The Impact of Research and Development Policy on Industry Output:

The Case of Japan

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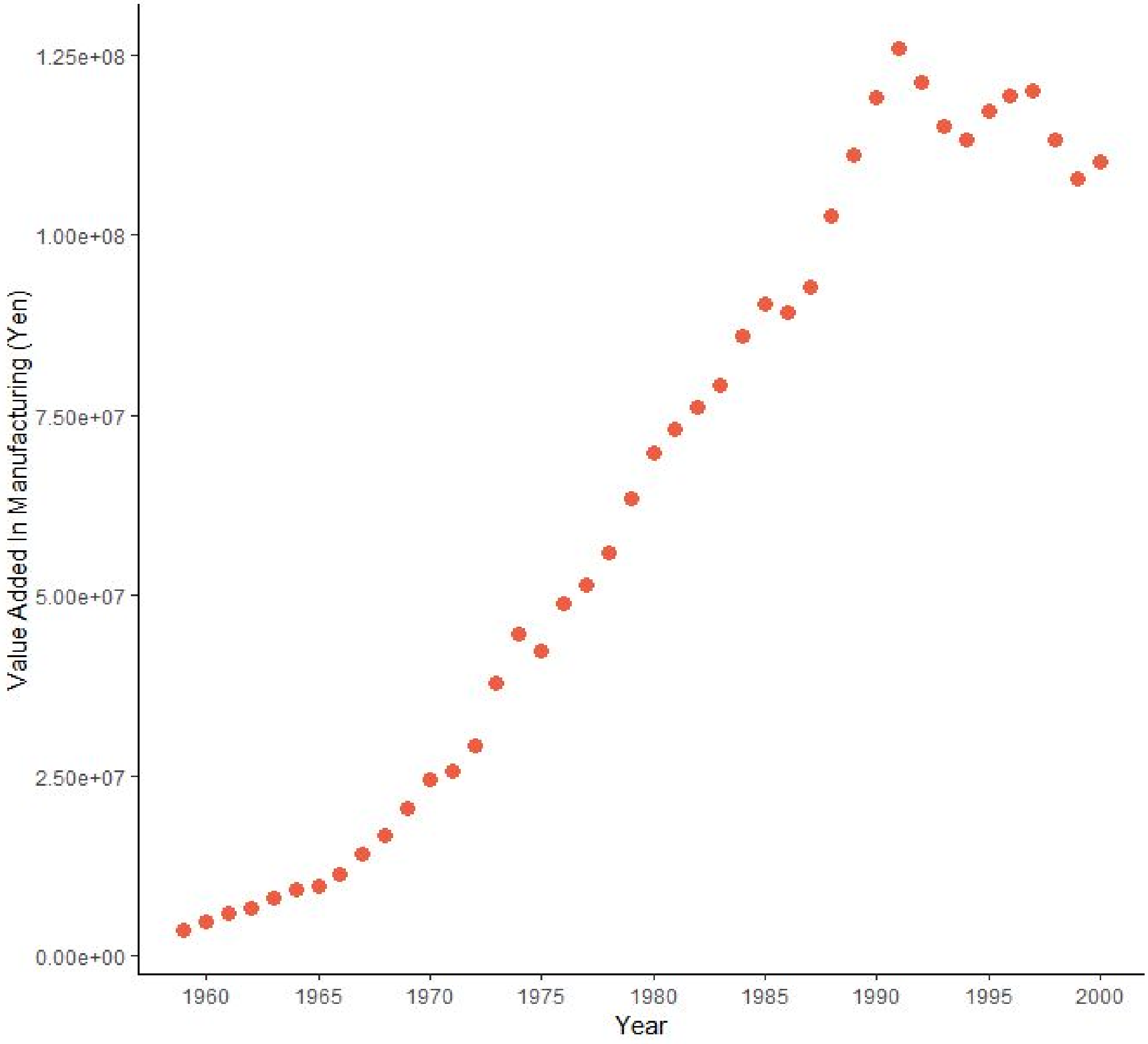
Overview

The goal of this paper is to attempt to find a direct link between broad scope R&D policy and industry output in a country. To that end, a natural experiment is studied using historical data from Japan to gauge the effect of a 1996 R&D policy on value added across some industries. The policy that is studied in the paper is the “The Science and Technology Basic Law” and moreover, its “First Basic Plan” (Cabinet Office, 1995). Industries differ in their relative focus on R&D efforts (High R&D intensity industries should gain more benefit from the policy than low R&D intensity industries) and through an identification strategy based on that, the policy’s effect can be roughly quantified. Two different measures are created for R&D focus, a labour and a capital expenditure measure and both are used in the analysis in the paper. The paper then goes on to look at some intermediate outcomes of the policy for various R&D related statistics, through which the effect on value added presumably occurred.

The choice to use Japan as the focus of this case study is a result of their large period of technological advancement and country wide economic growth after WWII which then (quite suddenly) came to an end in the 1990s. By looking at Figure 1, the substantial growth in industry-wide output for Japan in the long post-war period becomes immediately apparent. One can also see the period of growth comes to an end in the early 1990’s; however, there is a slight recovery around the mid 1990’s. This brief positive area of grown is of particular interest as it seems to align perfectly with the R&D policy this paper intends to study. Thus, the paper intends to investigate whether at least some part of the positive growth in industry value added after 1995 is brought about as a result of the R&D policy in question.

Figure 1

Manufacturing Value Added by Year (Japan 1959-2001)



This paper does find a significant link between the policy and increases in industry value added. It is shown that the value of the policy is approximately a 6% increase in value added on average in an industry per standard deviation of their initial R&D intensity measures. The intermediate results regarding possible mechanisms also show increases as a result of the policy, however, the results are not precise. These results show the policy leads to (similar to value added) close to 6% increases in R&D expenditure and self funded R&D expenditure per standard deviation of each of the R&D intensity measures. The estimates of the policy's effect on both total R&D employment and amount of researchers employed prove to be insignificant. Overall, the results of the paper are in line with the general hypothesis on the positive direction of the R&D policy's effect on industry output in the years following its implementation.

The structure of the paper is as follows, there first is the overview of the paper's motivation, its goals and a brief summary of its findings. After that, there is a discussion of similar literature and where this paper fits into the field of R&D policy. Next, there is some background on the time period and policy in question. Following that, the data is discussed. After the data, there is a section on the empirical strategy employed in the paper. Penultimately, there is the results section, which contains both the main results of the paper and some evidence on mechanisms. The final section concludes.

Literature Review

This section is broken into two parts, first "Effects of R&D Policy" and second "Returns to R&D" and in each there is a discussion of a number of related papers to that specific literature. Each category will start with a survey of the literature followed by a review of some classic and contemporary papers in that field of study. By examining the evolution of the literature in each field this author hopes to make both the purpose for and the background behind this paper increasingly clear to the reader.

A survey of the R&D policy literature is conducted by Becker (2014). In her paper she divides her review into three main parts: first “tax credits and direct subsidies,” second “support of the university research system and formation of high skilled human capital,” and last “support of formal R&D cooperations across a variety of institutions.” With regards to the first part, she finds that the recent literature moves away from the previous notion that government intervention crowds out private R&D spending (Goolsbee, 1998; Wallsten, 2000) and towards findings that subsidies and incentives stimulate private investment (Bloom et al. 2002; Bøler et al. 2015; Dechezleprêtre et al. 2016). Becker references evidence of an inverted U-shape in the elasticity of private R&D with respect to government subsidies (Guellec and Van Pottelsberghe de la Potterie, 2003). This potential U-shape means that high subsidies may crowd out private investment whereas medium subsidies may stimulate private investment. Moreover, small firms that are more often credit constrained can make use of the subsidies more than large firms who tend to have their private investment crowded out (Lach, 2002). Becker shows that the recent literature now shows tax credits are found to have positive effects as opposed to before (Czarnitzki et al, 2011). Becker mentions while the there are no comprehensive surveys of the second two parts of her literature and so, the following papers that will be reviewed will consider only fiscal incentives. Becker concludes that government funding becomes scarce in times of economic austerity, so funds must be targeted effectively. Lastly Becker mentions that some recent evidence shows awarding R&D subsidies could act as positive signals for firm quality which in turn will increase private investment (Meuleman and De Maeseneire, 2012).

A classic early paper about R&D policy's effect on scientists and engineers by Goolsbee (1998) shows evidence that government grants do not increase the quantity of researchers in a firm, but more often just end up as salary bonuses to those researchers who were already employed by the firm. Goolsbee makes note that since the supply of scientists and engineers (researchers) is shown to be inelastic, previous papers on government fiscal incentives tended to overstate their benefits to R&D investment. His paper provides evidence that R&D fiscal incentives seem to be less about increasing innovation and more about rewarding human capital.

In a classic paper by Wallsten (2000), he asks the question of whether increases in government spending also increase private R&D investment (as in the first part of Becker's survey). As in much of the earlier literature, the results he finds are that the government spending will crowd out private investment dollar for dollar. Wallsten mentions previous papers would find some measure of innovation and regress it on a subsidy to find some correlation. However, he poses the problem that there exists bias in these studies since firms are not awarded grants and subsidies randomly. The problem exists that the government chooses to award firms that already do more R&D with more grants for R&D which will cause these papers' analyses to be flawed. His method was to use a multi-equation model to both estimate a correlation between government spending on R&D and private R&D spending as well as to find whether firms who do more R&D also get more grants and test both hypotheses simultaneously.

As previously mentioned, he does find that there is crowding out of private spending, but he also finds evidence that firms with more employees and/or patents will receive more grants. Wallsten also finds that although the larger R&D firms receive more grants that the grants do not then cause further increases in employment. He does make note that while it seems there is crowding out of private R&D spending, the results could also be interpreted as constant levels of R&D being maintained, which allowed for no ongoing projects to be cancelled as well as for private funds to be reallocated by firms causing them to more optimally expend their resources.

Another early paper by Bloom, Griffith and Van Reenen (2000) shows the effects of R&D tax credits on levels of R&D investment in a panel of OECD countries. They find that fiscal incentives are effective both in the short and long run at stimulating levels of R&D across countries (even after accounting for country-specific characteristics). They find that a 10% fall in the cost of R&D leads to just over a 1% short run increase and just under a 10% long run increase in country wide R&D effort. The key method for the paper was to correctly measure the cost of R&D, more specifically "to derive the pre-tax real rate of return on marginal investment that is required to earn a minimum rate of return after tax" (Bloom et al, 2000). With this the authors can then measure the returns to R&D by evaluating increases or decreases in the real tax rate for country R&D spending. The authors find that the impact elasticity of R&D tax is small in the short run (as previous literature believed) but near unity in the long run. Overall, the paper finds that while many economists were skeptical about fiscal policy in R&D, that there is evidence of significant benefit in R&D investment from government policy intervention in industry R&D across many countries.

Another recent paper by Bøler, Moxnes and Ulltveit-Moe (2015) studies the impact of an R&D cost shock (through fiscal policy) on R&D investments and international sourcing, as well as the joint impact of those R&D investments and the international sourcing on firm performance. Through use of a difference in differences model they can estimate the effects of a 2002 R&D cost shock in Norway on R&D investment and international sourcing. The model they create shows that R&D investment and international sourcing are complementary and that one can stimulate investment by increased access to imported inputs which then will ultimately promote technological growth. This complementarity comes from increases in R&D causing future profits to rise, which leads to cutting current costs to invest more heavily in R&D today and the method through current costs can be cut is international sourcing of inputs. The contributions here highlight the complementarity between R&D investment and international sourcing and their impact on firm performance but also identify new possible gains from trade.

A more recent paper by Dechezleprêtre et al. (2016) also studies the effect of R&D tax incentives. The paper provides evidence of a causal link between innovation and fiscal incentives and R&D spending. The paper implements a regression discontinuity design using administrative tax data in the United Kingdom and a change in the asset-based threshold for firm R&D subsidy eligibility. They show that tax price elasticities are very large (2.6), but also make note that this is probably because these firms are smaller and subject to more financial constraints. Recall that this small firm benefit is in line with the literature covered in Becker's review. This paper goes on to show aggregate business R&D would be 10% lower in the absence of the tax incentives and that there are positive spillovers of the policy on technologically related firms. Overall, this paper reinforces the notion of the positive effects of R&D tax credits on private R&D spending. Moreover, it also builds on previous work by highlighting the large effect of said policies on small firms, as well as giving evidence of positive spillover effects as a result of the policies into related industries.

One can see that around 2000 the consensus that government R&D fiscal policy was crowding out private R&D investment began to change to one of R&D fiscal policy possibly benefiting private R&D investment (based on firm sizes). This new consensus on the positive impact of R&D policy gives a solid foundation for the relevance of this current paper. The following part of this section is a review of some literature in the "returns to R&D" field.

The chapter "Measuring the Returns to R&D" by Hall, Mairesse and Mohnen (2010) in the Handbook of the Economics of Innovation provides a broad overview of the literature in this field of study as well as common topics, methods and outcomes of articles in this field. The chapter contains a review of some pioneering papers by Griliches (1979; 2000) as well as some papers on social returns to R&D by Hall (1996; 2005). The main focus of the chapter is the methodology behind calculating returns to R&D. The common econometric approach to measuring returns is "based on the production function and its cost or profit dual" (Hall et al., 2010). So, there are two main methods to use. The first approach (Griliches, 1979) is through a macro approach making use of the Cobb-Douglas production function augmented with some measures of knowledge capital and through that making TFP growth a function of R&D capital shocks. The second approach (an extension of Griliches) is the dual approach, which expands on the previous method but now makes use of both costs and profits to create technology cost, profit or value functions which can be used to estimate the impact of R&D efforts. All the subsequent papers in this literature review (except Vernon) will use these types of analysis in their papers. However, the papers looked at will mainly be also be extensions of Griliches' 1979 framework, in an attempt to bring a more contemporary approach to the literature.

In an early paper by Grabowski and Vernon (1993), they measure R&D returns in the pharmaceutical industry on new drugs and find that the rate of return on investments is about 11.1 percent. Previously, measures like return on stockholder equity were used as measurement proxies for R&D return. However, the authors draw evidence from earlier studies to show these measures overstate the returns on R&D in pharmaceuticals by 20-25%. They believe previous works had problems of bias due to poor timing and aggregation, as well as being due to the pharmaceutical industry having large distortions in profitability as a result of intangible capital investments. The method of evaluation used in Grabowski and Vernon's paper is estimation of annual cash flows for new chemical entities across pharmaceutical companies. By using their cash flow analysis they show that short term losses from introduction are overtaken by long term gains in sales. Overall, the main findings of the paper are that the returns to R&D in pharmaceuticals are not as large as many people at the time believed (although they are still positive) as well as proposing a new proxy for R&D impact.

In an article by Griffith, Redding and Van Reenen (2004) they do an empirical study of the two faces of R&D. These being R&D's main effects, stimulation of innovation as well as increases in technology transfers. The stimulation of R&D is a common topic of much existing literature, whereas the second face technology transfer has had "almost no rigorous econometric work" done to assess its importance (Griffith et al. 2004). Technology transfer, or absorptive capacity, is the ability of people to better understand and use new technologies. Griffith et al. make the case that R&D will not just create new technologies but also help economies adapt to current technologies more effectively. Overall, this study fills the gap in literature with regards to the second face and finds that many studies before have understated gains from trade by not including the increases to absorptive capacity brought about by R&D.

Doraszelski and Jaumandreu (2013) is an example of the dual approach to studying the impact of R&D policy. However, instead of using the standard Griliches framework, which is to use an R&D shock to impact knowledge capital, they instead create a flexible functional form to measure the interactions between past and current investments. The model estimation is a large part of this paper, however, its real contributions are a deviation from the literature of the time, which is making a model that does not rely on unobservable R&D shocks. Using a panel of Spanish industries in the 1990s they find evidence of "significant uncertainties in the R&D process" (Doraszelski and Jaumandreu, 2013), including discovery chance, applicability of the new technology and implementation success. Their new model also finds strong evidence that R&D expenditures play a significant role in firm productivity and the evolution of said productivity over time.

The final paper to be discussed is Eberhardt, Helmers and Strauss (2013), in which the authors also seek to improve on Griliches' framework for analysis of returns to R&D. In this paper, which focuses on spillover effects of R&D, the authors consider if previous literature has overlooked or misrepresented this potentially important outcome. The authors use both the standard Griliches approach and a common factor framework which accounts for spillovers that they develop throughout the paper to compare the results between both model specifications. In their study they determine that the Griliches framework is significantly misspecified and that it is inadequate for use in analysis of returns to R&D. Due to the wide use of the Griliches framework, they find that conventional estimates of the effects of R&D could be understated (much like the results of Griffith et al.) as many studies do not directly account for spillover effects. Moreover, they find that studies can also conflate spillover effects and as such they make note that spillovers cannot be ignored when studying the private returns to R&D.

In this literature section in two parts, “Effects of R&D Policy” and “Returns to R&D” a brief history of the evolution of each field was given. The change in the consensus behind R&D fiscal policy from one of crowding out private investment to that of supplementing private investment was shown in the first half of this review. The second part focused on the modern improvements made to the 1979 Griliches framework in the returns to R&D literature. With both these two main points in mind, the purpose behind this paper should be increasingly clear. The literature is updating in both fields to more accurately capture what the implications of R&D are for both governments and firms, this paper's intent is to do this as well.

Background

The so-called "Japanese Economic Miracle" was the period following WWII in Japan, in which the economy grew very substantially which allowed the country to recover from the devastation brought about by the war (Johnson, 1982). This period lasted from the end of the war in 1946 until approximately 1992 when Japan's growth stagnated. The growth sustained throughout this period was extremely significant in propelling Japan to its current level on the world stage. As shown in Figure 1, even just the value added in manufacturing increased by an enormous amount during their decades long economic boom (from 3.6 million yen to 121 million yen over 1959-1992).

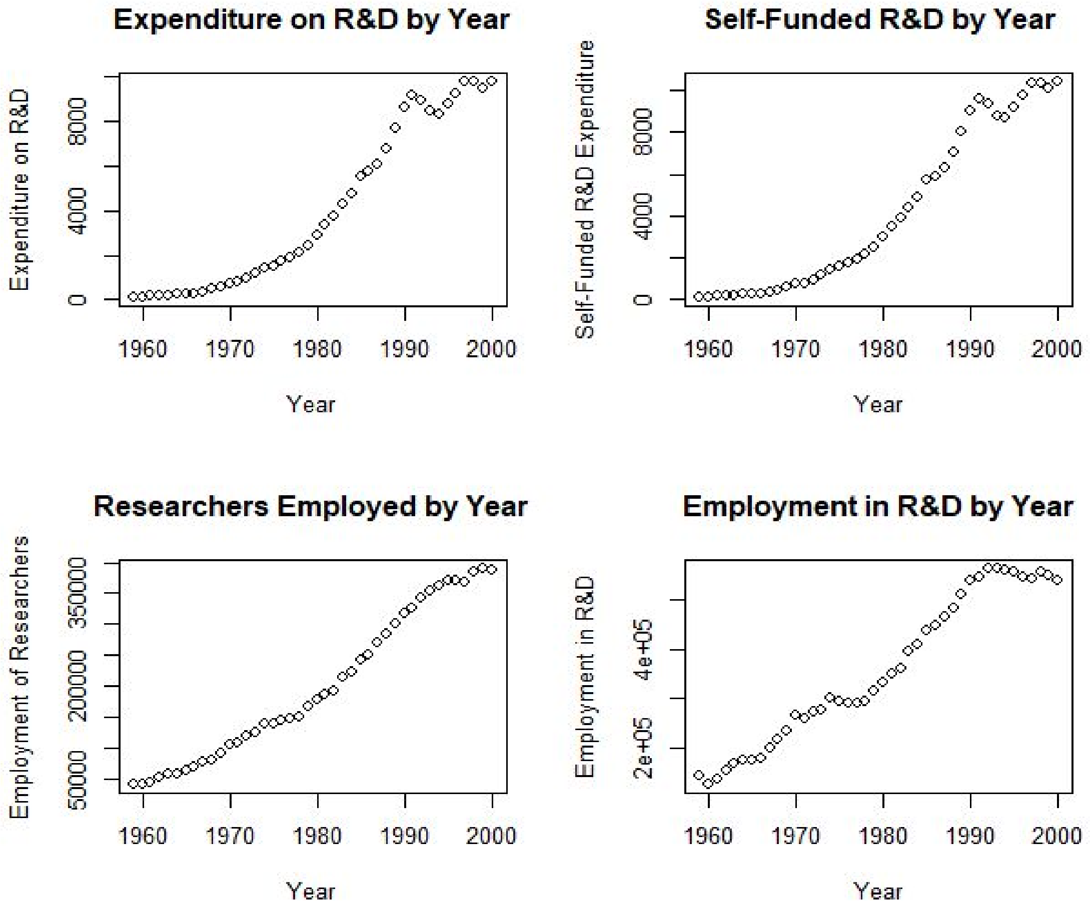
However, the large levels of sustained growth did not continue forever (Hayashi and Prescott, 2002). In the early 1990's the growth began to slow and production dropped country wide (once again this is evident in Figure 1). As the 1990's also gave rise to the advent of computer culture and increasing demand for high tech industries, the Japanese Government became aware that they were beginning to stagnate in growth and innovation. They decided that they would like to continue being economically successful into the upcoming 21st century and to do that the country would need to resume (or at least partially resume) its previous levels of economic growth. The Japanese Government believed to continue achieving economic success that they had to not only update the country to contemporary standards in innovation, but to go even further to prepare for the future. So, in an attempt to prepare Japan for the 21st century and to try and revitalize their previous economic growth, in November 1995 the Japanese Government passed “The Science and Technology Basic Law” (Cabinet Office, 1995). This law was designed to be a broad and overarching philosophy for the direction of the country in the future.

The Basic Law’s main idea was to promote growth, development and innovation in Japan. Moreover, it was to set the standard for any subsequent laws and policies regarding science and technology passed by any future Japanese Government.

> *“The objective of this law is to achieve a higher standard of science and technology (hereinafter referred to as "S&T"), to contribute to the development of the economy and society in Japan and to the improvement of the welfare of the nation, as well as to contribute to the progress of S&T in the world and the sustainable development of human society, through prescribing the basic policy requirements for the promotion of S&T (excluding those relevant only to the humanities in this law) and comprehensively and systematically promoting policies for the progress of S&T” (Cabinet Office, 1995)*

Because the Basic Law was really more of a philosophy towards the future of Japanese R&D rather than something that had a direct impact, provisions were created to enact what are known as “Basic Plans.” These plans are 5 year blocks of policies which specifically target the promotion of innovation through various methods (Cabinet Office, 1995). These methods range from subsidies to R&D, reform to hiring practices in R&D sectors or even attempts at creating fellowships with other countries to foster mutual cooperation through the joint advancement of innovation. Because growth in innovation was the target for the Basic Plans, the first plan by the Japanese Government attempted to widely expand the previous levels of R&D throughout the country.

Figure 2
Manufacturing R&D Employment and Spending (Japan 1959-2001)



Expenditure on R&D by Year

Self-Funded R&D by Year

Researchers Employed by Year

Employment in R&D by Year

The “First Basic Plan” was the first direct implementation of the “Basic Law” and it was enacted in July 1996. This Plan came with the goal of constructing a new system for Japanese R&D (Cabinet Office Basic Plan, 1996). Some goals of the first Basic Plan were to “develop and improve R&D infrastructure,” “expansion of various [R&D] funds,” and an “increase in R&D investment by the Government” to name just a few of its provisions (Cabinet Office Basic Plan, 1996). The first Basic Plan is the focus of this paper’s study, which again, is an attempt to determine the power of sweeping R&D reform on a country’s manufacturing output levels. Figure 2 shows historical levels of some R&D related statistics. Specific attention should be paid to the area after 1995 where most growth levels look as if they have ‘restarted’ as possibly a result of the “Basic Law” being passed. It is this period specifically that the paper will study in an attempt to test whether or not the first Basic Plan had an effect on industry value added.

Data

All of the data were retrieved from Statistics Japan, part of the Statistics Bureau in the Ministry of Internal Affairs and Communications (Statistics Japan, 2019). The data sets available are of Japanese industrial statistics at the two digit level of aggregation in the ISIC classification (ISIC, 2002). Because of the revisions of ISIC in 1958, 1968, 1989 and 2002, the range of years of data collected for the paper was between the first revision in 1958 and just before the third revision, i.e. in 2001. To allow for inferences across time, the data from before 1989 were adjusted to fit the standard of the 1989 revision (ISIC,1990).

The data set used in the paper was created as an amalgam of three data sets from the Statistics Bureau. The data sets that were combined and adjusted were an R&D data set (Table 17-6-a), and two value added data sets (Table 8-5 and Table 8-6). The data were then adjusted to have the same level of industry aggregation across sets and the same unit of measurement (thousands of yen). Some industries which could not be adjusted to the same aggregation level were dropped.

The data set contains information on employment through three categories, “Total Industry Employment”, “Employment in R&D” and “Researchers Employed.” It is worth noting that the total employment numbers were used only to create percentage R&D employment measures. Data for R&D expenditure exists as another two categories, “Total R&D Expenditure” and “Self-Funded R&D Expenditure”. A binary variable was added to denote the years before and after the first Basic Plan came into effect (in 1996). It was through the merging of the two value added tables that the “Value Added by Industry” category was created. The resulting data set was a panel of 17 industries across 42 years with 7 variables.

The years of study were two approximately 15 year blocks, 1970-1985 and 1985-2001. The first block is used to construct the measures of industry R&D intensity. Then the created intensity measures are used with the second block to create the main results of this paper.

Empirical Strategy

The method through which this paper attempts to study the effect of R&D policy on industry value added is through the use of a difference in differences approach. To properly gain some insight into the policy’s effect one must consider more just one set of changes; both across time and across industry are required to evaluate the effects of the policy. Parallel trends are assumed to run across both industry and time, with the measured difference in their interaction coming as a result of policy and the industry R&D intensity. In the absence of the policy the industries should maintain their relative differences between each other, as well as each industry should maintain the same path of growth across time. It is specifically the implementation of the first Basic Plan that should cause both these two paths (that should have been parallel) to diverge from their original courses. It is because of this divergence in trends the effect of the policy can be quantified successfully. This idea of parallel trends is the main assumption of the paper and the reasons for its validity are discussed in this section.

Because of the nature of the policy's timing (1996), any previous years should, in theory, be able to be used as a control group when studying the effect of the policy. A main assumption of the paper is that the policy was not created with a guess about the future in mind that turned out completely correct. This is a difficult assumption to make if one challenges how 'complete' this guess about future has to be. That is to say, if one assumes they created the policy predicting that there would be this exact level of growth anyways then the estimated relationship could end up being biased (then the policy would be only reactive to and not the cause of changes). However, this notion can probably be dismissed by the fact the policy states it wants to increase innovation forever, not target some specific level. So hopefully, this first assumption is more or less reasonable (that the growth trend in years was not forecasted perfectly). With this idea of policy timing in mind, the first of the differences (before and after) is created through the use of a simple post timing binary variable in the panel.

The second difference used the industry side of the panel to create a measure of how much effect a specific industry will benefit from the policy based upon their focus into R&D efforts. This focus on R&D is what the paper calls “research and development intensity.” There are two main assumptions here; first, that high R&D intensity industries should benefit more than low R&D intensity industries from R&D policy intervention. This first assumption can be rationalized in many ways, such as larger prior absorptive capacity in high R&D intensity industries, inelasticity of research labour supply or through economies of scale. The second assumption is that the the R&D intensity measures are time invariant, that is to say, that in the absence of the policy the measures of intensity would not be broadly different across time. This should allow the intensity measure from the first period to be used to study the industries in the second period (the one used for the main results). This assumption is reasonable, because one could probably expect that across an average of many years high R&D Intensity industries should stay high and low R&D intensity industries should stay low (and the fact they differ between industries is apparent in Table 1). This idea was taken from the various lists of industry rankings in R&D intensity across many different countries and years (Galindo-Rueda and Verger, 2016, OECD 2019). This second difference is less directly observable and due to that, two different indexes of what R&D intensity might actually look like are created. These Indexes are respectively, an R&D labour index and an R&D expenditure index.

The labour intensity measure is created using each industry’s employment in R&D as a percentage of their total industry employment. The values for each industry are taken as an average over the period from 1970-1985 in an attempt to mirror what the intensity would be in the absence of the policy in the subsequent 15 year period. The resulting measure should give a value for each industry which encapsulates how much they focus on R&D while also adjusting for the relative size of that industry. By ordering each industry by its intensity measure an index is created of the 17 industries by their relative focus on R&D through labour efforts.

The expenditure intensity measure is created by using each industry’s total expenditure on R&D. However, as the same problem of varying industry size exists, the values of expenditure are divided by the value added in that industry to give a percentage of relative capital used to fund R&D. Similarly to the labour measure, the values for each industry are taken as an average over the period from 1970-1985 for the same reasons stated above. Also similarly to the labour measure, the resulting expenditure measure is an index of the 17 industries by their relative focus on R&D through total spending efforts.

Both of these Indexes are created using data from 1970 to 1985 (first period) as to allow the use of the data in 1985 to 2001 (second period) to be untainted by bias, as some of the same measures are used on both the left and right hand side of the ensuing equations (as well as for the aforementioned parallel trends assumptions).

Table 1

Research and Development Intensity Measurements by Industry (1970-1985)

Intensity Measurements (High to Low)			
Expenditure on Research and Development Adjusted for Value Added (Measure 1)		Percentage of Industry Employment in Research and Development (Measure 2)	
Electrical Machinery	19.86	Chemical Products	12.06
Chemical Products	18.28	Electrical Machinery	9.97
Transportation	14.56	Transportation	8.16
Precision Equipment	7.23	Precision Equipment	7.04
Rubber Products	5.08	Petroleum Products	5.85
Mining	4.00	General Machinery	4.94
Petroleum Products	3.37	Rubber Products	4.87
Non-Ferrous Metals	3.18	Non-Ferrous Metals	4.70
Iron and Steel Products	3.16	Ceramic Products	4.40
General Machinery	3.03	Other	3.63
Other	2.56	Fabricated Metals	3.50
Ceramic Products	2.27	Iron and Steel Products	3.28
Textile Products	1.27	Food Products	3.07
Food Products	1.26	Pulp and Paper Products	2.84
Fabricated Metals	1.25	Mining	2.73
Pulp and Paper Products	1.00	Textile Products	2.53
Printing	0.22	Printing	1.10
Mean: 5.39		Mean: 4.98	
Standard Deviation: 6.12		Standard Deviation: 2.87	

Intensities are calculated using an averaged value over years 1970-1985 for each industry. To adjust for varying industry size, each industry's expenditure is divided by value added whereas R&D employment is taken as a percentage of each of the total industry's employment.

Table 1 shows the two intensity measures and one can see from a cursory glance the intensity measurement rank orders are not broadly different across the two measures. Both measures have the same few industries at the top and the bottom of their respective indexes. The two lists also have (close to) the commonly expected industries classified as higher or lower in R&D intensity (Galindo-Rueda and Verger, 2016). One can see industries which are commonly believed to be highly focused in R&D such as Chemicals Products and Electrical Machinery are at the top and low focus R&D industries such as Printing are at the bottom of each of the indexes. The middle sections of each do contain some seemingly large differences in rank order, but when comparing the lists using the values of the variables, the entries in question are actually very close in position. In fact, the correlation is found to be very large between the two measures (approximately 93%). It is worth noting that the standard deviation for the expenditure measure is a little more than double that of the employment measure, so care was taken in evaluating the final results of the paper (regression estimates should be multiplied by the respective distribution standard deviation). It is yet unclear which of the two versions of R&D intensity is more valid than the other and so both are used to calculate the main results of the paper.

Having now created the path through which each difference can emerge the main model of the paper will be as follows:

$$Log(Value\ Added)_{it} = \alpha_i + \gamma_t + \beta(\,post_t\ x\ R\&D\ Intensity_a\,) + \varepsilon_{it}$$

where α_i are industry fixed effects, γ_t are time fixed effects, $post_t$ is a dummy for being after 1996 and $R\&D\ Intensity_a$ is one of the two different measures of R&D intensity. Also estimated are specifications with non-logged measures of value added for comparison. The standard errors are clustered at the industry level because of potential correlation of the error term.

Secondary results are studied through intermediate outcome variables in an attempt to map the path through which value added is affected by the policy and R&D intensity. The four intermediate outcome equations are as follows:

$$Log(R\&D\ Expenditure)_{it} = \alpha_i + \gamma_t + \beta(post_t\ x\ R\&D\ Intensity_a) + \varepsilon_{it}$$

$$Log(Self\ Funded\ R\&D\ Expenditure)_{it} = \alpha_i + \gamma_t + \beta(post_t\ x\ R\&D\ Intensity_a) + \varepsilon_{it}$$

$$Log(R\&D\ Employment)_{it} = \alpha_i + \gamma_t + \beta(post_t\ x\ R\&D\ Intensity_a) + \varepsilon_{it}$$

$$Log(Researchers\ Employed)_{it} = \alpha_i + \gamma_t + \beta(post_t\ x\ R\&D\ Intensity_a) + \varepsilon_{it}$$

Akin to the main results of the paper, these equations include both time and industry fixed effects and the values are indexed by time and industry. Results are calculated for each of the two R&D intensity measures. Once again, the standard errors are clustered at the industry level.

Results

Table 2 shows the main model specifications and one can see that the results are all positive and significant or nearly significant with most p-values below the 10% rejection threshold. The implications of the results are that a one standard deviation increase in intensity of measure 1 (2) leads to roughly a 5.8% (6.1%) increase in value added after the implementation of the policy in an average industry. Or, in real yen value approximately 410,000 (345,000) yen of extra value added per standard deviation of measure 1 (2) intensity in the average industry. This is a clear indication that the R&D policy has a substantially larger effect on industries with higher R&D intensity than those of lower levels under the identification assumption.

Table 2

Effects of Research and Development Policy and R&D Intensity on Value Added by Industry in Japan, 1985 to 2001

		Outcome Variable							
		Log(Value Added)				Value Added			
R&D Intensity Measurement Specification		Estimate	Clustered Standard Error	Wild Bootstrap P-Value	R^2	Estimate	Clustered Standard Error*	Wild Bootstrap P-Value	R^2
Expenditure on R&D adjusted by Value Added	Basic Plan x R&D Measure 1	0.0093983	0.0072386	(0.092)	0.052841	66922	22801	(0.0388)	0.059214
Percentage of Total Employment working in R&D	Basic Plan x R&D Measure 2	0.021157	0.015354	(0.1736)	0.056422	120152	52107	(0.0816)	0.044789

Year and industry fixed effects for all regressions are included. Data are clustered at the industry level. Wild bootstrap p-values are calculated using the method described by MacKinnon (2002). Intensities are calculated using averaged data from 1970-1985. n=17, T=15, N=225.

One can see that the R-squared values are low; however, much of any industry value added is not determined by R&D policy and intensity in R&D alone. The time and industry fixed effects alone are not comprehensive enough amount of controls for a large R-squared to exist. Even the ~5% values that are reported are not too outrageously low when one considers the lack of other control variables in the equation.

As the main regression results indicate that the policy was sound and effective in its effect on value added, the next question is through what mechanisms does value added actually increase as a result of an R&D policy? This is achieved by now replacing the value added outcomes with some intermediate outcomes as dependant variables. The intermediate results are R&D related measures that should, in theory, change as a direct result of the Basic Plan. If the theory of the paper is sound, the intermediate results should follow the same direction as the final results for the value added regressions. So, by following the same ideas as in the previous model and simply replacing the outcome variable, the initial impact of the policy on actual R&D related statistics in each industry is obtained. The results of these intermediate regressions are split into two tables, one for each measure of Intensity.

Table 3

Effects of Research and Development Policy and R&D Intensity on Employment and Research Spending by Industry in Japan, 1985 to 2001

	Intensity Measurement x Basic Plan			
	Expenditure on Research and Development Adjusted for Value Added (Measure 1)			
Outcome Variable	Estimate	Clustered Standard Error	Wild Bootstrap P-Value	R^2
Log(Self Funded R&D Expenditure)	0.0110228	(0.0097427)	0.075	0.087263
Log(Total R&D Expenditure)	0.0091133	(0.0088895)	0.086	0.09471
Log(Total Employment in R&D)	0.0046427	(0.0070921)	0.2972	0.018004
Log(Researchers Employed)	0.0063721	(0.0058464)	0.1512	0.14542

Year and industry fixed effects for all regressions are included. Data are clustered at the industry level. Wild bootstrap p-values are calculated using the method described by MacKinnon (2002). Intensities are calculated using averaged data from 1970-1985. n=17, T=15, N=225.

Table 4

Effects of Research and Development Policy and R&D Intensity on Employment and Research Spending by Industry in Japan, 1985 to 2001

	Intensity Measurement x Basic Plan			
	Percentage of Industry Employment in Research and Development (Measure 2)			
Outcome Variable	Estimate	Clustered Standard Error	Wild Bootstrap P-Value	R^2
Log(Self Funded R&D Expenditure)	0.0203905	(0.0209756)	0.2276	0.081267
Log(Total R&D Expenditure)	0.017481	(0.019074)	0.2444	0.091245
Log(Total Employment in R&D)	0.0074784	(0.0152101)	0.5186	0.013357
Log(Researchers Employed)	0.011032	(0.012619)	0.516	0.14018

Year and industry fixed effects for all regressions are included. Data are clustered at the industry level. Wild bootstrap p-values are calculated using the method described by MacKinnon (2002). Intensities are calculated using averaged data from 1970-1985. n=17, T=15, N=225.

Both Table 3 and Table 4 show similar results to Table 2 in the direction of the estimates, in that all of the results are positive. However, the significance levels are now much lower than main value added regression (some p-values in the 50% range). So, great care should be taken when judging the results of the policy and R&D intensity on (specifically) employment. The expenditure results are more in line with conventional significance requirements with most of the p-values being in the 10% significance range. The R-Squared values for these regressions are also much higher than the main regressions, since (as one would probably assume) they should be directly impacted by the policy (perhaps through grants and/or subsidies). In Table 1 there was not a clear difference between the two different measures of R&D intensity, whereas in these two tables of results it seems likely that the expenditure measure more precisely proxies for R&D intensity as it has consistently lower p-values for each of the different outcome variables.

Since, in this case the expenditure measure seems to be a clearer choice for the R&D Intensity measurement, the analysis will focus on Table 3 (Measure 1) and not Table 4 (Measure 2). In Table 3, one can see that the expenditure outcome estimates are similar to the previous value added outcome estimates with approximately a 5.6% increase in expenditure and a 6.7% increase in self funded R&D expenditure per standard deviation in Intensity. The employment outcomes are about half the expenditure numbers with about a 2.8% increase in R&D employment and a 3.9% increase in the amount of researchers employed per standard deviation after the policy. Recall, the previous value added numbers for the expenditure measure was ~6%, So, these intermediate outcome variables are also in a reasonable range with respect to the overall value added increases.

From these intermediate results it seems apposite to conclude that the main channel through which value added is impacted is realistically some combination of these intermediate variables (since they all move in the same positive direction). Particular focus should be on the expenditure side of the R&D policy as its impact relative to the R&D intensity measures is much more apparent and precisely estimated than that of the labour side of the policy. Due to expenditure increasing without significant changes in employment it could be that more expensive researchers (better quality) were hired to replace the old (low quality) researchers or better equipment was purchased for use by the researchers, or both these effects in some combination.

Conclusion

This paper attempted to find a direct link between the implementation of sweeping R&D reform through a five year policy in Japan and industry level output. To study this, indexes of relative R&D intensity were created and in conjunction with the timing of the policy, they were used to estimate the relative effect of the policy on the average industry. Overall, this paper has shown that there is a positive effect on industry level manufacturing value added as a result of the first Basic Plan. These results have been shown to be robust to the two separate measures of R&D intensity and both measures lead to similar ranges of estimated impacts. The paper also shows some immediate effects of the policy on both R&D expenditures and R&D employment. The effects on R&D expenditure are more precise than those of the R&D employment measures and this is consistent across both intensity measures. The main conclusion of this paper is that it does find a significant link between the implementation of the first Basic Plan and the shown increases in value added in the immediately following years (shown in Figure 1).

However, further study and larger amounts of data are needed if one wants to more reliably estimate the true channels through which the policy impacted value added. Because of the broad scope of the Basic Plan, there probably were changes in almost all industry R&D related variables and it is because many of these variables are highly related to each other that spillover effects (both positive and negative) do almost certainly exist. At this time, the author's most reasonable guess is that it is some combination of all the different immediate policy effects that in conjunction cause the increases in industry value added. However, the specific decomposition of those effects is a study best left for a future paper.

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