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An Analysis of Global High Technology Leadership and the Role of Governmental Incentives

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ABSTRACT

The United States has long been considered a pioneer in emerging technologies. But there is an abundance of literature to document that other nations are catching up and that developing nations adopt advanced technologies by leapfrogging state of the art technology platforms. Countries such as Japan, Korea and more recently China, have emerged as contenders for technology leadership in various areas. In this paper, we first analyze the literature to identify the key factors that determine global technology leadership. Based on the literature, we develop a model to analyze the relationship between these factors and technology leadership. In addition, we propose that government support, such as incentives and expenditure on R&D etc., impact this relationship and strengthen it. We use panel data analysis to test this relationship and our findings indicate that R&D and main science and technology indicators (MSTI) are significant determinants of technology leadership. This work presents several implications and a path forward for global technology leadership.

Keywords:

Technology leadership, government incentives, panel data, global technology development.

INTRODUCTION

The United States has long been considered a technology superpower (Beckley, 2018). However, during the last 3-4 decades, several other nations (e.g., Japan, South Korea, and, more recently, China) have increased their technology development efforts and established their own technology leadership in some areas.

The race for technological superiority is not new, for instance the 'Space Race' is one of the most famous examples of competition among nations for achieving and showcasing technology leadership. Technology leadership itself is a complex construct with numerous interconnected factors. These factors differ among nations based on the diverging approaches to achieving technology leadership. For example, nations differ in the level of Research and Development (R&D) intensity and government policy support for technology development. Literature has captured these differences with regards to innovations machinery employed in Korea (Wang and Tsai, 2010) and a company-based technology development approach in Japan (Lockwood, 2015).

Various frameworks have been used to assess a nation's technology leadership and its characteristics. One perspective is focused on the position of these countries at different points of time in the global economy (Pasierbiak, 2013). The leading position the United States occupied since the pre-war era, Japan's technological development back in the Meiji restoration in the nineteenth century, the rise of South Korea in the 1960s during the military regime (Kim, 2015) and the current swift development in China (Cheung, 2018) reflect some of the dynamics in global technology leadership in different areas. Another perspective is the discussion on emerging economies that are posing a challenge to traditionally advanced economies, sometimes by leapfrogging the traditional technology stages in more developed economies (Brezis et al, 1991; Krugman, 2005). All the countries in this analysis are established leaders in the technology world and/or disruptors that compete for dominance in the market (Hemmert 2007).

The state or nation does not develop technology on its own but rather support its development through incentives and often even consider technology as a factor of production (Brynjolfsson and Hitt, 1995). In order to understand technology leadership, we study how prior literature has analyzed different forms of technology leadership. According to Cheng (1984), there are three forms of evaluating technology leadership which are the technological endowments available to a nation, its companies, entrepreneurs and innovators; the costs of Research & Development (R&D) incurred in an economy in comparison to its GDP; and preemptive behavior by nations to establish incentives schemes that promote the development of technology. In addition, technology leadership is shown through innovative products which serve as model examples of such technological progress of the nation. Improved efficiency through technological progress not only leads to a decrease in the cost of production, but also helps to improve the utility of goods and the introduction of new products and models. Technology leadership is also reflected in the level of foreign trade (or net exports of technological products and services by a nation). Last but not least, government support for these factors impact the relationship between them and nations' technology leadership which we analyze in this paper. In this regard we focus on the following research questions:

- RQ 1 - What are the factors that lead to technology leadership of nations?
- RQ 2 - How do R&D incentives impact these factors of technology leadership?

ROLE OF NATIONS IN FOSTERING TECHNOLOGY DEVELOPMENT

In our research, we envisage a key role of the nation in building, growing and maintaining technology competence on a global level. Nation states themselves serve as independent technological and economic entities that have to compete with other nations across the world for a dominant position in the global technology ecosystem. For doing this, it is the prerogative of the nation to undertake massive private and public investments in R&D. The nation also has to strive to improve its scientific and technical education output as a whole by investing in organized technology research and post-secondary education. Funding agencies in most countries are a traditional mechanism to support R&D in their respective nations.

The role of nations is not limited to fostering technology development through R&D support, but also includes their engagement in a seminal shift in how technology is viewed in not just machines and designs but also in processes and people which are a key part of high-tech environment in the world of today. Today, many researchers consider technological progress as a network phenomenon built on the efforts and inputs from multiple stakeholders and technology leadership is viewed as a function of many of these interacting people, firm, resources and infrastructure. Hemmert (2007) notes that technology leadership is influenced by a varied set of factors such as the innovative venture firms in an economy, various government supported innovation programs, a high general education level in the community, robust university research capabilities, the existence of a skilled and specialized human resources and greater technological linkages between business firms, government labs and universities. Specific activities within the nation play an important role in enabling technological innovation.

RESEARCH MODEL

Technology Leadership

According to Huang and Sharif (2015), technology leadership is commensurate with the R&D intensity of a nation which as an extension is measured by the number of R&D personnel, number of scientific publications and the number of patents filed by individuals and organizations in a country of origin. Other researchers stress that a nation's technology leadership is represented through its extensive economic ties with the rest of the world such as in trade (Paserbiak, 2013). Along with strong ties, the perception of being a global technology leader is associated with a high degree of quality, reliability, and low prices of the products that are developed off of the technology. Technology leadership is connected with the deliberate policy related to technology development on the national economy level which shows the pivotal role that the government plays in promoting and building technology leadership in the first place.

The different perspectives, as seen in the literature, study technology leadership based on different factors and assumptions. From a market-oriented perspective, the position of nations in the global economy signify their technological superiority (Paserbiak, 2013; Huang and Sharif, 2015). Hemmert (2007) and Karabag (2018) discuss technology leadership efforts by emerging nations wherein technological leapfrogging enables nations to achieve a dominant position in the global technology landscape. Some authors focus on the role of nations in formulating deliberate policies to foster technology development at a rapid pace (Cheng, 1984; Mazzucato, 2011; Capri 2020), while others focus on a product-oriented perspective that highlight the importance of developing products that can serve as model examples of technology leadership, for example the production of semiconductors in Taiwan (Paserbiak, 2013; Ozsoy et al, 2022). In addition to these perspectives, prior research has identified different macro-economic indicators that serve as proxies for technology leadership of nations. These relate to a trade-oriented perspective that focuses on the net exports of a nation which signify a dominant position in the global market (Paserbiak, 2013; Smith 2014) and a capital perspective that is based on investments made by a nation in technology development which serve as an indicator of its technology leadership aspirations (Paserbiak, 2013; Hurry et al, 2022). Finally, a growth-oriented perspective focuses on the growth rate of gross domestic product (GDP) of a nation as being indicative of its leading technological position in the world (Fagerberg, 1994; Mićić, 2017), although this indicator needs to be qualified to focus on specific industries. These varied perspectives are presented in Table 1 below.

Technology Leadership		**Articles**
Net Exports (Trade)	Focus on a favorable international balance of trade as being representative of technological progress and leadership.	Paserbiak, 2013; Smith 2014
Investment (Capital)	Focus on greater international investments in a nation as being representative of its favorable technological leadership position.	Paserbiak, 2013; Hurry et al, 2022
GDP (Growth)	Focus on higher growth rate of a nation as being representative of technological progress and leadership.	Fagerberg, 1994; Mićić, 2017

Table 1. Technology Leadership Perspectives

Factors of Technology Leadership

Research and Development (R&D)

Several researchers have proposed multiple parameters that can impact the technology position of a nation. Of them, foremost is the share of expenditure on R&D in relation to GDP which serves as an indicator of intent to foster technology leadership (Li, 2013; Huang and Sharif, 2015). Several studies have noted the importance of strong R&D efforts for enabling technology development and leadership (Paserbiak, 2013). Another important parameter of technology development is the involvement of private companies that are engaged in a constant drive to improve their operational efficiency through the implementation of innovation and advanced technologies. These technology development efforts by private companies result in greater business R&D expenditure within a nation that contributes to its global technological position. This is a major reason for nation states that have a high number of technology companies and engage in significant R&D efforts to achieve technology leadership (Hemmert, 2007). The effect of R&D is also observed on the level of a nation's foreign trade and the index of revealed comparative advantage (RCA). RCA refers to the relative trade performance of individual nations with regard to the technology products, services and commodities manufactured by it. R&D expenses also have a significant impact on achieving a high RCA and in turn on a nation's technological position.

Main Science and Technology Indicators (MSTI)

MSTI include macro indicators of a nation's scientific background, number of patents, level of innovation, risk-taking institutions, creation, development and dissemination of high-tech products and information & communication technology (ICT) goods and services (Nelson and Wright, 1992). ICT development has been characterized by innovation efforts of advanced economies such as USA, UK, Japan and Germany (Avgerou, 2010). ICT is considered as a critical component of global technology development efforts of nations and global technology value chains (Grimes and Yang, 2018). Another indicator is intellectual property (IP) balance of payments which has been linked to increased demand for a nation's technology products and greater foreign investments in the technology industry (Li, 2013). In addition, sophisticated high-tech goods that cannot be produced abroad and the number of overseas branches that remain dominant firms in host countries are strong indicators of technology leadership (Nelson and Wright, 1992) as is the existence of strong technology supply chains within a nation (Cavusgil, 2022).

Technology leadership can encompass various other factors including but not limited to advances in cost efficiency, value for money, rapid commercialization, new business models, new applications of existing technologies, development of stronger and more balanced international linkages, international competitiveness, reasonable quality and low-cost technology products. (Hemmert, 2007; Li, 2013). The different parameters identified in the literature and used in this study are presented in Table 2 below.

Technology Leadership Factors	**Description**	**Articles**
R&D expense	The research and development expenditure within a nation by individual, educational, and business entities.	Cheng, 1984; Nelson and Wright, 1992; Hemmert 2007; Paserbiak, 2013; Li, 2013; Huang and Sharif, 2015.

MSTI - Scientific Background (IP)	The intellectual property, researchers, universities and other MSTI institutions in a nation.	Nelson and Wright, 1992; Pasierbiak, 2013; Huang and Sharif, 2015; UNCTAD 2021
MSTI - No. of Patents (IP)	The number of patents applied for and accepted by residents of a nation.	Pasierbiak, 2013; Huang and Sharif, 2015; UNCTAD 2021
MSTI – High tech Goods and Services (High Tech, ICT)	The export of high tech and ICT goods and services produced in a nation.	Nelson and Wright, 1992; Li, 2013

Table 2. Technology Leadership Factors

Using the identified factors, we hypothesize:

H1a: R&D expenditure will be positively related to the growth rate of a nation.

H1b: MSTI will be positively related to the growth rate of a nation.

H2a: R&D expenditure will be positively related to capital invested in a nation.

H2b: MSTI will be positively related to capital invested in a nation.

H3a: R&D expenditure will be positively related to global trade by a nation.

H3b: MSTI will be positively related to global trade by a nation.

Government policy

There are several ways in which governments support the development and deployment of new technologies, mostly through the support for R&D. Examples include large-scale government grants and low interest loans from state-owned banks or actions to offset the Research and Development (R&D) cost of the companies through tax credits (Nomura & Bickle, 2020). A report from Organization for Economic Co-operation and Development (OECD, 2003) concludes that technology developments incentives range from capital expenditures to allowances and credits and may be targeted and incremental. These include financial perks as well such as cheap financing deals, credit programs, equity stakes in strategic companies and providing loan guarantees. The different types of incentives are presented in Table 3 below. In this study we use two of the support incentives capital expenditures and tax subsidy.

Incentives	Description	Source
Capital Expenditures	The capital expenditures incurred by nations, directly and indirectly supporting R&D activities.	Correa and Guceri, 2013
Allowances and Credit programs	Credit programs provided by governments to allow easy financing of R&D projects.	OECD, 2003; Correa and Guceri, 2013; UNCTAD 2021
Tax Subsidy	Implied and direct tax subsidies provided by government to enable R&D enterprises by businesses.	OECD, 2003; Nomura & Bickle, 2020; UNCTAD 2021

Table 3. Government Support Incentives for Technology Development

Since R&D incentives encourage technology development within a nation (Ohimain, 2013) and foster the rapid deployment and diffusion of high technology products (Andrews et al, 2018), one may posit that that the positive relationship between technology leadership and its factors is contingent on government support for technology development such that the posited relationship will be stronger when there is high provision of government support through expenditures and incentives.

H4a The relationship between technology leadership and its factors will be positively moderated by government support for R&D tax incentives.

H4b The relationship between technology leadership and its factors will be positively moderated by government support MSTI Expenditure.

The different perspectives of Technology Leadership identified from the literature are growth, capital and trade. A nation's growth rate, the amount of capital invested, and the volume of trade are effective indicators of the success of a nation's technology development efforts. These indicators depend on certain factors which affect such development efforts of nations. These are the Research and development (R&D) and the Main Science and Technology Indicators (MSTI). In our model, we propose that a nation's efforts on R&D and its MSTI enhance technology levels and have a direct effect on technology leadership (as observed through the three different perspectives of capital, trade and growth).

In addition to R&D and MSTI, government support is geared towards providing support for technology development efforts through tax subsidies and government financed expenditure on science and technology. In our model, We propose that this government policy support strengthens the direct effect that factors of technology development have on technology leadership. We posit that government support moderates the relationship between factors of technology development and technology leadership such that greater levels of support result in a nation's technology leadership. We present this in our proposed research model as in Figure 1.

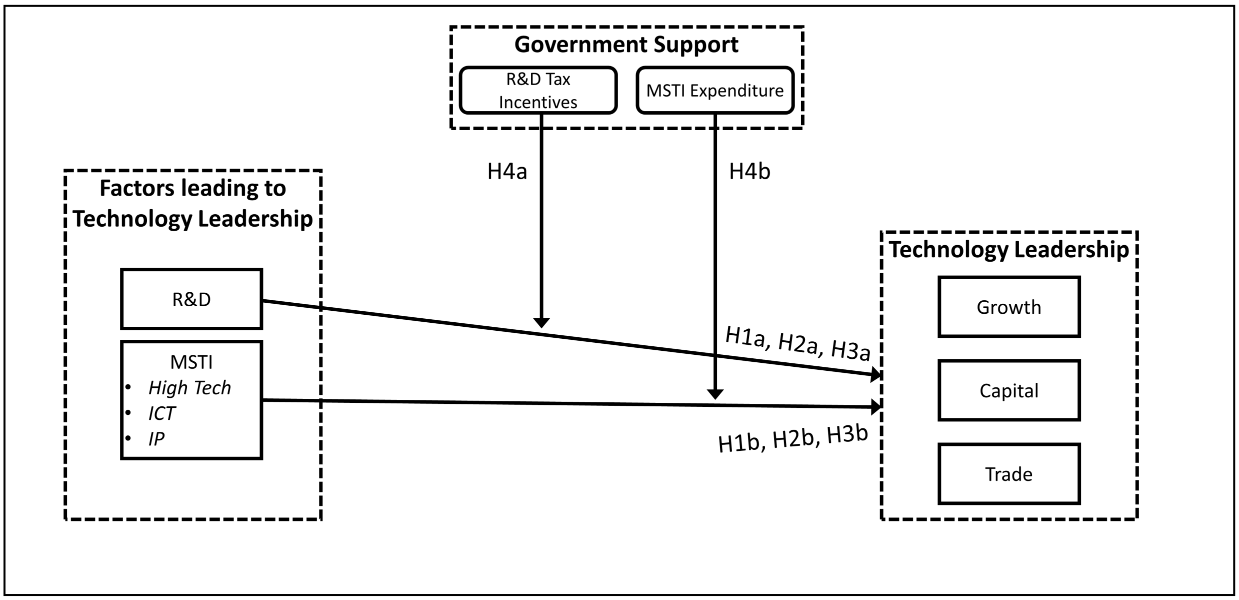

Figure 1. Research Model

METHODOLOGY

Data

To build the preliminary model, we collect longitudinal data for factors of technology leadership and government support in the form of incentives from public data made available by the World Bank and Organization for Economic Co-operation and Development (OECD including data on the R&D tax incentives and implied tax subsidies; and government expenditure on R&D for the development of MSTI. The data points are aggregated as a percentage of GDP across 38 OECD member nations and 5 non-member participating nations, normalized for each country and analyzed using annual data points from 2000 to 2019 for comparing technology leadership.

The data points used for analyzing technology leadership correspond to our stated hypotheses and are presented as below:

Indicator	**Description**	**Source**
R&D	Research and development expenditure incurred by nations as a percentage of the total gross domestic product.	World Bank
R&D Government Tax Incentives	indirect funding provided by the government for tax incentives to offset the cost of investments in R&D.	OECD
Main Science and Technology Indicators - MSTI	These represent the main science and technology indicators that contribute to nations technology development, production and dissemination across the globe. (% of GDP)	World Bank and OECD
• High Tech Manufacturing	Export of high technology goods and services internationally as percentage of the total goods exported by a nation.	World Bank
• ICT Industry	Export of ICT Goods and Services as a percentage of the total goods and services exported by a nation.	World Bank
• Intellectual Property	Payments inflows into a nation for the use of intellectual property.	World Bank
Government Support for MSTI	The expenditure by a nation on government financed activities to foster the development of MSTI.	OECD
Growth	The GDP annual Growth rate of nations.	World Bank
Capital	The level of annual Foreign Direct Investment inflows into a nation.	World Bank
Trade	The current account balance depicting the Balance of Payments of a nation.	World Bank

Table 4. Data Description

Techniques

We use panel data regression to test our hypothesized relationships and normalize the longitudinal data to run three separate models using the STATA MP14 software. Since there are multiple factors affecting technology leadership we start our analysis with an ordinary least square (OLS) model and fit it to our panel data. Further, as the different factors affecting technology leadership are not fixed over the years and change according to nations' policies and economic position, we run a fixed effect model to sufficiently capture individual effects of unobserved independent variables over time.

$$Y_{it} = \beta_1 X_{it} + \alpha_i + u_{it}$$

Here, Y_{it} is the value of the technology leadership variable i at time period (year) t. X_{it} represents the factors of technology leadership. B_1 is the coefficient for the factors. μ_{it} is the error term introduced by the nation-specific effect for nation i. α_i is the unknown intercept for each nation (n nation-specific intercepts)

The least square dummy variable model (LSDV) provides a reliable model to study fixed effects over panel data consisting of values for multiple nations across the different years in the panel (Torres-Reyna, 2007).Therefore using these metrics, we run models to determine the effect of factors of technology leadership on a nation's growth, capital and trade while considering varying levels of government support and tax incentives provided by a nation for fostering research and development of major science and technology indicators.

RESULTS

The results of our panel data analysis for all 43 OECD plus non-member partner nations indicate that the annual GDP growth rate of a nation and R&D expenditure as a percentage of overall GDP have a negative relationship. This may be attributed to the high variation in the development and expenditure among the nations in the panel dataset. While running the analysis for individual nations, we observe that nations that have higher development and R&D expenditure, have a positive relation with the growth rate. This is particularly true for nations like USA, UK, Germany, Canada, and Japan which are considered as highly developed economies (United Nations) and have a higher effect across all observed time periods (Appendix A) and consistent with prior research on technology leadership (Li, 2013; Huang and Sharif, 2015).

The second model was run by combining variables of R&D expenditure and government supported tax incentives while regressing it on the annual GDP growth rate of nations. As with the previous model, the combined model presented research expenditure to be negatively related to growth rate and significantly negatively related to tax incentives. A possible reason for such relationship is the existence of unobservable effects in the dataset, however upon running a fixed effects model the relationship did not change. This implies that government supported tax incentives, when applied together with research expenditure is not a significant relationship that affects technology leadership in the context of a nations' growth rate (Appendix B).

The third model was run for analyzing the overall interaction effects of government supported tax incentives on R&D expenditure and its impact on the GDP growth rate of nations. The model with robust estimations showed that the interaction effect of incentives and research expense by a nation is indeed significant at a p value of < 0.05. With a unit increase in the interaction term, the growth rate of nation rose in almost equal measure (by .91) (Appendix C). This presents support for our hypothesis, H1a, as is also evidenced by prior research that notes the importance of government funded tax incentives for technology development and leadership (Nomura and Bickle, 2020).

In addition to analyzing the growth perspective of technology leadership, we also focused on capital and trade. Using multiple models, we tested the effect of R&D and incentives on capital and trade as well. The model for trade was moderately significant with regression metrics of R-squared of .58, probability (p) of f-statistic (F) $p > F = 0.0000$; however the hypothesized relationship was not observed. The model for capital invested in a nation as a measure of foreign direct investment was not found to be significant for R&D.

Similarly, using a six-year panel data with completely balanced dataset size, we ran multiple models for measuring the effect of main science and technology indicators (MSTI) and its interaction with government expenditure support for MSTI. Capital and growth models were not found to be significant using this interaction relationship. However, we found significant support for the independent variables explaining the dependent variable in the trade model with the strong effect size of > 0.7 (r-squared of .86, $p > F = 0.0000$). 28 nations in the data set fit this model as a nation that had a higher balance of trade corresponded to the nation's higher MSTI and greater government policy support for expenditures on MSTI (Appendix D).

DISCUSSION

We draw several interesting insights from our data analysis. Using our proposed model, we first identify the significant indicators or parameters of technology leadership that can be used to evaluate the nations' technology development and level of advancement. These indicators enable a standardized cross-country analysis of economies that are competing for technological prominence on a global stage. Following the identification of the indicators, we ran multiple models which enabled a comparison of the identified parameters that best represent the technology development efforts of nations. Our findings indicate that R&D and MSTI are strong indicators of a nation's higher growth and greater trade intensity (H1a, H3b, H4a and H4b supported).

There are several contributions from this work which have implications for both research and practice. First, the identified factors of technology leadership can help to guide nations in their technology development, deployment and diffusion efforts. Second, there is limited research on what drives technology leadership at a global stage considering the recent challenges and opportunities that arise from the application of contemporary technologies such as artificial intelligence, quantum computing and online social networking which necessitate an analysis of technology leadership and its factors, such as the one we conduct in this work. From this panel data analysis of nations over multiple decades, we observe that the factors that are significant determinants of technology leadership (growth) are R&D and MSTI (trade linkages).

There are also certain limitations in this work. Our collected dataset includes the OECD nations but does not include the recent OECD members. Also, we consider the last two decades of data (2000-2019). Since we focused on collecting a balanced dataset, we had to eliminate recent years for which data was not available for all countries in the dataset. In our future work, we will collect additional data for recent years, extend our panel data and use more data points for government support variables in addition to MSTI expenditure and R&D tax incentives. In our future work we also plan to focus on analyzing specific high technology industries such as the semiconductor and the automotive industries and test our model with data obtained from the respective industries. We shall also use our model to analyze use cases related to global technology development and leadership efforts of nations as observed in the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act of US and similar acts in Europe.

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APPENDIX

Appendix 1. Country Abbreviations – R&D Model (t = 2000-2019)

Country Name	Country Code	Country_id
Argentina	ARG	1
Australia	AUS	2
Austria	AUT	3
Belgium	BEL	4
Bulgaria	BGR	5
Canada	CAN	6
Chile	CHL	7
Colombia	COL	8
Croatia	HRV	9
Cyprus	CYP	10
Czech Republic	CZE	11
Denmark	DNK	12
Estonia	EST	13
Finland	FIN	14
France	FRA	15
Germany	DEU	16
Greece	GRC	17
Hungary	HUN	18
Iceland	ISL	19
Ireland	IRL	20
Italy	ITA	21
Japan	JPN	22
Korea, Rep.	KOR	23
Latvia	LVA	24
Lithuania	LTU	25
Luxembourg	LUX	26
Malta	MLT	27
Mexico	MEX	28
Netherlands	NLD	29
New Zealand	NZL	30

Norway	NOR	31
Poland	POL	32
Portugal	PRT	33
Romania	ROU	34
Russian Federation	RUS	35
Slovak Republic	SVK	36
Slovenia	SVN	37
Spain	ESP	38
Sweden	SWE	39
Switzerland	CHE	40
Turkey	TUR	41
United Kingdom	GBR	42
United States	USA	43

Source: OECD

Appendix A. Model for direct effect of factors (R&D) on technology leadership (GDP)

GDP growth rate X R&D expense

growth	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
rd	-1.97056	0.43917	-4.49	0.000	-2.83269	-1.10844
country_id						
2	3.925629	1.356393	2.89	0.004	1.262935	6.588322
3	3.807169	1.362172	2.79	0.005	1.13313	6.481208
4	3.051975	1.24112	2.46	0.014	0.61557	5.488379
5	1.684785	0.997504	1.69	0.092	-0.27338	3.642955
6	3.333111	1.153966	2.89	0.004	1.067795	5.598428
7	0.895898	1.124916	0.8	0.426	-1.31239	3.104185
8	1.262087	1.004799	1.26	0.209	-0.7104	3.234578
9	0.808069	1.009266	0.8	0.424	-1.17319	2.789329
10	0.609421	0.997409	0.61	0.541	-1.34856	2.567404
11	2.869458	1.083495	2.65	0.008	0.742482	4.996435
12	3.825843	1.396921	2.74	0.006	1.083589	6.568097
13	3.580067	1.052936	3.4	0.001	1.51308	5.647054
14	5.028082	1.556879	3.23	0.001	1.97182	8.084344

15	2.714923	1.23305	2.2	0.028	0.29436	5.135487
16	3.732258	1.389827	2.69	0.007	1.003932	6.460585
17	-1.51221	1.030829	-1.47	0.143	-3.5358	0.51138
18	1.896241	1.033443	1.83	0.067	-0.13248	3.924961
19	5.131876	1.331618	3.85	0	2.517817	7.745936
20	4.560266	1.055579	4.32	0	2.48809	6.632442
21	-0.1907	1.043408	-0.18	0.855	-2.23898	1.857587
22	4.060566	1.529185	2.66	0.008	1.058668	7.062464
23	7.625716	1.577054	4.84	0	4.529849	10.72158
24	1.89388	0.996986	1.9	0.058	-0.06327	3.851034
25	2.86039	1.006834	2.84	0.005	0.883905	4.836876
26	2.73448	1.097887	2.49	0.013	0.579252	4.889708
27	2.542314	1.02449	2.48	0.013	0.531169	4.553458
28	-0.13192	0.998098	-0.13	0.895	-2.09125	1.82742
29	2.326122	1.169945	1.99	0.047	0.029439	4.622805
30	2.283944	1.259951	1.81	0.07	-0.18943	4.757316
31	1.984742	1.142685	1.74	0.083	-0.25843	4.227912
32	2.388108	1.00395	2.38	0.018	0.417285	4.358932
33	0.204333	1.036627	0.2	0.844	-1.83064	2.239304
34	1.950918	0.997167	1.96	0.051	-0.00659	3.908427
35	2.954939	1.03087	2.87	0.004	0.93127	4.978609
36	2.150446	0.999619	2.15	0.032	0.188125	4.112767
37	3.109526	1.155476	2.69	0.007	0.841246	5.377805
38	1.201633	1.040056	1.16	0.248	-0.84007	3.243334
39	5.8228	1.614012	3.61	0	2.654381	8.991218
40	4.705322	1.711082	2.75	0.006	1.346349	8.064295
41	3.408121	1.001896	3.4	0.001	1.44133	5.374913
42	2.03536	1.110168	1.83	0.067	-0.14398	4.214697
43	4.47464	1.394044	3.21	0.001	1.738034	7.211246
_cons	2.978829	0.739052	4.03	0	1.528018	4.42964

Appendix B1. Model for direct effect of factors (R&D) on technology leadership (GDP) and moderated effect of government support (tax incentives).

GDP growth rate X R&D expense X Tax Incentives

Source	SS	df	MS		Number of obs =	694
					F(2, 691) =	23.30
Model	466.438097	2	233.219049		Prob > F =	0.0000
Residual	6917.49055	691	10.0108402		R-squared =	0.0632
Total	7383.92865	693	10.6550197		Adj R-squared =	0.0605
					Root MSE =	3.164
growth	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
rd	.2791191	.2479635	1.13	0.261	-.2077333	0.765971
incentives	-3.811094	.8696491	-4.38	0.000	-5.518566	-2.10362
_cons	4.347611	.293482	14.81	0.000	3.771388	4.923835

ss - sum of squares; df - degrees of freedom; MS - mean squared errors; F - f-statistics

Appendix B2. Fixed effects model for direct effect of factors (R&D) and government support (tax incentives) on technology leadership (GDP).

GDP growth rate X R&D expense X Tax Incentives

R-sq:	SS	Obs per group:	MS		Number of obs =	694
within =	0.0482	min =	5		F(2, 6649) =	16.43
between =	0.1932	avg =	16.1		Prob > F =	0.0000
overall =	0.0575	max =	20		R-squared =	0.0632
corr(u_i, Xb) =	-0.7993	693	10.65501		Adj R-squared =	0.0605
					Root MSE =	3.164
growth	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
rd	-.7008564	.5569551	-1.26	0.209	-1.794508	.3927952
incentives	-6.751758	1.548355	-4.36	0.000	-9.792149	-3.711367
_cons	7.672523	.9457148	8.11	0.000	5.815493	9.529553
sigma_u	2.1758278					
sigma_e	3.0098518				rho	.3432232

F test that all u^i=0:	F(42, 649) =	2.73			Prob > F =	0.0000

ss - sum of squares; df - degrees of freedom; MS - mean squared errors

Appendix C. Model for direct effect of factors (R&D) on technology leadership (GDP) moderated by government support (tax incentives).

Growth rate X R&D*Tax Incentives

Number of obs =	694				R-squared =	0.0681
F(3, 690) =	17.93				Adj R-squared =	0.0605
Prob > F =	0.0000				Root MSE =	3.1579
growth	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
rd	-.4282065	.3418163	-1.25	0.211	-1.099331	.2429184
incentives	-4.84797	.9222763	-5.26	0.000	-6.658775	-3.037165
rd##incentives	.9098369	.3842606	2.37	0.018	.1553766	1.664297
_cons	5.025389	.4686895	10.72	0.000		

Appendix 2. Country Abbreviations – MSTI Model (t = 2014-2019)

Country Name	**Country Code**	**Country_id**
Argentina	ARG	1
Austria	AUT	2
Belgium	BEL	3
Canada	CAN	4
Chile	CHL	5
Colombia	COL	6
Czech Republic	CZE	7
Denmark	DNK	8
Estonia	EST	9
Finland	FIN	10
France	FRA	11
Germany	DEU	12
Greece	GRC	13
Hungary	HUN	14

Iceland	ISL	15
Ireland	IRL	16
Italy	ITA	17
Japan	JPN	18
Korea	KOR	19
Latvia	LVA	20
Lithuania	LTU	21
Luxembourg	LUX	22
Mexico	MEX	23
Netherlands	NLD	24
Norway	NOR	25
Poland	POL	26
Portugal	PRT	27
Russia	RUS	28
Slovak Republic	SVK	29
Slovenia	SVN	30
Spain	ESP	31
Sweden	SWE	32
Turkey	TUR	33
United Kingdom	GBR	34
United States	USA	35

Source: OECD

Appendix D. Model for direct effect of factors (MSTI) on technology leadership (Trade) moderated by government support (MSTI expenditure).

Trade X MSTI*GERD

Dummy for evaluating country specific effects

variable	ols.	ols_dum
msti	-.08215387	-.02510858
gerd	1.9370511***	-2.3106472*
msti##gerd	.05566777**	-.01368125

country_id	
2	10.876846***
3	8.6896511***
4	3.1046987*
5	-0.15085853
6	-2.2219706*
7	7.0165706***
8	16.52498***
9	6.9010818***
10	3.3093818
11	6.4774039**
12	16.823232***
13	2.5300738*
14	6.6294164***
15	12.238804***
16	4.8332746***
17	7.3269509***
18	12.564639***
19	16.446452***
20	3.1607105***
21	3.2554599
22	9.3749811***
23	0.92433143
24	16.531756***
25	13.179802***
26	3.3310147**
27	5.5156567***
28	8.008749***
29	2.1354503*
30	11.878626***
31	6.129987***
32	13.064875***
33	1.0333829

34	1.5477731
35	6.6471511*
_cons	-2.0866352***
legend:	* p<0.05; ** p<0.01; *** p<0.001