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Complexity of Global Banks and the Implications for Bank Risk: Evidence from Foreign Banks in Hong Kong

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Abstract

The complex nature of an overall banking group could potentially affect the riskiness of their affiliates through various channels, such as agency costs and diversification gains. This paper empirically investigates the effects of bank complexity of the global banks (in terms of their business activities and geographical locations) on the riskiness of their affiliates, using a confidential data set of foreign bank affiliates based in Hong Kong (FBHKs). Our empirical findings based on a panel regression model suggest that the complexity of global banks has significant effects on the riskiness of their foreign bank affiliates, but the effects differ between the two complexity dimensions. Specifically, a FBHK from a more business complex banking group tend to have higher risks, and the effect is likely to be attributable to an intensified agency problem. For the geographical complexity, there is tentative evidence to support the presence of both diversification and agency problems. However, the average effect on the riskiness of FBHKs is found to be less clear-cut. To strengthen the identification, we further employ an alternative difference-in-difference (DID) estimation approach. This approach exploits the exogenous decline in bank complexity of the parent group arising from the introduction of GSIB regulatory framework. The DID results are consistent with the findings identified from the panel regression model.

Keywords: Complexity, bank risk, foreign banks
JEL codes: G21, F65

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1. Introduction

The complexity of global banking organisations has received heightened attention from both academia and policy makers, especially after the 2008 global financial crisis. The Lehman Brothers bankruptcy and its aftermath prominently raised renewed concerns not only about "too-big-to-fail", but also "too-complex-to-resolve". To address these concerns, new regulations and reforms have been put in place internationally and domestically to enhance the resilience of these large and complex global banking organisations. Against this background, internationally active banks, particularly those designated as global systemically important banks (GSIBs), have undergone significant changes in their organisational structure and business models in the post-crisis period (Carmassi and Herring 2016).[2] Given that many of these global banks have established operations in the form of branch offices and subsidiaries across different business and geographical areas, such structural changes in the overall banking group will not only affect the operations where the global banks are headquartered but also have significant implications for the host countries where their foreign entities are located (Kwan et al., 2019).

Despite the high relevance of bank complexity for policymakers and bank supervisors, empirical evidence remains scant, with most of these studies emphasising on the effects of bank complexity on the performance of banks at the banking group's level (Berger et al., 2017, Liu et al., 2016). Relatively few studies have examined the effect of the complexity of the banking organisation on the riskiness of their bank affiliates located in other countries. A better understanding of the latter question is particularly important for host-country supervisors as this could potentially add another layer of risk to their financial system. Therefore, this paper which forms part of a wider International Banking Research Network (IBRN) project, aims to broaden our understanding of the effect of bank complexity on bank risk from an inward perspective. Through the lens of foreign banks in Hong Kong (hereafter referred to as FBHKs), this paper investigates how bank complexity of the overall banking organisation would influence the riskiness of their FBHKs. As an international financial centre, Hong Kong hosts a large number

[2] See Bank for International Settlements Committee on the Global Financial System Papers No 60 "Structural changes in banking after the crisis," January 2018.

of foreign banking operations which vary in size, complexity, and scope of activities. Some of them are active in both funding and lending activities, gathering domestic deposits to provide loans to domestic borrowers. Others tend to rely more heavily on either lending or funding in the local market, depending on the global bank's business model. As such, the coexistence of the large presence of global banks and the significant variation in the asset and liability management of FBHKs provide a rich and suitable empirical setting to study how the risk profiles of these foreign banking operations may be affected by the complexity of their respective parent banking groups.

In theory, there are various mechanisms through which bank complexity at the group level can alter the risk profiles of their affiliates. One potential channel is due to diversification gains. More complex banking organisations tend to have a more diversified source of income arising from different business activities that span a larger set of markets or locations. This would enrich the internal financing available to their affiliates and increase the ability of the parent to share risks among affiliates by reallocating resources. From the affiliates' perspective, a higher complexity at the group level may contribute to a lower risk for the affiliates via the internal capital market channel (Cetorelli and Goldberg 2012, 2014).

Another potential channel for complexity to affect the riskiness of affiliates could be due to worsened agency problems and higher monitoring costs. The parent manager from a more complex banking organisation may face greater difficulties in managing across all affiliates, particularly if these affiliates are engaging in various business segments other than banking or are in different locations (Baule, 2014). A reduction in the quality and quantity of management effort between the parent and affiliates would worsen the agency problems, which could encourage affiliates to take on more risks at the expense of other affiliates. In a theoretical framework, Scharfstein and Stein (2000) shows that the worsened agency problem between the parent and affiliates in an organisation may induce rent seeking behaviour by the weaker affiliates, leading to suboptimal risk-taking and inefficient investments. In addition, due to increased interconnectedness of affiliates, each affiliates may be exposed to the risk taken by other affiliates in the organisation, thus adding an extra layer of risk to the affiliates belonging to a more complex organisation. In view of the competing theoretical predictions from the hypotheses of diversification and agency problem, the extent to

which bank complexity at the parent group affects the risk of its affiliates would need to be determined empirically, as it is unclear *ex ante* which effect is dominant.

To empirically study the effect of bank complexity, one needs to obtain a measure of bank complexity. Since there is no readily available or consensus measure of bank complexity, we sought to measure bank complexity following the concept developed by Cetorelli and Goldberg (2014) and Buch and Goldberg (2020). In particular, two dimensions of bank complexity are considered, namely business and geographical complexity. The former perspective relates complexity to the activities of banks outside the core banking businesses (i.e. insurance, other financial, real estate, and other nonfinancial activities), while the latter relates complexity to the banks' geographic activities. It is noteworthy that as we do not have access to the supervisory data on the organisational structure of the FBHKs' parent organisations, the complexity measures are constructed based on publicly available data from S&P capital IQ. The detailed description of these measures will be discussed in the next section.

This study adopts two empirical approaches to assess the effect of parent complexity on FBHKs' risk. We first estimate the average effect of parent complexity based on a panel regression model. In this analysis, we have studied a range of different types of bank risks which are commonly examined in the banking literature, including default risk (measured by inverse log z-score), earnings risk (volatility of ROA and risk-adjusted ROA) and credit risk (non-performing loan and loan loss provision ratios) of FBHKs. We further rely on the bank balance sheet heterogeneity of FBHKs to make inference about the existence of the two hypotheses through which complexity could alter the bank risk.

Given that this study focuses on the risk of FBHKs, and that the risk profile of an operating unit should be less likely to be a major driver for the change in bank complexity of the overall banking organisation, our baseline specification should be less prone to the issue of the reverse causality problem.[3] Nevertheless, to further strengthen the identification, we employ an alternative difference-in-difference (DID)

[3] One common concern is the potential reverse causality that exists between bank complexity and bank risk. That is, while higher bank complexity may be associated with higher bank risk, such relationship could be due to the case that a risky banking group attempts to diversify the risk by expanding into new business activities or geographical exposures which results in an increase in bank complexity.

approach, which takes the GSIB regulation introduced by the Basel Commission on Banking Supervision (BCBS) as a regulatory event that leads to an exogenous change in bank complexity, to causally identify the effect of bank complexity on the risk adjustment of their affiliates. Specifically, we first determine whether GSIB parent groups have exhibited a greater decline in their complexity relative to other non-GSIB global banks after the regulatory change based on a DID estimator. As the regulation-induced change in the complexity of the GSIBs are exogenous to the risk of their affiliates, this enables us to identify the causal effect of complexity by comparing the difference in the risk adjustment between GSIB affiliates and other non-GSIB affiliates in Hong Kong during the pre- and post-regulation periods.

Based on a sample of 159 FBHKs between 2004 to 2017, our findings suggest that a higher degree of business complexity of a global banking group has significant effects on the riskiness of their FBHKs, and the effects appear to be due to the worsened agency problem. On average, FHBKs tend to have a higher default risk and earnings volatility relative to other banks if their parent banking groups are more business complex. Importantly, such higher risks are not justified by a higher return, given that the effect on FBHKs' risk-adjusted ROA is found to be statistically insignificant. For the effect of geographical complexity, while there is some tentative evidence to support the presence of both diversification gains and agency problem channels, the average effect on the risks of FBHKs is found to be less clear-cut.

The alternative DID analysis also points to similar empirical findings identified from the panel regression model. Specifically, our findings show that GSIB banks have reduced their business complexity (but not their geographical complexity) by more than their non-GSIB counterparts since the introduction of the GSIB regulatory framework. The corresponding larger decline in the business complexity of GSIBs relative to non-GSIBs is also associated with a larger decline in default risk and a lower earnings volatility for GSIB's FBHKs than that of non-GSIBs. These results remain robust under an alternative control group of non-GSIB affiliates, which was constructed based on a propensity-score matching (PSM) approach.

Our paper proceeds as follows: Section 2 first presents our main hypotheses and follows with the description of data used in this study. Section 3 describes the empirical specifications and presents the empirical results. Section 4 concludes.

2. Hypotheses and Data

2.1 Hypotheses

As mentioned, this study particularly focuses on the two key hypotheses, namely the diversification benefit hypothesis and agency problem hypothesis, through which the bank complexity of the parent banking group may affect the riskiness of its affiliates.

For the former hypothesis, a more complex banking group is associated with more diversified business activities or diversified geographic exposures. Williamson (1975) argues that business and geographical diversification could bring benefits to firms. To the extent that there is friction in external capital markets, internally generated funds in diversified firms can be efficiently pooled and allocated to the best opportunities efficiently. Therefore, diversification may therefore enhance the sources of income at the overall group level (Leaven and Levine, 2009; Stein, 1997; Li and Li, 1996), and the increased availability of internal financing sources within the group could help buffer troubled subsidiaries through internal capital market channels (Cetorelli and Goldberg, 2014). Indeed, there is evidence from the literature of business groups that diversified business conglomerates enable their affiliate members to share risk within the group by reallocating resources and thereby reducing their earnings volatility (Khanna and Yafeh 2005, 2007). In the banking literature, Cetorelli and Goldberg (2016) also find that the more complex the banking organisation is, the lending sensitivity of its branches is lower in response to a liquidity shock in the host country. Thus, under the diversification gain hypothesis, foreign affiliates of a more complex global banking group could benefit from an enhanced internal capital market channel and an organisational network in which they would be less prone to idiosyncratic risk compared with those from a less complex bank.[4] Hence, we postulate the first hypothesis:

[4] However, some studies argued that diversification may contribute to higher risk taking as large diversified banks enjoy a reduced cost of funding. Also, the expansion of activities may entail

Hypothesis 1: Due to the benefit of a strengthened internal capital market emerging from business and geographic diversification, a FBHK from a more complex banking group would have lower default risk, lower earnings volatility and higher risk-adjusted returns than those from a less complex institution.

On the other hand, the agency problem hypothesis posits that bank affiliates of a more complex institution have incentives to take on more risk. When the global banks expand into new business lines or locations, this may intensify the agency problem between the managers of the parent and affiliates in the organisational hierarchy. This leads to divisional rent seeking and less efficient investments taken by the affiliates (Scharfstein and Stein, 2000 and Baule, 2014). In addition, the increased complexity of the banking organisations (in terms of business and organisational structure) may limit the capacity of the parent's management to manage and monitor all of its subsidiaries due to the increased variety and interconnectedness among affiliates. As such, each affiliate within a more complex structure may be exposed to the risk taken by other entities in the institutions (Frankel, 2013).

Hypothesis 2: Due to the intensified agency problem, FBHKs from a more complex banking institution have a higher default risk, higher earnings volatility and lower risk-adjusted returns than other FBHKs from a less complex institution.

2.2 Data

2.2.1 Measures of bank complexity

To study the effect of bank complexity of global banks on their FBHKs, an empirical measure of global banks' complexity is needed. This paper follows Ceterolli and Goldberg (2014) and the IBRN guidance document to measure bank complexity along

diversification into riskier activities. As such, increasing parent complexity could result in higher risk taking of affiliates under the diversification hypothesis. De Nicola et al. (2004) find that larger and conglomerate firms exhibited levels of risk taking higher than smaller and specialised financial firms.

business and geographical dimensions. As we do not have access to supervisory data on global banks' organisational structure, our study compiles the complexity measures based on publicly available data from S&P Capital IQ.[5,6]

We consider three indicators to measure the business complexity of banks.

The first measure is a normalised Herfindal-Hirschman index (HHI) that depends on the number of distinct business types from which the global bank generates revenue from. In essence, the HHI measures the diversity of the business activity of a bank. Specifically, the normalised HHI of revenue is calculated as follows:

$$HHI = \frac{T}{T-1}(1 - \sum_{\tau=0}^{T}(\frac{revenue^{\tau}}{total\ \ revenue})^2)$$

With T being the number of distinct business types the banking group generates revenue from. Revenue is defined as the revenue generated from a specific business type in a given year. Business types are defined according to the 3-digit North American Industry Classification System (NAICS) codes for financial industries and 2-digit NAICS codes for all other industries. The normalised HHI has a value between zero and one, with a higher index value reflecting a higher degree of business complexity.

The second indicator is related to the global bank's business scope. Specifically, it measures the contributions of non-traditional banking revenues to the global banking organisation's total revenues, weighted by the distance to commercial banking. The formula for compiling the business scope is described as follows:

$$Scope = \sum_{\tau=1}^{T}(distance_{\tau} \times revenue_{\tau})/total\ \ revenue$$

[5] As S&P Capital IQ does not have historical data on the affiliate count, we use the revenue data generated from different business segments based on the NAICS code and geographical locations to construct their complexity measures. In view of the data limitation on the affiliate count, the organisational complexity measure as developed in Buch and Goldberg (2020) is not considered in this paper.

[6] The detailed description and the compilation of the complexity measures are summarised in Appendix Table A1.

Where τ is the distinct business type from which the global banking organisation generates revenue in a given year according to the NAICS, and distance has a value of 1 to 4 according to the NAICS's proximity to commercial banking (522).[7]

In addition, the share of the sum of revenue from the non-bank business lines to total revenue of the banking group is considered as the third measure of business complexity (i.e. *Non-bank revenue share*).

For geographical complexity, two measures are considered.[8] The first measure is calculated as the share of revenue generated from outside the home country where the banking group is incorporated to the group's total revenue (denoted as *Foreign revenue share*), while the second measure is calculated as the share of assets held outside the home country to the group's total assets (denoted as *Foreign asset share*).[9]

By construction, a higher value of complexity measures implies a higher degree of complexity. The correlation matrix among these measures is presented in Table 1. In general, the complexity measures within the same dimension share a high correlation with each other, while the correlation weakens notably across dimensions, suggesting that the concept of bank complexity may have multiple dimensions.

The development of global banks' business and geographical complexity measures are presented in Charts 1 and 2. In particular, we focus on the two subgroups of banks, namely GSIBs and other non-GSIB global banks, to better visualise the development of complexity measures of global banks over time. On average, global banks that are designated as GSIBs are generally more business and geographically complex than non-

[7] Specifically, a business type with NAICS equals to 522 has a value of one for *distance*. The value of *distance* increases when the NAICS of a business segment moves away from 522. For instance, *distance* for a segment starting with 524 would take a value of 2, *distance* for a segment starting with 511 would take a value of 3, and *distance* for a segment starting with 811 would take a value of 4.

[8] As there is no standardisation in the reporting of banks' revenue and assets by geographical location in the S&P Capital IQ database, this precludes us from constructing the HHI- and scope-type measures for geographical complexity. It is also noted that global banks which have affiliates with specific operating purposes established in offshore centres might be an indication of a higher degree of bank complexity. However, due to the data limitation in the S&P Capital IQ, this precludes us from distinguishing those global banks that have affiliates operating in offshore centres from others that do not.

[9] We have further excluded the revenue generated from and assets held in Hong Kong from the numerator of the two measures as a robustness check. As the results remain similar, the results are available upon request.

GSIBs. While GSIBs remain more business complex than non-GSIBs after the global financial crisis, there have been declining trends in their business complexity across difference proxies (Chart 1). By contrast, non-GSIBs appear to have increased their business complexity after the crisis, albeit remaining at lower levels relative to those of GSIBs. For geographical complexity, global banks generally saw a decline in their foreign revenue / assets share after the crisis but the changes appear to be relatively mild.

2.2.2 Risk indicators for FBHKs

Various risk indicators of FBHKs are examined in this paper, including default risk, earnings risk and credit risk. For FBHKs' default risk, we follow the literature to employ a log Z-score as the main indicator. Log Z-score is calculated as the logarithm of the sum of the ratio of the average return on assets (ROA) in the trailing 8-quarters and the equity to assets ratio of a bank, divided by the standard deviation of ROA in the trailing 8-quarters (SD (ROA)).[10] We further take an inverse of the log z-score (Inverse log (Z-score)) so that a higher value of the metric indicates a higher default risk. The earnings risk is measured by banks' earnings volatility and its risk-adjusted return on assets. The former indicator is measured by SD (ROA), while the latter is calculated as FBHK's ROA adjusted by its SD (ROA) (hereafter referred to as Adj ROA). The credit risk is measured by FBHKs' gross classified loans to total loan ratio (NPL ratio) and the loan loss provision to total loan ratio (LLP ratio).[11] We construct bank-level variables for FBHKs using regulatory data from the HKMA's supervisory data collections.

3 Empirical models and estimation results

In this section, we first explore the average relationships between bank complexity at the banking group level and various risk indicators for their FBHKs in a panel regression model. We further explore the possible mechanism through which bank complexity may affect the riskiness of FBHKs by examining how specific bank balance

[10] This risk measure is available for foreign bank subsidiaries. For hosted bank branches, as these entities do not have capital financing of their own, a z-score cannot be constructed.

[11] To eliminate outliers in dependent variables, observations exceeding the 98.5th percentile or less than 1.5th percentiles are dropped from the sample.

sheet factors that could be relevant to the diversification and agency problem hypotheses may determine the extent of impact of complexity on risks. In the later part of the analysis, a difference-in-difference approach which exploits the exogenous change in bank complexity stemming from the GSIB regulatory reform will be conducted as an alternative strategy to strengthen the identification of the impact of bank complexity on the riskiness of FBHKs.

3.1.1 Baseline specification based on a panel regression model

The baseline testing equation is specified as follows:

$$Risk_{b,t} = \alpha + \beta_1 C_{p,t-1} + \beta_2 X_{b,t-1} + \beta_3 X_{p,t-1} + \beta_4 Z_{p,t-1} + f_t + \epsilon_{b,t} \qquad (1)$$

where *b* denotes the bank affiliates in Hong Kong, *p* denotes the parent banking group of affiliate *b* and *t* denotes time. Our coefficient of interest is β_1, which captures the average effect of bank complexity of the parent banking group ($C_{b,t-1}$) on affiliate's risk ($Risk_{b,t}$), after controlling for their balance sheet characteristics ($X_{b,t-1}$ and $X_{p,t-1}$) as well as macro conditions in the home country of FBHK ($Z_{p,t-1}$). For FBHK's control, the log of real assets is included to control for size. Loan-to-asset ratio, deposit-to-asset ratio, net due to overseas office as a share of total assets (*NetDueTo*) are included to capture FBHK's business characteristics. In addition, FBHK's cost-to-income ratio is added to control for its operational efficiency. In addition, the model includes a dummy variable which takes a value of one if the FBHK is operating in the form of a subsidiary in Hong Kong and zero otherwise to control for the bank type.[12] For the control variables of the parent groups, the log of real assets and tier-one capital ratio are included to capture the parent's size[13] and balance sheet soundness. All balance sheet variables are lagged by one period to limit the potential simultaneity issue. To control for macro conditions, the real GDP growth of the home country of foreign banks ($Z_{p,t-1}$) and time fixed effects (f_t) which control for unobserved time variant

[12] We have further interacted the complexity measures with the subsidiary dummy to test whether there is a differential effect of complexity on bank risk between branches and subsidiaries. Overall, we did not generally find statistically significant result for the interaction term, suggesting there is no strong evidence for the effects to be differed across the two types of affiliates. These estimation results can be found in appendix Tables A2 and A3.

[13] Some papers also use banks' size as a proxy for organisational complexity.

factors that affect all banks in Hong Kong at time *t* are introduced.[14] Standard errors are clustered at the parent group level.

The estimation samples include 159 FBHKs covering the period 2004 to 2017, of which 39 are foreign bank subsidiaries while 120 are foreign bank branches.[15] The summary statistics for major variables are shown in Table 2.

3.1.2 Baseline results

This section presents our empirical findings. We present the estimation results of the baseline model (i.e. Eq. (1)) for the FBHK's Inverse log (Z-score), SD (ROA), Adj ROA, NPL ratio and LLP ratio in Tables 3-7 respectively. It should be noted that as foreign bank branches are not required to hold capital, the inverse log (Z-score) is not available for branches. As such, the result for the inverse log (Z-score) covers only foreign subsidiaries in Hong Kong, while the results for all other risk metrics cover all FBHKs in Hong Kong.

Table 3 presents the regression results for the effect of bank complexity on the inverse log (Z-score) of FBHKs. There is clear evidence to suggest that a higher business complexity of the banking organisation is positively associated with a higher default risk for their FBHKs, as all of the business complexity measures considered have statistically significant and positive coefficients (i.e. columns 1 to 3). This result is consistent with Ly et al. (2018) where an affiliate from a more complex bank holding company attains a higher default risk relative to those that belong to a less complex institution. The estimated effect is also found to be economically significant. Depending on the measures of business complexity considered, the inverse log z-score of a FBHK could increase in a range of 0.025 to 0.029 after a one-standard-deviation rise in the business complexity measures of its banking group. This is equivalent to an 8.9% to 10.3% increase in the default risk when compared with the sample mean of the

[14] The bank fixed effect may be introduced to control for time-invariant unobserved factors if there are enough temporal variations in bank complexity measures. Berger et al. (2017) show that adding bank fixed effect may be inappropriate if there is insufficient time variation in banks' internationalisation. Since the complexity measures of our sample exhibit a high degree of autocorrelation (ranging 0.88 to 0.96), we therefore follow Berger et al. (2017) not to include the bank fixed effect in the estimation.

[15] 27 of 29 GSIBS have operations in Hong Kong, which are in the form of subsidiaries or branches.

inverse log (Z-score)). By contrast, we do not find statistically significant effect of the geographical complexity on FBHK's default risk (i.e. columns 4 and 5).

Tables 4-5 provide the regression results for the FBHKs' SD (ROA) and Adj ROA. There is evidence to suggest a higher business complexity at the parent level would have a significant positive effect on the earnings volatility for their FBHKs (Columns 1 to 3 of Table 4). The increase in earnings volatility, however, appears not to be justified by a higher level of returns as the effect on the risk-adjusted ROA is found to be statistically insignificant. For a more geographically complex banking group of FBHK (as indicated by a higher value of foreign revenue share) they tend to have a higher SD (ROA) (column 4 in Table 4). But, the increased earnings volatility appears to be outweighed by higher returns as suggested by a higher level of risk-adjusted ROA (column 4 in Table 5), providing some tentative evidence for diversification gains from geographical complexity.

Finally, the regression results for FBHKs' NPL ratio and LLP ratio are presented in Tables 6 and 7. Interestingly, our estimation results do not find any significant effect of bank complexity (both business and geographical dimensions) on the credit risk of FBHKs. Taking this finding together with the above results suggests that increased default and earnings risks in FBHKs arising from higher business complexity at the banking group may be due to other non-lending business activities.

As mentioned in the introduction, our baseline specification should be less subject to reverse causality issues given that the riskiness of a FBHK (i.e. an entity at a lower layer of the overall banking group) is less likely to significantly affect the broader decision made by the parent banking group regarding the overall corporate structure and business strategies. Nevertheless, there may still exist other types of potential endogeneity issues, therefore, we have further applied the Durbin-Wu-Hausman (DWH) test to empirically assess the endogeneity issue in our specifications more generally. Overall, we find that there is no strong evidence of endogeneity in the specification.[16]

[16] The DWH test involves a two-stage instrumental estimation procedure. In particular, we use the second lag of the respective complexity measures as an instrument for the lagged complexity measures in the baseline equation (1). Under the null of no endogeneity, the original explanatory variable (i.e. the lagged complexity measure) and the instrumental variable produce similar estimates. Under the alternative hypothesis, the two regressors produce different estimates and, accordingly, the original

3.1.3 Agency problem versus diversification gain?

In this subsection, we rely on bank balance sheet heterogeneity to help shed light on the presence of the potential channels (i.e. agency problem or diversification gain) through which bank complexity at the parent group's level alter the risk of their FBHKs. Specifically, we interact specific FBHK's balance sheet variables ($BSF_{b,t-1}$) that could be relevant to the particular hypothesis being considered, with the respective complexity measures (i.e. Eq. (2)). Our parameter of interest in Eq. (2) is the coefficient θ_1 which captures the conditional impact of bank complexity on the risks of FBHKs based on the level of $BSF_{b,t-1}$.

$$Risk_{b,t} = \alpha + \beta_1 C_{p,t-1} + \theta_1 C_{p,t-1} * \ BSF_{b,t-1} + \theta_2 BSF_{b,t-1} + \beta_2 X_{b,t-1} + \beta_3 X_{p,t-1} + \beta_4 Z_{p,t-1} + f_t + \epsilon_{b,t} \quad (2)$$

Our conjecture is that if the diversification gain channel is present, a FBHK that is more reliant on intragroup funding resources (as captured by FBHK's *NetDueTo*) should receive a greater support from its parent group in times of stress, thereby resulting in lower default and earnings risks on average, compared with other FBHKs with a lower reliance on intragroup funding. For the agency problem hypothesis, we posit that the group's management would have relatively more effective monitoring of FBHKs that serve as important operating units for the overall banking group. The increased monitoring efforts might help mitigate the agency problem which prompt FBHKs to take relatively less risk. Therefore, conditional on the same level of complexity, we would expect an FBHK that contributes a higher fraction of revenue to the overall banking group (as a proxy for the importance of FBHK) would attain a lower risk relative to other less important FBHKs.

The estimation results for eq. (2) are shown in Tables 8-11. In view of the limited evidence of the effect of complexity on the credit risks of affiliates found from the

regressor would therefore be inconsistent. Overall, we cannot reject the null of no endogeneity across all regressions, suggesting that there is no strong evidence of endogeneity in the specifications. Results are presented in Appendix Tables A4-A8.

baseline specification, we therefore focus our discussion on the default and earnings risks of FBHKs in this subsection for the brevity of space.[17]

We first focus on the interaction terms that test the presence of the agency problem hypothesis for both business and geographical complexity (i.e. the interaction term between FBHK's share of revenue to the group's revenue and the respective complexity measures in Tables 8 and 9 respectively). On the whole, we find empirical support for the existence of the agency problem hypothesis in the business complexity dimension. In particular, the interaction term is found to be negatively and statistically significant for FBHK's inverse log z score and SD (ROA) (Table 8) for most of the complexity measures including HHI and non-bank revenue share. There is also some evidence for the agency problem in the dimension of geographical complexity dimension on FBHKs' SD (ROA) (Columns 3 and 4 in Table 9). These results are consistent with our conjecture that the management of the parent group would likely increase its monitoring efforts into the more important affiliates, which in turn, mitigate the extent of the agency problem, thereby lowering the extent of impact on the riskiness of the FBHK.

We next turn our attention to the interaction term for testing the presence of diversification gain for the two dimensions of complexity (i.e. the interaction term between the FBHK's *NetDueTo* and respective complexity measures in Tables 10 and 11 respectively). Overall, we do not find the presence of diversification gain in the business dimension of bank complexity. Indeed, the interaction terms were statistically insignificant across various risk indicators considered. However, there is tentative evidence to support the presence of diversification gain in the geographical complexity dimension as indicated by the positive and statistically significant coefficient on the interaction term for FBHKs' Adj ROA (column 6 in Table 11). In particular, a FBHK with higher reliance on intragroup funding tends to attain a higher risk-adjusted ROA than its counterpart, conditional on the same degree of geographical complexity.

3.2 *Difference-in-difference (DID) analysis: Evidence from the introduction of the GSIB regulatory framework*

[17] The estimation results for the credit risk of FBHKs are available upon request.

This section presents an alternative identification strategy to strengthen the identification of the effect of bank complexity on affiliates' risk. Specifically, our identification strategy uses the implementation of the GSIB regulatory framework[18] as one suitable policy event that may lead to an exogenous change in the complexity for large global banks (especially those designated as GSIBs). The exogenous change in the complexity of GSIBs thus allows us to identify the effect on the riskiness of affiliates by comparing the difference in the risk of GSIBs affiliates in Hong Kong relative to those non-GSIB affiliates in the post-reform periods. Specifically, two separate DID estimations will be employed. We first determine whether GSIBs have exhibited a greater decline in their business and geographical complexity in response to the regulatory change at the parent group level. We then identify the causal impact of bank complexity on the riskiness of affiliates by comparing the difference in the risk adjustment between GSIBs' FBHKs and other non-GSIBs' FBHKs during the pre- and post-regulation periods.

3.2.1 Has the GSIB regulatory framework triggered changes in the complexity for global banks?

Since the 2008 global financial crisis, various regulatory reforms have been introduced with the aim of reducing the systemic risk of these global systematically important banks (GSIBs), including the assessment methodology to identify GSIBs and the additional capital surcharges imposed on these banks. They are also subject to more intensive supervision (particularly in areas such as risk management and governance), and prioritised recovery and resolution planning. For the identification of GSIBs, the BCBS developed a framework that compares a global bank's activity over 12 indicators, which are grouped into five categories of systemic importance: (1) Size, (2) Interconnectedness, (3) Substitutability/financial institution infrastructure, (4) Cross-

[18] While the Basel Committee on Banking Supervision (BCBS) first developed a methodology in November 2011 to identify global systematically important banks (GSIBs), it was not until November 2012 when it introduced the "bucket approach" to identify GSIBs and disclosed the methodology in July 2013 (BCBS 2013). In this approach, banks that have a score produced by the indicator-based measurement approach that exceeds a cut-off score are identified as GSIBs and are allocated into five "buckets" of ascending levels of systemic importance. The assignment to a bucket then determines the higher loss absorbing (HLA) requirement for each GSIB. The HLA requirements were phased in from 1 January 2016, based on the end-2013 GSIB bucket results, with the full amount of the requirement effective by 1 January 2019.

jurisdictional activity, and (5) Complexity.[19] Under this framework, a systemic importance proxy (i.e. GSIB score), which is the weighted average of the 12 indicators, will be calculated for each of the global banks. These banks are then designated as a GSIB if their GSIB scores are above a cut-off point, and are allocated into five "buckets" of ascending levels of systemic importance.[20] A varying capital surcharge is then imposed on these GSIBs based on the bucket assignments.[21]

As capital is costly, the GSIB capital surcharges in the form of higher loss absorbing capital buffers should incentivise GSIBs to reduce their systemic importance by more than other global banks. Indeed, a recent study by Goel et al. (2019) finds that the overall GSIBs' systemic importance has gradually declined since the introduction of the GSIB regulatory framework, which is in line with the intended policy objectives. More importantly, they show that the decline in the GSIB score has been largely driven by a reduction in the complexity indicators of GSIB banks. Because the regulation-induced change in the complexity of GSIBs are exogenous to the risk of their FBHKs, this provides a suitable test for identifying the effect of bank complexity by comparing the difference in the risk adjustment of the affiliates of GSIBs relative to those of non-GSIB affiliates between the pre-and post-regulatory reform periods. However, given that the complexity measures considered in this paper are complementary to, but differ from, the complexity indicators used in the GSIB framework, we therefore need to first assess whether our complexity measures also exhibit similar declines after the introduction of the regulation.

To study this question, a DID estimator is carried out to assess the effect of the GSIB regulatory framework on the business and geographical complexity measures of global banks. As the designation of GSIB is determined based on the BCBS methodology, which is a non-random assignment, this may pose concerns about the validity of the parallel trend assumption underlying the DID estimation.[22] To evaluate this potential

[19] Under this framework, the 'Complexity' category is measured by three indicators: (i) Notional amount of OTC derivatives, (ii) Trading and available-for-sale securities, and (iii) Level 3 assets, which are intended to capture the bank's business, structural and operational complexity.
[20] The BCBS publicly publishes global banks' GSIB score annually since 2013.
[21] In addition to the GSIB capital surcharge, banking regulators around the world also require large and complex banking organisations to periodically submit a recovery and resolution plan.
[22] The underlying assumption of the DID model rests on the parallel trend assumption. It requires that both treatment and control groups follow parallel trends before the treatment and that they would

concern, we perform a test to assess whether the business and geographical complexity measures of the two subgroups of banks follow the parallel trends prior to the regulation. Specifically, we compare the annual change in the complexity measures between GSIBs and non-GSIBs for the years preceding the introduction of the GSIB regulatory framework. We further apply mean-difference t-tests to determine whether these variables are significantly different between the two subgroups of banks. Table 12 summarises the results of these tests for all complexity measures considered in this paper. As the average change in complexity measures between GSIBs and non-GSIBs were not significantly different prior to the regulatory change, this provides some evidence to support the validity of a parallel trend assumption for the DID estimation.

As such, the following DID model is adopted for our sampled parent banks:

$$C_{p,t} = \alpha + \beta_1 GSIB_p + \beta_2 Post_t + \beta_3\left(GSIB_p * Post_t\right) + \beta_4 X_{p,t-1} + \beta_5 Z_{p,t-1} + u_{p,t} \quad (3)$$

where $C_{p,t}$ are the sets of business and geographical complexity measures of our sampled parent banking group *p*, at time *t. GSIB* is a dummy variable which takes on value one if the parent banking group has been designated as a GSIB at least once over the sample period. Post is a time dummy variable separating the pre- and post-regulation reform periods, which is defined as one after year 2012 where the BSCB GSIB methodology and the bucket approach was introduced, and zero otherwise. We also include the same set of balance sheet controls for the parent banking group ($X_{p,t-1}$) and home-country macroeconomic condition ($Z_{p,t-1}$) considered in eq.(1) to account for the observable difference between GSIB and non-GSIBs. The coefficient of the interaction term, β_3, which is our parameter of interest, captures the effect of the GSIB regulation on the complexity measures controlling for the structural difference between GSIBs and non-GSIBs. The DID estimation results are presented in Table 13.

Two findings are worth highlighting. First, perhaps not surprising, global banks that are designated as GSIBs are, on average, more complex than non-GSIBs across all

continue to do so as if the treatment had not occurred. While the latter counterfactual condition is generally untestable in practice, the former condition can be empirically tested.

complexity measures considered. Second, in line with the findings of Geol.at el (2019), GSIBs are found to have reduced their business complexity measures after the regulatory reform as shown by the negative and statistically significant coefficients for the interaction variable when the dependent variables are Scope and Non-bank revenue share. The magnitude of the effect also appears to be economically significant. Taking the non-bank revenue share as an example, GSIBs on average reduce their share by around 7.3 percentage points more than their non-GSIB counterparts after the regulatory reforms. This is equivalent to around 0.5 standard deviation of the change in the non-bank revenue share for GSIBs during the pre-regulation period (see Table 12).[23]

Despite the significant impact of the GSIB regulation on GSIBs' business complexity, there appears to be no significant effect on the geographical complexity of GSIBs relative to non-GSIBs. This may be due to the fact that the complexity indictors employed under the GSIBs framework mainly capture the business and operational complexity in terms of business and operational activities (e.g. OTC derivatives, holding of trading and available-for-sale securities and level 3 assets) which are more related to our measures for business complexity, but not related to the geographical complexity. Thus, GSIBs are less inclined to reduce their geographical complexity.

3.2.2 Has the regulation-induced decline in the bank complexity of GSIBs impacted on the riskiness of their foreign bank affiliates in Hong Kong?

The larger decline in the complexity of GSIBs (particularly in the business complexity dimension) relative to other non-GSIBs is found to be driven by regulatory changes which are exogenous to the riskiness of their FBHKs. This provides a suitable empirical setting to identify the effect of bank complexity by comparing the foreign banks in Hong Kong, whose parent banking groups are GSIBs, with those of non-GSIBs before and after the regulatory changes.

Specifically, we compare the difference in the risk adjustment between GSIB affiliates and other non-GSIB affiliates in Hong Kong during the pre- and post-regulation periods. In particular, we follow Bertrand et al. (2004) by taking the averages of the observations

[23] As a reference, the estimated impact on the scope measure (-0.102) is also around 0.6 standard deviation of the change in scope for GSIBs over the pre-regulation periods.

in our sample in the pre-reform period (2010-2012) and in the post-reform period (2014-2017) to address the bias in standard errors when performing DID estimation with time series data of serially correlated outcomes. Hence, the testing equation is specified as follows:

$$\Delta risk_b^{Post-pre} = \alpha_0 + \alpha_1 GSIB_p + \alpha_2 \bar{X}_{b,10-12} + \alpha_3 \bar{X}_{p,10-12} + \alpha_4 \bar{Z}_{p,10-12} + \varepsilon_b \qquad (4)$$

where $\Delta risk_b^{Post-pre}$ is the change in the average risk measure between pre-reform period (year 2010 to 2012) and post-reform period (year 2014 to 2017). Similar to eq. (3), $GSIB_p$ is a dummy variable which takes value one if the parent of a FBHK has been designated as GSIB at least once over the estimation period, and zero otherwise. The coefficient α_0 measures the systematic change in the risk measures for FBHKs before and after the treatment. The coefficient α_1 is our parameter of interest, which tests whether a FBHK whose overall banking organisation is subject to the GSIB regulatory framework behaves differently with regard to the risk measures relative to other FBHKs. Given that the GSIB regulatory reform has led to a larger decline in GSIBs' business complexity relative to that of non-GSIBs, we should expect a FBHK whose parent is a GSIB to experience a larger reduction in its risk measures than that of a non-GSIB's FBHK if the agency problem hypothesis holds true. We also control for the pre-treatment average of balance sheet characteristics and the macroeconomic condition of the home country that were considered in the baseline model (i.e. $\bar{X}_{b,10-12}$, $\bar{X}_{p,10-12}$ and $\bar{Z}_{p,10-12}$ respectively).

Table 14 reports the estimation results. We find that GSIB's FBHKs tend to exhibit a larger decline in Inverse log (z-score) and SD (ROA) than that of non-GSIB's FBHKs after the introduction of the GSIB regulatory framework. These results are consistent with the findings from our panel regressions as shown in the previous section, where higher (lower) business complexity of the banking group leads to higher (lower) default risk and earnings volatility. Also, in line with the panel estimation results, no significant treatment effect is found in the credit risk of the GSIBs' FBHKs.

3.2.3 Robustness check using a propensity score matched (PSM) sample

To account for the observable heterogeneity in the balance sheet characteristics between the GSIB affiliates and non-GSIB affiliates in Hong Kong, as seen in Table 2, we further adopt a PSM approach to construct an alternative control group as a robustness check. Specifically, we estimate for each FBHK the probability of being a GSIB affiliate om a vector of balance sheet covariates during 2010-12. The estimation is based on a logit model, in which the dependent variable equals one when the FBHK's parent is a GSIB and zero otherwise. The set of balance sheet explanatory variables include FBHK's log real asset, loan-to-asset ratio, deposit-to-asset ratio, net due to overseas office to asset ratio, and cost-to-income ratio. Then, each GSIB FBHK was matched to the non-GSIB FBHK with the closest propensity score with replacement. We then re-estimate eq. (4) based using the alternative PSM sample. The results are shown in Table 15. On balance, the results based on the PSM sample are found to be qualitatively similar to those in Table 14.[24]

4. Conclusion

Using a confidential data set of foreign bank affiliates in Hong Kong, this paper aims to broaden our understandings of the relationship between the bank complexity of global banking groups and the risk implications for their affiliates. By running a battery of tests on various risk indicators and by applying different empirical specifications to identify the effects, our empirical evidence shows that the complexity of global banks has significant effects on the riskiness of their foreign bank affiliates. Specifically, a FBHK from a more business complex banking group tends to have higher risks (in terms of default and earnings risks) than other banks that belong to a less business complex banking group, and the effect appears to be mainly attributable to an intensified agency problem. For the geographical complexity, there is some tentative evidence to support the presence of both diversification and agency problem channels through which the bank complexity would affect the earnings risk of FBHKs. However, the average effect on the risks of FBHKs is generally found to be less clear-cut. Importantly, we find similar empirical findings under an alternative identification scheme which uses a DID approach to exploit the exogenous decline in bank complexity arising from the introduction of the GSIB regulatory framework.

[24] While we also find positive and statistically significant effect for Adj ROA, we refrain from making any strong conclusion on this result as it is based on a smaller sample.

Taken together, these findings provide some important policy implications for the host-country bank supervisors. In particular, in view of the significant impact of the bank complexity at the parent group level on the riskiness of its affiliates, any future international regulatory reforms that may drive changes in the bank complexity of global banks could potentially pose both intended or unintended impacts on the risk profiles of their affiliates. Therefore, it is important for host-country bank supervisors to monitor the development of the bank complexity of global banks (particularly GSIBs) in order to assess the potential consequences for the risks of their affiliates in the host country. In addition, as the responsibility for the supervision of global banks lies primarily with the home-country supervisors where the banks are headquartered, this may further call for greater cross-border collaboration between the home- and host-country supervisors, such as those through the International Data Hub or other international central bank platforms, including the cross-border supervisory college, to better exchange and analyse the development of the bank complexity of global banks on a timely basis.

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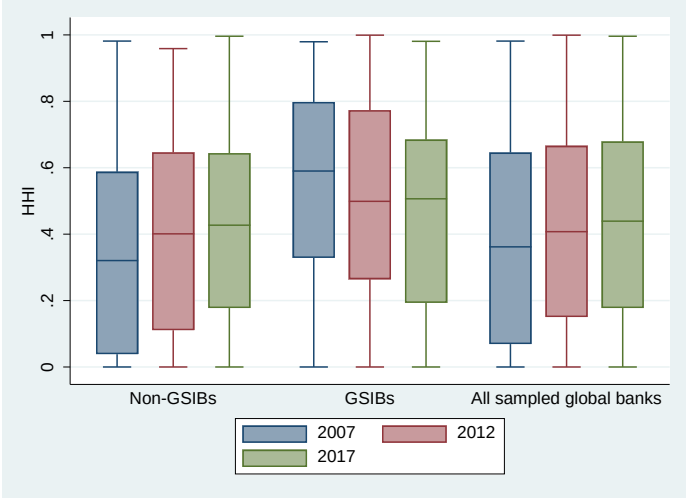
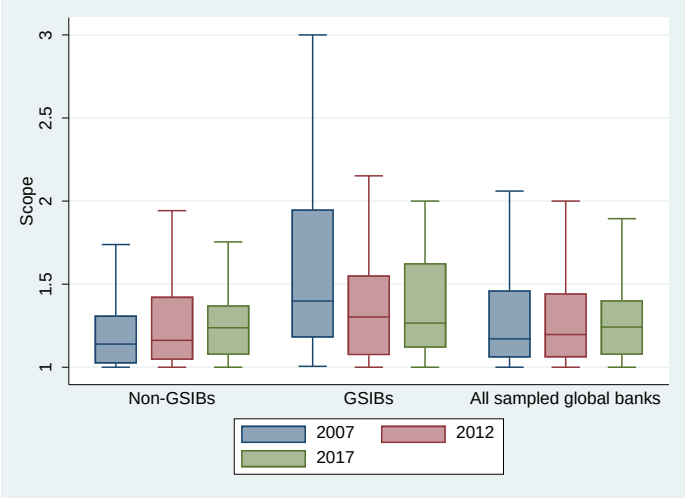
Chart 1: Business complexity measures of the sampled global banks

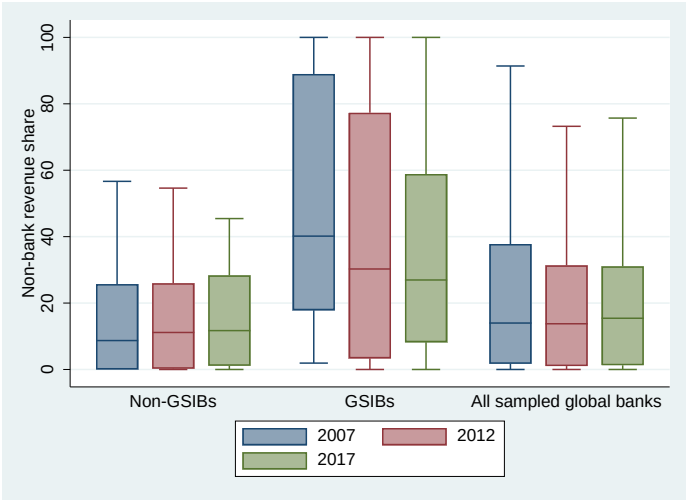
Panel A: Normalised HHI



Panel B: Business scope



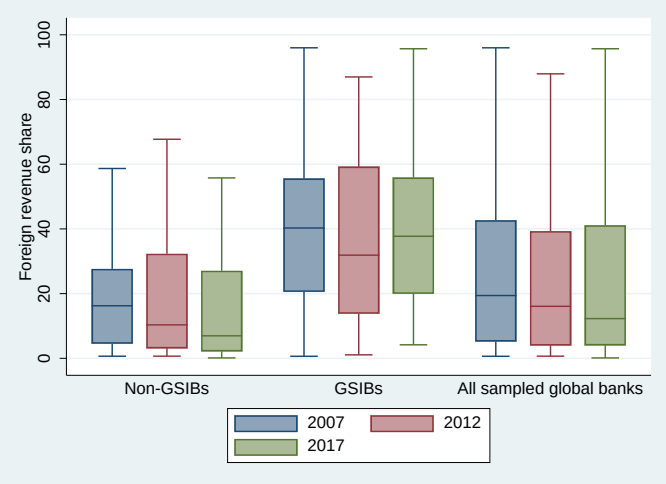
Panel C: Non-bank revenue share



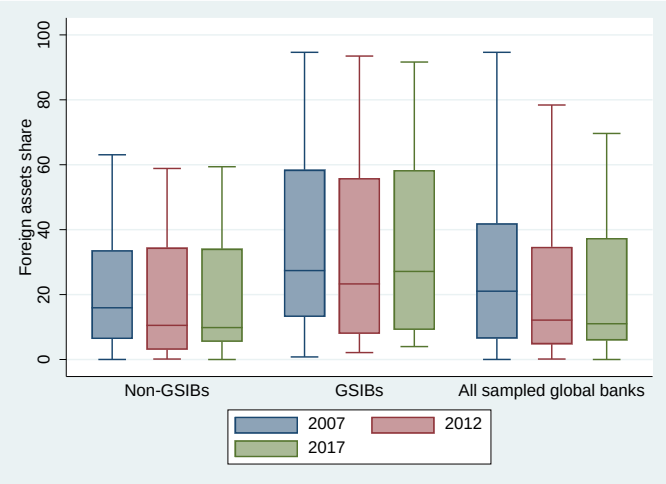
Note: The boxplots depict the lower adjacent value, 25th percentile, median, 75th and the upper adjacent value of the various business complexity measures for non-GSIBs, GSIBs and all sampled global banks for years 2007, 2012 and 2017. The sample contains 134 global banks, subject to data availability. Panel A shows the boxplots of the normalised HHI which depends on the number of distinct business segments from which the global banks generate revenue from. Panel B shows the boxplot of the Scope measure, which measures the contribution of non-banking revenues to the global bank's total revenue weighted by the distance to commercial banking according to the NAICS's proximity. Panel C shows the boxplot of the share of revenue from non-bank business segments to total revenue of the global bank.

Chart 2: Geographical complexity measures for the sampled global banks

Panel A: Foreign revenue share



Panel B: Foreign assets share



Note: The boxplots depict the lower adjacent value, 25th percentile, median, 75th and the upper adjacent value of the various geographical complexity measures for non-GSIBs, GSIBs and all sampled global banks for years 2007, 2012 and 2017. The sample contains about 134 global banks, subject to data availability Panel A shows the boxplots of the foreign revenue share, which is calculated as the share of revenue generated from outside the country where the global bank is headquartered to total revenue. Panel B shows the boxplots of the foreign asset share, which is calculated as the share of assets held outside the country where the global bank is headquartered to total assets.

Table 1: Correlation matrix among complexity measures

Correlation	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
HHI	1				
Scope	0.5189	1			
Non-bank revenue share	0.4734	0.888	1		
Foreign revenue share	-0.0117	0.1084	0.2229	1	
Foreign asset share	-0.0215	0.0654	0.1498	0.7882	1

Note: It is an unbalanced panel, the pairwise correlation among different complexity measures is calculated based on around 134 global banks over the sample 2004 to 2017 (subject to data availability). The total bank-year observations are around 1660.

Table 2: Summary statistics for key variables

Variable	No. of banks	Obs	Mean	S.D.	p25	p50	p75
Panel A							
All FBHK samples							
Risk measures							
Inverse log(Z-score)	39	296	0.282	0.130	0.223	0.254	0.300
SD (ROA)	159	1155	0.612	1.259	0.139	0.265	0.545
Adj ROA	159	1155	3.132	4.297	0.336	1.973	4.570
NPL ratio	159	1180	1.641	6.147	0.000	0.130	1.035
Loan loss provision ratio	159	1180	0.775	2.681	0.000	0.017	0.418
Balance sheet characteristics							
Log (real assets)	159	1180	10.020	2.061	8.584	10.143	11.610
Loan-to-asset ratio	159	1180	32.531	20.846	16.302	31.370	45.741
Deposit-to-asset ratio	159	1180	38.682	29.148	11.318	34.678	66.957
Net Due To (overseas) to asset ratio	159	1180	2.941	28.593	-7.441	0.000	14.449
Cost-to-income ratio	159	1180	64.542	59.700	31.469	53.995	82.000
FBHK affiliates whose parents are GSIBs							
Risk measures							
Inverse log(Z-score)	18	137	0.311	0.165	0.236	0.268	0.323
SD (ROA)	56	464	0.584	1.101	0.131	0.230	0.502
Adj ROA	56	464	3.301	4.738	0.268	1.879	4.949
NPL ratio	56	466	1.516	6.740	0.000	0.230	0.818
Loan loss provision ratio	56	466	0.573	2.343	0.000	0.049	0.290
Balance sheet characteristics							
Log (real assets)	56	466	11.317	1.645	10.456	11.541	12.425
Loan-to-asset ratio	56	466	28.049	19.631	12.795	27.104	41.633
Deposit-to-asset ratio	56	466	41.629	29.614	15.631	36.127	69.934
Net Due To (overseas) to asset ratio	56	466	-4.026	26.171	-15.018	-0.947	2.748
Cost-to-income ratio	56	466	69.558	51.806	37.182	61.519	89.472
FBHKs whose parents are non-GSIBs							
Risk measures							
Inverse log(Z-score)	21	159	0.257	0.082	0.214	0.242	0.280
SD (ROA)	103	691	0.631	1.355	0.147	0.291	0.565
Adj ROA	103	691	3.018	3.973	0.408	2.022	4.486
NPL ratio	103	714	1.722	5.730	0.000	0.021	1.442
Loan loss provision ratio	103	714	0.907	2.875	0.000	0.000	0.642
Balance sheet characteristics							
Log (real assets)	103	714	9.173	1.855	8.024	9.268	10.453
Loan-to-asset ratio	103	714	35.456	21.108	19.364	34.089	48.742
Deposit-to-asset ratio	103	714	36.758	28.697	8.272	33.272	62.924
Net Due To (overseas) to asset ratio	103	714	7.488	29.202	-4.015	0.499	19.551
Cost-to-income ratio	103	714	61.261	64.165	27.322	50.632	75.752
Panel B							
Parent bank's balance sheet characteristics							
Log (real assets)	134	1811	12.221	1.499	10.996	12.333	13.440
Tier-one capital ratio	132	1300	11.359	3.290	8.871	11.105	13.370
Business complexity measures							
HHI	134	1660	0.422	0.310	0.131	0.418	0.676
Scope	134	1660	1.300	0.325	1.059	1.193	1.441
Non-bank revenue share	134	1660	24.981	29.044	1.354	14.533	36.710
Geographical complexity measures							
Foreign revenue share	117	1115	25.863	22.173	5.589	21.072	40.651
Foreign asset share	93	918	26.669	23.673	7.326	20.669	37.792

Table 3: Estimation results on the average effect of bank complexity on FBHK's inverse log z-score

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	Inverse Log (Z-score)	Inverse Log (Z-score)	Inverse Log (Z-score)	Inverse Log (Z-score)	Inverse Log (Z-score)
Complexity measure p,t-1	0.082*	0.082*	0.001**	0.001	-0.001
	(0.089)	(0.057)	(0.012)	(0.690)	(0.468)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	0.004	0.005	0.004	0.004	-0.006
	(0.420)	(0.301)	(0.379)	(0.656)	(0.620)
Loan-to-asset ratio b,t-1	0.000	0.000	-0.000	-0.001	-0.000
	(0.829)	(0.931)	(0.887)	(0.270)	(0.518)
Deposit-to-asset ratio b,t-1	-0.000	-0.000	-0.000	-0.001	0.000
	(0.536)	(0.559)	(0.503)	(0.253)	(0.820)
Net due to (overseas offices) ratio b,t-1	-0.002***	-0.001	-0.001*	0.000	0.001
	(0.004)	(0.101)	(0.056)	(0.949)	(0.837)
Cost-to-income ratio b,t-1	0.001***	0.001***	0.001***	0.003	0.003
	(0.006)	(0.006)	(0.007)	(0.346)	(0.335)
Dummy (subsidiary)					
Parent characteristics					
Log (real assets) p,t-1	0.018**	0.018**	0.018**	0.019	0.048
	(0.044)	(0.036)	(0.042)	(0.302)	(0.211)
T1 capital ratio p,t-1	0.001	0.002	0.000	0.008	0.031
	(0.757)	(0.567)	(0.929)	(0.463)	(0.136)
Home-country conditions					
Real GDP growth j,t-1	-0.002	-0.002	-0.001	-0.002	-0.013
	(0.517)	(0.516)	(0.762)	(0.851)	(0.129)
Observations	296	296	296	277	233
R-squared	0.223	0.214	0.214	0.174	0.194
Cluster	parent	parent	parent	bank	bank
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	39	39	39	39	34

Note: The dependent variable is inverse log z-score of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of foreign subsidiary banks in Hong Kong. The complexity measures of the parent banking group in columns 1-3 are the normalised HHI, Scope and non-bank revenue share respectively, which capture the dimension of business complexity. The complexity measures of the parent banking group in columns 4-5 are the foreign revenue share and the foreign asset share respectively, which capture the dimension of geographical complexity. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level

Table 4: Estimation results on the average effect of bank complexity on FBHK's earnings volatility

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	SD (ROA)	SD (ROA)	SD (ROA)	SD (ROA)	SD (ROA)
Complexity measure p,t-1	0.266*	0.340**	0.005***	0.010*	0.000
	(0.092)	(0.039)	(0.002)	(0.063)	(0.977)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	-0.194**	-0.199**	-0.203**	-0.276***	-0.254***
	(0.015)	(0.013)	(0.011)	(0.002)	(0.005)
Loan-to-asset ratio b,t-1	0.004*	0.004*	0.004	-0.012	-0.001
	(0.096)	(0.100)	(0.119)	(0.103)	(0.766)
Deposit-to-asset ratio b,t-1	0.001	0.002	0.002	-0.005	0.001
	(0.619)	(0.547)	(0.553)	(0.298)	(0.830)
Net due to (overseas offices) ratio b,t-1	-0.001	-0.001	-0.000	0.004	0.003
	(0.702)	(0.831)	(0.919)	(0.199)	(0.403)
Cost-to-income ratio b,t-1	0.005*	0.005*	0.005*	0.004*	0.004**
	(0.051)	(0.051)	(0.050)	(0.059)	(0.035)
Dummy (subsidiary)	0.055	0.060	0.043	0.781	0.117
	(0.652)	(0.628)	(0.728)	(0.114)	(0.688)
Parent characteristics					
Log (real assets) p,t-1	0.122*	0.133*	0.131*	0.162**	0.189**
	(0.097)	(0.077)	(0.078)	(0.045)	(0.038)
T1 capital ratio p,t-1	0.019	0.015	0.012	0.043	0.046
	(0.319)	(0.401)	(0.519)	(0.277)	(0.166)
Home-country conditions					
Real GDP growth j,t-1	0.004	0.008	0.012	-0.002	-0.020
	(0.761)	(0.541)	(0.356)	(0.950)	(0.474)
Observations	1,155	1,155	1,164	1,002	857
R-squared	0.180	0.182	0.186	0.266	0.227
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	143	123

Note: The dependent variable is 8-quarter standard deviation of ROA of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of all foreign banks in Hong Kong (both foreign bank branches and subsidiaries). The complexity measures of the parent banking group in columns 1-3 are the normalised HHI, Scope and non-bank revenue share respectively, which capture the dimension of business complexity. The complexity measures of the parent banking group in columns 4-5 are the foreign revenue share and the foreign asset share respectively, which capture the dimension of geographical complexity. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level

Table 5: Estimation results on the average effect of bank complexity on FBHK's risk-adjusted ROA

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	Adj ROA	Adj ROA	Adj ROA	Adj ROA	Adj ROA
Complexity measure p,t-1	-0.435	-0.330	-0.003	0.021**	0.004
	(0.390)	(0.481)	(0.636)	(0.048)	(0.692)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	0.570***	0.576***	0.577***	0.346***	0.342***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Loan-to-asset ratio b,t-1	0.010	0.010	0.010	0.017	0.020*
	(0.308)	(0.307)	(0.292)	(0.106)	(0.070)
Deposit-to-asset ratio b,t-1	0.014**	0.014**	0.014**	0.005	-0.001
	(0.036)	(0.040)	(0.037)	(0.422)	(0.901)
Net due to (overseas offices) ratio b,t-1	0.010*	0.009*	0.010*	0.003	-0.004
	(0.084)	(0.068)	(0.052)	(0.592)	(0.606)
Cost-to-income ratio b,t-1	-0.016***	-0.016***	-0.016***	-0.012***	-0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummy (subsidiary)	3.495***	3.504***	3.516***	3.266***	3.435***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Parent characteristics					
Log (real assets) p,t-1	-0.406***	-0.425***	-0.429***	-0.224	-0.110
	(0.001)	(0.001)	(0.001)	(0.202)	(0.436)
T1 capital ratio p,t-1	-0.131**	-0.127**	-0.131**	-0.195***	-0.091
	(0.018)	(0.023)	(0.018)	(0.004)	(0.139)
Home-country conditions					
Real GDP growth j,t-1	-0.077	-0.080*	-0.084*	0.130*	0.134**
	(0.106)	(0.088)	(0.078)	(0.065)	(0.047)
Observations	1,155	1,155	1,164	1,002	857
R-squared	0.383	0.383	0.381	0.378	0.385
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	143	123

Note: The dependent variable is FBHK's risk-adjusted ROA. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of all foreign banks in Hong Kong (both foreign bank branches and subsidiaries). The complexity measures of the parent banking group in columns 1-3 are the normalised HHI, Scope and non-bank revenue share respectively, which capture the dimension of business complexity. The complexity measures of the parent banking group in columns 4-5 are the foreign revenue share and the foreign asset share respectively, which capture the dimension of geographical complexity. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level

Table 6: Estimation results on the average effect of bank complexity on FBHK's NPL ratio

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	NPL ratio	NPL ratio	NPL ratio	NPL ratio	NPL ratio
Complexity measure p,t-1	0.679	-0.380	-0.004	0.007	0.012
	(0.345)	(0.530)	(0.611)	(0.385)	(0.314)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	-0.167	-0.172	-0.166	-0.162	-0.355
	(0.354)	(0.342)	(0.352)	(0.336)	(0.123)
Loan-to-asset ratio b,t-1	-0.024*	-0.024*	-0.025*	-0.023	-0.037**
	(0.087)	(0.089)	(0.079)	(0.189)	(0.014)
Deposit-to-asset ratio b,t-1	-0.026**	-0.025**	-0.025**	-0.027**	-0.023**
	(0.015)	(0.016)	(0.016)	(0.017)	(0.031)
Net due to (overseas offices) ratio b,t-1	0.009	0.006	0.005	0.010	0.024
	(0.393)	(0.536)	(0.580)	(0.306)	(0.105)
Cost-to-income ratio b,t-1	-0.002	-0.002	-0.002	-0.005*	-0.003
	(0.478)	(0.473)	(0.473)	(0.065)	(0.387)
Dummy (subsidiary)	1.548	1.471	1.534	1.169	1.706**
	(0.148)	(0.167)	(0.150)	(0.275)	(0.049)
Parent characteristics					
Log (real assets) p,t-1	-0.108	-0.066	-0.070	0.122	-0.364
	(0.694)	(0.817)	(0.803)	(0.642)	(0.297)
T1 capital ratio p,t-1	-0.029	-0.024	-0.006	0.087	-0.058
	(0.645)	(0.702)	(0.918)	(0.178)	(0.497)
Home-country conditions					
Real GDP growth j,t-1	-0.012	-0.016	-0.012	0.040	-0.044
	(0.794)	(0.746)	(0.814)	(0.460)	(0.511)
Observations	1,180	1,180	1,189	907	799
R-squared	0.059	0.058	0.058	0.068	0.082
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	135	113

Note: The dependent variable is NPL ratio of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of all foreign banks in Hong Kong (both foreign bank branches and subsidiaries). The complexity measures of the parent banking group in columns 1-3 are the normalised HHI, Scope and non-bank revenue share respectively, which capture the dimension of business complexity. The complexity measures of the parent banking group in columns 4-5 are the foreign revenue share and the foreign asset share respectively, which capture the dimension of geographical complexity. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level

Table 7: Estimation results on the average effect of bank complexity on FBHK's LLP ratio

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	LLP ratio	LLP ratio	LLP ratio	LLP ratio	LLP ratio
Complexity measure p,t-1	0.063	-0.414	-0.004	0.003	0.008
	(0.836)	(0.181)	(0.254)	(0.506)	(0.209)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	-0.108	-0.106	-0.100	-0.092	-0.186*
	(0.209)	(0.212)	(0.224)	(0.191)	(0.095)
Loan-to-asset ratio b,t-1	-0.006	-0.006	-0.006	-0.002	-0.017*
	(0.457)	(0.449)	(0.443)	(0.586)	(0.073)
Deposit-to-asset ratio b,t-1	-0.014**	-0.015**	-0.014**	-0.010***	-0.018**
	(0.028)	(0.030)	(0.031)	(0.008)	(0.032)
Net due to (overseas offices) ratio b,t-1	-0.003	-0.004	-0.004	0.001	0.005
	(0.493)	(0.358)	(0.367)	(0.883)	(0.506)
Cost-to-income ratio b,t-1	-0.001	-0.001	-0.001	-0.003***	-0.001
	(0.672)	(0.661)	(0.681)	(0.007)	(0.707)
Dummy (subsidiary)	0.524	0.490	0.521	0.023	1.058*
	(0.378)	(0.407)	(0.386)	(0.923)	(0.095)
Parent characteristics					
Log (real assets) p,t-1	-0.076	-0.067	-0.070	0.009	-0.181
	(0.598)	(0.649)	(0.637)	(0.944)	(0.338)
T1 capital ratio p,t-1	-0.033	-0.028	-0.022	0.001	-0.025
	(0.314)	(0.386)	(0.499)	(0.976)	(0.525)
Home-country conditions					
Real GDP growth j,t-1	-0.002	-0.007	-0.006	0.013	-0.003
	(0.938)	(0.781)	(0.803)	(0.574)	(0.927)
Observations	1,180	1,180	1,189	907	799
R-squared	0.067	0.069	0.068	0.061	0.112
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	135	113

Note: The dependent variable is LLP ratio of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of all foreign banks in Hong Kong (both foreign bank branches and subsidiaries). The complexity measures of the parent banking group in columns 1-3 are the normalised HHI, Scope and non-bank revenue share respectively, which capture the dimension of business complexity. The complexity measures of the parent banking group in columns 4-5 are the foreign revenue share and the foreign asset share respectively, which capture the dimension of geographical complexity. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table 8: Estimation results on the testing of the agency problem hypothesis on FBHK's default and earning risks (Business complexity)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Business complexity measures	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share
Dependent variable	Inverse Log(Z-score)			SD (ROA)			Adj ROA		
Complexity measure p,t-1	0.109	0.132	0.002**	0.223	0.402*	0.006***	-0.669	-0.454	0.001
	(0.113)	(0.175)	(0.038)	(0.209)	(0.053)	(0.005)	(0.219)	(0.506)	(0.882)
Complexity measure p,t-1 * FBHK revenue share b, t-1	-0.026*	-0.027	-0.001**	-0.043	-0.207	-0.002*	0.757	0.653	-0.001
	(0.095)	(0.428)	(0.025)	(0.678)	(0.311)	(0.086)	(0.175)	(0.301)	(0.724)
FBHK revenue share b, t-1	0.008	0.027	0.006	0.157	0.394	0.191*	-0.455*	-0.914	-0.082
	(0.494)	(0.500)	(0.527)	(0.163)	(0.159)	(0.088)	(0.092)	(0.242)	(0.799)
Log (real assets) b,t-1	0.005	0.007	0.009	-0.238**	-0.242**	-0.244**	0.602***	0.606***	0.609***
	(0.565)	(0.418)	(0.348)	(0.024)	(0.021)	(0.019)	(0.000)	(0.000)	(0.000)
Loan-to-asset ratio b,t-1	0.000	0.000	-0.000	0.004	0.004	0.003	0.008	0.008	0.008
	(0.811)	(0.884)	(0.660)	(0.196)	(0.200)	(0.246)	(0.407)	(0.435)	(0.415)
Deposit-to-asset ratio b,t-1	-0.000	-0.000	-0.000	0.001	0.001	0.001	0.017***	0.017**	0.017**
	(0.557)	(0.651)	(0.622)	(0.800)	(0.731)	(0.702)	(0.009)	(0.010)	(0.010)
Net due to (overseas offices) ratio b,t-1	-0.002	-0.001	-0.000	-0.001	-0.001	-0.001	0.009*	0.010*	0.011**
	(0.556)	(0.794)	(0.904)	(0.570)	(0.705)	(0.826)	(0.072)	(0.053)	(0.034)
Cost-to-income ratio b,t-1	0.001***	0.001***	0.001***	0.004	0.004	0.004	-0.018***	-0.018***	-0.018***
	(0.007)	(0.007)	(0.005)	(0.117)	(0.118)	(0.114)	(0.000)	(0.000)	(0.000)
Dummy (subsidiary)				-0.012	-0.002	0.004	3.573***	3.602***	3.624***
				(0.932)	(0.986)	(0.977)	(0.000)	(0.000)	(0.000)
Log (real assets) p,t-1	0.017	0.016	0.012	0.171*	0.180*	0.175*	-0.465***	-0.487***	-0.492***
	(0.131)	(0.139)	(0.279)	(0.075)	(0.064)	(0.067)	(0.003)	(0.002)	(0.001)
T1 capital ratio p,t-1	0.001	0.001	-0.003	0.018	0.014	0.009	-0.134**	-0.131**	-0.140**
	(0.834)	(0.771)	(0.481)	(0.351)	(0.460)	(0.621)	(0.017)	(0.024)	(0.014)
Real GDP growth p,t-1	-0.002	-0.002	-0.002	0.007	0.010	0.012	-0.093**	-0.092**	-0.096**
	(0.451)	(0.410)	(0.545)	(0.533)	(0.391)	(0.331)	(0.037)	(0.038)	(0.035)
Observations	289	289	289	1,135	1,135	1,144	1,135	1,135	1,144
R-squared	0.227	0.222	0.247	0.168	0.171	0.174	0.390	0.389	0.387
Cluster	parent	parent	parent	parent	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
No. of FBHKs	36	36	36	154	154	154	154	154	154

Note: This table reports the results for specification (2) discussed in section 3, which aims to shed light on the existence of the agency problem hypothesis by assessing the interaction term between the share of FBHK's revenue to the total revenue of the overall banking group (FBHK revenue share b, t-1) and the various business complexity measures of the parent banking group. The dependent variable in columns 1 to 3 is Inverse Log (Z-score) of foreign banks in Hong Kong. The dependent variable in columns 4 to 6 is an 8-quarter standard deviation of ROA of foreign banks in Hong Kong. The dependent variable in columns 7 to 9 is ROA (adjusted by its SD (ROA)) of foreign banks in Hong Kong. The data are annual data from 2004 to 2017 for a panel of foreign banks in Hong Kong. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent banking group. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table 9: Estimation results on the testing of the agency problem hypothesis on FBHK's default and earning risks (Geographical complexity)

	(1)	(2)	(3)	(4)	(5)	(6)
Geographical complexity	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share
VARIABLES	Inverse Log(Z-score)		SD (ROA)		Adj ROA	
Complexity measure p,t-1	0.001	0.001	0.014***	0.003	0.017	-0.002
	(0.561)	(0.625)	(0.009)	(0.445)	(0.133)	(0.860)
Complexity measure p,t-1 * FBHK revenue share b, t-1	-0.001	-0.001	-0.007***	-0.005**	0.001	0.005
	(0.240)	(0.203)	(0.002)	(0.010)	(0.876)	(0.454)
FBHK revenue share b, t-1	0.032	0.049	0.457***	0.441***	0.354	0.348
	(0.309)	(0.215)	(0.003)	(0.003)	(0.327)	(0.415)
Log (real assets) b,t-1	0.004	-0.013	-0.321***	-0.324***	0.249**	0.228*
	(0.788)	(0.553)	(0.002)	(0.003)	(0.018)	(0.067)
Loan-to-asset ratio b,t-1	0.001	0.001	-0.013*	-0.001	0.016	0.019*
	(0.553)	(0.479)	(0.087)	(0.793)	(0.147)	(0.097)
Deposit-to-asset ratio b,t-1	-0.000	0.000	-0.005	-0.000	0.006	-0.002
	(0.663)	(0.821)	(0.222)	(0.966)	(0.392)	(0.768)
Net due to (overseas offices) ratio b,t-1	0.003	0.002	0.004	0.003	0.003	-0.004
	(0.454)	(0.693)	(0.168)	(0.478)	(0.636)	(0.608)
Cost-to-income ratio b,t-1	0.008	0.007	0.003	0.004	-0.013***	-0.011***
	(0.130)	(0.194)	(0.120)	(0.110)	(0.000)	(0.000)
Dummy (subsidiary)			0.701	-0.074	3.091***	3.124***
			(0.152)	(0.795)	(0.000)	(0.000)
Log (real assets) p,t-1	0.031	0.074	0.221**	0.245**	-0.130	0.017
	(0.386)	(0.151)	(0.023)	(0.019)	(0.547)	(0.912)
T1 capital ratio p,t-1	0.014	0.030	0.026	0.032	-0.206***	-0.107*
	(0.422)	(0.207)	(0.514)	(0.342)	(0.002)	(0.061)
Real GDP growth p,t-1	0.003	-0.006	0.000	-0.013	0.113*	0.131**
	(0.799)	(0.684)	(0.998)	(0.651)	(0.091)	(0.040)
Observations	265	231	977	847	977	847
R-squared	0.387	0.333	0.274	0.231	0.382	0.389
Cluster	parent	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y	Y
No. of bank	36	31	137	122	137	122

Note: This table reports the results for specification (2) discussed in section 3, which aims to shed light on the existence of the agency problem hypothesis by assessing the interaction term between the share of FBHK's revenue to the total revenue of the overall banking group (FBHK revenue share b, t-1) and the various geographical complexity measures of the parent banking group. The dependent variable in columns 1 to 2 is Inverse Log (Z-score) of foreign banks in Hong Kong. The dependent variable in columns 3 to 4 is an 8-quarter standard deviation of ROA of foreign banks in Hong Kong. The dependent variable in columns 5 to 6 is ROA (adjusted by its SD (ROA)) of foreign banks in Hong Kong. The data are annual data from 2004 to 2017 for a panel of foreign banks in Hong Kong. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent banking group. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table 10: Estimation results on the testing of the diversification hypothesis on FBHK's default and earning risks (Business complexity)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Business complexity measures	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share
Dependent variable	Inverse Log(Z-score)			SD (ROA)			Adj ROA		
Complexity measure p,t-1	0.088	0.082	0.001	0.264*	0.328**	0.005***	-0.442	-0.328	-0.003
	(0.109)	(0.216)	(0.169)	(0.096)	(0.048)	(0.004)	(0.380)	(0.497)	(0.636)
Complexity measure p,t-1 * Net Due to (overseas offices) ratio b, t-1	0.008	-0.000	-0.000	0.002	-0.002	-0.000	0.009	0.000	-0.000
	(0.504)	(0.941)	(0.978)	(0.660)	(0.601)	(0.541)	(0.466)	(0.979)	(0.920)
Net Due to (overseas offices) ratio b, t-1	-0.004	-0.001	-0.001	-0.002	0.002	0.000	0.006	0.009	0.010*
	(0.191)	(0.922)	(0.694)	(0.517)	(0.712)	(0.886)	(0.430)	(0.537)	(0.074)
Log (real assets) b,t-1	0.004	0.005	0.004	-0.196**	-0.198**	-0.203**	0.563***	0.576***	0.577***
	(0.406)	(0.303)	(0.392)	(0.015)	(0.014)	(0.011)	(0.000)	(0.000)	(0.000)
Loan-to-asset ratio b,t-1	0.000	0.000	-0.000	0.004*	0.004*	0.004	0.009	0.010	0.010
	(0.859)	(0.933)	(0.887)	(0.100)	(0.099)	(0.115)	(0.320)	(0.309)	(0.291)
Deposit-to-asset ratio b,t-1	-0.000	-0.000	-0.000	0.001	0.002	0.002	0.014**	0.014**	0.014**
	(0.547)	(0.561)	(0.505)	(0.603)	(0.552)	(0.557)	(0.033)	(0.040)	(0.038)
Cost-to-income ratio b,t-1	0.001***	0.001***	0.001***	0.005*	0.005*	0.005*	-0.016***	-0.016***	-0.016***
	(0.006)	(0.007)	(0.007)	(0.050)	(0.052)	(0.051)	(0.000)	(0.000)	(0.000)
Dummy (subsidiary)				0.051	0.063	0.046	3.477***	3.503***	3.517***
				(0.682)	(0.613)	(0.710)	(0.000)	(0.000)	(0.000)
Log (real assets) p,t-1	0.018**	0.018**	0.018**	0.123*	0.132*	0.131*	-0.403***	-0.425***	-0.429***
	(0.049)	(0.039)	(0.045)	(0.097)	(0.078)	(0.078)	(0.002)	(0.001)	(0.001)
T1 capital ratio p,t-1	0.001	0.002	0.000	0.020	0.015	0.011	-0.129**	-0.127**	-0.131**
	(0.729)	(0.649)	(0.945)	(0.306)	(0.431)	(0.545)	(0.018)	(0.021)	(0.016)
Real GDP growth p,t-1	-0.002	-0.002	-0.001	0.003	0.008	0.012	-0.080*	-0.081*	-0.083*
	(0.438)	(0.519)	(0.762)	(0.822)	(0.521)	(0.343)	(0.099)	(0.092)	(0.082)
Observations	296	296	296	1,155	1,155	1,164	1,155	1,155	1,164
R-squared	0.224	0.214	0.214	0.180	0.182	0.186	0.383	0.383	0.381
Cluster	parent	parent	parent	parent	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
No. of FBHKs	39	39	39	159	159	159	159	159	159

Note: This table reports the results for specification (2) discussed in section 3, which aims to shed light on the existence of the diversification hypothesis by assessing the interaction term between the share of FBHK's net due to overseas office to total assets (Net Due to (overseas offices) ratio b, t-1) and the various business complexity measures of the parent banking group. The dependent variable in columns 1 to 3 is Inverse Log (Z-score) of foreign banks in Hong Kong. The dependent variable in columns 4 to 6 is an 8-quarter standard deviation of ROA of foreign banks in Hong Kong. The dependent variable in columns 7 to 9 is ROA (adjusted by its SD (ROA)) of foreign banks in Hong Kong. The data are annual data from 2004 to 2017 for a panel of foreign banks in Hong Kong. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent banking group. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level

Table 11: Estimation results on the testing of the diversification hypothesis on FBHK's default and earning risks (Geographical complexity)

	(1)	(2)	(3)	(4)	(5)	(6)
Geographical complexity	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share
VARIABLES	Inverse Log(Z-score)		SD (ROA)		Adj ROA	
Complexity measure p,t-1	0.003	0.001	0.022**	0.003	0.011	-0.005
	(0.423)	(0.459)	(0.036)	(0.599)	(0.508)	(0.783)
Complexity measure p,t-1 * Net Due to (overseas offices) ratio b, t-1	0.000	0.000	0.000	0.000	0.000	0.001***
	(0.417)	(0.371)	(0.986)	(0.854)	(0.328)	(0.003)
Net Due to (overseas offices) ratio b, t-1	-0.002	-0.005	0.004	0.002	-0.005	-0.024**
	(0.501)	(0.379)	(0.240)	(0.553)	(0.642)	(0.015)
Log (real assets) b,t-1	0.007	-0.006	-0.272***	-0.256***	0.339***	0.372***
	(0.441)	(0.670)	(0.001)	(0.005)	(0.000)	(0.000)
Loan-to-asset ratio b,t-1	-0.001	-0.001	-0.012	-0.001	0.017	0.020*
	(0.151)	(0.323)	(0.106)	(0.782)	(0.112)	(0.065)
Deposit-to-asset ratio b,t-1	0.001	0.001	0.005	0.002	-0.003	-0.007
	(0.394)	(0.322)	(0.495)	(0.583)	(0.698)	(0.479)
Cost-to-income ratio b,t-1	0.003	0.003	0.004*	0.004**	-0.011***	-0.010***
	(0.345)	(0.343)	(0.070)	(0.037)	(0.000)	(0.000)
Dummy (subsidiary)			0.767	0.103	3.246***	3.457***
			(0.115)	(0.725)	(0.000)	(0.000)
Log (real assets) p,t-1	0.005	0.045	0.149*	0.188**	-0.212	-0.129
	(0.799)	(0.242)	(0.066)	(0.041)	(0.230)	(0.332)
T1 capital ratio p,t-1	0.008	0.031	0.044	0.048	-0.196***	-0.116**
	(0.491)	(0.159)	(0.256)	(0.160)	(0.004)	(0.037)
Real GDP growth p,t-1	-0.009	-0.014	-0.016	-0.021	0.139**	0.130**
	(0.286)	(0.102)	(0.652)	(0.448)	(0.036)	(0.036)
Observations	277	233	1,002	857	1,002	857
R-squared	0.186	0.198	0.279	0.227	0.382	0.397
Cluster	parent	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y	Y
No. of bank	39	34	143	123	143	123

Note: This table reports the results for specification (2) discussed in section 3, which aims to shed light on the existence of the diversification hypothesis by assessing the interaction term between the share of FBHK's revenue to the total revenue of the overall banking group (FBHK revenue share b, t-1) and the various geographical complexity measures of the parent banking group. The dependent variable in columns 1 to 2 is Inverse Log (Z-score) of foreign banks in Hong Kong. The dependent variable in columns 3 to 4 is an 8-quarter standard deviation of ROA of foreign banks in Hong Kong. The dependent variable in columns 5 to 6 is ROA (adjusted by its SD (ROA)) of foreign banks in Hong Kong. The data are annual data from 2004 to 2017 for a panel of foreign banks in Hong Kong. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent banking group. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table 12: Descriptive statistics of complexity measures for both GSIBs and non-GSIBs prior the GSIB regulatory reform

	GSIBs					Non-GSIB						
2004-12	No. of banks	Obs	Mean	Std		No. of banks	Obs	Mean	Std		t-test for diff in means	t-stat
Level												
HHI	30	232	0.534	0.313		104	797	0.392	0.310		0.143***	6.15
Scope	30	232	1.470	0.417		104	797	1.255	0.291		0.215***	8.90
Non-bank revenue share	30	239	45.918	35.552		104	796	19.504	24.638		26.413***	13.00
Foreign revenue share	29	218	35.967	24.202		69	412	21.333	17.821		14.634***	8.63
Foreign asset share	24	174	36.250	28.797		63	396	24.699	21.556		11.550***	5.29
Change												
Δ HHI	30	215	0.002	0.167		104	739	0.004	0.178		-0.002	-0.15
Δ Scope	30	215	-0.010	0.162		104	739	0.003	0.177		-0.013	-0.97
Δ Non-bank revenue share	30	223	-1.347	14.566		104	736	-0.066	12.868		-1.281	-1.26
Δ Foreign revenue share	29	199	0.707	9.964		69	370	0.792	7.237		-0.086	-0.12
Δ Foreign asset share	24	165	-0.099	8.045		63	362	0.078	8.416		-0.177	-0.23

Note: This table describes the number of observations, mean and standard deviations on the level of and change in the business and geographical complexity measures for GSIBs and non-GSIBs respectively before the introduction of the GSIB regulatory framework. The t-test (and the corresponding t-statistics) for the difference in means for the respective variables are presented in the last two columns. ***, **, * denote significance level at 1%, 5%, and 10%, respectively.

Table 13: Difference-in-difference Analysis: Effect of GSIB regulatory reform on the complexity of parent banking organisations

	(1)	(2)	(3)	(4)	(5)
	Business complexity			Geographical complexity	
Dependent variable	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
$Post_t$	0.012	0.012	0.121	-2.975**	-4.868***
	(0.455)	(0.473)	(0.929)	(0.017)	(0.001)
$GSIB_p$	0.106***	0.225***	31.248***	9.599***	8.517***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$Post_t$ x $GSIB_p$	-0.052	-0.102**	-7.275**	3.984	-0.402
	(0.154)	(0.014)	(0.048)	(0.125)	(0.904)
Log (real assets) p,t-1	0.013**	-0.006	-2.299***	1.554***	0.032
	(0.046)	(0.346)	(0.000)	(0.002)	(0.957)
T1 capital ratio p,t-1	-0.014***	-0.009***	-0.696***	-0.033	-0.173
	(0.000)	(0.002)	(0.003)	(0.874)	(0.444)
Real GDP growth j,t-1	0.010***	-0.007***	-0.533***	-2.299***	-2.589***
	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
Constant	0.221***	1.357***	22.782***	11.090*	35.682***
	(0.005)	(0.000)	(0.005)	(0.082)	(0.000)
Observation	1,188	1,188	1,188	801	682
R-squared	0.033	0.057	0.121	0.263	0.194
Cluster	parent	parent	parent	parent	parent
No. of banking organizations	134	134	134	105	90

Note: This table reports the results for specification (3) discussed in section 3, which assess the effect of the GSIB regulatory framework on the business and geographical complexity measures of global banks. The dependent variables are various indicators of business and geographical complexity of the parent banking group. $Post_t$ is a time dummy variable which equals to one after year 2012 when the BSCB GSIB assessment methodology was introduced and zero otherwise. $GSIB_p$ is a dummy variable which takes on one if the parent bank has been designated as GSIB at least once over the sample period. The data are annual data from 2004 to 2017 for a panel of global banking institutions that have bank affiliates in Hong Kong. Standard errors are clustered by parent bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table 14: Difference-in-difference estimation results on the risk measures of FBHKs before and after the introduction of GSIB regulatory reforms

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Δ Inverse Ln(Z-score) (post-pre)	Δ SD (ROA) (post-pre)	Δ Adj ROA (post-pre)	ΔNPL ratio (post-pre)	ΔLLP ratio (post-pre)
Dummy (GSIB)	-0.075***	-0.505*	0.672	0.534	-0.088
	(0.006)	(0.060)	(0.461)	(0.739)	(0.875)
FBHK balance sheet characteristics					
Log (real assets) b, average 10-12	0.011	0.062	-0.337*	0.185	0.119
	(0.361)	(0.616)	(0.072)	(0.579)	(0.358)
Loan-to-asset ratio b, average 10-12	-0.001	-0.005	0.038	0.089**	0.043**
	(0.261)	(0.275)	(0.106)	(0.026)	(0.012)
Deposit-to-asset ratio b, average 10-12	0.001	0.017*	-0.010	0.033	0.015
	(0.209)	(0.058)	(0.453)	(0.211)	(0.185)
Net due to (overseas offices) ratio b, average 10-12	0.009	0.004	-0.011	0.080**	0.021*
	(0.192)	(0.364)	(0.259)	(0.032)	(0.077)
Cost-to-income ratio b, average 10-12	-0.001*	-0.002	0.007	0.034	0.013
	(0.089)	(0.424)	(0.143)	(0.169)	(0.191)
Dummy (subsidiary)		-0.377	-0.563	-1.702	-0.893
		(0.308)	(0.362)	(0.179)	(0.144)
Parent characteristics					
Log (real assets) p, average 10-12	0.009	0.123	0.165	-0.110	0.099
	(0.510)	(0.377)	(0.548)	(0.854)	(0.656)
T1 capital ratio p, average 10-12	-0.005	-0.050	-0.001	0.001	0.008
	(0.700)	(0.306)	(0.996)	(0.997)	(0.920)
Home-country conditions					
Real GDP growth p, average 10-12	-0.007**	-0.059*	0.219**	0.075	0.039
	(0.050)	(0.095)	(0.043)	(0.547)	(0.415)
Constant	-0.061	-1.566	-0.502	-7.762	-5.677
	(0.817)	(0.156)	(0.884)	(0.420)	(0.148)
Observations	29	126	126	112	112
R-squared	0.388	0.157	0.123	0.215	0.228
Cluster	parent	parent	parent	parent	parent

Note: This table report the results for specification (4) discussed in section 3, which assesses the effect on various risk indicators of their FBHKs arising from the exogenous change in the complexity of GSIBs due to the GSIB regulatory framework. The dependent variables are the change in the average risk measures of FBHKs between the pre-reform period (year 2010 to 2012) and post-reform period (year 2014 to 2017). $GSIB_p$ is a dummy variable which takes on one if the FBHK's parent bank has been designated as GSIB at least once over the sample period, and zero otherwise. Standard errors are clustered by parent bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table 15: Difference-in-difference estimation results on the risk measures of FBHKs before and after the introduction of GSIB regulatory reforms (based on propensity score matched sample)

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Δ Inverse Ln(Z-score) (post-pre)	Δ SD (ROA) (post-pre)	Δ Adj ROA (post-pre)	ΔNPL ratio (post-pre)	ΔLLP ratio (post-pre)
Dummy (GSIB)	-0.134**	-1.022**	3.136***	1.950	0.871
	(0.033)	(0.041)	(0.007)	(0.512)	(0.429)
FBHK balance sheet characteristics					
Log (real assets) b, average 10-12	0.018	0.226	-0.110	-0.170	-0.050
	(0.186)	(0.112)	(0.665)	(0.532)	(0.729)
Loan-to-asset ratio b, average 10-12	-0.001	0.005	0.101**	0.044	0.021
	(0.397)	(0.552)	(0.026)	(0.207)	(0.305)
Deposit-to-asset ratio b, average 10-12	0.000	-0.003	-0.037*	0.076	0.036*
	(0.633)	(0.771)	(0.058)	(0.156)	(0.093)
Net due to (overseas offices) ratio b, average 10-12	0.015*	0.006	-0.022	0.084	0.038
	(0.092)	(0.346)	(0.158)	(0.180)	(0.141)
Cost-to-income ratio b, average 10-12	-0.002**	0.002	0.039***	0.039	0.020
	(0.050)	(0.534)	(0.000)	(0.184)	(0.160)
Dummy (subsidiary)		0.155	-0.094	-1.093	-0.284
		(0.732)	(0.921)	(0.447)	(0.751)
Parent characteristics					
Log (real assets) p, average 10-12	0.010	0.248	-1.873**	-0.243	-0.164
	(0.704)	(0.312)	(0.018)	(0.813)	(0.693)
T1 capital ratio p, average 10-12	-0.000	0.124	-0.002	-0.079	0.000
	(0.983)	(0.204)	(0.993)	(0.862)	(0.998)
Home-country conditions					
Real GDP growth p, average 10-12	-0.002	0.020	0.351**	0.090	0.056
	(0.847)	(0.684)	(0.018)	(0.672)	(0.633)
Constant	-0.081	-7.153	20.575*	-3.062	-1.787
	(0.899)	(0.100)	(0.066)	(0.828)	(0.791)
Observations	15	58	58	51	51
R-squared	0.652	0.308	0.381	0.188	0.239
Cluster	parent	parent	parent	parent	parent

Note: This table report the results for specification (4) discussed in section 3, using a propensity-score matched sample. The test assesses the effect on various risk indicators of their FBHKs arising from the exogenous change in the complexity of GSIBs due to the GSIB regulatory framework. The dependent variables are the change in the average risk measures of FBHKs between the pre-reform period (year 2010 to 2012) and post-reform period (year 2014 to 2017). $GSIB_p$ is a dummy variable which takes on one if the FBHK's parent bank has been designated as GSIB at least once over the sample period, and zero otherwise. Standard errors are clustered by parent bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Appendix

Table A1: Definition of complexity variables and data source

Variable	Formula	Definition and explanation	Data source
Complexity measures of global banking organization			
Business complexity			
HHI	$\frac{T}{T-1}\left(1-\sum_{\tau=1}^{T}\left(\frac{revenue_{\tau}}{total\ \ revenue}\right)^{2}\right)$	The normalised Herfindahl index has a value between 0 and 1, with a higher index value reflecting a higher degree of business complexity. τ is the distinct business type from which the global banking organization generates revenue in a given year, where business types are according to the North American Industry Classification System (NAICS). *T* is the total number of distinct business types from which the global banking organisation generates revenue in a given year. Commercial banking has a NAICS code of 522. Other business types are defined according to 3-digit NAICS codes for financial industries and 2-digit NAICS codes for all other industries.	Capital IQ
Scope	$\sum_{\tau=1}^{T}(distance_{\tau}\times revenue_{\tau})/total\ \ revenue$	The weighted average distance from commercial banking has a value between 1 and 4, with a higher value reflecting a higher degree of scope complexity. A global bank that engages solely in commercial banking activities has a scope complexity that equals 1, whereas an organization that engages solely in nonfinancial activities has a scope complexity of 4. τ is the distinct business type from which the global banking organization generates revenue in a given year, where business types are according to NAICS. *T* is the total number of distinct business types from which the global banking organisation generates revenue in a given year. *distance* has a value of 1 to 4 according to the NAICS's proximity to commercial banking (522). The value of distance increases when the NAICS of a business segment moves away from 522. For instance, distance for a segment starting with 524 would have a value of 2, distance	Capital IQ

		for a segment starting with 511 would have a value of 3, and distance for a segment starting with 811 would have a value of 4.	
Non-bank revenue share	1 – (*revenue generated from commercial banking / total revenue*)	The share of sum of revenue from non-bank business lines to total revenue of the banking group	Capital IQ
Geographical complexity			
Foreign revenue share	1 – (*domestic revenue / total revenue*)	The share of non-domestic revenue in total revenue has a value between 0 and 1, with a higher value reflecting a higher degree of geographic complexity. Domestic revenue includes revenues from the global banking organisation's home country.	Capital IQ
Foreign asset share	1 – (*domestic assets / total asset*)	The share of non-domestic assets in total assets has a value between 0 and 1, with a higher value reflecting a higher degree of geographic complexity. Domestic assets include assets held in the global banking organisation's home country.	Capital IQ

Table A2: Estimation results for the interaction between business complexity measures and dummy for subsidiary

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Complexity measure	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share	HHI	Scope	Non-bank revenue share
Dependent variable	SD (ROA)			Adj ROA			NPL ratio			LLP ratio		
Complexity measure p,t-1	0.152	0.268	0.004**	-0.446	-0.063	-0.004	0.351	-0.602	-0.008	0.310	-0.262	-0.002
	(0.389)	(0.109)	(0.012)	(0.378)	(0.898)	(0.538)	(0.602)	(0.225)	(0.196)	(0.338)	(0.351)	(0.474)
Complexity measure p,t-1 * Dummy (subsidiary)	0.529	0.533	0.003	0.052	-1.947*	0.005	1.554	1.700	0.023	-1.169	-1.165	-0.007
	(0.284)	(0.279)	(0.518)	(0.970)	(0.073)	(0.643)	(0.674)	(0.661)	(0.485)	(0.432)	(0.475)	(0.582)
FBHK balance sheet characteristics												
Log (real assets) b,t-1	-0.199**	-0.198**	-0.204**	0.569***	0.571***	0.575***	-0.181	-0.168	-0.174	-0.097	-0.108	-0.098
	(0.013)	(0.013)	(0.011)	(0.000)	(0.000)	(0.000)	(0.321)	(0.351)	(0.330)	(0.240)	(0.213)	(0.232)
Loan-to-asset ratio b,t-1	0.005*	0.004*	0.004	0.010	0.009	0.010	-0.024*	-0.024*	-0.026*	-0.006	-0.006	-0.005
	(0.091)	(0.093)	(0.130)	(0.303)	(0.314)	(0.298)	(0.095)	(0.092)	(0.080)	(0.435)	(0.438)	(0.442)
Deposit-to-asset ratio b,t-1	0.001	0.002	0.001	0.014**	0.014**	0.014**	-0.026**	-0.025**	-0.026**	-0.014**	-0.015**	-0.014**
	(0.647)	(0.533)	(0.560)	(0.036)	(0.045)	(0.038)	(0.015)	(0.018)	(0.015)	(0.025)	(0.031)	(0.030)
Net due to (overseas offices) ratio b,t-1	-0.001	-0.001	-0.000	0.009*	0.010*	0.010*	0.007	0.006	0.005	-0.002	-0.004	-0.004
	(0.592)	(0.795)	(0.884)	(0.074)	(0.058)	(0.060)	(0.443)	(0.551)	(0.627)	(0.600)	(0.373)	(0.382)
Cost-to-income ratio b,t-1	0.005**	0.005*	0.005*	-0.016***	-0.016***	-0.016***	-0.002	-0.002	-0.002	-0.001	-0.001	-0.001
	(0.050)	(0.050)	(0.050)	(0.000)	(0.000)	(0.000)	(0.483)	(0.477)	(0.466)	(0.665)	(0.655)	(0.691)
Dummy (subsidiary)	-0.164	-0.599	-0.023	3.473***	5.910***	3.389***	0.905	-0.630	1.003	1.008	1.929	0.675
	(0.434)	(0.315)	(0.875)	(0.000)	(0.000)	(0.000)	(0.607)	(0.898)	(0.430)	(0.378)	(0.446)	(0.427)
Parent characteristics												
Log (real assets) p,t-1	0.127*	0.133*	0.132*	-0.405***	-0.425***	-0.427***	-0.094	-0.065	-0.063	-0.086	-0.067	-0.072
	(0.086)	(0.075)	(0.076)	(0.001)	(0.001)	(0.001)	(0.745)	(0.819)	(0.828)	(0.560)	(0.644)	(0.630)
T1 capital ratio p,t-1	0.019	0.017	0.012	-0.131**	-0.133**	-0.130**	-0.029	-0.019	-0.002	-0.033	-0.031	-0.024
	(0.311)	(0.356)	(0.499)	(0.018)	(0.016)	(0.020)	(0.651)	(0.760)	(0.979)	(0.309)	(0.331)	(0.472)
Home-country conditions												
Real GDP growth j,t-1	0.005	0.009	0.013	-0.076*	-0.084*	-0.081*	-0.008	-0.013	0.001	-0.005	-0.009	-0.010
	(0.690)	(0.491)	(0.307)	(0.097)	(0.077)	(0.085)	(0.873)	(0.800)	(0.989)	(0.847)	(0.733)	(0.711)
Observations	1,155	1,155	1,164	1,155	1,155	1,164	1,180	1,180	1,189	1,180	1,180	1,189
R-squared	0.182	0.184	0.187	0.383	0.385	0.381	0.060	0.059	0.060	0.070	0.071	0.069
Cluster	parent	parent	parent	parent	parent	parent	parent	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	159	159	159	159	159	159	159	159	159

Note: We employ specification (1) discussed in Section 3 and interact various business complexity measures (HHI, Scope and Non-bank revenue share) with Dummy (subsidiary) respectively. The data are annual data from 2004 to 2017 for a panel of foreign subsidiary banks in Hong Kong. The dependent variable in columns 1-3 are SD (ROA) of FBHKs. The dependent variable in columns 4-6 are Adj ROA of FBHKs. The dependent variable in columns 7-9 are NPL ratio of FBHKs. The dependent variable in columns 10-12 are LLP ratio of FBHKs All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level.

Table A3: Estimation results for the interaction between geographical complexity measures and dummy for subsidiary

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Complexity measure	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share	Foreign revenue share	Foreign asset share
Dependent variable	SD (ROA)		Adj ROA		NPL ratio		LLP ratio	
Complexity measure p,t-1	0.004	-0.003	0.023	-0.008	0.011	0.016	0.006	0.010
	(0.486)	(0.495)	(0.186)	(0.538)	(0.234)	(0.288)	(0.282)	(0.193)
Complexity measure p,t-1 * Dummy (subsidiary)	0.017	0.013	0.004	0.036**	-0.012	-0.021	-0.009*	-0.013
	(0.160)	(0.182)	(0.833)	(0.031)	(0.387)	(0.257)	(0.097)	(0.258)
FBHK balance sheet characteristics								
Log (real assets) b,t-1	-0.266***	-0.258***	0.352***	0.347***	-0.129	-0.328	-0.088	-0.170
	(0.002)	(0.004)	(0.000)	(0.001)	(0.449)	(0.154)	(0.227)	(0.128)
Loan-to-asset ratio b,t-1	-0.013*	-0.003	0.020**	0.016	-0.022	-0.034**	-0.001	-0.015
	(0.068)	(0.634)	(0.048)	(0.140)	(0.229)	(0.029)	(0.811)	(0.125)
Deposit-to-asset ratio b,t-1	-0.003	0.002	0.010	0.003	-0.026**	-0.023**	-0.011***	-0.018**
	(0.539)	(0.651)	(0.203)	(0.684)	(0.011)	(0.031)	(0.006)	(0.028)
Net due to (overseas offices) ratio b,t-1	0.004	0.004	0.005	-0.003	0.011	0.024	0.001	0.005
	(0.169)	(0.353)	(0.446)	(0.719)	(0.263)	(0.110)	(0.885)	(0.520)
Cost-to-income ratio b,t-1	0.004*	0.004**	-0.012***	-0.010***	-0.005*	-0.004	-0.003***	-0.001
	(0.059)	(0.035)	(0.000)	(0.000)	(0.055)	(0.380)	(0.006)	(0.698)
Dummy (subsidiary)	0.331	-0.154	2.542***	2.622***	1.503	2.015**	0.215	1.247**
	(0.520)	(0.544)	(0.000)	(0.000)	(0.176)	(0.025)	(0.483)	(0.033)
Parent characteristics								
Log (real assets) p,t-1	0.200**	0.205**	-0.118	-0.051	0.107	-0.391	-0.004	-0.197
	(0.019)	(0.031)	(0.568)	(0.741)	(0.691)	(0.266)	(0.972)	(0.295)
T1 capital ratio p,t-1	0.045	0.049	-0.206***	-0.071	0.081	-0.057	-0.002	-0.024
	(0.241)	(0.141)	(0.003)	(0.291)	(0.213)	(0.515)	(0.952)	(0.554)
Home-country conditions	-0.001	-0.015	0.141*	0.135*	0.023	-0.061	0.009	-0.013
Real GDP growth j,t-1	(0.989)	(0.575)	(0.063)	(0.056)	(0.665)	(0.392)	(0.693)	(0.678)
Observations	1,002	857	1,002	857	907	799	907	799
R-squared	0.274	0.230	0.340	0.382	0.068	0.082	0.063	0.111
Cluster	parent	parent	parent	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y	Y	Y	Y
No of FBHKs	143	123	143	123	135	113	135	113

Note: We employ specification (1) discussed in Section 3 and interact various geographical complexity measures (foreign revenue share and foreign asset share) with Dummy (subsidiary) respectively. The data are annual data from 2004 to 2017 for a panel of foreign subsidiary banks in Hong Kong. The dependent variable in columns 1-3 are SD (ROA) of FBHKs. The dependent variable in columns 4-6 are Adj ROA of FBHKs. The dependent variable in columns 7-9 are NPL ratio of FBHKs. The dependent variable in columns 10-12 are LLP ratio of FBHKs All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by bank. P-values below coefficient estimates indicate the level of significance. ***/**/* denotes statistical significance at the 1%/5%/10% level

Table A4: Durbin-Wu-Hausman test for endogeneity for the effect of bank complexity on FBHK's inverse log z-score

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	Inverse Log(Z-score)	Inverse Log(Z-score)	Inverse Log(Z-score)	Inverse Log(Z-score)	Inverse Log(Z-score)
Panel A					
Complexity measure p,t-1 (instrumented variable)	0.086*	0.100	0.001	0.002	-0.000
	(0.079)	(0.253)	(0.119)	(0.502)	(0.904)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	0.003	0.005	0.003	0.005	-0.007
	(0.450)	(0.302)	(0.444)	(0.630)	(0.549)
Loan-to-asset ratio b,t-1	0.000	0.000	-0.000	-0.001	-0.000
	(0.753)	(0.859)	(0.951)	(0.448)	(0.486)
Deposit-to-asset ratio b,t-1	-0.000	-0.000	-0.000	-0.001*	0.000
	(0.509)	(0.529)	(0.529)	(0.082)	(0.909)
Net due to (overseas offices) ratio b,t-1	-0.002***	-0.001	-0.001**	-0.000	0.001
	(0.000)	(0.119)	(0.028)	(0.834)	(0.777)
Cost-to-income ratio b,t-1	0.001***	0.001***	0.001***	0.003	0.003
	(0.001)	(0.001)	(0.001)	(0.306)	(0.299)
Dummy (subsidiary)					
Parent characteristics					
Log (real assets) p,t-1	0.018**	0.019**	0.019**	0.014	0.048
	(0.024)	(0.022)	(0.022)	(0.491)	(0.192)
T1 capital ratio p,t-1	0.001	0.003	0.000	0.002	0.028
	(0.679)	(0.467)	(0.876)	(0.860)	(0.131)
Home-country conditions					
Real GDP growth j,t-1	-0.001	-0.001	-0.000	0.004	-0.011
	(0.622)	(0.662)	(0.897)	(0.762)	(0.172)
Panel B					
Endogeneity tests:					
Durbin Chi statistics					
(H_0: No endogeneity)	0.0000156	0.234	0.0373	1.255	0.798
p-value	(0.997)	(0.629)	(0.847)	(0.263)	(0.372)
Wu-Hausman Chi statistics					
(H_0: No endogeneity)	0.0000143	0.214	0.0341	1.146	0.714
p-value	(0.997)	(0.644)	(0.854)	(0.285)	(0.399)
Observations	285	285	285	262	220
R-squared	0.231	0.220	0.223	0.178	0.190
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	39	39	39	39	34

Note: The DWH test involves a two-stage instrumental estimation procedure. We use the second lag of the respective complexity measures as an instrument for the lagged complexity measures in equation (1). Under the null of no endogeneity, the original explanatory variable (lagged complexity measure) and the instrumental variable produce similar estimates. Under the alternative hypothesis, the two regressors produce different estimates and, accordingly, the original regressor is inconsistent. Panel A reports the 2SLS IV regression results based on the instrumental variable. The dependent variable is the inverse log z-score of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of FBHKs. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent. P-values below coefficient estimates indicate the level of significance. Panel B of the table reports the respective Durbin and Wu-Hausman statistics with the corresponding p-values shown below the test statistics.

Table A5: Durbin-Wu-Hausman test for endogeneity for the effect of bank complexity on FBHK's earnings volatility

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	SD (ROA)	SD (ROA)	SD (ROA)	SD (ROA)	SD (ROA)
Panel A					
Complexity measure p,t-1 (instrumented variable)	0.339**	0.403**	0.006***	0.011*	0.001
	(0.042)	(0.028)	(0.001)	(0.085)	(0.754)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	-0.195**	-0.200**	-0.209***	-0.274***	-0.214***
	(0.014)	(0.012)	(0.009)	(0.002)	(0.005)
Loan-to-asset ratio b,t-1	0.004	0.004	0.004	-0.013*	0.000
	(0.126)	(0.138)	(0.173)	(0.093)	(0.987)
Deposit-to-asset ratio b,t-1	0.001	0.002	0.002	-0.006	0.001
	(0.667)	(0.576)	(0.558)	(0.252)	(0.772)
Net due to (overseas offices) ratio b,t-1	-0.001	-0.000	0.000	0.004	0.002
	(0.749)	(0.896)	(0.945)	(0.179)	(0.533)
Cost-to-income ratio b,t-1	0.005*	0.005*	0.005*	0.004*	0.005**
	(0.065)	(0.065)	(0.065)	(0.057)	(0.011)
Dummy (subsidiary)	0.061	0.064	0.046	0.790	0.114
	(0.629)	(0.613)	(0.718)	(0.111)	(0.702)
Parent characteristics					
Log (real assets) p,t-1	0.116	0.129*	0.130*	0.131	0.139*
	(0.115)	(0.084)	(0.084)	(0.107)	(0.069)
T1 capital ratio p,t-1	0.019	0.014	0.009	0.040	0.038
	(0.338)	(0.449)	(0.639)	(0.346)	(0.248)
Home-country conditions					
Real GDP growth j,t-1	0.006	0.011	0.016	-0.003	-0.015
	(0.634)	(0.409)	(0.215)	(0.934)	(0.552)
Panel B					
Endogeneity tests:					
Durbin Chi statistics (H_0: No endogeneity)	0.408	0.721	2.15	0.86	0.0749
p-value	0.523	0.396	0.143	0.354	0.784
Wu-Hausman Chi statistics (H_0: No endogeneity)	0.399	0.705	2.106	0.837	0.0726
p-value	0.528	0.401	0.147	0.36	0.788
Observations	1,098	1,098	1,107	933	810
R-squared	0.174	0.175	0.180	0.273	0.237
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	143	123

Note: The DWH test involves a two-stage instrumental estimation procedure. We use the second lag of the respective complexity measures as an instrument for the lagged complexity measures in equation (1). Under the null of no endogeneity, the original explanatory variable (lagged complexity measure) and the instrumental variable produce similar estimates. Under the alternative hypothesis, the two regressors produce different estimates and, accordingly, the original regressor is inconsistent. Panel A reports the 2SLS IV regression results based on the instrumental variable. The dependent variable is 8-quarter standard deviation of ROA of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of FBHKs. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent. P-values below coefficient estimates indicate the level of significance. Panel B of the table reports the respective Durbin and Wu-Hausman statistics with the corresponding p-values shown below the test statistics.

Table A6: Durbin-Wu-Hausman test for endogeneity for the effect of bank complexity on FBHK's risk-adjusted ROA

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	Adj_ROA	Adj_ROA	Adj_ROA	Adj_ROA	Adj_ROA
Panel A					
Complexity measure p,t-1 (instrumented variable)	-0.619	-0.655	-0.005	0.026**	0.002
	(0.296)	(0.220)	(0.419)	(0.027)	(0.882)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	0.559***	0.568***	0.561***	0.324***	0.334***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Loan-to-asset ratio b,t-1	0.009	0.009	0.010	0.018*	0.019*
	(0.335)	(0.325)	(0.308)	(0.085)	(0.080)
Deposit-to-asset ratio b,t-1	0.013**	0.013**	0.014**	0.007	-0.001
	(0.034)	(0.041)	(0.039)	(0.287)	(0.930)
Net due to (overseas offices) ratio b,t-1	0.008	0.007	0.008	0.002	-0.004
	(0.146)	(0.149)	(0.117)	(0.740)	(0.582)
Cost-to-income ratio b,t-1	-0.016***	-0.016***	-0.016***	-0.011***	-0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummy (subsidiary)	3.574***	3.573***	3.589***	3.325***	3.439***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Parent characteristics					
Log (real assets) p,t-1	-0.365***	-0.390***	-0.400***	-0.218	-0.126
	(0.003)	(0.001)	(0.001)	(0.230)	(0.393)
T1 capital ratio p,t-1	-0.126**	-0.118**	-0.126**	-0.222***	-0.095
	(0.019)	(0.031)	(0.024)	(0.001)	(0.124)
Home-country conditions					
Real GDP growth j,t-1	-0.094*	-0.102**	-0.106**	3.325***	3.439***
	(0.060)	(0.040)	(0.035)	(0.000)	(0.000)
Panel B					
Endogeneity tests:					
Durbin Chi statistics					
(H_0: No endogeneity)	1.256	1.741	1.334	0.375	1.958
p-value	0.262	0.187	0.248	0.54	0.162
Wu-Hausman Chi statistics					
(H_0: No endogeneity)	1.229	1.704	1.306	0.366	1.902
p-value	0.268	0.192	0.253	0.546	0.168
Observations	1,098	1,098	1,107	933	810
R-squared	0.392	0.391	0.388	0.388	0.386
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	143	123

Note: The DWH test involves a two-stage instrumental estimation procedure. We use the second lag of the respective complexity measures as an instrument for the lagged complexity measures in equation (1). Under the null of no endogeneity, the original explanatory variable (lagged complexity measure) and the instrumental variable produce similar estimates. Under the alternative hypothesis, the two regressors produce different estimates and, accordingly, the original regressor is inconsistent. Panel A reports the 2SLS IV regression results based on the instrumental variable. The dependent variable is Adj ROA of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of FBHKs. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent. P-values below coefficient estimates indicate the level of significance. Panel B of the table reports the respective Durbin and Wu-Hausman statistics with the corresponding p-values shown below the test statistics.

Table A7: Durbin-Wu-Hausman test for endogeneity for the effect of bank complexity on FBHK's NPL ratio

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	NPL ratio	NPL ratio	NPL ratio	NPL ratio	NPL ratio
Panel A					
Complexity measure p,t-1	0.597	-0.440	-0.005	0.006	0.014
	(0.484)	(0.575)	(0.554)	(0.495)	(0.338)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	-0.134	-0.139	-0.121	-0.128	-0.349
	(0.466)	(0.452)	(0.503)	(0.474)	(0.126)
Loan-to-asset ratio b,t-1	-0.026*	-0.026*	-0.027*	-0.023	-0.039***
	(0.070)	(0.073)	(0.061)	(0.203)	(0.008)
Deposit-to-asset ratio b,t-1	-0.025**	-0.025**	-0.025**	-0.028**	-0.023**
	(0.024)	(0.025)	(0.025)	(0.020)	(0.032)
Net due to (overseas offices) ratio b,t-1	0.010	0.007	0.006	0.010	0.025*
	(0.336)	(0.465)	(0.514)	(0.359)	(0.096)
Cost-to-income ratio b,t-1	-0.002	-0.002	-0.002	-0.005*	-0.004
	(0.470)	(0.469)	(0.490)	(0.092)	(0.371)
Dummy (subsidiary)	1.464	1.390	1.443	1.115	1.599*
	(0.187)	(0.210)	(0.194)	(0.317)	(0.056)
Parent characteristics					
Log (real assets) p,t-1	-0.136	-0.097	-0.109	0.109	-0.388
	(0.632)	(0.742)	(0.713)	(0.682)	(0.269)
T1 capital ratio p,t-1	-0.037	-0.032	-0.012	0.101	-0.050
	(0.565)	(0.618)	(0.860)	(0.101)	(0.585)
Home-country conditions					
Real GDP growth j,t-1	-0.021	-0.027	-0.022	0.029	-0.039
	(0.630)	(0.583)	(0.661)	(0.583)	(0.561)
Panel B					
Endogeneity tests:					
Durbin Chi statistics					
(H_0: No endogeneity)	0.00101	0.0216	0.166	0.00179	0.259
p-value	0.975	0.883	0.684	0.966	0.611
Wu-Hausman Chi statistics					
(H_0: No endogeneity)	0.000986	0.0211	0.162	0.00174	0.251
p-value	0.975	0.884	0.687	0.967	0.617
Observations	1,118	1,118	1,127	840	758
R-squared	0.054	0.053	0.053	0.064	0.080
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	135	113

Note: The DWH test involves a two-stage instrumental estimation procedure. We use the second lag of the respective complexity measures as an instrument for the lagged complexity measures in equation (1). Under the null of no endogeneity, the original explanatory variable (lagged complexity measure) and the instrumental variable produce similar estimates. Under the alternative hypothesis, the two regressors produce different estimates and, accordingly, the original regressor is inconsistent. Panel A reports the 2SLS IV regression results based on the instrumental variable. The dependent variable is NPL ratio of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of FBHKs. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent. P-values below coefficient estimates indicate the level of significance. Panel B of the table reports the respective Durbin and Wu-Hausman statistics with the corresponding p-values shown below the test statistics.

Table A8: Durbin-Wu-Hausman test for endogeneity for the effect of bank complexity on FBHK's LLP ratio

	(1)	(2)	(3)	(4)	(5)
Complexity dimension	Business complexity			Geographical complexity	
Complexity measure	HHI	Scope	Non-bank revenue share	Foreign revenue share	Foreign asset share
Dependent variable	LLP ratio	LLP ratio	LLP ratio	LLP ratio	LLP ratio
Panel A					
Complexity measure p,t-1	-0.080	-0.516	-0.005	0.001	0.008
	(0.824)	(0.147)	(0.164)	(0.861)	(0.300)
FBHK balance sheet characteristics					
Log (real assets) b,t-1	-0.092	-0.089	-0.079	-0.074	-0.184*
	(0.284)	(0.293)	(0.337)	(0.308)	(0.094)
Loan-to-asset ratio b,t-1	-0.006	-0.006	-0.006	-0.002	-0.018*
	(0.396)	(0.393)	(0.393)	(0.663)	(0.055)
Deposit-to-asset ratio b,t-1	-0.014**	-0.014**	-0.014*	-0.010***	-0.018**
	(0.045)	(0.046)	(0.054)	(0.009)	(0.032)
Net due to (overseas offices) ratio b,t-1	-0.003	-0.004	-0.004	0.000	0.005
	(0.521)	(0.371)	(0.390)	(0.937)	(0.498)
Cost-to-income ratio b,t-1	-0.001	-0.001	-0.001	-0.003**	-0.001
	(0.652)	(0.646)	(0.678)	(0.011)	(0.728)
Dummy (subsidiary)	0.497	0.468	0.479	-0.030	1.023*
	(0.423)	(0.449)	(0.450)	(0.889)	(0.096)
Parent characteristics					
Log (real assets) p,t-1	-0.079	-0.076	-0.081	0.012	-0.185
	(0.595)	(0.619)	(0.601)	(0.925)	(0.328)
T1 capital ratio p,t-1	-0.036	-0.030	-0.022	0.012	-0.012
	(0.267)	(0.352)	(0.495)	(0.662)	(0.777)
Home-country conditions					
Real GDP growth j,t-1	-0.007	-0.014	-0.013	0.001	-0.001
	(0.736)	(0.556)	(0.577)	(0.945)	(0.963)
Panel B					
Endogeneity tests:					
Durbin Chi statistics					
(H_0: No endogeneity)	0.316	0.365	0.578	0.529	0.0817
p-value	0.574	0.546	0.447	0.467	0.775
Wu-Hausman Chi statistics					
(H_0: No endogeneity)	0.309	0.357	0.565	0.513	0.079
p-value	0.578	0.55	0.452	0.474	0.779
Observations	1,118	1,118	1,127	840	758
R-squared	0.060	0.062	0.060	0.054	0.109
Cluster	parent	parent	parent	parent	parent
Time fixed effect	Y	Y	Y	Y	Y
No of FBHKs	159	159	159	135	113

Note: The DWH test involves a two-stage instrumental estimation procedure. We use the second lag of the respective complexity measures as an instrument for the lagged complexity measures in equation (1). Under the null of no endogeneity, the original explanatory variable (lagged complexity measure) and the instrumental variable produce similar estimates. Under the alternative hypothesis, the two regressors produce different estimates and, accordingly, the original regressor is inconsistent. Panel A reports the 2SLS IV regression results based on the instrumental variable. The dependent variable is LLP ratio of foreign banks in Hong Kong. We employ specification (1) discussed in Section 3. The data are annual data from 2004 to 2017 for a panel of FBHKs. All specifications include time fixed effect as specified in the lower part of the table. Standard errors are clustered by parent. P-values below coefficient estimates indicate the level of significance. Panel B of the table reports the respective Durbin and Wu-Hausman statistics with the corresponding p-values shown below the test statistics.