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TRADEMARKING ACTIVITIES AND TOTAL FACTOR PRODUCTIVITY: SOME EVIDENCE FOR UK COMMERCIAL BANKS USING A METAFRONTIER APPROACH

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Meryem Duygun, University of Nottingham

Vania Sena, University of Essex

Mohamed Shaban, University of Sheffield

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Abstract

In this paper, we compute a non-parametric Metafrontier Malmquist index to evaluate the Total Factor Productivity (TFP) change among UK-based trademarking and non-trademarking commercial banks between 2005 and 2013. The use of the metafrontier approach allows us to: a) identify the drivers of TFP growth for each group of banks, b) compare the TFP growth of each group to the TFP growth experienced by the whole industry, and c) assess the extent to which the former catches up with the latter measured along the metafrontier. Our results suggest that TFP has been increasing among trademarking banks up to the onset of the financial crisis but this process has since reversed. The catch-up indexes suggest that both groups of banks were catching up with the metafrontier up to the financial crisis although the drivers of this process differed between the two groups. After the financial crisis, improvements in technology have been driven by a small number of commercial banks i.e. the non- trademarking banks. These results suggest that a large section of the commercial banking sector has not been able to overcome the effects of the financial crisis.

Key words: Total factor productivity, metafrontiers, DEA, trademarks.

1. Introduction

A trademark is defined as any sign (a word, a logo, a phrase, etc.) which makes distinctive the goods or services offered by a firm. Trademarks belong to the portfolio of legal mechanisms which protect a firm's intellectual property and have been mostly studied as such in conjunction with patents, design rights and so on (Schmoch, 2003; Greenhalgh and Rogers, 2005). However, economists have pointed out that they perform other roles: for instance, it has been suggested that firms use them to differentiate their products from those offered by their competitors (Landes and Posner, 1987; Elliott and Percy, 2006); also, they can signal consumers that the products on sale are of consistent quality contributing to solve the problem of asymmetric information between producers and consumers about the quality of the products.

Over the last fifteen years, British commercial banks have started to make extensive use of trademarks. Greenhalgh and Rogers (2006) reported a surge of the trademarking activity in the financial services sector around mid-Nineties and suggested it was the direct result of the increase in competition in the sector following a set of regulatory changes that allowed commercial banks to diversify their activities[1]. Nowadays, trademarking is quite common among commercial banks. Trademarks are associated to products and services for both consumers and companies. Trademarking banks include some of the largest British commercial banks (like Barclays, Lloyds Bank, Natwest and HSBC) although small banking groups (which serve regional markets) trademark as well (an example is Clydesdale Bank plc). The common feature of trademarking banks is that they do not operate in niche segments of the retail banking: on the contrary they offer generic retail banking services to consumers and since these are not necessarily tailored to the needs of specific customers, trademarking is quite important as it helps to attract more customers. Trademarking banks tend to be active in corporate banking and therefore they play a key role in helping both small and large firms to access credit.

Does trademarking matter to commercial banks? In other words, what are the economic benefits of trademarking to commercial banks? Despite the fact trademarks are widely used across the banking sector, these questions have been only partially explored by the banking literature. The existing research suggests trademarking may be beneficial to commercial banks in several ways. For instance, a couple of studies have found that there exists a positive association between the value of the Tobin's q among commercial banks and their trademarking activity (Gonzalez-Pedraz and Mayordomo, 2011; Greenhalgh and Rogers, 2006). In

[1] The European banking sector was deregulated during the Nineties and this process led to: a) the deregulation of interest rates, b) the abolition of credit ceilings and c) the lifting of the restrictions on cross-border activities.

a similar vein, Duygun et al. (2014) have found that trademarking banks tend to be more profit-efficient than their non trademarking counterparts. However, we argue that trademarking may potentially affect other dimensions of a bank's performance like Total Factor Productivity growth (TFP growth, henceforth) and its components. Although no previous study has tested directly whether trademarking is associated to faster (or slower) TFP growth in the banking sector, evidence from the manufacturing sector suggests that trademarking firms tend to be more productive as well[2]. This positive association is usually explained by the fact that trademarking induces consumers to demand more of the products offered by trademarking firms with the result that these have to produce more output (for a given level of inputs). However, whether such an association exists among commercial banks as well is unknown.

Against this background, the purpose of this paper is three-fold. First, we want to measure the TFP growth of trademarking and non-trademarking banks so to quantify the gains in productivity the two groups of banks have experienced; second, it will fill a gap in the academic literature by investigating the mechanisms that drive TFP growth among the two groups of banks by decomposing the TFP growth index into its main components (Ray and Desli, 1997). Third, we use a metafrontier approach to construct a catch-up index that allows to measure the speed at which each group is catching up with the TFP growth measured along the metafrontier. Our analysis is conducted on a panel of UK commercial banks, observed over the period 2005-2013 offering this way an opportunity to study the evolution of productivity among these two groups of banks during the most acute phase of the financial crisis as well as the start of the economic recovery. Data Envelopment Analysis (DEA) will be used to compute the TFP growth (and its components) of both trademarking and non- trademarking banks and will identify the sources of catch-up towards the industry best practice among commercial banks before and after the financial crisis[3] and explore whether there are differences between the two groups that prevent them from catching up with the metafrontier[4].

The structure of the paper is as follows. Section 2 discusses the channels through which trademarking can influence TFP growth. Section 3 focuses on the empirical methodology we employ in the paper as well as the data-sets and the measurement of the variables. The empirical results are presented in Section 4. Finally, Section 5 offers some conclusions.

2. Can Trademarking Influence Total Factor Productivity?

[2] Greenhalgh and Longland (2005) find that increasing trademarking intensity had a significant positive impact on the subsequent levels of output in the UK manufacturing. Also, Greenhalgh and Rogers (2012) show that trademarking is associated to a value-added premium ranging between 10 per cent and 30 per cent.

[3] See for instance Matousek et al. (2014) on this point.

[4] These may be due to imperfections in the market for new technology or to the incapability of some banks to benefit from the technology spillovers that are produced in the industry.

As mentioned in the Introduction, trademarks stimulate the demand for a company's products and it is through this main channel that trademarking can have a positive influence on TFP growth (Schautschick and Greenhalgh, 2013). To understand why this is the case, it is useful to recall the definition of TFP. This is usually defined as the ratio between an index of output and an index of total input usage (Grosskopf, 1993). Changes of TFP over time can be driven either by changes in the technology firms have access to with the result that they can produce more output (for a given level of inputs) or reduce the existing inputs' usage (for a given level of output). Equally, changes in technical efficiency (or the efficiency by which firms use their inputs) can contribute to TFP growth as again firms can produce more output with the same amount of inputs (or viceversa). If we allow variable returns to scale, then adjustments of the scale of operations of a firm may also create the conditions for an increase in output or a reduction in the amount of employed input (Ray and Desli, 1997). The frontier approach to the measurement of TFP defines a firm's TFP growth as the net change in output due to change in efficiency and technical change where the former is ascribed to movements towards the frontier while the latter is due to movements of the frontier (Caves *et al.*, 1982).

Potentially, trademarking can influence TFP growth through each of its components. As mentioned above, the main channel through which trademarking can influence a firm's TFP is by stimulating the demand for its services and products. How a firm responds to such an increase in demand may vary. It can be met by firms either by changing the level of usage of the existing inputs (i.e. by using some of the excess capacity) or by expanding the inputs (for instance, by hiring more workers) if there is no excess capacity left. In the former case, we should observe an improvement of the operational efficiency as more output can be produced for the same amount of inputs. In the latter case, the expansion of inputs can be followed by a change of the firm's scale as well as a change of the returns to scale (if the firm's technology is characterised by variable returns of scale).

In both cases, changes in the demand can be accommodated by a firm mostly by changing the existing inputs usage but without changing the existing production techniques. This is possible as long as there is some pre-existing unused capacity in the firm or some technical inefficiency in the firm (due to size or any other reason) which can be used to meet the surge in demand. However, if this is not possible, firms may decide to adopt different production techniques which would allow them to produce more output with the same (or less) levels of inputs and this way accommodate the increase in demand following the trademarking activities. This way, firms would experience technical change followed by increases in TFP. This relationship between trademarking activity, technical change and eventually TFP growth can be particularly relevant to firms which tend to invest more in the development of innovative production technologies and therefore tend to be the technological leaders in their industry. Interestingly, there is some evidence suggesting that trademarking is associated to innovation, in particular in the service industry. A few examples include Schmoch (2003) who has found that trademarks and product innovation are positively correlated in the service industry and Malmberg (2005) who compared the new trademark applications with the launch of new product innovations and found that there is a positive correlation between the two in particular among companies targeting consumers.

Although theoretically trademarking can be positively associated to each component of a firm's TFP growth, in practice the extent to which trademarking can drive efficiency change, technical change and scale efficiency change will vary according to the characteristics of the industry with the result that it is up to empirical analysis to quantify the contribution of trademarking to each source of TFP growth.

3. The Empirical Strategy: Data and Methodology

3.1 Data

Our empirical analysis has been conducted on a sample of commercial banks drawn from Bankscope. We first selected all the banks that have been recorded as commercial banks by Bankscope in Britain since 2001. The advantage of focusing on commercial banks for this type of analysis is two-fold: first, trademarks are widely used among commercial banks. Second, they tend to be more homogenous in terms of outputs and inputs so comparisons among different institutions are possible. The unconsolidated accounts (prepared under international accounting standards) were selected. We decided to use unconsolidated accounts (rather than the consolidated ones) for two reasons: first, it is easy to match the registered trademark with the bank that registers it. Most of the trademarks which are registered with the UK Intellectual Property Office belong to UK based subsidiary. Second, we assume that the commercial benefits of the trademarks which are registered by UK based banks will be mostly appropriated by them rather than by their parent companies.

Data from 2001 to 2004 could not be used because of the large amount of missing values. We also excluded banks which could only be observed before (or after) the financial crisis as comparisons could not be made with the result that a few observations from 2005 were lost. Therefore the analysis had to focus on the period from 2005 to 2013 where each bank is observed for four years on average. We checked whether our sample of banks is representative of the whole commercial banking sector and we found out that over our sample period, the banks in our sample owned 73% of the total assets owned by all the banks recorded as commercial banks by Bankscope. The advantage of the chosen time span is that the analysis can cover the period before the financial crisis (which started in 2008) and allow to compare TFP growth before and after the financial crisis. The original data are in British pounds and are expressed in 2001 prices. As it is usually done in this literature, we deflated the data using the GDP deflators (see for instance Lozano-Vivas and Pasiouras, 2010). Finally, all the variables were winsorized at the 5th and the 95th percentiles for every year they were observed[5].

Information on whether a commercial bank has filed an application for either a UK-based trademark or a Community trademark have been sourced from both the Intellectual Property Office (IPO) trademark database and the OHIM database (both publicly available). These cover applications for the UKIPO trademarks which offer legal protection only in the UK and applications for the more expensive Community trademarks which cover all the EU countries.

3.2 The Empirical Methodology

A central tenet of the frontier approach to the measurement of efficiency and productivity is the assumption that the decision-making units (DMUs) under analysis share a common technology in such a way that a meaningful benchmark can be estimated against which their efficiency can be measured. Of course, such an assumption is not always plausible or verifiable as in reality even DMUs drawn from the same sector may use different technologies for several reasons. For instance, in middle income countries foreign banks may be equipped with a superior technology that local banks cannot have access to (Casu *et al.*, 2013).

Several techniques have been developed in the efficiency analysis that would still allow to derive comparable measures of efficiency even for DMUs which have access to different technologies[6]. Among these, the metafrontier approach to the measurement of efficiency has become very popular. First introduced by Hayami (1969) and then developed by Battese and Rao[7] (2002), the metafrontier approach allows to measure the efficiency of a unit with respect to the group-specific technology as well as with respect to the metafrontier. The logic behind the use of the metafrontiers is quite straightforward. Assume there are two groups of firms which use different production technologies. If we measure their (in)-efficiency with respect to a common production frontier which does not take into account the heterogeneity in their technologies, it

[5] We also tested whether winsoring the sample at different percentiles made any difference to the results and in reality the direction of the TFP growth (and its components) did not alter. Finally, we also tried trimming the sample as an alternative to winsorisation.
[6] Examples include the latent class frontier - used to estimate stochastic frontiers in presence of technological heterogeneity (Greene, 2004).
[7] Battese *et al.* (2004) applied the metafrontier model to estimate technical efficiency of Indonesian garment firms in five different regions using a panel data of firms over the period 1990 to 1995.

is likely that we may consider inefficiency what is really a gap in the available technology which in turn may be outside the control of the firm. Therefore, we need to be able to disentangle the actual inefficiency of the firms under analysis from the technology gaps. Metafrontiers can help in this respect. The estimation of a metafrontier involves the estimation of a metatechnology which by definition, envelops the technologies (or frontiers) of the groups of firms and therefore, the efficiency measured with respect to a metafrontier can be decomposed into two components: a first component that measures the distance of the unit from the group frontier and a second component that measures the distance between the group frontier and the metafrontier. The ratio between the efficiency score measured with respect to the metafrontier and the score measured with respect to the group-specific frontier is defined as the Technology Gap Ratio which is a measure of the distance between the two frontiers and as the name suggests, it provides a measure of the gap between the technology available to the whole sector and the technology available to a group of firms. The measure of efficiency that is commonly used within the metafrontier approach is radial as it is assumed that both groups of firms can expand radially all their outputs (in the case of an output-oriented technical efficiency measure). In this respect, the metafrontier approach differs from other approaches to the measurement of productivity that rely on directional distance functions which assume that DMUs can only expand output in one direction (see for instance Fujii et al, 2014; Daraio and Simar, 2014). For our analysis, we prefer to use the radial measure of technical efficiency as we are not aware of any regulation that would prevent any bank in each group from expanding radially all their outputs.

Recently the metafrontier approach has been extended to the measurement of TFP through the Malmquist index. This is a very popular TFP index which measures productivity change from period t to period $t+1$ and is usually defined with respect to a reference period technology (Caves, Christensen and Diewert, 1982). The Malmquist index has been widely used by the banking literature as it offers a few advantages: first, it allows to decompose TFP growth into three components i.e. technical change, technical efficiency change and scale efficiency. In addition, the indicator of technical change derived from a Malmquist index is more appropriate for analyzing changes in productivity than alternative methods based on growth accounting (Barros et al., 2009) Second, its computation does not require input and output prices and this is particularly important for the banking industry where output prices do not reflect the working of a competitive market. Last but not the least it can be used on unbalanced panels (Caves et al., 1982).

Assuming constant returns to scale, the index can be decomposed into two components, technical efficiency change and technical change:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right]^{0.5} \qquad (1)$$

where the first ratio measures technical efficiency change and the ratio inside the parentheses measures technical change. A value greater than unity will indicate positive total factor productivity growth while a value less than one will indicate that productivity growth is slowing down. The Malmquist index assumes that the outputs of a DMU can be expanded radially and in this respect it differs from other indexes that allow to decompose TFP using the directional distance functions (see Fujii et al., 2014 for an application of alternative indexes for the measurement of TFP). Given the fact that theoretically there is no reason to assume that trademarking may lead banks to expand one outputs (over the others), we prefer to use the Malmquist index.

When applying the metafrontier approach to the measurement of TFP growth with the Malmquist index, this will be computed with respect to the group-specific technology, first and with respect to the meta-frontier, afterwards. The first index decomposes productivity growth with respect to the group-specific frontier while the second one does the same but it uses the metafrontier as the reference technology. The metafrontier Malmquist index can be also decomposed into technical efficiency change and technical change as in (1) with the key difference being that now the metafrontier is the reference technology.

The metafrontier Malmquist index can also be expressed as the product of two components: a group-specific productivity index and the inverse of the group catch-up from period *t* to period *t+1*.

$$M_{t,t+1} = M_{t,t+1}^g \times \left[\frac{M_{t,t+1}}{M_{t,t+1}^g} \right] \qquad (2)$$

where M^g identifies the group-specific Malmquist index and $\frac{M_{t,t+1}^g}{M_{t,t+1}}$ is the catch-up term. If the catch-up term is greater than unity, then the group is catching up with the sectoral technology from period *t* to period *t+1*. Chen and Yang (2011) show that the catch-up index can be decomposed into two components: the pure technological catch-up and the frontier catch-up. The pure technological catch-up is the ratio between the technical efficiency change computed by using the metafrontier as the reference technology and the technical efficiency change computed with respect to the group-specific technology. It is a growth index of the technology gap ratios and a value of this index less than one implies that the gap between the group frontier and the metafrontier is decreasing over time (Rao *et al.*, 2003). The frontier catch-up index is measured as the ratio of the technical change of a bank against the metafrontier to its technical change against the group frontier and provides a measure of the convergence speed with lower values indicating a speeding of the catch up process and viceversa. So, if the ratio is smaller (larger) than one, then the technical change experienced by the whole sector is faster (slower) than the technical change experienced by the group of firms with the result that the catching up speed between the group of firms and the industry is accelerating.

The assumption of constant returns to scale can be easily removed and if so, changes in technical efficiency can be shown to be the result of two components, changes in pure efficiency (i.e. gains in efficiencies due to changes of the firm's operations) and changes in the scale. Following Ray and Desli (1997), the Malmquist index can be decomposed in the following three components:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{v,t+1}(x^{t+1}, y^{t+1})}{D_o^{v,t}(x^t, y^t)} \left[\frac{D_o^{v,t}(x^{t+1}, y^{t+1})}{D_o^{v,t+1}(x^{t+1}, y^{t+1})} \frac{D_o^{v,t}(x^t, y^t)}{D_o^{v,t+1}(x^t, y^t)} \right]^{0.5}$$

$$\left[\frac{SE^t(x^{t+1}, y^{t+1})}{SE^t(x^t, y^t)} \frac{SE^{t+1}(x^{t+1}, y^{t+1})}{SE^{t+1}(x^t, y^t)} \right]^{0.5} \qquad (3)$$

Where the superscript *v* indicates that the output distance function is calculated with respect to a technology displaying variable returns to scale and the term *SE* denotes scale efficiency. So, the last term in the parentheses identifies the change in the scale of the unit under analysis. For each of these components, a score larger/smaller than one indicates an improvement/worsening of the corresponding measure. Similarly, the metafrontier Malquist index can be decomposed as in (3) where again the metafrontier is now the reference technology. As in the case of the constant returns to scale, we can compute the ratios of the technical change computed with respect to the metafrontier and the equivalent indicator computed with respect to the group frontier and these will have the same interpretation as before.

In our analysis the distance functions which are used to compute the several components of the Malmquist index are calculated using Data Envelopment Analysis (DEA) which is a widely used linear programming technique for the measurement of efficiency. First introduced by Charnes, Cooper and Rhodes (1978) for technologies with constant returns to scale and extended to the case of variable returns to scale by Banker *et al.* (1984), DEA allows to calculate the different distance functions of the Malmquist index under different assumptions about the returns to scale. One of the disadvantages of DEA is that it is sensitive to the size of the sample. Indeed, it has been argued that when the number of observations is small, the number of efficient units is large (Alirezaee et al., 1998). To avoid this problem, we first ensure that the number of observations is greater than the combined sum of inputs and outputs and then we check that the number of fully efficient observations is less than one third of the total observations in the sample (Manzoni and Islam, 2009).

To define the input and outputs of our sample of commercial banks, we follow a variation of the intermediation approach suggested by Sealey and Lindley (1977). Therefore we assume that loans and securities are the banks' outputs while deposits, labour and capital are its inputs. More specifically, we consider the following three outputs: net loans (the difference between the gross loans and the reserves allocated for non-performing loans), securities investments and the off balance sheet total business volume. Some studies which measure efficiency in the banking sector do not include off balance sheet activities among the outputs but the volume of these activities among British commercial banks is so large that ignoring such non-traditional outputs may produce mis-leading efficiency scores (Isik and Hassan, 2005; Lozano-Vivas and Pasiouras, 2008).

The inputs are a bank's total costs and its equity capital. Total costs are measured as the total operating cost i.e. the sum of interest expenses, salaries and employee benefits and other operating costs. To be able to calculate the total costs, we had to compute the prices of our inputs. The cost of loanable funds is calculated as the ratio of interest expenses to total assets, the cost of physical capital is calculated by dividing overhead expenses (other than personnel expenses) by the book value of the banks' fixed assets and the cost of labour is calculated as the ratio between the personnel expenses and the total assets. Equity is introduced among the inputs as researchers suggest to control for the differences in risk preferences among commercial banks (Berger and Mester (1997) and Lozano-Vivas *et al.* (2010)). Typically, equity capital is treated as a quasi-fixed input.

Table 1 presents some descriptive statistics computed on the full sample before it was winsorised. The results of the t-test on the equality of the means (reported in the last column) suggest that the on average the values of the inputs and outputs are significantly different between trademarking and non-trademarking banks suggesting that the two groups of banks cannot be pooled under the same frontier and that group-specific frontiers need to be computed. Overall, trademarking banks do experience larger total costs and have larger volumes of outputs. Equally, trademarking banks do have more equity capital which may reflect different risk preferences. Off balance sheet activities are quite substantial for trademarking banks. It is well documented that securitization and trading of derivatives became very common among British banks before the financial crisis and eventually this led to the recapitalization of some of these banks (like Lloyds and Royal Bank of Scotland) in 2008. Propensity to trademark varies over time and we can really distinguish in our sample three groups of banks: banks which register trademarks continuously both before and after 2009, banks which never registers trademarks over our sample period and banks which registers intermittently (effectively moving from the group of trademarking banks to the group of non-trademarking banks over time)[8]. As mentioned in the Introduction, a common feature of the trademarking banks is that they offer generic retail banking services to both consumers and companies. They include the largest commercial banks in the UK (for example, Barclays, Lloyds Banking group, Royal Bank of Scotland, HSBC, Santander UK, Co-op group among the others) and small banks which serve regional markets (Clydesdale group for instance)[9]. Among the non-trademarking banks, there is a group of foreign bank multinationals that have a presence in the UK. These have not registered a trademark in our sample period. Foreign banks tend to locate in London to get advantage of the benefits of being located in an international financial centre[10] while providing a set of services which are usually demanded by other banks co-located in the same financial centre (Clare et al., 2011). In addition, they offer personal banking services to members of the foreign community located in the UK and can do so either through a subsidiary or through a network of branches[11]. A simple explanation of why these banks do not register trademarks is related to their business model: indeed they do not offer large volumes of services and products but rather serve specific segments of customers.

Table 2 reports the distribution of trademarks among the banks before and after 2009 (but before the sample was winsorised). The figures suggest that the propensity to register a trademark has not changed radically after 2009. However, in both periods, a small number of banks is very active in registering a large number of trademarks in the UK.

4. The Empirical Results

4.1 Main Results

[8] This last group includes Airdrie Savings Bank, Anglo-Romanian Bank, Ghana International Bank, Habib Allied International Bank, ICBC, Turkish Bank (UK), Union Bank, Axis Bank, United National Bank, Reliance Bank, Bank of China (UK).

[9] Full list includes AIB Group (UK) plc, Ulster Bank, Bank of Scotland, Clydesdale Bank, Royal Bank of Scotland, Virgin Money, Bank of Ireland (UK), Barclays Bank, HSBC, NatWest, Lloyds Bank, Santander, Co-operative Bank.

[10] These include access to advanced settlements and payment systems as well as to deep and liquid financial markets where the sources and uses of funds are highly diversified (Clare et al, 2011).

[11] There exists a large literature analysing the behaviour of multinational banks. These enter foreign markets where their home customers are present because of the informational advantage with respect to their domestic customers. (Hultman and McGee, 1989; Yamori, 1998) This is the so-called "follow-the-customer" hypothesis and it is based on the argument that the costs of information-intensive products prevent banks from entering into licensing and franchising arrangements.

In our empirical analysis, we are interested in comparing the performance of trademarking and non-trademarking banks to a sectoral reference technology (or metafrontier). Therefore, we proceed to the computation of the two group-specific frontiers and of the metafrontier using DEA. We assume that banks have access to technologies with variable returns to scale and therefore we use the so-called DEA-VRS model proposed by Banker *et al.* (1984) to compute our frontiers. At this stage, we do not compute yet the TFP growth index and its components but we limit ourselves to compute both output-oriented efficiency scores and scale efficiency indicators for our banks with the reference technology being provided by group-specific frontiers first, and by the metafrontier afterwards. The metafrontier framework allows to decompose differences in overall performance into efficiency and a technology gap ratio which measures the distance between the group frontiers and the metafrontier. While efficiency relates mainly to the performance of a firm's management, the technology gap ratio measures the nature of the production environment ('O Donnell et al., 2008). Essentially, the technology gap ratio is not an indicator of efficiency but it simply captures the gain in technical efficiency that a bank would experience if a different technology is used as a reference. The DEA model we use does not take into account the fact that our sample is constructed as a panel and therefore it does not provide a full picture of the banks' performance (for instance, movements of the reference frontier due to technical change may be mis-interpreted as inefficiency); however, it is insightful in the sense that it provides a first picture of how the two groups of banks perform.

The mean efficiency scores, the scale efficiency indicators and the technology gap ratios for the two groups of banks are presented in Table 3[12]. Overall, the average technical efficiency score is around 0.79 for non trademarking banks and 0.87 for trademarking banks. They suggest that on average trademarking/non-trademarking banks produce 13% / 21% less than the best practice trademarking/non-trademarking banks. More importantly, the difference between the mean efficiency score of the two groups of banks is statistically significant. Trademarking banks score marginally better than non trademarking banks in terms of scale efficiency (0.94 for trademarking banks and 0.91 for not trademarking ones) and this may suggest that the latter group may be too large (compared to trademarking banks) and therefore they may suffer from scale inefficiency. On average, the average technology gap ratio among non trademarking banks is equal to 0.90 suggesting that they could increase their efficiency by 10% if they could have access to a better technology. However, the technology gap ratio among trademarking banks is 0.98 and suggesting that trademarking banks may have access to a slightly better technology.

[12] We have tested whether there are influential observations in our sample that may be included among the banks on the frontier using the methodology suggested by Tran et al. (2010) but the test shows there are no influential observations.

Finally, we then proceed to the calculation of TFP index and its components[13]. As mentioned above, we do use DEA to compute the output distance functions which allow us to compute the Malmquist index and its components (technical change, efficiency change and scale efficiency change) and as a reference technology we first use the group-specific frontiers and then the metafrontier. The results for each group of banks are reported in Table 4. We also report the same results before and after 2009 i.e. after some of the largest commercial banks were bailed out by the British government. The figures show clearly that the direction of the changes of TFP over the whole sample period differs between the two groups. TFP growth is negative between 2006 and 2013 for the trademarking banks but in reality, this negative growth has to be ascribed mostly to the fall in productivity experienced by these banks after the financial crisis. Beforehand, TFP among trademarking banks grew by 0.9% and the analysis of the components underlying the TFP growth shows that productivity growth occurs thanks to technical progress (the frontier shifted outwards slightly by more than 3%). The outward shift of the frontier was so large that some banks failed to catch-up with the movements of the frontier with the result that on average technical efficiency fell. After 2009, TFP growth is negative but the figures also show that on average scale efficiency is slightly improving (with an average improvement of 0.3%) between 2009 and 2013 suggesting that this group of banks has started to re-adjust their scale of operations in an attempt to reduce its inefficiencies. We have used the bootstrap procedure suggested by Simar and Wilson (2008) to test whether the TFP indexes (and each of its components) are statistically significant. Only the technical efficiency change is not significantly significant while the TFP index and the other two components are statistically significant at 5%[14].

Our result that technical progress drove TFP growth among trademarking banks is in line with existing evidence on the drivers of TFP growth in the banking industry before the financial crisis and complements what other authors have found for Europe, US and Japan (see for instance Assaf et al., 2011). Indeed, it is well documented in the run-up to the financial crisis, TFP in the banking sector grew as banks managed to consolidate the benefits they drew from the automation of the channels used to distribute financial products and services (Goddard et al, 2013). In addition, innovations in information processing and related technologies led to the development of new loan products which allowed banks to expand lending to new market segments that were previously under-serviced because of the perceived riskiness (Haldane et al., 2010). At the same time, analytics allowed banks to develop and value new securities (Berger, 2003) which led to the proliferation of financial products which were supposed to mitigate the risks associated to the

[13] We tried to estimate the bias-corrected measure of the Malmquist index (and its components) using the bootstrap procedure but the results show that the bias correction would increase the mean-square error.

[14] It could be argued that the TFP fall could be due to the recapitalisation of the Royal Bank of Scotland and of Lloyds bank (see Fethi et al., 2012, for a similar result). In reality, the effect of these two banks on the direction of the TFP change is negligible: we have re-estimated the Malmquist index without the two banks and the direction of the change is unaffected.

increasing lending (Haldane et al., 2010) and led to the well-documented increase in securitization we have observed for the trademarking banks. All these factors result into both technical efficiency change (as both offshore business and lending expanded given the existing costs) and technical progress (as financial innovation received a boost thanks to the extensive use of new technologies for data processing and collection). The financial crisis and the subsequent collapse of the financial derivatives markets led to a drastic reduction in lending with the result that these banks recorded negative TFP growth over the period 2009-2013.

The picture changes if we focus on the non trademarking banks. Before 2009, TFP growth was stationary although their scale efficiency was improving on average due to movements of the banks towards the optimal scale as identified by the technology with variable returns to scale. Because of their size and business model, they were not in position to develop new financial products in such volumes that would allow them to effectively compete with the trademarking banks and therefore improvements in TFP could only be achieved by changes to their scale of operations. Again, changes in the way the back office was organised is the most likely explanation for the increase in scale efficiency that we observe among the non-trademarking banks before the financial crisis. Indeed, Berger (2003) finds that before the financial crisis, banks expanded the use of electronic payments, Internet based transactional sites and information exchanges and all these technologies have changed the way the "back-office" activities were organised with the result that scale economies have reduced costs dramatically over time. More importantly, banks did not need to invest directly in the development of these new technologies (as they can outsource the provision of these services to external companies) but can still benefit from them in terms of improved scale efficiency (see Berger, 2003, for this point). In other words, banks can still experience scale efficiency improvements thanks to the changes in the back office but without experiencing positive technical change. After 2009, TFP starts growing (indeed TFP grows by 1.4%) thanks to technical progress (it increases on average by 0.3%). One potential explanation for the increasing importance of technical change for TFP growth among non-trademarking banks is that they had exploited most of the gains associated to improvements in scale efficiency by the onset of the financial crisis and therefore the only way to improve productivity is by positive technical change. There exists some empirical evidence suggesting that banks which are located in financial centres (like Luxembourg) have reacted to the financial crisis by innovating (Curi and Lozano-Vivas, 2015) as the dense network of banks in a specific location has stimulated innovation and its diffusion. In the UK, the "fin-tech" (financial technology) industry[15] is considered to be responsible for the technical

[15] The fin-tech sector refers to a variety of companies that provide online payments or other type of electronic payments as well as new solutions for customer services. The UK fin-tech sector has the leadership in peer-to-peer platforms, aggregator platforms and data products. The value of the fin-tech industry has increased eightfold between 2008 and 2013. After the financial crisis, most local banks were too leveraged to be able to

progress experienced within the banking sector after the financial crisis and its emergence was mostly driven by the demand for new technologies that could be embedded directly into the banks' existing processes (Earnst and Young, 2014). Finally, Tables 5 and 6 show the correlation coefficients among the different components of TFP and TFP growth for both groups of banks over the whole sample period. The correlation coefficients provide additional evidence on the drivers of TFP growth. Among non-trademarking banks, TFP growth is positively (and significantly) correlated with technical change and technical efficiency change but the correlation is stronger with the technical efficiency than with technical progress. On the contrary, in the case of trademarking banks, TFP growth is positively (and significantly) correlated with each of the three components although the strongest correlation is with technical efficiency change.

Of course, these are group-specific results which do not allow us to draw inferences at the industry level and therefore to be able to compare results across groups, we need to compare our TFP indexes with the corresponding indexes computed with respect to the metafrontier. As mentioned in the previous section, we have therefore computed: a) the (inverted) TFP catch-up index - the ratio between the metafrontier Malmquist index and the group equivalent[16]; b) the pure technological catch-up index (or growth index of the technology gap ratios) - the ratio between the metafrontier technical efficiency change and the technical efficiency change measured with respect to the group frontier, and c) the frontier catch-up index - the ratio of the technical change measured along the metafrontier and the technical change measured along the group-specific frontier.

Table 7 reports the average values of the three indexes across the two groups of banks before and after the financial crisis. These figures suggest that some convergence towards the metafrontier has taken place but this process has stopped after the financial crisis. Among the trademarking banks, convergence is driven by technical progress up to 2009 with the result that they have been able to catch-up with the metafrontier at an accelerating speed (thanks to technological progress) which also allowed them to narrow the technology gap with the metafrontier. Over the same time period, the technology gaps with the metafrontier get smaller for the non-trademarking banks but the convergence speed decreases suggesting that the benefits to the catching up process of the scale efficiency change were getting smaller and smaller. After the financial crisis, the convergence process reverses for both groups of banks. In the case of the trademarking banks, the convergence process stops altogether with the result that the technology gaps widen (on average) between

invest in new technologies with the result small start-ups filled the void. However, banks quickly recognised the potential that the new technologies could offer with the result that they tried to embed them into their processes.

[16] We inverted the TFP catch-up to facilitate the comparisons among the three indexes (which now share the same denominator). Notice that a value smaller than 1 means that the group is with catching up with the metafrontier. The opposite is true for values of the index which are larger than one.

2009 and 2013. Convergence stops after the financial crisis for the non-trademarking banks as well although the convergence speed accelerates. However, the average technology gaps still get wider and this suggests that the metafrontier moves faster than the group frontier[17] as the technical progress experienced by the non-trademarking banks is not sufficient to catch up with the metafrontier.

Overall, the results suggest that while some catching up took place before the financial crisis, it is not complete and productivity differences between the two groups still persist. As a result, it seems the industry is evolving towards a dual structure where the largest banks (in terms of services they provide and number of customers they serve) are unable to catch-up with the best performers in the industry while being surrounded by smaller institutions which may experience positive productivity growth but whose technological capabilities to compete with the best performing banks is limited. These results are consistent with the findings of the Bank of England (Barnett et al., 2014) and of the UK Treasury (HM Treasury, 2015). The Bank of England has found that productivity in the sector has fallen considerably following the financial crisis[18]; at the same time, our results concur with the view of the UK Treasury suggesting that the financial crisis has altered the nature of competition in the banking sector as concentration in the sector has increased with the result that the sector will evolve towards a market structure where a small number of large institutions will dominate the industry. Whether this process can be reversed hinges on the capability of the commercial banks to become more productive and to equally benefit from the existing technology spillovers existing in the industry. However, in this respect, our results have worrying implications as they show that the gap between the two types of institutions will widen as productivity growth among the trademarking banks has slowed down while non-trademarking banks cannot really catch-up with the TFP measured along the metafrontier. Given the size of the trademarking banks and the variety of financial services they provide to both consumers and companies, these results show that the whole sector is still weak and the prospects for its growth are not very robust.

4.2 Robustness Tests

[17] We made an attempt at exploring whether the movements of the catch-up indexes over time are associated to the trademarking status of the banks. This type of exercise is purely descriptive and does not want to identify causal relationships among the variables of interest. The model we have estimated is very simple. We regressed the catch-up index for each bank on its trademarking status (taking the value of one for a trademarking bank and zero otherwise) while controlling at the same time for its demographic characteristics (i.e. size - proxied by its total assets and age) and profitability (proxied by the Return on Assets). Finally, we added year dummies. Econometrically, we use the double bootstrap procedure suggested by Simar and Wilson (2008) to compute the standard errors of the coefficients (see also Wijesiri and Meoli, 2015). The results show that the trademarking status variable is significant and that trademarking banks' TFP is more likely to converge towards the TFP on the metafrontier than non-trademarking banks even after controlling for the size of the bank as well as its profitability and age. The sign of the coefficient on the dummy variable for 2008 shows that the catching up process with the TFP growth on the metafrontier has slowed down for both groups of banks (in line with the main results presented in Section 3).

[18]The general view is that the fall in productivity among commercial banks has contributed to the overall productivity slowdown the British economy suffers from. The explanation is that as commercial banks have become less productive, they have become less efficient in transforming their inputs into loans and therefore have slowed down the investment rate in the real economy and ultimately its recovery.

Our empirical analysis has shown that trademarking banks have experienced positive TFP growth up to the onset of the financial crisis but the process has since reversed. The analysis has also suggested that the productivity differences between the trademarking and non-trademarking banks still persist and that these may be driven by the fact that not all the banks have access to the same technology. To understand whether these results are driven by some specific characteristics of the trademarking banks (like size or age), we re-run our analysis for two specific groups of trademarking and non-trademarking banks, namely: a) banks whose total assets are larger than the median value in the sample (around three millions pounds) and b) banks which are more than 40 years old (i.e. the median value of age in our sample). The former group is very interesting for our purpose as their size suggests that they operate simultaneously in several segments of the retail market and therefore may make more extensive use of trademarks. The latter group of banks is relevant to us as well. As these banks have been established for long, their portfolio of trademarks may be more valuable and so the dynamics of TFP and its components may differ from what we observe in the main sample.

The results of these additional robustness tests are presented in Tables 8 and 9. First of all, among the old and large trademarking banks, the evolution of the TFP growth (as well as its drivers) is similar to what we observe for the whole group of trademarking banks. Indeed, TFP grew by 7.4% (for the old banks) and by 27% (for the large banks) with technical progress being the main driver of TFP growth in both cases. At the same time, the results also suggest that the two groups of banks had started to re-adjust their scale of operations with the result that both technical efficiency and scale efficiency improved up to 2009. Indeed technical efficiency grew between 0.3% (large trademarking banks) and 0.5% (old trademarking banks) while in the case of the old banks, this improvement has been accompanied by a positive change in the scale efficiency. These findings are consistent with the results we have obtained from the main sample and as in the main sample they may be ascribed to the development of new financial products jointly with investment in new IT systems (Haldane et al., 2010). However, after the financial crisis and in line with the results from the full sample, TFP stopped growing for both groups of trademarking banks.

Among the non trademarking banks, the evolution of TFP is not different from what we observe in the main sample. In both cases, TFP grows faster after 2009 – TFP increases by 4% for large banks – with technical change being the strongest driver of their TFP growth. Only the evolution of TFP among old banks is different from what we observe in the full sample. TFP appears to have grown slightly before 2009 and this growth has mostly been driven by improvements in scale efficiency and technical change. After the financial crisis, TFP continued to grow at a more sustained pace (an average increase of 11%) and such a large increase is explained by the large improvements in each component of TFP growth that these banks have experienced. In terms of convergence, the results on Table 9 show that up to 2009, old and large trademarking banks shared with the other trademarking banks the same convergence process with the result that the technology gaps narrow down. However, after 2009, the convergence process stops altogether and the technology gaps start to widen. Among the non trademarking banks, the old ones appear to have caught up with the metafrontier before 2009 and the process seems to continue after 2009. In reality, on average the technology gaps have not narrowed suggesting that the slowdown of the metafrontier movements may contribute to explain the catching up with the TFP on the metafrontier. Equally, the large banks do not catch up with the metafrontier and the technology gaps seem to be widening.

5. Conclusions

The purpose of this paper was to evaluate the productivity growth of the trademarking and non-trademarking banks in the UK, over the period 2005-2013 using a non-parametric metafrontier Malmquist index and decompose it into changes of efficiency, technical change and scale change for each group of commercial banks as well as the whole sector. The use of the metafrontier approach has allowed to explore the extent to which the group-level TFP catches up over time with the TFP on the metafrontier. Given the size of the trademarking banks and the variety of financial services they provide to both consumers and companies, evaluating their productivity growth as well as their relative position with respect to the best performers in the industry will help policy-makers to identify the group of institutions which is mostly contributing to the productivity slowdown in the sector.

Our results suggest that the evolution of TFP (as well as its main drivers) varies substantially between the two groups. TFP has grown among trademarking banks up to the start of the financial crisis but the trend has since reversed. This positive growth was mostly driven by technical progress (suggesting a strong link between trademarking status and capability to innovate and introduce new products into the market) as trademarking banks on the frontiers managed to fully benefit from the creation of digital channels to their services while at the same time investing in financial innovation. This effect was rather strong but the negative results on the average technical efficiency suggest that technical progress was driven by a small group of banks as the remaining trademarking banks did not manage to catch up with the frontier. The evolution of TFP growth among non trademarking banks is though totally different. Indeed, this was stationary before the financial crisis but it eventually it started to grow after 2009. As this positive growth seems to be driven by technical progress, it seems to suggest that some of these banks (namely those on the frontier) have reacted to the financial crisis by exploiting the developments of the new fin-tech sector as they may have exhausted all the sources of potential improvement in their scale efficiency. In terms of convergence, productivity differences between the two groups still persist. Before the financial crisis, TFP among both groups of banks appeared to converge towards the meta-frontier. Once the industry was hit by the financial shock, the convergence process stopped altogether for both groups of banks with the old, non-trademarking banks being the only exception.

Overall, these results are worrying as they show that the TFP growth of the trademarking banks is still negative. In addition it seems that not all the banks seem to benefit equally from the technology spillovers generated on the metafrontier with the result that productivity differences still persist. As mentioned in the Introduction, these are the institutions that offer a variety of services to consumers and producers and clearly if their TFP does not improve over time, then they will act as a brake to the economic recovery. However, the results also offer a silver lining: although TFP growth in the sector is negative, there is still a group of banks which can innovate and experience positive TFP. The positive technical change they experience allows them to catch up with the rest of the industry although the technology gaps have not narrowed yet. Even if this is a small group (in terms of total assets), the fact that they may be experiencing positive TFP suggests that they may grow and help to improve the degree of competition in the sector. However, their growth needs to be supported: if policy-makers support their investment in innovation and facilitate knowledge spillovers across the industry, then a virtuous circle can be started that can stop the TFP slowdown in the banking sector, improve its competitiveness and eventually support the recovery.

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Table 1. *Descriptive Statistics*

	POOLED SAMPLE	TRADEMARKING BANKS	NON TRADEMARKING BANKS	
	MEAN in millions (STANDARD DEVIATION in millions)	**MEAN in millions (STANDARD DEVIATION in millions)**	**MEAN in millions (STANDARD DEVIATION in millions)**	**t-test (p-value)**
Equity	5.161 (12.6)	14.6 (19.1)	0.909 (2.9)	0.000
Total Costs	3.292 (7.383)	9.42 (10.7)	0.539 (1.546)	0.000
Net Loans	55.7 (127)	166 (184)	6.507 (21.9)	0.000
Security	51.7 (167)	156 (273)	5.233 (18.3)	0.000
Offshore business	159 (389)	453 (592)	27.6 (88.2)	0.000
N	330	102	227	

Source: Monetary figures are expressed in millions British pounds. Bankscope (2013). The statistics have been computed on the sample before winsorisation. The p-value in the last column refers to the t-test on the equality of the means. More specifically, it has tested if the difference in means of the variables listed in the first column between trademarking and non-trademarking banks is equal to zero.

Table 2. Distribution of trademarks across the banks in the sample (before and after 2009)

Before 2009		After 2009	
Number of Trademarks	**Numbers of Banks**	**Number of Trademarks**	**Numbers of Banks**
1	7	1	3
2	1	2	2
4	1	3	1
6	1	4	1
9	1	5	1
10	1	6	1
11	1	7	1
14	1	8	1
15	1	11	1
18	1	14	1
19	1	15	1
21	1	16	1
23	1	17	1
27	1	21	1
29	1	26	1
34	1	29	2
35	1	35	1
36	1	42	1
38	1	61	1
43	1		
48	1		
73	1		

Note: The table reports the number of banks that have registered the corresponding number of trademarks before and after 2009.

Table 3. Mean Technical Efficiency Scores, Scale Efficiency and Technology Gap Ratios

	Non-trademarking banks	**Trademarking banks**	**t-test (p-value)**
TE (VRS)	0.79	0.87	0.0001
Scale Efficiency	0.91	0.94	0.02
Technology Gap Ratio	0.90	0.98	

Note: The technical efficiency scores are computed with DEA assuming a technology with variable returns to scale. Scale efficiency is computed as the ratio between the technical efficiency scores computed with respect to a technology with constant returns to scale and the scores computed with respect to a technology with variable returns to scale. The technology gap ratios are computed as the ratio between the metafrontier efficiency scores and the group-specific efficiency scores. The technology gap ratios are bound between zero and unity. The closer the ratio is to the unity, the closer the group is to the metafrontier. The t-test has tested whether the mean of the technical efficiency scores for non trademarking banks is equal to the mean of the corresponding variable for trademarking banks.

Table 4. Group-specific Malmquist Index – All banks (Winsorised sample)

	Technical Change		***Pure Efficiency Change***		***Scale Efficiency Change***		***TFP***	
	Non Trademarking banks	*Trademarking banks*	*Non Trademarking banks*	*Trademarking banks*	*Non Trademarking banks*	*Trademarking banks*	*Non Trademarking banks*	*Trademarking banks*
Mean, whole period	1.006**	0.988**	0.991	0.999	1.015**	0.996**	1.009**	0.981**
Mean, 2006-2008	0.964**	1.033**	0.993	0.999	1.048**	0.984**	1.000**	1.009**
Mean, 2009-2013	1.030**	0.961**	0.990	0.998	0.996**	1.003**	1.014**	0.963**

Note: The Malmquist index and its components have been computed by using output distance functions as specified in the paper. A value of the Malmquist index greater than unity indicates that Total Factor Productivity is growing from one year to the other. The same applies to each component of the Malmquist index. The sample has been winsorised at 95%. The test on the statistical significance of the TFP index (and its components) is based on the bootstrap methodology proposed by Simar and Wilson (2008).

Table 5. Correlation Matrix - TFP components, Non-trademarking banks

	Technical Change	*Pure Technical Efficiency*	*Scale Efficiency Change*	*TFP*
Technical Change	1			
Pure Technical Efficiency	0.038	1		
Scale Efficiency Change	-0.197**	-0.1691**	1	
TFP	0.1936**	0.9096**	0.0329	1

Note : ** Significant at 5%

Table 6. Correlation Matrix - TFP components, Trademarking banks

	Technical Change	*Pure Technical Efficiency*	*Scale Efficiency Change*	*TFP*
Technical Change	1			
Pure Technical Efficiency	-0.101**	1		
Scale Efficiency Change	0.235**	-0.125**	1	
TFP	0.340**	0.716**	0.520**	1

Note : ** Significant at 5%

Table 7. Catch-up index, Technical Efficiency Change Ratio and Technical Change Ratio – All banks

	Catch-up index	Technical Change Ratio	Technical Efficiency Change Ratio
Non trademarking banks			
Mean, whole period	1.007	0.9997	1.0101
Mean, 2006-2008	0.974	1.0031	0.9667
Mean, 2009-2013	1.029	0.9977	1.0362
Trademarking banks			
Mean, whole period	1.035	1.020	1.002
Mean, 2006-2008	0.966	0.940	0.960
Mean, 2009-2013	1.081	1.069	1.027

Note: The catch-up index is computed as the ratio between the metafrontier Malmquist index and the group-specific Malmquist index. If the catch-up index is less than unity, the group TFP is catching with the industry TFP from period *t* to period *t+1*. The technical efficiency change ratio (or pure technological catch-up ratio) is computed as the ratio between the technical efficiency change measured with respect to the metafrontier and the technical efficiency change measured with respect to the group frontier. If the ratio is less than unity, then the gap is decreasing over time. The technical change ratio is computed as the ratio between the technical change measured with respect to the metafrontier and the technical change measured with respect to the group frontier. If the ratio is less than unity, then the catching-up speed with the industry is accelerating.

Table 8. Robustness Tests: Group-specific Malmquist Index and Metafrontier Malmquist Index

	Non-Trademarking Banks							
	Panel A				***Panel B***			
	Technical Change	***Pure Efficiency Change***	***Scale Efficiency Change***	***TFP***	***Technical Change***	***Pure Efficiency Change***	***Scale Efficiency Change***	***TFP***
Mean, whole period	1.037	1.012	1.025	1.071	1.003	1.008	0.979	0.986
Mean, 2006-2008	1.001	0.998	1.004	1.004	0.923	1.049	0.928	0.893
Mean, 2009-2013	1.058	1.020	1.037	1.111	1.051	0.984	1.009	1.042
N	85				68			

	Trademarking Banks							
	Technical Change	***Pure Efficiency Change***	***Scale Efficiency Change***	***TFP***	***Technical Change***	***Pure Efficiency Change***	***Scale Efficiency Change***	***TFP***
Mean, whole period	1.015	0.999	0.994	1.005	1.096	1.000	0.989	1.072
Mean, 2006-2008	1.064	1.005	1.013	1.074	1.330	1.003	0.974	1.271
Mean, 2009-2013	0.985	0.995	0.982	0.963	0.956	0.998	0.997	0.953
N	70				82			

Note: Panel A refers to banks that are more than 40 years old while Panel B refers to banks whose total assets are larger than the median value of the total assets. The Malmquist index and its components have been computed by using output distance functions as specified in the paper.

Table 9. Robustness Tests: Catch-up index, Technical Efficiency Change Ratio and Technical Change Ratio

	Non-trademarking banks					
	Panel A			**Panel B**		
	Catch-up index	**Technical Change Ratio**	**Technical Efficiency Change Ratio**	**Catch-up index**	**Technical Change Ratio**	**Technical Efficiency Change Ratio**
Mean, whole period	0.952	0.992	0.990	1.079	1.063	0.998
Mean, 2006-2008	0.978	1.050	0.946	1.067	1.075	0.912
Mean, 2009-2013	0.937	0.957	1.016	1.086	1.056	1.050
	Trademarking banks					
Mean, whole period	1.008	1.002	1.003	0.986	1.042	1.004
Mean, 2006-2008	0.917	0.993	0.940	0.776	0.834	0.955
Mean, 2009-2013	1.072	1.007	1.041	1.179	1.168	1.034

Note: See note to Table 8