The Heterogeneous Impacts of R&D on Innovation in Services Sector: A Firm-Level Study of Developing ASEAN

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Abstract: Identifying the determinants of firms’ investment in knowledge, this study first explores the heterogeneous impacts of research and development (R&D) on product, process, organization, and marketing innovation. Second, it examines if there exists a complementary (substitute) relation in terms of firms’ preference between four types of innovation. Studying 1500 firms of seven developing economies of the Association of Southeast Asian Nations (ASEAN), we applied the least absolute shrinkage and selection operator (LASSO), a machine learning-based regression, to identify key predictors likely to influence firms’ R&D propensity and intensity. Estimating the knowledge function, we found—in line with LASSO—that medium-sized firms, human capital (training) and credit facilities favorably affect firms’ decision to invest in R&D. Contrarily, the impact is adverse if the first or main product generates firms’ large share of revenue, a unique finding not captured by previous studies. The marginal effects of four univariate probit models indicate that firms’ investment in R&D translates into innovation. However, the application of the Geweke–Hajivassiliour–Keane (GHK)-simulator based multivariate probit, which considers simultaneity of firms’ innovation decisions that univariate probit ignores, suggests that the relationship between different types of innovation is complementary. Firms’ strategy to adopt a particular type of innovation is influenced by other types. This led to the estimation of R&D’s impact on technological and nontechnological innovation, which shows that while firms innovate both types, there is a skewed link between nontechnological innovation and the services sector.

Keywords: R&D; technological innovation; nontechnological innovation; LASSO; Tobit; multivariate probit

1. Introduction
A large number of developing countries achieved rapid economic growth in the past few decades. However, very few have escaped the “middle-income trap” given their poor performance of total factor productivity (TFP), which is largely innovation-driven. Inadequate development of domestic innovation capabilities is at the core of the middle-income trap [1]. Theoretically, since the seminal contribution by Schumpeter [2], the role of innovation to sustain growth has been emphasized by several studies [3,4]. Investment in R&D (research and development) is regarded as a key strategy to achieve high technological potential for promoting innovation and sustaining economic growth [5]. However, despite the vast potential returns to innovation, developing countries invest far less in factors that could drive innovation, what some economists have dubbed as the “innovation paradox” [6]. Estimates indicate that the returns to R&D for advanced countries are about 40 to 60 percent annually [7].

Besides, diverging from the historic path of structural transformation, many developing countries are fast becoming service dominant, which is relatively less productive than manufacturing and
agriculture. This was prominently captured in Baumol’s analysis of the “cost disease of services,” which postulates that advanced economies, in particular, concentrate more and more workers to low-productivity services, adversely affecting productivity growth [8].

However, the advances in information and communication technologies (ICT) are likely to change this age-old scenario that services are less innovative, thus less productive. The growing penetration of ICT is making services mobile and facilitating cross-border trade-in information, financial, and other types of services. The rise of the mobile internet, the internet of things, big data, and advanced analytics are facilitating innovation in services [9].

As such, it is imperative to study the innovation in the services sector. Until recently, the study of innovation was highly concentrated on manufacturing. Empirical research on services firms’ innovative activities is a relatively nascent field of research [10–12]. Besides, most studies either on manufacturing or services largely focus on the role of product and process innovation. Whereas, less attention is being paid to the strategies of organizational and marketing innovation (nontechnological innovation), which could lead to technological (product and process) innovation improving overall performance of organizations [13,14]. Aboal and Garda [15] observed that the existing innovation policies in developing countries lean toward manufacturing and pay limited attention to nontechnological innovation.

Then, there is a debate whether technological innovation is more relevant to the manufacturing sector and nontechnological innovation to the services sector, resulting in three distinct views: the technicist, the demarcation, and the synthesis [16]. The technicist (or assimilation) approach, in particular, rejects any possibility that a technological innovation can be incubated within this sector. Contrarily, the demarcation (service-oriented) approach acknowledges the role of nontechnological innovation [16,17]. The synthesis (integrative) approach encompasses both goods and services as well as technological and nontechnological modes of innovation [18]. The importance of this framework is heightened by the fact that the boundaries between goods and services have become blurred [19], which is discussed in “servitization of manufacturing” literature at length [20].

Against this backdrop, using microdata of 1500 establishments, we study the linkages between knowledge input (R&D) and output (innovation), concentrating on a group of developing economies of the Association of Southeast Asian Nations (ASEAN). The study has two main objectives. First, identifying the determinants of investment in R&D, it explores the heterogeneities in terms of the relative impact of R&D on product, process, organization, and marketing innovation. Second, it identifies if there exists a complementary (substitute) relation concerning firms’ innovation preferences between the four types of innovation. If there is a complementary relationship among various types of innovation, then firms’ decision to innovate one type is not independent from other types. As such, we define technological innovation as the carrying out of product and process innovation jointly, and nontechnological innovation is the carrying out of organization and marketing innovation together, and estimated R&D’s impact on them. In doing so, our study can add significant value by providing evidence for a skewed link between nontechnological innovation and the services sector, which is one of the unresolved issues of services and innovation literature.

There are two specific reasons to study the developing economies of ASEAN. First, as an entity, it has already become services dominant. Figure 1 shows that the tertiary sector has experienced a steady rise in recent years with its share to GDP (gross domestic product), approaching 55%, whereas manufacturing’s contribution to GDP declines concomitantly, constituting one-third of the economy. Thus, innovation in services will largely determine ASEAN’s aggregate productivity performance, critical to avert the middle-income trap. Second, studies noted that the application of microdata to understand the various dynamics of innovation and productivity is relatively new to the Southeast Asia region [21]. Our literature review also suggests that there is no study on R&D and innovation in service firms of the region. As such, our study can add significant value by providing insights from microdata on the association between R&D and innovation. As Crespi, Tacisir [22] observed: “Considering the innovation results from the investment decisions made by individual firms, the
The reason being, traditionally the services sector has been seen as a low-innovative and low-productive sector compared to manufacturing. Nevertheless, the penetration of ICT and openness in services trade open the room for innovation. However, understanding the role of R&D and other intangible assets in the services sectors is very limited in developing countries. In the case of ASEAN, as Lee and Narjoko [21] show, there are some studies on individual countries, but no aggregate analysis is done following a global methodology.

Besides, given the interdependent nature of the innovation process [28], there is growing evidence that a mere product or process innovation is insufficient to interpret innovation in firms. Concerning organizational innovation, very little attention is paid to it, thereby leading to a scarcity of empirical evidence for understanding the role of organizational innovation in the services sector.

The rest of the paper is organized as follows. Section 2 discusses the theory and develops the hypothesis. Section 3 presents the data and descriptive statistics. Section 4 outlines the method of the study. Section 5 reports the result. The final section concludes the paper.

2. Theory and Hypotheses Development

According to Schumpeter [2], innovation involves the conversion of learning into new products, services, or business processes. The seminal contribution of Nelson and Winter, inspired by the Schumpeterian thoughts, interprets firms’ innovative behaviors, the dynamics of industries, and economic outcomes as a result of an evolutionary (continuous) process of innovation (variety generation) and market selection [23]. Endogenous growth theories, based on R&D activities, externalities, and the AK models, the simplest version of the endogenous growth model, developed approaches where the key growth factors are technological spillover, R&D efforts, and international technology transfer. Cohen and Levinthal [24] observed that “R&D is a primary source of knowledge that constitutes firms absorptive capacity, namely, their ability to identify, assimilate, and exploit new knowledge from the environment.” These theories mentioned above are applied in studying the association between knowledge input and knowledge output as well as innovation output (firm performance). Evidence demonstrates that firms that invest intensively in knowledge are more likely to develop innovation [25]. There exists a virtuous circle whereby investment in R&D, innovation, and productivity mutually reinforce each other, sustaining long-term growth [26,27].

However, the microlevel studies, notably in developing countries, on R&D, innovation, and firm performance, have squarely concentrated on the manufacturing sector. It is a relatively recent development that economists have started studying the role of R&D and innovation in services firms. The reason being, traditionally the services sector has been seen as a low-innovative and low-productive sector compared to manufacturing. Nevertheless, the penetration of ICT and openness in services trade open the room for innovation. However, understanding the role of R&D and other intangible assets in the services sectors is very limited in developing countries. In the case of ASEAN, as Lee and Narjoko [21] show, there are some studies on individual countries, but no aggregate analysis is done following a global methodology.

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Figure 1. Shares of services and manufacturing sectors of GDP in ASEAN: 2007–2018.
studies [29]. Marketing innovation, which contributes to generate “networks oriented to co-create value,” a key issue to develop innovative solutions, is also understudied [30]. In the case of Southeast Asia, we found only one study that explored the link between R&D and innovation that concentrated on product innovation [31]. Besides, it is observed that “the measurement of innovation is still at a relatively nascent stage in Southeast Asia” [21].

To address these limitations, we use all four types of innovation (product, process, organization, and marketing) to understand R&D investment’s relative contribution to both technological and nontechnological innovation. Figure 2, based on our sample, shows that there is a large gap of innovation effort based on firms’ intangibility, with R&D firms being much more innovative than non-R&D plants. (See Table A1 in the Appendix A for the mean test result). As such, we expect a positive link between investment in R&D and innovation among ASEAN firms. Besides, the figure also shows that firms in ASEAN that invest in R&D are more innovative in terms of process and marketing innovation. Whereas firms that do not invest in knowledge have more propensity to organization and marketing innovation (Figure 2).

![Figure 2. Mean of four types of innovation based on R&D and non-R&D firms.](image)

Thus, some heterogeneity is expected concerning the impact of R&D on innovation. As such, we formulate the following hypothesis:

**Hypothesis (H1): ASEAN services firms’ investment in knowledge translate into innovation, and there are heterogeneous impacts of R&D on innovation.**

While the estimates based on H1 could provide the evidence of heterogeneous impacts of R&D on innovation, such results could mask an important insight on firms’ innovation behavior: the complementarities (or substitutability) between different innovative activities. In other words, unobserved firms’ characteristics could influence firms’ innovation decisions on the four types of binary dependent variables (i.e., product, process, organization, and marketing) that we have. As Cirera [32] observed, “one vital component in the decision to innovate is that firms decide at a time what innovation results to produce based on existing knowledge capital investments. For this reason, one should expect some interdependency between the decisions to undertake product and process innovation, and perhaps organizational innovation.” Given the moderate to high correlation between various types of innovation in our sample (between 35 to 48 percent), firms’ decision to introduce product or process innovation, for instance, may not be independent of organization or marketing innovation. Further disaggregated data, based on the services subsector and reported on the horizontal axis of Figure 3, show that there is marked heterogeneity in terms of the services firms’ innovation preferences.
Sustainability (H1): ASEAN services firms’ investment in knowledge translate into innovation, and there are heterogeneous impacts of R&D on innovation.

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Thus, we investigate the potential complementarity (or substitute) relationship that the binary dependent variables may have, formulating the following hypothesis.

**Hypothesis (H2):** There exists complementary (substitute) relations between the four types of innovation.

3. Data and Descriptive Statistics

The data used in the analysis are drawn from World Bank’s Enterprise Survey (WBES) database that follows a methodology similar to that of the Oslo manual [33]. Innovation surveys in developing countries are generally conducted on a country-by-country basis without following a standardized methodology, thus limiting the scope of cross-country studies. However, WBES addresses this limitation. Our sample consists of nine subsectors of the services sector: wholesale and retail (International Standard Industrial Classification Revision 2 (ISIC2), Code 45), water transports (50), air transports (51), transport warehouse (52), accommodation (55), broadcast (60), information services (63), financial activities (64), and scientific research (72).

The sample is selected using stratified random sampling based on firm size, sector, and location (regional). The pooled cross-sectional data of seven ASEAN economies (Indonesia, Philippines, Vietnam, Malaysia, Cambodia, Lao PDR, and Thailand) representing 2015–2016 are used in this study. For the country-wise representation/frequency of firms, see Table A2 in the Appendix A. Based on 1506 firms, Table 1 shows summary statistics of key variables used in this study. The definition of each variable and underlying theory and studies behind their selection are elaborated in Table A3 of the Appendix A.
Table 1. Descriptive statistics.

| Variable                                      | N   | Mean  | Std. Dev. | Min  | Max  |
|-----------------------------------------------|-----|-------|-----------|------|------|
| **A. Dependent variable**                     |     |       |           |      |      |
| R&D Propensity (rd_d)                         | 1506| 0.0650| 0.2467    | 0    | 1    |
| R&D Intensity (rd_intensity)                  | 1506| 34.672| 312.99    | 0    | 6218.76|
| Product innovation (prod_i_d)                 | 1506| 0.1832| 0.3870    | 0    | 1    |
| Process innovation (proc_i_d)                 | 1506| 0.1985| 0.3990    | 0    | 1    |
| Organization innovation (org_m_i_d)           | 1506| 0.2197| 0.4142    | 0    | 1    |
| Marketing innovation (mrk_i_d)                | 1506| 0.2403| 0.4274    | 0    | 1    |
| Technological innovation (ti_d)               | 1506| 0.1115| 0.3149    | 0    | 1    |
| Nontechnological innovation (nti_d)           | 1506| 0.1434| 0.3506    | 0    | 1    |
| **B. Explanatory and control variable**       |     |       |           |      |      |
| Number of Employees (Emp)                     | 1506| 47.6706| 109.9060 | 3    | 1800 |
| Firm age (f_age)                              | 1476| 16.8292| 10.4171  | 2    | 93   |
| Location (capitalcity_d)                      | 1506| 0.3027| 0.4596    | 0    | 1    |
| Sales from first product (firstp_sale)        | 1506| 92.19 | 16.3522   | 6    | 100  |
| Foreign Direct Investment (FDI) (f_own_d)     | 1506| 0.0617| 0.2407    | 0    | 1    |
| Exporter (ex_d)                               | 1506| 0.0723| 0.2591    | 0    | 1    |
| Subsidiary (partgroup_d)                      | 1505| 0.1255| 0.3314    | 0    | 1    |
| Audited financial statement (audit_d)         | 1500| 0.3766| 0.4847    | 0    | 1    |
| Application of infoTech (info_d)              | 1503| 0.4058| 0.4912    | 0    | 1    |
| Acquire of quality certificate (qc_d)         | 1506| 0.0830| 0.2759    | 0    | 1    |
| Human capital1 (schooling_d)                  | 1506| 0.7483| 0.4341    | 0    | 1    |
| Human capital2 (formal_train_d)               | 1506| 0.2881| 0.4530    | 0    | 1    |
| Credit line (credit_d)                        | 1506| 0.2994| 0.4581    | 0    | 1    |
| Top manager’s experience (mg_exp)             | 1471| 16.1  | 9.3637    | 1    | 55   |
| Obstacle labor (Obstacle_labor)               | 1496| 0.1277| 0.3334    | 0    | 1    |
| Obstacle politics (Obstacle_politics)         | 1456| 0.1016| 0.3022    | 0    | 1    |

About 6.5 percent services firms engage in R&D, and per head R&D spending is USD 35. In terms of subsector, scientific research (72), information services (63) and broadcast (60) have higher propensity to invest in R&D, and scientific research, financial activities (64), and air transport (51) subsectors have higher R&D intensity. The percentage of firms that innovate product, process, organizational management (henceforth, organization), and marketing innovation ranges from 18 to 24 percent. However, there exists a large gap concerning innovation outcome between firms that invest in R&D and those that do not. Table A1 in the Appendix A shows the mean test of different types of innovation over R&D dummy. For instance, about 65 percent of firms innovate products if their R&D spending is positive, compared to only 17 percent for those that do not invest in knowledge. In ASEAN, over 40 percent of firms apply information technology. About 7 percent of firms are export-oriented. Only 6 percent of firms have foreign ownership (shareholding 10 percent and above). In terms of human capital, about 28 percent of firms provide formal training to its employees. Firms in ASEAN face a host of constraints, including human capital (inadequate education of labor force) and political instability. An average services firm employs 48 workers. The sales revenue of firms is heavily dependent on a single product. The correlation matrix involving the dependent and independent variables is provided in Table A4.

4. Empirical Model

The distribution of R&D intensity (R&D expenditure per employee) by firms captures excessive zeroes, suggesting that most services establishments in ASEAN do not invest in knowledge. Furthermore, the standard deviation (313) of R&D intensity is greater than the mean (35). This strongly suggests that such overdispersed data should be analyzed using limited dependent variable models (tobit, Heckman selection, etc.) or count data models (Poisson, negative binomial or zero-inflated Poisson, etc.). We need to formulate a knowledge function and innovation function to show the relations between R&D and innovation. The Crépon, Duguet [34] CDM model, which is one of the most crucial contributions to the economics of innovation literature [35] is widely applied to study the linkages between R&D, innovation and productivity. Crépon, Duguet [34] advanced the Pakes and Griliches [36] approach by developing a recursive econometric approach describing the process
that goes from new ideas to economic growth. We derive the knowledge function and the innovation equation in line with CDM to study the link between R&D and innovation. Models akin to CDM that are usually estimated by applying simultaneous estimators such as likelihood-based estimators and asymptotic least squares, among others, proven to be effective to control for selectivity and endogeneity problems [37].

Equation (1) captures a firm i’s innovative effort ($\Gamma_i^*$) which is proxied by R&D intensity, whereas $\chi_i'$ represents a vector of determinants of innovative efforts and $\epsilon_i$ is the error term.

$$\Gamma_i^* = \chi_i'\beta + \epsilon_i$$

(1)

However, a simple estimation of Equation (1) is prone to the selection bias risk [38]. To address this, in other words, to correct for endogeneity, we tested for selection by applying Heckman’s two-step selection-model [39] using a set of variables to capture observable differences in R&D intensity.

$$\mathbf{N}_i = \begin{cases} 1, & \text{if } \mathbf{N}_i^* = \chi_i'\alpha + \mathcal{E}_i > \hat{\varsigma} \\ 0, & \text{if } \mathbf{N}_i^* = \chi_i'\alpha + \mathcal{E}_i \leq \hat{\varsigma} \end{cases}$$

(2)

Equation (2) accounts for the possible selection into R&D. As an indicator function, the selection into innovative effort, $\mathbf{N}_i^*$ equals 1 if the firm i’s R&D intensity surpasses a certain threshold level at $\hat{\varsigma}$ . The variable $\chi_i'$ denotes a vector of explanatory variables concerning a firms’ R&D decision and $\mathcal{E}_i$ is an error term.

Subsequently, we estimated the R&D intensity, Equation (3), conditional on firm i’s decision to invest in R&D, where $\Gamma_i^*$ is the unobserved latent variable reflecting R&D intensity and $X_i'$ is a vector of explanatory variables.

$$\Gamma_i = \begin{cases} \Gamma_i^* = \chi_i'\beta + \epsilon_i, & \text{if } \mathbf{N}_i = 1 \\ 0, & \text{if } \mathbf{N}_i = 0 \end{cases}$$

(3)

The system of Equations (2) and (3) is estimated as the Heckman selection model [39] assuming that the error terms ($\mathcal{E}_i$ and $\epsilon_i$) exhibit a univariate normal distribution with zero mean and independent of regressors.

However, if there is no selection bias in the data, then a Type-I Tobit model akin to Equation (4) is generally applied.

$$\ln\{E(k_i)\} = x_i\beta, k \sim Tobit$$

(4)

where $k_i$ is the knowledge intensity for firm i, $x_i$ is a vector of determinants of knowledge intensity, and $\beta$ is a vector of estimated coefficients.

We next estimate the innovation function, which considers four types of innovation: product, process, organization and marketing, by applying a probit maximum likelihood (ML) model. There is a potential endogeneity of knowledge capital investments in innovation performance. As such, in the second stage, the predicted value of R&D intensity from the first stage was included as an independent variable in a probit model to estimate the probability of carrying out a product, process, organization, or marketing innovation.

However, when the error terms are dependent, the probit ML approach provides inconsistent estimates (of parameters) [40]. The reason given is that the existing knowledge capital investments firms decide simultaneously what to innovate. Since unobserved firms’ characteristics simultaneously influence the adoption of each innovation decision, the application of a multivariate probit (mvprobit) model is more appropriate. The mvprobit framework models the influence of the set of explanatory variables simultaneously, at the same time it allows the “unobserved and unmeasured factors” (error terms) to be correlated freely [41]. These correlations serve to test for likely complementarities (positive value of correlation) and ability to substitute (negative value of correlation) between firms’ innovation decisions. As such, we use a mvprobit framework, developed by Cappellari and Jenkins [42], based on the Geweke–Hajivassiliou–Keane (GHK) algorithm.
To test whether the services firms’ one type of innovation is independent of others, as proposed in hypothesis H2, we apply the mvprobit model, adopting an approach akin to that of [43], to jointly examine the correlations between the four dependent variables $y_1$ to $y_4$ (representing the four types of innovation), and independent and control variables $x_1$ to $x_n$. The explanatory variables include, among others, the predicted value of R&D intensity, derived from the previous stage.

The model consists of four binary choice equations as follows:

$$y_{ik} = \begin{cases} 
1, & \text{if } x_{ik}\beta_k + w_{ik} > 0 \\
0, & \text{otherwise} 
\end{cases} \quad k = 1, \ldots, 4; i = 1, \ldots, N$$

(5)

$$(\delta_1, \delta_2, \delta_3, \delta_4) \sim N(0, \Omega)$$

where $\Omega$ is the covariance matrix of the error terms.

One of the benefits of using the mvprobit model is that it estimates the variance-covariance matrix $\Omega$, which reveals complementary/substitute patterns between/among different types of innovation formulated in H2.

5. Result

Before estimating our models, we have selected the explanatory variables that could potentially influence R&D propensity and R&D intensity. In doing so, in addition to the relevant theory outlined pertaining to each variable in Table A3 (Appendix A), we have applied the technique of machine learning approach (MLA). Given the growing application of MLA in microeconometrics research [44], we applied the LASSO (least absolute shrinkage and selection operator) method of automatic variable selection [45]. This method is employed to select predictors $X^*$ of a target variable $Y$ from a set of potential explanatory and control variables. In doing so, the objective function penalizes the absolute size of the regression coefficients, based on the value of a tuning parameter $\lambda$ (lambda). As a result, the LASSO drives the coefficients of variables that are irrelevant to zero, selecting variables automatically. When $\lambda$ is markedly large, then coefficients are forced to converge to zero, reducing dimensionality. The larger is the parameter $\lambda$, the greater number of coefficients converges to zero. On the contrary, when $\lambda = 0$, we have an OLS (ordinary least square) regression. Thus, the LASSO increases a model’s interpretability by eliminating variables that are not associated with the response variable, thus reducing overfitting [46].

Using two separate equations, we applied the LASSO to select variables whereby R&D propensity and R&D intensity are dependent variables. For the binary dependent variable model (R&D propensity), we applied the lassologit and cvlassologit, and for the OLS model, we used lasso2 and rlasso. The tuning parameter is selected by lassologit as the value of lambda minimizing either the Akaike information criterion (AIC), the Bayesian information criterion (BIC), or the extended Bayesian information criterion (EBIC). -K-fold cross-validation, a statistical method used to estimate the skill of machine learning model, is backed by cvlassologit. Lambda is selected as the value that minimizes the estimated deviance (or misclassification rate). For a nondiscrete (continuous) dependent variable, lasso2 implements the elastic net and sqrt-lasso by applying coordinate descent algorithms.

The selected variables based on the LASSO are reported in Table 2: columns 2–7 and columns 8–11 list the variables that could affect firms’ R&D propensity and R&D intensity, respectively. As shown in Table 2, the larger the value of parameter lambda, the greater number of coefficients converge to zero. As such, based on cvlassologit ($\lambda = 20.79$), we find five variables, namely, firm size (medium), human capital (training), credit facilities, major sales from the first or main product, and audited firms, which are likely to affect firms’ R&D propensity. Based on lasso2 and rlasso (column 8–11), firm size (medium), human capital (formal training), credit facilities, and major sales from the first product, are likely to affect firms’ R&D intensity.
Table 2. Variable selection based on Machine Learning Approach (LASSO).

| Selected variable | With Respect to R&D Propensity (2–7) | With Respect to R&D Intensity (8–11) |
|-------------------|----------------------------------------|---------------------------------------|
|                   | lassologit, lic(ebic) λ = 1.73        | cvlassologit, lopt * λ = 4.41         |
|                   | cvlassologit, lse** λ = 20.79          | lasso2, lic(ebic)                      |
|                   | Lambda = 127.8                         | rlasso                                |
| Firm size (Medium) | 0.765 0.765 -0.022 -0.017 -0.019 -0.009 -0.018 -0.001 -0.003 -0.003 |
| Firm size (Large) | -0.165 -0.269 -0.101 -0.396            |                                       |
| Human capital2    | 1.343 1.405 1.173 1.261 1.029 1.384 0.113 0.183 0.096 0.183 |
| Credit line       | 0.662 0.703 0.668 0.787 0.397 0.754 0.060 0.129 0.043 0.129 |
| Sales from first product | -0.020 -0.022 -0.017 -0.019 -0.019 -0.018 -0.018 -0.003 0.000 0.003 |
| Audited firm      | 0.597 0.665 0.385 0.488 0.080 0.427 |                                       |
| Location          | 0.633 0.729 0.477 0.685 |                                       |
| Export            | 0.624 0.725 0.327 0.456 |                                       |
| Inoftech          | 0.237 0.276 0.158 0.252 |                                       |
| Quality certificate| 0.565 0.660 0.280 0.435 |                                       |
| Obstacle—politics | -0.261 -0.399 -0.155 -0.401 |                                       |
| Human capital 1   | 0.426 0.487 0.345 0.478 |                                       |
| Obstacle—worker   | 0.636 0.717 0.435 0.567 |                                       |
| Firm age          | -0.135 -0.164 |                                       |
| FDI               | -0.835 -1.001 |                                       |
| Subsidiary        | -0.722 -0.827 |                                       |
| _cons             | -2.799 -2.803 -3.130 -3.315 -2.637 -2.588 0.153 0.294 0.121 0.294 |

Note: * the lambda that minimizes loss measure; ** largest lambda for which Mean Squared Prediction Error (MSPE) is within one standard error of the minimum loss.

Next, we estimate our baseline models (the limited dependent variable models: Heckman selection and Tobit), in line with Equations (1)–(4). We estimated a Heckman two-stage selection model by using a rich set of variables aimed at capturing observable differences in R&D intensity (Equations (1) and (2)). This is to test whether services firms in ASEAN self-select into R&D. The first-stage selection equation is estimated via a probit model (column 1, Table 3). Subsequently, we compute the inverse Mills ratio (IMR, also termed Lambda), which takes account of the possible selection bias, which is insignificant at conventional levels (column 3 of Table 3). This implies there is no significant selection bias into R&D. As such, we use a Type-I Tobit model in line with Equation (4). We reported both coefficients and marginal effects (ME) of the respective models, save Heckman selection, in Table 3. ME better quantifies the actual effect of each predictor of the estimated probabilities. The estimates reported in Table 3 and the summary of key findings in Table 4 suggest that medium-sized firms show a higher probability of engaging in innovation and also affect R&D intensity positively. While the log value of employment shows a positive link between R&D propensity and intensity, we ran separate regressions considering small-, medium-, and large-sized firms, and found that it is medium-sized firms that influence firms’ likelihood of investment as well as decision to invest in R&D. Firms that have access to credit and provide training to employees have a higher probability of involvement in innovation efforts, and those firms also invest more in R&D. A firm’s location in a capital city also affects firms’ R&D intensity positively. On the constraints side, if the first or main product constitutes a large share of a firms’ sales revenue, then they show little or no incentive to engage in innovation, and the impact on R&D intensity is also negative. These variables, except for location, are also identified by the LASSO technique (Table 2) as potential predictors that could affect firms’ investment decision in knowledge.
### Table 3. Sample selection models: Heckman, Tobit, and Poisson.

|                | (1) (2) | (3) | (4) | (5) | (6) | (7) |
|----------------|--------|-----|-----|-----|-----|-----|
|                | Probit | Heckman | Tobit | Poisson |     |     |
| **Firm size**  | 0.319*** | 0.139** | 0.973*** | 0.063*** | 0.300** | 0.244** |
|                  | (0.088)  | (0.068)  | (0.281)  | (0.019)  | (0.128)  | (0.110)   |
| **Firm age**    | -0.053  | -0.030  | -1.811  | -0.011  | 0.013   | 0.001     |
|                  | (0.178)  | (0.027)  | (0.585)  | (0.039)  | (0.309)  | (0.025)    |
| **Location**    | 0.570** | 0.185   | 1.917**  | 1.126**  | 1.059**  | 1.086*     |
|                  | (0.275)  | (0.131)  | (0.915)  | (0.058)  | (0.515)  | (0.050)    |
| **Sales from**  | -0.033*** | -0.006  | -0.044*** | -0.003*** | -0.020*** | -0.002***  |
|                  | (0.004)  | (0.004)  | (0.013)  | (0.003)  | (0.006)  | (0.001)    |
| **FDI**         | -0.526  | -0.349*  | -1.812  | -0.119  | -0.980  | -0.079     |
|                  | (0.427)  | (0.023)  | (0.393)  | (0.087)  | (0.946)  | (0.078)    |
| **Export**      | 0.464   | 0.249   | 1.562*   | 1.067*   | 0.851**  | 0.669**    |
|                  | (0.313)  | (0.195)  | (0.937)  | (0.059)  | (0.422)  | (0.034)    |
| **Subsidiary**  | 0.226   | 0.174   | 0.848   | 0.056   | 0.575   | 0.047      |
|                  | (0.249)  | (0.115)  | (0.753)  | (0.049)  | (0.354)  | (0.031)    |
| **Audited firm**| 0.124   | 0.007   | -0.006  | 0.029   | 0.088   | 0.007      |
|                  | (0.241)  | (0.045)  | (0.824)  | (0.054)  | (0.573)  | (0.046)    |
| **Infotech**    | 0.276   | 0.216   | 1.311*   | 0.101*   | 0.830**  | 0.067**    |
|                  | (0.194)  | (0.073)  | (0.638)  | (0.042)  | (0.348)  | (0.030)    |
| **Quality certificate** | 0.449* | 0.210  | 1.311*   | 0.101*   | 0.830**  | 0.067**    |
|                  | (0.258)  | (0.078)  | (0.730)  | (0.047)  | (0.375)  | (0.030)    |
| **Human capital1** | -0.256  | -0.079  | -0.744  | -0.049  | -0.275  | -0.022     |
|                  | (0.249)  | (0.078)  | (0.133)  | (0.047)  | (0.375)  | (0.030)    |
| **Human capital2** | 0.437** | 0.023**  | 1.363**  | 0.089**  | 0.535*   | 0.043*     |
|                  | (0.183)  | (0.030)  | (0.615)  | (0.042)  | (0.305)  | (0.024)    |
| **Obstacle: Labor** | 0.287   | 0.141**  | 1.060    | 0.068    | 0.672*   | 0.054*      |
|                  | (0.217)  | (0.067)  | (0.702)  | (0.047)  | (0.362)  | (0.029)    |
| **Obstacle: Politics** | -0.260  | -0.112  | -0.655   | -0.043   | -0.056  | -0.004      |
|                  | (0.278)  | (0.070)  | (0.873)  | (0.056)  | (0.494)  | (0.040)    |
| **Credit line**  | 0.413** | 0.198**  | 1.351**  | 0.089**  | 0.875**  | 0.071**     |
|                  | (0.208)  | (0.011)  | (0.651)  | (0.040)  | (0.358)  | (0.031)    |
| **lambda**      | 0.281   | (0.217)  | (2.122)  | (2.122)  | (1.144)  |            |
| **cons**        | -1.828**  | -0.240  | -5.814**  | -5.814**  | -2.534**  |            |
|                  | (0.815)  | (0.354)  | (2.687)  | (2.687)  | (1.144)  |            |
| **N**           | 1242   | 1242   | 1242   | (left censored 1,317) | 1409   | 1409   |

Note: Regressions were run in STATA 15.1 using svy prefix. Population size, number of strata, and primary sampling units for probit, Heckman selection, Tobit, and Poisson models are 315,380 (315,380, 332,020, 332,020), 29 (29, 31, 31) and 524 (524, 578, 578), respectively. Standard errors are in parenthesis. *** p < 0.01, ** p < 0.05, * p < 0.1.
Table 4. Determinants to investment in R&D.

| R&D Propensity | R&D Intensity |
|----------------|---------------|
| Positively (highly) related |
| Firm size |
| Human capital-1 (training) |
| Credit facilities |
| Firm size (medium) |
| Human capital-1 (training) |
| Credit facilities |
| Location (capital city) |
| Positively (marginally) related |
| Location (capital city) |
| Acquisition of a quality certificate |
| Export |
| Negatively (highly) related |
| Major sales from first product |
| Major sales from first product |

Albeit significant at the 10% level, acquisition of a quality certificate influences both R&D propensity and R&D intensity positively. Firms export status also marginally affect R&D intensity. Among subsectors, scientific research has significant influence over R&D intensity, followed by broadcast and information services (Figure 4).

5.1. The Impact of R&D on Innovation

Instrumenting knowledge intensity with the predicted values derived from the previous stage (applying the Type I Tobit model), Table 5 shows that the marginal effects (MEs) for R&D intensity are statistically highly significant for all types of innovation, reflected in the signs and significance level of respective coefficients. However, the magnitude of MEs are low. Overall, the estimates indicate that greater R&D spending per employee in ASEAN leads to probability of having all types of innovation.
Table 5. The marginal effects of R&D intensity on innovation.

| Product Innovation | Process Innovation | Organization innovation | Marketing Innovation | Technological Innovation | Non-technological innovation |
|---------------------|--------------------|-------------------------|----------------------|-------------------------|-----------------------------|
| Coefficients        | Marginal effects   | Coefficients            | Marginal effects     | Coefficients            | Marginal effects            |
| R&D intensity (predicted) | 0.238 *** | 0.029 *** | 0.175 *** | 0.030 *** | 0.152 *** | 0.028 *** | 0.205 *** | 0.039 *** | 0.214 *** | 0.017 *** | 0.203 *** | 0.024 *** |
| (0.043)             | (0.006)           | (0.046)                 | (0.008)              | (0.040)                 | (0.007)                     | (0.045)                     | (0.009)              | (0.051)                 | (0.005)              | (0.044)                 | (0.005) |
| Firm size           | −0.085             | −0.010                  | −0.043               | −0.007                 | 0.010                       | 0.002                       | −0.109                  | −0.021                 | −0.061                  | −0.005              | −0.116                  | −0.014 |
| (0.113)             | (0.014)           | (0.117)                | (0.020)              | (0.108)                | (0.020)                     | (0.108)                     | (0.021)                | (0.150)                | (0.012)              | (0.109)                | (0.013) |
| Firm age            | −0.140             | −0.017                  | −0.292 *             | −0.049 *               | 0.028                       | 0.005                       | −0.099                 | −0.019                 | −0.242                  | −0.019              | 0.117                   | 0.014 |
| (0.150)             | (0.018)           | (0.158)                | (0.027)              | (0.217)                | (0.040)                     | (0.150)                     | (0.029)                | (0.172)                | (0.014)              | (0.165)                | (0.020) |
| Manager experience  | 0.054              | 0.006                  | 0.300 **             | 0.051 **               | 0.022                       | 0.004                       | 0.081                  | 0.016                 | 0.253                   | 0.020              | 0.194                   | 0.023 |
| (0.147)             | (0.018)           | (0.147)                | (0.026)              | (0.201)                | (0.037)                     | (0.138)                     | (0.027)                | (0.173)                | (0.014)              | (0.172)                | (0.021) |
| FDI                 | −0.016             | −0.002                  | −0.368               | −0.062                 | −0.719 **                   | −0.132 **                   | −0.501                 | −0.096                 | −0.191                  | −0.015              | −0.889 **                | −0.107 *** |
| (0.309)             | (0.037)           | (0.299)                | (0.051)              | (0.290)                | (0.054)                     | (0.328)                     | (0.063)                | (0.341)                | (0.027)              | (0.284)                | (0.037) |
| Infotech            | 0.191              | 0.023                  | 0.011                | 0.002                 | 0.263                       | 0.048                       | 0.586 ***              | 0.113 ***             | 0.162                   | 0.013              | 0.521 **                 | 0.063 ** |
| (0.210)             | (0.025)           | (0.215)                | (0.036)              | (0.206)                | (0.037)                     | (0.197)                     | (0.037)                | (0.218)                | (0.017)              | (0.227)                | (0.026) |
| Export              | −0.179             | −0.022                  | −0.031               | −0.005                 | −0.798 ***                  | −0.146 ***                  | −0.470                 | −0.090                 | 0.254                   | 0.020              | −0.793 **                | −0.095 ** |
| (0.305)             | (0.037)           | (0.305)                | (0.051)              | (0.294)                | (0.055)                     | (0.323)                     | (0.062)                | (0.324)                | (0.025)              | (0.318)                | (0.040) |
| Human capital 2     | −0.118             | −0.014                  | 0.121                | 0.020                 | −0.292                      | −0.054                      | −0.037                 | −0.007                 | 0.287                   | 0.022              | −0.092                  | −0.011 |
| (0.193)             | (0.023)           | (0.175)                | (0.029)              | (0.180)                | (0.034)                     | (0.165)                     | (0.032)                | (0.235)                | (0.019)              | (0.214)                | (0.026) |
| _cons               | 0.853              | 0.592                  | 0.234                | 0.792                 | −0.075                      | −0.482                      | (0.775)                | (0.677)                | (0.706)                | (0.703)              | (0.868)                | (0.748) |
| N                   | 1381              | 1381                   | 1381                 | 1381                  | 1381                       | 1381                       | 1381                  | 1381                  | 1381                  | 1381               | 1381                     | 1381 |
| Wald chi2           | 169.28            | 113.88                 | 181.47               | 145.55                | 162.12                      | 116.52                      | (72171.906)            | (100375.77)           | (107022.88)           | (112155.31)       | (47760.726)              | (70819.301) |
| Prob > chi2         | 0.000              | 0.000                  | 0.000                | 0.000                 | 0.000                       | 0.000                       | (0.000)                | (0.000)                | (0.000)                | (0.000)             | (0.000)                 | (0.000) |
| Log likelihood      | −72171.906        | −100375.77             | −107022.88           | −112155.31            | −47760.726                  | −70819.301                  | (0.267)                | (0.183)                | (0.283)                | (0.259)             | 0.2872                   | 0.2884 |
| Pseudo R2           | 0.2677             | 0.1833                 | 0.2830               | 0.2590                | 0.2872                      | 0.2884                      | ISIC dummy            | Yes                    | Yes                    | Yes                      | Yes              | Yes                     |
| Country dummy       | Yes                | Yes                    | Yes                  | Yes                   | Yes                         | Yes                         | Yes                   | Yes                    | Yes                    | Yes                      | Yes              | Yes                     |

Note: The linktest is used to detect a specification error, and it is conducted after the probit estimation. All of our probit equations satisfied the test. Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 
The economic explanation of the average marginal effects is that a doubling of predicted R&D intensity is associated with a 0.029 percentage points (pp) rise in the probability of reporting a product innovation, 0.030 pp increase of a process innovation, 0.028 pp rise of an organizational innovation, and a 0.039 pp increase of a marketing innovation. Other control variables show heterogeneous outcomes. Foreign Direct Investment (FDI) and exports have a negative effect on nontechnological innovation, whereas information technology has positive effect.

This result is in line with other studies that show R&D investment positively drives innovation in the services sector, but the effect is smaller. Studies show that the impact of R&D on innovation is more “noisy” in the service sector compared to manufacturing [47]. This is because R&D may not be a typical innovation investment for services firms [48]. Some studies show that investment in knowledge does not necessarily translate into firm-level innovation. For instance, using WBES data, Cirera [32] showed that in the case of Kenyan firms’ investments in knowledge and acquisition of capabilities in the form of R&D, equipment, and training did not have any impact on innovation.

However, this result of univariate probit should be analyzed with caution. Table 6 implements a multivariate probit framework, including all types of innovations. Using Stata’s mvprobit command and setting the appropriate draw level, we estimated Equation (5). The estimates apply the method of simulated maximum likelihood (SML) and use the GHK algorithm to evaluate the multivariate normal distribution. The assumption that the error terms across Equation (5) are uncorrelated (null hypothesis of the mvprobit model) is rejected, suggesting that the application of the mvprobit model is more appropriate than estimating four independent binary probit models. This is inferred from the positive and significant rho terms, the correlation of errors between the four equations, reported in the bottom panel of Table 6. This means that firms that have a higher likelihood of developing one type of innovation are also more likely to implement the other types of innovation, thus supporting our hypothesis (H2), i.e., the nexus between various types of innovation is complementary. As such, we also estimated the impact of R&D intensity on technological (joint effects of product and process) and nontechnological (joint effects of organization and marketing) innovation (Table 5). The estimates suggest that while firms innovate both types of innovation, the marginal effects are higher for nontechnological innovation, thus supporting H1.

### Table 6. The impact of R&D intensity on innovation: multivariate probit estimates.

|                           | Product Innovation | Process Innovation | Organization Innovation | Marketing Innovation |
|---------------------------|--------------------|--------------------|-------------------------|----------------------|
| Predicted value of R&D intensity | 0.236 ***          | 0.174 ***          | 0.142 ***               | 0.200 ***            |
| Wald chi²                 | 624.16             | (0.00)             | (0.00)                  | (0.00)               |
| Prob > chi²               | 0.000              |                    |                         |                      |
| Log likelihood            | -322809.4          |                    |                         |                      |
| N                         | 1381               |                    |                         |                      |
| Predicted value of R&D intensity | 0.258 ***          | 0.194 ***          | 0.195 ***               | 0.193 ***            |
| Wald chi²                 | 797.30             | (0.00)             | (0.00)                  | (0.00)               |
| Prob > chi²               | 0.000              |                    |                         |                      |
| Log-likelihood            | -1875.8            |                    |                         |                      |
| N                         | 1381               |                    |                         |                      |

**Correlation coefficients of error terms of dependent variables**

|                           | Cappellari and Jenkins p-value | Roodman p-value |
|---------------------------|--------------------------------|-----------------|
| rho21                     | 0.63                           | 0.000           |
| rho31                     | 0.57                           | 0.000           |
| rho41                     | 0.59                           | 0.000           |
| rho32                     | 0.73                           | 0.000           |
| rho42                     | 0.56                           | 0.000           |
| rho43                     | 0.62                           | 0.000           |

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0; chi²(6) = 655,924; Prob > chi² = 0.0000 (for the model estimated based on the Cappellari and Jenkins method). Note: The results of control variables are not reported. The estimates considered the ISIC 2-digit sector and country fixed effects.
5.2. Robustness Check

While estimates based on the Heckman selection and Tobit approaches are widely used to explore the link between R&D and innovation, given the zero research intensity of firms in our sample, we also applied a count data model to better cater for the number of zeros in the data. Cirera [32], for instance, used a Poisson estimator to account for the number of firms with zero investments. To check the validity of our results, we ran a Poisson estimator to see the determinants of R&D based on Tobit (columns 6–7 of Table 3), which shows a similar result, in line with the baseline model (Tobit, Table 3).

Concerning the linkages between R&D intensity and innovation outcomes, as reported in Table 7, we found that the marginal effects of R&D expenditure on four types of innovation are significant, in line with the result reported in Table 5. Besides, the signs of the respective coefficients as well as significance level do not vary at all, however, the magnitude does. The ME of R&D investment on nontechnological innovation is significantly higher vis-à-vis technological innovation compared to the estimates based on first stage Tobit model (Tables 3 and 5). The overall outcomes support our hypothesis H1.

We also revisited the results reported based on multivariate probit estimates in Table 6, following Roodman [49]. The results, both the coefficients and correlation of error terms (rho), concerning four types of innovation, shows a similar pattern of the estimates reported based on the Cappellari and Jenkins method. This confirms that the relations between the four types of innovation are complementary, supporting hypothesis H2. In other words, firms’ decision to innovate one type of innovation is not independent of other types of innovation. This reflects that services firms in ASEAN simultaneously innovate both technological and nontechnological innovation.
Table 7. The marginal effects of R&D intensity on innovation: The count data model.

|                | Product Innovation | Process Innovation | Poisson model (1-6) | Technological Innovation | Nontechnological Innovation | Product Innovation | Process Innovation | Negative binomial model (7-12) | Technological Innovation | Nontechnological Innovation |
|----------------|-------------------|--------------------|---------------------|--------------------------|-----------------------------|--------------------|-------------------|--------------------------|--------------------------|---------------------------|
| R&D intensity  | 0.082 ***         | 0.082 **           | 0.162 ***           | 0.529 ***               | 0.030 **                    | 0.111 ***          | 0.131 ***         | 0.352 ***               | 0.239 ***               | 0.215 ***                 |
| (predicted)    | (0.029)           | (0.039)            | (0.048)             | (0.049)                  | (0.017)                     | (0.033)            | (0.039)          | (0.053)                  | (0.062)                  | (0.072)                   |
| Firm size      | 0.035 ***         | 0.039 ***          | 0.042 ***           | 0.041 ***               | 0.022 ***                   | 0.032 ***          | 0.036 ***         | 0.037 **               | 0.021 ***               | 0.019 *                   |
|                | (0.010)           | (0.013)            | (0.015)             | (0.015)                  | (0.008)                     | (0.010)            | (0.014)          | (0.015)                  | (0.008)                  | (0.010)                   |
| Firm age       | −0.023            | −0.056 *           | 0.004               | −0.021                   | −0.024                      | 0.010              | −0.023           | −0.050 *               | 0.002                    | −0.022                    |
|                | (0.020)           | (0.027)            | (0.039)             | (0.029)                  | (0.015)                     | (0.021)            | (0.020)          | (0.027)                  | (0.039)                  | (0.029)                   |
| Manager experience | −0.000   | 0.041              | −0.005              | 0.003                    | 0.017                       | 0.013              | −0.000           | 0.040                    | −0.006                   | 0.000                     |
|                | (0.018)           | (0.026)            | (0.036)             | (0.028)                  | (0.014)                     | (0.021)            | (0.018)          | (0.026)                  | (0.026)                  | (0.028)                   |
| FDI            | −0.019            | −0.077             | −0.130 **           | −0.120 *                 | −0.030                      | −0.109 ***         | −0.013           | −0.069                   | −0.120 **               | −0.110                    |
|                | (0.035)           | (0.055)            | (0.054)             | (0.049)                  | (0.039)                     | (0.037)            | (0.034)          | (0.035)                  | (0.053)                  | (0.067)                   |
| Infotech       | 0.052 **          | 0.030              | 0.072 **            | 0.153 ***                | 0.028 **                    | 0.085 ***          | 0.052 **         | 0.027                    | 0.071 **                | 0.150 ***                 |
|                | (0.024)           | (0.034)            | (0.034)             | (0.036)                  | (0.016)                     | (0.024)            | (0.034)          | (0.034)                  | (0.036)                  | (0.016)                   |
| Export         | 0.039             | 0.071              | −0.108 **           | −0.002                   | 0.037 **                    | −0.062             | 0.029            | 0.056                    | −0.132 ***              | −0.018                    |
|                | (0.034)           | (0.062)            | (0.049)             | (0.080)                  | (0.023)                     | (0.040)            | (0.035)          | (0.065)                  | (0.051)                  | (0.084)                   |
| Human capital 2 | −0.023            | 0.009              | −0.061 *            | −0.021                   | 0.019                       | −0.016             | −0.024           | 0.008                    | −0.062 *                | −0.021                    |
|                | (0.025)           | (0.031)            | (0.034)             | (0.034)                  | (0.019)                     | (0.026)            | (0.025)          | (0.030)                  | (0.034)                  | (0.019)                   |
| Obs.           | 1381              | 1381               | 1381                | 1381                     | 1381                        | 1381               | 1381             | 1381                     | 1381                     | 1381                      |
| ISIC dummy     | Yes               | Yes                | Yes                 | Yes                      | Yes                         | Yes                | Yes              | Yes                      | Yes                      | Yes                       |
| Country dummy  | Yes               | Yes                | Yes                 | Yes                      | Yes                         | Yes                | Yes              | Yes                      | Yes                      | Yes                       |

Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 
6. Discussion and Conclusions

Given the limited insights on the association between R&D and innovation in services sectors of developing countries, this study, which identifies the determinants of firms’ investment in knowledge, first explored the heterogeneous impacts of R&D on product, process, organization, and marketing innovation. Then it examined if there exists a complementary relation concerning firms’ innovation preferences between four types of innovation. As such, we tested two key hypotheses, which are interlinked.

To identify firms’ R&D propensity (likelihood) and R&D intensity (actual investment), we first applied a machine learning application and then estimated conventional models. The techniques of MLA-based regression and the conventional regression produced nearly an identical result. Both the approaches show that for medium-sized firms, human capital (training) and access to credit determine firms’ likelihood, as well as their decision, to invest in innovation. Besides, the firms’ location, export status, and acquisition of a quality certificate have positive influence on R&D intensity. The firms’ location and acquisition of a quality certificate also marginally increase firms’ likelihood to invest in knowledge. Whereas, if the main or first product generates the largest share of revenue, then firms’ probability of engaging in innovation, as well as their decision to invest in knowledge, is low, which is probably a unique finding of our study and not common in R&D literature. Previous research identified that innovation in the services sector, compared to manufacturing and agriculture, is highly heterogeneous. The innovative activities of services firms do not simply mirror that of their manufacturing counterparts [12]. The descriptive statistics show that of the nine subsectors in our sample, scientific research, information services, broadcast, financial activities, and air transports have either higher propensity or intensity to invest in R&D. Our estimates suggest that of them, the first three subsectors have a statistically significant influence over firms’ R&D intensity.

We then showed the linkages between R&D intensity and innovation, which were methodologically challenging. The common approach that is generally applied to show the association between these two variables is based on univariate probit models (Hypothesis 1), masking an important issue concerning firms’ innovation behavior: simultaneity (Hypothesis 2). Taking this into account, we tested our second hypothesis by applying an algorithm-based multivariate probit technique.

The univariate probit model shows ASEAN firms’ investment in knowledge translates into innovation irrespective to product, process, organization, and marketing innovation. However, the application of the GHK-simulator-based multivariate probit model results suggest that the relationship between different types of innovation is complementary: firms’ strategy to adopt one type of innovation is influenced by other types, which the univariate probit model ignores, providing potentially biased results. This led to the estimation of R&D’s impact on technological (joint effects of product and process) and nontechnological (joint effects on organization and marketing) innovation. The result suggests that while firms in ASEAN innovate both types of innovation, there is a skewed link between nontechnological innovation and the services sector. The robustness checks based on an alternative approach also back the outcome.

Overcoming the methodological challenges and applying advanced techniques, we contribute to the scarce literature on R&D-innovation linkages in the services sector of developing countries. Our findings support the synthesis (the integrative) framework of service sector innovation, which acknowledges the role of both technological and nontechnological innovation in the sector [17]. This study reinforces the views that in services, the technological trajectories are not the only or central form of innovation [19]. However, there is a skewed link between nontechnological innovation and the services sector. The contribution of nontechnological innovation has also been recognized by a demarcation (service-oriented) approach of innovation [17]. In other words, in the service sector, organization and marketing innovation (or their joint impacts) play greater roles compared to product and process innovation.

Furthermore, the findings of the study have an important policy implication for developing countries. The experience of developing ASEAN, which has undergone steady structural transformation

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and becoming services dominant, suggests that the tertiary sector’s investment in knowledge pays off. As the service sector is increasingly playing a key role in developing economies, their catch-up with advanced economies depends to a large extent on innovation in this sector. As such, it is suggested that services firms in developing countries allocate more resources in R&D and other knowledge inputs.

Drawing from our study, further research could analyze single-product-dominant services firms’ (in terms of sales revenue) lower propensity as well as intensity to invest in innovation, preferably using panel data.

**Author Contributions:** M.S.I. and J.Z. designed the research, developed methodology, and interpreted the results; M.S.I. drew up the theoretical framework, gathered and analyzed the data, and wrote the introduction and conclusion of the paper; J.Z. provided extensive suggestions throughout the study and contributed to refining the theoretical arguments. All authors have read and agreed to the published version of the manuscript.

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### Appendix A

**Table A1.** Mean test (two-sample t-test) of different types of innovation of R&D and non-R&D firms.

| Innovation over R&D (0/1) | Mean (RD = 0) | Mean (RD = 1) | Dif   | St_Err | t_Value | p_Value |
|---------------------------|---------------|---------------|-------|--------|---------|---------|
| Product                   | 0.157         | 0.572         | −0.415| 0.039  | −10.65  | 0       |
| Process                   | 0.165         | 0.684         | −0.519| 0.04   | −13.15  | 0       |
| Organization              | 0.194         | 0.592         | −0.398| 0.042  | −9.45   | 0       |
| Marketing                 | 0.209         | 0.684         | −0.474| 0.043  | −11.05  | 0       |
| Technological             | 0.089         | 0.459         | −0.35 | 0.032  | −11.05  | 0       |
| Nontechnological          | 0.122         | 0.449         | −0.327| 0.035  | −9.15   | 0       |

**Table A2.** Distribution of sample firms, by country.

| Country     | Number of Firms | Percent |
|-------------|-----------------|---------|
| Cambodia    | 126             | 8.37    |
| Indonesia   | 228             | 15.14   |
| Lao PDR     | 226             | 15.01   |
| Malaysia    | 305             | 20.25   |
| Philippines | 200             | 13.28   |
| Thailand    | 174             | 11.55   |
| Vietnam     | 247             | 16.4    |
| Total       | 1506            | 100     |
The OSLO manual [33] defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." (OECD, 2005)

### Explanatory and control variables

| Variable                          | Definition                                                                 | Previous Research |
|-----------------------------------|---------------------------------------------------------------------------|-------------------|
| R&D propensity (rd_d)             | Dummy with a value 1 if firms engage in R&D, 0 otherwise                 | According to endogenous growth models, the accumulation of R&D and human capital is the main source of long-term economic growth [59,51]. R&D expenditures represent the key engine of technological progress, innovation, and economic growth [4,52]. The importance of R&D to innovation activity within firms is established by Roper, Du [53]. Firms’ involvement in R&D increase their existing stock of knowledge, facilitating commercial gains with the introduction of new products, processes, and organizational innovation [53]. Numerous empirical studies captured favorable impacts of innovation effort on innovation output [34,54,55]. |
| R&D intensity (ln_intensity)      | Logarithm of R&D expenditure per worker                                  |                   |
| Product innovation (prod_i_d)     | Dummy with value 1 if any new or significantly improved product or service is introduced by this establishment, 0 otherwise |                   |
| Process innovation (proc_i_d)     | Dummy with value 1 if any new or significantly improved process is introduced by a firm, 0 otherwise | Studies report human capital such as schooling, training, etc., enhance knowledge (capabilities) and has a cumulative effect [57]. |
| Organization and management innovation (org_m_i_d) | Dummy with value 1 if firms make any changes in their organizational and management structure, 0 otherwise | R&D activity by Multi-National Corporations (MNCs) are seen as significant factors for sustained economic growth and development of product and/or process innovation [58]. In an influential study, Melitz [59] shows that exporting firms have relatively high productivity. Export performance and innovation have mainly employed the intensity of R&D as a measure of innovation [49]. |
| Marketing innovation (mrk_i_d)    | Dummy with value 1 if establishments make any changes in their marketing strategy, 0 otherwise | Quality certification provides information about “unobservable process characteristics” and help enterprises to boost their legitimacy [61]. ISO900 certification may have two opposing effects: it facilitates process innovation but stifles product innovation [62]. |
| Application of information technology (info_d) | Dummy if firms apply information technology (email, website, etc.), 0 otherwise |                   |
| Human capital1 (schooling_d)      | Dummy if at least 80% employees received formal education, 0 otherwise     |                   |
| Human capital2 (formal_train_d)   | Dummy if employees of a firm receive formal training, 0 otherwise         |                   |
| FDI (fdi_d)                       | Whether foreign stakeholders own at least 10 percent share of a firm       | R&D service firms make marked contributions to innovation in other businesses [56]. |
| Exporter (ex_d)                   | A dummy variable takes value 1 if firms are exporter, 0 otherwise         | Studies report human capital such as schooling, training, etc., enhance knowledge (capabilities) and has a cumulative effect [57]. |
| Quality certificate (qc_d)        | Dummy with value 1 if firms acquire quality certificate, 0 otherwise       | R&D activity by Multi-National Corporations (MNCs) are seen as significant factors for sustained economic growth and development of product and/or process innovation [58]. In an influential study, Melitz [59] shows that exporting firms have relatively high productivity. Export performance and innovation have mainly employed the intensity of R&D as a measure of innovation [49]. |
| Access to finance (credit_d)      | Dummy with value 1 if firms have access to finance, 0 otherwise            | Quality certification provides information about “unobservable process characteristics” and help enterprises to boost their legitimacy [61]. ISO900 certification may have two opposing effects: it facilitates process innovation but stifles product innovation [62]. |
| Location (capitalcity_d)          | Dummy with value 1 for those firms located in a capital city and 0 otherwise | In a competitive market, R&D and innovative activities are difficult to finance [63], however, Stephen, Harhoff [64] show investment in R&D is not sensitive to financial constraints. |
| Subsidiary (partgroup_d)          | Dummy with value 1 if the firm’s financial statement is audited, 0 otherwise | Subsidiaries “proactive innovation” is an important capability of competitive firms ([65]) and that R&D is a key source of such innovation [66]. Further, a major intent of many subsidiary-based innovation is to enhance the technical capabilities of the firm [67]. |
| Firm size (ln_emp)                | The logarithm of level of employment                                     | Firm size matters for the decision to invest in R&D as well as for subsequent innovation output [68]. Huargo and Jaumandreu [69] find new firms are more innovative, however, Galende and de la Fuente [70] argue that “age reflects the experience and accumulated knowledge in the performance of R&D activities.” |
| Firm age (ln_f_age)               | The number of years a firm has been in operation (natural logarithm)      | Capabilities of managers are identified as a key factor to determining firm-level innovation of technology firms [71]. |
| Sales from first or main product (firstp_sale) | Percentage of sales derived from firms’ main product                  | Firm obstacles are discussed in literature. It is hard for politically unstable countries to attract FDI, a factor to enhance firms’ innovativeness [72]. |
| Top managers’ experience (exp_m)  | Year of experience that firms’ top managers possess                     |                   |
| Labor force obstacle (Obstacle_labor) | A dummy variable takes value 1 if inadequately educated labor force is considered as high to severe obstacle, 0 otherwise |                   |
| Political obstacle (obstacle_politics) | A dummy variable takes value 1 if political unrest is a high to severe obstacle, 0 otherwise |                   |
Table A4. Matrix of correlations.

| Variables  | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  | (7)  | (8)  | (9)  | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| (1) rd_d   | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (2) ln_rdintensity | 0.95 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (3) prod_i_d | 0.25 | 0.22 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (4) proc_i_d | 0.32 | 0.30 | 0.48 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (5) org_m_i_d | 0.23 | 0.22 | 0.34 | 0.54 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (6) mrk_i_d | 0.28 | 0.26 | 0.37 | 0.54 | 0.49 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (7) ln_emp | 0.12 | 0.11 | 0.16 | 0.26 | 0.24 | 0.24 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (8) ln_f_age | -0.01 | -0.01 | -0.05 | -0.02 | -0.01 | -0.05 | 0.20 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (9) capitalcity_d | 0.04 | 0.04 | 0.11 | 0.01 | -0.03 | -0.00 | -0.03 | -0.00 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |
| (10) firstp_sale | -0.12 | -0.12 | -0.21 | -0.20 | -0.16 | -0.17 | -0.09 | 0.02 | 0.08 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |
| (11) f_own_d | -0.01 | -0.01 | 0.09 | 0.00 | -0.01 | 0.02 | 0.17 | 0.07 | -0.01 | -0.12 | 1.00 |      |      |      |      |      |      |      |      |      |      |      |
| (12) ex_d | 0.07 | 0.08 | 0.04 | 0.10 | -0.00 | 0.04 | 0.14 | 0.07 | -0.02 | -0.19 | 0.23 | 1.00 |      |      |      |      |      |      |      |      |      |
| (13) partgroup_d | 0.00 | 0.01 | 0.18 | 0.17 | 0.11 | 0.12 | 0.22 | 0.02 | 0.00 | -0.13 | 0.18 | 0.09 | 1.00 |      |      |      |      |      |      |      |      |
| (14) fe_audit_d | 0.11 | 0.10 | 0.15 | 0.19 | 0.31 | 0.21 | 0.22 | 0.04 | -0.06 | -0.10 | 0.06 | -0.03 | 0.23 | 1.00 |      |      |      |      |      |      |      |
| (15) info_d | 0.12 | 0.11 | 0.18 | 0.19 | 0.16 | 0.20 | 0.44 | 0.06 | 0.04 | -0.05 | 0.12 | 0.10 | 0.22 | 0.19 | 1.00 |      |      |      |      |      |      |
| (16) qc_d | 0.09 | 0.10 | 0.05 | 0.10 | 0.08 | 0.10 | 0.25 | 0.10 | -0.04 | -0.10 | 0.18 | 0.15 | 0.18 | 0.12 | 0.18 | 1.00 |      |      |      |      |      |
| (17) schooling_d | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.12 | 0.11 | -0.05 | -0.04 | -0.07 | 0.03 | -0.04 | 0.02 | 0.08 | 0.12 | 0.06 | 1.00 |      |      |      |      |
| (18) formal_train_d | 0.21 | 0.18 | 0.29 | 0.29 | 0.25 | 0.32 | 0.38 | 0.06 | -0.00 | -0.10 | 0.12 | 0.09 | 0.27 | 0.25 | 0.35 | 0.20 | 0.10 | 1.00 |      |      |      |
| (19) obstacle_labor | 0.07 | 0.08 | 0.11 | 0.07 | 0.04 | 0.04 | 0.03 | -0.01 | 0.01 | 0.01 | 0.03 | -0.03 | 0.02 | -0.04 | 0.02 | -0.00 | 0.07 | 0.04 | 1.00 |      |      |
| (20) obst_politics | -0.03 | -0.03 | -0.02 | -0.02 | -0.06 | -0.06 | 0.04 | 0.06 | 0.13 | 0.08 | -0.04 | -0.01 | 0.01 | -0.04 | 0.05 | 0.01 | -0.18 | -0.01 | -0.06 | 1.00 |      |
| (21) credit_d | 0.14 | 0.15 | 0.10 | 0.18 | 0.23 | 0.24 | 0.25 | 0.04 | -0.10 | -0.11 | 0.03 | 0.05 | 0.01 | 0.11 | 0.17 | 0.12 | 0.09 | 0.17 | 0.03 | -0.03 | 1.00 |
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