JSEG

JOURNAL OF SMART ECONOMIC GROWTH

www.jseg.ro ISSN: 2537-141X Volume 5, Number 2, Year 2020

THE MARGINAL IMPACT AND SPILLOVER EFFECTS OF INCREASED EXPENDITURE ON CYBER SECURITY IN US IT INDUSTRY AND GDP GROWTH RATES

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Abstract: *Using simple baseline econometric equations and marginal impact differentials, the study finds that expenditure on cyber security increased over the period (2010 – 2019) to enhance security in cyber ecosystem. Furthermore, some of the legacy systems that are deployed for cyber defense are very porous and ineffective. In 2019, the threat continued to evolve and the complexities continued to increase. The expenditure variable shows positive relationship with IT growth rate. However, the marginal analysis does not indicate positive marginal impact on productivity growth rate in the US IT industry for eight years out of ten. The data show negative marginal impact for eight years except 2014 and 2017. The major reason is that these funds are spent on the protection of cyber ecosystem and not in the expansion of cyber / IT industry products. The spillover effect of this huge spending impacted positively on US GDP and increased its economic growth rate throughout the period of study.*

JSEG
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www.jseg.ro ISSN: 2537-141X Volume 5, Number 2, Year 2020

Keywords: Cybercrime, Cyber Security Expenditure, IT Industry Growth Rate, US GDP, Economic Growth Rate

1. Introduction

Attacks on the medical and the banking eco-systems are on the rise because the data stored in their system is beneficial and therefore, data safety is often fragile in comparison to other sectors of the economy (Warburton 2017). Most of the legacy systems used for cyber defense are very porous and ineffective. In 2019, the threat continued to evolve and the complexities continued to increase. Cyberattacks' average cost per breach surpassed near $2.5 million. These costs include but not limited to notification, forensics, legal fees, and fines (Takahashi 2019). Understanding and responding to the threats is the difference between abnormal and normal intrusion cases in a network. The most common types of identified signature and signature-less malware are: "phishing attacks, negligent and malicious insider attacks, advanced persistent threats, cyberattacks, zero day attacks, known software vulnerabilities, social engineering, denial of service attacks (DOS), and brute force attacks" (Opara et.al 2017).

Enterprise systems that process and maintain personal information is responsible for its protection. Laws and standards established by regulating agencies on how big-data and client information which are not used or in transit are protected and secured for network security reasons. These include bank information, healthcare records preservation, and customer confidentiality issues that may lead to legal fees, undetermined costs, and consequences on the firm's integrity when such data were are breached (McMillian et. al 2017). Assurance on encrypting data that is in motion or at rest is extremely critical. Data at rest is defined as inactive data that is stored in any digital form. This data could be housed in databases, data warehouses, and spreadsheets. Others storage methods include archives files, tapes, off-site backups, and mobile devices (Spadafor 2020). Encrypting this data is critical to prevent hackers or bad actors from hacking into the vaults to obtain information for malicious activities (Valinsky 2020). Security experts have predicted a more that 15% annual cybersecurity market trend until 2021, as compared to more than 10% predicted by various market specialists (Wawa data breach 2020).

The financial damage and costs by data breaches will continue to drive the rising cost of cyber security defense activities. Leading enterprise systems and global entities are categorized as leaders in the eco-platform due to mitigation and implementation of cyber best practices and responses to a breach. When they fail to respond, it could lead to extinction of the organization (Data breach 2019). Currently, the worldwide cybersecurity market is worth approximately $194B in 2020, and it is expected to grow to $290B by 2027. By 2026, 83% of cybersecurity spending will be for externally managed security services (Cyber Security Ventures 2020).

All systems are at risk and the number of these threats will continue to grow. Global cyber-security expenditures will continue to grow exponentially surpassing the trillion-dollar threshold that was originally predicted in 2017 (Steve Morgan 2019). Below is an overview of data exposure in 2019.

According to SonicWALL Global Cyberattack Trends (2019), analyst predictions are off target due to the exponential rise in cybercrimes. These include ransomware attacks that install destructive malware from laptops and PCs to smartphones and wireless devices. Others include the Internet of Things (IoT) and hackers-for-hire. Since malware does not have to be present on a system for it to be compromised, the arbitrator employs tools such as shell shock, Ghost RATs, Zero Day, Regi, Stuxnet, Advanced Persistent, and Ransomware as a mode of attack. Below is an overview of data exposure in 2019.

Table 1. Overview of Cyberattack Exposure in 2019

Institution	Category	Reported	Exposed (Million)
Orvibo	IoT	7/1/2019	2000
First American	Banking/Credit/Financial	5/25/2019	885
Facebook	Social Media	3/21/2019	600
Capital One	Banking/Credit/Financial	7/19/2019	106
LabCorp	Medical/Healthcare	6/4/2019	7.7
AMC Networks	Entertainment	5/1/2019	1.3
T-Mobile	Business	11/22/2019	1
Suprema	Medical/Healthcare	8/25/2019	1
Chtrbox	Social Media	5/20/2019	49

SonicWall Global Cyberattack Trends 2019

The explosion of these attacks necessitates the development of innovative technological and strategic remedies to secure the eco-system (McMillian et.al 2017) which has marginal impact and spillover effect on industry growth and that of the economy at large. The restructuring process infuses key features of macroeconomic measures both in short and long-run growth during business cycles. In the long run, the process of creative destruction is responsible for more than 50% in productivity growth (Schumpeter, 1942). This research attempts to answer the following questions: "Do the heavy expenditures by IT players in the United States to execute actionable solutions against threats in the cyber security eco-system enhance IT industry growth by its marginal impact? Do the increasing expenditures assist in increasing United States GDP growth?

2. Prior Studies

Steve Morgan (2019) summarized that the cybersecurity market has continued its growth towards the trillion-dollar mark that was predicted 2017. Winder (2019) suggested cyber expenditure at the federal level in United States has increased from about $8 billion in 2007, and may grow at 12% annually in order to reach approximately $25 billion mark by 2022.

Cybersecurity firms predict that the world blockchain transaction may be greater $40 billion the end of 2025. A survey shows that industry investors from pension and hedge funds as well as private equity agreed that blockchain market will exhibit the greatest influence on healthcare, financial and banking services. It is found that about 40% of industry players accept that blockchain will transform the banking sector just as the Internet is to media.

Whittaker (2019) summarized that the data breach is defined as a security occurrence in which critical important data are penetrated and used by an unauthorized person to gain access into the network systems. A large phishing incident of note, is the attack that affected major search engine and social media firms. Google and Facebook were swindled for more than $100 million in a highly complicated incident. This becomes a major concern due to its effect on the supply chain and trade because trade is generally motivated by trust.

In 2019, the per unit cost of a data breach was noted as $3.62 million worldwide. This is an increase of more than 20% from 2013. United States recorded about $8 million per unit cost per data incident. This indicated an increase of 25% from 2013 (Steve Morgan 2020). An earlier

study by Steve Morgan (2004) showed that the global cyber security expenditure was approximately 4.8 billion. However, a later study by Whittaker (2019) revealed that global expenditure on cybersecurity outputs will be greater than $1 trillion in aggregate by the year 2022.

Boniface (2020) found that the most perilous cyber-terrorism incidents are the one that impact national defense and intelligence networks, U.S. infrastructure systems, and market systems. While cyber-terrorism incident does not have the same visual optical effects as in bombing attack, cyber-terrorism incident usually often cause widespread financial losses that affects governments, businesses, and consumers. If there is a cyber-terrorist attack on Amazon.com website, likely clients would purchase online products and services from other online business. In this circumstance, it is not only Amazon.com that would potentially lose sales revenues, other online business may be affected and therefore some business or competitors could benefit from this incident. According to Ashok (2016), about 40 million online user accounts were breached, when hackers gained entry into a firm data network system in 2016. The report abridged that the data were provided to hackers by an anonymous source. The stolen data contain confidential information such as usernames, passwords, email addresses and IP addresses.

Steve Morgan (2019), stated that the cyber security market has continued its levels growth and is dashing towards the anticipated trillion-dollar target that was projected in2017. Williams (2019), Low (2019), and Stempel (2017) in their reports narrated that cyber security industry is growing at an astronomical rate. As the attacks grow, novel malware emerges. Even though, great funds are being employed to stop these cyber-incidents, structure and direction of this growth of the industry has to be studied and evaluated. In this research, marginal impact analysis and Spillover effects of the aforementioned expenditure on IT industry growth rate and GDP growth rate are carried out to test the validity of the above studies'.

3. Method

To find answers to the research questions; two baseline econometric models are constructed on expenditures impact on industry growth rate and the GDP growth rate for the period 2010 to 2019.

$$\text{ITindustrygrowthrate}_t = \alpha_0+\beta_1 Exp_t+\beta_2 X_t+\beta_3 \text{Interestrate}_t+ \beta_4 \text{Exp}_t \text{*Interestrate}_t + \beta_5 \text{edu}_{it} \geq \text{hs}_t +\varepsilon_{it} \quad (1)$$

$$\text{GDPgrowthrate}_t = \beta_0+\beta_1 Exp_t+\beta_2 X_t+\beta_3 \text{Interestrate}_t+\beta_4 \text{Exp}_t \text{*Interestrate}_t+ \beta_5 \text{edu} \geq \text{hs}_t + \varepsilon_t \quad (2)$$

In the first test on the impact of IT expenditure on industry growth rate, the study uses the model below:

$$\text{ITindustrygrowthrate}_t = \alpha_0+\beta_1 \text{Exp}_t+\beta_2 X_t+\beta_3 \text{Interestrate}_t + \beta_4 \text{Exp}_t \text{*Interestrate}_t + \beta_5 \text{edu}_{it} \geq \text{hs}_t +\varepsilon_{it} \quad (3)$$

Where Exp_t is the expenditure in the US IT industry to combat cyber-attacks. Exp_t is the volume of fund spent in the above industry for the period of study. X_t represents control variables for the industry IT at time t, Interestrate_t represents the interest rate in the loanable fund market for industry IT at time t (Interest rate determines market demand and Supply for loan), α_0 represents the sector fixed effects, Exp_t *Interestrate_t indicates the interaction effect of interest rate and expenditure on IT industry growth rate, edu_{it} captures literacy rate and ε_{it} represents the error term. In the second test which is the impact of expenditure on GDP growth rate, the study uses the following baseline econometric model:

$$\text{GDPgrowthrate}_t = \beta_0+\beta_1 Exp_t+\beta_2 X_t+\beta_3 \text{Interestrate}_t+\beta_4 \text{Exp}_t \text{*Interestrate}_t+ \beta_5 \text{edu} \geq \text{hs}_t + \varepsilon_t \quad (4)$$

Where Exp_t is the expenditure on the US IT industry to combat cyber-attacks. Exp_t is the volume of fund spent in the above industry for the period of study. X_t represents control variables for the industry IT at time t, Interestrate_t is the interest rate in the loanable fund market for industry IT at time t, α_o represents the sector unobserved effects, Exp_t *Interestrate_t is the interaction effect of interest rate and expenditure on IT industry growth rate, edu_{it} represents the number of the population with high school diploma or education captured by literacy rate and ε_{it} represents the error term. In order to find how the volume of fund impacts on IT industry growth rate and GDP growth rate, a partial derivative of the baseline equation on industry growth rate with respect to expenditure is taken as follows:

$$\frac{\partial y_t^*}{\partial Exp_t} = \beta_1 + \beta_4 Interestrate_t. \quad (5)$$

Where y* is the IT industry growth rate for the first baseline econometric model. In the second model, it stands for the GDP growth rate.

4. Procedure and Data

For the first and second models, data from Bureau of economic analysis are used. Firms are classified based on North American Industry Classification System (NAICS) criteria. The data picked are from firms that meet these criteria as IT firms. For both models, the period of focus is from 2010 to 2019.

Expenditure

This refers to the total fund spent in the IT industry for research and development of cyber-solutions to combat threats in the cyber ecosystem. It could be expenditure by government (public) or IT firms (private). This research outcome leads to innovation, technological breakthrough and growth in the long run. This targeted expenditure has spill-over or multiplier effects on the industry growth in terms of productivity. The increased spending encourages innovation and competition which translates to growth for the entire macro-economy (GDP) (Shanhong Liu, 2019).

Interest rate

This is the price of money in the loanable fund market. It shows the percentage change in the amount initially borrowed and the amount that is returned on maturity. The higher the rate of interest, the lower the amount borrowed; lower the interest rate, the higher the amount borrowed hence high expenditure all things being equal. Therefore, the interaction of fund spent and interest rates determine volume of expenditure and the magnitude of impact on growth in IT industry and the macro economy. (Source of Data: First Republic Bank, 2020)

Control Variables

These are various variables that impact on industry growth and growth of GDP. They are variables like inflation, terms of trade and tariff. This study controls for each of them.

Industry fixed effects

It is pertinent to estimate fixed effects because it helps in removing pernicious impact of omitted variable bias. It is good to worry about unobservable factors in econometric regression especially when they are correlated with variables that are in the regression model. Therefore, fixed effect models are used as good checks for omitted variable bias. In this study α stands for industry (IT industry) fixed effects and the economy as a whole in the two models.

GDP growth rate

This is the growth rate of GDP per capita over the period of study. It measures the economic growth within the study period. The study analyzes how increased spending in IT industry has impacted on general economic activities (output of goods and services) in US economy (Source of Data: Bureau of Economic Analysis, USA 2019).

Education (Literacy rate)

Education in this research paper implies high school diploma and above. The skills acquired from high school are good enough to understand information technology. If the population has high literacy rate, it means that there will be ease of IT technology adoption. There will also be effective labor force (Osho & Ebalunode, 2019). Workers can acquire skill by training easily if they are educated. This is because education enhances technology adoption. Education (literacy rate) in this research work is expressed as the percentage of the population that earned high school diploma and above. The percentage of the literacy level has remained constant and high for the past ten years according to available data in the US. (Source of Data: literacy rate: World Bank, 2019 and percentage of population with high school diploma: Statista, 2020).

IT (Information Technology)

Companies that fall in the information and computer services are classified as IT firms or IT sector. However, presently many companies have IT departments for managing network and

computers and other tech areas of their businesses. (Source of Data: Bureau of Economic Analysis, 2020).

5. Results

The correlation coefficients of all the variables are significant at 0.01 (2-tail) level of significance. It implies that the variables are mathematically relevant in the study and impacts on the regressand (IT industry growth rate and or GDP growth rate). The correlation coefficients are positive and strong. However, literacy rate remained constant throughout the years of study and so has no effect on the regressand and this does not change the outcome. It can be ignored. It has no effect on the outcome and analysis. The correlates of both regression equations show no sign of noise and so the test is good. The decline in interest rate increases expenditure in the IT industry with positive effect on the growth of the sector and the macro economy as a whole

Table 2. Correlates of USA GDP Growth Rate

	USAGDP Growth rate	Expenditure Got_IT	US Interest rate fund market	Interest rate Expend rate	US Literacy rate	Inflation rate
USAGDP growth rate	1					
Expenditure Got_IT	0.514	1				
USInterest Rate fund market	0.558	.771**	1			
Interest rate Expendrate	0.562	.784**	.999**	1		
USLiteracy rate	.a	.a	.a	.a	.a	.a
Inflation_rate	-0.29	-0.043	0.211	0.2	.a	1

**. Correlation is significant at the 0.01 level (2-tailed).
a. Cannot be computed because at least one of the variables is constant.

Table 3. Correlates of IT Industry Growth Rate

	ITIndustry Growth rate	Expenditure Got_IT	USInterest rate fund market	Interest rate Expend rate	USLiteracy rate	Inflation rate
ITIndustry growth rate	1					
Expenditure GotIT	.698*	1				
USInterest rate fund market	0.570	.771**	1			
Interest rate Expend rate	0.569	.784**	.999**	1		
USLiteracy rate	.b	.b	.b	.b	.b	
Inflation rate	0.090	-0.043	0.211	0.200	.b	1

**. Correlation is significant at the 0.01 level (2-tailed).

a. Cannot be computed

In Tables 4, both standardized and unstandardized regression coefficients of expenditure variable are positive which shows that as expenditure increases; GDP variable also grows. The interest rate coefficients are negative for standardized and unstandardized when inflation is controlled which implies that fall in interest rate in the loanable fund market increased demand for fund hence increased spending. However, in Table 5(standardized and unstandardized), when inflation variable is included it shows negative relationship with GDP growth; interest rate increases and expenditure variable declines which impacts negatively on GDP growth rate. Therefore, controlling for inflation in Table 4, it can be deduced that increased expenditure in IT industry in turn increased GDP growth rate in the economy.

Table 4. Regression of USA GDP growth rate without inflation rate variable

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.

		B	Std. Error	Beta		
1	(Constant)	1.677	2.149		.781	.465
	expenditureGot_IT	.000	.002	.156	.257	.806
	USInterestratefundmarket	-.748	6.188	-1.070	-.121	.908
	Interestrate_Expendrate	.001	.004	1.508	.166	.874

a. Dependent Variable: USAGDPgrowth_rate
b. Interest rate is negatively related to GDP growth rate. As interest rate goes down , GDP grows and the study controls for inflation.

Table 5. Regression of USA GDP growth rate with inflation rate variable

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
2	(Constant)	2.690	2.226		1.208	.281
	expenditureGot_IT	-4.269E-5	.001	-.017	-.029	.978
	USInterest_ratefundmarket	.305	6.011	.436	.051	.962
	Interestrate_Expendrate	8.812E-5	.003	.225	.026	.981
	Inflation_rate	-.299	.245	-.428	-1.222	.276

a. Dependent Variable: USAGDPgrowth_rate

In Tables 6 and 7 below, both standardized and unstandardized regression coefficients of expenditure variable are positive which shows that increased expenditure has positive relationship with industry growth rate. The interest rate coefficients are positive for standardized and unstandardized when inflation is or is not controlled yet expenditure increases which implies that increase in interest rate in the loanable fund market did not affect demand for fund hence increase in spending. This, thereby, confirms what the literatures are saying that spike in spending in IT industry is noticed within the period of study due to desperate attempt by industry players to safeguard it from increasing cybercrimes. The marginal impact derivation below will tell us if this massive expenditure has assisted in increasing IT industry growth rate.

JOURNAL OF SMART ECONOMIC GROWTH
JSEG
www.jseg.ro ISSN: 2537-141X Volume 5, Number 2, Year 2020

Table 6. Regression IT Industry growth rate without inflation variable

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
3	(Constant)	-2.462	4.196		-.587	.579
	expenditureGot_IT	.005	.003	.879	1.774	.126
	USInterest_rate_fund_market	11.684	12.084	6.968	.967	.371
	Interestrate_Expendrate	-.007	.007	-7.082	-.958	.375

a. Dependent Variable: IT Industry growth rate

Table 7. Regression IT Industry growth rate with inflation variable

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
4	(Constant)	-2.948	4.918		-.599	.575
	expenditureGot_IT	.005	.003	.914	1.647	.160
	USInterest_rate_fund_market	11.178	13.282	6.666	.842	.438
	Interestrate_Expendrate	-.006	.008	-6.825	-.842	.438
	Inflation_rate	.144	.541	.086	.266	.801

a. Dependent Variable: IT Industry growth rate

Marginal Impact Analysis

$\frac{\partial y_t^*}{\partial Exp_t} = \beta_1 + \beta_4 Interestrate_t$. Where y* is the IT industry growth rate for the first baseline econometric model. In the second model, it stands for the GDP growth rate. The study is interested in the magnitude of the standardized coefficients β_1 (volume of expenditure) such that even if β_4 (interaction effect) is negative; the former is big enough to offset the difference or vice versa. In baseline econometric equation of GDP growth rate controlling for inflation, the marginal impact is positive for GDP growth rate from 2010 to 2019 as shown in Table 8. This is mathematically derived by substituting coefficients β_1, β_4 and yearly interest rate values (2010 – 2019) in the equation(5) after taken partial derivative of the baseline econometric equation(4) with respect to expenditure and solving the equation. In the case of marginal impact with respect

to IT industry growth rate as shown in Table 9, it is almost negative for the period of study save 2014 and 2017. This implies that increased expenditure in cybersecurity has negative marginal impact on IT industry growth rate for the majority of the years under focus except in the two years mentioned above. Therefore, it is right to conclude that there is a positive marginal effect on the Macro economy (GDP) rather than IT industry growth rate. The reason being that these funds are spent on the protection of cyber ecosystem and not in the expansion of cyber / IT industry products.

Table 8. Marginal Impact Coefficients for the GDP growth Equation

Years	Interest Rate	β_1	β_4	$\beta_1 + \beta_4 Interestrate_t.$	Marginal Impact
2010	0.325	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.6461
2011	0.196	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.4516
2012	0.114	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.3279
2013	0.113	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.3264
2014	0.117	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.3324
2015	0.13	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.352
2016	0.39	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.7441
2017	0.132	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	0.3551
2018	1.79	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	2.8553
2019	2.16	0.156	1.508	$\beta_1 + \beta_4 Interestrate_t.$	3.4133

Table 9. Marginal Impact Coefficients for the IT Industry growth Equation

Years	Interest Rate	β_1	β_4	$\beta_1 + \beta_4 Interestrate_t.$	Marginal Impact
2010	0.325	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-1.4227
2011	0.196	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-0.5091
2012	0.114	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	.-0.0717
2013	0.113	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-0.0787
2014	0.117	..879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	0.0504
2015	0.13	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-0.4166
2016	0.39	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-1.883
2017	0.132	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	0.0558
2018	1.79	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-11.798
2019	2.16	0.879	-7.082	$\beta_1 + \beta_4 Interestrate_t.$	-14.418

7. Conclusion

The findings of this research work support the view that increased spending in innovation and research to protect IT industry from the activities of bad actors in the industry leads to enhanced cyber security defense system but has negative marginal impact on growth rate of the IT industry. The overall marginal impact of this huge spending leads to growth in GDP as a result of the spillover effect of the spending into the entire macroeconomic system. So, the research questions: "Do the heavy expenditures by IT players in the United States to execute actionable solutions against threats in the cyber security eco-system enhance IT industry growth by its marginal impact? And or do the increasing expenditures assist in United States GDP growth? The study has answers that are in the affirmative for the latter and not for the former except for two years. The increased expenditure does provide security by inventing new IT software against cybercrime but has not increased marginally IT industry growth rate (perhaps lack of spending in production of new IT consumer products). However, it has a positive spillover effect on US GDP growth rate. There is evidence of increased GDP growth rate for the years of study. Finally, the research does not test the significance level of the marginal coefficients under 95% to 99% confidence interval. It requires deriving the covariance using bootstrap. It is reserved for further studies.

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