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CHANGES IN BANK SPECIALISATION: COMPARING FOREIGN SUBSIDIARIES AND BRANCHES IN LUXEMBOURG

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Changes in bank specialisation: comparing foreign subsidiaries and branches in Luxembourg*

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Abstract

Presumably, foreign banks open subsidiaries and branches in Luxembourg to perform different tasks. This paper studies the balance sheet structure of banks in Luxembourg, testing for differences across groups and across periods. 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.

JEL Classification: C14; G21, D30

Keywords: Luxembourg Banks; Banking activities; Convergence; Distribution Dynamics; Non-Parametric kernel

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Résumé non-technique

Ce cahier d'études analyse les comptes financiers des banques luxembourgeoises afin de répondre à différentes questions. Les banques luxembourgeoises se spécialisent-elles dans différents domaines d'activité? La spécialisation a-t-elle évolué à travers le temps? Considérant la présence importante de banques étrangères au Luxembourg, les filiales et les succursales ont-elles choisi une forme de spécialisation différente? A travers le temps, la différence entre filiales et succursales a-t-elle diminué ou augmenté? En 1995, date du début de notre échantillon, il y avait 220 banques au Luxembourg dont 146 étaient des filiales de banques étrangères, 70 étaient des succursales de banques étrangères et 4 étaient des banques domestiques. Les filiales représentaient 79,0% de la somme des bilans, les succursales 15,7% et les banques domestiques 5,4%. En 2007, le nombre de banques était tombé à 156 unités, dont 108 filiales, 43 succursales et 5 banques domestiques. La somme des bilans a augmenté à un rythme annuel moyen de 6,3% pour la période sous revue. En 2007 les filiales représentaient 80,6% de la somme des bilans, les succursales 14,2% et les banques domestiques 5,2%.

Pour chaque banque, cette étude considère la part de différentes composantes du bilan dans l'actif total et analyse la distribution de cette part à travers la population des banques. Pour une composante donnée (de l'actif ou du passif), le secteur financier dans son ensemble est considéré comme diversifié si la distribution de sa part à travers les banques est relativement plate (l'activité en question est peu importante pour certaines banques, moyennement importante pour d'autres, mais très importante pour d'autres encore). En revanche, le secteur est considéré comme spécialisé si la distribution à travers les banques est caractérisée par des pics (concentration de banques pour lesquelles l'activité en question est peu/très importante).

L'hétérogénéité de la population bancaire peut engendrer des distributions asymétriques, voire caractérisées par plusieurs pics. Il est donc nécessaire d'estimer les distributions par des méthodes non-paramétriques appropriées.

La comparaison de distributions entre différentes années -ou entre différents sous-échantillons à un moment donné- exige une technique particulière, dite du *bootstrap*. La convergence/divergence entre groupes est étudiée à l'aide de tests développés dans le domaine de la croissance économique. Les résultats suggèrent que dans certains cas il y a eu convergence de la structure de spécialisation des succursales vers celle des filiales tandis que dans d'autres cas il y a eu divergence.

• **Activité interbancaire:** pour les prêts interbancaires, le secteur dans son ensemble est devenu moins spécialisé depuis 1995 (distribution plus plate). Ceci est largement le reflet de diversification entre filiales, puisque les succursales ont généralement connu une augmentation de leur spécialisation dans cette dimension. Cette différence entre filiales et succursales s'est accentuée pendant la crise financière et est devenue statistiquement significative. Du côté des dépôts interbancaires, l'ensemble du secteur semble être devenu moins diversifié (distribution moins plate), vu que plusieurs banques ont fortement réduit leur activité dans ce domaine. Les filiales en particulier ont généralement connu une croissance relativement faible des dépôts interbancaires (concentration vers des valeurs faibles). En revanche, les succursales ont développé une distribution bimodale dans les dépôts interbancaires (certaines se sont spécialisées dans ce domaine, tandis que d'autres ont préféré développer d'autres activités). Dans ce segment du marché, la divergence entre filiales et succursales est nette.

• **Activité avec la clientèle:** pour les prêts à la clientèle, le degré de spécialisation est resté plus stable à travers le temps, avec des niveaux d'activité relativement faibles dans ce domaine pour la plupart des banques. Ce résultat caractérise l'ensemble du secteur mais aussi les filiales et succursales séparément. Pour ce qui est des dépôts de la clientèle, l'ensemble du secteur est devenu plus spécialisé, vu qu'une distribution initialement plate est clairement devenue bimodale. Les filiales ont augmenté leur spécialisation dans les dépôts de la clientèle, tandis que les succursales ont davantage développé d'autres activités. Depuis 1995, la divergence entre les distributions des filiales et des succursales est devenue statistiquement significative.

• **Obligations:** La part des obligations détenues dans l'ensemble des actifs est très faible pour la plupart des banques luxembourgeoises, comme l'indique le pic vers zéro dans la distribution estimée (profil semblable pour filiales et succursales). Cependant, le bilan agrégé du secteur bancaire fournit une image différente, puisque les obligations y représentent presque un cinquième de l'actif total pour le secteur. Par conséquent, cette activité semble limitée à quelques grandes banques.

Ces résultats conduisent à plusieurs conclusions. Premièrement, l'étendue de la spécialisation (ou de l'hétérogénéité) est différente selon le segment du marché mais aussi à travers le temps. Deuxièmement, en comparant filiales et succursales, les distributions sont assez semblables pour les prêts interbancaires mais ont divergé pour les dépôts interbancaires. Pour les prêts à la clientèle et les dépôts de la clientèle, les différences entre groupes sont généralement plus importantes, notamment en ce qui concerne les dépôts de la clientèle. Troisièmement, en 2009 la crise financière a accentué les différences entre filiales et succursales pour toutes les variables considérées. Quatrièmement, en comparant 1995 et 2007, les distributions au sein des filiales ont changé de manière significative pour toutes les variables sauf pour les prêts à la clientèle. Entre 2007 et 2009, les distributions au sein des filiales ont changé significativement seulement pour les prêts et dépôts interbancaires. Pour les succursales, les distributions n'ont pas changé de façon significative à travers le temps ; toutefois la taille de l'échantillon est plus limitée.

Cette étude compare la spécialisation par type d'activité bancaire des filiales et des succursales et leur évolution à travers le temps. Ces résultats permettront une meilleure évaluation de la productivité et de l'efficacité des banques luxembourgeoises ainsi qu'une comparaison plus rigoureuse avec d'autres centres financiers.

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1. Introduction

The dominance of foreign banks in Luxembourg has several historical origins. Its roots lie in the 1970s with the development of international syndicated loans, euro-bonds and euro-currency markets (OECD, 2008). Then Luxembourg concentrated on private banking and more recently on the domiciliation of investment funds (currently the largest centre in Europe: IMF, 2009). As in many other financial centres, the interbank market plays an important role. In part this may reflect intra-group operations, with foreign banks using their Luxembourg branches and subsidiaries to manage their liquidity positions. More generally, Luxembourg offers foreign banks a favourable regulatory framework, political stability, a multi-lingual workforce, and the agglomeration of specialized skills in accounting and legal services. However, as financial institutions evolve and the lines between traditional banking activities blur, Luxembourg's "banking business model" may shift with the mix of activities. In particular, the financial crisis launched a wave of regulatory reform and international pressure to abolish banking secrecy which has challenged Luxembourg banks to maintain their competitiveness by raising the quality of financial services they provide. These changes will probably affect the structure of bank balance sheets and their profit and loss accounts.

This study explores data from Luxembourg banks' financial statements, with several questions in mind. Do Luxembourg 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 banks. 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.

This study provides preliminary results intended to guide analysis of efficiency and productivity in the Luxembourg banking sector. In cross-country comparisons of banking efficiency Luxembourg is often discarded as an "outlier". Where it is included, it ranks among the best performing countries (Lozano-Vivas, 2002), but this may reflect bias due to several sources. First, most banks in Luxembourg are subsidiaries or branches of foreign banks (see section 2). Although technically they qualify as universal banks, their role within international banking groups might be a source of error in measuring efficiency or productivity. Second, the different legal forms (subsidiary or branch) imply different regulatory regimes which might be a separate source of bias in comparing performance. Finally, as one of the countries with the highest per capita income, Luxembourg has a very high capital-labour ratio which could be another source of bias (e.g., Badunenko et al., 2008)¹. In Section 2 below we describe the structural features of the industry, clarifying the difference between branches and subsidiaries. Section 3 briefly reviews the historical background of Luxembourg's banking sector. In Section 4 we propose a generalization of the analysis in Quah (1996) to detect distributional similarities in small samples. Section 5 reports the empirical results, expressing each of

¹These authors decompose labour productivity change into efficiency change, technical change and change in the capital-labour ratio. They confirm the findings of Kumar & Russell (2002) that countries with higher capital-labour ratios appear to record higher technical change.

the main balance sheet items as a share of the balance sheet and estimating the distribution of these shares across banks. These distributions are then interpreted in terms of the specialization or diversification of branches and subsidiaries. Section 6 concludes.

2. Key Structural Features of the industry

Luxembourg's banking sector is mostly foreign owned. Almost all banks are local branches or subsidiaries of international groups that serve to provide them with cross-border banking services. Luxembourg legislation recognises two different legal forms: joint stock companies (*Société par Actions* or SA) and limited liability companies (*Société à Responsabilité Limitée* or SàRL). The first form includes both domestic banks and foreign-bank subsidiaries, while the second form only includes foreign-bank branches. Thus, the difference in legal form largely coincides with the distinction between subsidiary and branch. In addition, supervisory requirements in Luxembourg differ across three types of banks: banks incorporated under Luxembourg law (including foreign-bank subsidiaries), branches of banks incorporated in another EU country, and branches of banks incorporated in countries outside the EU.

A foreign bank's mode of entry may reflect regulatory differences between home and host country. For example, a parent bank may choose to establish a subsidiary that will be supervised under Luxembourg law, or it may prefer to establish a branch to remain subject to its home country supervisor. Other aspects also affect the choice between subsidiary and branch: subsidiaries must be at least 50% foreign-owned and the liability of the parent bank is limited to the amount of capital invested. On the other hand, branches are not independently incorporated but are fully owned by their foreign parent bank (Cerruti et al., 2007). Although organizationally less demanding, a branch only allows the parent bank to run a limited set of operations in the foreign country (Pozzollo, 2009), usually focussing on inter-bank activities. A subsidiary instead can operate more freely and provides the parent bank complete access to the host country in terms of customers served and product/services offered. This means that subsidiaries can compete directly with domestic banks as well as with subsidiaries of other foreign banks. As an international financial centre, Luxembourg has relatively few domestic banks. Of these, only two are wholly state-owned banks: *Banque et Caisse d'Épargne de l'État* and *Société Nationale de Crédit et d'Investissement*. There are also two domestic banks with a mix of public and private ownership (*Fortuna Banque* and *Banque Raiffeisen*²) as well as one domestic bank that is privately owned (*Compagnie de Banque Privée*). None of them holds a dominant position in any segment of the market (see Figure 2 below). This suggests the absence of barriers to entry, which probably encouraged foreign banks to establish a local presence.

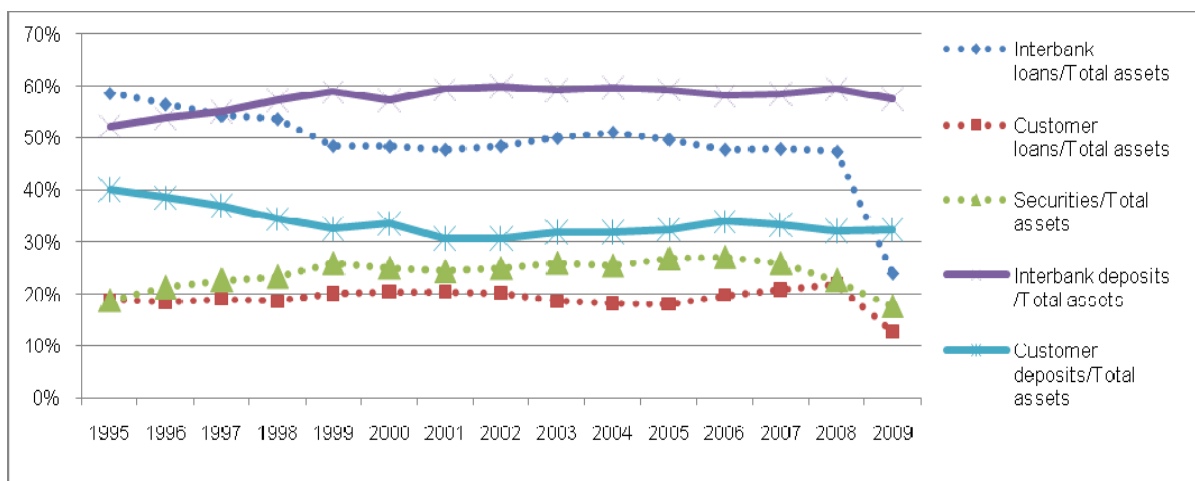
Across time, the number of subsidiaries has always been substantially greater than the number of branches. This is consistent with other studies on the growth of cross-border European banking (e.g. Dermine, 2006), which also found that banks extending abroad preferred the subsidiary structure. However, some foreign banks have established both a subsidiary and a branch in Luxembourg, presumably to perform different functions. For example: the parent bank may initially open one branch and one subsidiary, and then allow the branch to take over the subsidiary. The branch *Banca Novara* took over the subsidiary *Banca Novara International S.A.* in 2002; the parent bank may initially open one branch and one subsidiary, and then allow the subsidiary to take over the branch. This was the case for *Banca Popolare dell'Emilia Romagna*, as well as for *M.M. Warburg & CO*; the parent bank may continue to operate in Luxembourg through a mix of

²*Banque Raiffeisen* and its local *caisses rurales* are treated as a single credit institution (CSSF, 2007).

branches and subsidiaries. This is often the case for the largest multinational banks (Deutsche Bank, BNP Paribas, Commerzbank, etc.). Thus the choice between branch and subsidiary is not mutually exclusive. International banks may use the financial centre in Luxembourg to pursue different strategies simultaneously. By combining branches and subsidiaries they may be responding to the trade-off between economies of agglomeration and economies of scale. Branches are wholly owned by their parent bank and this is usually the case also for subsidiaries. However, there are some subsidiaries where ownership is shared, sometimes even among banks from different countries. For instance, in 2007 the subsidiary BNP Paribas Luxembourg was controlled by the Dutch bank BNP Paribas International BV (75.34%) and by the French bank BNP Paribas (24.66%). Another example is the subsidiary Banque BCP SA, which was controlled by the Dutch bank BCP Investment BV (19%), the French bank Caisse Nationale des Caisses d'Epargne et de Prévoyance (30%) and the French bank Financière OCEOR (50.10%).

Banks in Luxembourg vary in the extent to which they engage in different financial activities. Most are universal banks, running both traditional intermediation and financial market activities. However, these co-exist with some very specialized banks. Figure 1 below illustrates the structure of the aggregate balance sheet for the sector as a whole.

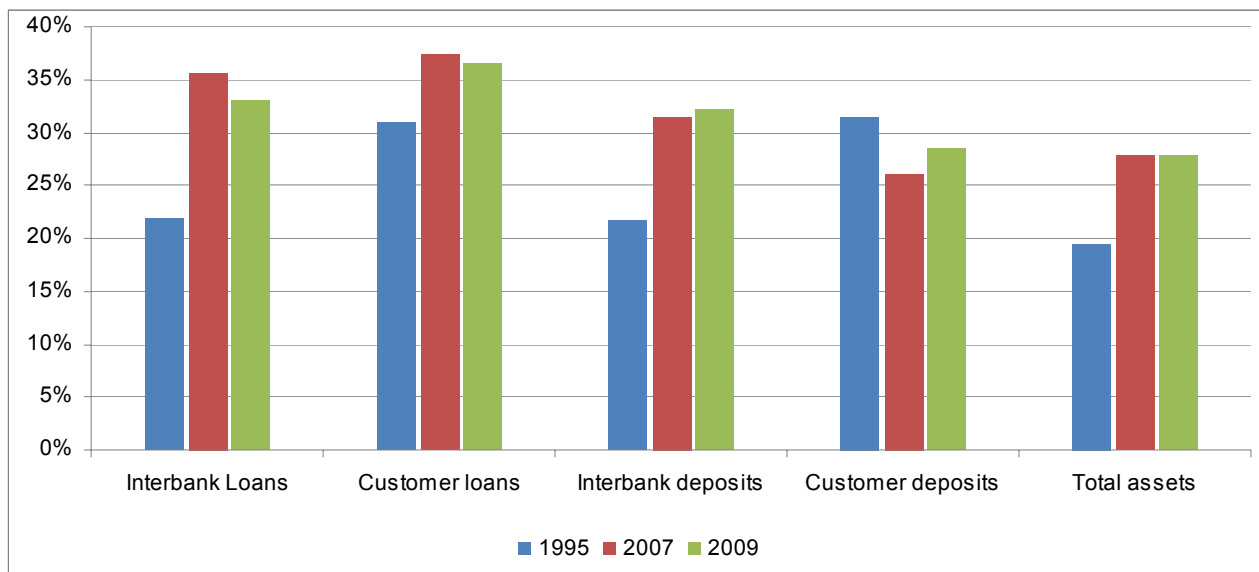
Figure 1: Main industry ratios aggregated across banks.



Source: BCL

Several studies found a relatively high level of competition among Luxembourg banks. Goddard et al. (2007) ranked the country third in Europe (after Italy and Germany) in terms of the lowest CR5 (five-firm concentration ratio for total assets), which they calculated at 29.7% in 2004. More recently, Carbo et al. (2006) ranked Luxembourg among the countries with the highest levels of bank competition using a vector of different measures: lowest net interest margin (0.79%), lowest Lerner Index (11%) and lowest Hirschman-Herfindahl Index (305). They found that Luxembourg's level of bank competition was comparable only to those in Ireland, UK and Germany. Figure 2 reports the CR5 index calculated separately for four segments (interbank loans, customer loans, interbank loans and interbank deposits).

Figure 2: Concentration index (CR5) for individual segments and total assets



Source: BCL

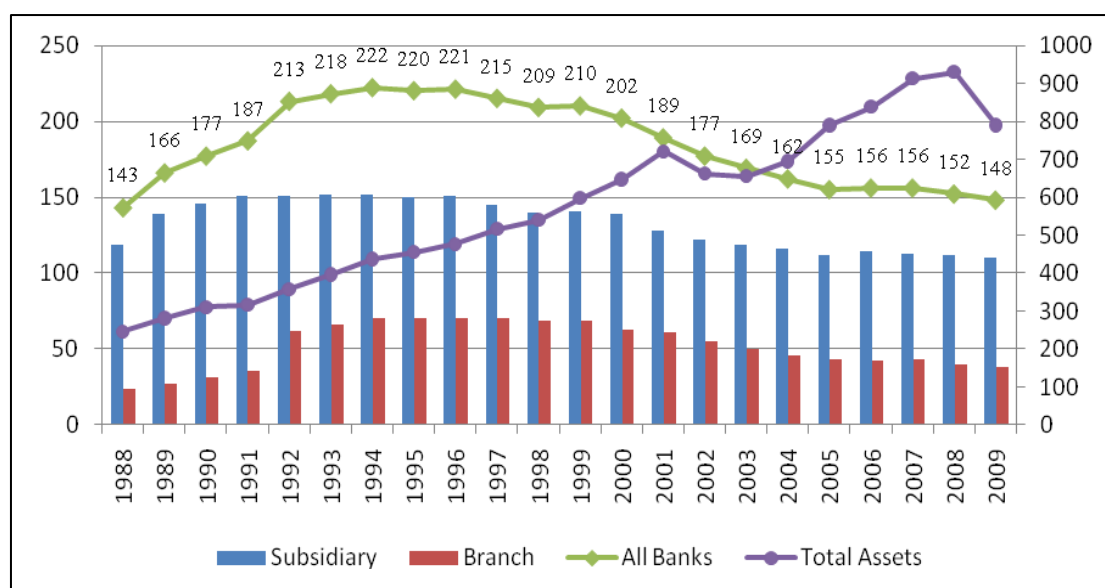
In interbank loans and deposits, both subsidiaries and branches appear among the five largest players. However, in customer loans and deposits only subsidiaries appear. On both the asset and the liability side, customer activity displays more market concentration than interbank activity. Over time, concentration appears to increase on these measures, probably reflecting the wave of consolidations also observed in other financial centres (Tschoegl, 2000). However, it is important to note that the link between market concentration and competition is more tenuous in Luxembourg because the customer client base is mostly international and inter-bank activities may be mostly within international banking groups. Finally, banks may be attracted to Luxembourg specifically to specialise their customer activity in products/services differentiated according to geographical market or type of operations.

3. Historical Background

Luxembourg's banking system developed through several stages, which are presented in detail in the subsections below. Separate waves of foreign bank arrivals often accompanied the introduction of taxation and/or regulatory measures in their home countries (IMF, 2000). More generally, growth was encouraged by Luxembourg's tax and regulatory advantages as well as its swift implementation of EU directives (OECD, 2008, 2010).

Figure 3 presents the number of banks in Luxembourg, including the breakdown by subsidiaries and branches, as well as the evolution of total assets aggregated across banks. The total number of banks peaked in 1994 at 222, mainly due to rapid growth in the number of branches in the preceding two years. After that, the number of both branches and subsidiaries declined to reach a total of 148 in 2009. Despite this fall in the number of banks, the aggregate balance sheet grew in all years except during the crises of 2002 and 2009. This indicates that most exits were through mergers, leaving the size of the aggregate balance sheet unaffected, but raising the size of the average bank.

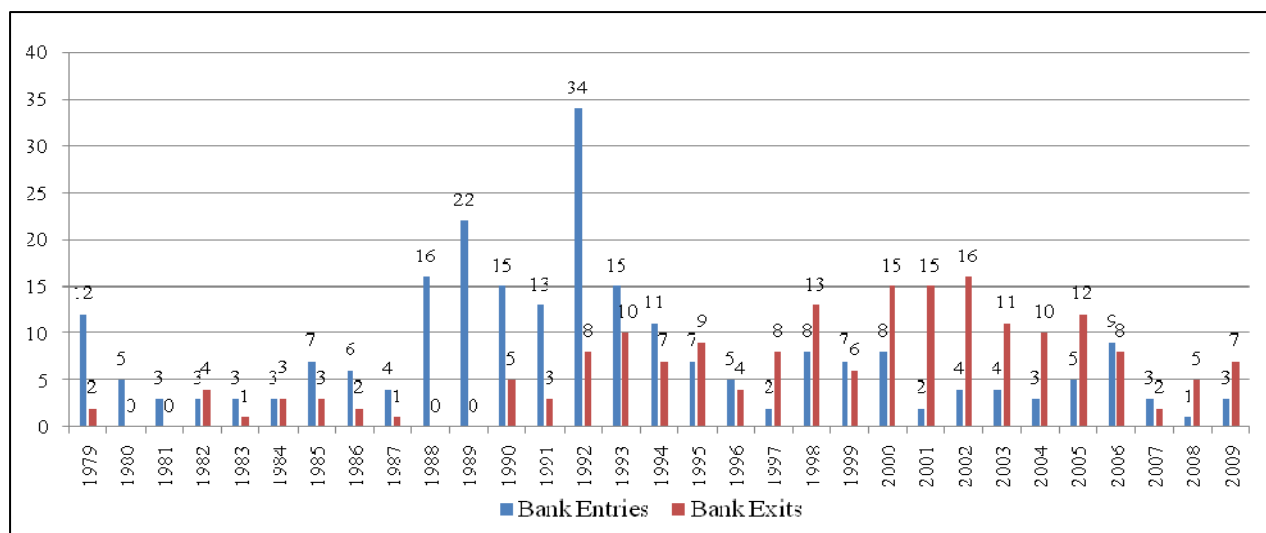
Figure 3: Number of banks and total assets of the sector.



Source: BCL

Figure 4 focuses on the flows in and out of the stock of banks reported in Figure 3. We define a bank entry as a de-novo bank established in Luxembourg. A bank exit, instead, may be (i) a bank taken over via a merger (ii) a bank which closed or transferred its activity to another bank of the same group, or (iii) a bank which abandoned its banking license to become a Financial Sector Professional (PFS) with other regulatory requirements. Along with Table 1, Figure 4 serves to identify the main waves of bank entries and bank exits which will be described in the remainder of this section. It becomes clear that growth in the number of banks up to 1994 was mostly driven by the combination of many entries and few (often zero) exits. Following that date, the number of entries per year fell and the number of exits increased sharply. The wave of exits between 1997 and 2001 must be considered in the international context of bank consolidation, which is discussed in more detail below.

Figure 4: Bank Entries and Exits



Source: BCL

Table 1 provides detail on bank entries and exits by banks' home country. Although all foreign-bank subsidiaries are Luxembourg banks in the sense that they are incorporated in Luxembourg law, in the following we designate them with the nationality of their majority owner (parent bank).

Table 1: Bank Entry and Exit by Nationality

	1979-1989		1990-1999		2000-2009	
	Entry	Exit	Entry	Exit	Entry	Exit
<i>Total</i>	83	16	118	73	42	102
<i>of which:</i>						
Germany	17(10)	2(2)	45(12)	16(7)	6(3)	28(8)
Belgium	3(3)	0	9(7)	4(3)	7(4)	12(10)
Luxembourg	0	1(1)	0	3(3)	1(1)	1(1)
France	8(6)	2(2)	11(8)	7(5)	3(2)	11(7)
Italy	5(4)	0	18(10)	4(3)	1(1)	12(5)
Switzerland	9(7)	1(1)	4 (2)	6(2)	3(2)	6(5)
Sweden	3(3)	0	4(0)	5(3)	1(1)	2(1)
US	5(3)	5(0)	2(2)	3(3)	2(2)	1(1)
UK	5(3)	0	3(0)	1(1)	2(1)	3(3)
Japan	5(5)	0	1 (1)	1(1)	0	4(4)
Netherlands	5(5)	0	2 (2)	2(2)	2(0)	4(3)
Korea	1(1)	0	4 (4)	3(3)	0	2(2)
Others	17(12)	5(4)	15(8)	18(15)	14(7)	16(13)

Note: number of subsidiaries within parentheses.

3.1 Euro-bond markets & international lending syndicates (1963-1979)

The origins of Luxembourg's banking sector lie in two important developments that date back to the 1960s. First, restrictive legislation in the US (the 1933 Regulation Q and the 1963 Interest Equalization Tax³) prompted American firms to begin issuing US Dollar-denominated bonds in European markets. The first of these Eurobond issues was listed on the Luxembourg Stock Exchange in 1963. Luxembourg was particularly attractive for this activity given its more favourable securities legislation, flexible stock exchange regulations, lower transaction costs and zero withholding tax on interest income. Growth of the Eurobond market in Luxembourg was boosted by German banks, who found that foreign currency liabilities held by their subsidiaries in Luxembourg were not subject to the reserve requirements imposed by the Bundesbank. German banks also contributed significantly to the growth of multinational issuing syndicates.

The Euro-bond markets became so well established that the abolition of Interest Equation Tax in 1974 had no substantial effect on their growth. By this time, issuers originated in Europe and South-East Asia as well as the US. The number of Euro bonds listed on the Luxembourg Stock exchange rose from 56 in 1963 to 630 in 1973 (Bourse de Luxembourg). The German banks in Luxembourg made it a prime location to issue Deutschmark-denominated euro-bonds. Euro-loans and deposits in foreign currencies other than US Dollars also increased with the entry of new foreign banks. Swiss banks set up subsidiaries to invest part of their customers' funds in these Euro-markets, attracted by lower taxes and the opportunity to do business with German banks (IMF, 2002). Scandinavian banks opened subsidiaries in Luxembourg to access international lending activities that were not authorised in their home country.

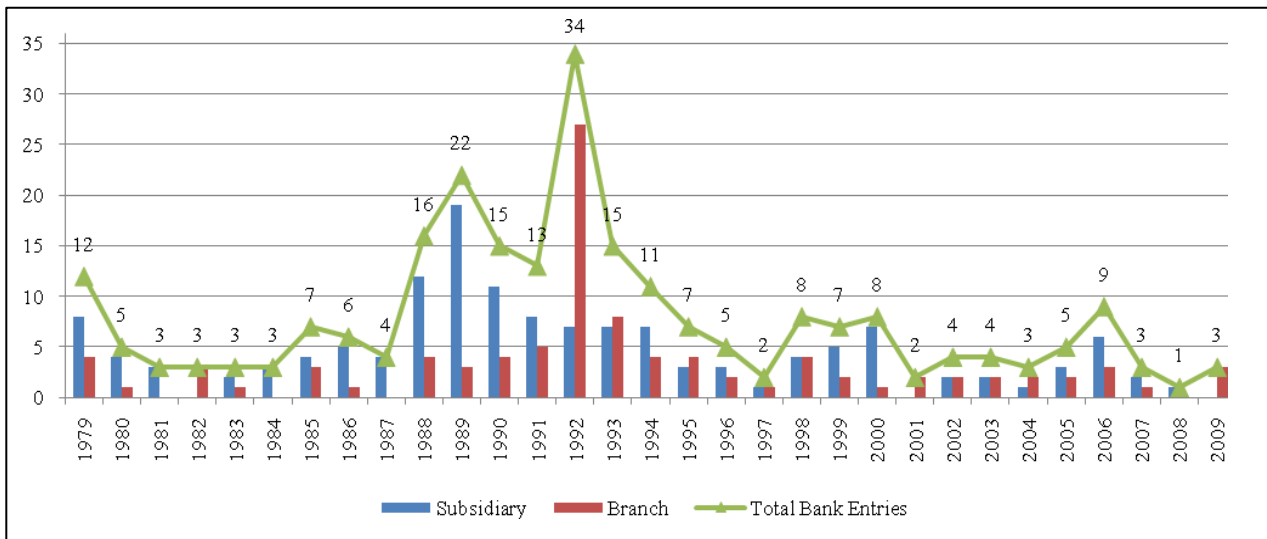
3.2 Private banking (1980s)

The Latin American debt crisis triggered an important portfolio shift in the 1980s (OECD, 2008) leading to a change in banking activities. Banks moved from international syndicated lending to offer more cash flow services and wealth management (private banking), while inter-bank activity continued to grow (IMF, 2002). Luxembourg maintained an attractive legal framework, being among the first countries to transpose EU directives into national law⁴. Other advantages, such as bank secrecy legislation and non-taxation of non-residents' savings income also contributed to growth. The financial centre developed new activities in investment funds, private banking and credit administration. As indicated in Figure 5, foreign banks arrivals continued, with 83 new entries in this phase, in particular German (17), French (8), and Swiss (8) banks. The individual years 1988 and 1989 saw a significant number of entries, respectively 16 and 22. Over the whole decade, 16 banks left Luxembourg (Figure 6), of which five were American banks apparently losing interest in private banking.

³These discouraged US investment abroad by taxing interest income on foreign securities.

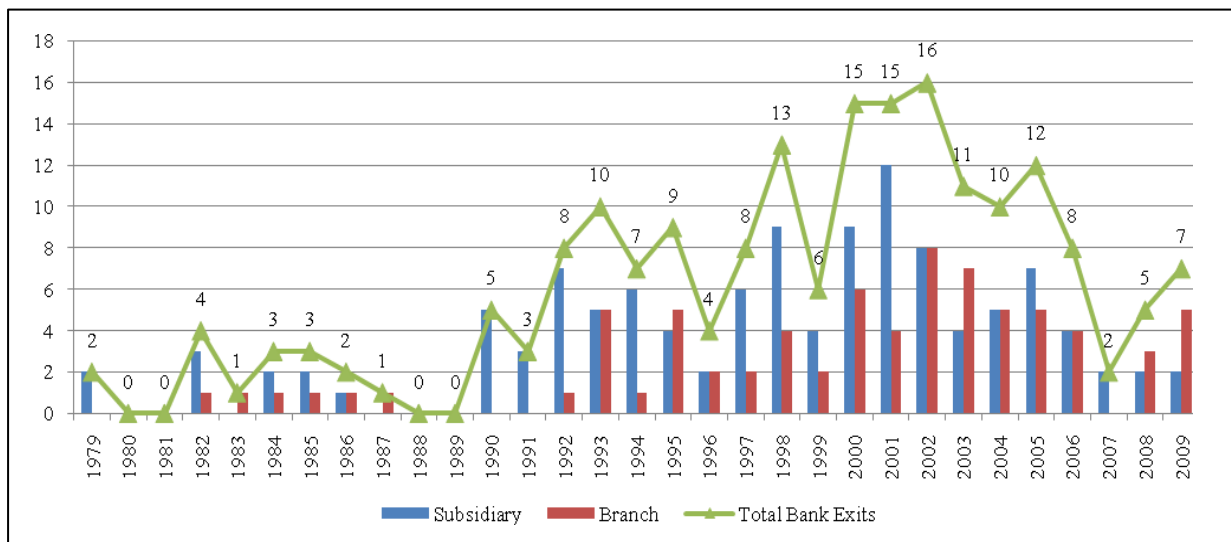
⁴1st EU Directive on banking (1981); UCITS Directive (1985); Directive on free provision of financial services (1988), 2nd EU Directive on banking (1989).

Figure 5: Bank Entries by legal form



Source: BCL

Figure 6: Bank Exits by legal form.



Source: BCL

3.3 Single Market for Financial Services (1990-1996)

The Single Market for Financial Services was established on January 1st 1993 but was broadly anticipated following a long preparation⁵. Its centrepiece was the Second EU Banking Directive, which introduced (i) a single banking license valid throughout the EU, (ii) restrictions on branching and product mix to those authorised by home country regulators, (iii) harmonization of capital requirements. It also defined a new EU banking model based on the concept of the universal bank⁶. This triggered a consolidation process that cut the number of banks in other EU countries. However, this number actually grew in Luxembourg, which attracted more foreign banks, in part by promptly transposing the directive into national law. Luxembourg

⁵ 1st EU Banking Directive (1977), EU White Paper (1985), 2nd EU Banking Coordination Directive (1988).

⁶ Banks were allowed to engage in any activity listed in the annex of the Second Banking Directive, including commercial and investment banking services, leasing, etc.

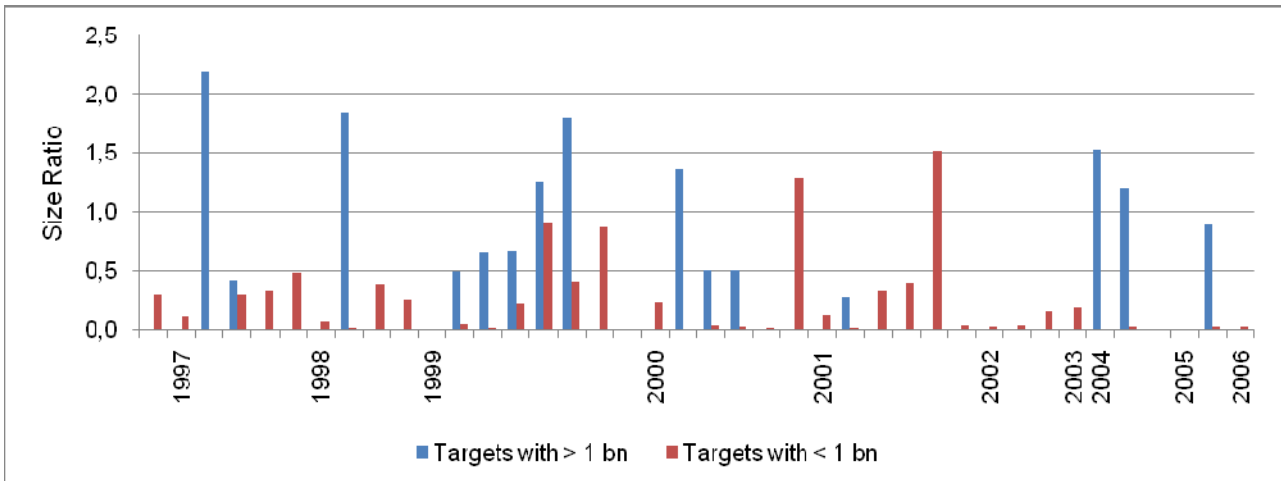
branches of banks accredited in other EU countries remained subject to supervision in their home country. However, branches of non-EU banks were subject to the Luxembourg supervisor, under the same regime as subsidiaries. This encouraged most non-EU banks to open subsidiaries rather than branches in Luxembourg. The introduction of Economic and Monetary Union (EMU) began with Stage One in 1990 when exchange controls were abolished and capital movements were liberalised. This enhanced the process of financial integration, complementing the EU directives. This period also saw rapid expansion of the Luxembourg Stock Exchange, which moved to fully electronic trading and increased activities related to securities trading and listing. It soon gained the dominant position in European bond issues, most of which were European cross-border securities. The banking sector underwent a major expansion in 1991 and 1992, with the number of banks increasing by 10 and then 26. The latter year alone saw the creation of 27 new branches and 7 new subsidiaries, of which most were German banks (20 branches and 4 subsidiaries). This reflected the re-introduction of the German withholding tax on savings income, which did not apply to Luxembourg branches and subsidiaries. The rapid growth in the number of banks in Luxembourg climbed to a peak in 1994 at 222 institutions. However, the average increase in total assets was more gradual (1.11%), indicating that most new banks were relatively small.

3.4 Banking consolidation (1997-2001)

The proliferation of small banks and the new framework provided by the Single Market for Financial Services prompted an unprecedented wave of mergers in which 26 banks disappeared in Luxembourg. This was part of a more general cross-border consolidation process associated with the single banking market⁷, with mergers in Luxembourg often reflecting mergers among parent banks abroad. In Luxembourg a total of 36 banks were involved and mergers usually increased the combined balance sheet of the merged Luxembourg subsidiary, much as it increased the balance sheet of the merged parent banks. Of the 36 mergers in this period, only 10 involved banks of different nationalities: (see top part of Table in Annex A). Mergers also differed in terms of bank size, measured by total assets of the target banks. Figure 7 below reports the size ratio in the merger process, using the average of total assets over the last six months of activity (banks usually reduce activity gradually before closure). About 70% of target banks were small banks, with less than €1 billion. For the remaining 30% of mergers target banks were similar in size to bidders. More detail on mergers during this period is provided in Annex A.

⁷ See ECB (2004), Dermine (2006).

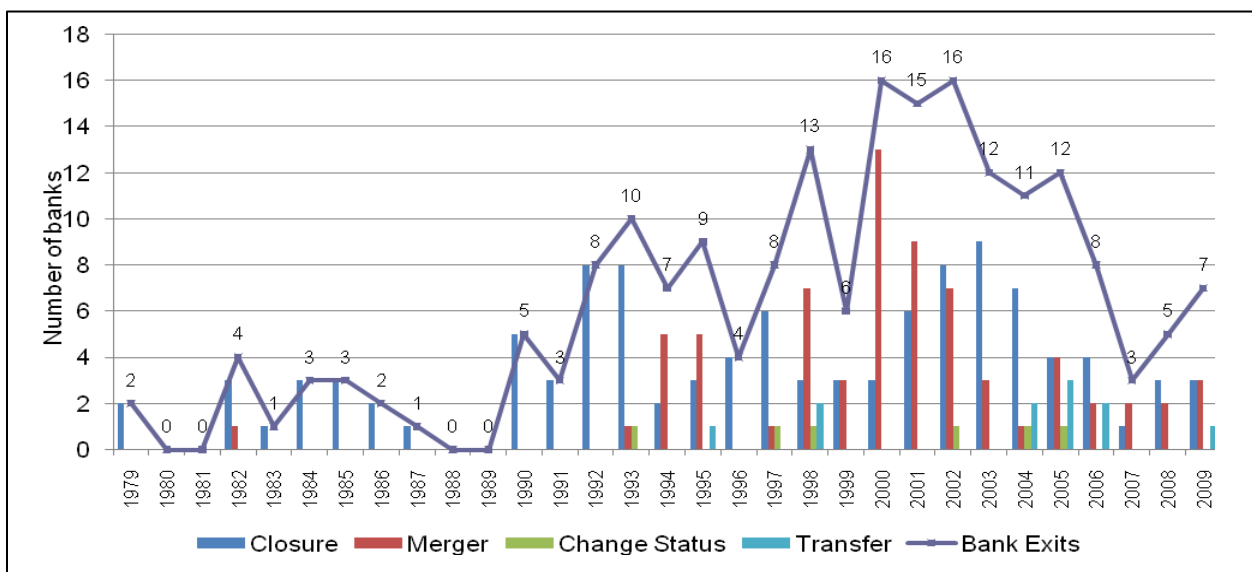
Figure 7: Size ratio (total assets target bank/total assets bidder bank), 1997-2006



Source: BCL

Figure 8 provides detail on the mode of exit, illustrating that mergers really dominated closures during this period of consolidation. Although the sector lost 18 banks, total assets were only marginally affected, as mostly small banks were involved (average assets €200 million).

Figure 8: Bank Exit by Mode: Cession, Merger, Activity Transfer, and Status Change



Source: BCL

Summing up, during this period of banking consolidation the number of banks shrank but total assets continued growing, with an average annual rate of 7.95% and a peak in 2001 at 11.48% (Figure 3). Several factors contributed to the consolidation process (i) technological advances and financial innovation, (ii) the introduction of the single currency, stage three of EMU, in particular for inter-banking activities (iii) the creation of the Banque Centrale du Luxembourg in 1998, which contributed to growth of Luxembourg money market funds.

3.5 Aftermath of the Internet Bubble (2002-2006)

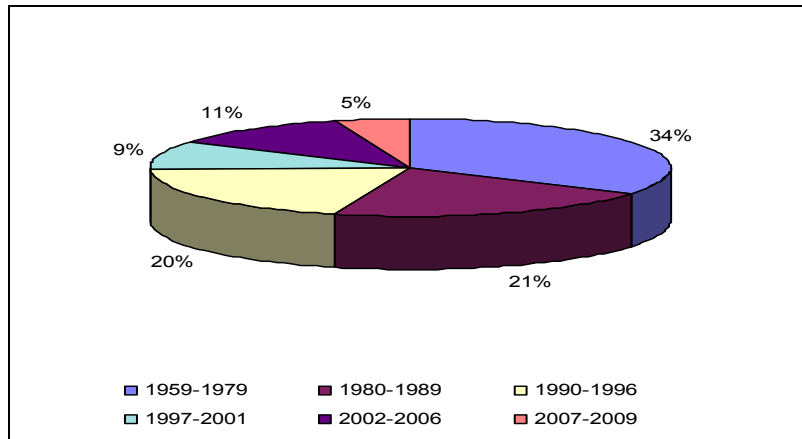
The bursting of the Internet bubble in 2000 led to a sharp drop in world stock markets that strongly affected Luxembourg's financial sector as well as its economy as a whole. There followed a cyclical slowdown that reduced total assets (by 8% in 2002 and 1% in 2003). Bank exits were relatively stable, but bank entries dropped. As illustrated in Figure 8, bank exits switched from mergers (which dominated the previous consolidation period) to closures, mostly affecting banks created in the 1990s. Growth of total assets in the aggregate balance sheet continued, although more slowly, averaging 5.34% per year. In part this was because most exits involved smaller banks (65% of which were branches) with total assets averaging less than €1 billion. The EU Savings Tax Directive introduced in 2003 eliminated the zero withholding tax on investment income that had previously contributed to attract foreign funds to Luxembourg. Along with Belgium and Austria, Luxembourg agreed to progressively increase the withholding tax⁸ rather than implement an automatic information exchange that violated its bank secrecy legislation. While this change posed a challenge for the private banking industry in Luxembourg, the impact on activity was less than originally feared (OECD, 2008, 2010, IMF 2009). The consolidation process continued as the number of small banks shrank. About 80% of target banks had total assets averaging less than €400 million, four times less than bidder banks (Figure 7). On the other hand, for the remainder, total assets of target banks averaged €6 billion and were only slightly smaller than bidder banks.

3.6 Global Financial Crisis (2007-2009)

The global financial turmoil that started in 2007 marked a turning point for the financial industry world-wide. In Luxembourg, bank balance sheets grew only about 1% in 2007 and 2008 and fell sharply in 2009 (-14.4%). The banking sector saw 15 banks disappear: half of them through mergers and the rest through bank closures (Figure 8). Some of these belonged to the waves of bank arrivals in 1992 or in the early 2000s. On average, they involved €1 billion in total assets (see appendix). For the mergers, target banks averaged less than €1 billion total assets between 2007 and 2008, while bidders averaged about €9 billion. In 2009, the pattern reversed: bidder banks were only about 20% the size of target banks. Most bank closures were small banks (about €500 million) and the remainder averaged about €3 billion. In 2010, the banking sector includes 148 banks, of which 110 subsidiaries and 38 branches. Figure 9 shows that despite successive waves of new entries, about 34% of the sector is composed of "old" banks (entered before 1980), about 50% are relatively young banks (entered between 1980 and 2001) and 16% are newcomers (entered after 2001). This suggests that the Luxembourg financial industry is centred on a "core system" of relatively stable banks and a rotating periphery of innovative newcomers.

⁸ A 15% withholding tax was introduced on 1 July 2005, increasing to 20% on 1 July 2008 and 35% on 1 July 2011. Three quarters of tax revenues are transferred to the investor's country of residence.

Figure 9: Surviving banks by year of creation (situation in 2010).



Source: BCL

4. Research Methodology

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. 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.

4.1 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,

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

where $x_i (1, \dots, n)$ 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.

4.2 Testing for Equality of Distributions

The literature on economic growth and convergence includes many alternative approaches. The traditional framework focuses on average behaviour⁹, but Quah (1996) was among the first to analyse convergence dynamics in terms of distributions. This section applies these ideas, with some modifications, to banking. 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:

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

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

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

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

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

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

and where the variance is estimated as

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

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

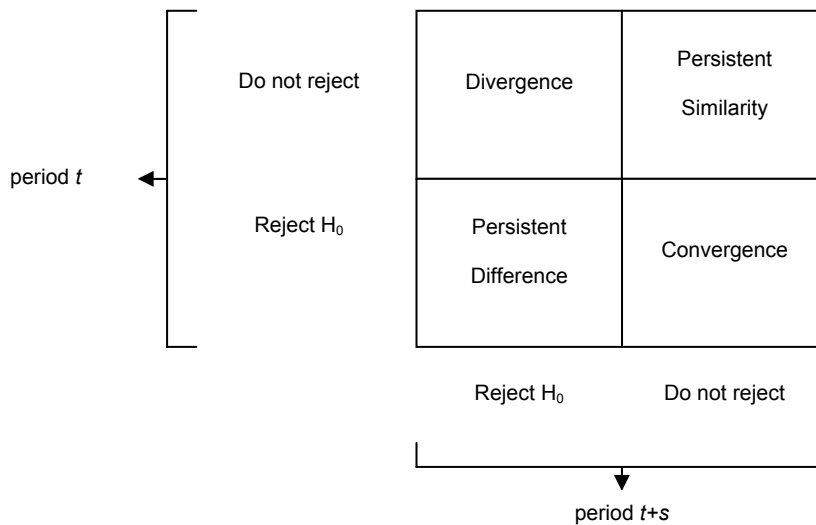
⁹ See Baumol (1986), Mankiw et al. (1992), Sala-i-Martin (2006) and references therein.

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:

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

where $\mathfrak{S}(\hat{J}^b > \hat{J})$ 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 10): Convergence, Divergence, Persistent Similarity and Persistent Difference.

Figure 10: Taxonomy of Distribution Dynamics.



“Convergence” means that statistical differences between distributions were significant at time t and became insignificant at time $t+s$. “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.

5. Empirical Results

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. In this section, we focus on the following five balance sheet items¹⁰:

- 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 assets¹¹ 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 113 in 2007 and 148 and 110 in 2009. Table 2 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.

¹⁰ Other variables, including some from the profit and loss account, are considered in the annex.

¹¹ Deposits are normalised by total liabilities, but these are identical with total assets in what follows.

Table 2 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 3 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 3: Li (1996) test of equal distributions (p-values) across groups and across periods

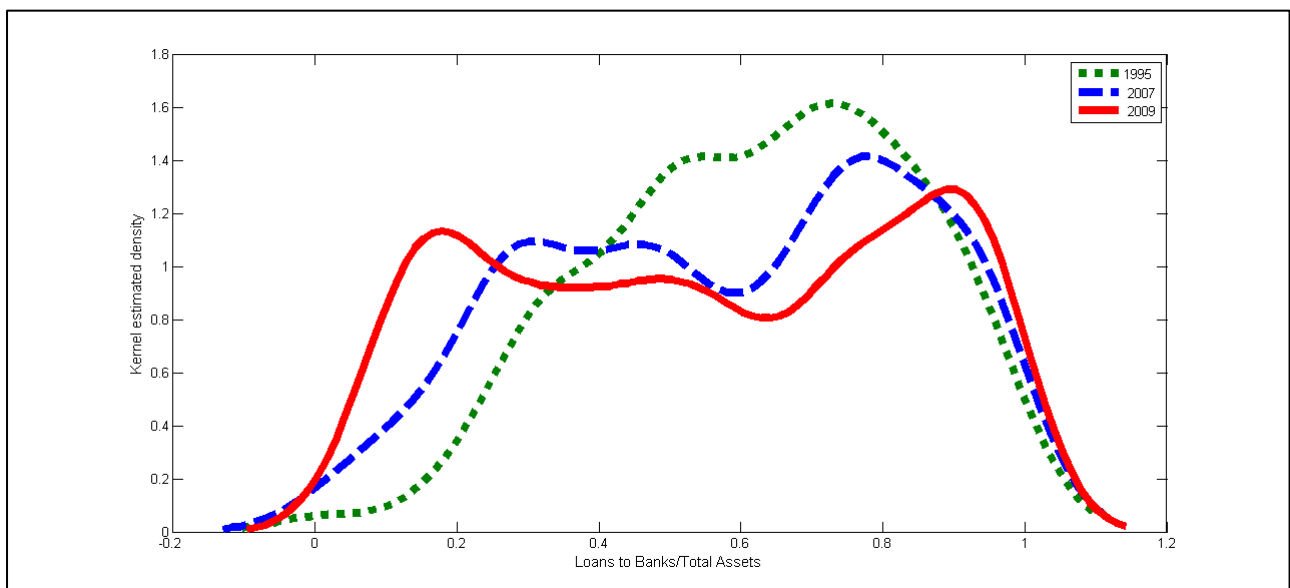
Period	Activities				
	Interbank Loans	Interbank Deposits	Customer Loans	Customer Deposits	Securities
Branches and Subsidiaries combined					
1995-2007	0.044	0.002	0.223	0.235	0.044
2007-2009	0.804	0.662	0.044	0.591	0.018
Within group analysis: Subsidiaries					
1995-2007	0.033	0.012	0.216	0.012	0.008
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

5.1 Interbank loans: Changes in specialization

Subsidiaries and Branches combined

Figure 11 reports the share of interbank loans in total assets across 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. 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).

Figure 11: All banks - Ratio of interbank loans to total assets.



Source: Own calculations

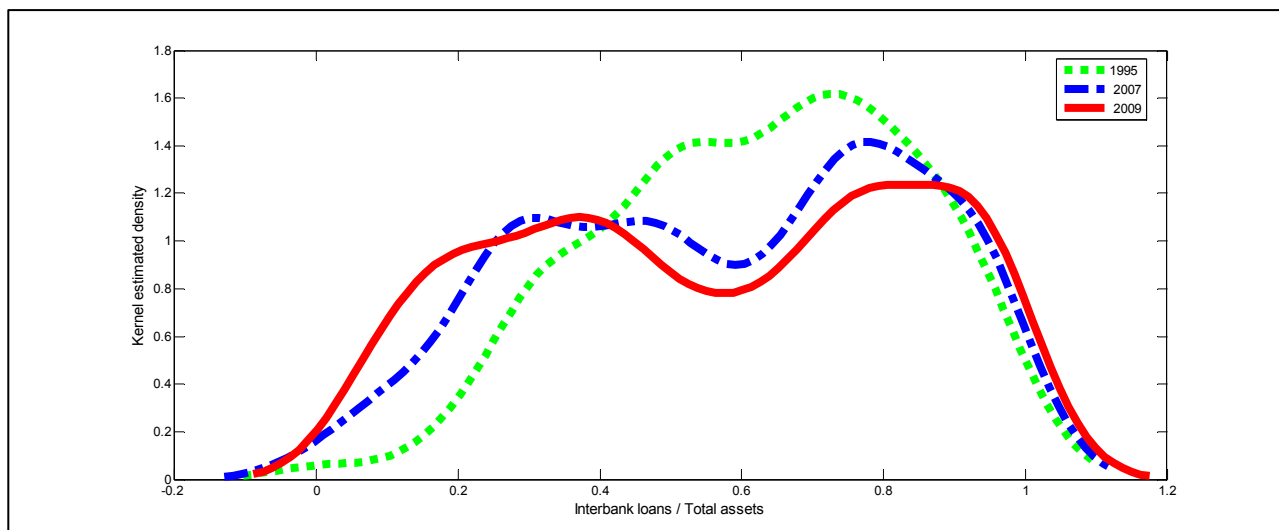
Note that the information reported in Figure 1 concerning the aggregate balance sheet for the industry as a whole only records a gradual decline in the share of interbank loans from nearly 60% of total assets in 1995 to just above 50% in 2007, with a more sudden dip during the financial crisis to around 47% in 2009. The contrast with Figure 11 is natural, as the evolution of the (weighted) average across banks in Figure 1 can provide no information about the increase in diversification in Figure 11 as suggested by the progressive flattening of the distribution. Nor can the weighted average reveal the strong specialization apparent at the extremes with the emergence of a second mode on the left.

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 11a 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).

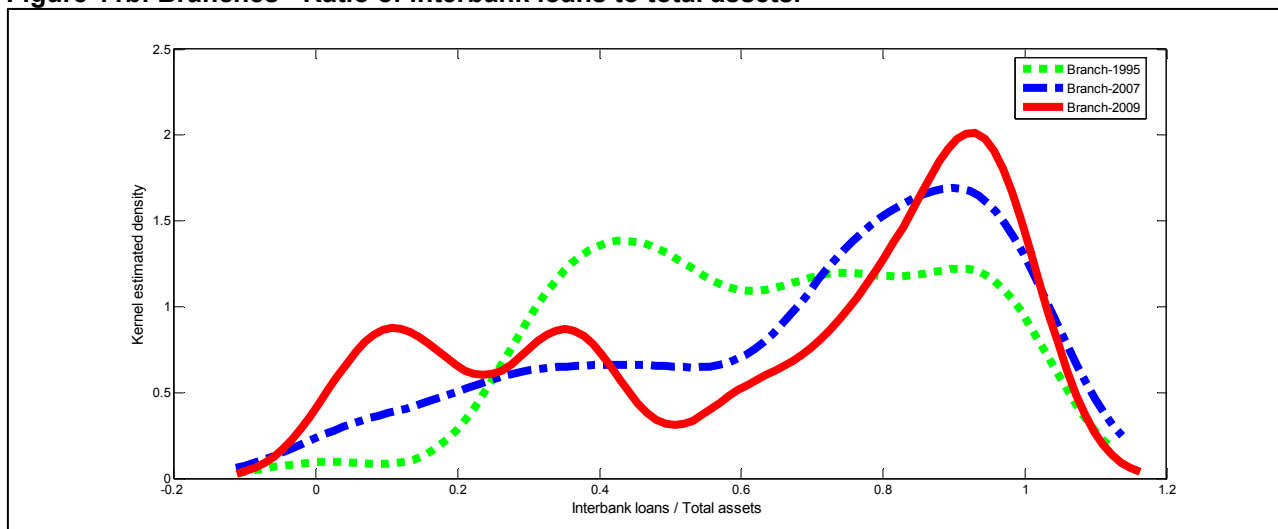
Figure 11a: Subsidiaries - Ratio of interbank loans to total assets.



Source: Own calculations

Figure 11b 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).

Figure 11b: Branches - Ratio of interbank loans to total assets.



Source: Own calculations

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.

Between-group analysis

Comparing the distributions for branches and for subsidiaries there is limited evidence of persistent similarity. Table 3 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.

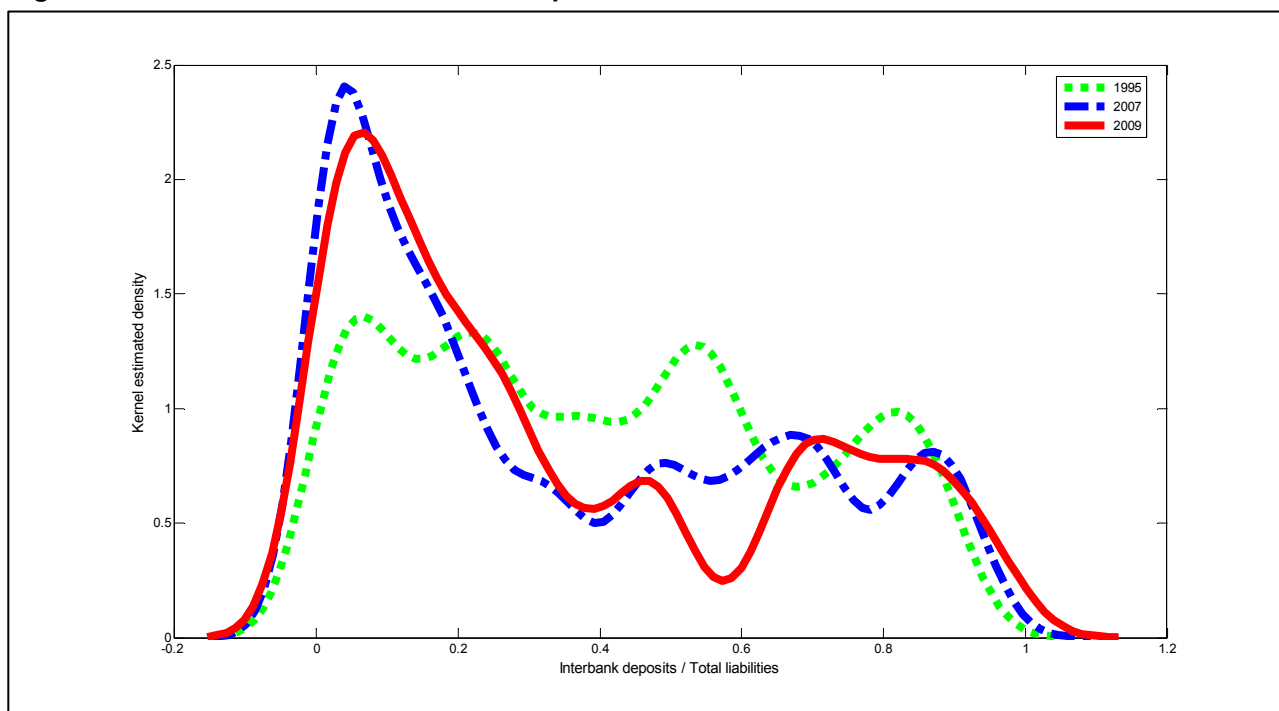
5.2 Interbank deposits: Changes in specialization

Subsidiaries and Branches combined

The distribution of interbank deposits (Figure 12) contrasts with the distribution of interbank loans discussed previously. First, the distribution went from relatively flat to relatively concentrated 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 12: All banks - Ratio of interbank deposits to total liabilities.



Source: Own calculations

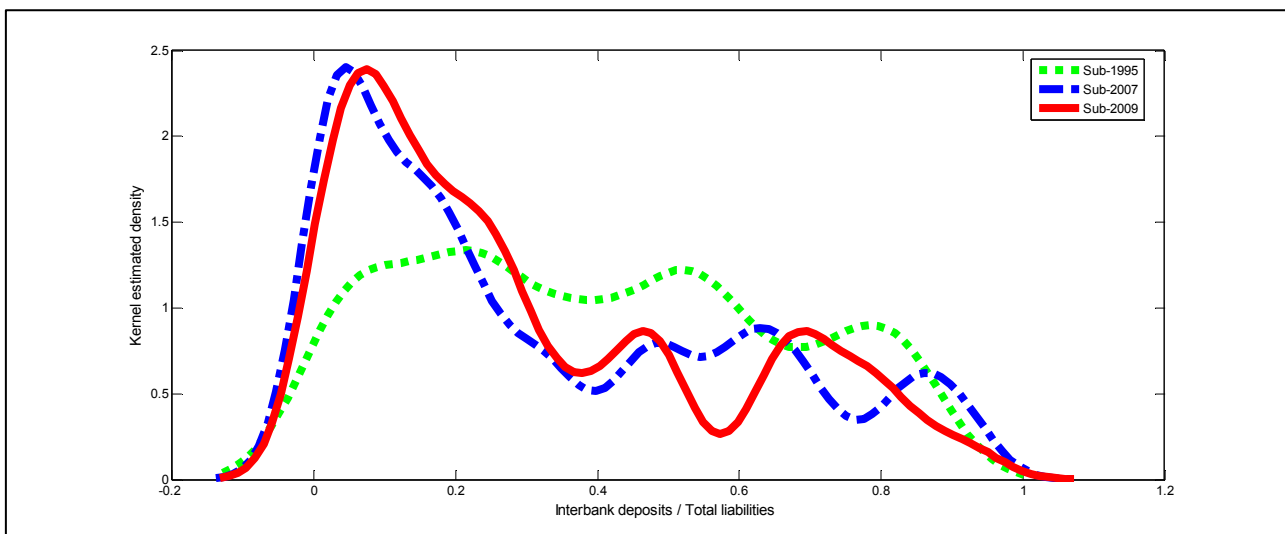
The Li (1996) test rejects the hypothesis of equal distributions in 1995 and 2007, (p-value 0.002), but does not detect significant changes between 2007 and 2009 (p-value 0.669). The data aggregated over the whole banking sector disguises these changes completely. In Figure 1, the (weighted) average share of interbank deposits in total liabilities actually increased from 45.8% in 1995 to 47.8% in 2007, although the appearance of the left peak in Figure 12 suggests that for most banks this share was falling. In 2009, the (weighted) average share increased further to 48.0%, so the aggregate data suggests a stable increasing trend. Instead, the distribution across banks in Figure 12 reveals that this share fell in most banks, which means that the relatively fewer banks with a large share of interbank deposits must also be larger in size.

This is consistent with Figure 2, which reported a sharp increase in the CR5 concentration ratio in this segment.

Within-group analysis

Figure 12a 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.

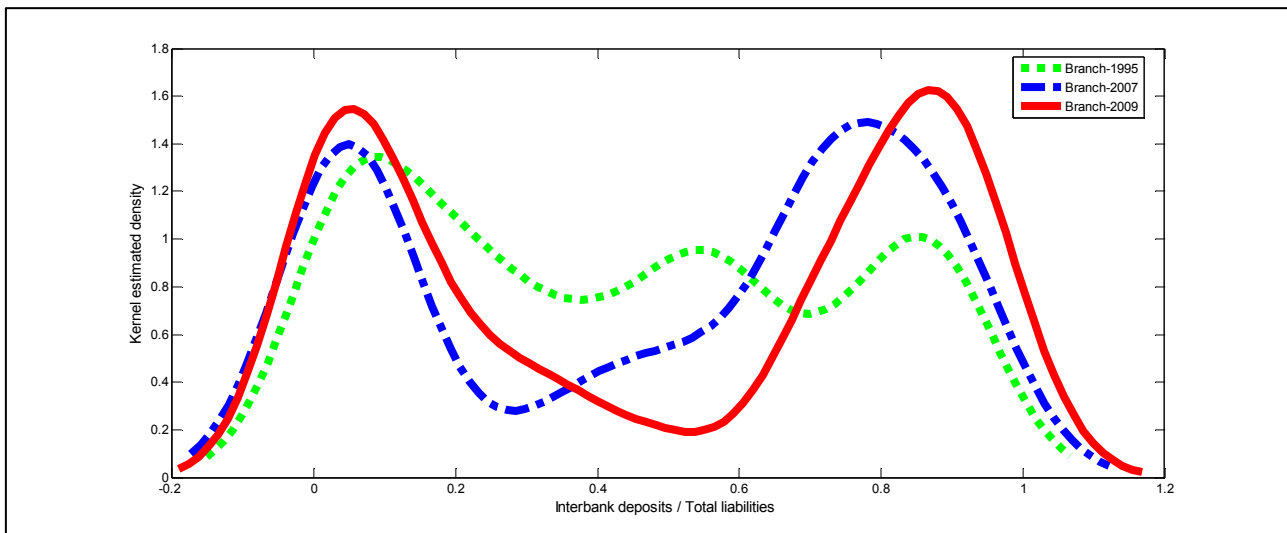
Figure 12a: Subsidiaries - Ratio of interbank deposits to total liabilities.



Source: Own calculations

Instead, the distribution for branches (Figure 12b) 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. 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.

Figure 12b: Branches - Ratio of interbank deposits to total liabilities.



Source: Own calculations

Between-group analysis

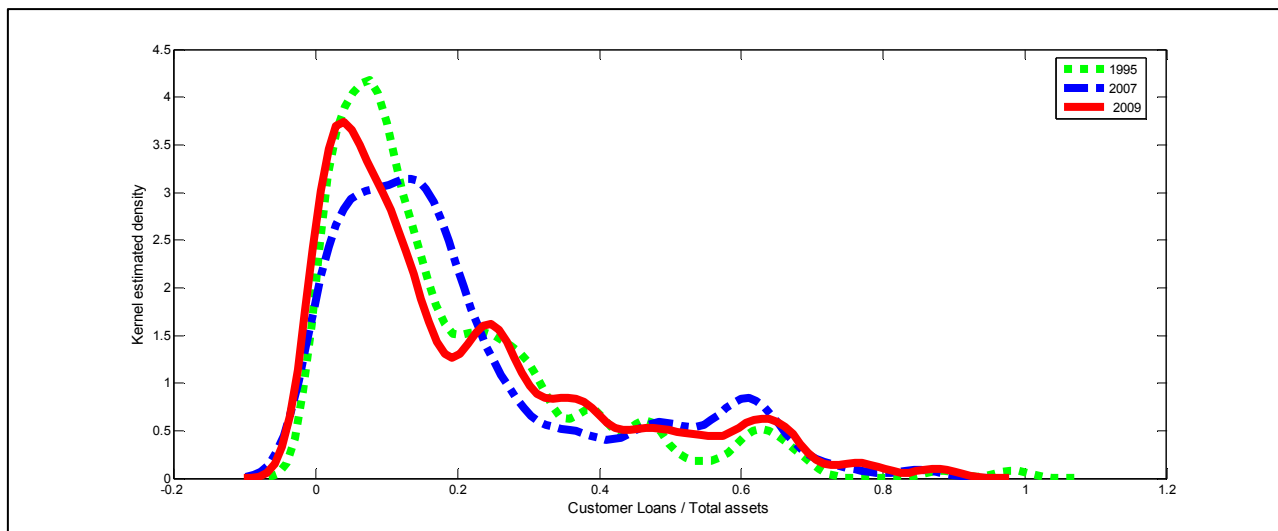
As could be expected from the visual comparison, the Li test suggests divergence between branches and subsidiaries (p-value falls substantially, from 0.905 in 1995 to 0.005 in 2007 and to 0.001 in 2009). This is consistent with increasing differences between branches and subsidiaries in terms of the 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.

5.3 Customer loans: Changes in specialization

Subsidiaries and Branches combined

For most banks, customer loans do not constitute the major activity, as indicated by the left skew of the distribution in Figure 13 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 in Figure 2 (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 13: All banks - Ratio of customer loans to total assets.



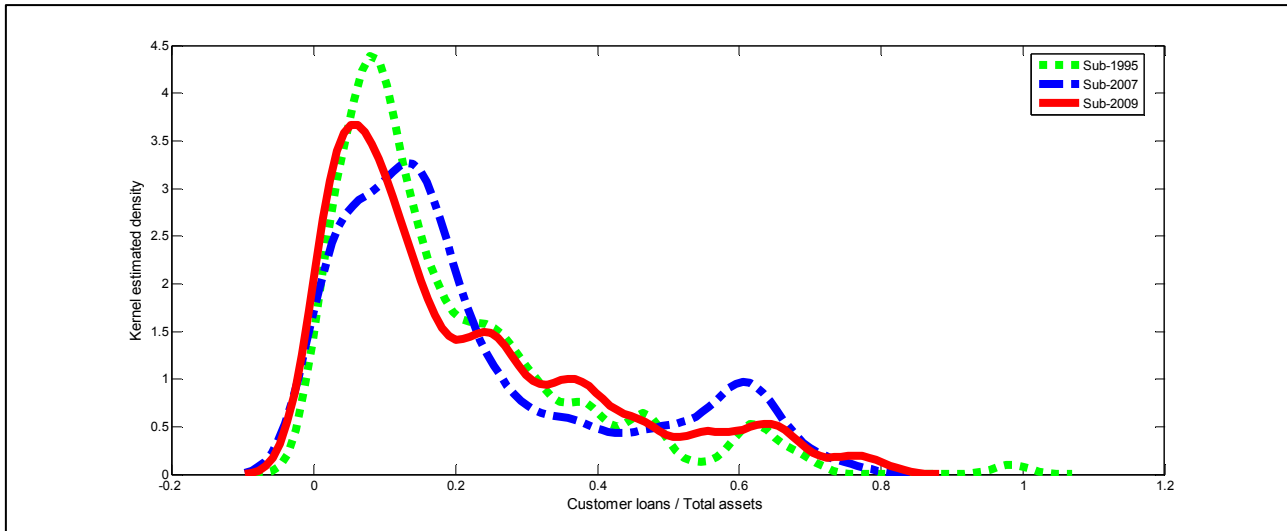
Source: Own calculations

Again, the data reported in Figure 1, which aggregates across all banks in the industry, fails to illustrate and measure the phenomenon of the left skew of the distribution. The (weighted) average share of customer loans in total assets rose from 18.1% in 1995 to 19.9% in 2007 and then surged during the financial crisis to 23.9% in 2009. One can conclude that while most banks appear to be concentrated in the left peak with low shares of customer loans, growth among the largest banks systematically raised the weighted average share over time. In other words, the sector seems to have specialised away from customer lending, but growth among large banks has increased the share of this item in the aggregate balance sheet.

Within-group analysis

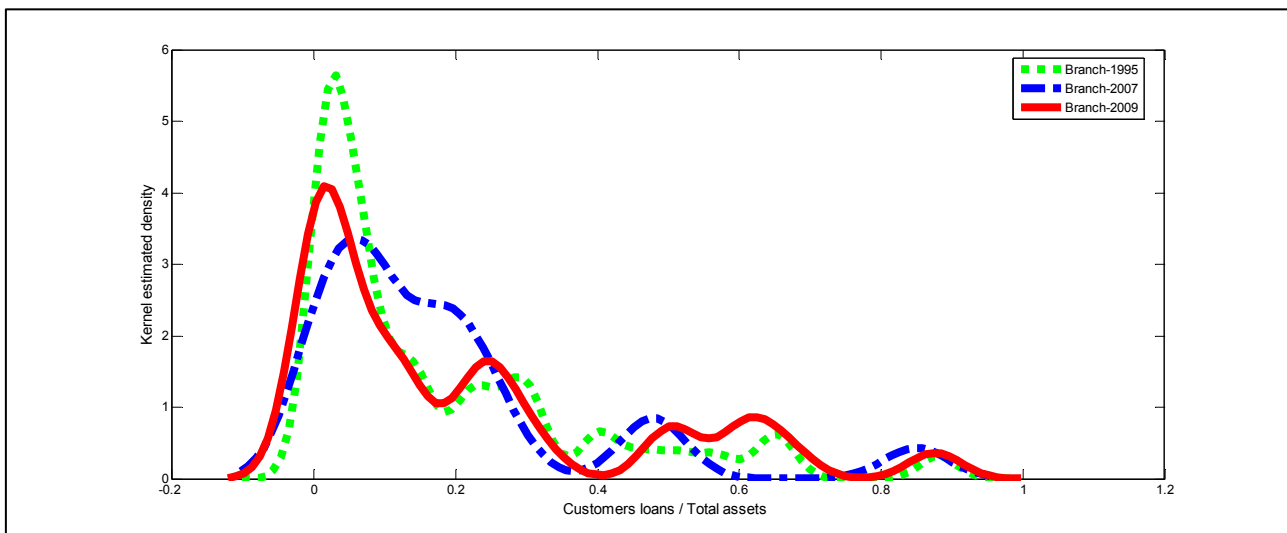
Separate analysis for subsidiaries (Figure 13a) and branches (Figure 13b) reveals no significant differences across time. In fact, the p-values reported in Table 3 are not very high. Neither subsidiaries nor branches appear to have changed their customer lending behaviour over time. The temporary flattening 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 13a: Subsidiaries - Ratio of customer loans to total assets.



Source: Own calculations

Figure 13b: Branches - Ratio of customer loans to total assets.



Source: Own calculations

Between-group analysis

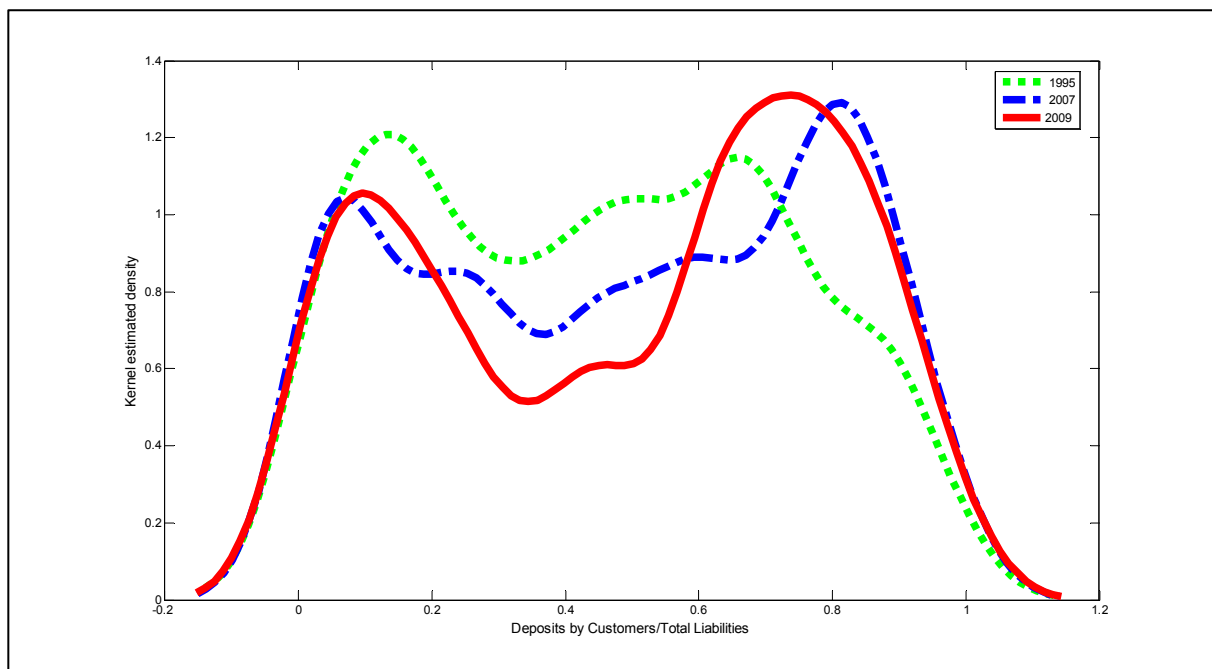
Comparing the share of customer loans across groups, differences between subsidiaries and branches are always significant. However, the p-value increased from 0.000 in 1995 to 0.037 in 2007, suggesting persistent difference, and then fell during the financial crisis (0.0018 in 2009). This suggests persistent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

5.4 Customer deposits: Changes in specialization

Subsidiaries and branches combined

The share of customer deposits in total liabilities is fairly dispersed, as shown in Figure 14. 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 3).

Figure 14: All banks - Ratio of customer deposits to total liabilities.



Source: Own calculations

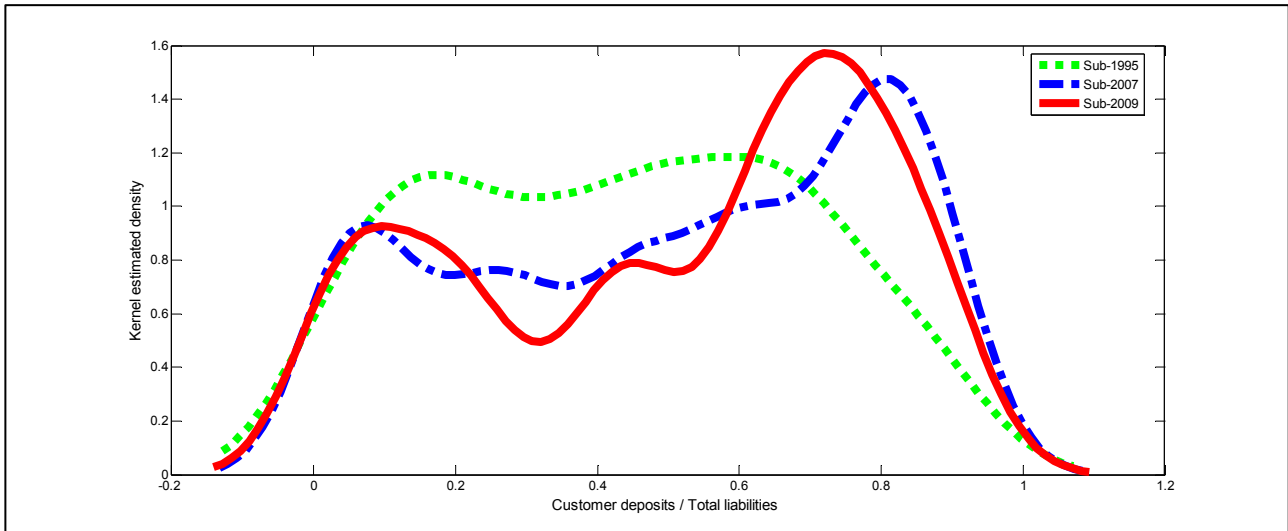
At the aggregate level, the data in Figure 1 indicate that overall customer deposits fell from 41.0% of total liabilities in 1995 to 34.0% in 2007 and 32.6% in 2009. This steady decline in the aggregate share disguises the steady growth in mass at the right end of the distribution in Figure 14. Presumably, the falling aggregate share means that it is smaller banks that have increased their activity in customer deposits, while larger banks tended to find themselves towards the left, with customer deposits representing a lower share of total liabilities.

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 14a 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). This trend continued during the financial crisis, with a possible bi-modal

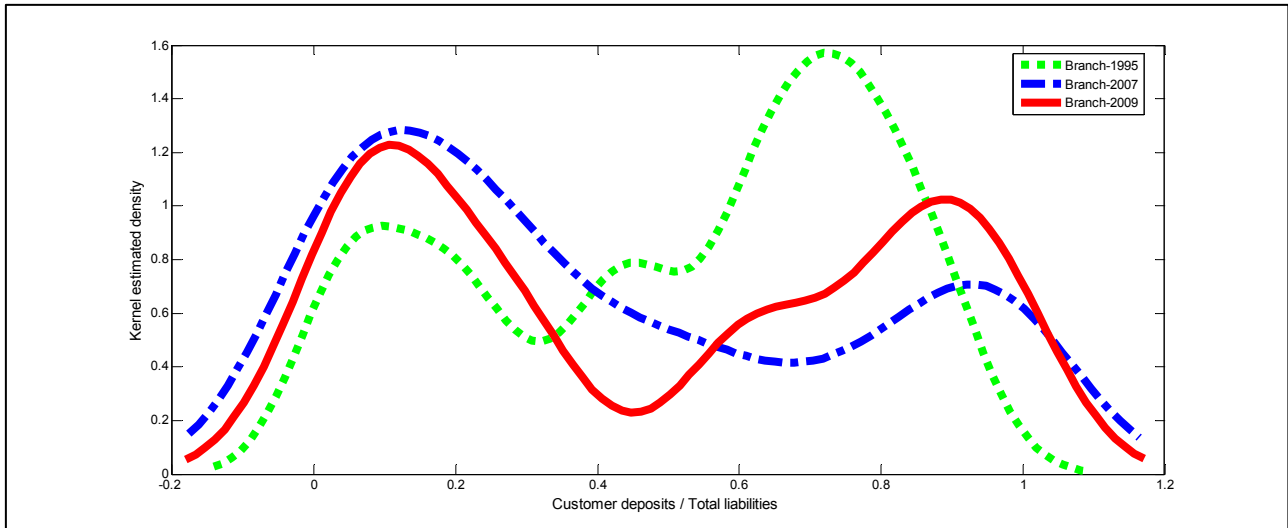
distribution appearing (less mass in the middle, second peak at low shares). Overall, the distribution for subsidiaries went from fairly diversified to fairly specialised, with many subsidiaries holding a very large share of liabilities as customer deposits, while others specialised away from this activity,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

Figure 14a: Subsidiaries - Ratio of customer deposits to total liabilities.



Sources: Own calculations

Figure 14b: Branches - Ratio of customer deposits to total liabilities.



Sources: Own calculation

Similar specialization appeared for branches (Figure 14b), 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.

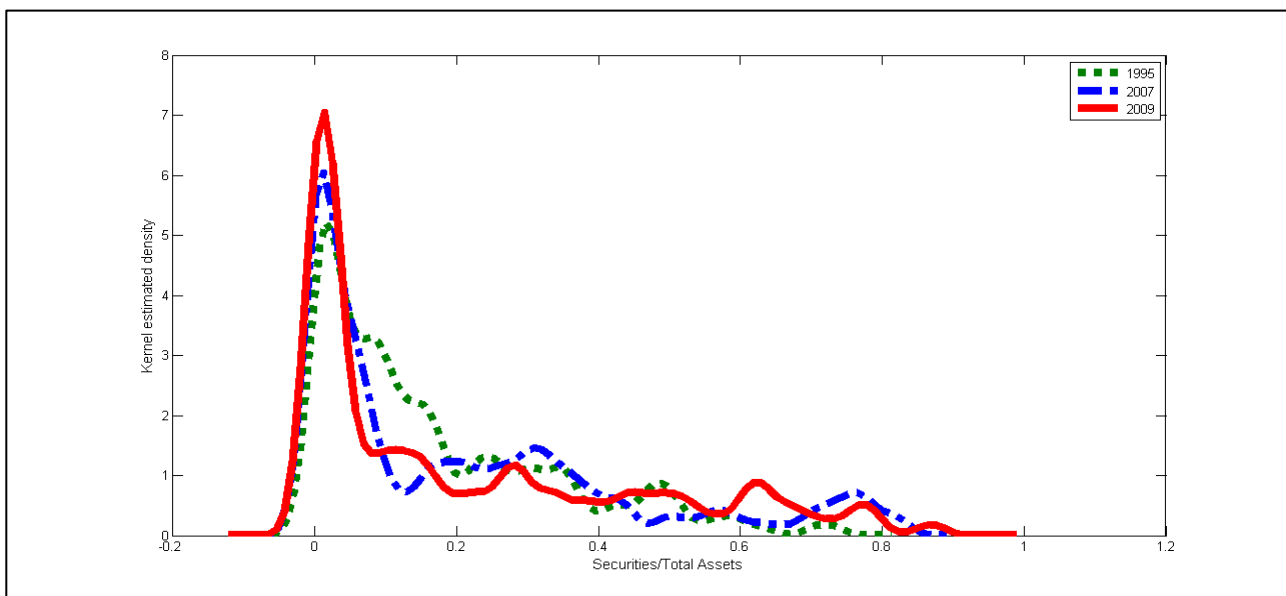
5.5 Securities held: Changes in specialization

Subsidiaries and branches combined

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 15. 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.

Aggregating across banks, the data in Figure 1 indicate that securities held represented 19.1% of total assets in 1995 and rose to 26.9% in 2007. They dropped below 20% in 2009 (18%). This is consistent with the appearance of bumps in the right tail of the distribution in Figure 15, but neglects the changes in the peak at the left, which steadily grew taller. The latter fact suggests that many banks in Luxembourg hold very few assets in the form of securities; something obscured by the high and apparently stable share in the aggregate data. One could also deduce from the behaviour of the aggregate share that it is mostly the smaller banks that are concentrated in the peak near zero.

Figure 15: All banks - Ratio of securities held to total assets.

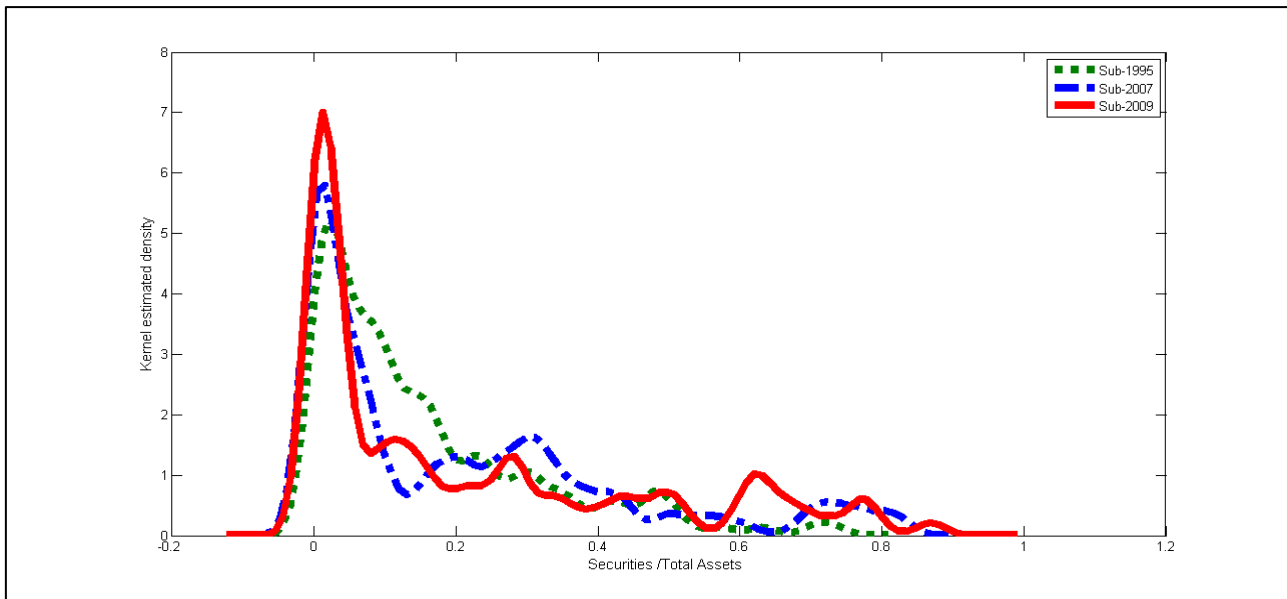


Source: Own calculations

Within-group analysis

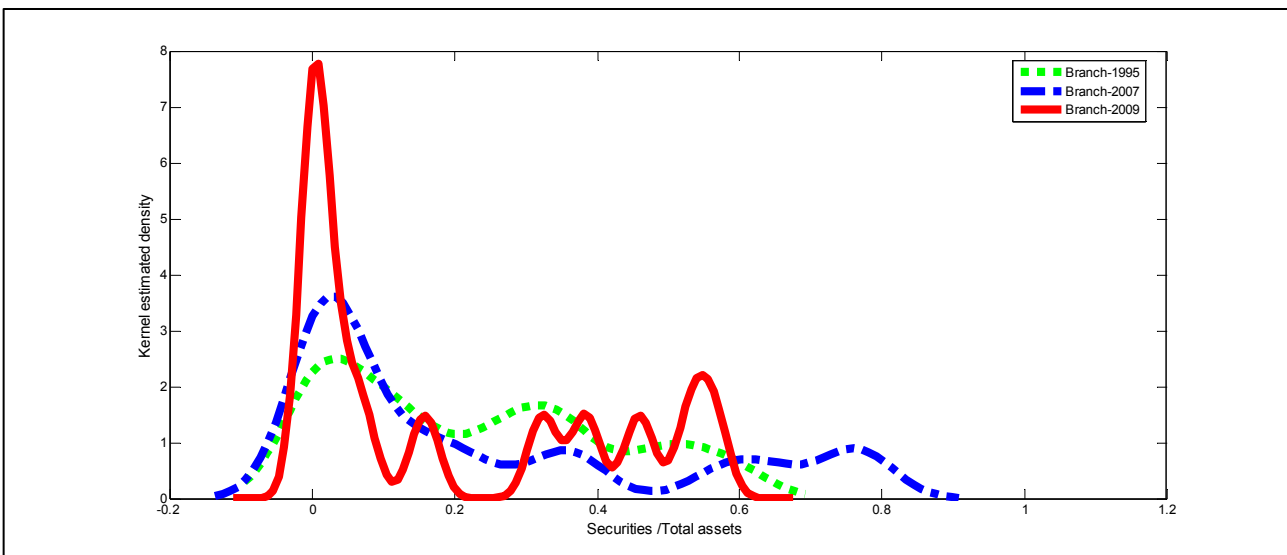
The separate distributions for subsidiaries (Figure 15a) and branches (Figure 15b) both resemble Figure 15, with a sharp peak at the left and a bumpy tail at the right. The p -values for the Li (1996) test reported in Table 3 indicate statistically significant changes in the distribution for subsidiaries 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 15a: Subsidiaries - Ratio of securities held to total assets.



Source: Own calculations

Figure 15b: Branches - Ratio of securities held to total assets.



Source: Own calculations

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.

6. Conclusions

Luxembourg's banking sector evolved through several stages: the Euro-bond markets, private banking, Economic and Monetary Union and the accompanying financial liberalisation and integration, the Single Market for Financial Services, the intensification of the international competition and the resulting bank consolidation process, the aftermath of the Internet Bubble and the Global Financial crisis. These have all brought important changes to the financial centre with likely impact on the pattern of specialisation and the degree of heterogeneity.

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 focussed 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.

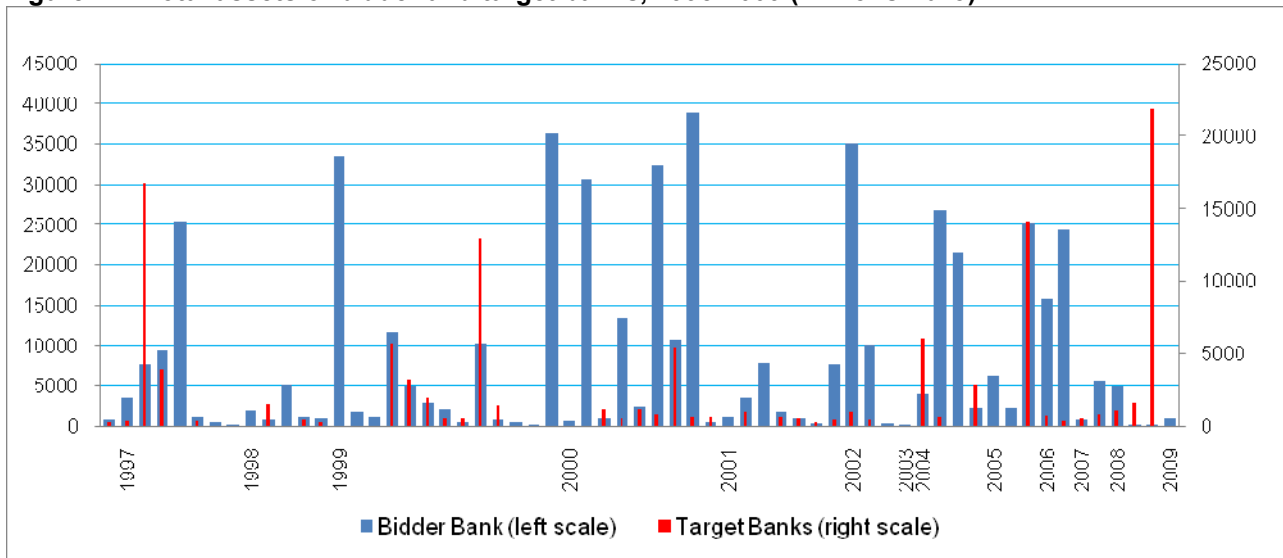
There are several conclusions we can draw from these results. First, the degree of specialisation and heterogeneity varies across different market segments as well as through time. Second, comparing subsidiaries and branches, estimated distributions across banks have been relatively similar for Interbank 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.

This study provides background intended to improve efficiency and productivity analysis of the Luxembourg banking sector, including international comparisons, which often drop Luxembourg as an outlier because of its high per capita GDP and dominant financial sector. However, Luxembourg plays a crucial role in European financial market integration, acting as a catalyst to construct cross-border links both in the interbank market and in retail banking. Furthermore, the Luxembourg financial sector benefits from the agglomeration of specialised skills that should encourage innovation in the sector at a European level. Our results confirm the specificities of this banking sector (high heterogeneity between branches and subsidiaries) and provide both qualitative and quantitative indications of changing structure within the sector.

Appendix A: Merger activity

Figure A1: Total assets of bidder and target banks, 1995-2009 (millions Euro)



Source: BCL

Table A1: Bank Exit by mode¹⁶.

Year	TOT	Mergers			Closure Tot(sub)	Transfer Branch- Sub	Status Change
		Sub- Sub	Branch- Sub	Branch- Branch			
1995	6	NA	NA	NA	3(0)		
1996	0				4(2)		
1997	2	2			6(4)		
1998	7	6	1		3(2)	2	1
1999	5	3	1	1	1(1)		
2000	13	9	2	2	2(1)		
2001	9	8		1	6(3)		
2002	7	6		1	8(2)		1
2003	3	2		1	9(2)		
2004	1	1			7(3)	2	1
2005	4	4			5(2)	2	1
2006	3	2	1		5(3)		
2007	2	2			1(1)		
2008	2	2			3(1)		
2009	3	1	1	1	3(2)	1	
Total	67	48	6	7	66	7	4

Note: Number of subsidiaries in parentheses

Source: BCL

¹⁶Information about mergers before 1995 is unreliable.

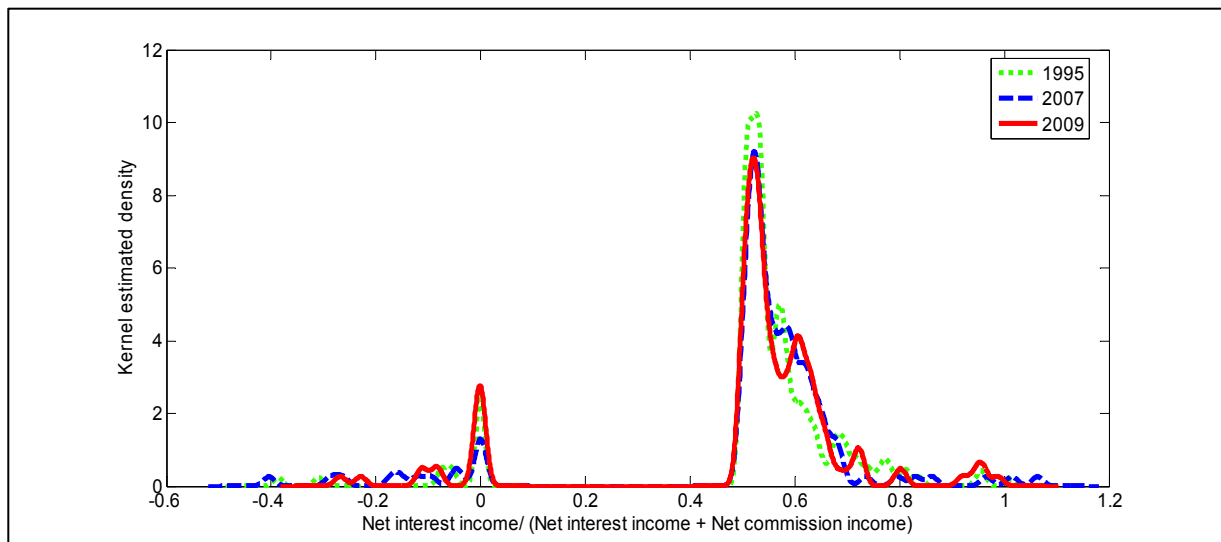
Table A2: Cross-Border Mergers among Luxembourg banks.

Year	Target	Nat	Bidder	Nat
1997	Crédit Agricole Luxembourg S.A.	FR	Caisse Hypothécaire du Luxembourg S.A.	LU
1998	BR & Associés, Banquiers S.A.	CH	Cerabank (Luxembourg), S.A.	LU
1998	Préfilux	LU	Banque Internationale à Luxembourg, S.A.	BE
1999	Robeco Bank (Luxembourg), S.A.	CH	Rabobank Luxembourg S.A.	FR
1999	Bankers Trust Luxembourg S.A.	US	Deutsche Bank Luxembourg S.A.	DE
2000	MeritaNordbanken Luxembourg SA	FI	Unibank S.A.	SE
2001	Crédit Commercial de France (Luxembourg), S.A.	FR	HSBC Republic Bank Luxembourg, S.A.	GB
2001	Banque Baumann & Cie S.A.	CH	VP Bank Luxembourg, S.A.	LI
2001	Bank Labouchere (Luxembourg), S.A.	NL	Dexia Banque Internationale à Luxembourg	BE
2002	Artesia Bank Luxembourg	BE	Banca Lombarda International S.A.	IT
2002	Dexia Nordic Private Bank Luxembourg S.A.	DK	Dexia Banque Internationale à Luxembourg S.A.	BE
2003	ING Bank (Luxembourg), S.A.	NL	ING Luxembourg S.A.	BE
2005	Banque Continentale du Luxembourg SA	LU	Kredietbank, S.A. Luxembourgeoise	BE
2005	Banque Corluy Luxembourg, S.A.	BE	ABN Amro Bank	NL
2006	United European Bank, Luxembourg, S.A.	CH	BNP Paribas Luxembourg	FR
2006	Banca Nazionale del Lavoro International, S.A	IT	BNP Paribas Luxembourg	FR
2007	Unibanco (Luxembourg) S.A.	BR	Banco Itau' Europa Luxembourg, S.A.	PT
2009	BNY Mellon Asset Servicing B.V., Luxembourg Branch	NL	Bank Mellon S.A., Flash NV Luxembourg Branch	BE

Appendix B: Interest Income and Commission Income

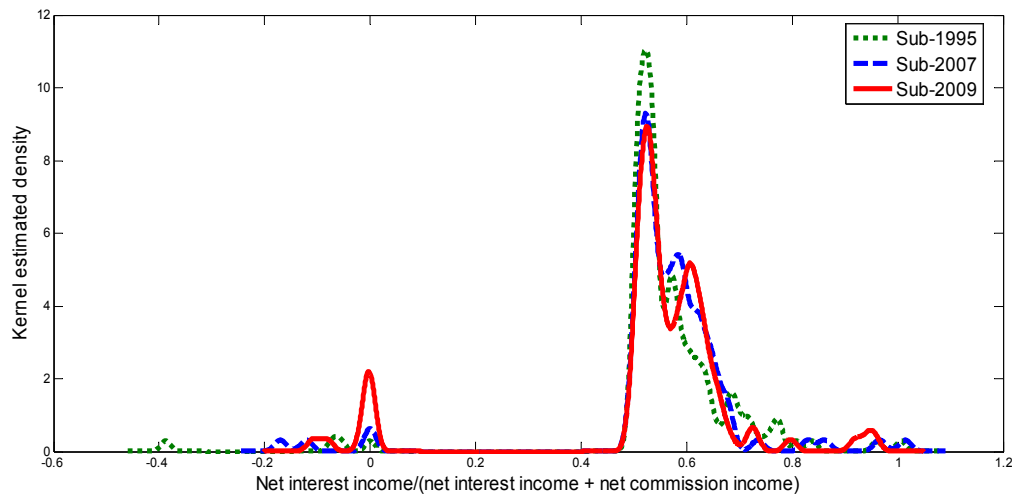
An important part of the production process in the Luxembourg bank sector concerns income from commissions. Since this activity does not appear directly on the balance sheet, we cannot provide the same analysis as for the other financial products considered. However, the graphs below plot the estimated distribution of the share of net interest income in the sum of net interest income and net income from commissions. If we consider the interval $[0,1]$, banks focused on traditional intermediation activity should have values of this ratio around unity. Instead, banks focused on activities generating commission income should have much lower values of this ratio. Since banks can also face losses on net commissions, sometimes entirely offsetting net interest income, some observations take values greater than 1. The interesting feature of the graph below is the apparent « dead zone » between 5% and 45%. This suggests that (i) most of banks generate their net income from traditional intermediation and (ii) there are twin peaks in the distribution of this ratio. The distribution also appears to be stable over time.

Figure B1: All banks - Ratio of net interest income to net income.



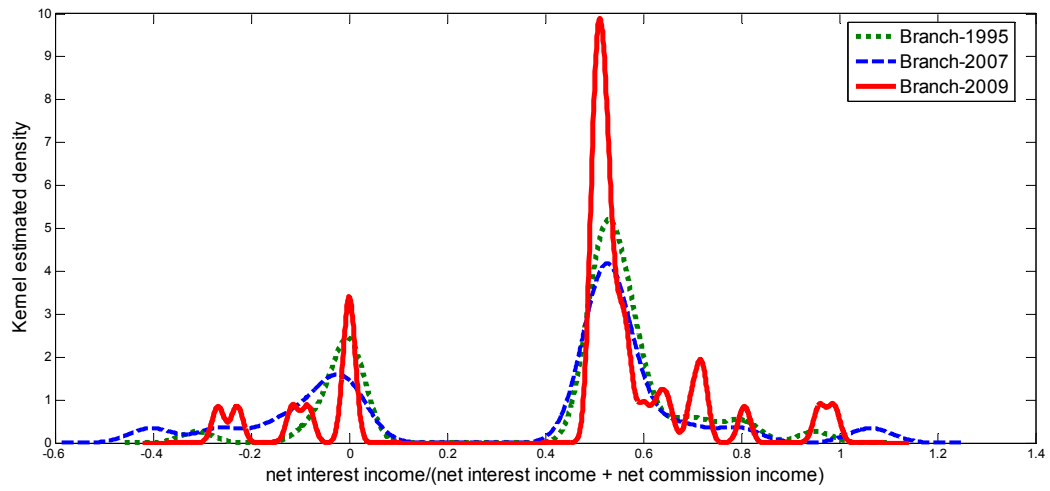
Source: Own calculations

Figure B2a: Subsidiaries - Ratio of net interest income to net income.



Source: Own calculations

Figure B2b: Branches - Ratio of net interest income to net income.

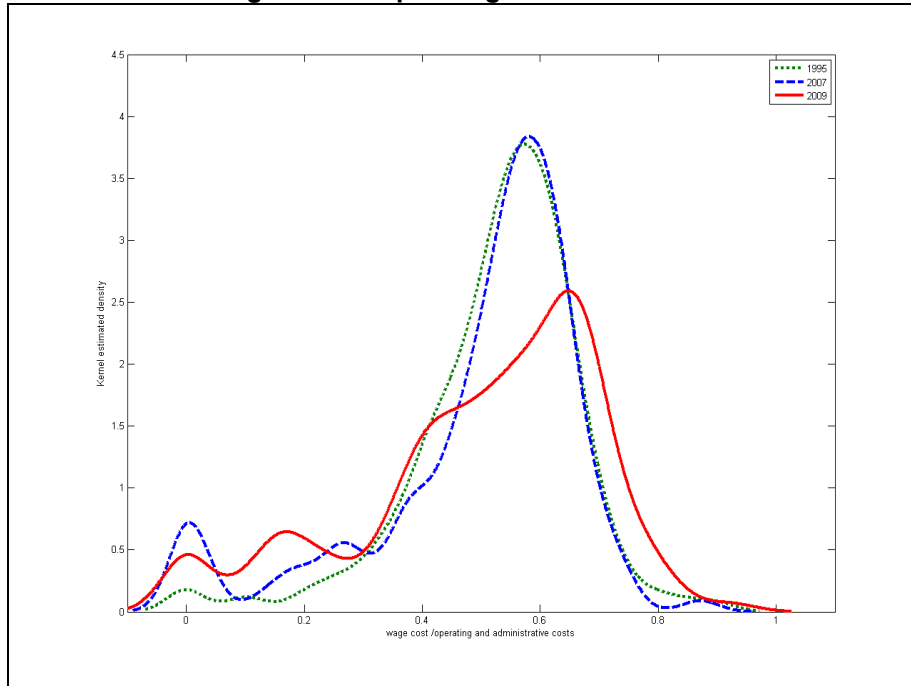


Source: Own calculations

Appendix C: Labour costs

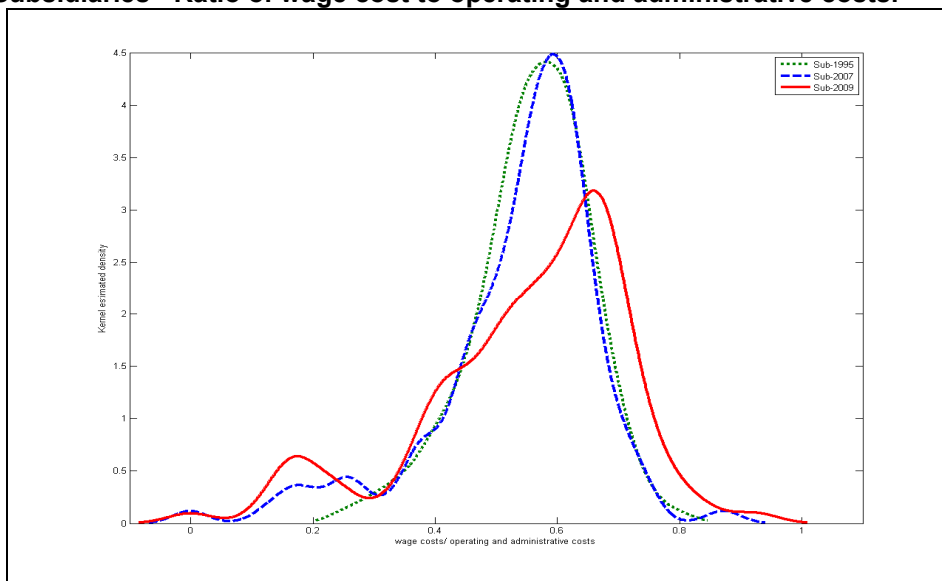
Changes in the mix of different outputs produced might also require adjusting the level and combination of inputs. Compared to branches, subsidiaries tend to invest more in local fixed assets and to employ more staff (Figure C2). Moreover, the number of employees of subsidiaries has increased at higher growth rate than the number of employees of branches. Fixed assets appear to have remained stable over time. The figures below report the share of wage costs in the sum of operating costs and administrative costs. This share tends to be higher in subsidiaries.

Figure C1: All banks - Ratio of wage cost to operating and administrative costs.



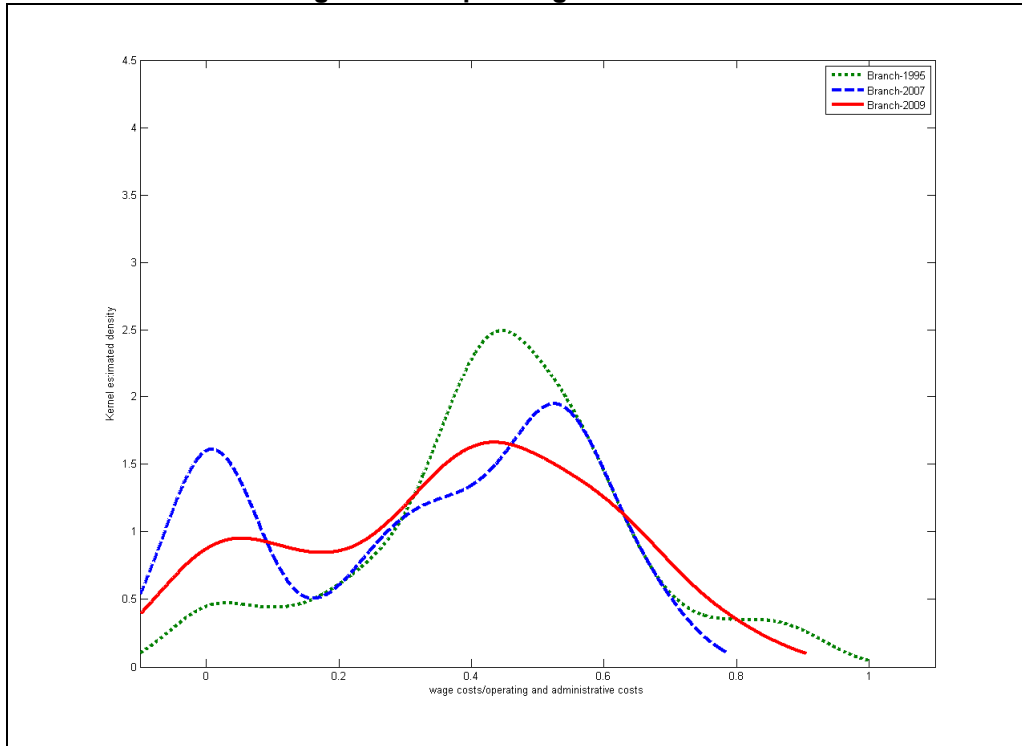
Source: Own calculations

Figure C1a: Subsidiaries - Ratio of wage cost to operating and administrative costs.



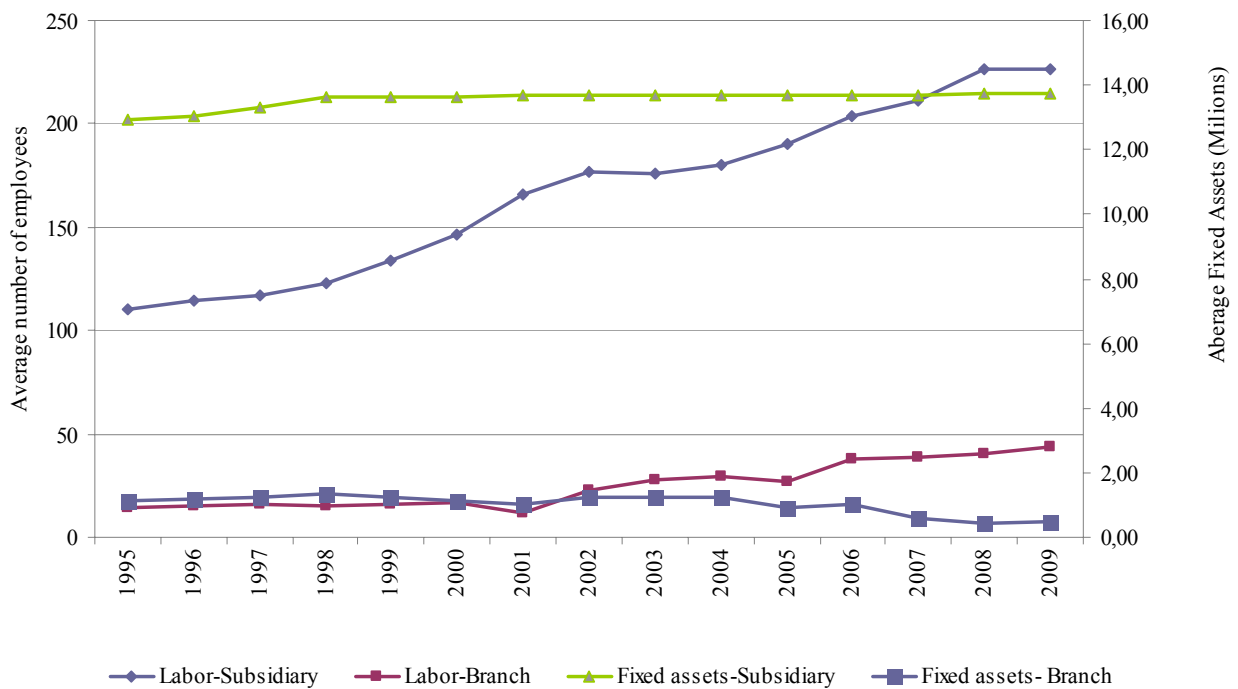
Source: Own calculations

Figure C1b: Branches- Ratio of wage cost to operating and administrative costs.



Source: Own calculations

Figure C2: Subsidiaries vs. Branches-Evolution of number of employees and fixed assets



Source: Own calculations

References

- Atkinson, A.B. (1970) "On the measurement of inequality," *Journal of Economic Theory*, 2(3):244-263.
- Badunenko, O., D.J. Henderson & V. Zelenyuk (2008) "Technological change and transition: relative contributions to worldwide growth during the 1990s," *Oxford Bulletin of Economics and Statistics*, 70(4).
- Baumol, W.J. (1986) "Productivity growth, convergence and welfare: What the long-run data show," *American Economic Review*, 76:1072-1085.
- Berger, A.N., R. DeYoung, H. Genay, & G.F. Udell (2000) "Globalization of financial institutions: evidence from cross-border banking performance," *Brookings-Wharton Papers on Financial Services*, Vol.3.
- Bourse de Luxembourg, N° 33/17.07.03, *Bourse Informations*.
- Cerruti, E., G. Dell'Ariccia & M.S.M. Peria (2007) "How banks go abroad: branches or subsidiaries?" *Journal of Banking and Finance*, 31:1669-1692.
- Cocco, J.F., F.J. Gomes & N.C. Martins (2009) "Lending relationships in the interbank market," *Journal of Financial Intermediation*, 18:24-48.
- CSSF (2007) Annual Report.
- Dermine, J. (2006) "European banking integration: don't put the cart before the horse," *Financial Markets, Institutions & Instruments*, 15(2):57-106.
- Di Nardo, J. & J.L. Tobias (2001) "Nonparametric density and regression estimation," *Journal of Economic Perspectives*, 15(4):11-28.
- ECB (2000), EU Banks' income structure.
- ECB (2010), Report on EU Banking Structures.
- Furfine, C. (2002) "The interbank market during a crisis," *European Economic Review*, 46:809 – 820.
- Henderson, D.J. & R.R. Russell (2005) "Human capital and convergence: a production frontier approach," *International Economic Review*, 46(4):1167-1205.
- Henderson, D.J. & V. Zelenyuk (2007) "Testing for catching-up: statistical analysis of DEA efficiency estimates," *Southern Economic Journal*, 73(4):1003–1019.
- IMF (2000), Luxembourg, Staff Report for the 2000 Article IV Consultation.
- IMF (2009), Luxembourg: Staff Report for the 2009 Article IV Consultation.
- Kumar, S. & R.R. Russell (2002) "Technological change, technological catch-up, and capital deepening: relative contributions to growth and convergence," *American Economic Review*, 92:527-548
- Li, Q. (1996) "Nonparametric testing of closeness between two unknown distribution functions," *Econometric Reviews*, 15:261–274.
- Li, Q. (1999), "Nonparametric testing the similarity of two unknown density functions: local power and bootstrap analysis," *Nonparametric Statistics*, 11:189–213.
- Lozano-Vivas, A., J.T. Pastor & J.M. Pastor (2002) "An efficiency comparison of European banking systems operating under different environmental conditions," *Journal of Productivity Analysis*, 18:59–77.
- Mankiw, N.G., D. Romer, & D.N. Weil (1992) "A contribution to the empirics of economic growth," *Quarterly Journal of Economics*, 107:407-437.
- OECD (2008), Luxembourg, OECD Economic Surveys, volume 2008/12.
- OECD (2010), Luxembourg, OECD Economic Surveys, volume 2010/5.

- Park, B.U. & J.S. Marron (1990) "Comparison of data-driven bandwidth selectors," *Journal of the American Statistical Association*, 85:66-72.
- Pozzolo, A.F. (2009) "Bank cross-border mergers and acquisitions: causes, consequences, and recent trends," in *The Changing Geography of Banking and Finance*, Springer US.
- Quah, D. (1996) "Twin peaks: growth and convergence in models of distribution dynamics," *Economic Journal*, 106:1045-1055.
- Rosenblatt, M. (1956) "Remarks on some nonparametric estimates of a density function," *Ann. Math. Statist.* 27(3):832-837.
- Rychtarik, S. & F. Stragiotti, (2009) "Liquidity risk monitoring framework: a supervisory tool," Banque centrale du Luxembourg Cahier d'études working paper, n. 43.
- Sala-i-Martin, X. (2006) "The world distribution of income: falling poverty and...convergence, period," *Quarterly Journal of Economics*, 12:298-302.
- Sheather, S.J. & M.C. Jones (1991) "A reliable data based bandwidth selection method for kernel density estimation," *Journal of the Royal Statistical Society*, 3:683-690.
- Shorrocks, A.F. (1978) "The measurement of mobility," *Econometrica*, 46(5):1013-1024.
- Silverman, B.W. (1986) *Density estimation for statistics and data analysis*, Chapman & Hall, London
- Simar, L. & V. Zelenyuk (2006) "On testing equality of distributions of technical efficiency scores," *Econometric Reviews*, 25(4), 497-522.
- Steinherr, A. & C. Huveneers (1994) "On the performance of differently regulated financial institutions: some empirical evidence," *Journal of Banking and Finance*, 18:271-306.
- Tschoegl, A.E. (2000) "International banking centers, geography, and foreign banks," *Financial Market, Institutions & Instruments*, 9(1).



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