Achieving a sustainable cost-efficient business model in banking: The case of European commercial banks[*]

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We analyze banks' abilities to achieve a sustainable business model. We first argue that assessment of the sustainability of a business model on the market requires consideration of the broad set of choices bank managers face, because such a set of business strategies and their adjustment affect performance in both the short and long-run. By measuring the variety of bank business strategies using a diversity index, we present a new framework to analyze the effect of a business model on bank performance (measured by a state-of-the-art stochastic frontier model). In particular, our method links the business model to performance by taking into account the long- and short-run effects. Using data that includes European commercial banks over the period 1993–2016, we find that a combination of (i) a persistent income business model together with the adjustment of an asset-focused business model in the long-run and (ii) diversification of the funding and income portfolios in the short run describes a sustainable cost-efficient business model. Our findings are robust to alternative specifications.

Keywords: OR in Banking; Decision Analysis; Business model

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1. Introduction

Firms design and adapt their business model to gain competitive advantage and successfully operate in the market. As any other firm, banks usually reassess and/or adjust their business strategies and models when the operating environment changes. Such reassessments and adjustments of the business model are essential for a bank to earn a healthy and sustainable profit and influence firm value. Since the differences in banks' business models could be systematically associated with differences in their performances and because of banks' special social and economic role, bank business models (BBMs) are also of interest to the policymakers. To increase the resilience of credit institutions and to support the stability of the financial system overall, policymakers should establish the prudential framework by considering the vulnerabilities and supporting sustainability in terms of the performance of the bank business model (BBM).

Although banks face a new operating environment as a consequence of regulatory, technological, and economic changes, policymakers began to truly pay attention to BBMs only after the financial crisis in 2008 (Farnè & Vouldis, 2017). Since the end of the financial crisis, the importance of BBM analysis has increased and has become an integral part of the annual Supervisory Review and Evaluation Process in Europe, constituting a top supervisory priority.

Despite the growing interest of policymakers and researchers in analyzing the BBM, there is no established approach to discover the optimal BBM that allows for the survival of banks in the market. The literature on the BBM presents two approaches to identify and analyze the business model for banks: the first uses the cluster method[1] to classify banks following different business models, and the second uses econometric (regression) analysis to determine the effect of the business model on bank performance.

Studies that follow the first approach identify the type of business model by classifying banks into mutually exclusive groups with similar strategic choices. However, since a bank's strategic possibility set

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[1] Section 2 presents a detailed review of the literature on BBMs.

for defining its business model is based on its features in terms of assets, liability, and income, some banks could choose intermediate strategies. Moreover, such strategies can vary over time. In such a case, the identification of a business model through a strategic group cannot properly detect similarities in strategic choices, since banks can share the characteristics of two or more groups. Additionally, this method disregards the effect of the business model on performance and adjustments by banks in the face of a new environment, failing, in particular, to accommodate the time-varying nature of the BBM. Although performance is crucial to sustainability, it is missing from these studies. Studies that adhere to the second approach and perform a regression analysis to link particular characteristics of the BBM with bank performance ignore the choice of business model. Within this strand of research, some studies resort to a diversification index to identify the type of business model. Papers following either approach, however, do not consider the degree of success with which bank managers achieve sustainable performance by optimizing the business model. In addition, neither a bank's production process nor its optimization approach has been modeled in any of these studies.

We propose an approach to rectify these shortcomings and link the business model to bank performance while identifying which types of business models result in sustainable bank performance. Conceptually, the approach requires three elements. First, the definition of the BBM needs to account for all the combinations of choices bank managers face. These combinations belong to the strategic possibility set describing *what banks do*. Second, *how successfully banks perform* needs to be determined, that is, a measure of bank performance is required. Third, since banks need to adjust their business model when the environment changes, their ability to achieve sustainable performance might depend not only on management's good habits in making decisions over time, but also on management's temporal behavior.

Empirically, for the first element, we resort to diversification measures (Acharya et al., 2006) by defining a bank's strategic choice possibility set with respect to assets, liabilities, and income characteristics. The BBM thus measures the continuum of combinations of bank strategies. It also captures the possibility of intermediate strategies chosen by management.

For the second element, we choose the notion of a bank's cost efficiency. The literature suggests that cost efficiency is an informative performance measure, since it is strongly associated with bank failure (Wheelock & Wilson, 2000). Profit efficiency is a more general concept than cost efficiency since it includes both cost and revenues. However, in intertemporal analysis of both types of performance (including normal time and crisis time period, as it is in our case during the time period used in our empirical analysis) Assaf et al. (2019) found that while higher cost efficiency during normal times reduces failure probabilities, decreases risk, and enhances profitability during subsequent financial crisis, higher profit efficiency has limited benefits to unconditionally assure better future bank outcomes. Results that are mainly explained by the risk-taking channel that profit efficiency considers, which allows banks to earn high returns in normal times, but creates problems in a subsequent crisis. Those findings explain why the manager ability is better signaled by cost efficiency than by profit efficiency, although it is true that the managerial skills must have enough ability to minimize cost and maximize revenues and as result profitability. Thus, based on the fact that we are interested to analyze intertemporal BBM managerial decisions, we use cost efficiency. Additionally, the profit efficiency approach requires output prices, but these are either difficult to find or very noisy. For service industries, where outputs are deemed exogenous, the cost function approach is the most appropriate. Cost efficiency contains information about the most important challenges for banks not only during bad times,[2] but also during good times (Barr & Siems, 1994; Kick & Koetter, 2007). For example, in his speech "Bank Regulation and Supervision: Balancing Benefits and Costs," Bernanke (2006) stresses that, historically, the promotion of competition and bank efficiency has been one of the goals of banking regulation.[3] Actually, in a competitive environment, banks

[2] For instance, nowadays, cost efficiency is a challenge for banks, given that the weakness in their profitability is linked to difficulties in increasing revenues in an environment with low nominal growth, a low-interest rate, and a relatively flat yield curve. For many euro area banks, a return to sustainable profitability is increasingly dependent on improvements in operational efficiency, since a significant number of banks have managed to consistently outperform their peers in terms of the common goal to contain costs (Angeloni, 2017).

[3] In particular, Bernake (2006) points out that historically, the goals of banking regulation were not only the safety and soundness of bank operation, the stability of the broader financial system, assistance to law enforcement, consumer protection, broader social objectives but the promotion of competition and efficiency as well. Since in a competitive environment, banks need to be more efficient if they want to survive in the long run it seems that bank stakeholders

need to be more efficient if they want to survive in the long run. Thus, we resort to cost efficiency as a bank's chosen objective, because it is a necessary condition for ensuring sustainability of bank's operation in the market.

As the final element in the proposed approach, we link the business model to bank performance by using a stochastic frontier approach that can evaluate how changes in the rules of the game (e.g., adjustments in business models) affect cost efficiency, not only in the short run, but also in the long-run. More specifically, we introduce the diversification measures into a stochastic cost frontier model that decomposes cost inefficiency into persistent and transient components (Colombi et al., 2014; Kumbhakar et al., 2014; Tsionas & Kumbhakar, 2014; Badunenko & Kumbhakar, 2017).

To link the BBM to cost efficiency, we need to relate our chosen measure of business model to both short- and long-run cost efficiency. Thus, we propose a procedure to distinguish between constant (long-run or persistent) and time-variant (short-run or transient) aspects of a business model. To account for the business model's effect on time-variant cost efficiency, we introduce diversification indices as determinants of cost inefficiency. However, to identify the effect of the persistence of the BBM, we use the coefficient of variation (CV) of the diversification index as a determinant of long-run cost inefficiency. The separation of overall inefficiency into short- and long-run inefficiency enables us to examine whether banks can achieve a sustainable cost-efficient business model. We judge the sustainability of a bank's business model by the bank's ability to operate at low levels of persistent inefficiency while improving transient cost efficiency.

We apply this approach using data on commercial banks in 15 European countries from 1993 to 2016. We find that the sustainability of a bank's business model requires different strategies in the short- and

(including policymakers, regulators, creditors, supervisors, owners) besides managers need to monitor bank costs closely to ensure bank survival. Actually, related with the finding of Assaf et al. (2019) it seems that managerial policies and procedures that promote cost efficiency, may help to reach good performance during subsequent crises.

long-run: first, diversify the funding and income portfolios in the short run. Second, sustain a persistent income business model and adjusts the asset-focused business model in the long-run.

The remainder of the paper is organized as follows. Section 2 reviews the literature on bank business models. Section 3 introduces the empirical framework. Section 4 discusses the data and construction of the variables. Section 5 presents the results, and Section 6 concludes the paper.

2. Literature review

The literature on BBMs can be broadly divided into two strands in terms of how the business model is identified and analyzed. One strand focuses on the identification and description of types of BBM (i.e., the first approach in the introduction), while the second strand examines the effect of business models on bank performance (i.e., the second approach).

Following the pioneering work of Amel and Rhoades (1988), the first strand of the literature is oriented toward identifying and classifying several business models in the banking industry. Ayadi et al. (2011), Ayadi and de Groen (2014), Farnè and Vouldis (2017), and Roengpitya et al. (2017) have deployed balance sheet ratios in cluster analysis to identify and classify BBMs. The common finding of these studies, which use different periods and data, is that there are four BBMs. For instance, Ayadi and de Groen (2014) use 173 European banks from 2006 to 2013; Farnè and Vouldis (2017) use 365 Euro area banks in 2014, and Roengpitya et al. (2017) use 178 European banks from 2005 to 2015. These authors have demonstrated that the business models that provide deeper commercial banking focus are easily identified from those with more widespread capital market activities.[4]

[4] The difficulty in clearly identifying some strategic group of banks can be explained by the fact that the cluster approach disregards intermediate or granular banking strategies on the various dimensions of the business model mix. It should resort to judgmental criteria to eliminate candidates that do not represent clear and easily interpretable groups (i.e., distinct BBMs) or to focus only on partitions that are clear winners to define exclusive groups of banks (i.e., types of business models).

A second strand of the literature focuses on the link of BBMs to bank performance. This research varies not only in the performance measure, but also in the bank activities or characteristics selected to define the business model. Moreover, in terms of the characterization of business models, some papers have used particular bank characteristics, whereas others have applied measures of bank diversification.

In exploring the effects of a business model on bank performance, the primary studies belonging to this second strand of research determines the business model by diversification measures. Some studies have focused on relating just the income strategies of banks to the profitability performance measure. For instance, DeYoung and Roland (2001), Stiroh (2004), and Stiroh and Rumble (2006) examine whether diversification can reduce earnings volatility when considering non-interest income activities jointly with traditional intermediation activities. A common finding is that, since fee-based activities increase the volatility of bank income, marginal increases in revenue diversification are not associated with better profitability in U.S. banks. However, the evidence is mixed for the European banks. Smith et al. (2003) and Chiorazzo et al. (2008) suggest that increased reliance on non-interest income stabilizes profits. However, Lepetit et al. (2008) find that expansion into non-interest income activities raises the risk of volatility and insolvency.

When the focus is on bank asset characteristics instead of income strategies, the findings are mixed. Rossi et al. (2009) demonstrate that asset diversification raises profit efficiency by reducing bank risk and cost efficiency. Curi et al. (2013) find that asset diversification is positively associated with the technical efficiency of foreign banks in Luxembourg, while Elyasiani and Wang (2012) obtain opposite results for a sample of U.S. bank holding companies.

After the financial crisis, some authors extended the dimension of bank business models by considering the diversification of banks' funding strategies. Demirgüç-Kunt and Huizinga (2010) focus on funding structure and income diversification to analyze the effects of bank business models on bank risk. Their results suggest that a higher share of wholesale funds and greater diversification in income imply higher bank risk. Berger et al. (2010) indicate that specialization in deposits (along with loans and assets) is associated with greater profits and cost efficiency for a sample of Chinese banks, although income diversification was not covered. Curi et al. (2015) find that the most technically efficient business model appears to follow a focused asset, funding, and income strategy in the case of foreign banks in Luxembourg. However, during the financial crisis, branch organizational form diversified in terms of assets, funding, and income proved advantageous for efficiency.

In the second strand of the literature, some papers attempt to analyze the link between the business model and bank performance by only using particular bank characteristics in place of diversification measures. Most of these papers appeared after the financial crisis and examine, as a matter of routine, the effects of BBM characteristics on bank stability and/or profitability. In this vein, Altunbas et al. (2011) analyze the relations between risk and BBM characteristics during the banking crisis (2006–2009). By using different indicators to identify the asset, funding, and income dimensions of bank structure in describing a business model's characteristics, these authors demonstrate that banks with a strong deposit ratio are less exposed to risk than those with low capital, a greater share of short-term funding, a large size, and expansive credit growth.[5]

The study of Mergaerts and Vander Vennet (2016) is the first to analyze the effects of long-term performance on BBMs. Using individual bank characteristics to describe the business model, the authors account for the within and between business models dimensions by constructing variations in business model characteristics and then apply common factors. This empirical strategy has several drawbacks. First, the authors identify the BBM by assigning each bank to a cluster, where it remains permanently. The authors thus assume that banks choose only long-run strategies and that the BBM is stable over time. Second, their approach does not consider managers' optimal decisions in terms of performance. Third, to identify the type of business model, they use factor analysis to relate the characteristics of the BBM to profit.

[5] Overall, the studies within this second strand use diversification measures to identify BBMs models, or only individual bank characteristics. However, this literature uses a regression approach to link BBMs to bank performance. These studies do not analyze banks' optimal decisions in terms of performance, given the business model, or the long- or short-run effects of business model adjustments on performance.

None of the papers mentioned above uses the concept of the business model as a representation of the firm's underlying strategic choices that can build a competitive advantage in the market through an optimization decision, and they fail to model banks' production and optimization processes. The present paper contributes to the second strand of literature by using an approach that considers the business model as an indicator of the strategies and activities banks use, taking into account the relation between the business model and their adjustment in the short and long-run. The paper considers how banks optimize cost (i.e., value capture) and build a sustainable competitive advantage in the market. The approach our study proposes links the BBM to bank performance, identifying which types of business models allow for sustainable bank performance.

3. Empirical framework

We resort to the concept of the BBM as a representation of the firm's underlying core logic and strategic choices that explain how firms create and capture value. That is, how bank managers optimize the structure of cost (Zott et al., 2011) to build a sustainable competitive advantage in the market (Morris et al., 2005). Considering that the banking sector in Europe has undergone a significant transformation related to deregulatory, competition, technological, and economic changes, this is an appropriate way of defining a BBM. Improving the original concept of a business model in terms of strategic groups (Porter, 1979), this definition understands the business model as a holistic tool that gives information about what banks do and how they do it. We propose the following multi-component approach.

First, we resort to the notion of a diversification index to define a bank's strategic choice set, which includes all the combinations of strategies. Using diversification indices enables the changes in a variety of business models to be monitored over a long period, thereby tracking adjustments to the business model in reaction to changes in the environment. Second, as argued previously, banks strive to minimize costs. We model this behavior by specifying a cost function. To measure the inability of banks to minimize costs, we employ a stochastic cost frontier approach that includes inefficiency, which can be viewed as banks' inability to fully minimize costs. This econometric approach enables the modeling of multi-input multi-output technology and can identify cost efficiency. Third, we assume that the BBM explains bank managers' extent of success in achieving sustainable performance in the short and long-run.

To identify how the business model and its adjustment affect short- and long-run performance, we estimate a state-of-the-art four-component stochastic cost frontier with the determinants of the inefficiency components (Badunenko & Kumbhakar, 2017).[6] The separation of short- and long-run inefficiencies in the four-component stochastic cost frontier model is essential to our approach, since the sustainability of a bank's business model is judged by its ability to operate at a low level of persistent inefficiency and with improvements in transient cost efficiency. The cost frontier model we use is formally specified as

$$\ln TC_{it} = \mathrm{f}(y_{it}, w_{it};\ \theta) + v_{it} + v_{0i} + u_{it} + u_{0i}, \tag{1}$$

where TC_{it} is the total cost of bank i observed at time t, and f(.) is the deterministic cost frontier that represents the multi-output production technology specified below. The error term consists of four components. The term v_{0i} captures latent bank heterogeneity, and v_{it} represents the usual random noise. The random noise and random effects components are assumed to be distributed normally, with zero mean and variances σ_v^2 and σ_{v0}^2, respectively. Here, $u_{0i} \geq 0$ and $u_{it} \geq 0$ stand for persistent (long-run) and transient (short-run) cost inefficiencies, respectively. The term u_{oi} is assumed to be half-normally distributed, with a pre-truncated variance that depends on the time-invariant determinants of the persistent inefficiency $\mathbf{z}_{0i}$, that is,

$$u_{0i} \sim N^{+}\left(0, \sigma_{u0i}^2\right),\ \sigma_{u0i}^2 = \exp(h_{0i}) = \exp(\mathbf{z}_{0i}\boldsymbol{\omega}). \tag{2}$$

[6] Kumbhakar et al. (2014) estimate the four random components stochastic frontier using multiple steps, while Colombi et al. (2014) derive the log-likelihood function of the model by using the results from a closed skew-normal distribution, in conjunction with a single-step maximum likelihood method. Tsionas and Kumbhakar (2014) introduce persistent and transient technical inefficiency in a generalized true random effects model, using a Bayesian approach to the estimation. Badunenko and Kumbhakar (2017) use a single-step maximum likelihood method with determinants of both persistent and transient cost efficiency components.

where $\mathbf{z}_{0i}$ is a vector of m constant covariates $[1\ z_{01}\ \dots\ z_{0m}]$ that determine the persistent cost inefficiency u_{0i} through its variance. Given that $E(u_{u0i}) = \sqrt{\frac{2\sigma_{u0i}^2}{\pi}} = \sqrt{\frac{2}{\pi}}\exp(0.5h_{0i})$, $\mathbf{z}_{0i}$ is viewed as a determinant of persistent inefficiency. Similarly, l time-varying determinants $\mathbf{z}_{1it} = [1\ z_{11}\ \dots\ z_{1l}]$ of transient, or short-term, inefficiency, that is, u_{it}, is introduced through the pre-truncated variance of u_{it}, as follows:

$$u_{it} \sim N^+\left(0, \sigma_{uit}^2\right),\ \sigma_{uit}^2 = \exp(h_{it}) = \exp(\mathbf{z}_{1it}\boldsymbol{\psi}). \tag{3}$$

To accurately link the BBM to cost efficiency in both the short- and long-run, we use the diversification indices as determinants of both transient and persistent cost inefficiency. For the transient cost inefficiency component, we use the diversification indices as they are, but the persistent cost inefficiency component requires time-invariant determinants. We model the persistence of the BBM by calculating the CVs of the diversification indices. The smaller the CV, the more persistent the business model, implying that bank managers stick to a similar business model over a long time. Large CV values indicate that the business model is adjusted frequently. We then use the CVs of the diversification indices as determinants of persistent, or long-run, cost inefficiency.

After estimating the model, we compute the marginal effect of each determinant on persistent and transient inefficiency. The marginal effect of z_{0k} on persistent inefficiency is given by

$$0.5\sqrt{\frac{2}{\pi}}\exp(0.5h_{0i})\frac{\partial h_{0i}}{\partial z_{0k}}. \tag{4}$$

If $\mathbf{z}_{0i}$ does not contain interaction terms involving z_{0k}, the marginal effect of z_{0k} in (4) will have the same sign as its coefficient, which is ω_k. Given the specification in (4), the marginal effect of z_{1k} on transient inefficiency is given by

$$0.5\sqrt{\frac{2}{\pi}}\exp(0.5h_{it})\frac{\partial h_{it}}{\partial z_{1k}} \tag{5}$$

The determinants $\mathbf{z}_{1it}$ are allowed to vary by bank and over time, while the $\mathbf{z}_{0i}$ determinants are time invariant.

4. Empirical model and data

4.1.Bank business model

We conceptualize the business model by using a set of bank activities or characteristics that describe the bank's strategic choices to achieve optimal performance. The BBM is defined in terms of the strategic framework in which the bank chooses its assets, funding, and income portfolios over time. As pointed out in Section 2, most studies analyze the bank business model in terms of the asset mix and/or income mix.[7] However, the funding strategy of a bank is increasingly being recognized as crucial for bank intermediation.[8] Thus, to properly characterize the bank portfolio, we define the BBM in three dimensions[9]: (i) lending and investment, (ii) sources of funding, and (iii) sources of income.

Assuming that the banking sector is portrayed by a continuum of possible strategies, we resort to the Herfindahl–Hirschman Index (HHI) to measure how focused or diversified banks are in choosing their assets, funding, and income portfolios to determine their business activities. Instead of using the modified HHI, as Elsas et al. (2010) and Curi et al. (2015), we follow Acharya et al. (2006) and apply the standard HHI to banking to construct a diversification index. In defining the business model along the three dimensions noted above, we take into account the complete array of bank assets, funding, and income operations.

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[7] The income mix plays an important role in the definition of the bank business model. The European Union (EU) Second Banking Directive (1989/646/EEC) prompted many banks to revise their business models, increasing their share of non-interest income and non-traditional activities. On the other hand, the income mix is relevant when cost efficiency is used to measure bank performance, because non-interest income increases operational leverage. Actually, DeYoung and Roland (2001) have highlighted how an increase in non-interest income can imply a rise in fixed costs. Thus, non-interest income also increases operational leverage.

[8] Borio (2009) note that changes in funding strategies could be triggered by weaknesses on the asset side.

[9] Curi et al. (2015) also use these three dimensions in defining the BBM.

In terms of assets, we include loans (L), loans to banks (LTB), derivatives (DERV), securities less derivatives (SEC), non-earning assets (NEA), and fixed assets (FA). Therefore, for each bank i at time t, we calculate the HHI of assets, HHIA, as

$$HHIA_{it} = \left(\frac{L_{it}}{A_{it}}\right)^2 + \left(\frac{LTB_{it}}{A_{it}}\right)^2 + \left(\frac{DERV_{it}}{A_{it}}\right)^2 + \left(\frac{SEC_{it}}{A_{it}}\right)^2 + \left(\frac{NEA_{it}}{A_{it}}\right)^2 + \left(\frac{FA_{it}}{A_{it}}\right)^2, \tag{6}$$

where A is the sum of the six variables in the numerators.

For the funding dimension, we consider deposits (DEP), deposits from banks (DEPB), other deposits and short-term borrowings (STB), derivatives and trading activities (DEVT), long-term funding (LTF), reserves (REV), and equity (EQT). Consequently, for each bank i at time t, we calculate the HHI of funding, HHIF, as

$$HHIF_{it} = \left(\frac{DEP_{it}}{FUND_{it}}\right)^2 + \left(\frac{DEPB_{it}}{FUND_{it}}\right)^2 + \left(\frac{STB_{it}}{FUND_{it}}\right)^2 + \left(\frac{DEVT_{it}}{FUND_{it}}\right)^2 + \left(\frac{LTF_{it}}{FUND_{it}}\right)^2 + \left(\frac{REV_{it}}{FUND_{it}}\right)^2 + \left(\frac{EQT_{it}}{FUND_{it}}\right)^2, \tag{7}$$

where FUND is the sum of the seven variables in the numerators.

Finally, we consider interest income (II) and non-interest income (NII) to define the income mix. Then, for each bank i at time t, we calculate the HHI of income, HHII, as

$$HHII_{it} = \left(\frac{II_{it}}{TI_{it}}\right)^2 + \left(\frac{NII_{it}}{TI_{it}}\right)^2, \tag{8}$$

where TI is the sum of II and NII. [10]

[10] The complete array of banks' total assets obtained from the database used includes earning and non-earning assets, since loans, loans and advances to banks, derivatives, and other securities are considered earning assets. Non-earning assets correspond to money invested in non–interest-bearing bank accounts (called non-earning assets in the database) and fixed assets that contain information about real estate or other property that does not generate an income or gain value over time. The complete range of bank funding includes total liabilities and equity, where total liabilities are split into total customer deposits, deposits from banks, other deposits and short-term borrowings, derivatives plus trading liabilities, long-term funding, and loan loss reserves plus other reserves. Finally, to build the diversification income index, we consider interest income on loans plus other interest income and other income from non-interest sources, called total non-interest operating income in the database.

[10] In particular, $HHIA \in \left[\frac{1}{6}, 1\right]$; $HHIF \in \left[\frac{1}{7}, 1\right]$ and $HHII \in \left[\frac{1}{2}, 1\right]$.

All the indices will be bounded between 1/n and one, where n is the number of assets, funding, and revenue characteristics used in the definition of each HHI.[11] The closer the value of an index (e.g., the closer the HHI of assets is to one), the greater a bank's portfolio focus. An index value closer to the lower bound of 1/n implies a higher level of diversification in each of the portfolios chosen by the bank in its business strategy.

4.2. Technology and model specification

The bank production technology is modeled using an intermediation approach (Sealey & Lindley, 1977), which is common in the bank efficiency literature (Berger & Humphrey, 1997). The chosen technology for (1) is the full translog multi-output cost function:

$$\begin{aligned}\ln TC_{it} &= \beta_0 + \sum_{q=1}^{2} \beta_q \ln Y_{qit} + \sum_{w=1}^{2} \gamma_w \ln P_{wit} + \alpha_t T_{it} \\ &+1/2 \sum_{q=1}^{2} \sum_{j=1}^{2} \beta_{qj} \ln Y_{qit} \ln Y_{jit} + 1/2 \sum_{w=1}^{2} \sum_{j=1}^{2} \gamma_{wj} \ln P_{wit} \ln P_{jit} + \alpha_{tt} T_{it}^2 \\ &+ \sum_{q=1}^{2} \sum_{w=1}^{2} \zeta_{qw} \ln Y_{qit} \ln P_{wit} + \sum_{q=1}^{2} \alpha_{tq} T_{it} \ln Y_{qit} + \sum_{w=1}^{2} \theta_{tw} T_{it} \ln P_{wit} \\ &+\alpha_b \ln \mathrm{Bankgdp}_{it} + v_{it} + v_{0i} + u_{it} + u_{0i},\end{aligned} \tag{9}$$

where TC_{it} is the total cost of bank i in time t. The multi-output nature of the bank production technology is defined by three inputs used to produce two outputs. The outputs are loans (Y_1) and other earning assets (Y_2). The inputs are labor, physical capital, and total loanable funds, which are common in the bank efficiency literature. The price of labor (P_1) is defined as total labor expenses divided by total assets; the price of physical capital (P_2) is total operating costs minus labor expenses, divided by fixed assets; and the price of total loanable funds (P_3) is the ratio of interest expenditures to total loanable funds. Total cost (TC) is defined as the sum of the costs for the three inputs.

We allow technical change to have neutral and non-neutral components by including linear and quadratic time trends, T, as well as interactions of the trend variable with input prices and outputs. Following Casu et al. (2013), we also introduce a variable that measures the reliance of the economy on

[11] In particular, $HHIA \in \left[\frac{1}{6}, 1\right]$; $HHIF \in \left[\frac{1}{7}, 1\right]$ and $HHII \in \left[\frac{1}{2}, 1\right]$.

the banking sector, the ratio of banking to the gross domestic product (GDP), Bankgdp. This variable is used to account for the macroeconomic environment and to avoid possible bias in the estimation of technical change.

The determinants of both types of inefficiencies are the three dimensions of the BBMs (assets, funding, and income dimensions). The indices $HHIA_{it}$, $HHIF_{it}$, and $HHII_{it}$ are the time-varying determinants of transient inefficiency, entering the pre-truncated variance of u_{it} in Equation (3). A positive estimated marginal effect of $HHIA_{it}$, $HHIF_{it}$, and $HHII_{it}$ in Equation (5) means that transient cost inefficiency is higher when a bank chooses a more focused portfolio on assets, funds, and income.[12] Consequently, the bank's short-run cost efficiency decreases.

The persistent inefficiency in Equation (2), u_{0i}, does not change over time. Thus, to determine the impact of a business model on long-term bank performance, we select a business model aspect that is persistent or constant and bank specific. The measure that we propose mimics management's business model decision over a long period and can be roughly viewed as the bank's business model persistence. To preserve the concept that a bank is characterized by a continuum of possible business models, this proxy will show the extent of variation of bank BBMs in the long-run. Given that the CV is a standardized measure of dispersion that indicates the heterogeneity of the variable values, we use the CV of each focus index to examine how BBM persistence is related to long-run cost inefficiency. In our case, the CV of each focus index is represented by $CVHHIA_{0i}$, $CVHHIF_{0i}$, and $CVHHII_{0i}$, where higher (lower) values imply that the asset, fund, or income focus index of each bank changes more (less) frequently over time. This constructed measure reflects the extent to which a bank manager decides to vary the BBM over time.

[12] A negative marginal effect means that a more diversified bank portfolio enhances cost efficiency.

4.3.Data sample

Our sample comprises commercial banks from 15 European countries (Austria, Belgium, Denmark, Germany, Finland, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain, Portugal, Sweden, and the United Kingdom) over the period 1993–2016. The countries are chosen to safeguard uniformity among them, since they correspond to those that existed in the EU before the wide enlargement of countries in 2004. This 24-year period covers a number of economic and regulatory changes, such as the liberalization of capital markets, the creation of the Economic and Monetary Union (EMU), the implementation of the Financial Sector Assessment Program (FSAP), and the financial crisis. A long analysis period is central to consider accurately the adjustment of the BBM in face of changes in the environment and to reveal the model's sustainability.

We obtain banks' balance sheets and income statements from BankScope and BankFocus, both maintained by Bureau Van Dijk. Because of our long period, we have a series of challenges to make the data consistent. To fully exploit the database, we use balance sheet data based on International Financial Reporting Standards and General Accepted Accounting Principles accounting standards merging the data, following Mergaerts and Vander Vennet (2016). Moreover, to ensure comparability across countries, we select only commercial banks (Bos & Schmiedel, 2007; Casu et al. 2016; Kontolaimou & Tsekouras, 2010). The database is constructed by tracing the bank history for each bank. We allow for bank exits, entries, and mergers and acquisitions over the sample period, where banks involved in the latter are treated as different banks prior to the merger. Furthermore, we exclude banks missing data on basic accounting variables, including assets, loans, deposits, equity, interest income, and non-interest income. [13][14] Finally, we exclude extreme outliers, applying a number of filters to the sample following Cetorellu

[13] Following Casu et al. (2016).

[14] This excludes 5,953 observations.

and Goldberg (2012), and banks observed for less than four continuous years.[15] The final sample includes 10,034 bank–year observations (with a minimum of 173 banks for the year 2016). Stock variables from the balance sheets are averaged, and flow variables from the profit and loss statements are reported year to year. All the variables are in real terms, obtained by deflating the nominal values using the GDP deflator, with 2010 as the base year.

Table 1 presents summary statistics for bank outputs and inputs, focus indices, and their respective CVs for the whole sample and subperiods.

[15] This excludes only 424 observations.

Table 1. Outputs, inputs, focus indices, and CVs: Summary statistics, 1993–2016

Name	Period	Mean	Median	Min	Max	SD	name	period	Mean	Median	Min	Max	SD
TC	1993-1997	1,311,207	90,217	1508	28,149,579	3,580,444	*HHIA*	1993-1997	0.4426	0.3963	0.2434	0.9652	0.1402
TC	1998-2002	1,659,745	93,018	770	79,098,892	5,552,283	*HHIA*	1998-2002	0.4692	0.4338	0.2444	0.9874	0.1421
TC	2003-2007	1,452,745	69,483	944	108,885,310	5,670,574	*HHIA*	2003-2007	0.5119	0.4826	0.2532	0.9549	0.1527
TC	2008-2013	1,853,335	81,496	1353	66,027,608	6,492,805	*HHIA*	2008-2013	0.5145	0.4885	0.2513	0.9684	0.1472
TC	2014-2016	2,228,491	91,140	1388	50,707,964	6,415,646	*HHIA*	2014-2016	0.4932	0.4673	0.2626	0.9469	0.1360
TC	Whole sample	1,653,392	82,711	770	108,885,310	5,734,991	*HHIA*	Whole sample	0.4923	0.4595	0.2434	0.9874	0.1482
Y1	1993-1997	9,674,594	422,223	130	302,811,835	31,435,687	*HHIF*	1993-1997	0.4681	0.4354	0.1967	0.9295	0.1448
Y1	1998-2002	1,3692,396	652,780	415	416,849,328	43,570,593	*HHIF*	1998-2002	0.4581	0.4273	0.1961	0.9285	0.1544
Y1	2003-2007	16,735,242	648,650	697	825,161,309	62,541,596	*HHIF*	2003-2007	0.4853	0.4521	0.1758	0.9559	0.1647
Y1	2008-2013	27,477,939	1,040,779	900	744,015,097	90,118,878	*HHIF*	2008-2013	0.4755	0.4387	0.1585	0.9364	0.1626
Y1	2014-2016	41,153,649	1,612,402	2031	749,082,277	103,955,983	*HHIF*	2014-2016	0.4747	0.4494	0.1614	0.8933	0.1543
Y1	Whole sample	19,903,947	775,666	130	825,161,309	69,215,946	*HHIF*	Whole sample	0.4731	0.4390	0.1585	0.9559	0.1588
Y2	1993-1997	8,76,536	588,763	1617	225,219,824	22,790,952	*HHII*	1993-1997	0.7117	0.7101	0.5000	0.9948	0.1225
Y2	1998-2002	11,438,599	623,336	98	571,098,590	40,880,423	*HHII*	1998-2002	0.6648	0.6442	0.5000	0.9978	0.1242
Y2	2003-2007	16,271,519	524,846	565	116,417,7497	71,365,921	*HHII*	2003-2007	0.6498	0.6189	0.5000	0.9930	0.1213
Y2	2008-2013	27,707,060	621,034	460	1450,444,603	122,821,860	*HHII*	2008-2013	0.6542	0.6283	0.5000	0.9963	0.1221
Y2	2014-2016	38,171,781	934,579	1776	101,868,7375	126,900,727	*HHII*	2014-2016	0.6265	0.5933	0.5000	0.9995	0.1158
Y2	Whole sample	18,40,548	592,821	98	1450,444,603	85,230,840	*HHII*	Whole sample	0.6602	0.6357	0.5000	0.9995	0.1238
P1	1993-1997	0.0165	0.0153	0.0020	0.0723	0.0097	*CVHHIA*	1993-1997	13.18	11.50	1.35	45.05	7.95
P1	1998-2002	0.0165	0.0149	0.0019	0.0862	0.0106	*CVHHIA*	1998-2002	15.02	14.15	1.38	47.81	7.38
P1	2003-2007	0.0150	0.0129	0.0020	0.0818	0.0108	*CVHHIA*	2003-2007	15.14	14.19	0.44	49.17	7.33
P1	2008-2013	0.0129	0.0108	0.0019	0.0841	0.0098	*CVHHIA*	2008-2013	14.92	13.72	0.44	49.17	7.50
P1	2014-2016	0.0114	0.0096	0.0020	0.0710	0.0079	*CVHHIA*	2014-2016	14.42	12.87	1.02	47.81	7.70
P1	Whole sample	0.0147	0.0127	0.0019	0.0862	0.0103	*CVHHIA*	Whole sample	14.76	13.63	0.44	49.17	7.52
P2	1993-1997	1.8753	0.9276	0.1450	17.8621	2.3078	*CVHHIF*	1993-1997	13.57	12.05	1.23	44.65	7.82
P2	1998-2002	2.2604	1.1039	0.1170	22.3522	2.8905	*CVHHIF*	1998-2002	14.59	13.37	0.98	47.51	7.56
P2	2003-2007	3.1099	1.4930	0.1184	22.9758	3.8821	*CVHHIF*	2003-2007	14.81	13.86	0.98	47.51	7.55
P2	2008-2013	3.4336	1.5525	0.1289	22.7910	4.3102	*CVHHIF*	2008-2013	14.80	13.86	0.98	47.51	7.30
P2	2014-2016	3.4808	1.5732	0.1217	22.7098	4.5716	*CVHHIF*	2014-2016	15.13	14.05	0.98	42.30	7.14
P2	Whole sample	2.8673	1.3150	0.1170	22.9758	3.7375	*CVHHIF*	Whole sample	14.63	13.63	0.98	47.51	7.50
P3	1993-1997	0.1046	0.0868	0.0093	0.3482	0.0665	*CVHHII*	1993-1997	9.38	8.49	0.43	31.60	5.14
P3	1998-2002	0.0728	0.0539	0.0066	0.3542	0.0582	*CVHHII*	1998-2002	10.37	9.54	0.43	31.60	5.33

P3	2003-2007	0.0552	0.0367	0.0066	0.3428	0.0527	*CVHHII*	2003-2007	10.79	9.84	0.90	31.60	5.46
P3	2008-2013	0.0431	0.0310	0.0067	0.3493	0.0445	*CVHHII*	2008-2013	10.92	10.17	0.90	29.90	5.34
P3	2014-2016	0.0245	0.0167	0.0066	0.3400	0.0294	*CVHHII*	2014-2016	11.00	10.49	0.90	27.35	5.24
P3	Whole sample	0.0598	0.0410	0.0066	0.3542	0.0568	*CVHHII*	Whole sample	10.57	9.76	0.43	31.60	5.36

n this table, TC is total cost, Y_1 stands for loans, Y_2 stands for other earning assets, P_1 is the price of labor, P_2 is the price of physical capital, P_3 is the price of total loanable funds, HHIA stands for the HHI of an asset portfolio, HHIF is the HHI of a funding portfolio, HHII is the HHI of an ncome portfolio, CVHHIA is the CV of HHIA, CVHHIF is the CV of HHIF, and CVHHI stands for the CV of HHII.

The total costs of the average (and median) bank in the sample increases over time, except during the subperiod before the crisis (2003–2007), while production, in terms of loans and other earning assets, has an increasing trend during the entire time span. In terms of input prices, the price of physical capital shows the same trend as the outputs, but it is the reverse of the trends for the price of labor and total loanable funds. The descriptive statistics of the focus indices and their corresponding CVs show that banks' business models are slightly more diversified in the funding dimension than in the asset dimension over time, except during the first subperiod (1993–1997). The asset (funding) business model experiences the most adjustments over time, toward greater (lower) concentration. Most significantly, banks unambiguously diversify their business models in the income dimension, with a slightly increasing trend over time. By looking at the CV of each focus index, we see the income (asset) business model is, on average (and in the median), the most (least) persistent. The evolution of the entire distribution of BBMs over time is discussed below.

5. Empirical results

5.1. Baseline estimates

We estimate the model in Equation (9) using panel data on commercial banks operating in 15 European countries from 1993 to 2016.[16] The estimation is performed using a maximum simulated likelihood method.

[16] To ensure that the regularity conditions of the cost function in (1) hold, we impose the usual symmetry restrictions by setting $\beta_{qw}=\beta_{wq}$ and $\gamma_{wj}=\gamma_{jw}$, as well as linear homogeneity in the input prices by dividing total cost and P_1 and P_3 by P_2.

In the next sections, we discuss the estimates of the technology, followed by an analysis of efficiency and the effect of the BBM on bank performance.

5.2. Technology

Table 2 presents the simulated maximum likelihood estimates of the baseline model for the cost frontier and the determinants of persistent and transient inefficiency. The majority of the cost function parameter estimates in panel A are statistically significant. Since the coefficients of the time trend interacted with input prices and outputs are statistically significant, the technological change is not neutral. Given that the estimated parameter of the variable Bankgdp is negative and statistically significant, all else being equal, if the proportion of bank credit in the GDP increases by 1%, the costs decrease by 0.06%.

Table 2. Baseline model estimation results:
Parameter estimates of the four components' stochastic cost frontiers

Parameter	Estimate	z-Value
Panel A		
Intercept	2.206	(13.91)
lnY1	0.511	(28.19)
lnY2	0.665	(36.62)
lnP1	0.106	(5.21)
lnP2	0.937	(39.81)
0.5*lnY1 ^{2}	0.144	(95.98)
0.5*lnY2 ^{2}	0.132	(92.29)
0.5*lnP1 ^{2}	0.002	(0.56)
0.5*lnP2 ^{2}	0.045	(10.98)
lnY1*lnY2	-0.146	(-299.21)
lnY1*lnP1	-0.007	(-4.36)
lnY1*lnP2	-0.015	(-7.83)
lnY2*lnP1	0.004	(2.28)
lnY2*lnP2	-0.011	(-5.32)
lnP1*lnP2	-0.009	(-3.25)
t	-0.016	(-2.12)
T ^{2}	6.2e-5	(0.27)
lnY1*t	0.004	(10.43)
lnY2*t	-0.002	(-5.43)
lnP1*t	-0.001	(-2.24)
lnP2*t	0.007	(13.72)
ln(bankgdp)	-0.064	(-5.60)
Panel B		
Random effects component: $\mathbf{log}\boldsymbol{\sigma}^2_{v0i}$		
Intercept	-0.452	(-9.49)
Persistent inefficiency component: $\mathbf{log}\boldsymbol{\sigma}^2_{u0i}$		
Intercept	-12.940	(-7.03)
CVHHIA	-0.108	(-2.22)
CVHHIF	-0.120	(-1.33)
CVHHII	0.417	(3.85)
Random noise component: $\mathbf{log}\boldsymbol{\sigma}^2_{vit}$		
Intercept	-4.716	(-53.93)
Transient inefficiency component: $\mathbf{log}\boldsymbol{\sigma}^2_{uit}$		
Intercept	-6.842	(-42.49)
HHIA	-0.181	(-1.19)
HHIF	1.811	(13.18)
HHII	3.215	(20.36)
D9802	0.618	(5.95)

D0307	0.694	(6.63)
D0813	1.033	(10.04)
D1416	1.312	(7.41)
	Sample size	
N	1071	
$\sum_{i=1}^{N} T_i$	10034	
Sim. logL	2223.36	

5.3.Short- and long-term inefficiencies and their determinants

Panel B of Table 2 presents the estimated parameters of the logarithm of the variance of each of the four error terms. The BBM in the three dimensions (assets, funding, and income) is embedded in the persistent and transient inefficiency components. In particular, the effects of a BBM on persistent inefficiency are estimated via Equation (2), in which σ_{u0i}^2 is a function of the CV of the three dimensions of the focus index, that is, $CVHHIA_{0i}$, $CVHHIF_{0i}$, and $CVHHII_{0i}$, which represent the BBM's persistence. The indices $HHIA_{it}$, $HHIF_{it}$, and $HHII_{it}$ enter the pre-truncated variance of u_{it} in Equation (3) to model the effects of the BBM on transient inefficiency.[17] Since each index is bank and time specific, it captures the short-run strategy of managers regarding the BBM. Given the time-varying nature of transient inefficiency, the baseline model includes not only the BBM (i.e., $HHIA_{it}$, $HHIF_{it}$, and $HHII_{it}$) indices as determinants, but also time dummy variables corresponding to changes in the economic and regulatory environment during the 24 years under study. In particular, we define five dummy variables corresponding to the liberalization of the capital markets (1993–1997); the creation of the EMU (1998–2002), the implementation of the FSAP (2003–2007), the crisis period (2008–2013), and the post-crisis period (2014–2016).

We first consider the determinants of persistent inefficiency. The estimated coefficients of $\ln \sigma_{u0i}^2$ in Panel B of Table 2 show that, while the CVs of the asset and income focus indices are statistically

[17] For estimation purposes, we reparametrize the variances of the four components to enter the likelihood function in logarithms.

significant in explaining persistent inefficiency, the CV of the funding index is not. Given the sign of the estimated parameters, the results suggest that managers' decisions to follow a less persistent BBM in the asset portfolio dimension enhance long-term efficiency. A steadier BBM in terms of the income portfolio contributes to a decline in persistent inefficiency. Finally, persistence of the focus index of the funding portfolio over time does not affect long-run inefficiency.

We now turn our attention to the determinants of transient inefficiency. The estimated parameters of $\ln \sigma_{uit}^2$ show that the bank funding and income business models are the main determinants of short-run inefficiency. The bank asset business model does not have a statistically significant effect on transient inefficiency. Greater diversification in the funding and income dimensions enhances short-run efficiency. These findings are congruent with those of Ayadi et al. (2011) and Mergaerts and Vander Vennet (2016), who suggest that a more diversified funding dimension and income structure, improve profitability. All the estimated parameters of the dummy variables are positive and statistically significant, meaning that their presence in the model increases transient inefficiency. Interestingly, the magnitude of the estimated coefficients is greater for the dummy variables for later years, suggesting that economic and regulatory changes over time have had adverse effects on short-run efficiency. The highest level of inefficiency is observed during the crisis period and its aftermath, potentially due to a lengthy post-crisis rebound.

The baseline model estimates persistent and transient inefficiency separately, information that could be desirable for policy purposes, especially in regulated industries such as banking. These results show that the persistent inefficiency in the European banking industry appears to be primarily explained by managers' decisions to alter the composition of their income and asset portfolios over time. Banks that are more stable in their income portfolios and that change their asset business model strategies more often are more cost-efficient in the long- run. On the other hand, transient inefficiency can be improved over time by diversifying the bank's funding and income portfolios in the short run.

Overall, the results show that all three dimensions of BBMs have an effect on the long- and short-run cost inefficiency of European banks. Thus, to precisely analyze the effects of a BBM on performance, our empirical model must consider all three dimensions, rather than focus on just one. Interestingly, the income business model plays a very important role in such an analysis, since it affects short- as well as long-run bank cost inefficiency. On the other hand, the fact that the asset dimension affects long-run cost inefficiency while the funding dimension influences short-run inefficiency can be explained by the asset–liability mismatch. The short-run financial term of liabilities allows managers to design strategies for funding business models that improve transient cost efficiency, whereas strategies for the asset business model require more time to affect cost efficiency, given that the assets are governed by long-run financial terms.

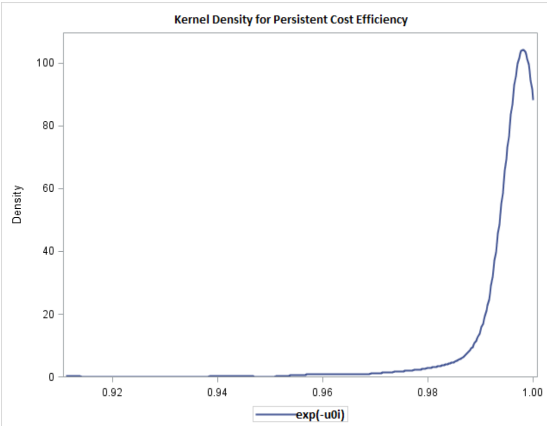
The estimates of persistent efficiency present useful information, because high values of long-run inefficiency are indicators of uncompetitive market conditions. In a competitive market, persistent inefficiency should be nonexistent, because persistently inefficient firms would go out of business. On average, the extent of persistent cost efficiency is very close to one, that is, 0.996.

Table 3 presents the means of the estimated transient inefficiencies over time. We observe an increase in cost efficiency during the period of the liberalization of capital markets (1993–1997) and a decline in transient efficiency from 1998 to 2002. Short-run efficiency was greater before and after the financial crisis, whereas transient cost efficiency was lowest during 2007 and 2008. Transient cost efficiency increased from 2009 to 2011, a period of urgent restructuring and resolution processes in the banking system, before declining in 2012, the year after which transient cost efficiency has remained virtually constant. Thus, the financial crisis appears to have had a positive short-run effect on the cost inefficiency of banks in the EU. These results are in line with those obtained by Andries and Ursu (2016) in terms of the evolution of total cost efficiency.

Table 3. Estimated transient cost efficiency

Years	Transient
1993	0.872
1994	0.892
1995	0.887
1996	0.896
1997	0.895
1998	0.876
1999	0.884
2000	0.862
2001	0.857
2002	0.871
2003	0.876
2004	0.877
2005	0.875
2006	0.862
2007	0.827
2008	0.800
2009	0.860
2010	0.873
2011	0.865
2012	0.838
2013	0.838
2014	0.836
2015	0.835
2016	0.837

Finally, we report the cross-sectional distribution of persistent efficiency, using the kernel density and the Gaussian kernel and optimal bandwidth selected by the method of Sheather and Jones (1991). Figure 1 plots the distribution of long-run cost efficiency, with more cost-efficient banks shown on the right and more cost-inefficient banks on the left. In the baseline model, the greater mass of banks is nearly fully cost-efficient (the average persistent cost efficiency is 0.996), that is, they have negligible persistent inefficiency. However, a few banks have a level of persistent efficiency as low as 0.911, that is, around 91% of the long-run cost efficiency.



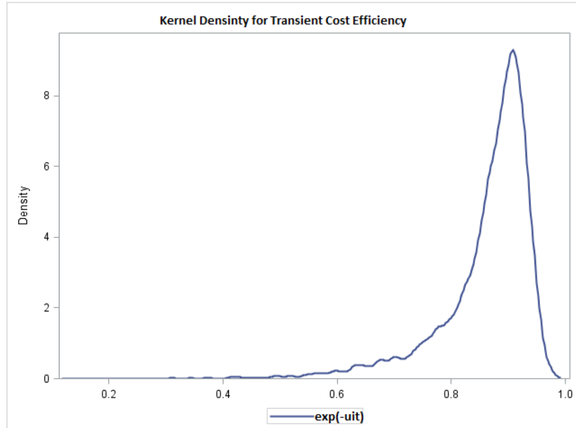


Fig. 1. Persistent cost efficiency

Fig. 2. Transient cost efficiency

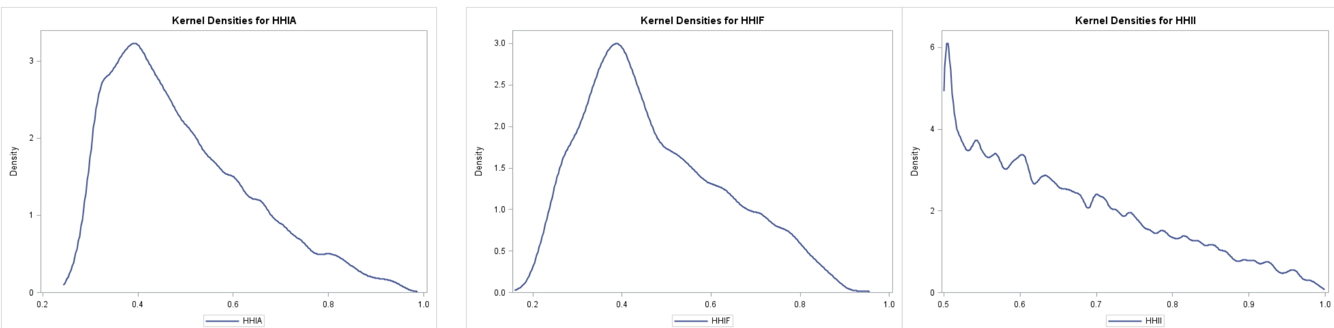
Figure 2 shows the distribution of short-run cost efficiency. The large mass of the distribution concentrated around 0.89 implies that the level of transient inefficiency at which a large proportion of banks operate is about 11%. However, the left tail is quite long, indicating considerable heterogeneity in terms of short-term efficiency within the industry. Overall, banks are less efficient in the short run. Long-run efficiency is quite close to 100%. Hence, the low levels of persistent inefficiency indicate that the European banking industry is competitive; however, there is considerable potential for cost-efficiency improvements in the short run.

Overall, the results suggest that managers who achieve a sustainable banking business model follow a long-term strategy of varying their asset business model and holding to their income business model, accompanied by a short-term strategy of greater diversification in the funding and income portfolios.

5.4. Actual bank business models

Now that we know more about the optimal behavior of banks concerning a sustainable cost-efficient model, we want to identify the types of decisions actually made by managers in designing their business models. Any correspondence between actual decisions taken with the above empirical results would indicate that managers consciously chose to target a sustainable business model in terms of cost efficiency.

We identify the actual decisions made by managers in terms of the business model by analyzing the distribution of the three business model dimensions, on average, over the entire time period and separately for different time periods representing various regulatory environments. This type of analysis allows us to take a comprehensive look at the actual strategy followed by banks in terms of their business models and adjustments over time, as well as whether such a strategy is consistent with our earlier findings from the estimated model.



(a) Asset dimension (b) Funding dimension (c) Income dimension

Fig. 3. Kernel distributions of the asset, funding, ands income focus indices

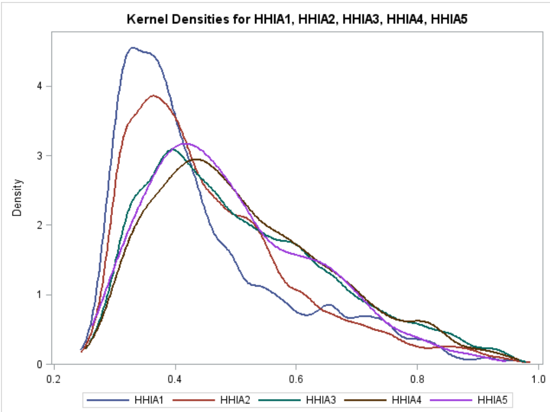
Figure 3 presents the distributions of the three focus indices for the entire time period.[18] Plot (a) of Figure 3 shows that a large, relatively homogeneous group of asset-diversified banks (with a distribution peak near 40%) coexists with banks that their business models' asset dimensions are more focused. The distribution in plot (b) is fairly similar to that in plot (a), although it peaks slightly below 40%, implying a large, homogeneous group of banks with a business model that is, to a certain extent, more diversified in the funding than in the asset dimension. As for the asset dimension, there are banks whose business models are strongly focused on the funding dimension, with indices approaching one. Plot (c) in Figure 3 suggests that the business model is the most heterogeneous in the income dimension. Many banks are

[18] Given that HHIA, HHIF, and HHII have different theoretical minima (0.16, 0.14, and 0.5, respectively), the scales of panels (a) to (c) of Figure 3 differ.

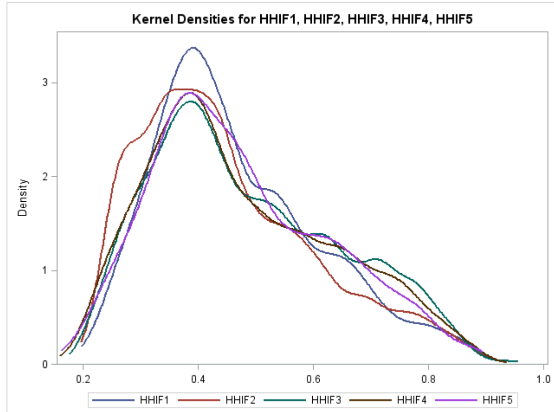
characterized by a high degree of income diversification; however, the right tail of the distribution is very thick, showing important groups of banks with business models on income dimension more focused.

Overall, the three distributions imply no single preferred business model for all commercial banks in the EU. Heterogeneous (i.e., both diversified and focused) commercial banks in all three dimensions coexist. Generally, commercial banks are more diversified in funding and income than in assets. Considering that, in terms of short-run inefficiency, funding diversification and income diversification enhance transient efficiency, it seems that a large group of banks exists whose managers' decisions pertaining to these two dimensions of the business model help facilitate short-run efficiency.

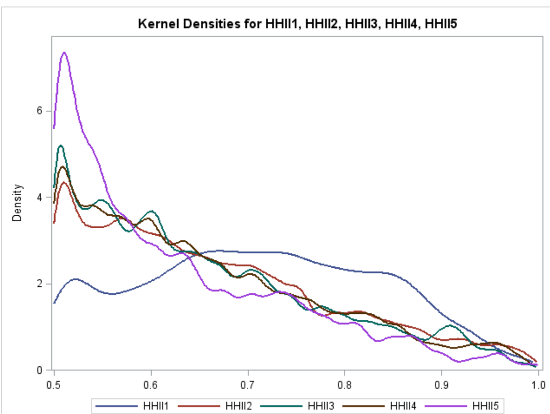
An analysis of the variation of business models over time is required to examine the extent to which a manager's decision is beneficial in terms of long-run efficiency. We thus assess the evolution of the business model indices over time to understand how European banks have adjusted their operations. In presenting the results, we split the 24-year period into five subperiods to more properly detect potential changes in BBMs, given that structural changes could have occurred in these European banks' environment. Any change in the cross-sectional distribution over time will indicate that banks have adjusted their business models to maneuver through different changes.



(a) Asset dimension



(b) Funding dimension



(c) Income dimension

Fig. 4. Asset, funding, and income focus index kernel distributions over time

Notes: The variables indexed 1 to 5 correspond, respectively, to: (1) the period of the liberalization of the capital markets (1993–1997),(2) the period of the creation of the EMU (1998–2002), (3) the implementation of the FSAP (20032007), (4) the financial and debt crises (2008-2013), and (5) the post-crisis period (2014–2016).

Figure 4 shows that BBMs are quite dynamic in all three dimensions, confirming earlier findings that BBMs are not static but, rather, evolve over time under the influence of a complex combination of pressures (Llewellyin, 2013). The actual analysis of the dynamics of business models weakens the veracity of the strong assumption in the approach developed by Mergaerts and Vander Vennet (2016), which assumes that banks choose only long-run strategies and that the BBM is stable over time.

Plot (a), showing the evolution of the business model in the asset dimension, suggests that, before the creation of the EMU (1993–1997 and 1998–2002), there was a larger group of more asset-diversified banks (peaking near 40%) than during the liberalization, crisis, and post-crisis periods. The distributions of the first and second subperiods are characterized by peaks to the left of those of the subsequent subperiod. Thus, managerial decisions shifted over time to ensure a more focused asset business model. Plot (b) of Figure 4 shows that commercial banks in Europe prefer a more persistent funding business model than the asset business model. Indeed, changes in the funding business model's distribution over time are less pronounced than in the asset business model distributions. Finally, significant changes can be seen over time in the income business model dimension, shown in panel (c) of Figure 4. The distribution of the first subperiod stands out from the rest by being almost uniform. Starting from the second subperiod, the shape of the distribution becomes unimodal. Many banks embraced a high-income diversification business model, attributable to circumstances by which financial margins made way for fee and commission revenues (Vives, 2001). The shapes of the kernel distributions during the last four periods are very similar. The post-crisis period presents a large proportion of banks that are more diversified in terms of the income dimension, but the right tail of the distribution is similar for the last four periods.

On the one hand, banks seems to follow an actual strategy in terms of how they adjust their business models over time. The asset business model becomes more focused. In contrast, the income business model becomes more persistent over time for the majority of banks, and more diversified for a small group of banks. On the other hand, based on regression analysis, we find that the expected strategy for a cost-efficient sustainable business model is contingent on changes in the asset and income business models, since they are significant determinants of persistent inefficiency. In particular, staying away from a more stable asset business model enhances persistent efficiency, whereas some banks' strategy of becoming more diversified in the income business model precludes any improvement in long-run efficiency.

Based on the above findings, banks that seek to maintain a more stable income portfolio and amend their asset business model to a greater extent are exhibiting behavior consistent with the prediction of the estimated model; that is, such behavior is more cost-efficient in the long run. In particular, only banks represented by the right tail of the distribution of the income dimension opted to become more stable in their income portfolio. Nevertheless, the actual strategy followed by banks indicates that they decided to develop a more concentrated asset business model.

5.5.Marginal effects of changes to business models

Having analyzed the overall effect of the three dimensions of the BBM on persistent and transient cost inefficiency, we now examine the marginal effects of changes in the business model. In particular, we estimate these marginal effects on persistent and transient cost inefficiency, using Equations (4) and (5), respectively.

The estimated parameters, shown in Panel B of Table 2, imply that, all else being equal, the variance of persistent inefficiency is smaller for banks that alter their asset business model to a greater extent ($CVHHIA_{0i}$) and maintain a more stable income business model ($CVHHII_{0i}$) over time. The conclusions of the analysis in the previous section suggest that commercial banks actually increased the concentration of their asset business models and the diversification of their income portfolios. Hence, the choices of banks whose asset business model and/or income portfolio becomes more concentrated are consistent with a long-run sustainable strategy. We consider the marginal effects of these changes to quantify their potential effects.

The descriptive statistics of the marginal effects calculated using Equation (4) are presented in Table 4. The mean values of the marginal effects given a one-standard-deviation change in the respective variable are -0.001955, -0.002175, and 0.00536 for CVHHIA, CVHHIF, and CVHHII, respectively. If a bank's business model is one standard deviation less persistent (e.g., CVHHIA increases by 7.516), the bank's inefficiency drops by 0.00195 annually. This result further implies that the total costs are 0.195% lower annually in the long-run.

Table 4. Marginal Effects on Persistent Inefficiencies, in Percent

Variable	Mean	P25	P50	P75
CVHHIA	-0.1955	-0.1730	-0.0752	-0.0376
CVHHIF	-0.2175	-0.1950	-0.0825	-0.0450
CVHHII	0.5360	0.1018	0.2144	0.4878

Notes: The variable CVHHIA is the CV of the HHI of an asset portfolio, CVHHIF is the CV of the HHI of a funding portfolio, and CVHHI is the CV of the HHI of an income portfolio. Presented in the table are the descriptive statistics of the annual percentage change in total costs if the persistence of the bank business model is reduced by one standard deviation.

In terms of the average values of the specific marginal effects of changes to the business model on transient cost inefficiency, a one standard deviation increase in the concentration in the funding dimension implies a 0.024 increase in inefficiency, which translates into a 2.4% increase in total annual costs. A one standard deviation increase in the focus index in the income direction increases costs by 3.29%, on average. Therefore, greater diversification in the funding and income portfolios improves short-run cost efficiency.

The analysis of marginal effects suggests that, for both long- and short-run cost inefficiency, the income dimension of the BBM has the greatest explanatory power. The income portfolio is the dimension of the BBM that affects both types of cost inefficiency with higher intensity. Overall, the discussions in Sections 5.3 and 5.5 suggest that all three dimensions of the BBMs affect various aspects of cost inefficiency to some extent. Our analysis corroborates the need to consider all three dimensions of the bank portfolio to analyze the impact of the BBM on performance.

The results of Section 5.4 have shown that banks continue to adjust their business models in the three dimensions to negotiate important challenges dictated by economic, technological, and regulatory changes. The regression results present a superior strategy by which European banks can implement such adjustments to guarantee a sustainable business model. Specifically, the results involve a combination of strategies to maintain the income dimension and adjust the asset dimension of a business model. Our findings show that European banks have adjusted their asset portfolios toward a more concentrated asset business model. Moreover, a successful short-run strategy requires greater diversification, whereas less diversification is beneficial for the long-run strategy.

6. Robustness analysis

We perform a number of robustness checks. The results of the estimations are presented in Table 5. Models 1 to 4 increase the set of efficiency determinants.

Table 5. Robustness analysis: Alternative estimated models

	Model 1		Model 2		Model 3		Model 4	
Panel A								
Parameter	Estimate	z-Value	Estimate	z-Value	Estimate	z-Value	Estimate	z-Value
Intercept	2.286	(8.04)	2.330	(4.23)	2.241	(3.71)	2.109	(19.15)
lnY1	0.495	(18.85)	0.494	(10.17)	0.495	(9.89)	0.513	(28.38)
lnY2	0.667	(26.27)	0.658	(15.33)	0.665	(13.59)	0.654	(36.13)
lnP1	0.102	(5.25)	0.108	(5.45)	0.108	(5.16)	0.099	(4.87)
lnP2	0.924	(41.64)	0.920	(39.65)	0.921	(40.42)	0.928	(38.70)
.5*lnY1 ^{2}	0.145	(58.61)	0.145	(31.39)	0.145	(30.09)	0.143	(83.12)
.5*lnY2 ^{2}	0.132	(64.34)	0.132	(36.86)	0.133	(32.95)	0.132	(83.99)
.5*lnP1 ^{2}	0.002	(0.65)	9.3e-4	(0.23)	0.001	(0.34)	0.002	(0.78)
.5*lnP2 ^{2}	0.045	(10.35)	0.046	(7.90)	0.046	(7.67)	0.046	(11.20)
lnY1∗lnY2	-0.146	(-277.23)	-0.146	(-171.40)	-0.146	(-158.40)	-0.145	(-350.03)
lnY1∗lnP1	-0.007	(-3.78)	-0.007	(-3.04)	-0.007	(-2.85)	-0.007	(-3.82)
lnY1∗lnP2	-0.015	(-7.55)	-0.014	(-6.86)	-0.015	(-6.78)	-0.015	(-7.45)
lnY2∗lnP2	-0.010	(-4.73)	-0.011	(-4.53)	-0.010	(-3.96)	-0.010	(-5.04)
lnY2∗lnP1	0.004	(2.09)	0.004	(2.16)	0.003	(1.94)	0.004	(1.89)
lnP1∗lnP2	-0.008	(-2.91)	-0.007	(-2.32)	-0.007	(-2.36)	-0.008	(-3.13)
t	-0.018	(-2.87)	-0.018	(-2.34)	-0.018	(-2.26)	-0.019	(-3.56)
T ^{2}	9.8e-5	(0.58)	1.1e-4	(0.65)	1.0e-4	(0.59)	6.3e-5	(0.43)
lnY1∗t	0.004	(8.97)	0.004	(6.41)	0.004	(6.31)	0.004	(9.23)
lnP2∗t	0.007	(13.93)	0.007	(13.12)	0.007	(13.24)	0.007	(13.65)
lnP1∗t	-0.001	(-2.42)	-0.001	(-2.16)	-0.001	(-2.22)	-1.0e-3	(-1.91)
lnY2∗t	-0.002	(-5.60)	-0.002	(-5.49)	-0.002	(-5.46)	-0.002	(-4.90)
log(bankgdp)	-0.069	(-6.01)	-0.066	(-5.54)	-0.066	(-5.69)	-0.067	(-4.66)
Panel B								

Random effects component: $\log\sigma^2_{v0i}$								
Intercept	-0.460	(-8.39)	-0.472	(-6.21)	-0.489	(-5.96)	-0.422	(-6.72)
Persistent inefficiency component: $\log\sigma^2_{u0i}$								
Intercept	-13.385	(-5.98)	-66.255	(-0.01)	-13.987	(-4.73)	-4.341	(-13.15)
CVHHIA	-0.131	(-2.02)	0.196	(6.73)	-0.248	(-2.05)	-0.038	(-3.74)
CVHHIF	-0.169	(-1.40)	-0.014	(-0.44)	-0.311	(-1.90)	0.019	(1.84)
CVHHII	0.464	(3.32)	0.647	(6.68)	0.597	(3.10)	0.036	(2.67)
PIGS			42.809	(0.01)	-9.106	(-3.71)		
PIGS*CVHHIA					0.437	(3.34)		
PIGS*CVHHIF					0.294	(1.72)		
PIGS*CVHHII					0.047	(0.27)		
Spain							-0.442	(-1.28)
Belgium							-0.108	(-0.34)
Germany							-0.733	(-2.11)
Denmark							-36.387	(-0.01)
Greece							0.255	(0.66)
Finland							-2.079	(-1.26)
France							-40.838	(-0.01)
Great Britain							-0.109	(-0.38)
Netherlands							-0.091	(-0.25)
Ireland							1.116	(2.92)
Italy							-1.753	(-3.58)
Luxembourg							-0.218	(-0.67)
Portugal							-3.093	(-2.21)
Sweden							0.983	(2.79)
Random noise component: $\log\sigma^2_{vit}$								
Intercept	-4.77	(-58.13)	-4.767	(-44.02)	-4.766	(-42.81)	-4.745	(-79.90)
Transient inefficiency component: $\log\sigma^2_{uit}$								
Intercept	-7.562	(-40.51)	-7.586	(-29.54)	-7.545	(-26.45)	-7.749	(-44.80)
D0307	0.713	-7.72	0.736	-7.94	0.718	-7.85	0.688	-7.34
D0813	1.06	-10.88	1.091	-11.06	1.072	-10.5	1.022	-10.53
D1416	1.338	-9.19	1.367	-9.22	1.354	-8.69	1.311	-9.94
D9802	0.634	-7.1	0.634	-6.64	0.623	-6.59	0.625	-7.25
HHIA	-0.285	(-1.85)	-0.272	(-1.59)	-0.313	(-1.80)	-0.19	(-1.26)
HHIF	1.48	-9.84	1.521	-10.25	1.504	-10.05	1.571	-10.27
HHII	3.127	-18.97	3.169	-18.54	3.168	-18.34	3.146	-18.89
SizeTA2	0.771	-3.5	0.732	-1.95	0.735	-1.79	0.885	-6.57
SizeTA3	1.102	-5.38	1.035	-2.84	1.047	-2.64	1.188	-9.8
SizeTA4	1.109	-5.68	1.072	-3.37	1.056	-2.99	1.196	-9.01
N	1071		1071		1071		1071	
$\sum_{i=1}^{N} T_i$	10034		10034		10034		10034	
Sim. logL	2254.96		2272.84		2281.13		2346.1	

In modeling transient inefficiency, we control not only for the three dimensions of the business model, but also for bank size. We define three dummy variables that indicate a bank's size class by quartiles of total assets in the entire sample. The three dummy variables representing size class 2 (total assets below the 75th percentile and above the median), size class 3 (total assets below the median and below the 25th percentile), and size class 4 (total assets below the 25th percentile) enter the transient inefficiency component as determinants in Model 1. Interestingly, larger banks are more efficient in the short run, and the differences are statistically significant between class 1 (total assets above the 75th percentile), class 2, and classes 3 and 4 combined. The difference between classes 3 and 4 is not significant. This result holds for the three other models that we introduce below. Although we control for size, the conclusions regarding the effects of the three dimensions of the business model on short-run inefficiency from the baseline model remain unchanged.

Models 2 through 4 use the same determinants of transient cost inefficiency as Model 1, but they also introduce different variants in the determinants of persistent inefficiency. Model 2 is estimated to ascertain whether commercial banks in Portugal, Ireland, Greece, and Spain have varying levels of efficiency in the long-run. The no significant dummy variable PIGS (Portugal, Ireland, Greece, and Spain) suggests that, on average, the level of persistent inefficiency is no different across these and other European countries. The effect of the funding focus becomes no significant, probably due to the lack of flexibility of Model 2. We address this in two different ways. First, in Model 3, the effect of the persistence of the business model in three dimensions is based on whether a bank is located in Portugal, Ireland, Greece, or Spain (PIGS group) or not. The effect of greater variation in the asset business model remains favorable for persistent efficiency, but only for countries outside the PIGS group. To improve their long-run efficiency, commercial banks in the PIGS group need to be more persistent and stable in terms of their asset business model. The more focused commercial banks outside the PIGS group are more efficient in the long-run. There are no changes concerning the effect of the CV in the income direction. Second, instead of just one dummy variable PIGS, we add dummy variables for each country in the sample, leaving Austria as a reference group in Model 4. The last column of Table 5 supports the earlier results. More specifically, the effects of the persistence of the focus indices have the same direction and significance as in the baseline specification. Moreover, regardless of the model, the effects of the time-varying focus indices in the case of short-run inefficiency maintain the same type of impact and significance as in the baseline model. Even though there are somewhat differences between the results presented in Table 5, the results of our baseline model are qualitatively verified.[19]

7. Concluding remarks

This paper proposes a new methodological framework to investigate the long- and short-term effects of banks' business model choices on performance, to assess if banks are successful in achieving a sustainable cost-efficient business model. Nowadays, business model analysis to assess the sustainability of bank's strategy has become a top supervisory priority in Europe.

Two important findings from our model contribute to the literature on the concept of the business model. First, we demonstrate that bank business models change over time. Therefore, any analysis that does not consider the possibility of short- and long-term adjustments to the bank business model is incomplete. Second, our results show that the funding dimension and especially the income dimension in the definition of the BBM cannot be neglected. All three dimensions—assets, funding, and income—of the BBM have an effect on performance when long- and short-run adjustments are considered.

This study applies the proposed methodology to a sample of banks from 15 European countries observed during the period 1993–2006. We show that the optimal strategy to guarantee a sustainable business model requires different strategies in the long- and short-run. While the optimal long-term strategy is to vary the asset business model and maintain a more stable income business model, the short-

[19] We re-estimate our baseline model, introducing financial equity capital as fixed netput in the technology specification. Financial equity capital is input under the asset approach, which we treat as fixed, partly because it is difficult to change quickly and partly because its price (the risk-adjusted expected return on equity) is difficult to measure. In addition, banks must meet regulatory capital requirements that might not be consistent with cost minimization or profit maximization. Such a specification can be seen as a sensitivity analysis of the technology. The results, which are available from the authors upon request, do not change our conclusions.

run strategy involves greater diversification in the funding and income portfolios. The analysis of the actual adjustments that European banks have undertaken over time indicates that banks strived to achieve a sustainable business model.

Finally, our results provide some comfort to those who advocate the key principle of the traditional theory of financial intermediation that bank diversification improves bank performance. For bank performance measured by cost efficiency, diversification is advantageous, but, at least for the case of European banks, only as a short-run strategy, and not for an asset portfolio.

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