FEATURE ARTICLE

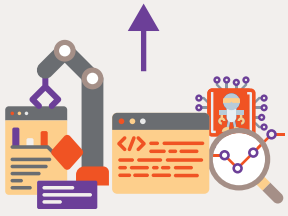
DIGITAL ADOPTION AMONG FIRMS AND IMPACT ON FIRM-LEVEL OUTCOMES IN SINGAPORE

INTRODUCTION

In recent years, digitalisation efforts have taken centre stage as policymakers and firms alike become more aware of the benefits that firms can derive from the adoption of digital technologies. Indeed, technological progress has allowed firms to harness digital software and hardware tools to streamline internal processes, cut costs and enhance their profitability. This study sets out to investigate digitalisation trends among firms in Singapore, and empirically examine the impact of digital adoption on firms' performance.

FINDINGS

While the prevalence of digital technology usage amongst firms in Singapore has improved from 2014 to 2016, the adoption of more advanced tools, such as e-commerce, data analytics and the Internet of Things, remains low. Small- and medium-sized enterprises (SMEs) were the main drivers of the low adoption rate of the more advanced digital technologies among firms in Singapore.



The adoption of more digital technologies by firms is associated with better performance in terms of value-added and productivity. This result holds for SMEs.

POLICY TAKEAWAY

Our findings suggest that there is room for firms in Singapore, especially SMEs, to make further progress in their digitalisation efforts by using more advanced digital technologies (e.g., e-commerce, data analytics). Moreover, as the adoption of an additional digital tool is linked to an improvement in firms' performance, the Government will also continue to help firms overcome hurdles in their digitalisation journey so that they can reap the benefits of digitalisation.

EXECUTIVE SUMMARY

- There is general consensus among policymakers and firms that the adoption of digital technologies is associated with improved performance among firms. Indeed, technologies like the Internet of Things, artificial intelligence and e-payments allow firms to streamline internal processes, cut costs and enhance their profitability. International studies examining digitalisation and its associated impact on firm-level outcomes such as productivity have also generally found positive results.

- Our study augments existing research on Singapore's digital economy by investigating digitalisation trends among firms in Singapore. In particular, we examine firms' adoption of: (i) Basic Digital Tools (BDT), comprising Internet Usage, Computer Usage, Web Presence and Infocomm Security; (ii) Digital Platform Tools (DPT), made up of E-payments, E-commerce and Software as a Service; and (iii) Advanced Digital Tools (ADT), including the Internet of Things, Data Analytics and Artificial Intelligence. In addition, we also empirically estimate the impact of digital adoption by firms on their performance.

- We find that while BDT are widely adopted by firms in Singapore, the adoption rates for DPT and ADT are considerably lower, particularly in the case of ADT. Focusing on DPT and ADT, we observe that a sizable share of firms only adopted at most one of these digital tools, even though this share had seen a decline between 2014 and 2016. Taking a closer look at the characteristics of the firms, we find that small- and medium-sized enterprises (SMEs) were the main drivers of the low adoption rate of the more advanced digital technologies (DPT and ADT) among firms in Singapore.

- Our regression results show that the adoption of an additional digital tool (either DPT or ADT) by firms is associated with a statistically significant increase in their value-added and productivity, at 25% and 16% respectively on average. The results for SMEs are similarly positive and statistically significant.

- Our findings suggest that there is room for firms in Singapore, especially SMEs, to make further progress in their digitalisation efforts by using more advanced digital technologies (e.g., e-commerce, data analytics). Moreover, as the adoption of an additional digital tool is linked to an improvement in firms' performance, the Government will also continue to help firms overcome hurdles in their digitalisation journey so that they can reap the benefits of digitalisation.

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, Info-communications Media Development Authority, or the Government of Singapore.[1]

INTRODUCTION

In recent years, digitalisation efforts have taken centre stage as policymakers and firms alike become more aware of the benefits that firms can derive from the adoption of digital technologies. Indeed, technological progress has allowed firms to harness digital software and hardware tools to streamline internal processes, cut costs and enhance their profitability. For example, connected devices facilitate the collection of real-time data, while data analytics can reveal costly operational inefficiencies.

1 *We would like to thank Ms Yong Yik Wei and Mr Kenneth Yeow for their useful suggestions and comments. We are also grateful for the inputs and support provided by the Info-communications Media Development Authority. All errors belong to the authors.*

As a small economy that relies heavily on external markets, digitalisation plays an important role in ensuring that Singapore's firms remain competitive in the global economy. It is hence critical for policymakers to gain a deeper understanding of the progress of our digitalisation efforts. In this regard, an earlier study by MTI – which examined the broad trends in the digital economy in Singapore – found that Singapore has made significant progress in its digitalisation efforts, as evidenced by the strong growth of the infocomm media (ICM) sector and cross-border data flows over the years.[2]

In this study, we add to the existing research on Singapore's digital economy by examining the digitalisation trends among firms in Singapore, and also empirically estimating the impact of digital adoption on firms' performance. The latter will, in turn, help to inform policymakers on whether there is value in having policies and schemes in place to assist firms to adopt digital technologies.

We begin with a brief overview of the academic literature, followed by a description of the data and trends in digital adoption among firms in Singapore. We then describe the empirical methodology used to estimate the impact of digital adoption on firms' performance, before reporting our results. The final section concludes.

LITERATURE REVIEW

Past empirical studies overseas have generally found that the adoption of digital technologies has a positive and statistically significant effect on firm-level outcomes. For instance, using firm-level data from European countries, Gal et al. (2019) observed that digital adoption in an industry was associated with productivity gains at the firm-level, with relatively stronger effects found for firms in sectors with a high degree of routine-intensive activities.[3] The effects also tended to be stronger for more productive firms, but weaker in the presence of shortages in skills such as technical and managerial skills.

Closer to home, Agarwal et al. (2018) found that the introduction of a mobile wallet payment technology in 2017 had a positive and statistically significant effect on firms' sales growth in Singapore, with a larger effect observed for small merchants as compared to large merchants. The authors concluded that the payment technology had promoted sales growth among new businesses by facilitating their customer acquisition.

DATA

Our study utilises data from Info-communications Media Development Authority (IMDA)'s annual Infocomm Usage by Enterprise survey, which captures information on the adoption rate of various digital tools among firms in Singapore. Specifically, we focus our analysis on the adoption of the following ten digital tools over the 2014-2016 period: Internet Usage, Computer Usage, Web Presence, Infocomm Security, E-payments, E-commerce, Software as a Service (SaaS), Internet of Things (IoT), Data Analytics and Artificial Intelligence (AI).[4] Exhibit 1 provides a description of the ten digital tools.

The data on digital adoption by firms obtained from IMDA's survey is then merged with data on firms' characteristics from the Inland Revenue Authority of Singapore (IRAS) and the Ministry of Manpower (MOM). After merging the various datasets, we derive a longitudinal dataset that comprises around 1,150 firms, with their digital adoption and performance tracked over the period of 2014 to 2016.[5]

Of the firms in our dataset, around 56 per cent belong to the services sector, with the remaining firms roughly equally distributed between the manufacturing sector and the construction sector. In addition, around 83 per cent of the firms in our dataset are small- and medium-sized enterprises (SMEs).[6]

2 *See Box Article 1.1 on "The Digital Economy in Singapore" of the 3Q17 Economic Survey of Singapore.*
3 *Routine-intensive activities refer to occupations with a relatively low degree of independence and freedom in planning and organising the tasks to be performed on the job.*
4 *Due to changes in IMDA's survey questions over the years, the time period and digital tools were selected to ensure comparability of the survey results across the years.*
5 *Our matched dataset is a sub-sample of all the firms captured in IMDA's surveys. As such, the findings may not be representative of all the firms that were surveyed by IMDA.*
6 *We follow Enterprise Singapore's SME definition whereby a SME is defined as a firm with employment less than or equal to 200 or revenue less than or equal to S$100 million.*

Exhibit 1: Definition of the Digital Tools in the 2016 Infocomm Usage by Enterprise Survey

S/N	Digital Tool	Definition
1	Internet Usage	The use of Internet by the enterprise for its work
2	Computer Usage	A desktop, laptop, netbook, tablet, tablet computer, portable or handheld computer, minicomputer, mainframe or workstation used by the enterprise for its work
3	Web Presence	A website (including mobile versions) or any other web pages where the business has control over the content of the page (e.g., homepage, presence on another entity's website, blogsites, etc.)
4	Infocomm Security	Measures such as virus checking, protection or anti-spyware software which is regularly updated, firewall, spam filter and anti-phishing protection, etc.
5	E-payments	Make or receive payment through electronic means for procurement and/or sales of products and/or services (e.g., GIRO, mobile payment such as DBS Paylah, OCBC Pay Anyone, FAST electronic fund transfer, etc.)
6	E-commerce	Sale or purchase of goods or services over computer mediated networks or the Internet. Payment and delivery of the good or service can be offline. Orders received/ placed by telephone, fax or normal mail are excluded
7	Software as a Service	Software provided as a service by an IT vendor to multiple customers, typically characterised by the following: license based on usage (subscription), web-based system (requires Internet connection), service including maintenance, support and upgrades, and data storage
8	Internet of Things	Network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment
9	Data Analytics	Analyse data collected to obtain key insights to help with better business using analytics software
10	Artificial Intelligence	A computer system or programme that is able to perform operations analogous to learning and decision-making as humans. Such systems or programmes may include expert decisions, decision support systems, fraud detection systems, computer vision systems, speech recognition programmes, chat bot programmes, robots, etc.

Source: IMDA

To facilitate our analysis of firms' progress in their digitalisation efforts, we group the ten digital tools in Exhibit 1 into three clusters based on factor analysis and our assessment of the complementarities between the different tools. The three clusters are: **(i) Basic Digital Tools (BDT), (ii) Digital Platform Tools (DPT)**, and **(iii) Advanced Digital Tools (ADT)** (Exhibit 2).

Exhibit 2: Digital Tools Categorised under BDT, DPT and ADT

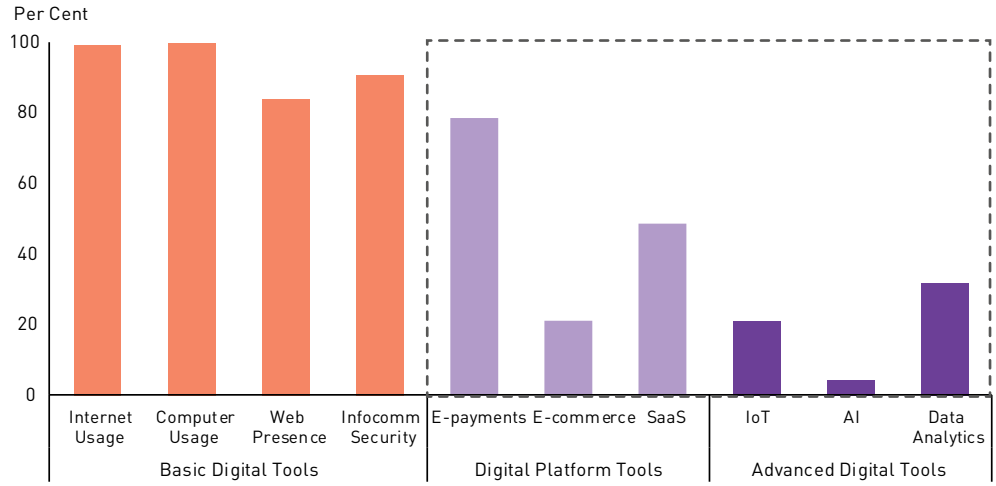
Basic Digital Tools (BDT)	Digital Platform Tools (DPT)	Advanced Digital Tools (ADT)
• Internet Usage • Computer Usage • Web Presence • Infocomm Security	• E-payments • E-commerce • Software as a Service	• Internet of Things • Data Analytics • Artificial Intelligence

TRENDS IN DIGITAL ADOPTION BY FIRMS

Based on the data, we find high levels of adoption of BDT among firms in Singapore, with almost all the firms in our dataset indicating that they use computers and the Internet, and more than 80 per cent declaring that they adopt infocomm security measures and have a web presence (Exhibit 3).

Comparatively, the adoption rates observed for DPT and ADT are lower. For instance, for DPT, while more than 75 per cent of firms indicate that they have adopted e-payment solutions, only around a fifth of the firms leverage e-commerce platforms. Likewise, the adoption rates for all three tools within ADT are low (less than 35 per cent), particularly in the case of AI. This shows that while BDT are widely adopted by the firms in our sample, most firms have yet to make significant inroads in the adoption of more advanced digital technologies (i.e., DPT or ADT).

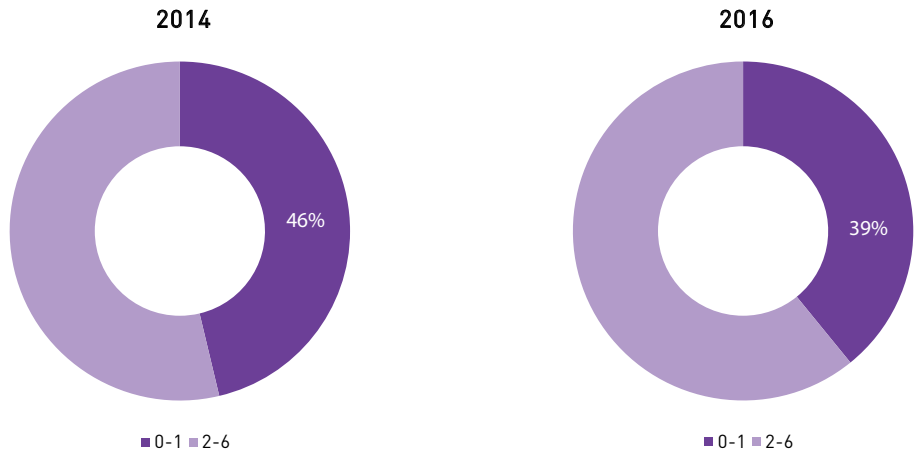
Exhibit 3: Adoption Rates of the Ten Digital Technologies in 2016



Source: Authors' calculation, based on data from IMDA

Focusing on DPT or ADT adoption, we find that a sizable share of firms in our dataset have low digital adoption levels, which we define as the adoption of at most one digital tool among the DPT and APT. Specifically, around two-fifths of firms adopted at most one DPT or ADT in 2016, although this was an improvement from the situation in 2014 when close to half of the firms adopted at most one DPT or ADT (Exhibit 4).

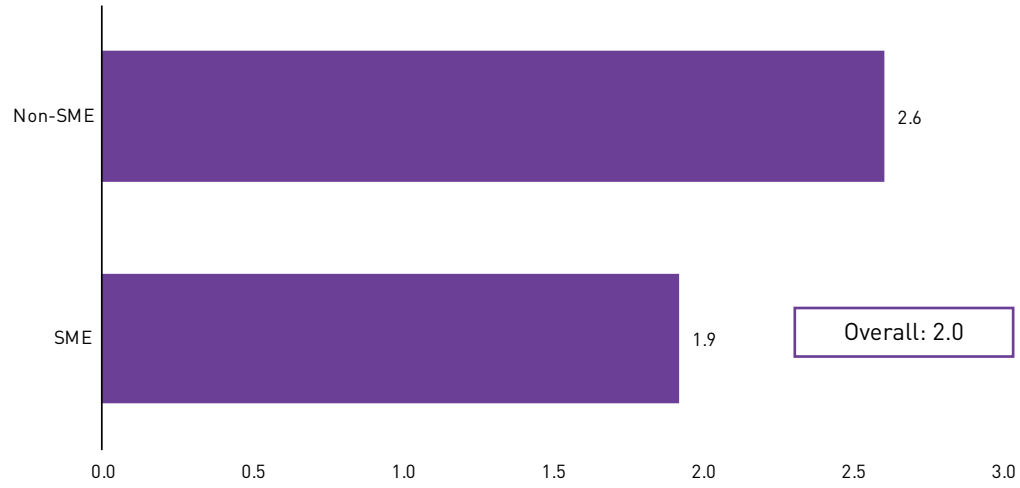
Exhibit 4: Share of Firms by Number of DPT or ADT Adopted in 2014 and 2016



Source: Author's calculation, based on data from IMDA

Overall, the firms in our dataset only adopted an average of 2.0 digital tools (either DPT or ADT) in 2016 (Exhibit 5). The low level of adoption of DPT and ADT among the firms was mainly driven by SMEs. Indeed, a comparison of non-SMEs and SMEs shows that in 2016, SMEs adopted an average of 1.9 digital tools (either DPT or ADT), lower than the average of 2.6 tools adopted by non-SMEs.

Exhibit 5: Average Number of DPT or ADT Adopted by Non-SMEs and SMEs in 2016



Source: Author's calculation, based on data from IMDA, IRAS and MOM

EMPIRICAL METHODOLOGY AND RESULTS

Methodology

Next, we estimate the impact of digital adoption on firms' performance in terms of their value-added (VA) and productivity (measured as VA per worker).

Given the high degree of correlation in the take-up of some of the digital tools, a regression that incorporates all the individual tools is likely to lead to multicollinearity problems. To avoid this problem, we group the DPT and ADT together to create a Digital Adoption index, which by definition lies within the range of 0 to 1.[7] To construct the index, we sum up the values of the six binary variables under the DPT and ADT and divide it by the total number of variables, giving each digital tool an equal weight. Specifically, for each firm i in year t, the Digital Adoption index, D_{it}, is calculated as follows:

$$D_{it} = \frac{\sum_{1}^{6} K_j}{6} \qquad (1)$$

Where K_j=1 if firm i adopted digital tool j in year t, and 0 otherwise

7 *The index does not include BDT as the majority of firms in our sample have already adopted such tools since 2014. Nonetheless, we will control for the adoption of BDT in our regression analysis.*

We then run a fixed effects regression using the following specification:

$$In(Y_{it}) = \alpha D_{it} + \beta B_{it} + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (2)$$

Where Y_{it} is firm i's value-added (VA) or VA per worker (productivity) in year t[8]

D_{it} is the Digital Adoption index for firm i in year t

B_{it} is the BDT index[9] for firm i in year t

X_{it} is a vector of firm-level control variables for firm i, including the firm's SME status, ownership, government funding and costs incurred for research & development

φ_i is the fixed effects term for firm i

θ_t is a dummy for year t

ε_{it} is an error term associated with firm i in year t

The regression controls for both the observable (e.g., firm's SME status and ownership) and time-invariant unobservable (e.g., managerial quality) characteristics of the firms. It also controls for macroeconomic factors that can affect firms' performance from year to year.

The coefficient of interest is α, which can be scaled to estimate the impact of adopting an additional digital tool on firms' VA or productivity. For instance, the adoption of an additional DPT or ADT is equivalent to a 0.167 (1/6) increase in the Digital Adoption index. The coefficient of interest, α, can then be scaled by a factor of 16.7 to determine the effect of adopting an additional tool on firms' VA or productivity.[10]

To examine whether digital adoption has a different impact on SMEs compared to non-SMEs, we also run the following regression:

$$In(Y_{it}) = \alpha D_{it} + \omega D_{it} * nonSME_i + \beta B_{it} + \gamma X_{it} + \varphi_i + \theta_t + \varepsilon_{it} \quad (3)$$

Where $nonSME_i$ is a dummy variable that takes on a value of 1 when firm i is a non-SME and 0 when it is an SME. In this specification, α represents the impact of digital adoption on SMEs.

Results

Overall, our findings suggest that digital adoption has a positive and statistically significant impact on firms' VA and productivity.

Notably, the adoption of an additional digital tool (either DPT or ADT) is associated with a statistically significant increase in firms' VA and productivity of 25 per cent and 16 per cent respectively on average (Exhibit 6). This result is in line with international studies such as those by Acemolgu and Restrepo (2018) and the International Monetary Fund (2018), which found that the usage of digital technologies increased the efficiency of task completion and improved both revenue collection and expenditure targeting among firms.

The regression results for SMEs are similarly positive and statistically significant. Specifically, for SMEs, using an additional digital technology is correlated with a statistically significant increase in VA and productivity of 26 per cent and 17 per cent respectively.[11]

8 In this study, VA is measured as the sum of profits and remuneration. Productivity is then derived by dividing VA by total employment.

9 The BDT index is derived using a similar formula as that used to calculate the Digital Adoption index (i.e., $B_{it}=\frac{\sum_i^4 K_i}{4}$).

*10 Specifically, α represents the increase in VA or productivity (in percentage terms) associated with a 100% increase in the index (i.e., an increase in the index by 1 unit). Since a 0.167 increase in the index is equivalent to the adoption of an additional digital tool (either DPT or ADT), we can multiply α by a factor of 16.7 (=100*0.167) to derive the impact on VA or productivity (also in percentage terms) from using one more tool.*

11 For all the firms in our sample, an increase of 0.1 in the index is associated with a 15% and 9.8% increase in VA and productivity respectively. For SMEs, an increase of 0.1 in the index is associated with a 15% and 10% increase in VA and productivity respectively.

Exhibit 6: Effect of the Adoption of an Additional Digital Tool on Firm-Level Outcomes

Outcome Variable	Overall	SMEs
VA	25%**	26%**
Productivity	16%**	17%**

*, ** and *** indicate significance at the 90%, 95% and 99% level, respectively.
Source: Author's calculation, based on data from IMDA, IRAS and MOM

CONCLUSION

Our study finds that while the prevalence of digital technology adoption among firms in Singapore has improved in recent years, there is room for firms to make further progress in their digitalisation efforts, especially in terms of the use of more advanced digital technologies such as e-commerce, data analytics and IoT. Additionally, we find that digital adoption has a positive and statistically significant effect on the VA and productivity of firms, including SMEs. These results are in line with the findings of other international studies, and provide further evidence that a higher level of digital adoption by firms is linked to better firm performance.

Going forward, the Government will continue to assist firms, including SMEs, to embrace digitalisation and build up their digital capabilities. Firms are also encouraged to tap on existing Government schemes that are in place to help them in their digitalisation journey, such as the Productivity Solutions Grant and SME Go Digital programme. Collectively, our efforts will enhance Singapore's competitiveness in an increasingly digital global economy, and allow firms to reap the benefits of digitalisation.

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