Supplementary Appendix to

Economies of Diversification in the US Credit Union Sector*

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Abstract

Significant scale economies have been recently cited to rationalize a dramatic growth in the US retail credit union sector over the past few decades. In this paper, we explore another plausible supply-side explanation for the growth of the industry, namely, economies of diversification. We focus on the fact that credit unions differ among themselves in the range of financial services they offer to their members. Since larger credit unions tend to offer a more diversified financial service menu than credit unions of a smaller size, the incentive to grow in size may be fueled not only by present scale economies but also by economies of diversification. This paper provides the first robust estimates of such economies of diversification for the credit union sector. We estimate a flexible semiparametric smooth coefficient quantile panel data model with correlated effects that is capable of accommodating a four-way heterogeneity among credit unions. Our results indicate the presence of non-negligible economies of diversification in the industry. We find that as many as 27–91% (depending on the type and the cost quantile) of diversified credit unions enjoy substantial economies of diversification; the cost of most remaining credit unions is invariant to the scope of services. We also find the overwhelming evidence of increasing returns to scale in the industry.

Keywords: correlated effects, credit union, diversification, economies of scope, returns to scale, semiparametric, varying coefficient, quantile regression

JEL Classification: C13, C14, D24, G21

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A Computation of $GED_{1\to 2,\tau}$ and $GED_{2\to 3,\tau}$

Since both $ED_{1\to 2}$ and $ED_{2\to 3}$ measures depend on the allocation [controlled by the choice of weights $(\varpi_1, \varpi_3, \varpi_4)$] of a diversified credit union's output quantities across more specialized production units, we employ a conservative approach to measuring economies of diversification by focusing on the *smallest* ED estimates in the data-defined observation-specific admissible regions defined by the diversified credit unions' output vectors. Essentially, for each credit-union-year, we perform a grid search of the lowest ED value across different combinations of (relevant) weights $(\varpi_1, \varpi_3, \varpi_4)$ yielding estimates that lie within the admissible region. The grid search is performed over the weights' permissible range between 0 and 1 at the 0.10 increments. The obtained smallest ED estimate is referred to as the measure of the credit union's "global" economies of diversification, i.e., GED.

To make matters more concrete, consider Table A.1, where we report the estimates of $ED_{1\to 2,0.50}$ for a hypothetical "median" Type 2 credit union in the middle of our sample period (the year of 2004) across different values of (ϖ_3, ϖ_4). The reported $ED_{1\to 2,0.50}$ estimates are constructed using the sample median values of all covariates appearing in the Type 2 credit union's cost function and the parameter estimates from our model (3.15) fitted for the 0.50 quantile of the credit union cost distribution. According to Table A.1, the $ED_{1\to 2,0.50}$ estimates for a median Type 2 credit union in 2004 vary quite significantly within the admissible region, from a low of 0.4849 to a high of 0.6328. Following our methodology, one would say that a median Type 2 credit union in 2004 is found to enjoy statistically significant "global" economies of diversification of the magnitude of 0.48, which implies that the integration of the issuance of real estate loans (y_1) with consumer loans and investments (y_3, y_4) yields a 48% reduction in this credit union's costs.

Tables A.2–A.4 report analogous estimates of economies of diversification for a hypothetical "median" Type 3 credit union in 2004 estimated at the conditional median of the cost distribution $(\tau = 0.50)$. Since the computation of $ED_{2\to 3,0.50}$ necessitates the allocation of three output quantities across more specialized credit unions, here we perform a 3-dimensional grid search over different combinations of $(\varpi_1, \varpi_3, \varpi_4)$ lying within the admissible region. As an example, Tables A.2–A.4 report the results for such a search over (ϖ_3, ϖ_4) for three fixed values of $\varpi_1 = \{0.20;\ 0.50;\ 0.80\}$. Depending on the value of ϖ_1, the smallest $ED_{2\to 3,0.50}$ estimates range from 0.4368 to 0.5450 and correspond to different combinations of the (ϖ_3, ϖ_4) weights. From these three tables, we conclude that a median Type 3 credit union in 2004 exhibits statistically significant $GED_{2\to 3,0.50} = 0.44$ at the conditional median of costs.

Our prior discussion has focused on the GED statistics computed at the sample median of the cost function covariates in 2004, where the latter is a somewhat arbitrarily chosen data point. In the paper, we therefore report $GED_{1\to 2,\tau}$ and $GED_{2\to 3,\tau}$ estimates obtained using actual data for the already diversified Type 2 and Type 3 credit unions, respectively.

Table A.1. Estimates of $ED_{1\to 2,0.5}$ for the "Median" Type 2 Credit Union in 2004

$\varpi_3 \backslash \varpi_4$	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	0.6328	0.5478	0.5357	0.5282	0.5227	0.5184	0.5148	0.5118	0.5091	0.5066	—
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	
0.10	0.5883	0.5560	0.5505	0.5471	0.5447	0.5428	0.5412	0.5399	0.5388	0.5377	—
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	
0.20	—	0.5506	0.5463	0.5437	0.5418	0.5403	0.5391	0.5381	0.5373	0.5365	—
		(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0004)	
0.30	—	0.5464	0.5428	0.5407	0.5391	0.5379	0.5369	0.5362	0.5355	0.5349	—
		(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0004)	
0.40	—	0.5431	0.5401	0.5382	0.5369	0.5359	0.5351	0.5345	0.5340	0.5336	—
		(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0005)	
0.50	—	0.5404	0.5379	0.5363	0.5352	0.5343	0.5337	0.5332	0.5329	0.5326	—
		(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0005)	(0.0006)	
0.60	—	0.5382	0.5361	0.5347	0.5338	0.5331	0.5326	0.5323	0.5320	0.5319	—
		(0.0003)	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0006)	(0.0007)	
0.70	—	0.5364	0.5346	0.5334	0.5326	0.5321	0.5317	0.5315	0.5314	0.5314	—
		(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0007)	(0.0009)	
0.80	—	0.5345	0.5330	0.5320	0.5314	0.5310	0.5307	0.5306	0.5307	0.5310	—
		(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0008)	(0.0008)	(0.0009)	(0.0010)	(0.0012)	
0.90	—	0.5313	0.5300	0.5293	0.5288	0.5286	0.5285	0.5286	0.5289	0.5295	0.5108
		(0.0013)	(0.0013)	(0.0013)	(0.0013)	(0.0014)	(0.0014)	(0.0015)	(0.0016)	(0.0019)	(0.0086)
1.00	—	0.4863	0.4854	0.4850	0.4849	0.4851	0.4856	0.4864	0.4877	0.4901	0.4867
		(0.0082)	(0.0083)	(0.0083)	(0.0084)	(0.0084)	(0.0085)	(0.0086)	(0.0088)	(0.0091)	(0.0192)

NOTES: Missing ED estimates lie outside the admissible region. Bootstrap standard errors are in parentheses.

Table A.2. Estimates of $ED_{2\to 3,0.5}$ for the "Median" Type 3 Credit Union in 2004 ($\varpi_1 = 0.20$)

$\varpi_3 \backslash \varpi_4$	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	—	0.4409	0.4398	0.4389	0.4383	0.4378	0.4375	0.4373	0.4372	0.4368	—
		(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0010)	(0.0011)	(0.0012)	(0.0014)	(0.0018)	
0.10	—	0.5574	0.5568	0.5563	0.5559	0.5556	0.5555	0.5554	0.5554	0.5553	—
		(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0010)	(0.0010)	(0.0011)	(0.0014)	
0.20	—	0.5569	0.5563	0.5558	0.5555	0.5552	0.5551	0.5551	0.5551	0.5551	—
		(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0010)	(0.0010)	(0.0011)	(0.0012)	(0.0015)	
0.30	—	0.5553	0.5548	0.5543	0.5540	0.5538	0.5537	0.5537	0.5538	0.5539	—
		(0.0009)	(0.0009)	(0.0009)	(0.0010)	(0.0010)	(0.0011)	(0.0011)	(0.0013)	(0.0016)	
0.40	—	0.5540	0.5534	0.5530	0.5527	0.5525	0.5524	0.5525	0.5526	0.5528	—
		(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0011)	(0.0012)	(0.0013)	(0.0014)	(0.0018)	
0.50	—	0.5530	0.5525	0.5521	0.5518	0.5516	0.5516	0.5517	0.5520	0.5523	—
		(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0013)	(0.0014)	(0.0016)	(0.0020)	—
0.60	—	0.5526	0.5521	0.5517	0.5515	0.5514	0.5514	0.5516	0.5519	0.5525	—
		(0.0012)	(0.0012)	(0.0013)	(0.0013)	(0.0014)	(0.0015)	(0.0016)	(0.0018)	(0.0023)	
0.70	—	0.5527	0.5523	0.5519	0.5517	0.5517	0.5518	0.5521	0.5526	0.5533	—
		(0.0015)	(0.0015)	(0.0016)	(0.0016)	(0.0017)	(0.0018)	(0.0020)	(0.0022)	(0.0028)	
0.80	—	0.5536	0.5532	0.5529	0.5528	0.5528	0.5530	0.5534	0.5541	0.5551	—
		(0.0020)	(0.0021)	(0.0021)	(0.0022)	(0.0023)	(0.0024)	(0.0026)	(0.0029)	(0.0035)	
0.90	—	0.5551	0.5548	0.5547	0.5546	0.5548	0.5552	0.5558	0.5568	0.5583	—
		(0.0036)	(0.0036)	(0.0037)	(0.0037)	(0.0038)	(0.0039)	(0.0041)	(0.0045)	(0.0052)	
1.00	—	—	—	—	—	—	—	—	—	—	—

NOTES: Missing *ED* estimates lie outside the admissible region. Bootstrap standard errors are in parentheses.

Table A.3. Estimates of $ED_{2\to 3,0.5}$ for the "Median" Type 3 Credit Union in 2004 ($\varpi_1 = 0.50$)

$\varpi_3 \backslash \varpi_4$	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	—	—	—	—	—	—	—	—	—	—	—
0.10	—	0.5450	0.5452	0.5451	0.5451	0.5452	0.5453	0.5456	0.5459	0.5463	—
		(0.0010)	(0.0010)	(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0013)	(0.0014)	(0.0018)	
0.20	—	0.5472	0.5474	0.5474	0.5474	0.5475	0.5476	0.5479	0.5483	0.5487	—
		(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0013)	(0.0015)	(0.0019)	
0.30	—	0.5473	0.5475	0.5475	0.5475	0.5476	0.5478	0.5482	0.5486	0.5492	—
		(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0012)	(0.0013)	(0.0014)	(0.0016)	(0.0020)	
0.40	—	0.5472	0.5474	0.5475	0.5475	0.5477	0.5479	0.5483	0.5488	0.5495	—
		(0.0012)	(0.0012)	(0.0012)	(0.0013)	(0.0013)	(0.0014)	(0.0015)	(0.0017)	(0.0022)	
0.50	—	0.5474	0.5477	0.5477	0.5478	0.5480	0.5483	0.5487	0.5493	0.5502	—
		(0.0013)	(0.0013)	(0.0014)	(0.0014)	(0.0015)	(0.0015)	(0.0017)	(0.0019)	(0.0024)	
0.60	—	0.5481	0.5484	0.5485	0.5486	0.5489	0.5492	0.5497	0.5504	0.5514	—
		(0.0015)	(0.0015)	(0.0015)	(0.0016)	(0.0016)	(0.0017)	(0.0019)	(0.0021)	(0.0027)	
0.70	—	0.5494	0.5498	0.5499	0.5501	0.5504	0.5508	0.5514	0.5522	0.5534	—
		(0.0017)	(0.0018)	(0.0018)	(0.0018)	(0.0019)	(0.0020)	(0.0020)	(0.0025)	(0.0031)	
0.80	—	0.5517	0.5521	0.5523	0.5525	0.5529	0.5534	0.5541	0.5551	0.5566	—
		(0.0023)	(0.0023)	(0.0024)	(0.0024)	(0.0024)	(0.0026)	(0.0027)	(0.0030)	(0.0037)	
0.90	—	0.5551	0.5556	0.5559	0.5563	0.5568	0.5574	0.5583	0.5596	0.5616	—
		(0.0038)	(0.0038)	(0.0038)	(0.0038)	(0.0039)	(0.0040)	(0.0040)	(0.0045)	(0.0053)	
1.00	—	—	—	—	—	—	—	—	—	—	—

NOTES: Missing ED estimates lie outside the admissible region. Bootstrap standard errors are in parentheses.

Table A.4. Estimates of $ED_{2\to3,0.5}$ for the "Median" Type 3 Credit Union in 2004 ($\varpi_1 = 0.80$)

$\varpi_3 \backslash \varpi_4$	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	—	—	—	—	—	—	—	—	—	—	—
0.10	—	0.5394	0.5401	0.5405	0.5408	0.5411	0.5416	0.5422	0.5430	0.5441	—
		(0.0019)	(0.0019)	(0.0019)	(0.0020)	(0.0020)	(0.0021)	(0.0023)	(0.0025)	(0.0030)	
0.20	—	0.5435	0.5442	0.5445	0.5448	0.5452	0.5457	0.5464	0.5472	0.5484	—
		(0.0019)	(0.0019)	(0.0020)	(0.0020)	(0.0021)	(0.0021)	(0.0023)	(0.0025)	(0.0031)	
0.30	—	0.5449	0.5456	0.5460	0.5463	0.5467	0.5472	0.5479	0.5488	0.5501	—
		(0.0020)	(0.0020)	(0.0020)	(0.0021)	(0.0021)	(0.0022)	(0.0024)	(0.0026)	(0.0032)	
0.40	—	0.5460	0.5468	0.5471	0.5475	0.5480	0.5485	0.5492	0.5502	0.5516	—
		(0.0021)	(0.0021)	(0.0021)	(0.0022)	(0.0022)	(0.0023)	(0.0025)	(0.0027)	(0.0033)	
0.50	—	0.5474	0.5482	0.5486	0.5490	0.5495	0.5501	0.5509	0.5519	0.5534	—
		(0.0022)	(0.0022)	(0.0022)	(0.0023)	(0.0023)	(0.0024)	(0.0026)	(0.0028)	(0.0034)	
0.60	—	0.5494	0.5502	0.5507	0.5511	0.5516	0.5523	0.5531	0.5543	0.5559	—
		(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0025)	(0.0026)	(0.0027)	(0.0030)	(0.0036)	
0.70	—	0.5523	0.5531	0.5536	0.5541	0.5546	0.5553	0.5563	0.5575	0.5594	—
		(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0028)	(0.0030)	(0.0033)	(0.0039)	
0.80	—	0.5564	0.5573	0.5578	0.5584	0.5590	0.5598	0.5608	0.5622	0.5643	—
		(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0033)	(0.0035)	(0.0037)	(0.0044)	
0.90	—	0.5629	0.5638	0.5644	0.5651	0.5658	0.5667	0.5679	0.5696	0.5721	—
		(0.0046)	(0.0045)	(0.0045)	(0.0045)	(0.0045)	(0.0046)	(0.0047)	(0.0050)	(0.0056)	
1.00	—	0.5607	0.5622	0.5634	0.5647	0.5663	0.5682	0.5706	0.5740	0.5794	—
		(0.0316)	(0.0314)	(0.0313)	(0.0312)	(0.0310)	(0.0309)	(0.0308)	(0.0308)	(0.0309)	

NOTES: Missing *ED* estimates lie outside the admissible region. Bootstrap standard errors are in parentheses.

Table B.1. Economies of Diversification Estimates based on Alternative Models

Model	*Point Estimates* 1st Qu.	Median	Mean	3rd Qu.	*Categories, %* ED<0	ED=0	ED>0
			Type 1 → Type 2				
Par. $\mathbb{Q}_{0.25}$	0.540	0.567	0.571	0.594	0.01	0.01	99.98
Par. $\mathbb{Q}_{0.50}$	0.523	0.548	0.557	0.584	0.02	0.00	99.98
Par. $\mathbb{Q}_{0.75}$	0.502	0.525	0.535	0.563	0.02	0.01	99.97
SPSC Mean	0.424	0.468	0.416	0.487	0.53	11.13	88.34
			Type 2 → Type 3				
Par. $\mathbb{Q}_{0.25}$	0.548	0.605	0.603	0.649	0.48	0.09	99.43
Par. $\mathbb{Q}_{0.50}$	0.423	0.584	0.554	0.646	0.64	0.25	99.11
Par. $\mathbb{Q}_{0.75}$	0.290	0.551	0.491	0.625	0.85	14.21	84.94
SPSC Mean	0.147	0.306	0.198	0.391	1.44	75.50	23.06

NOTE: Percentage points may not sum up to a hundred due to rounding.

B Alternative (Less Flexible) Specifications

To investigate the consequences of overlooking the heterogeneity across credit unions of different sizes as well as the heterogeneity across different (conditional) quantiles of the cost distribution, we also consider two alternative, more restrictive, specifications of the credit union cost relationship. Specifically, in addition to our flexible semiparametric quantile regression model (3.8), we also estimate:

(a) A *parametric* quantile panel data model with correlated effects. This is a parametric counterpart of our model (3.8), where all parameter functions $\mathscr{B}_{r,\tau}(\cdot)$ are restricted to be fixed constants for all r and τ. Comparing the results from this auxiliary model to those from our preferred specification in (3.8) enables us to analyze the sensitivity of our findings to accounting for heterogeneity across credit unions of different asset size. Model *(a)* is estimated as a standard pooled quantile regression model.

(b) A semiparametric smooth coefficient *conditional mean* panel data model with correlated effects. This is a conditional mean counterpart of our preferred model, where, unlike in (3.8), we fit the credit union cost function at its conditional mean for each service menu type r. The model is given in (3.17) and is a standard pooled smooth coefficient model of Cai et al. (2000) and Li et al. (2002). Comparing the estimates from model *(b)* to those from our preferred specification in (3.8) lets us assess the sensitivity of our findings to accounting for heterogeneity across quantiles of the credit union cost distribution.

Table B.1 presents the estimates of economies of diversification from the two alternative models. The results are directly comparable to those reported in Table 2 based on our preferred semiparametric quantile model.

We find that the parametric quantile regression model tends to dramatically *over*estimate GED in both the "Type 1 → Type 2" and "Type 2 → Type 3" directions of diversification. Consequently, larger fractions of Type 2 and 3 credit unions are said to exhibit statistically significant "global" economies of diversification across all quantiles of the cost distribution. For instance, based on the estimates of $GED_{2\to 3,0.50}$ from a parametric model, the integration of business loans (y_2) with the mix of real estate and consumer loans and investments (y_1, y_3, y_4) is estimated, on average, to reduce credit union costs by 55% whereas the corresponding figure from our preferred semiparametric

Table B.2. Returns to Scale for Estimates based on Alternative Models

Model	*Point Estimates* 1st Qu.	Median	Mean	3rd Qu.	*Categories, %* DRS	CRS	IRS
			Type 1 Credit Unions				
Par. $\mathbb{Q}_{0.25}$	1.611	1.696	1.706	1.792	0.00	0.02	99.98
Par. $\mathbb{Q}_{0.50}$	1.620	1.741	1.758	1.870	0.00	0.06	99.94
Par. $\mathbb{Q}_{0.75}$	1.856	2.036	2.075	2.236	0.00	0.13	99.87
SPSC Mean	1.943	2.276	2.465	2.696	0.00	0.36	99.64
			Type 2 Credit Unions				
Par. $\mathbb{Q}_{0.25}$	1.282	1.319	1.319	1.355	0.00	0.00	100.00
Par. $\mathbb{Q}_{0.50}$	1.246	1.290	1.290	1.332	0.00	0.00	100.00
Par. $\mathbb{Q}_{0.75}$	1.218	1.267	1.266	1.313	0.04	1.89	98.07
SPSC Mean	1.507	1.722	1.783	1.974	0.00	0.07	99.93
			Type 3 Credit Unions				
Par. $\mathbb{Q}_{0.25}$	1.170	1.187	1.185	1.202	0.00	0.05	99.95
Par. $\mathbb{Q}_{0.50}$	1.178	1.187	1.187	1.196	0.00	0.00	100.00
Par. $\mathbb{Q}_{0.75}$	1.144	1.156	1.157	1.168	0.34	14.07	85.59
SPSC Mean	1.451	1.524	1.532	1.596	0.00	0.05	99.95

NOTE: Percentage points may not sum up to a hundred due to rounding.

model is modestly smaller by a third (36% only). Such findings support our view of the likely inappropriateness of modeling a common cost relationship across credit unions of all sizes.

The results from the semiparametric mean regression model expectedly point to its general incapacity of adequately capturing variation across quantiles of the cost distribution. For instance, the median $ED_{2\to 3}$ estimate from this model (0.31) lies well outside the median interval of the same statistic for 0.25th–0.75th percentiles of the conditional cost distribution based on our semiparametric quantile model [0.37; 0.47]. Subsequently, the mean regression model makes a weaker case in support of statistically significant economies of diversification among Type 3 credit unions.

The estimates of returns to scale from both alternative models are reported in Table B.2. Both models seems to universally *under*estimate the magnitude of scale economies. Qualitatively, the results are however quite similar to those from our preferred semiparametric quantile model indicating that the overwhelming majority of credit unions enjoy statistically significant IRS.

References

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