Feature Article

IMPACT EVALUATION OF A*STAR'S TECHNOLOGY FOR ENTERPRISE CAPABILITY UPGRADING (T-UP) PROGRAMME

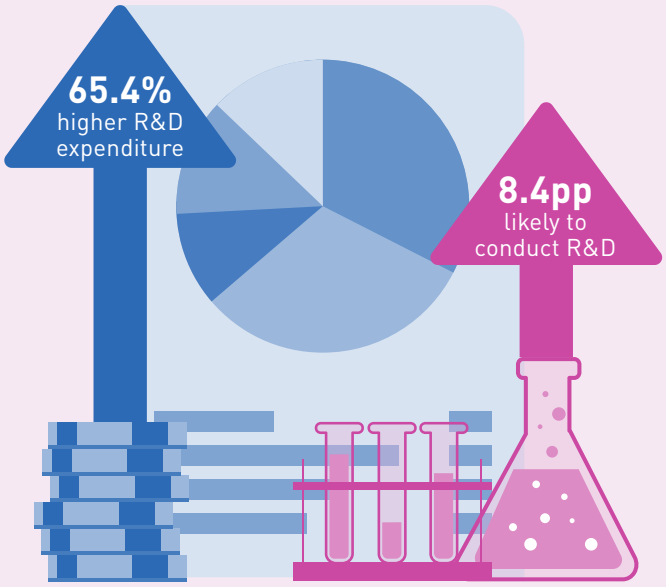
OVERVIEW

Technology for Enterprise Capability Upgrading (T-Up) is a secondment programme, funded through Enterprise Singapore and administered by A*STAR, where A*STAR's research scientists and engineers are seconded to local firms to help build in-house R&D capabilities and enhance business competitiveness.

FINDINGS

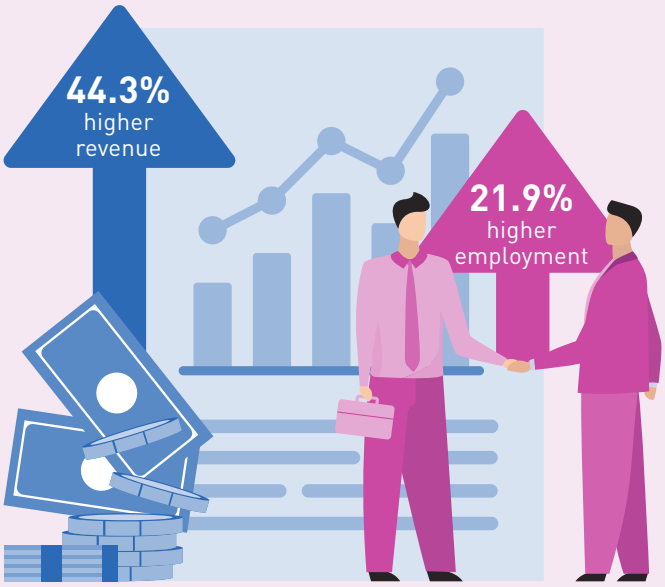
Finding 1:

We find that, on average, firms participating in the T-Up programme had 65.4 per cent higher R&D expenditure and were 8.4pp more likely to conduct R&D.



Finding 2:

Firms participating in the T-Up programme also saw 44.3 per cent higher revenue and 21.9 per cent higher employment.



POLICY TAKEAWAY

The T-Up programme was effective in supporting local firms in enhancing their business competitiveness through upgrading their R&D capabilities and growing business revenue. The T-Up programme is a Funding Initiative as part of the Research, Innovation and Enterprise (RIE) 2025 plan to develop Singapore into an innovation-driven economy. A*STAR will continue to support firms in enhancing their R&D capabilities through T-Up and other R&D-related schemes.

EXECUTIVE SUMMARY

- Launched in 2003, the Technology for Enterprise Capability Upgrading (T-Up) programme is a secondment programme funded by Enterprise Singapore and administered by A*STAR, where A*STAR's research scientists and engineers are seconded to local enterprises to help them build in-house research and development (R&D) capabilities and grow their business revenue. This study evaluates the impact of the T-Up programme on participating firms' outcomes.

- Our findings show that firms participating in the T-Up programme spent 65.4 per cent more on R&D and were 8.4 percentage-points more likely to conduct R&D in a given year compared to a control group. They also correspondingly enjoyed 44.3 per cent higher revenue and 21.9 per cent higher employment than the control group. These findings suggest that the T-Up programme has been effective in supporting local firms to upgrade their R&D capabilities and grow their business revenue.

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) or the Government of Singapore.[1]

INTRODUCTION

The Technology for Enterprise Capability Upgrading (T-Up) programme is a funding initiative under the Research, Innovation and Enterprise (RIE) 2025 plan to develop Singapore into an innovation-driven economy. Started by A*STAR in 2003, T-Up aims to help promising local small- and medium-sized enterprises (SMEs) as well as large local enterprises (LLEs) build in-house research and development (R&D) capabilities and grow their revenue, by enabling them to tap on A*STAR's scientific talent pool.

As part of the scheme, A*STAR researchers are seconded to participating local enterprises for up to two years to aid in their R&D projects (see Annex A for examples of these projects). Seconded researchers share product development strategy and impart knowledge in technical areas to support the firm in the development of new products and processes, as well as build up their intellectual property portfolio. At the same time, participating firms are provided funding support by Enterprise Singapore, at up to 70% of allowable costs for SMEs or startups and up to 30% for LLEs, with the support levels capped at S$250,000 per project.

This study evaluates the effectiveness of the T-Up programme in enhancing firms' outcomes in R&D, as well as their revenue, employment, value-added, productivity and wages.

The rest of the article is organised as follows. We first present a literature review of the impact that the movement of researchers from public research institutions to private entities has on the private entities. We then describe the data and methodology used in the study before reporting the results. The final section concludes.

LITERATURE REVIEW

In the literature, technology transfer is generally seen as essential to boost firms' competitiveness and foster innovation. Foundational research, which forms the basis of technological advancements, is often conducted by universities and public research institutions (Wrisich et al., 2016). Meanwhile, firms conducting R&D often face significant challenges, including high costs and uncertain outcomes. For SMEs in particular, these challenges are compounded by limited resources and constraints in their capacity to absorb complex technological advancements. To address the impediments to R&D in the private sector, government agencies often promote collaborations, such as through secondments, between public research institutions and the private sector (Hilkenmeier et al., 2021). These partnerships allow firms to adopt advanced technologies more quickly and enhance their overall innovative capacity.

1 *We would like to thank Ms Yong Yik Wei, Dr Andy Feng, Ms Jamie Poh, Mr Lee Zen Wea, Dr Gwee Yi Jie and Dr Tan Yi Jin for their useful suggestions and comments. We are also grateful to colleagues from MTI's Innovation, Research and Development Division, A*STAR as well as Enterprise Singapore for their input.*

A review of the empirical literature highlights the positive outcomes of secondment policies and other initiatives involving the movement of researchers from public research institutions to private firms. For instance, Herrera (2010) found that Spanish firms that hired personnel from the public R&D system registered a 2.6 percentage-point (pp) increase in their total R&D intensity, measured as the ratio of total R&D expenditure to total sales. Hilkenmeier et al. (2021) surveyed firms that participated in a public-private partnership programme in Germany where scientists from a public research organisation were temporarily seconded to SMEs to jointly work on projects. The study found that apart from reporting technological advancements in their operations, the majority of the participating firms also engaged in follow-up projects as a result of the partnership.

In the local context, an earlier evaluation of the T-Up programme by Ho et al. (2016) found that the seconded researchers imparted new technologies to the participating firms, and also improved the firms' capacity for learning and innovation. In particular, the T-Up secondment improved firms' product innovation intensity, which was measured as the percentage of sales derived from new products, by 3.2 per cent.

This study extends Ho et al.'s 2016 study in two ways. First, while the previous study relied on survey data, this study leveraged firm-level administrative data, which in turn enabled more robust quantitative methods to be used and more firm outcomes of policy relevance to be examined. Second, this study tracked more recent cohorts of firms that participated in the T-Up programme (i.e., from 2011 to 2018), whereas the previous study covered firms that participated before 2012 when the scheme was at a more nascent stage.

DATA AND SUMMARY STATISTICS

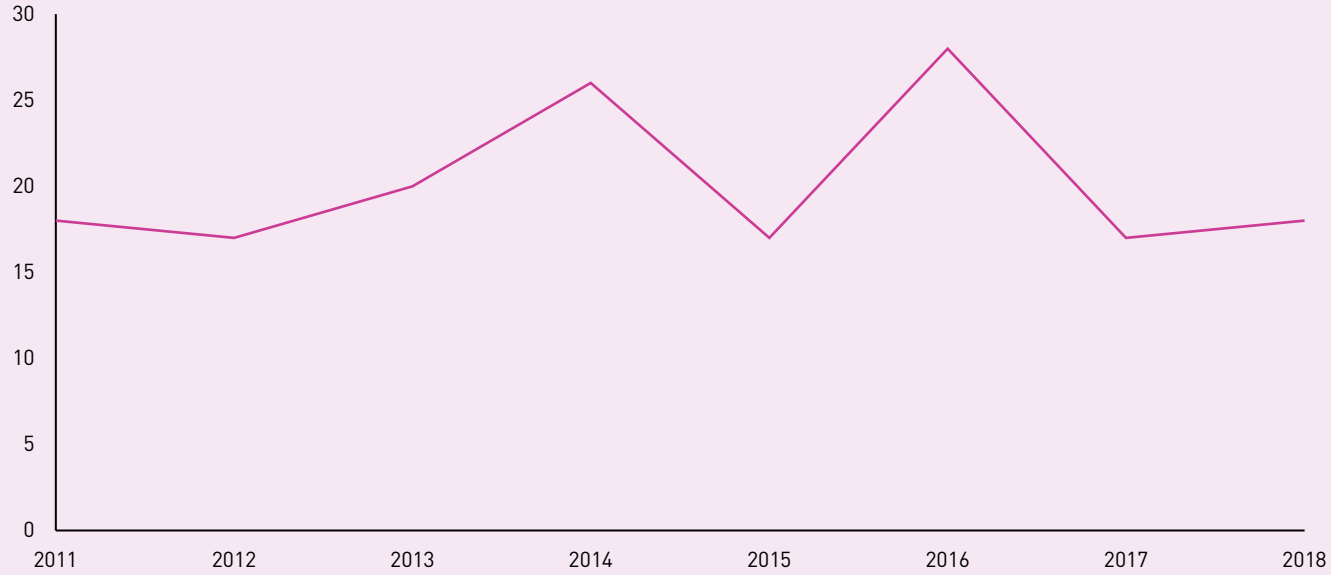
For the purpose of our study, we merged three datasets: a longitudinal firm-level administrative dataset containing firms' characteristics from the Department of Statistics, data on T-Up participants from A*STAR, and data on R&D conducted by firms in Singapore from A*STAR's National Survey of Research, Innovation and Enterprise[2]. The merged dataset contained firm-level data such as revenue, value-added, employment size and age of the firm, as well as R&D-related data[3] like firms' R&D expenditure.

Our study focused on firms that participated in the T-Up programme for the first time between 2011 and 2018. We examined cohorts up to 2018 because the firm-level administrative and A*STAR's survey datasets at the point of the study were only available up to 2020.[4] This is particularly since the effects of R&D policies may take time to materialise.[5]

Based on the dataset assembled, a total of 161 firms participated in the T-Up programme between 2011 and 2018. The number ranged from 15 to 30 firms per year throughout the period of analysis, with an average of 20 firms per year (Exhibit 1). The data also showed that T-Up firms tended to be micro and small firms with annual revenue below S$10 million and fewer than 50 employees (Exhibit 2).

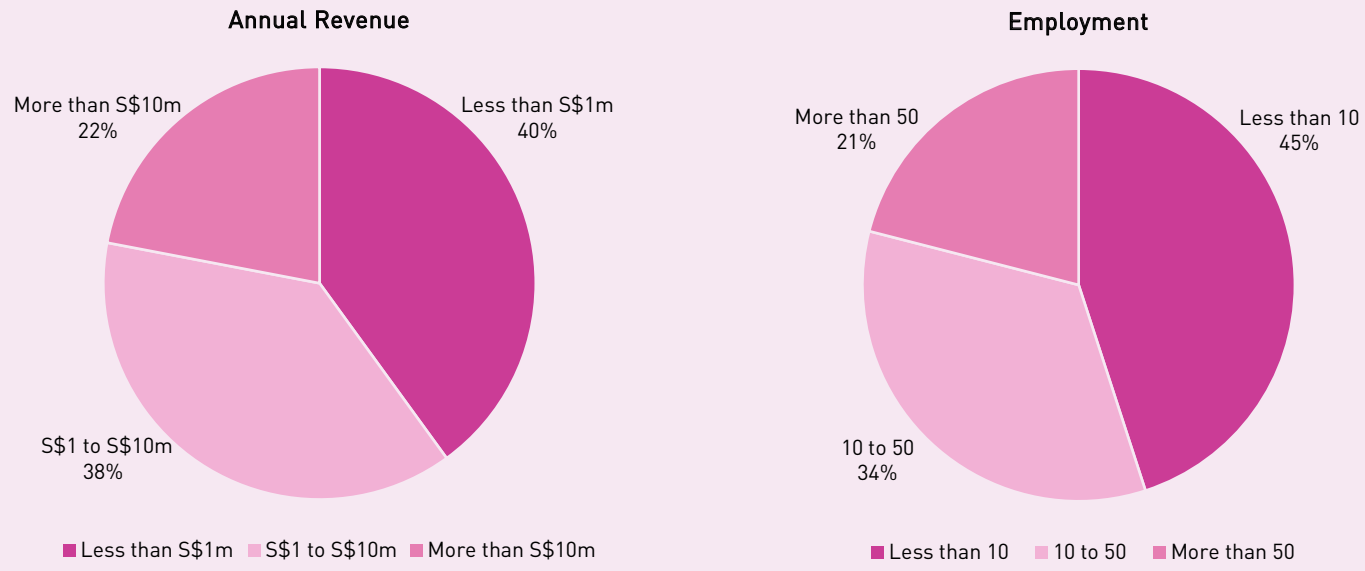
2 *A*STAR's National Survey of Research, Innovation and Enterprise (RIE) is conducted annually and provides insights on Singapore's R&D ecosystem, including information on the R&D performed by firms.*
3 *R&D-related data are from A*STAR's RIE Survey, and are subject to entities' responses.*
4 *In recent years, the archetype of firms participating in the T-Up programme has evolved, with more T-Up projects involving start-ups within the deep tech, artificial intelligence and biomedical space. However, as we were only able to study T-Up cohorts up to 2018, our results would not incorporate the effects of these recent shifts.*
5 *Moreover, while around 90% of the T-Up projects last for up to one year, there are some that could last for up to two years. Given that data on firms' outcomes are only available up to 2020, the 2018 cohort would represent the latest cohort that could be studied.*

Exhibit 1: Number of Firms that Participated in T-Up, 2011 to 2018 cohorts



Source: Authors' estimates, based on data from A*STAR

Exhibit 2: Number of Firms that Participated in T-Up, 2011 to 2018 cohorts



Source: Authors' estimates, DOS, A*STAR

EMPIRICAL METHODOLOGY

Summary statistics from the data compiled showed that firms that participated in the T-Up programme differed in observable characteristics from firms that did not participate (Exhibit 3). In particular, compared to non-T-Up firms, T-Up firms had on average (i) higher employment, (ii) higher total R&D expenditure, but (iii) lower productivity (measured as value-added per worker). They were also more likely to be in the manufacturing sector.

Given these differences, there is a need to mitigate potential selection biases when examining the impact of the T-Up programme in order to obtain a causal estimate of the impact. To do so, we constructed a group of non-participating firms (i.e., control firms) with characteristics that were comparable to the participating firms (i.e., treated firms) through coarsened exact matching (CEM), with the matching performed separately for each T-Up cohort. The matching variables used included the firm's age, total R&D expenditure, value-added, value-added per worker, total employment and sector.[6] Exhibit 3 shows that upon matching, firms in the control group were observably more similar to the treated firms in terms of their characteristics.

Exhibit 3: Summary Statistics on Firm Characteristics Before and After Matching[7]

	Before Matching		After Matching	
	Control	Treated	Control	Treated
Firm age (years)	10.9	11.5	12.5	12.4
Total R&D expenditure (S$ Thousand)	45.2	222.9	155.7	187.5
Value-added (S$ Million)	2.1	6.1	2.7	2.2
Value-added per worker (S$ Thousand)	77.0	44.9	60.2	47.2
Total employment	19.6	68.2	34.1	33.3
Share of manufacturing sector (%)	5.6	33.3	34.0	34.0
Share of professional services sector (%)	12.4	24.0	21.8	21.8

As there were multiple treatment cohorts, we used a staggered Difference-in-Differences (DiD) regression model (Wooldridge, 2021) to uncover the causal impact of the T-Up programme on firm outcomes.[8] Our main specification regression was as follows:

$$Y_{ict} = \gamma_{ic} + \theta_{tc} + \sum_{c=2011}^{2018} \sum_{t=2010}^{2020} \beta_{c,t} \cdot Treat_i \times Cohort_c \times Time_t + \varepsilon_{ict}$$

Where:

- Y_{ict} is the outcome variable for firm i in cohort c at time t;
- $Treat_i \times Cohort_c \times Time_t$ is a dummy variable which takes on the value of 1 for the observation at year t for firm i, if firm i was treated at year c (i.e., treated firm belonging to cohort c);
- γ_{ic} denotes the firm × cohort time-invariant fixed effects;
- θ_{tc} denotes the year × cohort fixed effects; and
- ε_{ict} is the error term assumed to be uncorrelated with the independent variable in all time periods.

We included firm fixed effects to account for time-invariant firm characteristics (including those not observed in the dataset) that could affect firms' outcomes (e.g., managerial practices). We also included time fixed effects to control for factors that affected all firms over time (e.g., macroeconomic conditions). The firm and time fixed effects were interacted with cohort fixed effects to ensure that the comparisons were made between treated and control firms within cohorts.

6 *For each cohort, the CEM algorithm was implemented using data in the year prior to the commencement of the T-Up project. For instance, 2014 data was used to identify a suitable control group for the 2015 cohort.*

7 *Summary statistics were generated based on the pooled data in the year before each cohort's participation in T-Up (i.e., in the year used for matching). For instance, for the 2015 cohort, the summary statistics were generated using the corresponding data in 2014, as well as 2014 data for control firms.*

8 *This was preferred to the traditional DiD using two-way fixed effects as the latter could lead to biased estimates when there is staggered treatment timing and treatment heterogeneity across cohorts or time.*

The coefficients of interest, $\beta_{c,t}$s, measure the causal impact of the T-Up programme on the outcomes of firms in cohort c at year t, relative to the base year of 2009. We aggregated combinations of $\beta_{c,t}$ into event-time (i.e., the time relative to the start year of the project) average treatment effects (ATEs). Specifically, to get the ATE for the year after treatment had started (i.e., the causal impact one year after the firm had started participating in the programme, which we denoted as $\tau = 1$), or $\beta_{\tau=1}$, we took the average of the coefficients $\beta_{c=2011,t=2012}$, $\beta_{c=2012,t=2013}$, … , $\beta_{c=2018,t=2019}$. Repeating this for different event-times will give us a set of event-time coefficients β_{τ}.

RESULTS AND DISCUSSION

The empirical strategy outlined above would be valid only if the trends in the outcomes of the T-Up firms were similar to those of the control firms in the years before the T-Up firms received treatment (i.e., the parallel trends assumption holds). We conducted a parallel trends test to examine this. The second column in Exhibit 4 below shows that none of the outcome variables have statistically significant coefficients in the one to three years before T-Up participation (i.e., $\tau < 0$), indicating that the treatment and control firms displayed similar trends in outcomes prior to the treatment firms' participation in T-Up.

We present the results as the averages of several event-time coefficients in Exhibit 4. For example, in the third column, $\beta_{\tau=0 \text{ to } 3}$ is the average of $\beta_{\tau=0}$,…,$\beta_{\tau=3}$, which reflects the average annual effect of the T-Up programme from the year of commencement of the T-Up project (i.e., $\tau = 0$) to three years after commencement (i.e., $\tau = 3$). Likewise, in the fourth column, $\beta_{\tau=0 \text{ to } 5}$ shows the average annual effect from the year of commencement of the T-Up project to five years after commencement.

Exhibit 4: Regression Results

(1)	(2)	(3)	(4)
Dependent Variable	**-3 to -1 years ($\beta_{\tau=-3 \text{ to-}1}$)**	**0 to 3 years ($\beta_{\tau=0 \text{ to } 3}$)**	**0 to 5 years ($\beta_{\tau=0 \text{ to } 5}$)**
R&D Outcomes			
Whether the firm did R&D	-4.3pp	8.4pp**	8.9pp**
Total R&D expenditure	-43.2%	65.4%*	73.2%**
Whether the firm filed any patents	0.5pp	1.0pp	0.6pp
Patents	-0.053	0.054	0.015
Revenue from R&D commercialisation	24.5%	63.5%*	71.8%**
Other Firm Outcomes			
Revenue	16.0%	44.3%***	44.5%***
Total employment	5.5%	21.9%***	21.8%***
Value-added	12.5%	15.3%	13.5%
Value-added per worker	6.6%	0.1%	0.8%
Average local wages	4.4%	5.3%	3.3%

*, ** and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively

The results suggest that the T-Up programme had a positive and significant impact on participating firms' outcomes.[9] For the R&D-related outcomes up to three years after starting the T-Up project, we found that the T-Up programme was associated with positive and significant effects on firms' R&D expenditure. These effects occurred at both the intensive margin – R&D expenditure was 65.4 per cent higher, and extensive margin – the probability of conducting R&D in a given year was 8.4pp higher. Similarly, T-Up firms saw 63.5 per cent higher revenue derived from commercialised products, suggesting that the R&D efforts led to successful commercialisation. The effects on patents-related outcomes were also positive, although not statistically significant.

9 *These findings were robust to the inclusion of additional control variables such as other government grants and firm age, different matching specifications, different transformations of the dependent variable (e.g., logs, levels), as well as different specifications of the staggered DiD regressions proposed in the literature (e.g., Callaway and Sant'Anna, 2021).*

In terms of other firm outcomes up to three years after starting the T-Up project, our findings suggest that firms that participated in T-Up had higher revenue (44.3 per cent) and total employment[10] (21.9 per cent) than non-participating firms. While the effects on value-added, value-added per worker and average local wages were positive, they were not statistically significant.

Finally, we found that the effects on both R&D-related and other firm outcomes persisted up to five years after the firm started participating in the T-Up programme.[11]

CONCLUSION

This study found that the T-Up programme was effective in helping local firms to upgrade their R&D capabilities and grow their business revenue. In particular, participating in T-Up led to improvements in a number of outcomes for the firms, including R&D expenditure, revenue from commercialised products due to R&D, total revenue and total employment. Given these encouraging results, and T-Up's contribution to RIE 2025's goal of developing Singapore into an innovation-driven economy, A*STAR will continue to support firms in enhancing their R&D capabilities through T-Up and other R&D-related schemes.

Contributed by:

Mr Isaac Tham
Economist
Economics Division
Ministry of Trade and Industry

Mr Neo Yu Xuan
Senior Economist
Economics Division
Ministry of Trade and Industry

REFERENCES

Herrera, L., Muñoz-Doyague, M. F., & Nieto, M. (2010). Mobility of public researchers, scientific knowledge transfer, and the firm's innovation process. *Journal of Business Research*, 63(5), 510-518.

Ho, Y. P., Ruan, Y., Hang, C. C., & Wong, P. K. (2016). Technology upgrading of small-and-medium-sized enterprises (SMEs) through a manpower secondment strategy–A mixed-methods study of Singapore's T-Up program. *Technovation*, 57, 21-29.

Ho, Y. P. & Wong, P. K. (2017). The Impact of R&D on the Singapore Economy: A Time Series Analysis. Available at SSRN: or http://dx.doi.org/10.2139/ssrn.2719442.

Kolympiris, C., Hoenen, S., & Klein, P. G. (2019). Learning by seconding: evidence from national science foundation rotators. *Organization Science*, 30(3), 528-551.

O'Donoughue Jenkins, L., & Anstey, K. (2017). The use of secondments as a tool to increase knowledge translation. *Public Health Res Pract.* 2017;27(1):e2711708.

10 *We excluded the T-Up researcher(s) seconded to the firm from the total employment of the firm, and found that the results were robust to this adjustment, with the estimated impact of T-Up on employment remaining statistically significant at 18.4 per cent.*

11 *We were unable to examine firm outcomes more than five years after the firm started participating in the programme due to the lack of data available to precisely estimate these coefficients. Nevertheless, our analysis does not preclude the possibility that the positive effects of the T-Up programme lasted longer than five years after the firm started participating.*

ANNEX A: EXAMPLES OF T-UP PROJECTS

Themes	Examples of Project Titles
Smart Integrated Systems and Automation	• Enhanced Work Order Module of Tracking System • Enterprise Resource Application Web Integrated Service (ERAWIS)
Advanced Materials and Manufacturing Processes	• Development of Nano-Composite Compounding Capabilities • Application of conformal cooling channels to injection moulding tool insert using additive manufacturing technology
Imaging and Object Detection	• LIDAR Navigation and Applications for Mobile Robot • Analytics for Vision and RFID
Medical Diagnostics and Validation	• Development of Self-Administered Medical Devices Using Microneedles • Design and Optimisation of Existing OCT Probe for Prostate Cancer
Energy Efficiency and Analysis	• Design and development of new water heater • Thermal Flow and Light Distribution Analysis for LED Lamp Design