

Subsidiary vs. Branch Banks: Are Their Balance Sheet Compositions Converging?

Claudia CURI

Faculty of Economics and Management, Free University of Bozen-Bolzano, E-mail: claudia.curi@unibz.it

Abstract Presumably, foreign banks open subsidiaries and branches to perform different tasks. This paper studies the balance sheet composition of subsidiary and branch banks, testing for differences across groups and periods. We use as laboratory of analysis the Luxembourg banking sector, which is composed mainly by foreign banks. Non-parametric methods yield several findings. First, specialisation and heterogeneity vary across years as well as across different market segments. Second, comparing subsidiaries and branches, estimated distributions across banks have been relatively similar for Interbank Loans but have become rather different for Interbank Deposits. For Customer Loans and Customer Deposits, the differences across groups are generally greater, especially for Customer Deposits. Third, in 2009 the financial crisis generally sharpened the differences between subsidiaries and branches for all variables considered. Fourth, long-term changes between 1995 and 2007 appeared to be (temporarily?) reversed between 2007 and 2009 by the financial crisis.

Key words Foreign bank, balance sheet compositions, convergence, kernel density estimator, bootstrap

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1. Introduction

Business models in foreign banks are crucial to understand the strategy adopted by large and complex banks operating in several countries. However, the attention devoted to this topic is limited to few empirical cases (i.e.; Curi *et al.*, 2015). This paper aims at addressing several questions on business model of foreign banks. Do foreign banks specialize in different business lines? Has the pattern of specialization changed over time? Does the specialization pattern differ between foreign bank subsidiaries and branches? If so, has this difference narrowed or diverged over time? To address these questions, we focus on the main balance sheet items, expressing them as a share of total assets and estimating the distribution of this share across banks¹. Since heterogeneity in the banking population can lead to asymmetric distributions, possibly with multiple peaks, standard statistical tools can be misleading in this context. Therefore, we use non-parametric density estimators (Silverman, 1986, DiNardo and Tobias, 2001) and related bootstrap-based tests (Li, 1996, 1999) to compare distributions across time or across sub-groups (Simar and Zelenyuk, 2006). Borrowing from the applied literature on economic growth, we also test for convergence or divergence, applying the approach in Quah (1996) and its recent extensions. As laboratory of analysis, we use data from Luxembourg banking sector as composed mainly by foreign banks.

The contribution of this paper is threefold. First, although foreign banks are qualified as universal banks, their role within international banking groups might bias any estimation related to performance measurement. Second, the different legal forms (subsidiary or branch) imply different regulatory regimes, which might be a separate source of bias in comparing performance.

¹ For instance there are some papers dealing with the harmonization of banking business models to better control exposure to risk (Damankah *et al.*, 2014)

2. The statistical framework

2.1. Density estimation

Let x be a variable of interest (e.g., deposits or loans), whose (marginal) distribution at a point x^0 is characterized by the probability density function $f(x^0)$, and let $\{x_i: i=1, \dots, n\}$ be a random sample of realizations of this random variable across the sample of n banks. To estimate this density f we can use the Rosenblatt (1956) kernel density estimator,

$$\hat{f}_h(x^0) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x_i - x^0}{h}\right) \quad (1)$$

Where x_i ($i=1, \dots, n$) are the data points, x^0 is a point at which we want to estimate the density, h is a suitable bandwidth, and $K(\cdot)$ is an appropriate kernel function.

The choice of the kernel function is generally not crucial in estimation, and the estimator is consistent and asymptotically normal as long as standard regularity conditions are satisfied. We follow common practice and use the Gaussian kernel for $K(\cdot)$. While consistency and asymptotic normality of the Kernel Density Estimator is ensured for any $h \rightarrow 0$, with $nh \rightarrow \infty$ when $n \rightarrow \infty$, choosing an optimal h is critical to achieve good fit and we adopt the plug-in method of Sheather and Jones (1991), which is an improved version of the Park and Marron (1990) bandwidth selector.

2.2. Testing for equality of distributions

The literature on economic growth and convergence includes many alternative approaches. The traditional framework focuses on average behaviour², but Quah (1996) was among the first to analyse convergence dynamics in terms of distributions. This section applies these ideas, with some modifications. In his seminal work, Quah (1996) built on the ideas in Atkinson (1970) and Shorrocks (1978) by noting that convergence could be identified as a progressive movement from a multi-mode distribution towards a unimodal distribution. Distributional convergence or divergence, however, can occur even if there is no change in modes, but substantial change in some moments of distributions. Here, we extend a more generalized concept of convergence (or catch-up), similar to that in Kumar and Russell (2002), Henderson and Russell (2005), and more recently used by Henderson and Zelenyuk (2007) and Badunenko, Henderson and Zelenyuk (2008). In particular, we address the following question: “Do the individual distributions of different subgroups become more similar (or more different) over time?”

A natural way to investigate this question is to test for the equality of distributions of subgroups in a sample. Formally, suppose we have two random sub-samples, $\{x_{A,i} : i=1, \dots, n_A\}$ and $\{x_{Z,i} : i=1, \dots, n_Z\}$ coming from potentially different distributions characterized at a point x^0 by the density functions $f_A(x^0)$ and $f_Z(x^0)$, respectively. We want to test whether these distributions are the same, that is, we can formulate our null and alternative hypotheses as:

$$H_0 : f_A(x^0) = f_Z(x^0), \forall x^0 \text{ in the support of the random variables } x_j \ (j = A, Z)$$

$$H_1 : f_A(x^0) \neq f_Z(x^0), \text{ on a set of positive measure.}$$

To confront these hypotheses, we can employ the test statistic proposed by Li (1996, 1999),

$$\hat{J} = n_A h^{1/2} \hat{ISD}_{n_A n_Z h}^0 / \sqrt{\hat{\sigma}_{n_A n_Z h}^2} \xrightarrow{d(\text{under } H_0)} N(0, 1) \quad (2)$$

Where $\hat{ISD}_{n_A n_Z h}^0$ represents the Integrated Squared Difference given by:

² See Baumol (1986), Mankiw *et al.* (1992), Sala-i-Martin (2006) and references therein.

$$\begin{aligned} \hat{ISD}_{n_A n_Z h}^0 &= \frac{1}{n_A^2 h} \sum_{i=1}^{n_A} \sum_{k=1}^{n_A} K\left(\frac{x_{A,i} - x_{A,k}}{h}\right) + \frac{1}{n_Z^2 h} \sum_{i=1}^{n_Z} \sum_{k=1}^{n_Z} K\left(\frac{x_{Z,i} - x_{Z,k}}{h}\right) \\ &- \frac{1}{n_A n_Z h} \sum_{i=1}^{n_A} \sum_{k=1}^{n_Z} K\left(\frac{x_{A,i} - x_{Z,k}}{h}\right) - \frac{1}{n_Z n_A h} \sum_{i=1}^{n_Z} \sum_{k=1}^{n_A} K\left(\frac{x_{Z,i} - x_{A,k}}{h}\right) \end{aligned} \quad (3)$$

and where the variance is estimated as:

$$\begin{aligned} \hat{\sigma}_{n_A n_Z h}^2 &:= 2 \left\{ \frac{1}{n_A^2 h} \sum_{i=1}^{n_A} \sum_{k=1}^{n_A} K\left(\frac{x_{A,i} - x_{A,k}}{h}\right) + \frac{\lambda_n^2}{n_Z^2} \sum_{i=1}^{n_Z} \sum_{k=1}^{n_Z} K\left(\frac{x_{Z,i} - x_{Z,k}}{h}\right) \right. \\ &+ \left. \frac{\lambda_n}{n_A n_Z h} \sum_{i=1}^{n_A} \sum_{k=1}^{n_Z} K\left(\frac{x_{A,i} - x_{Z,k}}{h}\right) + \frac{\lambda_n}{n_Z n_A h} \sum_{i=1}^{n_Z} \sum_{k=1}^{n_A} K\left(\frac{x_{Z,i} - x_{A,k}}{h}\right) \right\} \int K^2(z) dz \end{aligned} \quad (4)$$

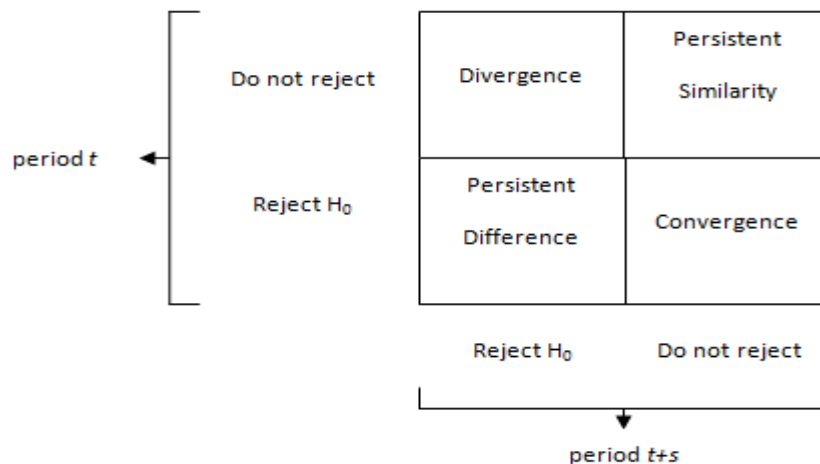
with $\lambda_n = \frac{n_A}{n_Z}$, $n = n_A + n_Z$.

Intuitively, the Li-test detects the overlap between the masses of the distributions considered and therefore it can detect differences in all of the moments simultaneously. Conveniently, the test statistic has an asymptotically standard normal distribution. More accurate inference can be achieved by using the consistent bootstrap procedure suggested by Li (1999). Specifically, we estimate the bootstrap-based *p*-value as:

$$\text{bootstrap } p\text{-value} = \frac{1}{B} \sum_{b=1}^B \mathfrak{I}(\hat{J}^b > \hat{J})$$

where $\mathfrak{I}(\hat{J}^b > \hat{J})$ is an indicator function yielding 1 if $(\hat{J}^b > \hat{J})$ is true and 0 otherwise, *B* is the number of bootstrap replications, \hat{J} is the Li (1996) test statistic given above, and \hat{J}^b is its bootstrap analogue. A consistent bootstrap involves re-sampling under the null hypothesis by drawing randomly from the largest group in the sample using the empirical distribution function (see Li, 1999 for details). For a given random variable of interest (e.g., deposits), we use this Li (1996) statistic to test the equality of distributions for different groups (e.g., A and Z) at time *t* and then at time *t* + *s*. The resulting *p*-values from these two tests can suggest four basic cases (see Figure 1): Convergence, Divergence, Persistent Similarity and Persistent Difference.

Figure 1. Taxonomy of Distribution Dynamics



“Convergence” means that statistical differences between distributions were significant at time t and became insignificant at time $t+s$ ³. “Divergence” means that statistical differences between distributions were not significant at time t and became significant at time $t+s$. Two additional cases appear when the test gives the same result for different times. If differences between distributions were not significant at time t and remained insignificant at time $t+s$ then we call this “Persistent Similarity.” If differences between distributions were significant at time t and remained significant at time $t+s$ then we call this “Persistent Difference.” In the latter case, the nature of the difference may have changed, so visual inspection of the estimated densities remains important, to compare the shape of the distributions.

In addition, for all four cases described above, changes in the p -values may be informative. For example, if the p -value drops from 90% at time t to 15% at time $t+s$, then we cannot reject the hypothesis of equality of distributions in either period and conclude there is “Persistent Similarity.” However, the drop in p -value also suggests evidence that similarity has lessened, possibly leading to divergence. Conversely, an increase in p -value over time is suggestive of increased similarity and therefore possible convergence. To ensure robust inference, whenever the p -value is relatively close to the conventional significance level (e.g., 5%) we repeat the bootstrap with a substantially larger number of replications to obtain higher accuracy.

3. Empirical results

In the following, we analyse patterns of specialization within the Luxembourg banking sector. First, we estimate the distribution of variables of interest across all banks (as well as separately for subsidiaries and branches). To control for differences in bank size, we normalise the data for each institution by the size of its balance sheet. For our purpose - that is a comparison of balance sheet items distributions in different points in time- the relative balance sheet item transformation is purely a scale transformation which does not affect the shape of the density distribution of the original data. To estimate the distribution across banks, we use the Rosenblatt (1956) non-parametric kernel density estimator (KDE), which is particularly useful to capture some features of the data, such as skewness and multiple modes, which might reveal important economic information. Second, we compare the estimated densities at different points in time. Following the distributional convergence analysis of Quah (1996) and its recent extensions, we establish evidence of catch-up, convergence or divergence in different Luxembourg banking activities, using the Li (1996) bootstrap-based test. Banks maximize expected profits through a sequence of decisions determining the size and composition of their assets and liabilities. These decisions might involve shifting funds from one asset to another or from one loan category to another, possibly in response to changes in the composition of liabilities. Bank decisions are also subject to regulatory constraints (such as reserve ratios and capital requirements) and reflect changes in the intensity of competition. Thus, to survive in the long run, banks are continually adjusting balance sheet structure and their mix of activities. We focus our analysis on the following five balance sheet items:

- Interbank loans and interbank deposits: these include activity within the parent banking group as well as with other banks.
- Customer loans and Customer deposits: these include activities with non-financial corporations as well as households.
- Securities held: these include government securities, fixed-income securities, shares, participations and other variable-income securities.

Each of these six variables is expressed as a share of total assets⁴ to control for differences in bank size. We first analyze how of each variable is distributed across banks and how this distribution changed from 1995 to 2007. We then focus on the recent financial crisis and compare the distributions in 2007 and 2009. The analysis is carried out for the whole sample of banks, and then separately for subsidiaries and branches. In 1995 the sample included 220 branches and 113 subsidiaries. These numbers became 156 and

³ The most used approach to test convergence is the one proposed by Barro and Sala-i-Martin (1992): For instance, it has been use by Tibulca (2014) to test the fiscal convergence among the EU Member States.

⁴ Deposits are normalised by total liabilities, but these are identical with total assets in what follows.

113 in 2007 and 148 and 110 in 2009. Table 1 reports the standard descriptive statistics for the normalised variables for the three years of interest. The *p*-values for the Jarque-Bera test (in parentheses) indicate substantial divergence from the standard assumption of a normal distribution.

Table 1. Descriptive statistics 1995, 2007 and 2009

Activity	Year	Mean	St. dev.	Skewness	Kurtosis	Normality (Jarque-Bera)	p-value
Interbank loans (% total assets)	1995	0.620	0.218	-0.319	2.347	7.248	(0.027)
	2007	0.582	0.261	-0.267	1.952	8.155	(0.017)
	2009	0.298	0.184	0.491	3.071	5.761	(0.056)
Interbank deposits (% total assets)	1995	0.448	0.285	0.039	1.706	14.592	(0.001)
	2007	0.398	0.325	0.280	1.539	14.220	(0.001)
	2009	0.389	0.324	0.348	1.594	15.294	(0.000)
Customer loans (% total assets)	1995	0.187	0.182	1.566	5.458	130.697	(0.000)
	2007	0.203	0.198	1.238	3.595	35.625	(0.000)
	2009	0.098	0.118	1.837	6.759	162.196	(0.000)
Customer deposits (% total assets)	1995	0.433	0.283	0.099	1.810	12.672	(0.002)
	2007	0.477	0.312	-0.098	1.606	11.593	(0.003)
	2009	0.475	0.315	-0.145	1.575	13.230	(0.001)
Securities held (% total assets)	1995	0.147	0.166	1.317	4.067	66.761	(0.000)
	2007	0.157	0.216	1.57	4.641	68.694	(0.000)
	2009	0.104	0.172	2.077	7.12	201.258	(0.000)

The estimated distributions presented below can be interpreted in terms of specialization or diversification within the industry. If banks are specialized in a given activity, one would expect the estimated distribution to be concentrated at (or near) a particular level of activity represented by certain variable and skewed to the right if this activity represents an important share of the balance sheet. If the distribution is skewed to the left, then most banks devote little resources to this activity; the industry is still specialized, but specialized away from this activity. If the distribution is fairly flat (high dispersion, no clear peak), e.g., as a uniform distribution or a bell-shaped with very high variance, then the industry as a whole is relatively diversified, with some banks specializing in the given activity (right tail) others specializing away from it (left tail) and still others located in the middle ground. A final, more surprising form may appear with two peaks (left and right) and a valley between. This means that banks tend to either specialize in the given activity or specialize away from it, with few occupying the intermediate positions. The aggregate picture may appear to be one of diversification, but in reality some banks are very dependent on the given

activity while others are not exposed to it at all. Because the kernel density estimator involves some smoothing of the data, the plotted distributions may exceed unity or fall in negative territory, which makes no sense from an economic point of view. It would have been possible to cut off these parts of the distribution and reallocate them uniformly between zero and one, but we preferred to present the raw estimator as it is unlikely to be misleading once this warning is kept in mind. Table 2 reports the *p*-values from the Li (1996) test of the hypothesis of equal distributions (across periods or across groups). These will be referred to in the text that follows.

Table 2. Li (1996) test of equal distributions (*p*-values) across groups and across periods

Period	Activities				
	Interbank Loans	Interbank Deposits	Customer Loans	Customer Deposits	Securities
Branches and Subsidiaries combined					
1995-2007	0.044	0.002	0.223	0.235	0.044
2007-2009	0.804	0.662	0.044	0.591	0.018
Within group analysis: Subsidiaries					
1995-2007	0.033	0.012	0.216	0.012	0.008
2007-2009	0.033	0.000	0.192	0.56	0.471
Within group analysis: Branches					
1995-2007	0.733	0.847	0.316	0.963	0.905
2007-2009	0.763	0.538	0.574	0.345	0.000
Between group analysis: Branches vs. Subsidiaries					
1995	0.126	0.905	0.000	0.013	0.012
2007	0.184	0.005	0.037	0.019	0.949
	persistent similarity	divergence	persistent difference	persistent difference	convergence
2009	0.003	0.001	0.018	0.009	0.000
	divergence	divergence	persistent difference	persistent difference	divergence

3.1. Interbank loans: Changes in specialization

Figure 2 reports the share of interbank loans in total assets across all banks (subsidiary and branch banks). In 1995, most banks appear to be active in interbank lending (the mode is near 80%), although there are two minor concentrations in the middle range with a relatively lower share of interbank loans in total assets.

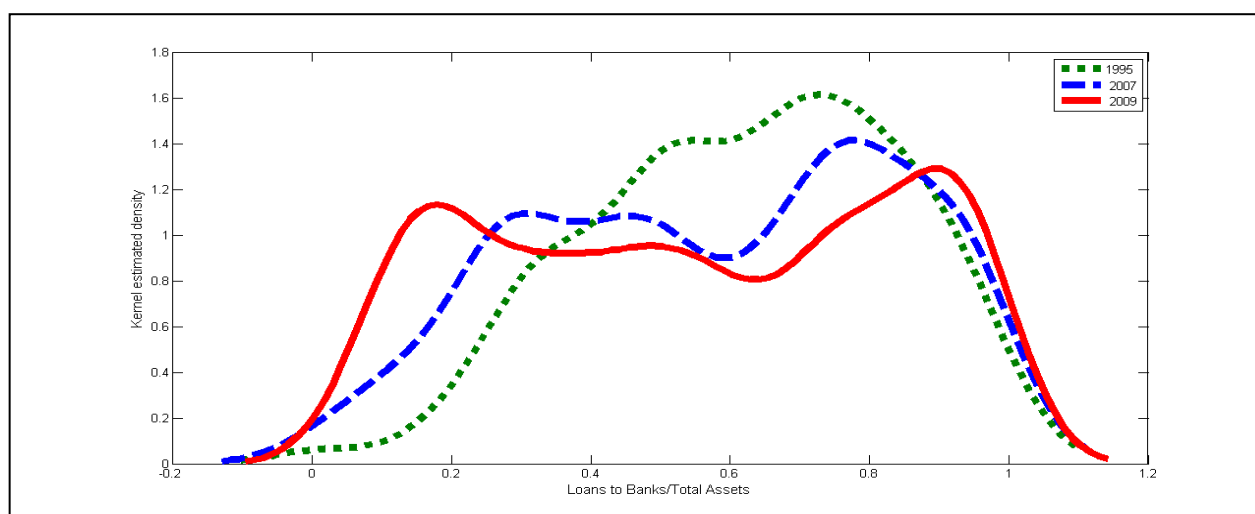


Figure 2: All banks -Ratio of interbank loans to total assets

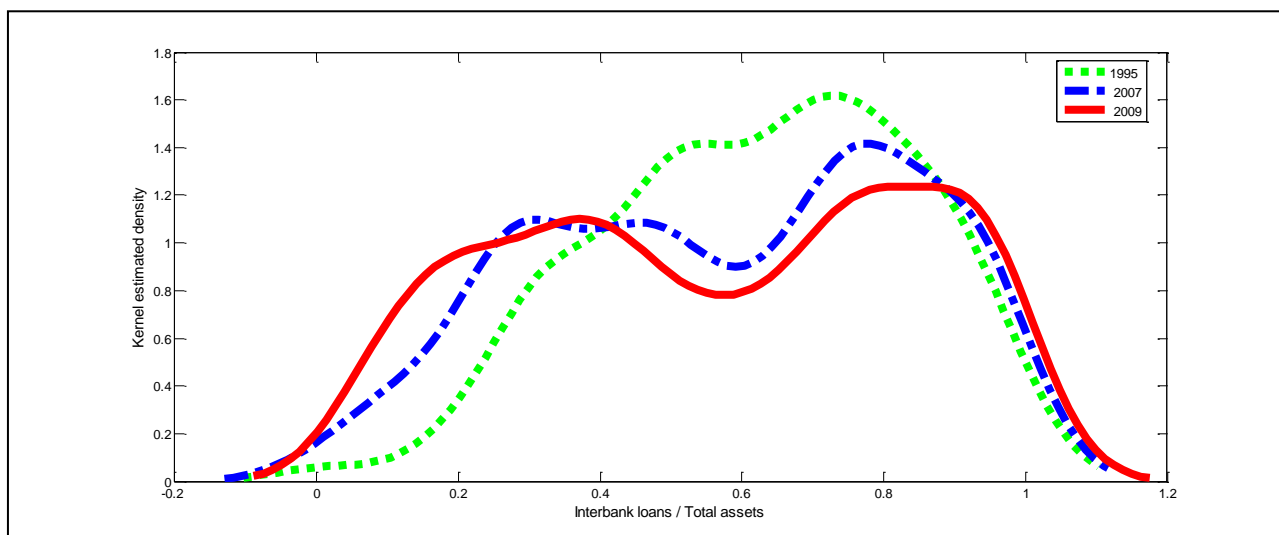
Source: Own calculations

By the end of 2007, the distribution has become notably flatter (increase in diversification) with more banks moving towards lower levels of interbank loans (in the range between 20% and 50% of total assets). This change registers as statistically significant (p -value 0.044, see Table 3). By the end of 2009, heterogeneity among banks deepened, as separate peaks appear at both the left and right extremes of the distribution. This bimodal distribution suggests that many banks decided to specialize strongly in interbank lending while others decided to specialize away from this activity. However, there is no statistically significant difference compared to the estimated distribution in 2007 (p -value 0.804).

Within-group analysis

The emergence of a bimodal shape can be better understood if the share of interbank deposits in the balance sheet is analyzed separately for subsidiaries and branches. Figure 2a depicts the distribution of this variable among subsidiaries only, taking the same three points in time. Compared to the previous graph (which also included branches) the distribution appears to be more clearly unimodal in 1995 and more clearly flatter in 2007 (the null hypothesis of equal distributions in these two periods is rejected at the 1% level). This trend continued in 2009, with further flattening suggesting that the distribution became more uniform (less specialization or more diversification). Focussing on subsidiaries only, there are statistically significant differences between 2009 and 2007 (p -value 0.000).

Figure 2a: Subsidiaries - Ratio of interbank loans to total assets.

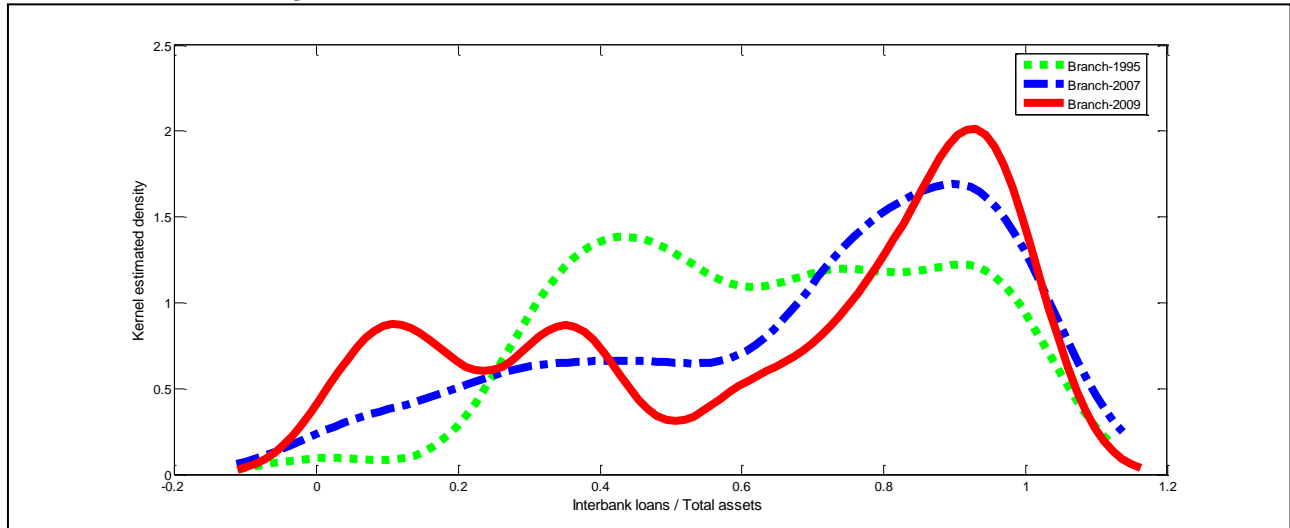


Source: Own calculations

Figure 2b reports the same distribution but only for branches. In this case, the distribution became more skewed to the right between 1995 and 2007, suggesting most branches increased their specialization in interbank loans (contrary to the case for subsidiaries). This may reflect the considerable decrease in the number of branches due to the consolidation process and/or bank closures. Apparently many of the branches that disappeared had a more diversified production mix, while those already active in interbank lending may have become more specialized in this activity. In so far as some of the branches became subsidiaries, this may have contributed to the flattening of the distribution in Figure 11a. In 2009, the mode at the right became more peaked, but some of the mass moved from the centre of the distribution to the left. This suggests that the emerging bi-modality in Figure 11 was mostly due to increasing specialization among branches (towards and away from interbank loans). However, for branches (unlike subsidiaries) there were no statistically significant differences across time (p -values of 0.733 in 2007 and 0.763 in 2009).

In summary, between 1995 and 2007 subsidiaries appear to have become more diversified in interbank loans, while branches became more specialized. This is consistent with the conjecture that most branches specialise in interbank lending while subsidiaries have progressively turned to other activities.

Figure 2b: Branches - Ratio of interbank loans to total assets



Source: Own calculations

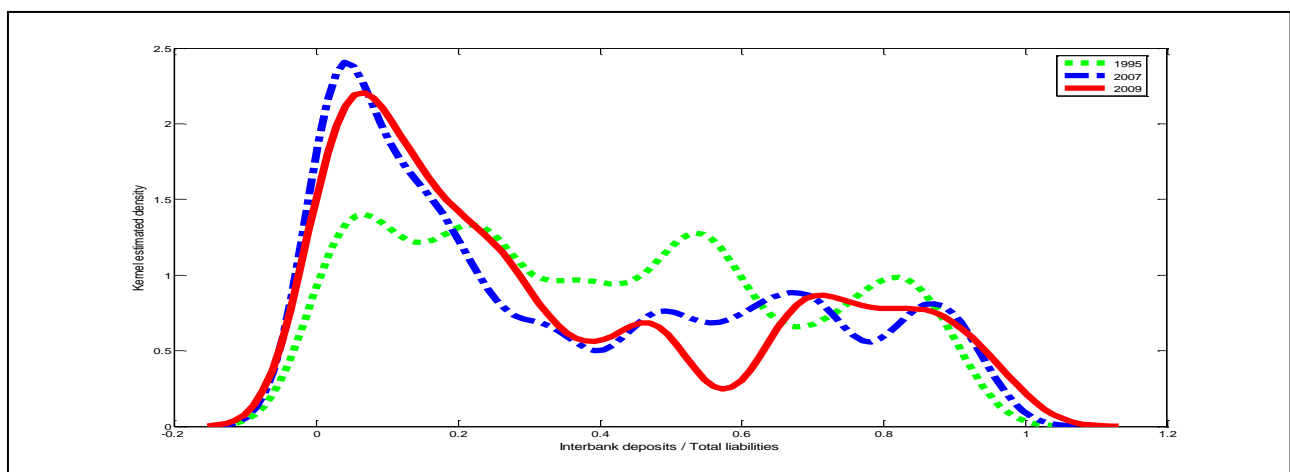
Between-group analysis

Comparing the distributions for branches and for subsidiaries there is limited evidence of persistent similarity. Table 2 reports p -values of 0.126 in 1995 and 0.184 in 2007. However, significant differences appeared during the financial crisis (p -value of 0.003 in 2009). This provides formal confirmation that recent developments took opposite directions for branches and subsidiaries.

3.2 Interbank deposits: Changes in specialization

The distribution of interbank deposits (Figure 3) contrasts with the distribution of interbank loans discussed previously. First, the distribution went from relatively flat to relatively concentrate over time. Second, low shares increasingly dominate the distribution (for interbank loans instead, the higher peak was always at the right). Third, the more complicated multi-modal shape suggests that banks may be more heterogeneous in interbank deposits than in interbank loans. Between 1995 and 2007, the distribution went from a fairly flat (diversified) shape to one that is clearly peaked at the left. This means that many banks saw a decline in the share of interbank deposits in total liabilities. In 2009, the change is marginal, but interbank deposits may have slightly gained in importance: mass around 80% increased and banks that had previously specialised away from interbank deposits saw a slight increase in their share in total liabilities (rightward shift of the left peak).

Figure 3: All banks - Ratio of interbank deposits to total liabilities



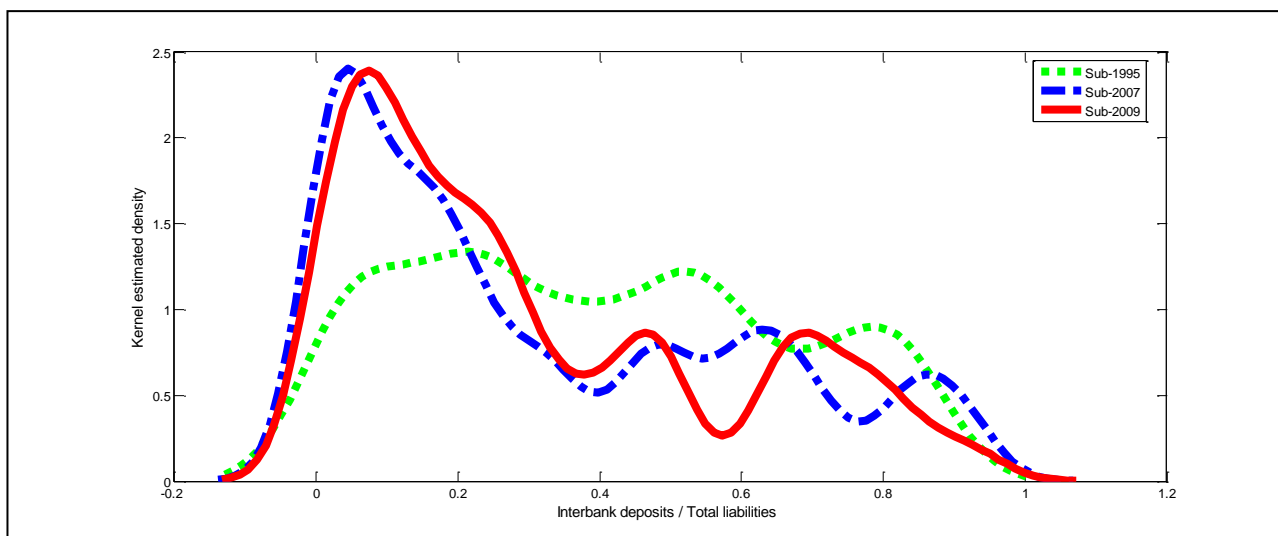
Source: Own calculations

The Li (1996) test rejects the hypothesis of equal distributions in 1995 and 2007, (p -value 0.002), but does not detect significant changes between 2007 and 2009 (p -value 0.669). The data aggregated over the whole banking sector disguises these changes completely.

Within-group analysis

Figure 3a plots the share of interbank deposits in total liabilities only for subsidiaries. Again, there are statistically significant differences between 1995 and 2007 (p -value of 0.012) and the distribution shifts from a fairly flat shape (diversification or lack of specialisation) to one that is peaked at the left (specialisation away from interbank deposits). This left peak is accentuated in 2009 but the differences with 2007 are not statistically significant. Overall, the picture for subsidiaries is very similar to that for all banks, meaning that most institutions saw interbank deposits grow slower than total liabilities.

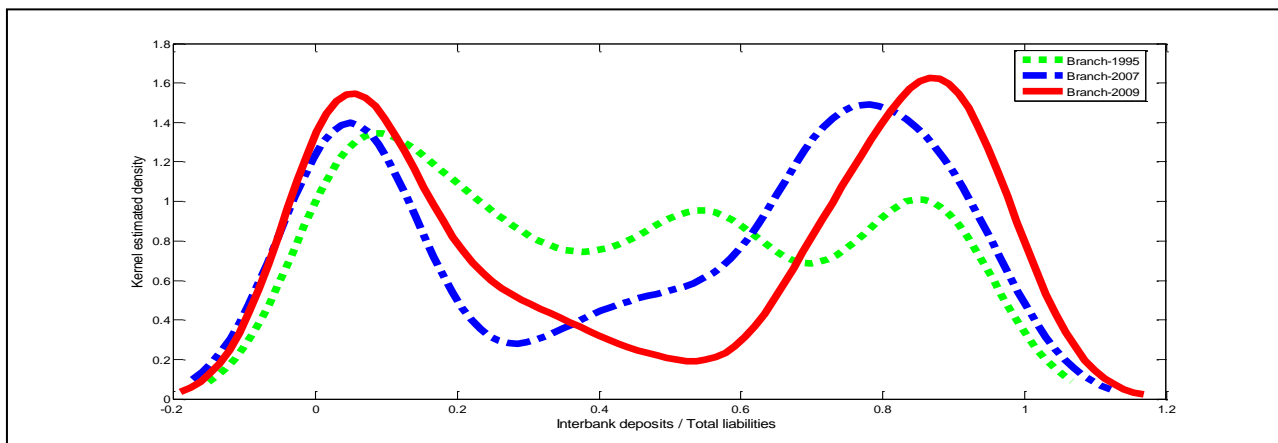
Figure 3a: Subsidiaries - Ratio of interbank deposits to total liabilities.



Source: Own calculations

Instead, the distribution for branches (Figure 3b) became clearly bimodal between 1995 and 2007, suggesting specialisation both towards and away from interbank deposit-taking. This shape was not much affected by the financial crisis, although a slight rightward shift of the distribution suggests that in many institutions interbank deposits grew faster than total liabilities. One explanation could be that international financial groups responded to the crisis by raising liquid assets for precautionary purposes through central bank refinancing operations by their Luxembourg branches.

Figure 3b: Branches - Ratio of interbank deposits to total liabilities



Source: Own calculations

The contrast between the left skewed distribution for subsidiaries and the relatively balanced bimodal distribution for branches confirms that a specialisation in interbank deposits is more common in the branches, which are more often used to manage intra-group liquidity.

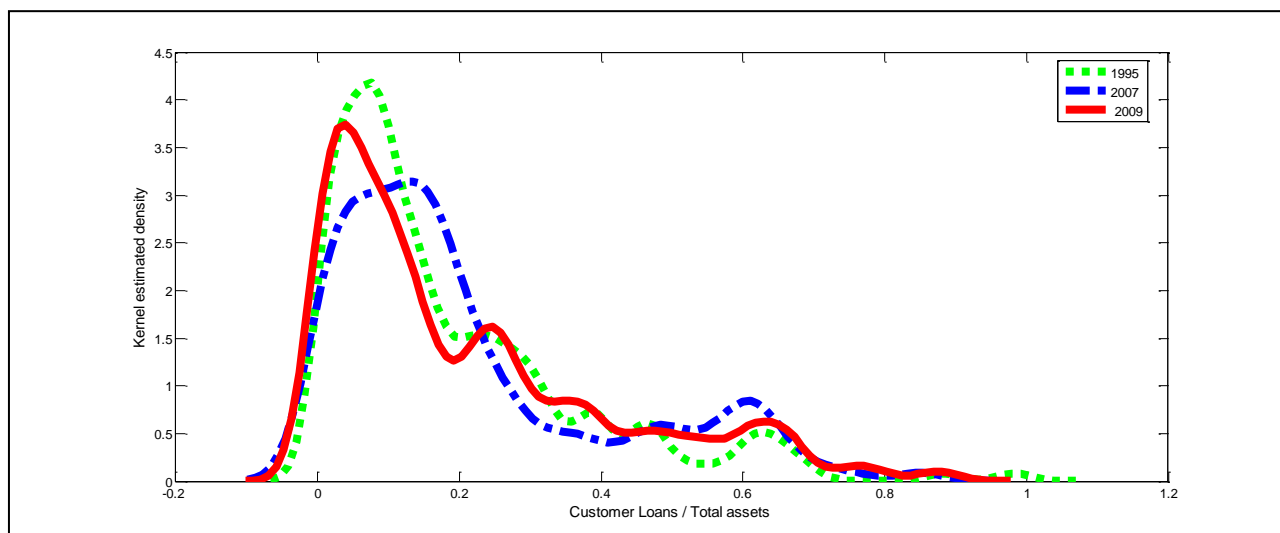
Between-group analysis

As could be expected from the visual comparison, the Li test suggests divergence between branches and subsidiaries (p -value falls substantially, from 0.905 in 1995 to 0.005 in 2007 and to 0.001 in 2009). This is consistent with increasing differences between branches and subsidiaries in terms of the share of interbank deposits in total liabilities. Subsidiaries appear to have mostly specialised away from this activity, while branches have developed a bimodal distribution with some concentrating on interbank deposits while others specialised away from them.

3.3 Customer loans: Changes in specialization

For most banks, customer loans do not constitute the major activity, as indicated by the left skew of the distribution in Figure 4 with a long, although bumpy, right tail. This is consistent with the conclusions of Steinherr and Huveneers (1994), who found that it is difficult for foreign banks to expand in customer loans, particularly in countries where a small number of banks dominate. In fact, the loan market is relatively concentrated in Luxembourg as this segment scored the highest concentration ratios (see also Rychtarik and Stragiotti 2009). However, from 1995 to 2007, many banks increased their customer loans faster than their total assets, as suggested by the fall in the left peak, the rightward shift of the distribution in 2007 and the increase in dispersion (however the Li test does not register these changes as significant). The many bumps in the right tail of the distribution in 1995 reflect a small number of observations. These became less sparse during 2007, suggesting an increase in the share of banks that were more specialized in customer loans. During the financial crisis, these changes were partially reversed as between 2007 and 2009 the left peak became sharper and shifted back towards the origin. However, the mass also increased at the centre of the distribution in the range 0.5-0.6. In this case, the changes to the distribution were significant, but only at the 5% level (p -value 0.044).

Figure 4. All banks - Ratio of customer loans to total assets



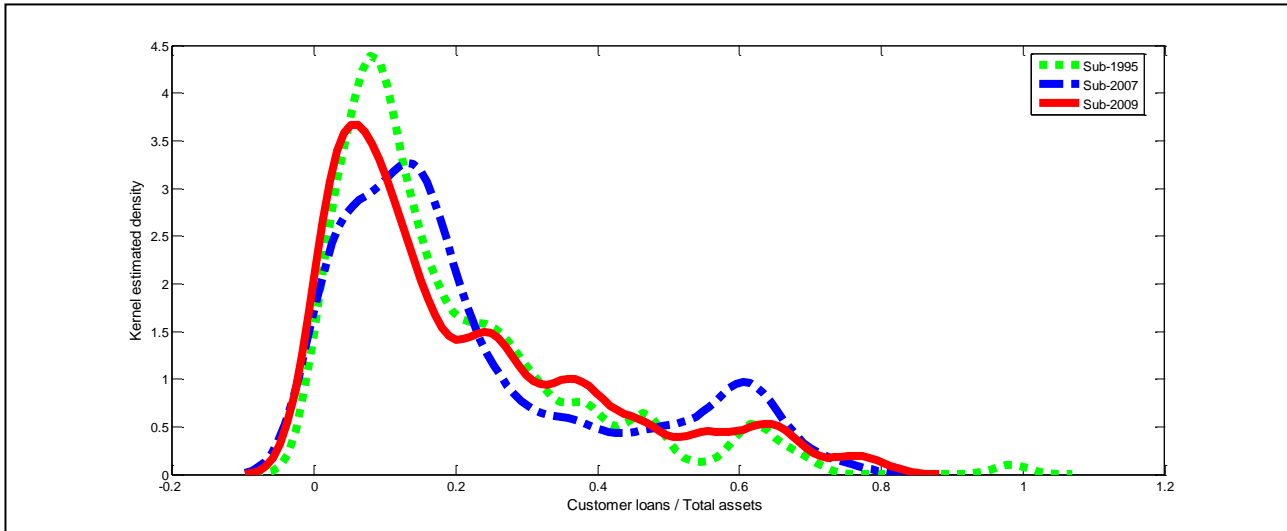
Source: Own calculations

Within-group analysis

Separate analysis for subsidiaries (Figure 4a) and branches (Figure 4b) reveals no significant differences across time. In fact, the p -values reported in Table 3 are not very high. Neither subsidiaries nor branches appear to have changed their customer lending behaviour over time. The temporary flattening of

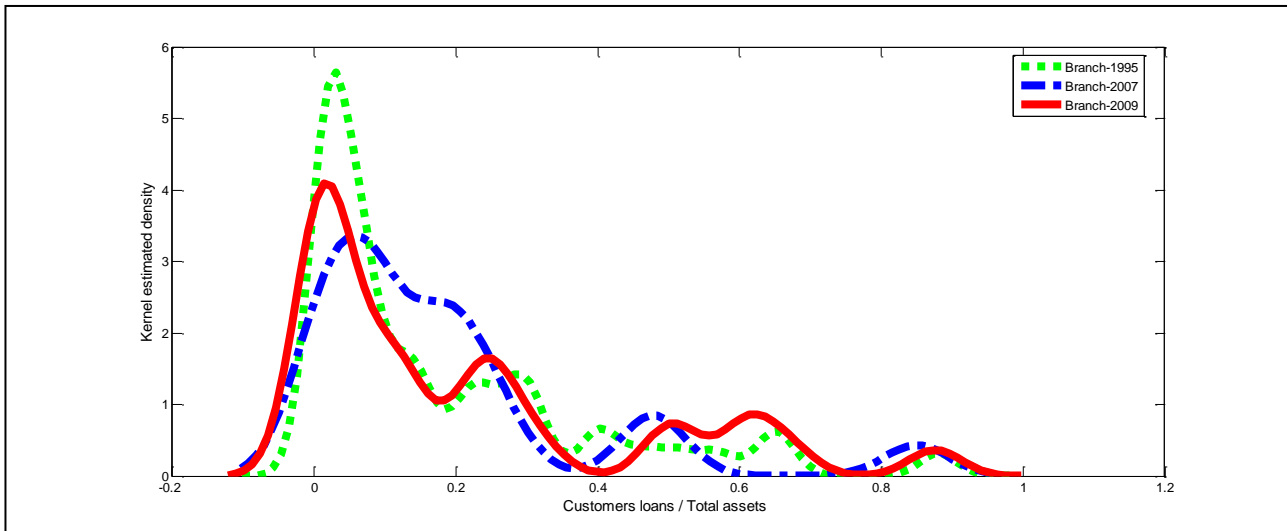
the peak in 2007 appears for both subgroups, and is more clearly marked for branches. The shift back in 2009 to a sharp peak at left is also apparent for both subgroups. However, for branches the 1995 peak appears to be much higher than the peak in either 2007 or 2009. This suggests that branches were much more specialised away from customer loans in 1995.

Figure 4a. Subsidiaries - Ratio of customer loans to total assets



Source: Own calculations

Figure 4b. Branches - Ratio of customer loans to total assets



Source: Own calculations

Between-group analysis

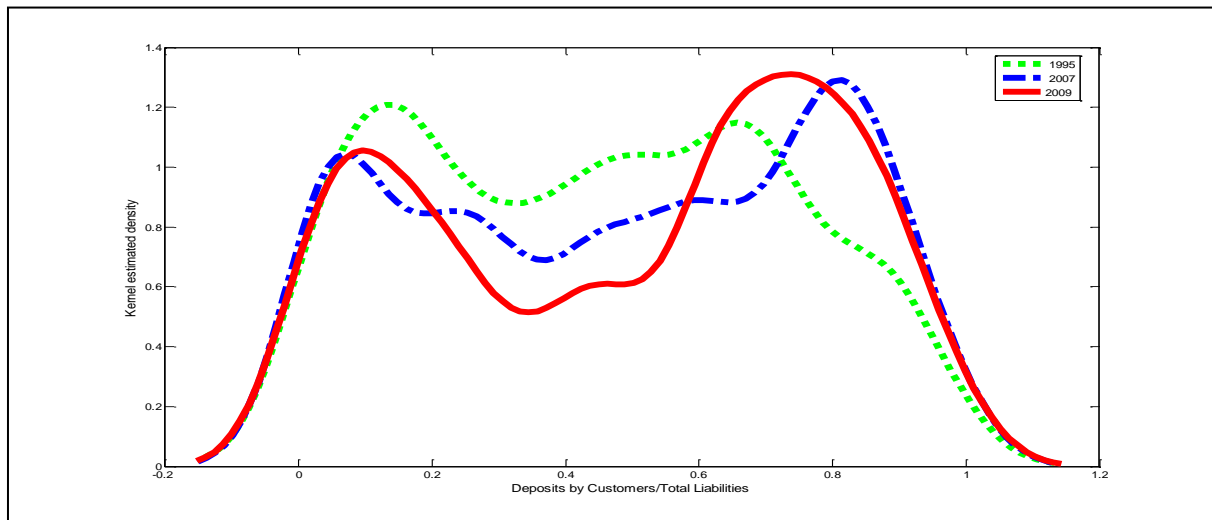
Comparing the share of customer loans across groups, differences between subsidiaries and branches are always significant. However, the *p*-value increased from 0.000 in 1995 to 0.037 in 2007, suggesting persistent difference, and then fell during the financial crisis (0.0018 in 2009). This suggests persistent difference between subsidiaries and branches.

3.4 Customer deposits: Changes in specialization

Subsidiaries and branches combined

The share of customer deposits in total liabilities is fairly dispersed, as shown in Figure 5. The relatively flat distribution suggests a fairly diversified sector, meaning that it would be inaccurate to describe Luxembourg simply as a “deposit centre,” where banks collect local deposits to fund loans abroad (Tschoegl, 2000). However, the distribution became more clearly bimodal over the financial crisis, suggesting an increase in heterogeneity across banks. In other words, banks tended to cluster at the extremes, specialising either towards or away from client deposit-taking. No statistically significant difference is found between distributions over time (Table 2).

Figure 5. All banks - Ratio of customer deposits to total liabilities

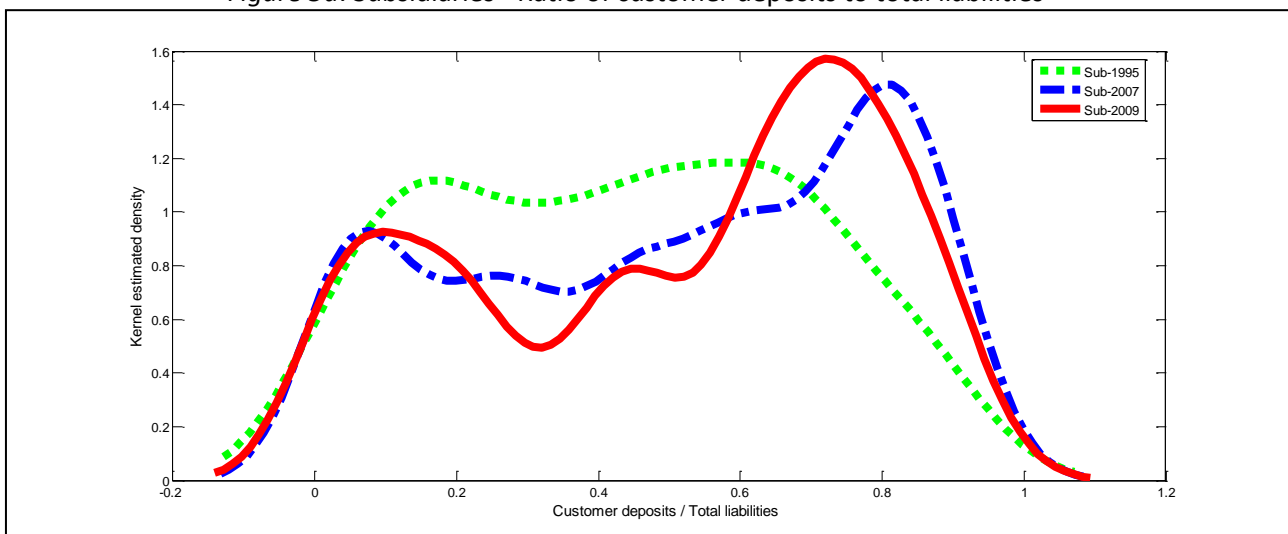


Source: Own calculations

Within-group analysis

Focussing on subsidiaries only, the distribution of customer deposits as a share of total liabilities changed significantly between 1995 and 2007 (p -value 0.012). Figure 5a reveals that the distribution for subsidiaries was remarkably flat in 1995 and fell off to zero at higher shares. In 2007, this was replaced by an increased dependence on customer deposits (rightwards shift of the mass, drop in the middle of the distribution and clear peak at highest shares).

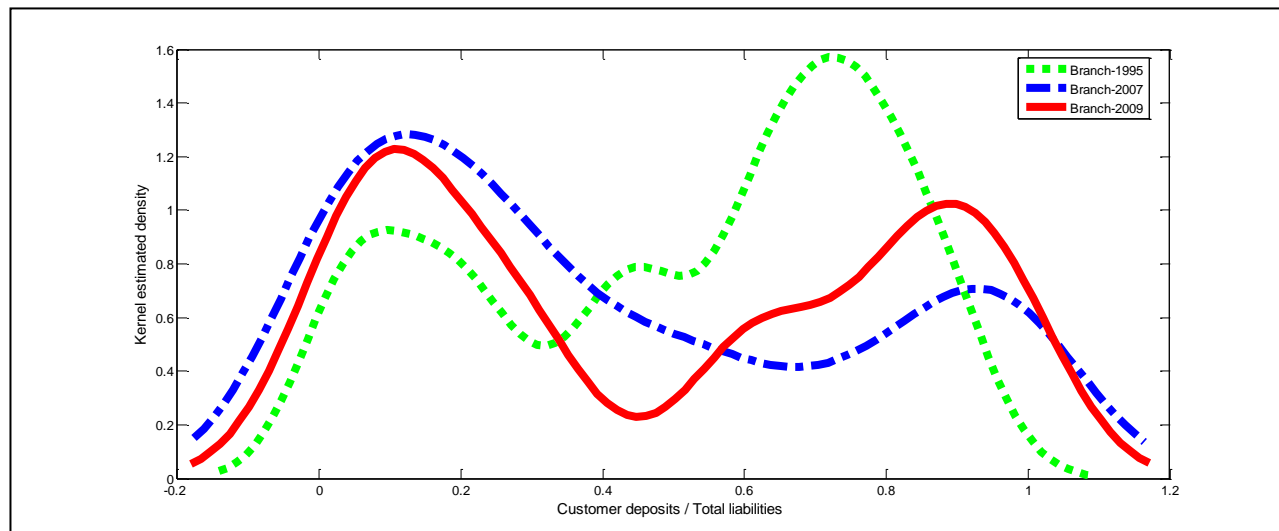
Figure 5a. Subsidiaries - Ratio of customer deposits to total liabilities



Source: Own calculations

This trend continued during the financial crisis, with a possible bi-modal distribution appearing (less mass in the middle, second peak at low shares). Overall, the distribution for subsidiaries went from fairly diversified to fairly specialised, with many subsidiaries holding a very large share of liabilities as customer deposits, while others specialised away from this activity, increasing heterogeneity.

Figure 5b. Branches - Ratio of customer deposits to total liabilities



Source: Own calculation

Similar specialization appeared for branches (Figure 5b), but they relied less on customer deposits over time (greater concentration in the left peak). In this case, the initial distribution in 1995 was already specialised, with many branches concentrated in the right peak. This fell dramatically in 2007, with many branches shifting to low shares where a new dominant peak emerged. However, the right peak recovered partially in 2009, accentuating the trough in the middle of the distribution. Thus comparing 2009 to 2007, some branches appear to have moved towards higher dependence on customer deposits, but in a much smaller proportion than that observed in 1995. This change during the crisis may reflect the mechanical impact of the sharp decrease in interbank activity. However, the results in Table 3 indicate that changes over time are not statistically significant according to the Li (1996) test, possibly because the sample is smaller for branches.

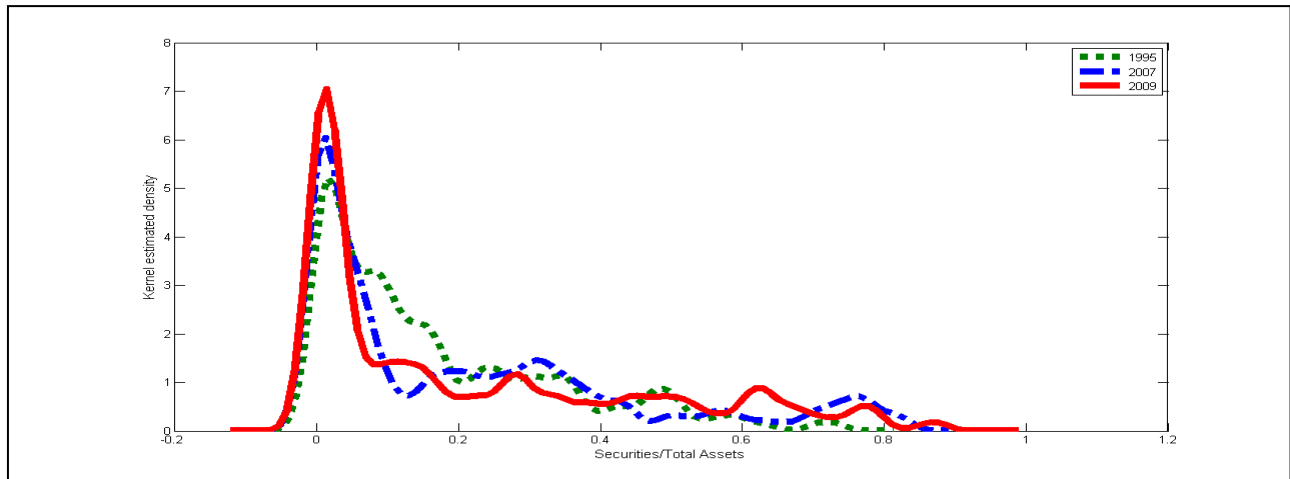
Between-group analysis

Comparing subsidiaries to branches, significant differences appear in 1995 and 2007 (p-values 0.013 and 0.01, respectively). This reflects the different patterns of specialization in branches and subsidiaries. Both saw the development of twin peaks at the extremes, but the initial distribution for subsidiaries was flatter and the trough that developed was shallower, suggesting more diversification than among branches. The process of divergence between subsidiaries and branches persisted in 2009 (p-value dropped further to 0.009). While both subgroups had bimodal distributions in this year, for subsidiaries there was a clearly dominant peak at the right, while for branches the higher peak was at the left, but was less clearly dominant. The most recent developments could be linked to differences in national deposit guarantee schemes, as subsidiaries are covered by the Luxembourg scheme while branches are covered in their parent bank's home country. In so far as subsidiaries saw more banks specialise at high levels of customer deposits, this may have been a vote of confidence in the Luxembourg scheme. Alternatively, it may simply have been the mechanical result of the drop in interbank deposits. Finally, it is worth considering that customer activities carry important costs, which parent banks apparently prefer to manage through subsidiaries.

3.5 Securities Held: changes in specialization

The share in total assets of securities held by banks is usually low in Luxembourg as indicated by the sharp peak at the left in Figure 6. While this strong left skew increased over time, significant changes appeared in 2007 (p-value 0.044) and reconfirmed 2009 (0.018). In 2007 the peak became sharper, as some mass between 0.1 and 0.2 shifted leftwards. Bumps in the right tail appeared in 2007 (around 0.8) and in 2009 (around 0.6) possibly suggesting the entry of banks specialized in this activity.

Figure 6. All banks - Ratio of securities held to total assets

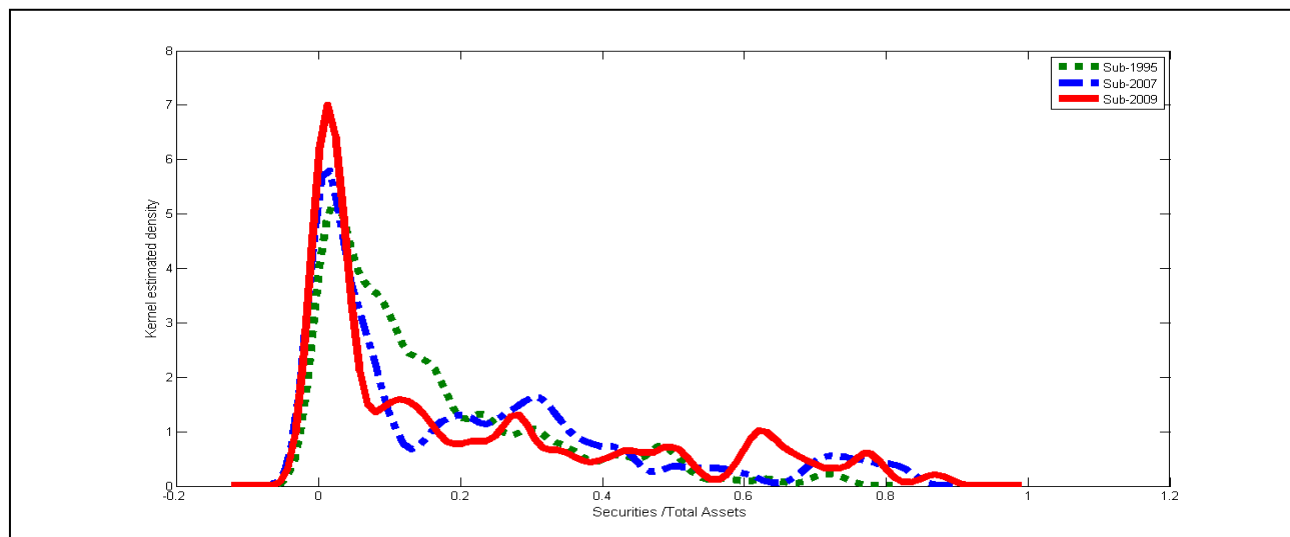


Source: Own calculations

Within-group analysis

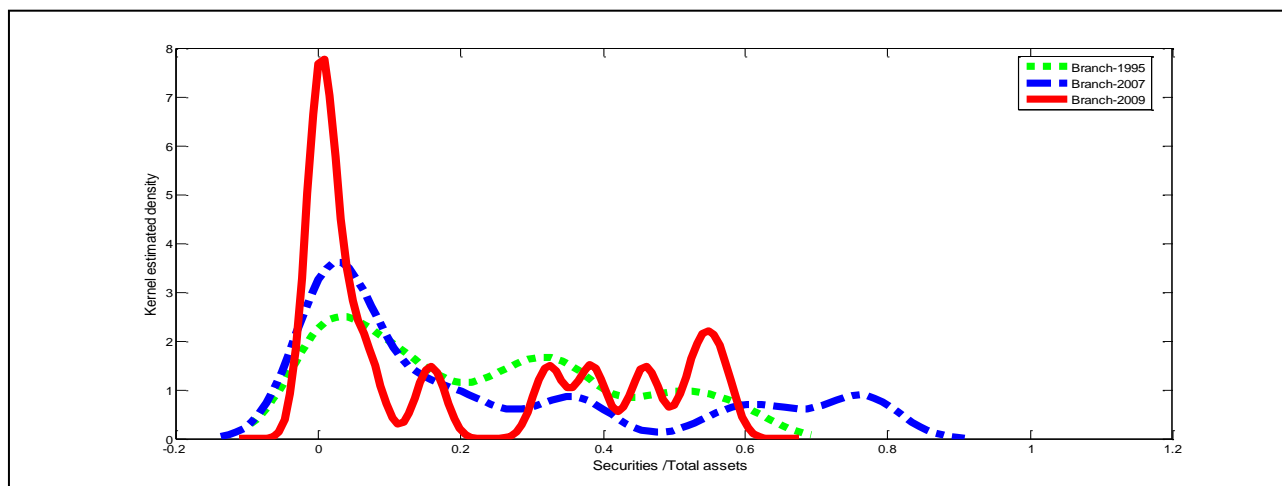
The separate distributions for subsidiaries (Figure 6a) and branches (Figure 6b) both resemble Figure 15, with a sharp peak at the left and a bumpy tail at the right. The p-values for the Li (1996) test reported in Table 3 indicate statistically significant changes in the distribution for subsidiaries between 1995 and 2007 (a visible leftwards shift of mass between 0.1 and 0.2) but not between 2007 and 2009 (a slight increase in the height of the left peak).

Figure 6a. Subsidiaries - Ratio of securities held to total assets



Source: Own calculations

Figure 6b. Branches - Ratio of securities held to total assets



Source: Own calculation

For branches, the initial distribution in 1995 was surprisingly flat (diversification). There were no significant changes between 1995 and 2007, although the peak at the left became more pronounced, but significant changes between 2007 and 2009 when the peak near zero increased dramatically. This result needs to be interpreted cautiously given the limited number of branches on which the distribution is estimated. The significantly different shape of the distribution in 2009 may also reflect different treatment of securities under the new IFRS accounting principles.

Between group analysis

Comparing the distribution of branches to that of subsidiaries, the Li (1996) test finds significant differences in 1995 (p-value of 0.01) and in 2009 (p-value of 0.00) but not in 2007, when both distributions displayed a clear peak at the left and a long tail at the right.

4. Conclusions

In this paper, we find that analysis based on standard descriptive statistics (mean, median, variance, etc.) might fail to identify some important changes in the industry, given that data distributions across individual banks feature asymmetries and often multiple peaks. For this reason, we use non-parametric density estimators and related bootstrap-based tests to compare distributions across time or across sub-groups. Borrowing from the applied literature on economic growth, we also test for convergence or divergence of distributions using the methods in Quah (1996). Considering *interbank loans*, the sector as a whole appears to have become more diversified between 1995 and 2007. This was largely due to changes among subsidiaries, in contrast to branches, which appear to have become increasingly specialised in this area. This is consistent with the conventional wisdom that branches are primarily focused on interbank lending while subsidiaries have progressively turned to other activities. During the financial crisis, this difference between subsidiaries and branches became more substantial and statistically significant.

For *interbank deposits*, the sector as a whole appears to have become less diversified, with most banks specialising away from this activity. In particular, most subsidiaries have seen interbank deposits fall as a share of total liabilities, while branches developed a bimodal distribution (some branches concentrated on interbank deposits while others specialised away from them). In this market segment there is clear evidence of divergence between subsidiaries and branches.

For *customer loans*, the changes in specialisation were less dramatic, with a persistent concentration at low levels of involvement for the sector as a whole (also for subsidiaries and branches separately). While in this segment changes in the distribution registered as statistically significant, there was no clear convergence/divergence process.

For *customer deposits*, there was an increase in specialisation, the distribution for the sector as a whole starting fairly flat and becoming clearly bimodal. This reflected different changes for subsidiaries, which mostly increased their specialisation in customer deposits, and for branches, which tended to specialise away from this activity. Since 2007, there has been an increase in evidence of divergence between subsidiaries and branches. Finally, with respect to *securities held* by Luxembourg banks, the estimated distributions feature a sharp peak towards zero, suggesting that for most banks this is not an important activity (similar pattern for subsidiaries and branches). The balance sheet data aggregated across banks provides a different picture, as securities represent up to a fifth of total assets, which suggests that this activity is mostly confined to some relatively large banks.

There are several conclusions we can draw from these results. First, the degree of specialisation and heterogeneity varies across different market segments as well as through time. Second, comparing subsidiaries and branches, estimated distributions across banks have been relatively similar for Interbank Loans but have become rather different for Interbank Deposits. For Customer Loans and Customer Deposits, the differences across groups are generally greater, especially for Customer Deposits. Third, in 2009 the financial crisis sharpened the differences between subsidiaries and branches for all variables considered. Fourth, changes in the estimated distributions for branches were generally not statistically significant (although the sample size was limited). For subsidiaries, there were significant changes between 1995 and 2007 for all variables except Customer Loans. Between 2007 and 2009, the distributions for subsidiaries changed significantly only for Interbank Loans and Interbank Deposits, although divergence with respect to branches appeared also for the other variables.

These results suggest that increased competition led subsidiaries to diversify. On the other hand, branches tended to become more specialised as dedicated business units within multinational groups. There appears to be clear convergence in interbank lending activity. Movement toward more similar distributions is less pronounced in customer loans and deposits. This could reflect the limited role still played by customer deposits in most branches relative to that in subsidiaries. A divergence process appears in interbank deposits. This could be due both to the different structure of liabilities and different levels of deposit guarantees. Clear convergence appears in activity connected to securities held. Thus, for those activities requiring less investment, branches seem to converge with subsidiaries. For activities requiring more skilled labour, evidence clearly suggests divergence.

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