# Fiscal Policy, R&D, and Innovation.

Evidence from OECD countries

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# Abstract

Innovation, made possible through Research and Development (R&D) is a major driving force of economic growth. Due to its quasi-public good nature investments in R&D is usually below the social optimum. Governments use different policy instruments to correct this market failure. In this paper, the Westmore, 2014 paper is reexamined for the role of two fiscal policy instruments, Tax Incentives and Direct Funding, in stimulating private investments in R&D. The analysis is extended for 27 OECD countries in the time period 2000-2017 using Dynamic Fixed Effects Model. Further, the role of income inequality in the private investment in R&D is explored.



**Keywords:** Innovation, R&D, Tax Incentives and Direct Funding, Dynamic Fixed Effects, Macroeconomic Panel Data, Income Inequality.

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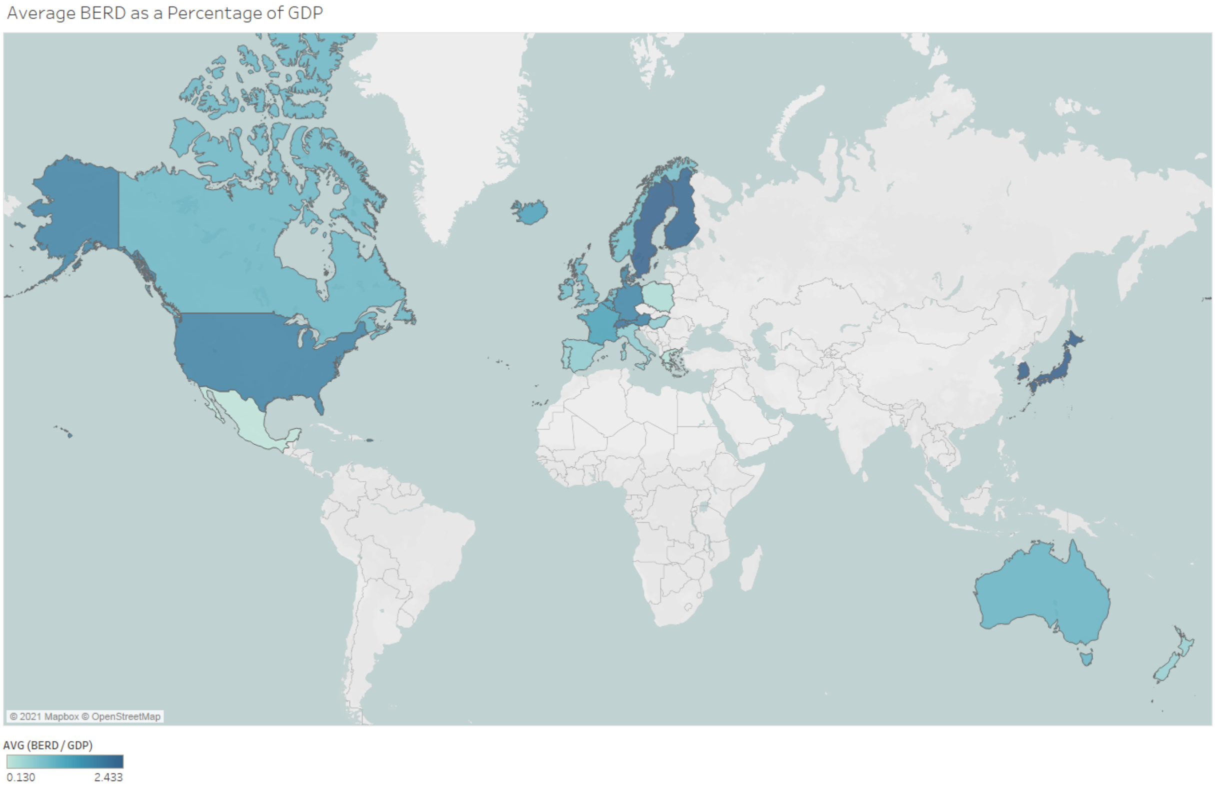
# 1. Introduction

Research and innovation has always been in the forefront of modern economic growth. Every major period of growth from the prehistoric times has been preceded by breakthrough innovations in technology. The first three industrial revolutions, the steam engine, age of science and mass production, and the rise of the digital technology transformed our modern society drastically. We are now at the cusp of the fourth industrial revolution with cutting edge research in the field of artificial intelligence and machine learning. A study by McKinsey Global Institute estimates that between 400 million and 800 million individuals could be displaced by automation by 2030 (McKinsey Global Institute, 2017). Now, more than ever, there is a need for some of the investments in Research and Development to be stimulated and nudged towards R&D that benefits the society at large, through the government policies.

Welfare theories suggest research should be focused to be moved to areas which have higher social returns than private returns as more parts of the society is going to be reliant on the government for support, due to the disruption of the labour market. Borrás et al., 2009 find that globalisation has increased the uncertainty around innovation as firms are faced with rapidly changing international market and institutional conditions. This is an opportunity for the government to intervene and formulate new innovation policies.

In this study an attempt is made to see the effectiveness of targeted fiscal policies, particularly Tax Incentives and Direct Funding in creating innovation. This can used as an indicative signal to the governments when formulating their fiscal policies in the long term to be in tune with the soon to be new world order and in the short term as an effective tool to kick-start the economy, especially during the current pandemic driven recession. Figure1.1 shows the private R&D intensity of the countries in this study.

**Figure 1.1:** Private R&D intensity as a percentage of GDP




As countries move from the early stages of development to the later stages, the economies changes to innovation-based growth, as opposed to investment-based growth (Acemoglu et al., 2016). Due to the high risk and the quasi-public good nature associated with innovations, governments have to step in to foster more innovation to sustain the growth. A mixture of policies can be used to achieve this goal.

The link between fiscal policy, innovation and economic growth has been established by several authors ,Westmore, 2013b and OECD and Eurostat, 2018. This creates a bigger interest for the governments to use innovation to stimulate growth. This paper aims to investigate the policy determinants of R&D, in stimulating innovations in the economy.

This paper is organized as follows: The paper begins with the overview of the relevant Theory in Section2, which is followed by the review of relevant Literature in Section 3. In Section4 the Data and Methodology used in this study is discussed. In Section5 the Results and the Discussion are presented. Section 6 concludes the findings of this paper and recommendations for further research is made.

# 2. Theory

In this chapter the theoretical framework of innovation, the need for government policy instruments in stimulating R&D, the two policy instruments explored in this study and the R&D model used to estimate the policy determinants of private R&D investment is explored.

## 2.1 Innovation

Research and Development has been recognised as a major driving force of economic growth, starting from the work that follows Schumpeter, 1942, Arrow, 1972. Economic growth is is seen as being reflective of the improvements in productivity. The improvements in productivity comes from innovations which in essence is improvements in knowledge. Innovations come from dedicated efforts in Research and Development, which over time could result in a success or failure. In the Schumpeterian growth theory outlined by Aghion and Howitt in their book, ”The Economics of Growth”, innovation has been modelled as a deciding factor of the growth rate of the economy (Aghion and Howitt, 2008). In their theory, an economic agent, ”entrepreneur” has as opportunity to attempt an innovation, by engaging in research activities. If the process is a success, there is a new product which is more productive than previous products. Research is a costly activity and comes with a high risk. The probability of success, $\mu_t$, the innovation function depends on the, final amount $R_t$ spent on research and is defined by the following Equation 2.1, where $A_t^*$ is the productivity of the new product.

$$\mu_t = \phi(R_t/A_t^*) \tag{2.1}$$

Assuming the probability of innovation remains a function of the total amount spend in R&D, increasing the level of R&D could lead to more innovations, productivity and growth.

## 2.2 The Role of the Government

Since economic growth is directly related to the amount spent on R&D, the governments, under whose purview the state of the economy comes, becomes an interested party in the innovation process. The different definitions and schools of thought define different extends to government involvement in the market, but even under the most conservative ones, governments have some role in correcting market failures. Depending on the type of the market failure, the government can adopt multiple policy instruments or a policy mix.

Tassey, 1996 outlines several types of market failures when it comes to R&D. The most compelling reason for justifying government involvement in private R&D is the difference between the social returns and private returns to an investment in R&D, due to knowledge spillovers and appropriability trade-off. Hence the investments in R&D are below the socially optimal level. Other reasons include the high risk nature and the long time of the R&D process acts as deterrents when firms form spending decisions on R&D.

The governments across the world employ several policy instruments to raise the level of capital invested in Research and Development. However, the extend of market failures does not end with the funding stage. Even if the capital invested in Research and Development is at the socially optimal level, the quasi-public good nature of knowledge production presents yet another reason for government intervention.

The private firm's motivation to invest in R&D comes from the monopoly profits of the innovation. The knowledge and research conducted by agencies are excludable and rival prior to the allocation of the Intellectual Property Rights (IPR), but becomes publicly accessible after the allocation. While the use of this knowledge is still restricted, it is not fully excludable. After the expiration of the patent rights, the knowledge is no longer excludable, making R&D a quasi-public good. The quasi-public good nature of innovation threatens to reduce the profits from the research activity and in theory could reach perfect competition levels from monopoly profits, depending on the extend of the spillovers.

To correct this market failure, government steps in to provide legal frameworks to protect the returns from innovation, through market regulations and granting monopoly rights to the use of the new technology, in the form of patents and other protections.

The government can influence the private sector R&D in three stages, before during and after. Before and during the process of the R&D investment, governments can use tax incentives, direct funding, policy frameworks to keep the capital invested in R&D at the socially optimal level. After the innovation is made, the governments can use strong patent rights to correct the market failure.

The governments can use several policy instruments to affect the private investment in R&D, both on tax side and expenditure side. The tax path includes tax incentives,direct funding, IP Box Regimes and other policy frameworks through barriers to entry, product market regulation and signalling. In this study, the impact of two policy instruments, Tax Incentives and Direct Funding is analysed.

## 2.3 Direct Funding and Tax Incentives

Two widely used government policies increase the private R&D are, Direct Funding of the private R&D and Tax Incentives for R&D. These two instruments are designed to correct different types of market failures. Tassey, 1996.

Direct funding of the government is a way for the governments to target specific research projects. Kleer, 2010 finds theoretical evidence that if government subsidies are accompanied by a quality signal, it can lead to better selected or increased private investments in R&D. However, Direct Funding is also susceptible to adverse selection due to asymmetric information and bureaucratic rent seeking behaviour. As for start-ups and small firms, the risk and the time to be taken for an investment in R&D to be successful might be a big deterrent from making the investment, Direct Funding is more effective for applied research and start-ups or small firms. Direct Funding can be in the form of grants, loans and procurement. It may be argued that specific one to one inspection and grants are the best way at stimulating innovation and hence growth however it comes with a cost.

Tax incentives on the other hand is a one size fits for all instrument, used by the governments to effectively increase aggregate R&D. Governments provide tax incentives to increase the funding or performance of R&D. This is done in the national level or in the sub-national level. Tax Incentives have a cost advantage as the administrative costs are lower than the the case of Direct Funding both for the government and the firms applying for grants requires time and expenditure from the firms. Tax incentives are more effective for basic research. Tax incentives include tax credits, tax allowances,tax base, carryovers, refunds, accelerated depreciation of R&D capital and tax relief redeemable against payroll. Tax is non-discretionary hence eliminates human biases and errors.

Understanding the R&D investments, economic theory gives three main reasons for the gap between the internal and external costs of capital (B. H. Hall and Lerner, 2010). Moral Hazards from the inventor/entrepreneur due to the separation of ownership and management , Asymmetric Information between the inventor and the investor, and Tax considerations which could drive a wedge between external finance and finance by retained earnings.

## 2.4 R&D Model

The innovation could be measured in several ways reflected by patent counts Griliches, 1990, or through various measures of R&D stock or flow variables.

The empirical model for estimating the policy determinants for R&D is taken from Westmore, 2014, which is further taken from Jaumotte and Pain, 2005, inspired from Bloom et al., 2002. The production function is assumed to have constant returns to scale. From the first order condition for R&D investment, equating the Marginal Cost to the Marginal Benefit, the long-run relationship of R&D derived as given below.

$$lnRDS_{i,t} = \alpha_i + \beta_t lnY_{i,t} + \tau ln(usercost_{i,t}) + \sum_{j=1}^{n} \varphi_{j,i} Z_{j,i,t} + u_{i,t} \tag{2.2}$$

Where, $RDS_{i,t}$ is a stock variable measuring the total business investment in R&D, for country i at time t. $Y_{i,t}$ is the real output GDP of country i at time t. User cost measures the real cost of R&D for country i at time t. and Z is a vector of additional influences. $u_{i,t}$ measures the error term.

Equation2.2 can be specified as an error-correction specification using $ARDL_{p,q}$ of the Equation 2.2 as given by Westmore, 2014. The error-correction specification is given below in Equation 2.3. This gives insights about the short run dynamics and divergences from an underlying cointegrating long-run relationship, accounting for the time lag between the determinants and the private investments made in R&D.

$$\Delta lnRDS_{i,t} = \alpha_{1,i}\Delta lnRDS_{it-1} + \sum_{j=1}^{m}\rho_{j,i}\overline{Z}_{j,i,t} + \phi_i[ln(\frac{RDS_{it-1}}{Y_{it-1}}) - \delta lnusercost_{it-1} - \sum_{k=m+1}^{n-m}\gamma_{k,i}\tilde{Z}_{k,i,t}] + \alpha_i + \alpha_t + \mu_{i,t} \tag{2.3}$$

In Equation 2.3, $\alpha_i$ measures the country fixed effects and the $\alpha_t$ measures the time fixed effects, capturing the international factors. Z is a vector of m variables that may affect the short-run dynamics and n variables that could explain the long-run cross-country differences in R&D. $\mu_{i,t}$ is the error term.

The R&D model presented in Equation2.3 is the basis for the analysis of this paper and uses a stock measure of the R&D as an indicator of innovation.

# 3. Literature Review

In the last few several decades several studies have tried to explain the innovation process, its drivers and impacts. The heavyweight of innovation comes from its impact on productivity and economic growth, creating a particular interest among economists due to the heterogeneity of the policy framework, possible indicators of innovation and observable and comparable data. Hanusch et al., 2017 examined the impact of several categories of public spending on economic growth in the G20 countries and it found that the public expenditures for R&D have a significant positive effect on macroeconomic growth. Their findings were in accordance with Schumpeterian theory and shows how “innovation driven” GDP growth is necessary for sustainable macroeconomic growth.

The financing of the private R&D is a valid place to explore to understand how private investments in R&D are made. Kerr and Nanda, 2015 find that financial constraints have a large impact on the rate and trajectory of innovation for firms decisions on R&D spending, highlighting the importance of the policy frameworks to raise the level of investment in R&D. B. H. Hall and Lerner, 2010 analyse the financing of innovation in firms, and find evidence of a ”funding gap” and that the R&D is underinvested, even when externalities are absent. They find that large firms prefer internal funds as a source of finance to innovation, and venture capital has limits to bridge the funding gap.

These innovations are quasi-public good, and this means that innovations have positive externalities. These externalities create knowledge spillovers and leads to a higher social rate of return compared to the private rate of return, (Arrow, 1972). This necessitates the government to step in and correct the market failure, through public policies. Also owing to the asymmetric information about the research activity between the inventors and the investors securing funds for the investment comes with a high cost, especially for small firms and start-up firms (Neubig et al., 2016).

Acemoglu et al., 2016 concludes that the government subsidies are more important for economies further from the technological frontier, to prevent the economies switching to innovation-based from investment-based strategy too soon. Without the investment subsidies or product market competition, the countries are likely to be trapped in the investment-based strategy and fail to converge to the world technology frontier.

Kleer, 2010 develops a theoretical framework for the signaling effects of government subsidies for R&D and concludes that the subsidies can be shown as a signal to the private investors to choose to invest in projects with higher social returns and hence spillovers. A government subsidy accompanied by a quality signal can lead to increased or better selected private investments.

Marceau, 2002 find evidence that a national approach rather than a industry specific approach to innovation policy is unlikely to be effective, especially in countries like Australia and New Zealand, where the bulk of R&D decisions are made overseas. Evers et al., 2015 demonstrate that the inclusion of IP Box regimes can result in large reductions in effective tax rates. They also find that there is some evidence of tax competition using the IP Box regimes.

Using a micro-panel, Binelli and Maffioli, 2007 find evidence from Argentinian firms that Direct Funding by the government has a positive effect on private R&D, and also found evidence of adverse selection. Colombo et al., 2011 use micro-data in Italy in the time period 1994-2003 and found evidence that selective R&D subsidies awarded to high-tech startups had a positive impact on Total Factor Productivity, while those granted by automatic process did not have an impact.

Tingvall and Poldahl, 2012 found that international technology spillovers were larger and more significant than domestic inter – and intra- industry spillovers in Sweden using firm level data from 1990-2000. Montmartin and Herrera, 2015 use spatial dynamic panel data to analyse the impact of Direct Funding and the Tax Incentives in 25 OECD countries from 1990- 2009. Their findings suggest crowding out and leverage effects, substitution/competition effect between the two policy instruments and find evidence of positive spatial spillovers among private R&D. Zachariadis, 2004 use aggregated data for a group of 10 OECD countries from 1971-95 to potentially capture the overall R&D spillovers, thereby has a clear advantage over sectoral or industry-level data. The evidence of international spillovers point to the benefits of a macro-panel estimation, as micro studies do not account for these spillovers.

Guellec and Van Pottelsberghe De La Potterie, 2003 finds both direct funding and tax incentives have an impact on stimulating private R&D spending in the short term. Guellec and Van Pottelsberghe de la Potterie, 1997 find evidence that both tax incentives and Direct Funding stimulate private R&D spending and in the long run Direct Funding was more effective, using 17 OECD countries, using an error correction model during 1981-96. Appelt et al., 2019 find that both Direct Funding and Tax Incentives has a positive impact on the level of Business Expenditure on R&D in OECD countries using fixed-effects instrumental variable procedure, from 2000-16. B. H. Hall, 2020 study the effect of taxes on innovation and further reiterates the link between tax incentives and innovation.

Frascatti Manuel (OECD, 2015) outlays the ways to collect data on R&D statistics and sets the base for a uniforms internationally comparable data sets for analysing determinants of R&D. Oslo Manuel (OECD and Eurostat, 2018) outlays guidelines for collecting reporting and using data on innovation. These manuals lays the ground for internationally comparable data and statistics on R&D and innovation, making the econometric analysis of the innovation, research and policies more accessible.

In their review paper of the major research done on the sphere of policy incentives to R&D, B. Hall and Van Reenen, 2000 conclude by predicting that the governments move away from government tax credits to direct funding, which is yet to be explored. Aghion et al., 2019 find evidence of a positive relation between measures of innovation and top income inequality. They also find that social mobility can help spur innovation.

This points to a gap in the research where a model analysing the dynamic nature of the relationship between policy instruments and private investments in R&D has not been estimated in recent time period, in a macro setting. The more recent studies use static models to determine policy determinants of private R&D. Considering that the impact of the globalisation, the possible short-run adjustments , long -run relationships and the fact that the third industrial revolution became more apparent in the recent years and that this has not been studied, I attempt to reexamine the policy determinants of R&D, especially the Tax incentives and Direct Funding, over a bigger geographical area, using macroeconomic panel data and dynamic estimation methods. This paper closely follows Westmore, 2014. An attempt is also made to study the impact of inequality on private R&D spending.

# 4. Data and Methodology

The data used for the estimation of the policy determinants of private R&D stock and methodology used is presented in this chapter.

## 4.1 Data

The countries included in the study are twenty seven member countries of Organisation of Economic Corporation and Development (OECD), Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States. The period under the study was 18 years, from 2000 to 2017, making the total observations 486.

### 4.1.1 Variables

The variables used in the model are, Business Expenditure on R&D (BERD), real User Cost of R&D, Inflation, GDP growth rate, Government Financed Business R&D, B-Index, Product Market Regulation and Policy Reversal Dummy.[1]

**Business enterprise expenditure on R&D (BERD)**

BERD, measured in national currency is the private R&D stock variable from Equation 2.3 of the R&D model presented in Section2. OECD, 2015 defines Business enterprise

[1]IP Box regimes was excluded from the estimation due to lack of comparable data

expenditure on R&D (BERD) as the ”component represents of Gross domestic expenditure on R&D incurred by units belonging to the Business enterprise sector. It is the measure of intramural R&D expenditures within the Business enterprise sector during a specific reference period, measured in national currency”. The BERD data is taken from the OECD Main Science and Technology Indicators (MSTI) Database. BERD is also included in the regression as an autoregressive variable, to check if the change of stock of R&D is path dependent.

**Short-Run Variables**:

**B-Index** : Warda, 2001 developed an index to measure the overall generosity of the R&D tax incentives. The B-Index is the before-tax income needed by a “representative” firm to break even on USD 1 of R&D outlays after-tax cost of investment on R&D for a given pre-tax cost. The B-Index is taken from the The OECD R&D Tax Incentives database, of large and profitable firms. The B-Index is used as a measure of the Tax Incentives, encompassing all different tax policies.

GDP growth rate: The annual growth rate of Gross Domestic Product is taken from the OECD National Accounts Database.

Inflation: Inflation is measured by the Consumer Price Index taken from the OECD Main Economic Indicators Database.

Top 1% Income Share: The share of the pre-tax national income of the Top 1 percentile of adults for country i at time t is used as a measure of inequality. The data is taken from World Inequality Database[2]

**Long-Run Parameters**

User Cost: The real user cost is calculated following Jaumotte and Pain, 2005 and Westmore, 2014 using the formula,

$$usercost_{i,t} = B - index_{i,t} * r_{i,t} + \delta \tag{4.1}$$

where r is the long term real interest rate and delta is the depreciation rate on R&D capital, assumed to be 15% for all countries and all time periods, as in the previous literature (Westmore, 2013a, Guellec and Van Pottelsberghe de la Potterie, 2004 ). The interest rate is taken from the OECD Monthly Monetary and Financial Statistics database. The interest rate is measured as the long term (10 year) interest rates of government bonds.

[2]https://wid.world/data/

Direct Funding of BERD: Government Financed Business Expenditure on R&D is taken from the OECD R&D Tax Incentives database, measured in the respective national currencies. This is the Direct Funding policy instrument of the government in private R&D.

Product Market Regulation: PMR is taken from the OECD Product Market Regulation Database. This variable measures the extend to which policies promote or inhibit competition in the product market. The series covers PMR index from 1998 over every five years. For the purposes of estimation of this paper, for each year and each country in the period under the study, the PMR index of the closest in time to the year was assigned.

Policy reversal: The number of times countries changed their tax policy from generous to stricter and changed it back immediately, as captured by the changes in B-index was tallied and the countries in the top $10^{th}$ percentile were classified as countries with high policy reversal using dummy variables, proxying uncertainty in the tax policy and or the fiscal policy or stability in the government. The countries with high number of policy reversals were, Belgium, Ireland and South Korea. An interaction term between the User Cost and the Policy Reversal dummy is included in the model to investigate if the benefits of a low real user cost of R&D is offset by the uncertainty in policy.

Eurozone: Eurozone is a dummy variable introduced in the model to capture the effects, if any, of the common currency and further the common monetary policy. The dummy variable is measured as 1 from the year the country started using Euro as their national currency.

### 4.1.2 Data Visualisation

To visually explore the data, the Business Expenditure in R&D as a percentage of GDP is plotted for the countries under the study in Figure 4.1. The figure shows the heterogeneity across the countries for the amount spend on Business Expenditure of R&D. In the period under the study, Mexico spent the lowest proportion of their GDP on BERD. Korea and Japan has the highest average over the years, However, Korea's spending on BERD has more variation.

Further, the two policy instruments under study, the average of Tax Incentive and Direct Funding, averaged across time is plotted in Figure 4.2.

**Figure 4.1:** BERD as a Percentage of GDP

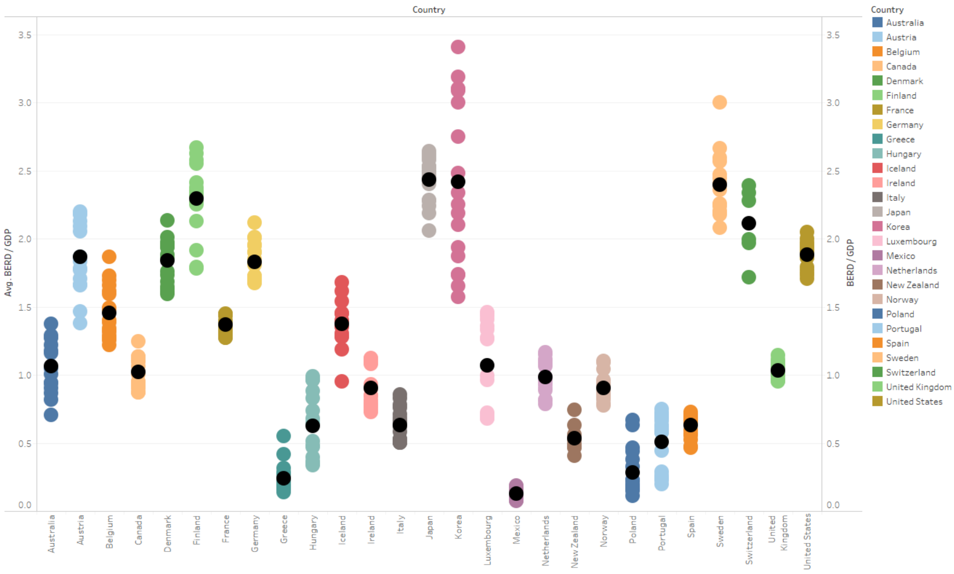
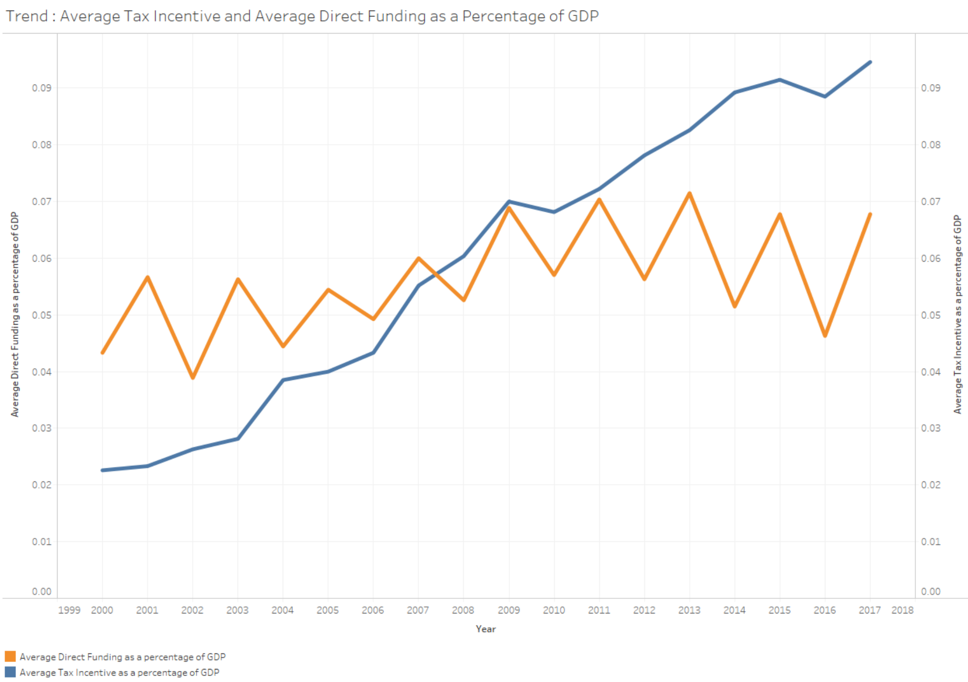



**Figure 4.2:** Trend: Average Tax Incentive and Direct Funding as a Percentage of GDP



From the figure, we can observe that there has been a shift towards Tax Incentives as a preferred fiscal policy instrument over Direct Funding. In the beginning of the period under the study, Direct Funding was the preferred instrument to target R&D spending, but in 2007, Tax Incentive becomes the preferred instrument, and remains so. The preference for Tax incentive could be owing to the governments pushing for an increase in aggregate R&D. Whether this is also indicative of tax competition among the countries is yet to be explored.

The further visualization of variation of the data across time and across countries is included in Appendix in Figure A.2 and Figure A.1.

## 4.2 Methodology

This study uses macroeconomic panel data to estimate the policy determinants of the Business R&D stock. Analysing macroeconomic panel data requires a different technique than micro panels, as the characteristics of the data affect the performance of the estimator (Judson and Owen, 1999). With an unbalanced panel and observations for 18 years and 27 countries, a large T large N panel might have a non-stationarity problem. To investigate this, panel unit root tests are conducted.

### 4.2.1 Panel Unit Root Tests

The R&D model was tested for panel unit root test, both by Augmented Dickey Fuller test and Phillips–Perron unit-root tests. The results showed that the null hypothesis that the panel had a unit root could not be rejected, making the panel non-stationary. Hence, the non-stationary heterogeneous panel data estimation method, dynamic fixed effects is used to analyse the determinants of R&D stock variable. Pesaran et al., 1999 finds that the dynamic heterogeneous panel regression can be incorporated into the error-correction model using $\text{ARDL}_{p,q}$, where p is the lag of the dependant variable and q is the lag of the independent variables.

### 4.2.2 Dynamic Fixed Effects

Blackburne III and Frank, 2007 find that in the event of non-stationarity in a macro panel, traditional fixed effects or random effects model cannot be used as the assumption of homogeneity of the slope parameter is not viable. They suggest the dynamic fixed effects model as an alternative to the traditional fixed effects model. The dynamic fixed effects model estimates the error-correction specification of the dynamic heterogeneous panel. The method restricts the coefficients of the cointegrating vector to be equal across all panels and further restricts the speed of adjustment coefficient and the short-run coefficients to be equal while allowing panel specific intercepts. Dynamic fixed effects is also the methodology used in the literature closest in scope to this paper, Westmore, 2014.

The ARDL lag structure for the model is chosen in accordance with the current literature, Westmore, 2014, and according to the data limitations, as the time dimension is not long enough to overextend the lags. The following variables are lagged by one period, BERD, B-Index, Inflation, Government Financed R&D, User Cost and Product Market Regulation.

The estimation of the R&D model is done in Stata, using the xtpmg routine, developed by Blackburne III and Frank, 2007. Due to the unbalanced panel, dynamic fixed effects option of xtpmg routine is used.[3]

# 5. Results and Discussion

The results and discussion of the estimated model is presented in this chapter.

## 5.1 Results

Table 5.1 summarises the results from the dynamic fixed effects estimation of the R&D presented in Equation 2.3 R&D model. The intra-group correlation is taken into account during the estimation by using clustered standard errors.

[3]For balanced panels, xtpmg provides pooled mean-group and mean-group options

**Table 5.1:** The Determinants of Business R&D

| | $\Delta ln(BERD)_t$ | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Long-Run Parameters | | | | | |
| $\Delta ln(GovtFinancedBERD)_{t-1}$ | -0.167 | -0.126 | -0.363 | -0.327 | -0.345 |
| | (0.238) | (0.193) | (0.555) | (0.892) | (0.473) |
| Product Market Regulations$_{t-1}$ | -0.937$^{+}$ | -0.844$^{*}$ | -1.005 | | -1.162 |
| | (0.482) | (0.379) | (0.816) | | (0.832) |
| ln(User Cost)$_{t-1}$ | -0.079 | | | 0.056 | -0.039 |
| | (0.082) | | | (0.134) | (0.102) |
| ln(User cost)$_{t-1} * (Policyreversal)$ | | | | -0.298 | -0.187 |
| | | | | (0.395) | (0.178) |
| Short Run Dynamics | | | | | |
| ECM$_{t-1}$ | -0.113$^{*}$ | -0.122$^{**}$ | -0.115 $^{*}$ | -0.118 $^{*}$ | -0.094$^{+}$ |
| | (0.049) | (0.046) | (0.050) | (0.051) | (0.056) |
| Inflation$_{t-1}$ | -0.002 | -0.002 | | -0.007 | -0.002 |
| | (0.005) | (0.004) | | (0.004) | (0.004) |
| GDP growth$_t$ | 0.003 | 0.003 | | 0.002 | 0.003 |
| | (0.002) | (0.002) | | (0.002) | (0.002) |
| $\Delta ln(BERD)_{t-1}$ | 0.326$^{**}$ | 0.317$^{**}$ | | 0.262$^{***}$ | 0.271$^{**}$ |
| | (0.113) | (0.116) | | (0.073) | (0.086) |
| $\Delta ln(B - Index)_{t-1}$ | -0.016 | -0.029$^{**}$ | | -0.014 | -0.024$^{*}$ |
| | (0.010) | (0.010) | | (0.012) | (0.010) |
| ln(Top 1% Income share)$_{t-1}$ | | 0.036 $^{**}$ | | 0.036$^{**}$ | 0.026$^{**}$ |
| | | (0.004) | | (0.005) | (0.005) |
| Intercept | 0.335$^{+}$ | 0.388$^{+}$ | 0.381 | 0.246 | 0.505 |
| | (0.186) | (0.234) | (0.241) | (0.275) | (0.309) |
| $N$ | 486 | 486 | 486 | 486 | 486 |

Standard errors in parentheses
$^{+}$ $p < 0.1$, $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

## 5.2 Discussion

The results of the dynamic fixed effects estimation of the R&D Model is mixed. The impact of different variables on the BERD, is presented below, classified into long-run and short-run variables.

### 5.2.1 Long-Run Parameters

The Product Market Regulation was found to have a negative and weakly significant effect on the R&D,in line with the findings of Westmore, 2014, indicating that the R&D stock is lower when there is high PMR in place which is in line with the expectations as high level of protection makes it difficult for new entrants to enter the markets and make investments inn R&D. This is also in line with the findings of Aghion et al., 2015, that product market competition enhances innovation.

Contrary to the previous studies,Guellec and Van Pottelsberghe De La Potterie, 2003, Guellec and Van Pottelsberghe de la Potterie, 1997, Appelt et al., 2019, and Westmore, 2014 the direct funding of the government had no statistically significant effect on the R&D, there by ruling out any possibility of Direct Funding of the government being complimentary or a substitute for Business R&D. However, there is no comparable study in the same geographical area and time period to make direct comparisons.

### 5.2.2 Short-Run Dynamics

The error correction coefficient, $ECM_{t-1}$ is statistically significant, further proving the support for the model with the long-run disequilibrium in the cointegrating relationship corrected with short-run adjustments. The findings are in line with the findings of Westmore, 2014, however the coefficients of the ECM is higher. As the period under this study is more recent and includes more countries it can be interpreted as in the recent years, the short-run dynamics are faster and 9.4%-12.2% of the adjustment of R&D stock in response to a shock in one of the long-run parameters occurs each year.

The B-index, is significant and negative, indicating the an increase in the generosity of the tax system, indicated by a decrease in the B-Index, affects Business R&D positively.

The measure of income inequality was found to be statistically significant and positive for the level of R&D stock.This is in line with the findings of Aghion et al., 2019, that measures of innovation and income inequality are positively correlated, although their study uses patent data as a measure of innovations. However, the relationship between R&D and patents is already well established in the literature (Hausman et al., 1984, Westmore, 2013b), the findings of the R&D model estimated and the evidence from the previous literature shows that a higher income inequality leads to an increase in Business R&D stock. This could be because as the income share of the Top 1% increases, their investments could increase the venture capital or angel investing, in more lucrative research. Contrary to the findings of B. Hall and Van Reenen, 2000, the results of this study suggests that the shift of the policy mix is towards Tax Incentives, and away from Direct Funding.

# 6. Conclusion

In this study, the impact of two policy instruments, Tax Incentives and Direct Funding of the government in stimulating private investment in R&D is explored for 27 OECD countries for the time period 2000-17. The paper closely follows the methodology and theory outlined by Westmore, 2014. The review of relevant literature also suggested a possible relation between income inequality and innovation. So a measure of income inequality, the income share of the Top 1% of the population for each country was included in the analysis. The R&D model was estimated using dynamic fixed effects model, to account for the non- stationary heterogeneous nature of the macroeconomic panel data.

The results indicate Tax Incentives as having a significant impact on the level of Business Expenditure on R&D, while no significant effect was found for the Direct Funding. This could be a possible reason for a shift towards Tax Incentive as a preferred policy instrument, in the years after 2007. As Tax incentives impact the aggregate spending of R&D, and in the light of the innovation theories that formulate innovation as a function of the total spending on R&D and the results of this study could suggest that governments across the world are trying to increase the probability of innovation, as innovation is the driving force for productivity growth, reflected in the GDP growth rate.

Furthermore, Product Market Regulations had a negative impact on the stock of private R&D stock, possibly meaning that the it is difficult for new entrants to make investments in R&D. The results also suggest that the stock of R&D is path dependant.

In a Schumpeterian model of innovation, research is uncertain, and the probability that innovation occurs is a function of the total amount spent on R&D, of Schumpeter, 1942. In the light of this theory, it is not surprising that the results of this study and the general trend in the fiscal policy of the countries in this study towards R&D is heading towards more tax based incentives rather than direct funding of the R&D expenditure. Another possible reason towards this shift could be the tax competition between the countries, and this remains to be explored.

Furthermore, the study revealed evidence on inequality positively affecting the level of private R&D, in line with Aghion et al., 2019. This along with the ”funding gap” of innovation as evidenced by B. H. Hall and Lerner, 2010 in the financing of R&D indicate a need for policy intervention by government to fill the funding gap, if welfare is a policy objective for the government, and if there exists bidirectional causality between innovation and inequality.

Further research could focus on the impact of Patent boxes as a policy instrument on private R&D,as there is some evidence suggesting that IP box regimes are being increasingly used for tax competition. (Evers et al., 2015). However, the lack of internationally comparable measures and data of IP Box regimes could be a potential setback. Another possible extension for this research could be empirically testing the tax competition between countries for private R&D investments using Tax incentives. Given the impact Tax Incentives have on stimulating private R&D investment, more research could be done across different geographical regions taking into account the dynamic nature of innovation, with also taking into consideration the spatial influences of the data.

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# A. Appendix

**Figure A.1:** Heterogeneity across countries

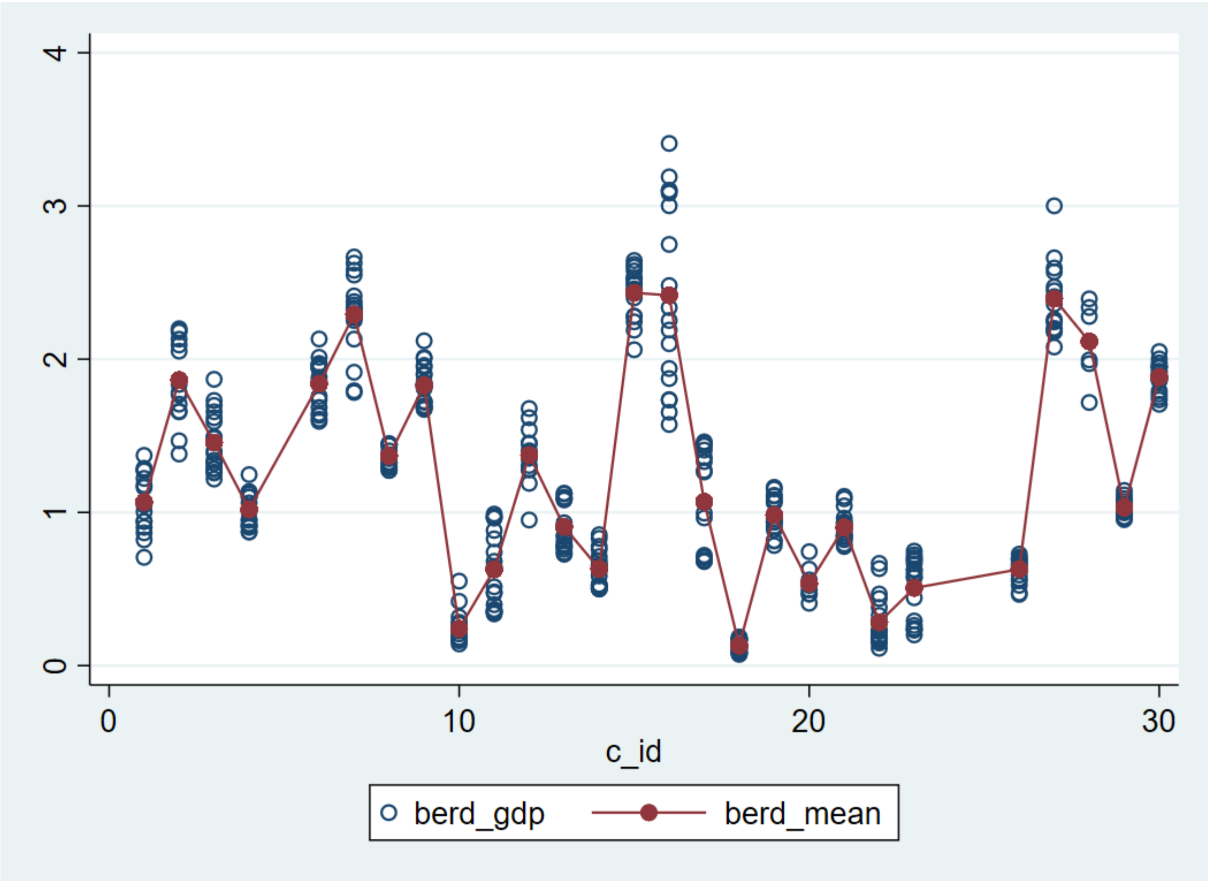

**Figure A.2:** Heterogeneity across time