j=1}^{n} AC_j \sum_{j=1}^{n} q_j}{TR}, \tag{9}$$

where $\sum_{j=1}^{n} AC_j \sum_{j=1}^{n} q_j > \sum_{j]1}^{n} AC_j q_j = TC$ (see the proof in (iv)). Consequently, $L_{KKS} < 0$ in long-run competitive equilibrium (in which $MC_j = AC_j$ for $j = 1, \ldots, n$). Hence, $L_{KKS} = 0$ would correspond to a multi-output firm with market power. Since L_{KKS} varies as a function of other factors, $L_{KKS} = 0$ does not correspond to any fixed degree of market power. Furthermore, since the value of L_{KKS} for a perfectly competitive multi-output firm would depend on the number of products and other factors, there is no unique value of L_{KKS} that corresponds to long-run competitive equilibrium for a multi-output firm. □

(iii) In (7), the term $\sum_{j=1}^{n} MC_j$ should correspond to the marginal cost of one unit of aggregate output. However, marginal cost $\partial C/\partial(q_1 + \ldots + q_n)$ is only defined if the associated increase in each individual q_j is specified. The definition of L_{KKS} assumes that $\partial C/\partial(q_1 + \ldots + q_n) = \sum_{j=1}^{n} MC_j$, which means that the q_j's are assumed to be perfectly correlated. □

(iv) We rewrite L_{WA} and L_{KKS} as

$$L_{WA} = \frac{TR - \sum_{j=1}^{n} MC_j q_j}{TR}, \quad L_{KKS} = \frac{TR - \sum_{j=1}^{n} MC_j \sum_{j=1}^{n} q_j}{TR}. \tag{10}$$

We observe that

$$\sum_{j=1}^{n} MC_j \sum_{j=1}^{n} q_j = \sum_{j=1}^{n} MC_j q_j + \sum_{j=1}^{n} \sum_{i \neq j} MC_j q_i > \sum_{j=1}^{n} MC_j q_j, \tag{11}$$

if $MC_j \geq 0$ and $q_j \geq 0$ for all $j = 1, \ldots, n$ and $MC_j > 0$ and $q_j > 0$ for at least one $j \neq i$. Since we assumed from the start that $q_j > 0$ and $MC_j > 0$ for $j = 1, \ldots, n$, the former conditions will certainly hold. Consequently, $L_{KKS} < L_{WA}$. □

Result 2 (i) illustrates that the statistical meaning of L_{KKS} is unclear, while Result 2 (ii) implies that it is difficult to interpret the value of L_{KKS} economically due to a lack of a unique competitive benchmark. Result 2 (iii) tells us that a subjective assumption underlies the definition of L_{KKS}. Finally, Result 2 (iv) implies that, if L_{KKS} is used anyhow, it will *underestimate* a multi-output firm's weighted-average degree of market power, which may have serious welfare consequences if policy decisions are based on it. By contrast, L_{WA} is a weighted-average of the output-specific Lerner indices, equals 0 in long-run competitive equilibrium, and makes no assumption about the correlations among the q_j's.

3. Empirical application

To illustrate the measurement of market power in a multi-output setting, we consider U.S. commercial banks during the period 2000 – 2016.

3.1. Data and sample statistics

We assume that banks employ a production technology with four inputs and two output factors. The four inputs we consider are purchased funds, core deposits, labor services, and physical capital (Wheelock and Wilson, 2012). The corresponding input prices are (i) the price of purchased funds of bank $i = 1, \ldots, N$ in year $t = 1, \ldots, T$ ($P_{1,it}$), (ii) the core deposit interest rate ($P_{2,it}$), (iii) the wage rate ($P_{3,it}$), and (iv) the price of physical capital ($P_{4,it}$). Total operating costs (C_{it}) are defined as the sum of expenses on purchased funds, core deposits, personnel expenses, and expenses on physical capital. The two output factors we consider are total loans (Y_{it}) and total securities (Z_{it}). The choice of inputs and outputs is based on the intermediation model for banking (Klein, 1971; Monti, 1972) and similar to Koetter et al. (2012). Appendix A explains how the Call Report Data have been used to obtain the required variables.

We use year-end Call Report Data to create three annual (unbalanced) samples of U.S. banks containing the above variables. We consider a pre-crisis period (2000 – 2007), a crisis period (2006 – 2009) and a post-crisis period (2010 – 2016). We restrict the samples to commercial banks with a physical location in a U.S. state, which are part of a bank-holding company and subject to deposit-related insurance. We filter out inconsistent values and use some trimming to get rid of outliers. Table 1 provides sample statistics. We see that, on average, total loans have much larger output and revenue shares than total securities. We also observe a substantial decline in the prices of purchased funds and core deposits after the onset of the crisis, which reflects the actions taken by the Fed to boost the U.S. economy. A comparison of the sample means over the three subperiods indicates a substantially larger bank scale over time, which can be explained from the consolidations that took place over time.

3.2. Translog cost functions

In the present multi-output setting, we consider five different Lerner indices: (i) L_{TLNS}: an output-specific Lerner index for total loans, based on Equation (2); (ii) L_{TSEC}: an output-specific Lerner index for total securities based on (2); (iii) L_{WA}: the weighted-average Lerner index based on (6); (iv) L_{KKS}: the Lerner index of Koetter et al. (2012) as given in (7), and (v) L_{TA}: a Lerner index based on the assumption that total assets is the single aggregate output. Output-specific Lerner indices as in (i) and (ii) were also obtained in e.g. Forssbæck and Shehzad (2015), Degl'Innocenti et al. (2017) and

Table 1: **Sample statistics for U.S. commercial bank data (2000 – 2016)**

	2000 – 2006		*2007 – 2009*		*2010 – 2016*	
price of purchased funds (P_1)	4.0%	1.4%	3.8%	1.2%	1.4%	0.8%
price of core deposits (P_2)	2.2%	1.0%	2.1%	0.8%	0.5%	0.4%
wage rate (P_3)	47.4	13.5	57.8	16.5	66.2	19.1
price of physical capital (P_4)	32.6%	29.0%	33.2%	36.3%	34.5%	42.4%
total loans (Y)	668,856	9,703,133	1,058,674	17,100,676	1,463,494	22,645,052
total securities (Z)	210,282	2,990,525	314,627	5,749,204	580,635	9,614,227
total assets (TA)	1,131,708	18,381,186	1,904,576	36,004,672	2,765,245	47,962,018
total equity (EQ)	102,166	1,564,547	184,574	3,191,163	300,111	4,990,139
total costs (C)	43,549	708,962	65,878	1,206,561	55,489	912,196
output share total loans ($\tilde{w}_1$)	72.9%	15.3%	76.3%	15.2%	72.4%	16.7%
output share total securities ($\tilde{w}_2$)	27.1%	15.3%	23.7%	15.2%	27.6%	16.7%
revenue share total loans (w_1)	69.3%	12.9%	71.6%	13.4%	71.2%	13.6%
revenue share total securities (w_2)	30.7%	12.9%	28.4%	13.4%	28.8%	13.6%
# bank-years	41,155		15,826		31,712	
# banks	7,275		5,812		5,419	
# years	7		3		7	

Notes: The column captioned 'mean' reports the sample means, while the column captioned 's.e.' shows the sample standard error. All level variables are in thousands of $.

Huang et al. (2017), while L_{TA} has been calculated in Fu et al. (2014), Delis et al. (2016), Calderon and Schaeck (2016), Dong et al. (2016), and Leroy and Lucotte (2017).

To calculate L_{TLNS}, L_{TSEC}, L_{WA} and L_{KKS}, we adopt a translog cost function similar to Koetter et al. (2012) and many others. As usual, we impose linear homogeneity in input prices by normalizing total costs and input prices with the price of purchased funds ($P_{1,it}$). Throughout, variables with a tilde have been normalized with the price of purchased funds prior to taking the logarithmic transformation to ensure linear homogeneity. This results in the following four-input and two-output translog cost function for bank i in year t:

$$\begin{aligned}
\log(\widetilde{C}_{it}) \;=\;& \alpha_i + \sum_{j=2}^{4}\beta_{j,p}\log(\widetilde{P}_{j,it}) + (1/2)\sum_{j=2}^{4}\sum_{k=2}^{4}\beta_{jk,pp}\log(\widetilde{P}_{j,it})\log(\widetilde{P}_{k,it}) + \sum_{j=2}^{4}\beta_{j,py}\log(\widetilde{P}_{j,it})\log(Y_{it}) \\
&+ \sum_{j=2}^{4}\beta_{j,pz}\log(\widetilde{P}_{j,it})\log(Z_{it}) + \beta_y\log(Y_{it}) + \beta_z\log(Z_{it}) + (1/2)\beta_{yy}\log(Y_{it})^2 + (1/2)\beta_{zz}\log(Z_{it})^2 \\
&+ \beta_{yz}\log(Y_{it})\log(Z_{it}) + \beta_{time,y}t\log(Y_{it}) + \beta_{time,z}t\log(Z_{it}) + \beta_{time2,y}t^2\log(Y_{it}) + \\
&+ \beta_{time2,z}t^2\log(Z_{it}) + \beta_e\log(EQ_{it}/TA_{it}) + \beta_{time}t + \beta_{time2}t^2 + \varepsilon_{it}, \qquad (12)
\end{aligned}$$

with α_i a bank-specific intercept, t a time trend accounting for technological change and ε_{it} a zero-mean error term that is orthogonal to the regressors. The partial log-log derivatives of total costs with respect to each of the two outputs equal

$$\frac{\partial \log C_{it}}{\partial \log Y_{it}} = \sum_{j=2}^{4} \beta_{j,py} \log(\widetilde{P}_{j,it}) + \beta_y + \beta_{yy} \log(Y_{it}) + \beta_{yz} \log(Z_{it}) + \beta_{time,y} t + \beta_{time2,y} t^2, \tag{13}$$

and

$$\frac{\partial \log C_{it}}{\partial \log Z_{it}} = \sum_{j=2}^{4} \beta_{j,pz} \log(\widetilde{P}_{j,it}) + \beta_z + \beta_{zz} \log(Z_{it}) + \beta_{yz} \log(Y_{it}) + \beta_{time,z} t + \beta_{time2,z} t^2, \tag{14}$$

The within estimator allows for bank-specific unobserved heterogeneity, including time-invariant inefficiency.[3] Equations (13) and (14) are used to calculate the MC that are need for the first four Lerner indices. The price proxy used in each of the four Lerner indices is the average revenue associated with each output; for a detailed definition see Appendix A.

To calculate L_{TA}, we estimate the following single-output translog cost function in terms of total assets:

$$\begin{aligned} \log(\widetilde{C}_{it}) &= \alpha_i + \sum_{j=2}^{4} \beta_{j,p} \log(\widetilde{P}_{j,it}) + (1/2) \sum_{j=2}^{4} \sum_{k=2}^{4} \beta_{jk,pp} \log(\widetilde{P}_{j,it}) \log(\widetilde{P}_{k,it}) \\ &+ \sum_{j=2}^{4} \beta_{j,py} \log(\widetilde{P}_{j,it}) \log(TA_{it}) + \beta_y \log(TA_{it}) + (1/2) \beta_{yy} \log(TA_{it})^2 \\ &+ \beta_{time,y} t \log(TA_{it}) + \beta_{time2,y} t^2 \log(TA_{it}) + \beta_e \log(EQ_{it}/TA_{it}) + \beta_{time} t + \beta_{time2} t^2 + \varepsilon_{it} \end{aligned} \tag{15}$$

with α_i a bank-specific intercept, t a time trend accounting for technological change and ε_{it} a zero-mean error term that is orthogonal to the regressors. This single-output cost function has recently been used in several Lerner studies in banking; see e.g. Fu et al. (2014), Delis et al. (2016), Calderon and Schaeck (2016), Dong et al. (2016), and Leroy and Lucotte (2017). The partial log-log derivative of total costs with respect to total assets (while keeping the equity ratio constant) now equals

$$\frac{\partial \log C_{it}}{\partial \log TA_{it}} = \sum_{j=2}^{4} \beta_{j,py} \log(\widetilde{P}_{j,it}) + \beta_y + \beta_{yy} \log(TA_{it}) + \beta_{time,y} t + \beta_{time2,y} t^2. \tag{16}$$

Equations (13) and (14) are used to calculate the MC that are required for calculating L_{TA}. The price proxy used in the fifth Lerner index is the average revenue of total assets; for a detailed definition see Appendix A.

[3]Because especially total loans and total securities contain very little time-series variation, we use random instead of fixed effects estimation. We notice that Koetter et al. (2012) estimate marginal costs in the Lerner index using a pooled stochastic frontier approach. We include random effects instead, which capture any time-invariant heterogeneity uncorrelated with the regressors. The results of our study remain qualitatively the same if use a stochastic-frontier approach instead. The panel estimation results for the translog cost function are available upon request.

3.3. Estimation results

The sample statistics for all five Lerner indices are given in Table 2, where we provide sample medians and interquartile ranges instead of sample means and standard errors to deal with any outliers.[4]

Table 2: **Sample statistics for five Lerner indices and their associated MC (in %)**

	L_{TLNS}	L_{TSEC}	L_{WA}	L_{KKS}	L_{TA}
	2000 – 2006				
median	40.1	57.4	45.7	-23.7	41.9
IQR	14.4	16.2	11.2	27.5	11.4
5% quantile	15.8	35.2	31.8	-65.6	28.2
95% quantile	56.4	80.1	59.7	9.3	56.3
median *MC*	4.4	3.8	4.1	8.2	3.8
IQR *MC*	1.7	1.8	1.6	3.2	1.5
	2007 – 2009				
median	35.2	62.2	43.1	-27.1	39.1
IQR	14.8	15.5	11.6	29.4	11.4
5% quantile	9.8	30.5	26.5	-83.8	22.5
95% quantile	51.9	82.2	57.5	5.4	54.0
median *MC*	4.5	3.5	4.2	8.1	3.9
IQR *MC*	1.3	1.8	1.2	2.5	1.1
	2010 – 2016				
median	52.4	66.4	56.6	-0.7	52.7
IQR	12.9	15.4	9.4	27.6	10.2
5% quantile	29.2	35.4	43.7	-49.7	38.4
95% quantile	66.5	85.9	68.6	30.1	65.7
median *MC*	2.6	2.0	2.3	4.7	2.2
IQR *MC*	0.9	1.1	0.8	1.7	0.7

Notes: L_{TLNS} is the output-specific Lerner index for total loans, L_{TSEC} the output-specific Lerner index for total securities, L_{WA} the weighted-average Lerner index, L_{KKS} the Lerner index of Koetter et al. (2012), and L_{TA} the Lerner index with total assets as the single aggregate output factor.

The results are consistent over the three subsamples. As expected, the sample median of L_{WA} lies between the sample medians of the individual Lerner indices L_{TLNS} and L_{TSEC}. Furthermore, we observe that both the median and the 5% and 95% sample quantiles of L_{KKS} are much smaller than those of L_{WA}, while the interquartile range of L_{KKS} is much larger. This is consistent with our theoretical result that L_{KKS} severely underestimates banks' average degree of market power over the various outputs. We notice that L_{KKS} is negative for a substantial fraction of the bank-year observations, while percentage negative values is negligibly small for the other Lerner indices. Also this finding is consistent with our theoretical analysis, where we pointed out that the economic interpretation of the values of L_{KKS} is difficult due to the lack of a unique competitive benchmark. Although the median and the

[4] Such outliers may arise if the denominator of the Lerner index is small.

5% and 95% sample quantiles of L_{TA} are somewhat below those of L_{WA}, these two Lerner indices seem relatively similar in terms of sample distribution. A consistent pattern across all Lerner indices is their higher post-crisis median value. Similarly, all Lerner indices have lower median values of MC during the post-crisis period.

Table 3: **Spearman rank correlations between the five Lerner indices**

	L_{TLNS}	L_{TSEC}	L_{WA}	L_{KKS}	L_{TA}
	2000 – 2006				
L_{TLNS}	1.00	0.06	0.79	0.74	0.73
L_{TSEC}	0.06	1.00	0.53	0.36	0.55
L_{WA}	0.79	0.53	1.00	0.81	0.94
L_{KKS}	0.74	0.36	0.81	1.00	0.80
L_{TA}	0.73	0.55	0.94	0.80	1.00
	2007 – 2009				
L_{TLNS}	1.00	0.00	0.73	0.63	0.69
L_{TSEC}	0.00	1.00	0.47	0.34	0.50
L_{WA}	0.73	0.47	1.00	0.74	0.94
L_{KKS}	0.63	0.34	0.74	1.00	0.74
L_{TA}	0.69	0.50	0.94	0.74	1.00
	2010 – 2016				
L_{TLNS}	1.00	-0.06	0.77	0.70	0.71
L_{TSEC}	-0.06	1.00	0.45	0.30	0.47
L_{WA}	0.77	0.45	1.00	0.78	0.95
L_{KKS}	0.70	0.30	0.78	1.00	0.79
L_{TA}	0.71	0.47	0.95	0.79	1.00

Notes: L_{TLNS} is the output-specific Lerner index for total loans, L_{TSEC} the output-specific Lerner index for total securities, L_{WA} the weighted-average Lerner index, L_{KKS} the Lerner index of Koetter et al. (2012), and L_{TA} the Lerner index with total assets as the single aggregate output factor.

To further explore the relation between the five different Lerner indices, Table 3 displays the Spearman rank correlations between them. Again the results are consistent over the three subsamples. The highest sample correlation is found between L_{WA} and L_{TA}, which is at least 0.94, showing an almost perfect monotonic relation between these two Lerner indices. Given the large revenue share of total loans relative to total securities, it comes as no surprise that L_{WA} is more strongly correlated with L_{TLNS} ($>$ 0.73) than with L_{TSEC} ($>$ 0.45). The correlation between L_{WA} and L_{KKS} is above 0.7, which reflects a strong monotonic relation. Hence, although L_{KKS} underestimates banks' average degree of market power over the outputs, it is nevertheless strongly correlated with L_{WA}. This suggests that, if L_{KKS} is used as an explanatory variable in a regression, the sign of its coefficient – unlike its magnitude – might still be correct. We had already seen that the level of L_{TA} is similar to that of L_{WA}. Our correlation analysis further shows that L_{TA} also has a strong monotonic relation with L_{WA}.

4. Conclusions

In the analysis of multi-output firms' market power, it if often attractive to calculate a weighted-average Lerner index over the various outputs. Such a summary measure of market power may be conveniently used as an explanatory variable in a regression analysis to assess the impact of market power on any relevant economic variable. This study has proposed a weighted-average Lerner index that imposes relatively mild data requirements.

Multi-output measures of market power have become increasingly important in banking, as banks have been broadening their focus from interest-bearing activities to fee-based activities. The alternative Lerner index of Koetter et al. (2012) has recently gained popularity in the multi-output banking literature. We have compared our weighted-average Lerner index to the latter Lerner index, both theoretically and empirically. The theoretical part of this study has shown that the alternative Lerner index has no sensible economic interpretation and underestimates a multi-output bank's average degree of market power. Its use for policy decisions may have therefore serious adverse welfare implications. We therefore recommend against its use.

Our empirical analysis based on U.S. banking data during the 2000 – 2016 period confirms that the weighted-average Lerner index is much larger than the alternative Lerner index. Surprisingly, a simple Lerner index based on the assumption that total assets are the single aggregate output turns out to resemble the weighted-average Lerner index to a large extent.

Because our empirical findings are specific to the selected sample period, they do not imply that it is always safe to use the simple Lerner index instead of the more complicated weighted-average measure. If a summary measure of a multi-output firm's market power is required, the economically and statistically most sound strategy is to use the weighted-average Lerner index proposed in this study.

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APPENDIX

A. Call report data

Table A.1 explains how the Call Report Data have been used to define the variables used in the empirical part of this study.

Table A.1: Definition of variables

Variable	Series/Definition
total loans	RCFD1400
total securities	RCFD1754+RCFD1773
total assets	RCFD2170
purchased funds	RCON2604+RCFD2800+RCFD3548+RCFD3200+RCFD3190+RCFD2200-RCON2200
core deposits	RCON2200-RCON2604
# of full-time equivalent employees	RIAD4150
physical capital	RCFD2145
expenditures on purchased funds (interest)	RIAD4172+RIAD4180+RIADA517+ RIAD4185+RIAD4200
expenditures on core deposits (interest)	RIAD4170-RIADA517- RIAD4172
expenditures on labor services (salaries)	RIAD4135
expenditures on physical capital	RIAD4217
total costs	sum of all expenditures
price of purchased funds	(expenditures on purchased funds)/(purchased funds)
core deposit rate	(expenditures on core deposits)/(core deposits)
wage rate	(expenditures on labor services)/(# of full-time equivalent employees)
price of physical capital	(expenditures on physical capital)/(physical capital)
total interest and fee income on loans	RIAD4010
total interest income	RIAD4107
total non-interest income	RIAD4079
total operating income	total interest income + total non-interest income
average revenue of total loans	(total interest and fee income on loans)/(total loans)
average revenue of total securities	(operating income - total interest and fee income on loans)/(total securities)
average revenue of total loans + total securities	(operating income)/(total loans + total securities)
average revenue of total assets	(operating income)/(total assets)
is bank part of BHC?	RSSD9364
bank index	RSSD9050
time index	RSSD9999

Notes: This table explains how the variables in this study have been calculated from the data available in the Call Reports. The average revenue of total loans is used as the price proxy in L_{TLNS}, the average revenue of total securities is used as the price proxy in L_{TSEC}, the average revenue of total loans + total assets is used as the price proxy in L_{WA} and the average revenue of total assets is used as the price proxy in L_{KKS} and L_{TA}.