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Empirical Evidence on R&D Targeting and Transitions

Autores:
Roberto Álvarez
Claudio Bravo-Ortega
Dan Poniachik

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sdt@econ.uchile.cl
econ.uchile.cl/publicaciones

Empirical Evidence on R&D Targeting and Transitions*

Roberto Alvarez — University of Chile — robalvar@fen.uchile.cl

Claudio Bravo-Ortega — University of Chile — clbravo@fen.uchile.cl

Dan Poniachik — University of Chile — dponiachikc@fen.uchile.cl

Abstract

Over the last five decades a growing number of governments in developed and developing countries have implemented targeting policies to increase the R&D to GDP ratio. However, until now there have been few attempts either to evaluate the effectiveness of these policy efforts or to identify the characteristics of substantial, country-level R&D-intensity increases. In this paper we address both of those issues. First, we compile information about the R&D targeting goals for 53 countries, finding that most of them have failed to fulfill their self-imposed targets. Second, and complementarily, we study episodes of substantial acceleration in R&D expenditure, using a larger longitudinal dataset of 62 countries between 1960 and 2007. We find that transitions to higher levels of R&D-intensity are relatively infrequent phenomenon. These transitions are positively correlated with higher income levels, knowledge production variables (patents and scientific publications), intellectual property rights, technological exports, and terms of trade. We also find that the private sector is a main driver of R&D expenditure increases.

JEL Codes: O3, O5

Key words: R&D, innovation, productivity, transitions

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1. INTRODUCTION

The pioneer works of Schultz (1953) and Griliches (1958) were the first to study the relationship between R&D and productivity. However, only relatively recent theoretical models have assigned a substantial role to R&D as an engine of productivity and economic growth (e.g. Romer, 1990; Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991; Aghion and Howitt, 1992).

From an empirical perspective, there have been substantial efforts during the past two decades to quantify the impact of R&D on productivity. This literature has shown that R&D activities can explain up to 75%of total factor productivity (TFP) growth rates once externalities are considered (Griliches, 1995). Moreover, it has been found that close to half of income per capita and growth rates differences across countries can be explained by differences in TFP (Hall and Jones, 1999). Hence, it is not unexpected to find that R&D activities show high private and social returns. Indeed, private returns of R&D seem to be around 30% as the studies of Griliches and Mairesse (1984) and Goto & Suzuki (1989) show with American, French, and Japanese firms. Meanwhile, social returns are even higher. Terleckyj (1980), Scherer (1982), and Griliches & Lichtenberg (1984), for example, find returns over 70%.[1]

Therefore, it is not surprising that many countries have begun considering Gross Domestic Expenditure on R&D (GERD) over GDP ratio as a public policy variable and have chosen different GERD targets as national goals. Across the globe, there are few countries that have successfully achieved their self-imposed GERD targets. Most have failed, both in the developing and developed world. Below we review some emblematic cases that illustrate the relevance of the questions addressed by our research and the difficulties faced by countries attempting to significantly increase their R&D intensity levels.

[1]When using country data, returns differ significantly across groups of countries. In G7 and selected OECD countries, returns vary from 20% to 123% (Lederman & Maloney, 2003; and Coe and Helpman, 1995). In developing countries, returns range from 60 to nearly100% ((Lederman & Maloney (2003) and Bravo-Ortega & Garcia (2011)).

Let us use Mexico as an example for illustrating the challenges that many developing countries face when trying to increase R&D spending. Between 1994 and 2001, the R&D to GDP ratio increased from 0.2% to near 0.4% with private participation being less than 30% of the total. Universities and research centers remained almost the sole producers of new technology. Mexico then set a goal in 2001 through the "Special Program on Science and Technology." One of the objectives of this program was to increase R&D intensity to 1% of GDP by the end of 2006. These efforts have not been successful as Mexico has failed to meet its goal, by 2010 its GERD was only 0.5% (See Figure 1).

An OECD report indicates that this spending has remained low mainly due to governance problems in the innovation system, preventing proper coordination and efficiency. It also shows that it is essential to improve human capital, access to private financing, and improve collaboration between the public and private sectors (OECD; 2010b).

As an example of a fast growing East-Asian economy, in 2006 Singapore announced a 3% target for 2010. Although it reached 2.6% in 2008, it has decreased in recent years (Figure 1). According to the Agency for Science Technology and Research of Singapore (2011) the main reason for not fulfilling its goal was rapid GDP growth that has outpaced R&D growth. [2]

In Europe the first attempt to set an R&D target was in the Lisbon Strategy of 2002, setting a collective target of 3% for the entire EU (i.e. the average figure for all its members) by 2010. However, in 2005 the Lisbon Strategy was re-launched and each member adopted an individual national goal also for 2010. Despite this effort, the simple average of the individual new goals only amounted to 2.5%, which is insufficient to reach the common target. After evaluating this situation, the EU set the same 3% common goal for 2020 with each country adopting an individual new target.

R&D targeting has been adopted in the EU in a context of slower R&D growth compared to other economies. According to European Commission (2011) total R&D

[2] In 2010 R&D investment grew 7.4% compared to the previous year, but GDP grew at 13.9%.

investment in real terms grew 50% between 1995 and 2008, much slower than that in leading Asian countries (75%), BRIS countries[3] (154%), and almost 100% in the rest of the world. In Europe, only Denmark and Ireland met their national targets (Figure 2), though Austria, Finland, and Germany made significant progress towards their goals.

In this paper we systematically address whether countries have been able to meet their goals and then, using a large sample of countries during the past four decades, see whether there is evidence of significant changes in R&D efforts. In the first part of this paper, using 53 developed and developing countries that have established R&D targets, we address whether this has been a successful strategy and if these countries have closed the expenditure gap to some extent. We find that countries rarely achieve their self-imposed goals, although sometimes these goals help to mobilize resources towards R&D.

The disappointing results associated with R&D targeting policies, and the difficulties faced by developed and developing countries led us to a second set of questions. Ultimately, R&D targeting policies are aimed at increasing R&D expenditures, however we have not found a systematic approach in the literature that can account for successful increases in this type of expenditure. For this purpose, we identify what countries increased their R&D share to GDP ratio over a given threshold in a specific period of time. Similar to Rodrik (2000), we define these episodes as R&D transitions and explore the following questions: which countries have actually increased R&D intensity? Are these transitions more frequent in short periods of time or in the long run? Which variables are significantly correlated before and after these transitions?

Using this data set, we present formal evidence on the likelihood of transitioning to higher GERD levels. We show the main stylized facts regarding these transitions and investigate how economic performance and other relevant variables evolve around an R&D transition as well as the relevance of the private sector in achieving these transitions.

[3] BRIS stands for Brazil, Russia, India and South Africa.

We find that transitions are a rare phenomenon. These transitions are generally positively correlated with higher income levels, knowledge production variables (patents and scientific publications) intellectual property rights, technological exports, and terms of trade. Finally, we also find that private sector R&D leads the way to these transitions.

The rest of the paper is organized as follows. In Section 2 we study R&D targeting as a public policy tool, while Section 3 describes R&D transitions and shows the main stylized facts around these transitions. Long run transitions are also presented in this section. Finally, Section 4 summarizes the main findings.

2. R&D TARGETING

Since the late 1990s, several governments worldwide have begun to self-impose national R&D targets. As of our knowledge, there has not been yet a systematic overview of this policy using a large sample of developed and developing countries. The European Commission (2011) shows the accomplishment rate of 27 member countries, and the OECD (2012) does the same for 32 countries, mainly OECD ones.[4]

We compile information based on official governmental documents and international agencies (see data sources in Annex 1). We gather information for 53 countries, which we cross with UNESCO data to measure the degree of accomplishment. It is important to notice that the sample does not only contain developed countries, but also by developing ones (e.g. Tunisia, Egypt, South Africa, Brazil, Chile, and Thailand among others).

The R&D target and the year in which this goal should be achieved can be appreciated in Table 1. As it a relatively new policy objective, many countries' R&D goals are after 2013, and thus there is not any accomplishment information available. However, there still are a number of countries that we can evaluate. As it can be seen in Table 1, most countries set a specific target figure for the R&D ratio (over GDP),

[4] In a previous paper Sheehan, J. and A. Wyckoff (2003) analyze some of the challenges that face the economies, especially OECD countries, when targeting higher levels R&D, but they do not study targeting accomplishments, neither the occurrence of R&D transitions.

although some countries such as Canada and Nigeria establish the target in relative terms. The median and the mode targets are 2% and 15 respectively.

The case of the European Union (EU) is especially interesting, as it is a forerunner in R&D targeting and because there is an important degree of heterogeneity across member countries. Table 2 shows the success rate of their national goals set for 2010. The overall degree of achievement is very low, just 2 countries of the 27 met their goal: Ireland and Denmark. Denmark established a GERD target of 3% and Ireland 1.58%. In 2010, Denmark's GERD intensity was 3.06% and Ireland's was 1.79%.

Although the majority of countries have not achieved their targets, it can be interesting to compare their progress. Figure 3 illustrates progress to target for OECD, EU, and developing countries with current information. In the vertical axis, we show annual R&D intensity as a fraction of the country's goal (if it reaches 100% by the end of the X-axis, the goal is accomplished). In the horizontal axis, time is measured relative to the date when the goal was established, i.e. "year zero." The last year at the end of the X-axis shows the goal date.

First it can be noted that when establishing the target, OECD countries already had an average 64% completion rate, EU countries 60% and developing countries 48%. Second, even there is progress, the Figure 3 suggests that it has been slower in OECD and EU than developing countries.

In sum, looking at the experience of several countries, it seems that targeting R&D is a common practice but it is very hard to meet goals. In general, we find that the success rate is very low for developing and developed countries.

3. R&D TRANSITIONS

This section aims to identify countries and the timing in which they experienced a significant increase in the R&D to GDP ratio. By identifying this transition year, it can be investigated whether this timing coincides with changes in policies and evaluate potential causes and consequences of this change. Thus using this year, we create an event study methodology to compare the before and after evolution of several country-specific variables. This is studied econometrically using matching techniques, the behavior of a number of relevant variables such as per capita GDP, total factor productivity, and innovation and scientific outcomes (patents and publications)

We use a longitudinal dataset of 62 countries between 1960 and 2007. The information on R&D over GDP was built by merging two different databases: Lederman & Saenz (2005) and the World Development Indicators (WDI), publicly available in the World Bank's website. The first database accounts for the period between 1960 and 2000 and the second from 2001 to 2007. The rest of the variables come from WDI except the Property Rights Index taken from (Gwartney, et al. 2011),[5] total factor productivity growth, Isaksson (2007), and R&D performed by the private and public sector which was retrieved from the Science, Technology and Innovation Dataset provided by UNESCO.

Table 3 shows the list of countries included in our sample, and Table 4 presents a summary of the data for selected years. It can be noted that the number of countries with available information grows substantially over time. The world mean and median of R&D to GDP shows a clear upward trend. In 1970 - with observations for 24 countries - the world's GERD average was 0.77%, while in 2007 this figure reached 1.31%. The world's median increased from 0.3% to 1.1% between both years. The standard deviation has also grown, from 0.76 in the 1970s to 1.1 in 2007. In 2007, the world's lowest value was 0.06% (Guatemala) and the highest was 4.76% (Israel).

3.1 R&D Transitions

A country is defined as experiencing an R&D transition when there is a persistent and significant increase in the R&D to GDP ratio relative to its previous performance. Following Rodrik (2000), we start by defining year T as the beginning of a transition whenever the five-year moving average of the R ratio over a five-year period starting at T exceeds the five-year average of its R&D ratio prior to T by more than y percentage points

[5] "Legal System & Property Rights" is the variable used from the dataset.

More formally, let X_f^5 the five-year moving average of the R&D ratio with year T as the first year of the average, and X_l^5 as the five-year moving average with year T as the terminal year of this average. Then, T is a transition year whenever:

$$X_f^5 - X_l^5 > y$$

There are several parameters needed to identify the transition year. First, we need to define the number of years for the change in R&D. By using before- and after-five-year moving averages, we have a total horizon of ten years in which the evolution of the R&D ratio is analyzed. Second, the "significant" difference in the R&D ratio given by y also needs to be defined. A low value for y allows for us to identify transitions where the change in the R&D ratio is less important in quantitative terms. By construction this would increase the number of episodes. In contrast, larger values for y are useful to identify transitions that indicate a sharp break with past performance. To check the result's robustness and to illustrate the potential differences between gradual and more abrupt transitions we look at the transitions using three values for y: 0.75, 0.5 and 0.25 percentage points.[6]

In the case that transitions occur consecutively or are very closely together in the same 10 year period, we only identify it for the first year in which the difference between the moving averages reaches the defined level.

In Table 5, we show transition years and countries for each defined threshold. As expected, the number of transitions diminishes when analyzing higher thresholds. Only 5 cases register when y>0.75, compared to 45 episodes when y>0.25. Only Israel, Sweden and South Korea evidence a transition when y>0.75. They also have the higher number of transition episodes. However, Finland, Austria, Singapore, and Japan experience four or more episodes of transitions when considering different thresholds.

[6] Therefore, y>0.75 addresses transitions considering changes in R&D over GDP over 0.75 percentage points, y>0.50 transitions between 0.50 and 0.74 percentage points, and y>0.25 transitions between 0.25 and 0.49 percentage points.

This evidence, independently of the threshold used, indicates that very few R&D transitions occur in developing countries. We find that only Hungary, China and Russia have experienced a transition.

To give information on the magnitude of levels before and after a transition, Figure 4 and Figure 5 show the mean of the R&D to GDP ratio using the thresholds of 0.5 and 0.25 percentage points. In both figures, it can be seen that, on average, countries experiencing R&D transitions increase this variable steadily over time. There is not an abrupt change in this variable in the year of the transition. When y>0.5, the mean R&D to GDP ratio during 5 years before the transition is 1.86% and 2.48% in the following 5 years after the transitions. For y>0.25, these figures are 1.69% and 2.07%, respectively.

3.2 R&D Transitions and Relevant Variables

This section presents the behavior of several variables around an R&D transition. This is interesting for looking at potential factors than can drive a significant increase in R&D, and the likely consequences of these transitions. We analyze several variables linked to knowledge production and other variables of interest (property rights index, openness as % GDP,[7] domestic credit to the private sector as % GDP, net FDI inflows as % GDP, and terms of trade).

To shed light on the potential drivers and impacts of R&D transitions, we present an econometric analysis for testing whether there are significant changes in relevant variables in respect to countries that did not experience a transition.

Using nearest-neighbor matching estimators for sample average treatment effects (SATE) we study the effect of treatment (e.g. experiencing a R&D transition) on variables of interest by comparing them to control countries matched by a series of observable variables. We use the average results of four matches, as suggested by Abadie & Imbens (2002) because it performs well in terms of mean-squared error.

[7] Exports plus imports as a share of GDP.

To look at potential variables affecting the probability of experiencing an R&D transition, we follow the previous work by Wang (2010) and Bebczuk (2002) looking at the determinants of R&D expenditure, thus using the following variables: Gross Capital Formation (% GDP), Tertiary School Enrollment Rate (% Gross), Property Rights Index, Domestic Credit to the Private Sector (% GDP), High Tech Exports (% Total Exports), Openness (% GDP), FDI Inflows (% GDP), and GDP per capita (constant 2005 US$). In the case that some of these variables are also of interest for looking at the relationship with transitions, the outcome variable is excluded from the matching procedure.

More formally, let $[Y_i(0), Y_i(1)]$ denote the two potential outcomes of interest: $Y_i(1)$ is the outcome of i when exposed to the treatment and $Y_i(0)$ is the outcome of i when not exposed to the treatment.[8] In this manner, the sample average treatment effect is:

$$\tau^{sample} = \frac{1}{N}\sum_{i=1}^{N}\{Y_i(0) - Y_i(1)\}$$

As only one of the two outcomes is observable, to estimate the average treatment effect, we estimate the unobserved potential outcome for each observation in the sample. Thus, to estimate $Y_i(0)$ for observation i with covariates Xi, which was exposed to the treatment, the average outcome of selected similar observations is used to estimate the untreated outcome. This is, for each i, matching estimators generate the missing outcome by finding other observations whose covariates are similar.

In sum, the average treatment effect estimator for the treated is:

$$\hat{\tau}^{sm,t} = \frac{1}{N_1}\sum_{i:W_1=1}\left\{Y_i - \widehat{Y_i}(0)\right\} = \frac{1}{N_1}\sum_{i=1}^{N}\{W_i - (1 - W_i)K_M(i)\}Y_i$$

[8] For a more detailed analysis, see Abadie et al. (2004)

Where $W_i \in (0,1)$ and indicate the treatment received, i.e. W0 is no treatment received, while W1 indicates treatment, N1 is the summation of W1, and KM denotes the number of times i is used as a match weighted by the total number of matches.

For our analysis, we define a set of dummies to study how different variables evolve with respect to the transition year T. Hence, D(T-10,T-6) is a dummy variable for the five-year period from T-10 to T-6, D(T-5,T-1) is a dummy variable for the five-year period before the year of transition, D(T+1,T+5) is defined for the first five-year period after a transition, and finally D(T+6,T+10) is a dummy variable for the second five-year period after the transition.

To illustrate how some variable might evolve around R&D transitions, we present an event study considering only countries experiencing a transition and the average GDP growth and patenting activity across countries. The evolution of average annual GDP growth rates during episodes of transitions, presented in Figure 6, shows high volatility, and non-relevant changes can be identified before and after a transition. Some literature suggests that increase in R&D expenditure should be associated with higher economic growth (Romer, 1990; Grossman and Helpman, 1991). However, at least for the countries in this sample, we do not find evidence fot it. Assuming that R&D increases the knowledge output, we would expect an increase in patents after a R&D transition. There is some evidence for this. In fact, patenting activity increases after the transition year for both thresholds.

This evidence is only illustrative and does not allow us to infer whether R&D transitions were associated with changes in relevant variables. To do that, we use our estimations using the control group as counterfactual. In such case, we estimate how these variables evolved compared to a group of similar countries that did not experience a transition.

Tables 6 and Table 7 show our econometric analysis of the evolution of key variables around the transitions. Table 6 is R&D transition for the threshold y>0.5 and Table 7 for y>0.25.

We do not find any evidence that R&D transitions would be associated with higher economic growth. In terms of TFP and GDP growth, both thresholds generally show that economic growth is not accelerated either before or after the transition. The only exception is the positive and significant coefficient for the case of y>0.25 for the parameter (T-5,T-1) indicating that in five years previous to a transition, countries experienced an increase of 0.43 percentage points in TFP growth in comparison with control countries.

Our results for both thresholds show consistent evidence that countries that experience a transition have significantly higher GDP per capita than control countries, both before and after the transition. This effect increases after the transition. This finding is more evident for the lowest threshold comparing GDP per capita in the five-year period before and after the transition. The coefficient augments from 0.56 to 0.91 indicating an increase in the income difference between the treated and control groups of about 40%.

Regarding the evolution of knowledge outputs such as patents, scientific publications, and high-tech exports, the evidence is positive. In general, it suggests that R&D transitions are associated with a better performance in these three dimensions. For transitions of y>0.25, the patent coefficients tend to increase after the transition. During the 10 years before the transition the treated countries have 291 more patents per every million habitants, and 10 years after the transition they have 341 more. For the same threshold, our results show that transition countries publish more scientific articles both before and after the transitions. These differences range between 556 and 1,300 more articles per million inhabitants. However, we do not find any evidence that this increases after the transition. These findings are similar when looking at the 0.5 threshold. Countries experiencing this type of transition also increase patenting but not scientific publications compared with the control group.

With respect to high tech exports, we find a significant increase during the ten-year period after the transition for transitions of y>0.5. This difference reaches to 6% compared to control countries. With the lowest threshold (y>0.25), the estimated difference is 4% but only for the then period corresponding to 5 and 10 year after the transition. Thus, it seems that significant changes in R&D expenditure are positively associated with increased technological content of exports.

In terms of potential drivers of R&D transitions, we now look at several variables that could increase the probability of increased expenditures. The literature mainly suggests that better protection of property rights should be associated with an increase in innovation efforts (Chen and Puttitanun, 2005; Lerner, 2009). Therefore property rights should improve before the transition. For both thresholds, we find some evidence for this during the period between ten and five years before the transition. After the transition, the coefficient is also positive and significant, indicating that transition countries continue to better protect property rights.

We also estimate the relationship among R&D transitions, trade openness, and financial development. In the first case, it can be argued that changes in trade openness may promote R&D transition considering that increasing the relevant market may increase innovation incentives. However, the relationship with trade could be negative whenever changes in comparative advantage towards less sophisticated goods may reduce innovation efforts. In the case of financial development, the expected effect is positive considering that relaxing financial constraints may increase innovation (Savignac, 2008; Hall and Lerner, 2010). However, our results for estimations with both thresholds do not prove this out. None of the coefficients are statically significant, suggesting that there are not relevant differences between the two types of countries either before or after transitions.

We also look at the relationship between R&D transitions and Foreign Direct Investment (FDI). Based on the literature about international technologic diffusion, more FDI may increase incentives to innovate and invest in R&D whenever domestic producers can learn from new technologies used by foreign firms located in their countries. However, our results do not suggest this has happened in transition countries. We actually generally find a negative and significant parameter for the ten-year period before the transition, suggesting that transitions are experienced by countries that have lower levels of FDI inflows comparatively.

Another relationship we analyze is between changes in trade terms and R&D transitions. The idea is that positive trade term shocks may precede a transition since windfalls may help to alleviate financial constraints and the economy may allocate more resources to R&D. We find some evidence of this positive relationship for estimations with both thresholds. In general, our results show that R&D transitions are preceded by positive trade term shocks, but said shocks do not persist after the transition.

Finally, we analyze whether these transitions are associated with higher increases in private or public R&D expenditure. To do so we estimate the equation for both shares – public and private – on total R&D expenditure. Our results show that the private sector is a key driver of R&D performance. Previous to a transition, countries have a higher share of R&D financed by the private sector. As it can be inferred from our estimations, in the years after the transition, there is an increase in these differences between transition and non-transition countries. This is illustrated in Figure 7 for the average evolution of these variables in countries experiencing transitions. The private R&D share increases substantially during transitions, meanwhile publicly financed R&D decreases. To reinforce these findings, we show that the same behavior can be seen in particular transition episodes such as those in Israel and Finland (Figure 8).

3.3 Long-Run R&D Transitions

A complementary methodology is used in order to study changes in R&D over time. In this case, rather than identifying the transition year, we explore whether there are countries that have significantly increased their R&D ratio in comparison to the rest of the world, looking at changes between the beginning and the end of the sample.

Thus we follow a methodology applied by Quah (1993) for studying economic growth[9]. Consider a cross-country distribution of R&D-to-GDP-ratio in year t given by

[9] A similar methodology has been used for analyzing trade specialization dynamics by Proudman and Redding (2000) and Redding (2002), and also by Mancusi (2001) for studying technological specialization in industrial countries.

Xt. The evolution of this distribution over time may be described by the following law of motion:

$$X_{t+1} = M \cdot X_t \tag{1}$$

Where M is an operator mapping one distribution onto another between two time periods, t and t+1.

The law of motion for X does not need to be first order nor does the relationship need to be time-invariant, however it is useful to assume that for analyzing intra-distribution dynamics in X. One advantage of this methodology is that iteration of the operator M yields a prediction for future or long run cross-section distribution:

$$X_{t+s} = (M \cdot M \cdot M \cdot M ...... \cdot M) X_t = M^s X_t \tag{2}$$

By letting s→∞ we can obtain the long-run distribution of the cross-country R&D ratio. Then we can discuss if the long run distribution X_{t+s} tends to a point mass or to a bimodal distribution. This is a useful way to identify if countries are converging to different levels of R&D expenditure.

The law of motion described by (1) is generally simplified by discretizing the set of possible values of the variable of interest. In such a case, the operator M simply becomes a transition matrix probability. Each cell of this matrix shows the conditional probability of moving between states over time, i.e., we can compute the probability of moving from "bad" (low R&D-to-GDP) to a "good" state (R&D-to-GDP) for different time periods.

As we are interested in long-run transitions, we calculate a transition probability matrix between the initial and the final period of the sample. In this transition probability matrix, every cell represents the probability $P(q/q')$ of being in state q in t+s, given that a country was in state q' in t, with q and q' ∈ {1,2,3,4,5}. To define these five states, we use the quintiles of R&D distribution across countries, with four thresholds corresponding to the 20^{th}, 40^{th}, 60^{th}, and 80^{th} percentiles. Then, state 1 represents the 20% of the sample with the lowest R&D to GDP ratio. In the same way, state 5 corresponds to the top 20% of countries.

The matrices are computed averaging the R&D ratio in two initial periods 1960-1965 and 1965-1970 and then for the period 2002-2007. We investigate how likely it for some countries to, change, for example, from state 1 to state 5 during the period (ie. from the lowest to highest R&D to GDP ratio).

The results for both matrices are shown in Table 8 and 9. When comparing 1960-1965 to 2002-2007, we find that Singapore and Austria are the only countries that achieved a significant long-term transition, moving from the first quintile in 1960-1965 to the fifth in 2002-2007. South Korea also achieved an important transition from the second to the fifth quintile. Only the United States and Switzerland maintained their leadership roles; they are the only countries that started and ended in the fifth quintile.

Very similar results are found when comparing the periods 1965-1970 and 2002-2007. The most significant transition is made by Singapore. Austria and South Korea moved from the second to the fifth quintile. Finally, again the U.S. and Switzerland maintain their leadership. In sum, this evidence suggests that long-term transitions are a rather infrequent event.

4. CONCLUSIONS

The present work expands existing economic literature by studying R&D targeting as a variable of public policy, using a information for 53 developed and developing countries that have established R& targets.. It also addresses incidence of R&D transitions from 1960 to 2007 for a larger sample of 62 countries, analyzing the likelihood of transitioning and main stylized facts.

The first main finding is that R&D targeting has not been an effective policy. Of the 32 countries that established a target for 2010, only 2 achieved their target, a success rate of 6.3%. However, some few countries do show consistent progress toward their goal.

In our study of R&D transitions we find that these are also infrequent and even when using the lowest threshold analyzed (y>0.25), only 45 episodes are recorded. These transitions occur at around the 2% R&D to GDP ratio and US $23,000 (constant 2005 US$) per capita income.

R&D transitions are associated with higher income levels. Knowledge production variables (patents and scientific publications) show a stronger association. During the 5-year period immediately after a transition, countries have 291-341 more patents and 557-1,081 more scientific articles every million habitants, than comparable countries. We also find that High tech exports increase up to 6 percentage points after transitions.

Our findings indicate that countries seem to increase their property rights index previous to a transition; but transitions require a high index, tending to occur when the score is above 80. We find that trade openness and private sector credit do not show positive and significant correlations with R&D transitions. Also, our findings suggest that FDI (as proportion of GDP) tends to be smaller for countries before they transition. Foreign knowledge acquisition through FDI does not seem to be a catalyst of R&D transitions. We also find that R&D transitions rely strongly on private R&D spending more than from public sources, therefore increasing private share of total R&D.

Finally, long-run transitions are also infrequent. Only Singapore, Austria and South Korea seem to have experienced a significant transition from a low R&D to GDP state to the highest one. Additionally, only the U.S. and Switzerland have stayed in the highest quintile throughout time. However, improvement is possible as 48% of the sample advanced their relative position between 1965-1970 and 2002-2007.

Both of our exercises show evidence of the difficulties that many countries face when increasing their economies' R&D intensities. It requires careful policy design, as most efforts have been doomed to failure. Moreover, we found that significant increases do not occur at any level of R&D intensity; instead they occur at significantly high levels, which is consistent with countries having developed significant absorptive, learning, and innovation capabilities. Indeed, countries experience increases in patents and published papers both before and after transitions. The existing institutional setting is crucial, particularly a high level of respect to intellectual property rights is a prerequisite to transitions.

One of the good news of our research is that still many countries have experienced important increases in R&D intensities, although not as structural changes, measured by our “transitions.” All these findings open a new and unexplored area of research, a detailed understanding of the private and public efforts deployed to increase R&D in countries that experienced successful transitions. There is a vast array of public polity tools that can and should be evaluated for success. It seems likely that sequenced, prioritized, and targeted areas could make the difference between a successful transition and a failure, but future research should determine this to be sure.

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Table 1: R&D Targets across the world

Country/Region	Goal (R&D % GDP)	Target Year	GERD in 2010*
Mexico	1.00%	2006	0.37%
Tunisia	1.25%	2009	1.21%
Brazil	1.50%	2010	1.10%
Canada	Top 5 OECD	2010	1.95%
EU	3.00%	2010	2.50%
Singapore	3.00%	2010	2.14%
Egypt	1.00%	2012	0.21%
India	2.00%	2012	0.76%
United States	3.00%	2012	2.83%
Korea	5.00%	2012	3.36%
Turkey	2.00%	2013	0.85%
Kuwait	1.00%	2014	0.11%
Ukraine	1.50%	2014	0.83%
United Kingdom	2.50%	2014	1.81%
Albania	0.60%	2015	0.15%
Argentina	1.00%	2015	0.51%
Serbia	1.00%	2015	0.76%
Thailand	1.50%	2015	0.21%
China	2.20%	2015	1.48%
Russian Fed.	2.50%	2015	1.16%
Kazakhstan	2.50%	2015	0.23%
Qatar	2.80%	2016	0.33%
Chile	0.70%	2017	0.50%
South Africa	2.00%	2018	0.93%
Japan	4.00%	2020	3.26%
Nigeria	Top 20 Dev. Economies	2020	0.22%
Philippines	2.00%	2020	0.11%

Note: * 2010 or latest year available. Tunisia (2009), Egypt (2009), India (2007), Qatar (2007), Kuwait (2009), Albania (2008), Kazakhstan (2009), Thailand (2007), Nigeria (2007), Philippines (2007).

Source: *a) R&D Targets*: UNESCO (2010), OECD (2004), OECD (2010), Sheehan & Wyckoff (2003) and governmental documents publicly available (see Annex 1).

b) GERD in 2010 (or latest year available): Battelle (2011), Erawatch (2012) and UNESCO Institute for Statistics Database.

Table 2: R&D Targets in the European Union

Country	Goal for 2010 (% of GDP)	GERD in 2010	Goal in 2020 (% of GDP)
Belgium	3,00	1,99	2,60-3,00
Bulgaria	*	0,6	1,50
Czech Rep.	2,06	1,56	2,70
Denmark	3,00	3,06	3,00
Germany	3,00	2,82	3,00
Estonia	1,90	1,62	3,00
Ireland	1,58	1,79	*
Greece	1,50	0,58	2,00
Spain	2,00	1,39	3,00
France	3,00	2,26	3,00
Italy	2,50	1,26	1,53
Cyprus	1,00	0,5	0,50
Latvia	1,50	0,6	1,50
Lithuania	2,00	0,79	1,90
Luxemburg	3,00	1,63	2,60
Hungary	1,40	1,16	1,80
Malta	0,75	0,63	0,67
Netherlands	3,00	1,83	*
Austria	3,00	2,76	3,76
Poland	0,92	0,74	1,70
Portugal	1,80	1,59	2,70-3,30
Romania	1,80	0,47	2,00
Slovenia	3,00	2,11	3,00
Slovak Rep.	0,80	0,63	0,90-01,10
Finland	4,00	3,87	4,00
Sweden	4,00	3,42	4,00
United Kingdom	2,50	1,77	*

Source: European Commission (2011a) and European Commission (2011b).

Note: * not available.

Table 3: Countries present in the database

North America	Latin America	Europe	Asia	Africa	Oceania	Middle East
Canada	Argentina	Austria	China	Madagascar	Australia	Cyprus
United States	Brazil	Belgium	India	Mauritius	New Zealand	Egypt
	Chile	Switzerland	Indonesia	Nigeria		Israel
	Colombia	Czech Republic	Japan	Uganda		Jordan
	Costa Rica	Germany	Korea	South Africa		Turkey
	Ecuador	Denmark	Kazakhstan			
	Guatemala	Spain	Sri Lanka			
	Mexico	Estonia	Pakistan			
	Panama	Finland	Philippines			
	Peru	France	Singapore			
	El Salvador	United Kingdom	Thailand			
	Uruguay	Greece				
	Venezuela	Croatia				
		Hungary				
		Ireland				
		Italy				
		Lithuania				
		Latvia				
		Norway				
		Portugal				
		Russia				
		Slovenia				
		Slovakia				
		Sweden				

Table 4: R&D to GDP

Year	Countries	Median	Mean	Std. Dev.	Min	Max
1960	2	0,126	0,126	0,052	0,089	0,163
1970	24	0,315	0,769	0,766	0,116	2,572
1980	25	0,519	0,897	0,861	0,091	2,956
1990	36	1,143	1,264	0,896	0,152	3,414
2000	48	0,918	1,230	1,093	0,0476	4,601
2007	49	1,098	1,309	1,109	0,0576	4,760

Source: Lederman & Saenz (2005) and World Development Indicators (2010)

Table 5: R&D Transitions Using Different Thresholds

Economy	Transition Year y>0,75	y>0,5	y>0,25
Israel	1975, 1995	1974, 1994, 2001	1971, 1982, 1992, 2002
Sweden	1980, 1996	1978, 1992, 1998	1972, 1985, 1997
Korea	1984	1981, 1992	1979, 1989, 1995, 2003
Finland		1982, 1993, 1999	1978, 1984, 1990, 2001
Austria		1977, 2000	1976, 1997, 2003
Singapore		1985, 1995	1982, 1993, 2001
Denmark		2000	1985, 1992, 1998
Switzerland		1984	1968, 1983
Hungary		1969	1967
Japan			1967, 1979, 1985, 2000
Australia			1989, 2001
Canada			1980, 1999
Germany			1978, 1985
Belgium			1998
China			1998
France			1980
Ireland			1990
Italy			1983
Norway			1982
Russia			1998
USA			1979
Nº of Transitions	5	18	45

Source: Author's calculations based in WDI and Lederman & Saenz (2005)

Table 6: Variables of interest around R&D transitions, y 0.5

	Annual TFP Growth Rate	Annual GDP Growth Rate	Log. GDP per capita	Patents by Mill Hab	Scientific Pub by Mill Hab	High Tech (% Exports)	Property Rights Index	Openness (% GDP)	Credit to Private Sector (% GDP)	FDI net Inflows (%GDP)	Terms of Trade	Private Sector R&D (%, Total R&D)	Public Sector R&D (%, Total R&D)
(t-10, t-6)	0.27	-0.47	0.86**	131.27	1,363.61**	0.00	10.49*	0.93	-4.52	-1.68	2.47	5.95	-5.63
	(0.89)	(-0.53)	(3.69)	(0.68)	(4.97)	(0.05)	(2.75)	(0.12)	(-0.45)	(-1.87)	(0.77)	(1.35)	(-1.55)
(t-5, t-1)	0.35	0.68	0.86**	184.96	1,369.59**	0.03	5.78	1.95	-4.80	-1.76*	13.01	12.45**	-9.13**
	(1.53)	(1.05)	(3.69)	(1.27)	(6.94)	(1.55)	(1.93)	(0.32)	(-0.61)	(-2.48)	(3.90)**	(3.89)	(-3.42)
(t+1, t+5)	0.27	0.48	0.91**	238.64	1,081.33**	0.06**	9.86**	3.42	6.59	-0.44	7.12*	18.89**	-12.25**
	(1.10)	(0.71)	(5.21)	(1.68)	(6.51)	(3.56)	(3.30)	(0.55)	(0.83)	(-0.52)	(2.07)	(6.23)	(-4.99)
(t+6, t+10)	0.53	0.09	0.72**	216.36	737.87**	0.06**	10.95*	-1.38	8.43	0.13	4.81	21.57**	-12.48**
	(1.88)	(0.13)	(4.26)	(1.63)	(5.47)	(3.51)	(2.76)	(-0.25)	(1.18)	(0.16)	(1.49)	(6.62)	(-4.90)
Obs	684	789	790	687	785	789	789	789	790	790	697	529	540

Note: * significant at 5%, ** significant at 1%. Fit measures for nearest-neighbor-matching estimators are not included, as it is not applicable.

Table 7: Variables of interest around R&D transitions, y 0.25

	Annual TFP Growth Rate	Annual GDP Growth Rate	Log. GDP per capita	Patents by Mill Hab	Scientific Pub by Mill Hab	High Tech (% Exports)	Property Rights Index	Openness (% GDP)	Credit to Private Sector (% GDP)	FDI net Inflows (%GDP)	Terms of Trade	Private Sector R&D (%, Total R&D)	Public Sector R&D (%, Total R&D)
(t-10, t-6)	0.28	0.41	0.80**	291.50*	897.86**	0.02	20.40**	-9.61	-0.71	-2.09*	10.22*	9.26*	-5.74
	(1.21)	(0.60)	(4.11)	(2.50)	(4.42)	(0.96)	(6.95)	(-1.50)	(-0.10)	(-3.04)	(3.18)	(2.44)	(-1.91)
(t-5, t-1)	0.43*	-0.50	0.56**	281.39*	892.96**	0.03	2.96	-4.08	-6.90	-1.71*	8.83**	11.43**	-6.01*
	(1.99)	(-0.91)	(4.55)	(2.90)	(5.92)	(1.91)	(1.20)	(-0.85)	(-1.27)	(-3.18)	(3.57)	(4.33)	(-2.96)
(t+1, t+5)	0.25	-0.14	0.91**	345.60**	556.70**	0.02	11.32**	-3.95	-4.21	-0.43	-0.66	15.23**	-7.02**
	(1.01)	(-0.27)	(5.21)	(4.04)	(5.63)	(1.69)	(4.96)	(-0.90)	(-0.89)	(-0.70)	(-0.31)	(6.71)	(-4.20)
(t+6, t+10)	0.20	0.20	0.83**	341.62**	885.69**	0.04*	7.89**	-1.86	1.03	-0.91	8.37*	15.28**	-7.22**
	(0.91)	(0.44)	(6.92)	(4.62)	(6.44)	(3.13)	(3.60)	(-0.42)	(0.22)	(-1.51)	(2.78)	(7.83)	(-4.53)
Obs	684	790	790	688	786	790	790	790	790	790	697	529	540

Note: * significant at 5%, ** significant at 1%. Fit measures for nearest-neighbor-matching estimators are not included, as it is not applicable.

Table 8: Long-Run Transitions, 1960-65 to 2002-07

State in 1960-1965	*State in 2002-2007*				
	1	2	3	4	5
1	Philippines	Greece, Mexico	Spain		Austria, Singapore
2	Madagascar	Pakistan	India, Italy, Portugal		Korea
3	Thailand	Argentina		Ireland, Norway	
4				Belgium, Canada	Israel, Japan, Sweden
5			Hungary	France, United Kingdom	Switzerland, USA

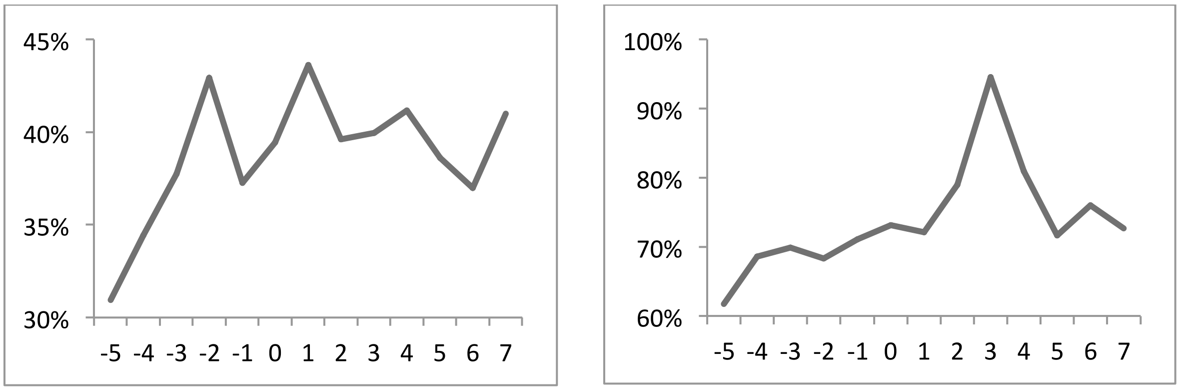
Table 9: Long-Run Transitions, 1965-70 to 2002-07

State in 1960-1965	*State in 2002-2007*				
	1	2	3	4	5
1	Guatemala, Sri Lanka, Philippines	Greece, Uruguay	Spain		Singapore
2	Ecuador	Argentina, Pakistan, Turkey	India, Portugal		Austria, Korea
3	Madagascar, Thailand		Italy	Belgium, Ireland, Norway	Finland
4				Canada	Israel, Japan, Sweden
5			Hungary	France	Switzerland, USA

Figure 1: Example of Unsuccessful Attempts to Reach Target

Mexico's Progress to Target
1996-2008

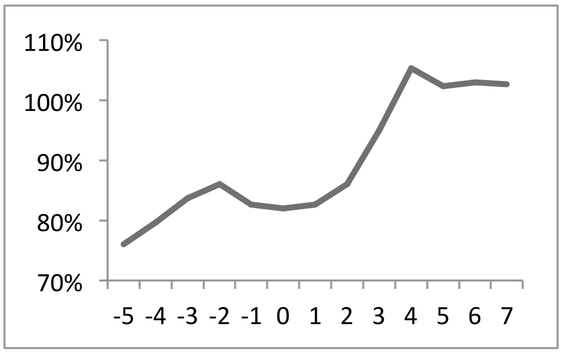
Singapore's Progress to Target
2000-2012



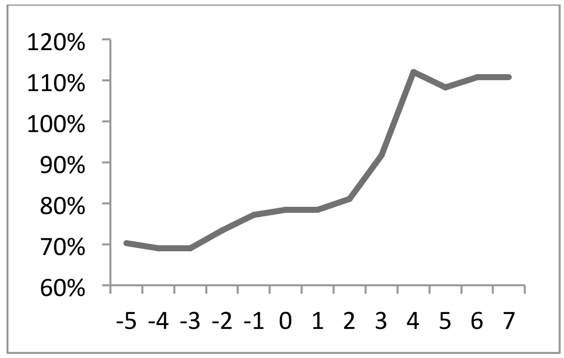
Source: UNESCO Institute for Statistics Database.

Figure 2: Example of Successful Attempts to Reach Target

Denmark's Progress to Target.
2000-2012



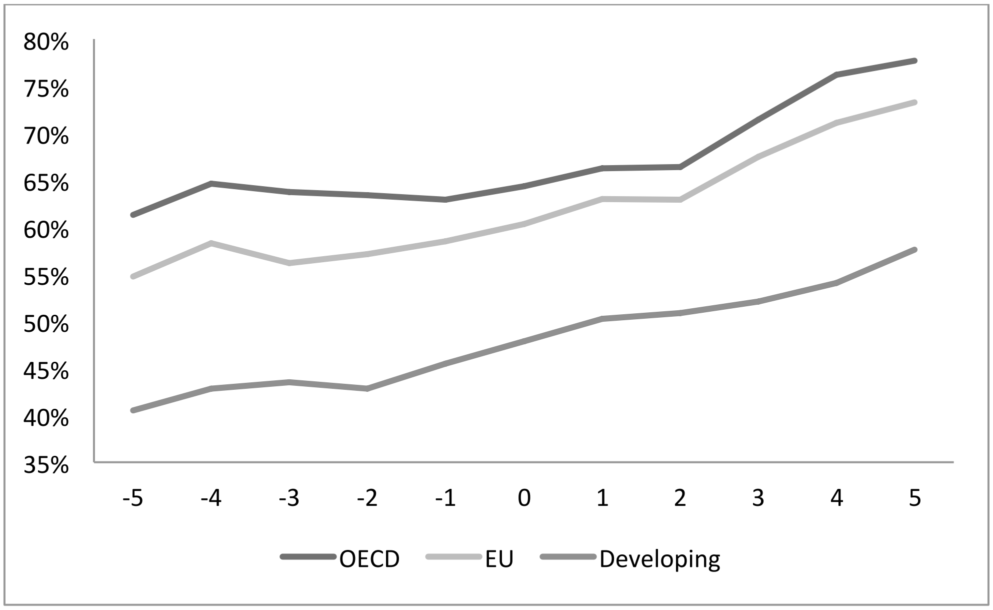
Ireland's Progress to Target.
2000-2012



Source: UNESCO Institute for Statistics Database and Battelle (2012)

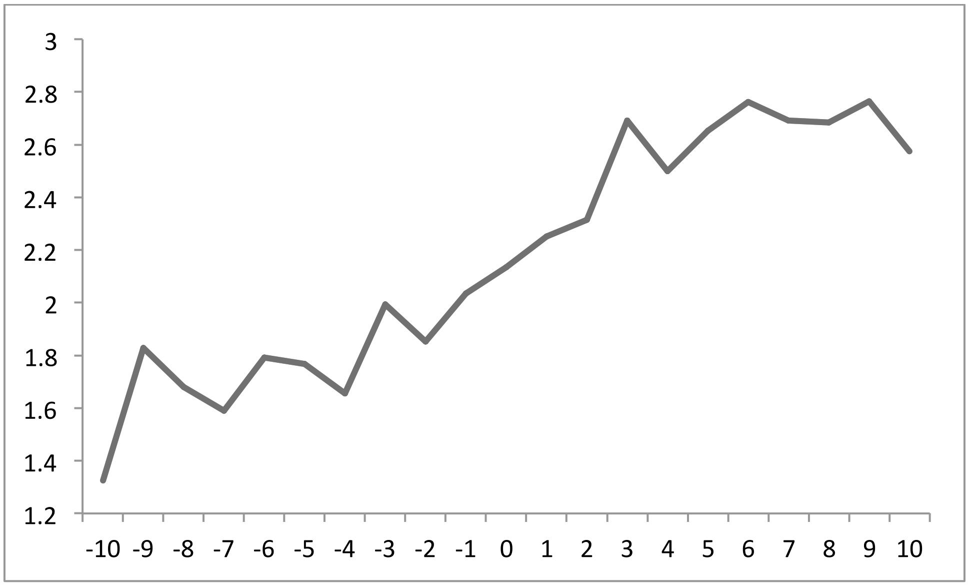
Figure 3: Progress to Target

OECD, European Union and Developing Countries[i]



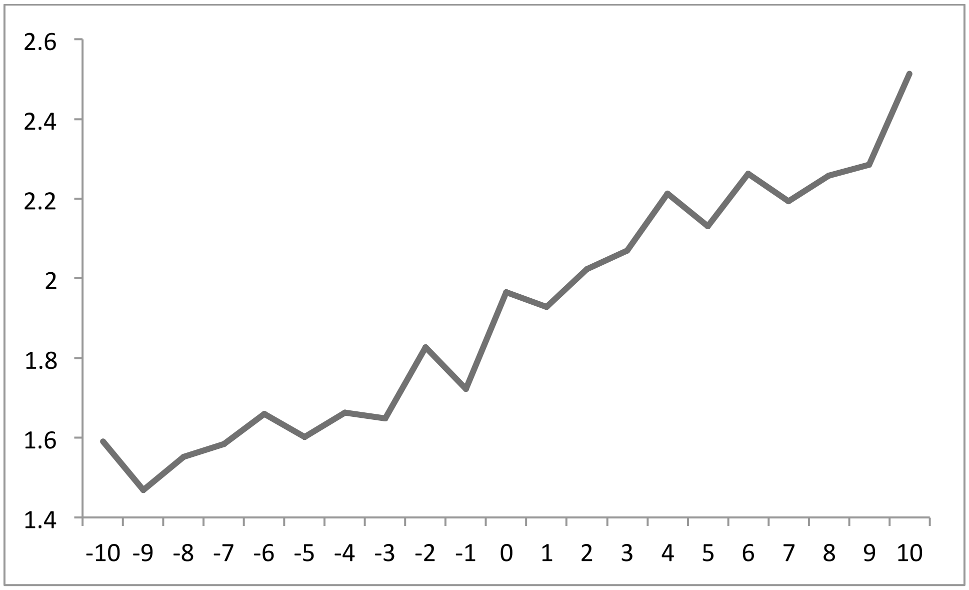
Note: i. developing countries according to IMF (2011)

Figure 4: Mean R&D Transition, when y>0.5



Source: Lederman & Saenz (2005) and World Development

Figure 5: Mean R&D Transition, when y>0.25

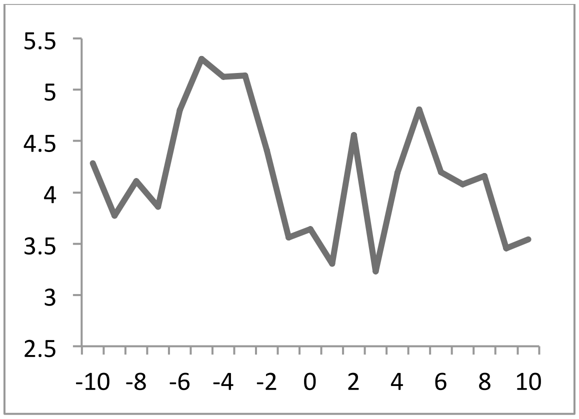


Source: Lederman & Saenz (2005) and World Development Indicators

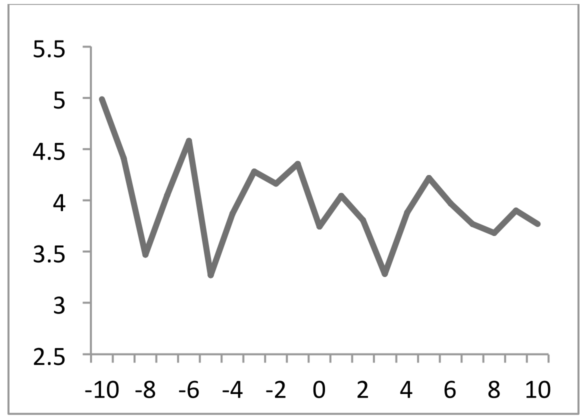
Figure 6: Annual GDP Growth and Patents by million habitants around Transitions

Annual GDP Growth Rate

y>0.5

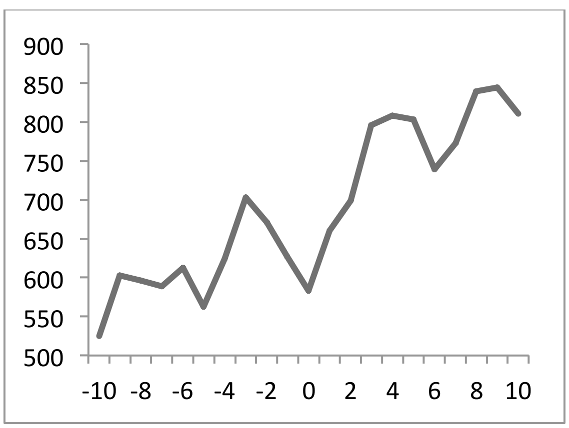


y>0.25



Patents by million habitants

y>0.5



y>0.25

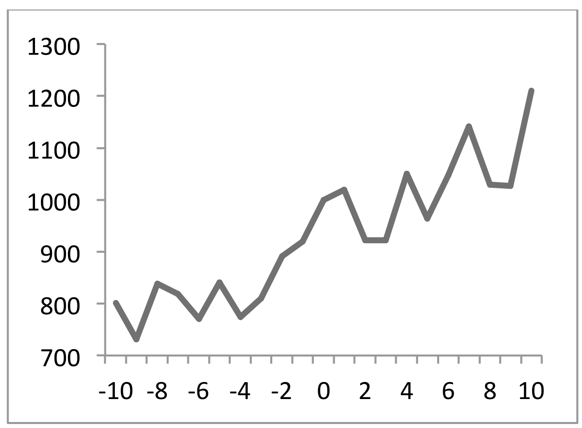
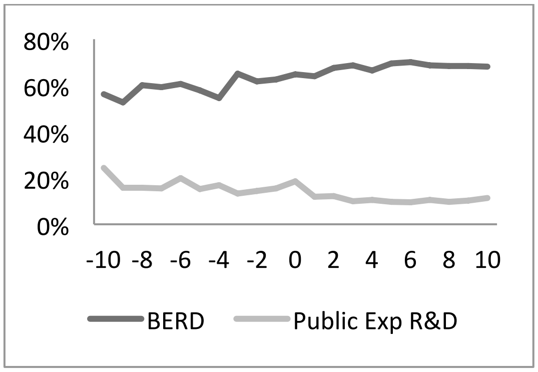


Figure 7: Business and Public Sector R&D around Transitions

y>0.5



y>0.25

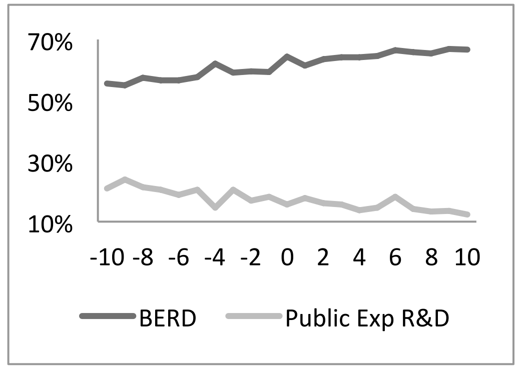
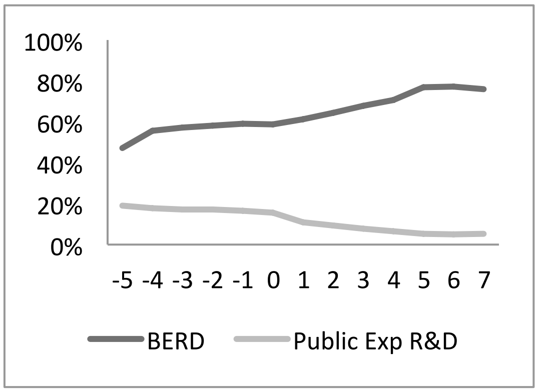
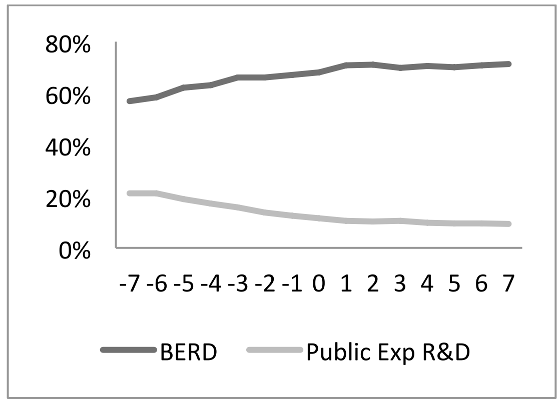


Figure 8: Business and Public Sector R&D around Transitions, Israel 1995 and Finland 1999.

Israel 1995



Finland 1999



Annex 1:

Table A1: Government S&T Official Documents (Incl. R&D Targets)

Country	**Document**	**Year**	**Org. Responsible**
Mexico	Science and Technology Law	2002	Decree of the Chamber of the Deputies, Congress of Mexico
Tunisia	National Development Plan 2007/2016	2006	Ministry of Development and International Cooperation
Brazil	Innovation Law	2004	Federal Government
EU	Mid-term review of the Lisbon strategy	2005	European Parliament
Singapore	Science & Technology Plan 2010	2006	Min. of Trade and Industry
Egypt	The Developing Scientific Research Plan 2007-16	2007	Presidential Decree Nº 218
India	Report of the Steering Committee on S&T for XIth Five Year Plan	2006	Steering Committee on S&T
United States	A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs	2008	Office of Science and Technology Policy
Turkey	National Science, Technology and Innovation Strategy 2011-2016	2010	Supreme Council of Science and Technology (BTYK)
Ukraine	The programme of economic reforms for 2010-2014	2010	President of Ukraine
Albania	National Strategy of Science, Technology and Innovation 2009 - 2015	2009	Ministry of Education and Science
Argentina	Medium-term Strategic Plan in Science, Technology, and Innovation 2005-2015	2005	Ministry of Education, Science and Technology
Serbia	Strategy of Scientific and Technological Development of the Republic of Serbia 2010-2015	2010	Ministry of Education and Science
China	Medium and Long-term National Plan for Science and Technology Development 2006-2020	2006	The State Council of China
Qatar	Qatar National Development Strategy 2011-2016	2011	Qatar General Secretariat for Development Planning
Chile	National Innovation Agenda for Competitiveness 2010-2020	2010	Chilean National Innovation Council for Competitiveness
South Africa	The Ten-Year Plan for Science and Technology, 2007	2007	Department of Science and Technology

Source: Public documents available online. Internet link can be provided upon request. Information on the remaining countries present in Table 1 was gathered from UNESCO (2010), OECD (2004), OECD (2010) and Sheehan & Wyckoff (2003).