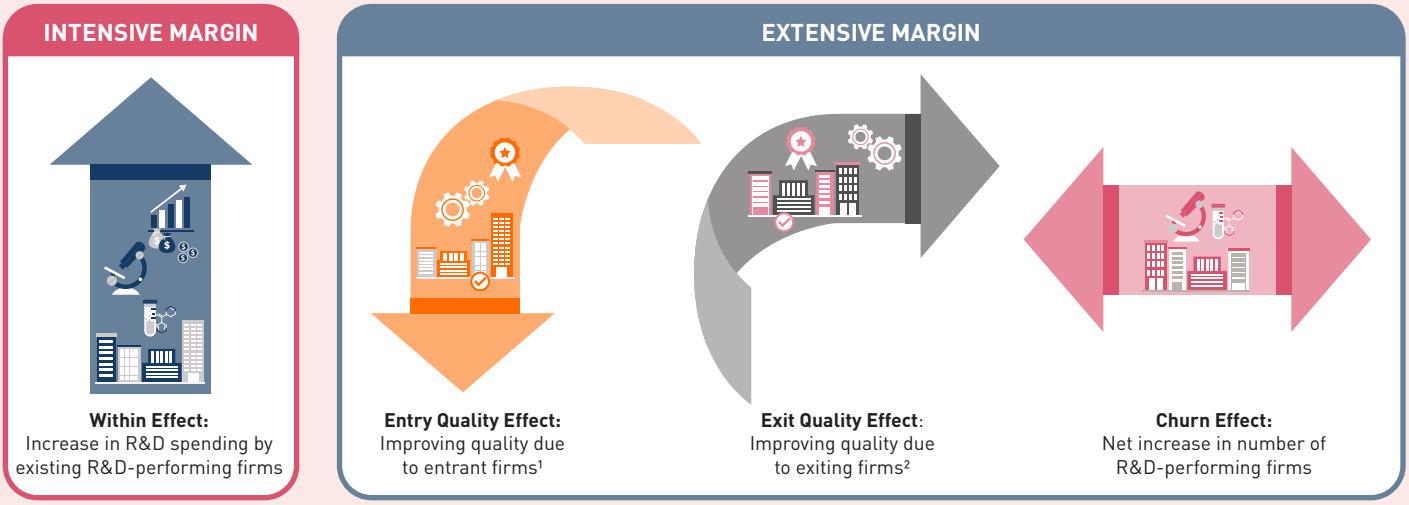
FEATURE ARTICLE

EXAMINING THE EXTENSIVE AND INTENSIVE MARGINS OF PRIVATE RESEARCH AND DEVELOPMENT (R&D) EXPENDITURE GROWTH IN SINGAPORE

INTRODUCTION

In the innovation ecosystem, the private sector is an important driver of value creation and source of R&D. To obtain a deeper understanding of the drivers of private R&D expenditure growth in Singapore, this study examines the intensive and extensive margins of business expenditure on R&D (BERD) growth.

BERD growth can be decomposed into the following components:



[1] Improving quality arises when entrant firms spend more on R&D compared to the average R&D spending of firms of the same firm archetype in the previous period.
[2] Improving quality arises when exiting firms spent less on R&D compared to the average R&D spending of firms of the same firm archetype in the previous period.

FINDINGS

Finding 1

Since the 2009 Global Financial Crisis, BERD growth in Singapore has largely been weighed down by weaker extensive margins, as the number of entrant R&D firms fell and the number of firms that stopped performing R&D increased. By contrast, the intensive margin of BERD growth remained resilient.

Finding 2

Government funding for R&D-performing firms has been supportive of positive outcomes, with government-funded firms exhibiting stronger BERD growth than non-government-funded firms.

CONCLUSION

The Government will continue to encourage existing R&D-performing firms to deepen R&D activities (i.e., intensive margin), and incentivise new firms to start performing R&D (i.e., extensive margin). Supported by the Government's investments under the Research, Innovation and Enterprise 2025 Plan, private enterprises will continue to play an important role in accelerating Singapore's transformation into an innovation-led economy.

EXECUTIVE SUMMARY

- Using a panel dataset from the Agency for Science, Technology and Research's (A*STAR) annual National Survey of Research and Development (R&D), this study examines the dynamics of Business Expenditure on R&D (BERD) growth in Singapore, at the overall economy level and by different firm archetypes, over two periods (2002-2010 and 2010-2018).

- This study decomposes BERD growth into four components – (i) Within Effect, (ii) Entry Quality Effect, (iii) Exit Quality Effect, and (iv) Churn Effect. The Within Effect can be interpreted as the intensive margin of BERD growth and reflects changes in R&D spending by firms that already perform R&D. The Entry Quality Effect, Exit Quality Effect and Churn Effect can be interpreted jointly as the extensive margin of BERD growth, which reflects changes in R&D spending due to (i) quality changes in the composition of firms that perform R&D (caused by the entry and exit of firms), and (ii) the net change in the number of R&D-performing firms.

- Since the 2009 Global Financial Crisis, overall BERD growth in Singapore has largely been weighed down by weaker extensive margins. Notably, there was a significant moderation in the Churn Effect, as the number of entrant R&D firms fell and the number of firms that stopped performing R&D increased. By contrast, the intensive margin of overall BERD growth remained resilient, easing only slightly during the period of 2010-2018 compared to the earlier period of 2002-2010.

- The study also finds that government funding for R&D-performing firms has been supportive of positive outcomes, with government-funded firms exhibiting stronger BERD growth (supported by positive Within, Churn and Exit Quality Effects) than non-government-funded firms.

- Overall, these findings highlight the complementary roles that the public and private sectors play in the R&D ecosystem, with public funding catalysing private R&D expenditure and strengthening private firms' R&D capabilities over time. In order to drive BERD growth in the coming years, the Government will continue to encourage existing R&D-performing firms to deepen their R&D activities (i.e., intensive margin) and incentivise new firms to start performing R&D (i.e., extensive margin). Supported by the Government's $25 billion investment under the Research, Innovation and Enterprise (RIE) 2025 Plan, private enterprises will continue to play an important role in accelerating Singapore's transformation into an innovation-led economy.

*The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Ministry of Trade and Industry (MTI), Agency for Science, Technology and Research (A*STAR), Economic Development Board (EDB), Enterprise Singapore (ESG), National Research Foundation (NRF) or the Government of Singapore.*[1]

INTRODUCTION

In the innovation ecosystem, the private sector is an important driver of value creation and source of research and development (R&D). Recognising the key role that the private sector plays in Singapore's ambitions to become an innovation-led economy, the Government has been encouraging firms to undertake R&D and also to strengthen their capability to innovate and scale up. Between 2002 and 2018, the number of organisations performing R&D in the private sector rose from 519 to 857 (or 3.2 per cent per annum, p.a.). During this period, business expenditure on R&D (BERD) grew robustly by 6.5 per cent p.a., supported by an increase in BERD by both local (2.6 per cent p.a.) and foreign (8.8 per cent p.a.) enterprises. In turn, private R&D investments have contributed positively to productivity growth, with an earlier MTI study finding that a 1 per cent increase in R&D stock raised firm-level productivity by 0.135 per cent on average (see Teo et al., 2019).

1 *We would like to thank Ms Yong Yik Wei for her useful suggestions and comments, as well as EDB, ESG and NRF for their inputs to this study. We would also like to acknowledge the statistical support from A*STAR's Research and Statistics Unit. All errors belong to the authors.*

However, analysis of aggregate BERD trends tends to mask firm-level dynamics and variations over different time periods. For instance, since the 2009 Global Financial Crisis, BERD growth in Singapore has slowed. Between 2010 and 2018, BERD increased by 5.1 per cent p.a. (or 49 per cent cumulatively), compared to 7.9 per cent p.a. (or 84 per cent cumulatively) between 2002 and 2010. During the two periods, the R&D expenditure and entry/exit dynamics of firms also differed across different enterprise segments.

Against this backdrop, this study examines the intensive and extensive margins of BERD growth to obtain a deeper understanding of the drivers of private R&D expenditure in Singapore. We define the intensive margin of BERD growth to be the component that can be attributed to changes in R&D expenditure by firms that already perform R&D. In comparison, the extensive margin of BERD growth is defined as the component that is influenced by the quantity and quality of R&D entrant and exiting firms.

LITERATURE REVIEW

Various studies overseas have examined the drivers of private R&D growth across selected economies at the sectoral and firm levels, with variations in the methodology adopted.

At the sectoral level, the studies generally decompose private R&D intensity growth into intrinsic (i.e., due to changes within industries) and structural (i.e., due to changes in sectoral composition) components. Using industry-level panel data, Van Reenen (1997) examined the factors behind the United Kingdom's (UK) slow business R&D growth between 1973 and 1992 by decomposing the aggregate changes in R&D intensity into within-industry and between-industry (i.e., changes in the sectoral shares of output, which affected aggregate R&D intensity because sectors had varied R&D intensities) effects. From this shift-share analysis, the author found that the UK's slow growth in R&D intensity was primarily caused by the within-industry effect (e.g., slow R&D intensity growth in the manufacturing sectors), rather than the between-industry effect (e.g., slow restructuring towards high-tech sectors). Applying a similar approach using data from the 2008 European Union (EU) Industrial R&D Investment Scoreboard, Moncada-Paternò-Castello et al. (2010) examined the contributions of intrinsic and structural effects in explaining the EU's lower corporate R&D intensity relative to the United States (US), and found that the difference was mainly attributable to the structural effect because of the US' greater specialisation in sectors with high R&D intensity (e.g., information communications technology, ICT).

At the firm level, Higón et al. (2011) decomposed the private R&D expenditure growth of Spanish manufacturing firms between 1990 and 2006 by its intensive (i.e., contribution of R&D deepening among firms that already performed R&D) and extensive (i.e., contributions of entrant firms that started to perform R&D and exiting firms that ceased to perform R&D) margins. The authors found that the relative importance of each component differed for small and large firms. For small firms, R&D expenditure growth was largely driven by the extensive margin, with the R&D spending of entrant firms exceeding the loss in R&D spending by exiting firms. For large firms, R&D expenditure growth by continuing firms was the main contributor to overall R&D expenditure growth (i.e., intensive margin).

EMPIRICAL METHODOLOGY

For this study, we draw on Higón et al.'s (2011) approach to decompose changes in BERD between time t and $t\text{-}1$ (i.e., $\Delta\text{BERD}_{i,t}$) into (i) changes in BERD by continuing firms c, and (ii) the net change in BERD from entering and exiting firms (i.e., increase in BERD from entering firms e, net of loss of BERD from exiting firms x). However, we build on their methodology by further decomposing the net change in BERD from entering and exiting firms into the contributions from (i) the net change in the number of firms, and (ii) changes in the relative quality of entering and exiting firms. To do this, we re-write the mathematical equation in terms of the number of firms and the average BERD of firms in each group and re-arrange the terms. The final decomposition of BERD growth for firm archetype[2] i between time t and $t\text{-}1$ (i.e., $BERD\ growth_{i,t}$) is obtained by dividing all the terms by BERD in time $t\text{-}1$:

$$\begin{aligned}\Delta\text{BERD}_{i,t} &= \sum_{f\in c}(BERD_{f,i,t} - BERD_{f,i,t-1}) + \sum_{f\in e} BERD_{f,i,t} - \sum_{f\in x} BERD_{f,i,t-1} \\ &= n_{c,i,t}\,(b_{c,i,t} - b_{c,i,t-1}) + n_{e,i,t}\,b_{e,i,t} - n_{x,i,t-1}\,b_{x,i,t-1} \\ &= n_{c,i,t}\,(b_{c,i,t} - b_{c,i,t-1}) + n_{e,i,t}\,(b_{e,i,t} - b_{i,t-1}) - n_{x,i,t-1}\,(b_{x,i,t-1} - b_{i,t-1}) + (n_{e,i,t} - n_{x,i,t-1})\,b_{i,t-1}\end{aligned}$$

2 *For the aggregate-level BERD growth decomposition, the firm archetype i includes all firms in the economy.*

$$BERD\ growth_{i,t} = \frac{\Delta BERD_{i,t}}{BERD_{i,t-1}} = \frac{n_{c,i,t}(b_{c,i,t} - b_{c,i,t-1})}{BERD_{i,t-1}} \quad \text{[Within Effect]}$$

$$+ \frac{n_{e,i,t}(b_{e,i,t} - b_{i,t-1})}{BERD_{i,t-1}} \quad \text{[Entry Quality Effect]}$$

$$- \frac{n_{x,i,t-1}(b_{x,i,t-1} - b_{i,t-1})}{BERD_{i,t-1}} \quad \text{[Exit Quality Effect]}$$

$$+ \frac{(n_{e,i,t} - n_{x,i,t-1})b_{i,t-1}}{BERD_{i,t-1}} \quad \text{[Churn Effect]}$$

Where:

- Firm f is a continuing R&D firm (c), new entrant R&D firm (e), or exiting R&D firm (x)
- $BERD_{f,i,t}$ is the BERD of firms (where f is c, e or x) of firm archetype i at time t
- $n_{f,i,t}$ is the number of firms (where f is c, e or x) of firm archetype i at time t
- $b_{i,t}$ is the average BERD of all firms of firm archetype i at time t
- $b_{f,i,t}$ is the average BERD of firms (where f is c, e or x) of firm archetype i at time t

Based on the above decomposition, BERD growth can be mathematically expressed as four components – (i) Within Effect, (ii) Entry Quality Effect, (iii) Exit Quality Effect, and (iv) Churn Effect. The Within Effect contributes positively if continuing firms spend more on R&D between time *t-1* and *t*. The Entry Quality Effect contributes positively if new entrants in time *t* spend more on R&D on average in time *t*, compared to the average R&D spending of firms of the same firm archetype *i* in time *t-1*. Similarly, the Exit Quality Effect contributes positively if exiting firms in time *t-1* spent less on R&D on average in time *t-1*, compared to the average R&D spending of firms of the same firm archetype *i* in time *t-1*. Lastly, the Churn Effect contributes positively if the number of entrants in time *t* exceeds the number of exiting firms in time *t-1*.

The Within Effect can be interpreted as the intensive margin of BERD growth, as it measures the contribution to BERD by existing firms that perform R&D in both the previous and present periods. The Entry Quality, Exit Quality and Churn Effects can be interpreted jointly as the extensive margin of BERD growth, as they measure the contribution to BERD by new firms performing R&D net of the contribution of firms that stopped performing R&D. Specifically, the Entry Quality and Exit Quality Effects reflect whether BERD growth is due to quality changes in the composition of firms that perform R&D (caused by the entry and exit of firms), while the Churn Effect measures the net change in the number of R&D-performing firms.

DATA

This study uses an anonymised panel dataset from the Agency for Science, Technology and Research's (A*STAR) annual National Survey of R&D over the period of 2002 to 2018. The dataset contains information on firms' R&D expenditure, revenue, employment, industry classification and sources of R&D funding, among others. In this study, we examine the drivers of BERD growth over two eight-year periods[3] (i.e., 2002-2010 and 2010-2018), covering 1,127 and 1,347 firms respectively.

Our analysis is conducted at the overall economy level (i.e., for all firms), as well as by firm archetypes. The segmentation of firms is based on their ownership status (i.e., local[4] and foreign firms), small- and medium-sized enterprise (SME) status[5], and whether they received government support (e.g., R&D funding[6] from agencies such as A*STAR, Economic Development Board and Enterprise Singapore).

SUMMARY STATISTICS

Between 2002 and 2018, the number of firms performing R&D in Singapore rose (Exhibit 1). Notably, the number of R&D-performing local firms rose more rapidly (3.4 per cent p.a.) than the number of R&D-performing foreign firms (2.8 per cent p.a.). During this period, both local and foreign firms also saw growth in their average BERD (Exhibit 2). Reflecting the contribution of foreign firms to Singapore's innovation landscape, their average BERD ($12.5 million) was almost 1.9 times the average BERD across all firms ($6.6 million) in 2018.

3 *Cumulative BERD growth between 2002 and 2010 (or 2010 and 2018) reflects eight years of growth, with 2002 (or 2010) as the base year.*
4 *Local firms are defined as firms that have at least 30 per cent local equity ownership.*
5 *SMEs are defined as firms with sales revenue that does not exceed $100 million, or with employment size that does not exceed 200.*
6 *In 2018, R&D expenditure in the private sector was primarily sourced from its own funds (83 per cent). Other sources of funding included foreign-based companies (10 per cent), Government sector (4.3 per cent), private sector (1.7 per cent), foreign governments and international organisations (0.3 per cent), and higher education sector (0.01 per cent).*

Exhibit 1: Number of Local and Foreign Firms Performing R&D, 2002-2018

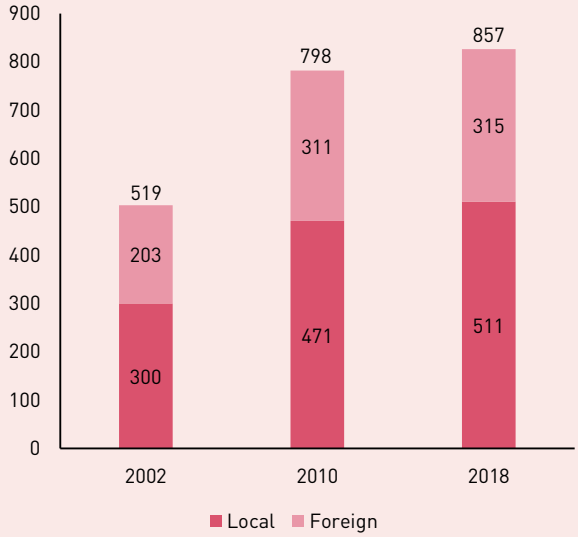
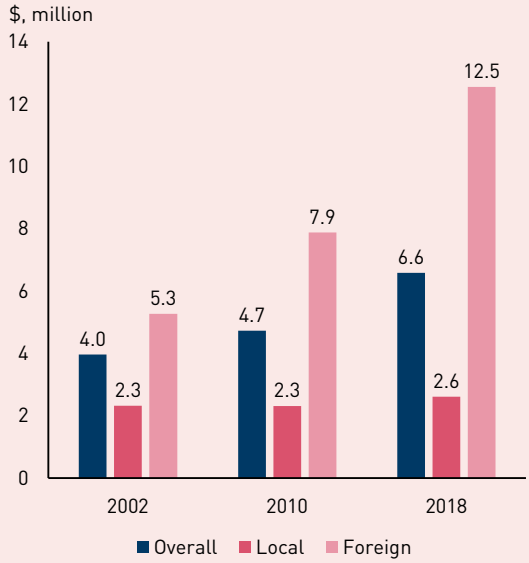


Exhibit 2: Average BERD for Local and Foreign Firms Performing R&D, 2002-2018



Source: Authors, A*STAR
Notes: The number of local and foreign firms may not sum to the overall figure because the analysis of local/foreign firms excluded firms that changed their ownership status in the period. The number of firms and average BERD in 2010 reflect the number of firms and average BERD at the end of the 2002-2010 period. This may differ from the corresponding figures at the start of the 2010-2018 period because of changes in the local/foreign ownership status of some firms.

Over the years, there was a sizeable increase in the number of R&D-performing SMEs, although non-SMEs remained a key driver of overall BERD in the economy because of their higher average R&D spending. Between 2002 and 2018, the number of R&D-performing SMEs and non-SMEs both rose, with the increase in SMEs (3.3 per cent p.a.) outpacing that of non-SMEs (1.6 per cent p.a.) (Exhibit 3). During this period, the average BERD increased for both SMEs (3.9 per cent p.a.) and non-SMEs (1.7 per cent p.a.) (Exhibit 4). Nonetheless, as at 2018, non-SMEs continued to be the main contributor to overall BERD in the economy, with an average BERD of $20.6 million. As a comparison, the average BERD of R&D-performing SMEs was $2.9 million in 2018.

Exhibit 3: Number of SMEs and Non-SMEs Performing R&D, 2002-2018

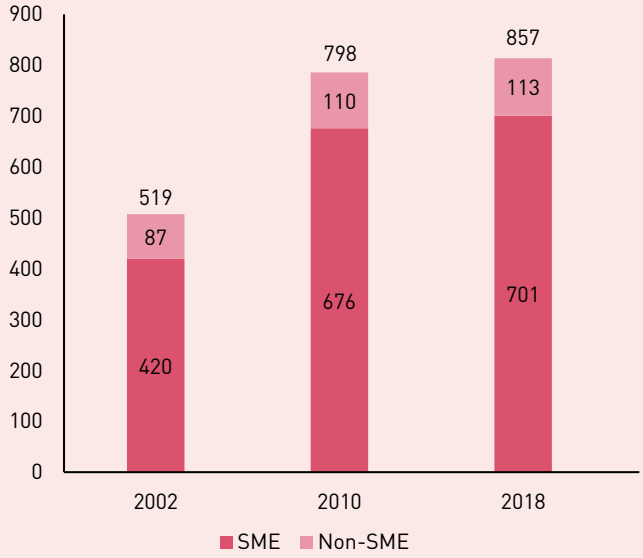
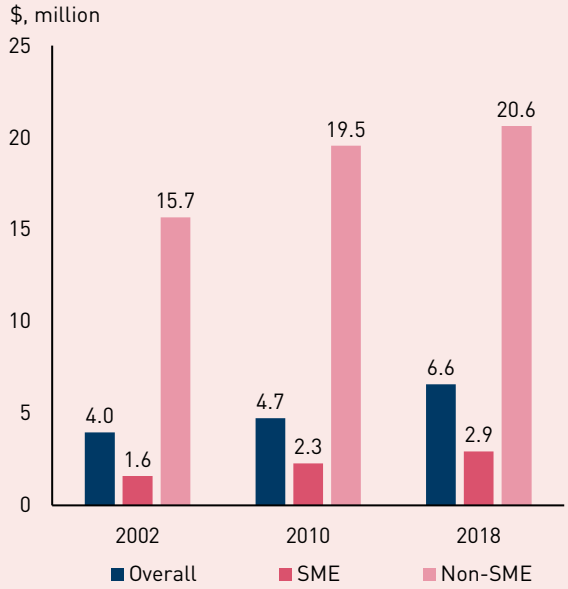


Exhibit 4: Average BERD for SMEs and Non-SMEs Performing R&D, 2002-2018



Source: Authors, A*STAR
Notes: The number of SMEs and non-SMEs may not sum to the overall figure because the analysis of SMEs/non-SMEs excluded firms that changed their SME ownership status in the period. The number of firms and average BERD in 2010 reflect the number of firms and average BERD at the end of the 2002-2010 period. This may differ from the corresponding figures at the start of the 2010-2018 period because of changes in the SME status of some firms.

By government funding status, the share of R&D-performing firms without government funding rose from 57 per cent in 2002 to 62 per cent in 2018, in tandem with a 3.7 per cent p.a. increase in the number of such firms over this period (Exhibit 5).[7] Both firms with and without government funding saw their average BERD levels rise between 2002 and 2018 (3.6 per cent p.a. and 3.3 per cent p.a. respectively) (Exhibit 6). Given its stronger growth, the BERD of firms with government funding pulled further ahead of the BERD of firms without government funding. In 2018, BERD in firms with government funding averaged $11.1 million, almost three times the average BERD in firms without government funding ($3.8 million).

Exhibit 5: Number of Firms Performing R&D With Government Funding and Without Government Funding, 2002-2018

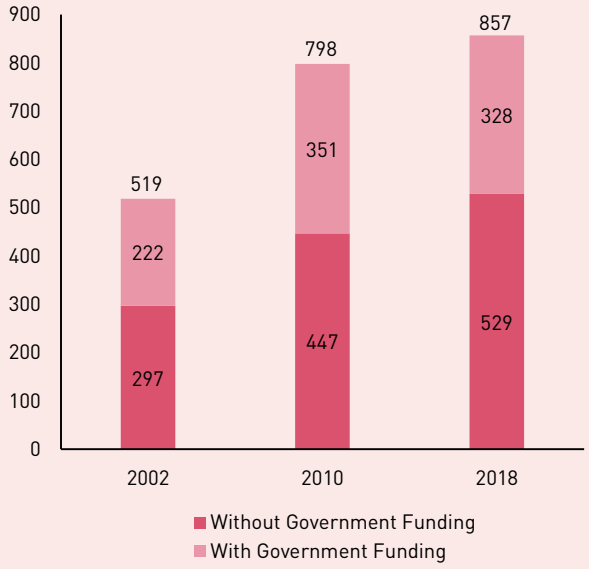
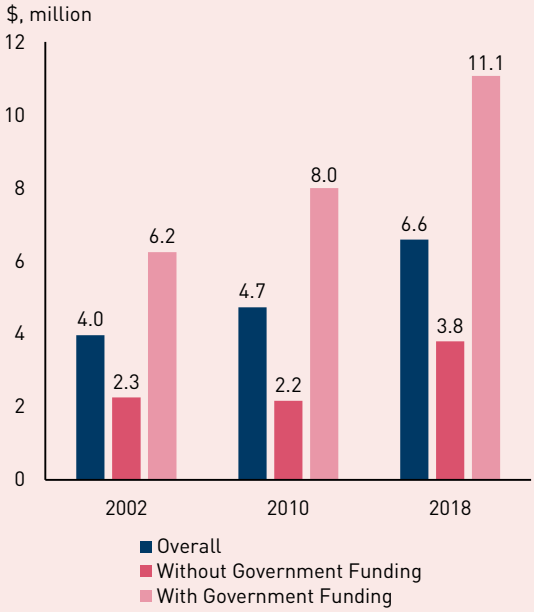


Exhibit 6: Average BERD for Firms Performing R&D With Government Funding and Without Government Funding, 2002-2018



Source: Authors, A*STAR
Notes: Firms with government funding in 2002 and 2010 received it at least once in the 2002-2010 period, while those with government funding in 2018 received it at least once in the 2010-2018 period. The number of firms and average BERD in 2010 reflect the number of firms and average BERD at the end of the 2002-2010 period. This may differ from the corresponding figures at the start of the 2010-2018 period because of changes in the government funding status of some firms between the 2002-2010 and 2010-2018 periods.

DECOMPOSITION RESULTS

In this section, we examine the intensive and extensive margins of BERD growth in Singapore over two periods (i.e., 2002-2010 and 2010-2018) at the overall economy level, and also for the following firm archetypes: (i) local and foreign firms, (ii) SMEs and non-SMEs, and (iii) firms with and without government funding. We do so by decomposing BERD growth into the Within, Entry Quality, Exit Quality and Churn Effects (see equation in the section on empirical methodology above).

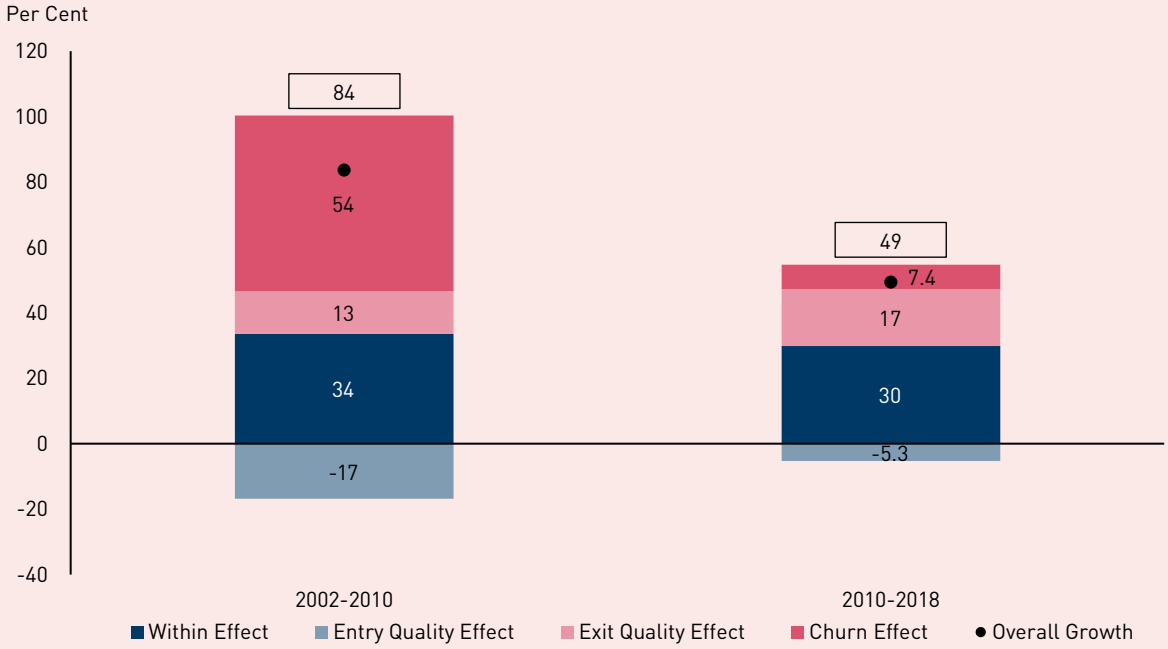
Overall Economy

As highlighted earlier, BERD growth in Singapore has slowed since the 2009 Global Financial Crisis. Between 2010 and 2018, BERD increased by 49 per cent cumulatively, compared to 84 per cent cumulatively between 2002 and 2010. Decomposing the BERD growth for the two periods into its components, we find that the slowdown in BERD growth was primarily due to a moderation in the Churn Effect (from 54 per cent for 2002-2010 to 7.4 per cent for 2010-2018) (Exhibit 7). The latter was in turn caused by a smaller net increase in the number of firms performing R&D in the later period.[8] On the other hand, the Within Effect (i.e., increase in BERD by continuing firms) remained resilient, easing only slightly in the later period (from 34 per cent for 2002-2010 to 30 per cent for 2010-2018).

7 *In comparison, the number of R&D-performing firms with government funding increased by 2.5 per cent p.a. between 2002 and 2018.*
8 *Specifically, between the 2002-2010 and 2010-2018 periods, the net increase in R&D-performing firms moderated from 279 to 59, as the number of new R&D-performing firms (i.e., entrant firms) fell (from 608 to 550), while the number of R&D-performing firms that exited (i.e., exiting firms) increased (from 329 to 491).*

At the same time, the Entry Quality and Exit Quality Effects improved between 2002-2010 and 2010-2018. The average BERD of entrant firms rose over time[9], although it remained lower than the BERD of the average R&D-performing firm in the overall economy (i.e., negative Entry Quality Effect, which eased from -17 per cent for 2002-2010 to -5.3 per cent for 2010-2018). For exiting firms, their BERD remained below that of the average R&D-performing firm in the overall economy, with the differential widening between the two periods (i.e., positive Exit Quality Effect, which improved from 13 per cent for 2002-2010 to 17 per cent for 2010-2018).

Exhibit 7: BERD Growth Decomposition (Overall Economy), 2002-2010 and 2010-2018



Source: Authors

Ownership Status

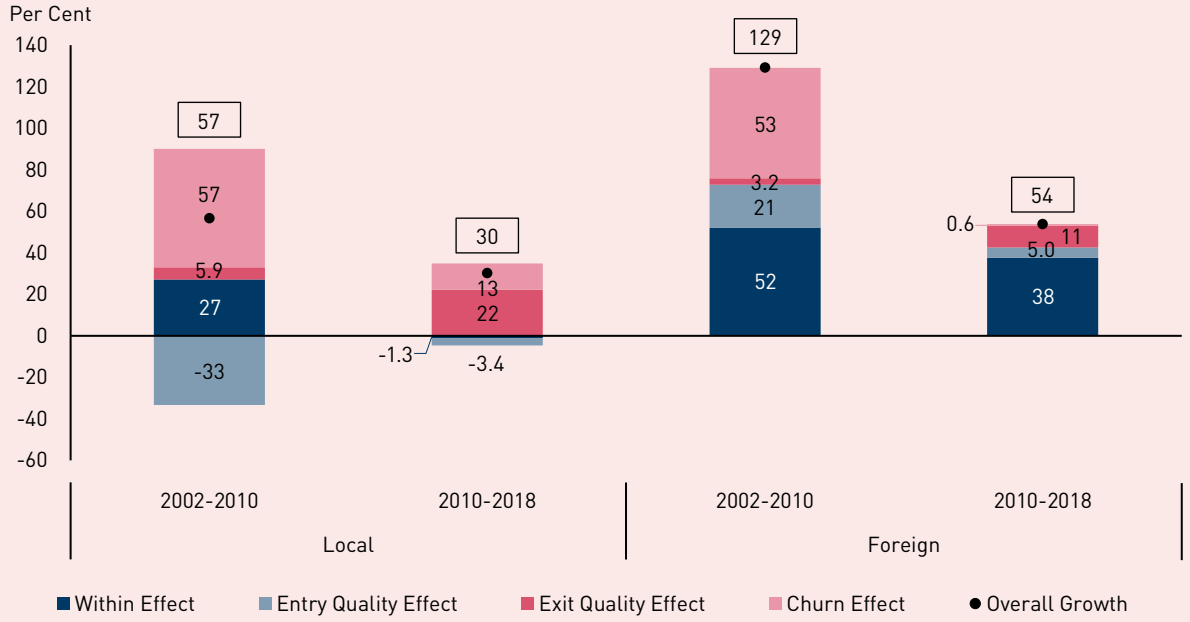
Between the 2002-2010 and 2010-2018 periods, cumulative BERD growth for both local (57 per cent to 30 per cent) and foreign (from 129 per cent to 54 per cent) firms moderated (Exhibit 8). Similar to the trends for the overall economy, the moderation in BERD growth for both archetypes was primarily driven by a slowdown in the Churn Effect, with the slowdown being sharper for foreign firms than for local firms. In the case of local firms, a decline in its Within Effect (27 per cent to -1.3 per cent) also contributed to the moderation in its BERD growth.

On the other hand, improvements in the Exit Quality Effect helped to support BERD growth in the later period for both archetypes. In both cases, their respective Exit Quality Effects remained positive and improved in the later period as (i) lower-quality firms (i.e., firms with BERD below the average level for their firm archetype) continued to exit the R&D ecosystem, and (ii) the gap between the average BERD of exiting firms and that of their firm archetype widened. Reflecting progress in attracting higher-quality new entrants to perform R&D, the Entry Quality Effect for local firms also improved between the two periods (from -33 per cent to -3.4 per cent), although it remained negative.

Notwithstanding the moderation in the BERD growth of foreign firms, they continue to be an important source of BERD in Singapore, with their average BERD ($12.5 million in 2018) remaining far higher than that for local firms ($2.6 million in 2018) (see Exhibit 2).

9 *Between the 2002-2010 and 2010-2018 periods, the average BERD of entrant firms rose from $3.4 million to $4.4 million.*

Exhibit 8: BERD Growth Decomposition (Local/Foreign Ownership), 2002-2010 and 2010-2018



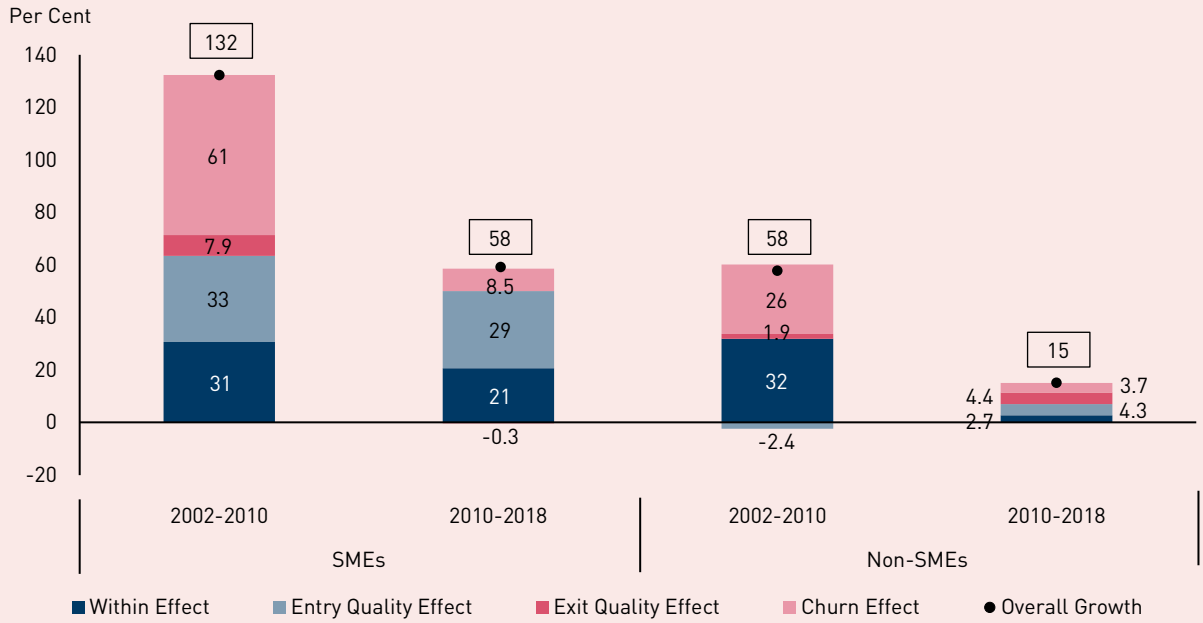
Source: Authors

SME Status

Likewise, cumulative BERD growth moderated between 2002-2010 and 2010-2018 for both SMEs (from 132 per cent to 58 per cent) and non-SMEs (from 58 per cent to 15 per cent) (Exhibit 9). The slowdown in BERD growth for SMEs was largely due to a moderation in the Churn (from 61 per cent to 8.5 per cent) and Exit Quality (from 7.9 per cent to -0.3 per cent) Effects. As for non-SMEs, the slowdown in their BERD growth could be attributed to a reduction in both the Churn (from 26 per cent to 3.7 per cent) and Within (from 32 per cent to 2.7 per cent) Effects. By contrast, there were improvements in the Entry Quality (from -2.4 per cent to 4.3 per cent) and Exit Quality (from 1.9 per cent to 4.4 per cent) Effects.

While BERD growth remained stronger for SMEs relative to non-SMEs in the more recent period (i.e., 2010-2018), non-SMEs continue to be an important source of BERD given their significantly higher average BERD levels ($20.6 million in 2018) compared to SMEs ($2.9 million in 2018) (see Exhibit 4).

Exhibit 9: BERD Growth Decomposition (SME Status), 2002-2010 and 2010-2018



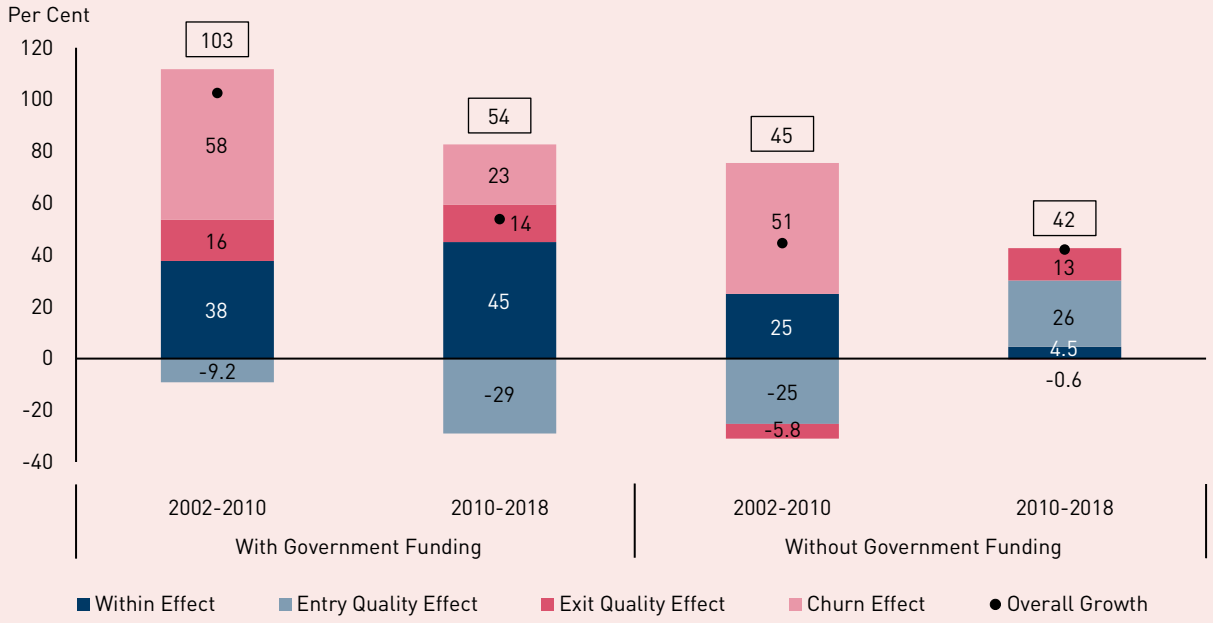
Source: Authors

Government Support Status

Between 2002-2010 and 2010-2018, the cumulative BERD growth of firms that received government funding slowed more sharply as compared to those that did not receive government funding (Exhibit 10). Notwithstanding this, in the later period, the BERD growth of firms with government funding (54 per cent) remained stronger than that of firms without government funding (42 per cent).

For firms with government funding, the Within Effect strengthened (from 38 per cent to 45 per cent) between 2002-2010 and 2010-2018 (i.e., continuing firms increased their R&D expenditure – and to a larger degree – over time). The BERD growth for these firms in the later period was also supported by positive Churn and Exit Quality Effects. By contrast, a negative Entry Quality Effect continued to weigh on their BERD growth (i.e., entrant firms with government funding spent less on R&D than the average R&D-performing firm with government funding). This is likely because government support for newer R&D firms might be in new growth areas or more experimental areas where the risk is higher. Nonetheless, over time, these firms are likely to increase their R&D spending in Singapore's innovation ecosystem, as evidenced by the strong Within Effect for continuing firms.

Exhibit 10: BERD Growth Decomposition (Government Funding Status), 2002-2010 and 2010-2018



Source: Authors

CONCLUSION

Since the 2009 Global Financial Crisis, BERD growth in Singapore has largely been weighed down by weaker extensive margins. Notably, there was a significant moderation in the Churn Effect, as the number of entrant R&D firms fell and the number of firms that stopped performing R&D increased. By contrast, the intensive margin of BERD growth remained resilient, with the Within Effect easing only slightly in the more recent period (i.e., 2010-2018) compared to the earlier period (i.e., 2002-2010). There are also substantial variations in the drivers of BERD growth across the different firm archetypes.

A key finding of this study is that government funding for R&D-performing firms has been supportive of positive outcomes, with government-funded firms exhibiting stronger BERD growth (supported in turn by positive Within, Churn and Exit Quality Effects) than non-government-funded firms. The positive results reaffirm the complementary roles that the public and private sectors play in the R&D ecosystem, with public funding catalysing private sector R&D expenditure, and strengthening private firms' R&D capabilities over time.

In order to drive BERD growth in the coming years, the Government will continue to encourage existing R&D-performing firms to deepen their R&D activities (i.e., intensive margin) and incentivise new firms to start performing R&D (i.e., extensive margin). To this end, a broad suite of measures has been put in place, including tax deductions on R&D expenditure, and grants such as the Enterprise Development Grant and the Research and Innovation Scheme for Companies. At the same time, to enhance the vibrancy and dynamism of Singapore's innovation ecosystem, the Government has also embarked on other initiatives. These include the establishment of Centres of Innovation to help SMEs bridge the gap between research and commercialisation, and the setting up of the Open Innovation Network to provide a single gateway to the open innovation ecosystem in Singapore, where enterprises can seek out co-innovation and test-bedding opportunities. Supported by the Government's $25 billion investment under the Research, Innovation and Enterprise (RIE) 2025 Plan[10], private enterprises will continue to play an important role in accelerating Singapore's transformation into an innovation-led economy.

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10 The RIE 2025 Plan is for the period of 2021 to 2025, and forms the main thrust of the Singapore Government's investments in R&D, particularly in strategic domain areas. For more details, see National Research Foundation (2020).

REFERENCES

Higón, D. A., Máñez, J. A., & Sanchis-Llopis, J. A. (2011). *The Role of Extensive and Intensive Margins in Explaining Corporate R&D Growth: Evidence from Spain*. Ivie Working Papers WP-EC 2011-05. Valencia: Instituto Valenciano de Investigaciones Económicas.

Moncada-Paternò-Castello, P., Ciupagea, C., Smith, K. T., & Tubbs, M. (2010). Does Europe Perform Too Little Corporate R&D? A Comparison of EU and Non-EU Corporate R&D Performance. *Research Policy, 39(4)*, 523-536.

National Research Foundation. (2020). *Research, Innovation and Enterprise 2025 Plan*. Singapore: National Research Foundation.

Teo, M., Loo, A., & Kuan, M. L. (2019). Returns to Research and Development (R&D) Among Firms in Singapore. In *Economic Survey of Singapore Third Quarter 2019* (pp. 42-50). Singapore: Ministry of Trade and Industry.

Van Reenen, J. (1997). Why Has Britain Had Slower R&D Growth? *Research Policy, 26(4-5)*, 493-507.