Should I stay or should I go? Forecasting Return Rates for Non-US Citizens Holding US Ph.D. Degrees

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Abstract

Over the past 30 years, more and more Ph.D. graduates from US universities have come from abroad. Many of these individuals are temporary visa holders and though the majority tend to remain in the US after graduation, some decide to return to their home countries. This paper estimates the overall return rate to an individual's home country for non-US citizens holding US doctoral degrees as well as return rates for the top 10 countries send their citizens to the US for doctoral degrees. The paper also estimates return rates by major academic fields. Using several approaches, forecasts of these return rates are generated. The results suggest that with the major exception of China, the rate of return by graduation year cohorts has been declining over the past decade by around one percentage point suggest more and more scientist and technical graduates are staying in the US. Chinese citizens who receive US Ph.D.'s have experienced a growing return rate of roughly 0.6% a year for each new graduating cohort between 2001 and 2011. We review some of China's policy efforts made to encourage return of scientists and speculate as to how these may account for China's growing return rate. We conclude by speculating on the implication of these trend for the future.

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Introduction

The US has become an international leader in producing Ph.D. students since the end of the Second World War. Since that time the composition of graduates has slowly sifted to reflect a more international makeup. In the 1970s each graduating cohort of US doctoral students was more than 80% US citizens but by 2010 that number was only slightly more than 50%. This shift reflects many factors including increased capacity in the US system, prestige of US program (Stephan, Franzoni et al. 2015), and growing worldwide demand for highly skilled labor, particularly in the science, technology, engineering and math (STEM) fields.

At the same time, policy makers have begun to view this particular group a major engine of scientific and technical innovation and that such innovation also promotes economic growth (Bush 1945, Nelson and Rosenberg 1993). These perspectives have influenced US science, technology and higher education policy. Since the 1990s these same perspectives have been embraced in other developed and developing countries leading to an increased emphasis on training and hiring Ph.D. level research scientists(Thorn and Holm-Nielsen 2006). Consequently, one might expect there to be growing pressure for many non-US citizens with US Ph.D. degrees to return home, especially to countries with active policies designed to increase their STEM workforce. The central question we ask in this paper is to estimate and forecast increases, or decreases, in the rate at which individual are returning to their home countries with US based doctoral degrees over time. The next section provides a literature review of what scholars think are the main forces that effect why non-native advance degree holder living abroad might wish to return home. This is followed by a description of the data source and sample data we use in our analysis. Our discussion of the data also includes how we go about measuring return rates from the data and some of the potential problems associated with using these data and our approaches to measurement. The next section describes how we use our data to model and forecast overall return rates for each graduation cohort beginning in 2001. We then apply the same approach to forecasting return rates for the 10 countries which contribute the most graduating Ph.Ds. and also forecast trends by field of study. We then summarize and report these finding including some discussion on why one country, China, seems to be bucking the trends. The paper concludes with a discussion of the overall findings, limitation and next steps.

Literature Review

Motivated by concerns over so called ‘brain drain’ impacts, a number of scholars have begun to study why foreign scientists living and working in a host country may decide to return to their countries of origin. Thorn and Holm-Nielsen (Thorn and Holm-Nielsen 2006) provide a useful summary of current proposed theoretical explanations as well as some descriptive data analysis. They identify a number of potential push and pull factors which are then organized under three broad categories. The first is titled ‘neoclassical factors’ which focuses primarily on economic conditions like wage differentials and market factors. The term ‘transnationalism’ describes the second category of factors which include connection to home countries, such as family ties, a sense of national identity and commitments to the future developments of their home nations. The last group of forces is labeled ‘social network factors’ and pick up a number of contextual and institutional considerations including connections to ‘invisible colleges’ and research networks. Their empirical work focused on OECD countries and was primarily descriptive of trends.

Fontes (Fontes 2007) identified several data issues in the context of foreign scientist whose origins are from countries with weaker scientific and technical systems. Using the case of Portugal, Fontes proposed an approach to identifying and studying Portuguese born scientists working in other countries. A test of their approach generated 41 detailed case studies. While the author notes the empirical results are not generalizable, they are suggestive. While many of these expatriates expressed some interest in returning home specifically to make a difference, they remained unwilling to return due to awareness of 'difficulties' at home. These difficulties tended to reflect on the quality of the research environments in Portugal. Interestingly many of these respondents were part of networks that had some attachment to Portuguese scientists and/or research institutions.

Recent work by Franzoni, Scellato and Stephan (Franzoni, Scellato et al. 2012, Scellato, Franzoni et al. 2015) provides a more current statistical review of mobility patterns of foreign born scientists. This work makes use of a sample of over 17,000 respondents from 16 countries and four academic fields. They found significant variation across country by both country of origin and host country. For example Switzerland had almost 57% of respondents currently living in Switzerland self-identify as foreign nationals. India, Italy and Japan had the least foreign scientists. The authors speculate that some of this variation may be the result of post-doctoral opportunities which would in part reflect the overall quality of research environments. Similarly the authors found that India was the country with the highest rate of emigration and that Japan had the smallest. The authors also compared the unconditional estimates of the probability of returning home and found that Spanish nationals were the most likely to return and that Indians were the least likely. The most common reason provided by respondents for returning home was for family and personal reasons.

The paper by Baruffaldia and Landoni (Baruffaldia and Landonib 2012) takes a relatively more analytic perspective and models both the choice to return and the productivity of 497 foreign researchers in Italy and Portugal. The principle finding was that for these foreign scientists both the likelihood of return and their productivity were positively related to maintaining some form of professional linkage to their home countries. These results controlled for a number of other relevant factors including research area, position and personal characteristics of the scientist.

Another recent analytic study conducted by Gaule (Gaule 2011) used over 1900 individual foreign scientists born after 1944 associated with a single US Ph.D. granting department in chemistry, chemical engineering and biochemistry. This data collection strategy focused on a single institution's graduates over time was applied because of the general lack of data that follows scientist over time. The author used a discrete time hazard model for the decision to return. This model considers, as time goes on, how the likelihood of return is affected, conditioned on other variables. While the study found that only 9% of foreign faculty returned home, the most successful scientists were the least likely to do so, though they were more likely to move within the US. Interestingly, though, the author also found that after an adjustment period, return migration seemed to have no negative effects on scientific productivity for returnees. Earlier work by Borjas and Bratsberg (Borjas and Bratsberg 1996) also found negative self-selection into return but in their work, negative selection occurred only at the top of the distribution and not for the average scientist.

Previous work on the rate of non-US citizens who hold US Ph.D.s stay rate (Finn 2012, Finn 2014) suggest that over time this has remained relatively constant and very high. These results, though, do not necessarily provide an accurate view of return rates for a number of reasons. First the data look only at individuals living and working in the US, secondly it relies on matching individual data to Internal Revenue data which requires voluntarily provided social security numbers. Over time the rate of non-response to this has grown making the quality of this process more problematic. Consequently, while these results provide a baseline for thinking about return rate over time they have become less and less useful for that purpose.

Aggregate trends build upon many individual choices. Individuals over time reassess their options and may choose to return home or not. Therefore a useful starting place is to understand aggregate trends in return rate. By exploiting the International Survey of Doctoral Recipients (ISDR) beginning from 2010, we are now able to directly identify individual with US base Ph.D. degrees living in their home countries, the country for which they held citizenship in at the time of receiving their Ph.D. Thus this paper focuses on first describing and then forecasting the trends in return rates for non-US citizen holding US Ph.D. degrees. This analysis will look at the overall return rate as well as trends by the countries send the most students to the US and by major field of study.

Data and Measurement of Return Rates

The data are from the Survey of Doctorate Recipients (SDR), a panel study sponsored by NSF and conducted every two years on representative cohorts of Ph.D. students who received degrees from universities in the US. It contains two sample components: the National SDR (NSDR) and International SDR (ISDR). NSDR targets the population of Ph.D. students who received doctoral degrees in the US and were living in the US on the survey reference date, while the ISDR includes Ph.D. students who lived outside of the US on the survey reference date. As a sample of Ph.D. students wherever they reside after graduation, SDR can be employed to estimate the return rates of non-US citizens holding US Ph.D. degrees based on the information of citizenship and residence location.

Using the 2013 ISDR, we identify the US based Ph.D. degree holders living in their countries of origin after and from the 2013 NSDR we identified all non-US citizens. The 2013 ISDR sampling frame was constructed from the returning cohort in 2010 ISDR who received doctoral degrees before 2009, and the new cohort with degrees rewarded between 2009 and 2011.[1] The sample size of 2013 SDR is 35,265, including 30,696 NSDR cases and 4,569 ISDR cases, from the target population of about 924,600 doctorate recipients.

The data on graduates living abroad who received degrees before 2001 is not adequate to characterize returnees due to limitation of sampling. Survey data were not collected from non-US residents until the 2003 SDR, and the non-US citizens consistently residing outside the US were ineligible for sampling prior to the 2003 SDR (Grigorian 2012, Yang 2012). Therefore the data only permits reliable estimates of return rates for Ph.D.'s receiving doctorates after 2001. Each

[1] The technical notes of 2013 SDR, http://ncsesdata.nsf.gov/doctoratework/2013/sdr_2013_tech_notes.pdf.

observation in the SDR has a sampling weight that account for oversampling and non-response and allowed us to generate population estimates (Larson 2011). The data from the 2013 SDR only contain responses for those individuals graduating through 2011, thus time series for return rates only spans 2001 to 2011 for 11 observations.

The return rate for non-US citizens holding US doctoral degrees is defined as the proportion of individual currently living in their home countries during the reference year of the survey by the year of graduation. Thus we have an estimate by graduation year of the proportion of returnees. The returnees are identified by checking whether the country of residence is the same as where they hold citizenship at the time they receiving their doctorates. The return rates we estimate are for cohorts by their year of graduation and we applied sampling weights to account for oversampling and non-response bias.

There are some measurement issues associated with this approach. One problem with this approach is that some individuals counted as returnees may not stay 'returned.' Individuals many have returned to their home only temporarily. To shed some light on how serious a problem this might be we compared this approach to estimating returnees in both the 2010 and 2013 version of the SDR a looked for individual changes. Of those who were defined as returnees in both 2010 and 2013 only 102 or 5.7% of the returnees from 2010 changed their status by either returning to the US, 61 individuals, or moving to another different foreign country, 41 individual. It is worth noting that 35% of these individuals continued to work for the same employer thus representing a job transfer away from their home country. Another problem arises from a combination of dropout cases and adding new cases to each round of the survey. There were also individuals surveyed in

2010 but not in 2013 as well as new respondents in 2013 not included in 2013. From these two groups using the 2013 survey excludes 348 returnees in the 2010 survey but not in the 2013 survey but includes 669 returnees from the newly sampled cases. The lost cases of returnees from the 2010 survey was 20.5% of the total cases dropped out but the gain in newly sampled returnee cases was 27.5% of total new cases in 2013. A final point is that in some cases individuals surveyed in both rounds of the SDR were not returnees in 2010 but were in 2013. Of this group 85 moved from the US to their home and 50 from a different foreign countries to their home country. While beyond the scope of this paper the 237 individuals who change status between the surveys may provide more details about micro level forces on decision to return or leave once they have returned.

As noted above the individual returnees identified in the ISDR and the total number of non-US citizens with Ph.D. degrees were identified in the NSDR by year of graduation allow us to generate return rate estimates by year of graduation cohort from 2001 through 2011. We are also able to decompose the return rate by nation of citizenship and by field of study. The 10 countries included Germany, China, India, Japan Korea, Taiwan, Thailand, Turkey, Canada, and the European Union minus Germany. We organized field using those designation typically provided by the National Science Foundation (NSF) into seven groupings; Biological, agricultural and environmental life sciences; Computers, mathematics and statistics; Physical sciences, Psychology, Social sciences, Engineering and Health. Table 1 summarizes the average return rates overall and by country and field. As reported in the literature the return rate varies significantly across various sub-populations.

Table 1: Average Cohort Return Rate 2001-2011

	Average	Std. Dev.
Overall	22.7%	39.1%
Countries		
Germany*	18.6%	8.9%
China	9.9%	2.8%
India	9.7%	5.7%
Japan	35.5%	10.8%
Korea	45.7%	13.2%
Taiwan	47.0%	16.9%
Thailand	86.5%	9.6%
Turkey	40.5%	14.8%
Canada	23.8%	8.7%
EU	22.9%	6.8%
Field		
Agriculture	19.4%	4.5%
Computers	19.7%	6.0%
Physical	19.3%	4.8%
Psychology	27.7%	9.7%
Social	35.5%	4.3%
Engineering	21.8%	5.7%
Health	31.8%	12.8%

* 2001-2010 No Graduates 2011

Forecasting Return Rates

As noted in the discussion of sampling and measurement we are working with relatively short time series. Given a total of 11 observations we do not have enough data to conduct a typical rolling origin forecast tournament to empirically identify the best forecasting approach (Levenbach and Cleary 2006). Alternatively we applied three standard approaches that have been successful in previous forecasting comparisons (Makridakis and Hibon 1979, Makridakis 1982). Simple and double exponential smoothing (Brown 1959) were developed specifically for situations with short time series and limited computer capacity to implement forecast of level and trend by using a form of weighted averaging. In both cases these approaches weight the most recent observations in the sample more heavily and the weights decline exponentially the older the observation. The weighting process is based on a single parameter, α. When the parameter is small such as 0.0001, the forecast tends to use all the information available equally, like the sample mean, but as this parameter gets large, it places more and more emphasis on the most recent data values. We also fit a standard linear time trend to the data using ordinary least squares estimation. One of the advantages of the trend model is that it provides an estimate of how the return rate may be changing over time, particularly whether the rate is growing, shrinking or remaining the same.

Table 2 summarizes the estimation and fitting process for these three approaches applied to the 18 different time series we developed; total return rate, return rates for the major 10 foreign countries represented over the past 20 years among US Ph.D. graduates, and six categories for organizing substantive field. The coefficient estimates for alpha, the weighting parameter used by simple and double exponential smoothing are arrived at through a grid search process. The basic model is applied repeatedly with different values of alpha between zero and one, selecting the final value based on minimizing the one-step-ahead forecasting errors. Unlike typical statistical models these approaches a based on recursive estimates updated through the most recent observation at time t, which is then used to forecast t+1. The one-step-ahead forecast error is then computed and used in the revision process. Thus the method generate these one-step-ahead errors as a part of the normal process of estimation making them the more relevant error statistic. This is in contrast to the standard approach used in fitting statistical models like the linear trend, which batches up all the data at once and generates errors from the model in the entire dataset for analysis. Hence we use the heading RMSFE to indicate these are forecast errors.

A major objective for using these approaches is to identify those time series for which a trend is more appropriate that just a weighted average for forecasting. A trend if supported suggest that, at least for the past 10 year, there is some consistent tendency to grow or decline. Given that we are looking at cohorts, support for a trend is important. This suggests that the net impact of many factors is adjusting the base probability of return for the next cohort. Future work will look more specifically at individuals taking into account their cohort year but this aggregate analysis provides a useful basis for understand the net impact of individual and environmental forces on these decisions over time. Therefore identification of a trend is important.

Using standard statistical criteria are one approach but it should be understood that given the short time series and the likelihood that multiple assumptions necessary to the application of formal statistical inference analysis for these data are likely untrue. Consequently p-values should be viewed more descriptively. We try to interpret these statistics along with more qualitative inspection of graphs provided in the appendix for each of the time series and forecasts through 2025.

Table 2: Exponential Smoothing and Trend Forecasts for Return Rates (Data 2001-2011)

Series	Simple Coef.	RMSE	Double Coef.	RMSE	Trend Coef.	P-value	RMSE	R-Sqr
Total	0.693	0.028	0.436	0.029	-0.010	0.001	0.022	0.716
Germany	0.112	0.094	0.104	0.095	0.013	0.185	0.084	0.208
China	0.378	0.027	0.271	0.028	0.006	0.025	0.022	0.445
India	0.009	0.058	0.001	0.057	0.000	0.998	0.060	0.000
Japan	0.069	0.114	0.046	0.113	-0.004	0.706	0.113	0.017
Korea	0.603	0.104	0.351	0.105	-0.034	0.001	0.072	0.737
Taiwan	0.650	0.134	0.410	0.141	-0.043	0.001	0.094	0.725
Thailand	0.032	0.098	0.137	0.108	-0.012	0.199	0.091	0.176
Turkey	0.269	0.151	0.229	0.159	-0.027	0.048	0.124	0.367
Canada	0.678	0.072	0.363	0.071	-0.019	0.009	0.062	0.548
EU	0.155	0.071	0.214	0.079	-0.010	0.125	0.062	0.241
Biological	0.759	0.033	0.403	0.034	-0.011	0.001	0.024	0.710
Computer	0.000	0.060	0.153	0.064	-0.010	0.093	0.053	0.282
Physical	0.098	0.050	0.162	0.055	-0.006	0.188	0.045	0.184
Psychology	0.056	0.101	0.098	0.109	-0.004	0.697	0.101	0.018
Social Science	0.493	0.038	0.304	0.040	-0.010	0.004	0.028	0.617
Engineering	0.313	0.058	0.199	0.060	-0.010	0.054	0.048	0.353
Health	0.411	0.128	0.234	0.138	-0.023	0.053	0.109	0.354

Statistics associated with the linear trend model identify seven of the series with reasonably precise trend estimates that are statistically significant at less than 5% - total, China, Korea, Taiwan, Turkey, Canada, Biological and Agricultural Sciences, and Social Sciences - and an addition three time series that are significant at less than 10% - Computer Sciences, Engineering and Health. In all but one case the trend is negative suggesting that over the past decade the probability of return has been going down. The one exception to this is the case of China, where the trend over the past decade has been increasing by roughly .6% each year. The review of the graphs generally support these results with some important caveats. The three with larger p-values – Computer Science, Engineer and Health- seem to be influenced by higher (significantly above trend) return rates in 2001 through 2004 and lower (significantly below trend) in 2007 or 2008. This may suggests a change in level more than a trend. This is a similar unusually low observation for Turkey in 2007 but even if this observation were adjusted to the trend level there is still evidence of trending in the other observations. Finally China, the only time series exhibiting a growing probability of return graphically appears to begin trending half way through the time period. The first 5 years the graph suggest an average level with random variation around it but starting with 2005 or 2006 there appears to be a positive trend. This is different from the other series that both statistically and graphically depict trends over the entire 11 year time frame.

In order to provide more confidence in these results we also developed an alternative approach to estimating the trend. Based on a sample of 6,609 non-US citizens from the ISDR and SDR we estimated the following logit model:

$$r(i) = \beta 0 + \beta 1 y(i) + \delta_j + \gamma_j y(i) c(i) + \epsilon(i)$$

where

r(i) is a binary variable indicate whether the individual returned home,

y(i) is the year individual i graduated (cohort i runs from 2001 to 2011,

δ_j is a fixed effect for country j where j=1,…,10 are the 10 top contributors to US Ph.D. programs and j=11 is an all other non-US countries,

c(i) is the individuals home country, and

$\epsilon(i)$ is a random error term.

In this model the slope β1 is time trend for the base case of all other counties and γ_j is the shift from the base case for country j. From this model we can generate country specific time slopes based on the changing rate of return by cohort in the sample. The model is estimated using robust standard errors. Table 3 present the estimated country unique trends and their associated p-value derived from joint significant test.

Table 3: Trend Estimate from Cohort Trends

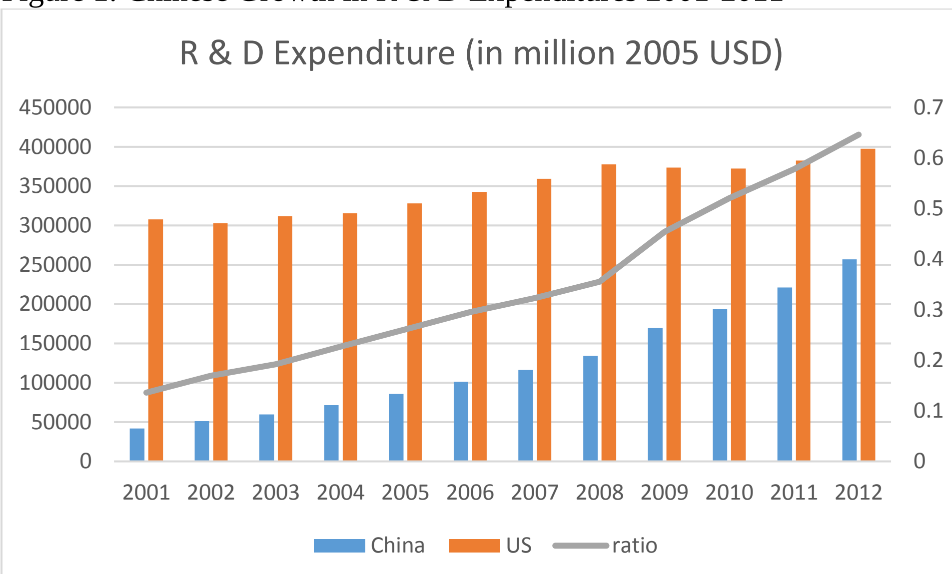
Country	Trend	P- Value	Observation
Germany	0.023	0.7142	120
China	0.064	0.0646	1,314
India	0.005	0.9124	668
Japan	0.010	0.8784	140
South Korea	-0.146	0.0001	534
Taiwan	-0.179	0.0001	289
Thailand	-0.127	0.0844	229
Turkey	-0.107	0.0214	254
Canada	-0.087	0.0611	261
EU	-0.069	0.0671	768
Other	-0.019	0.0180	2030
Nobs			6607

Comparing the results found in table 2 with these the story remains the same. Given the larger sample employed we now have more confidence in our trend results. Overall during the study period, return rates have be dropping with the one clear exception of China.

Why China?

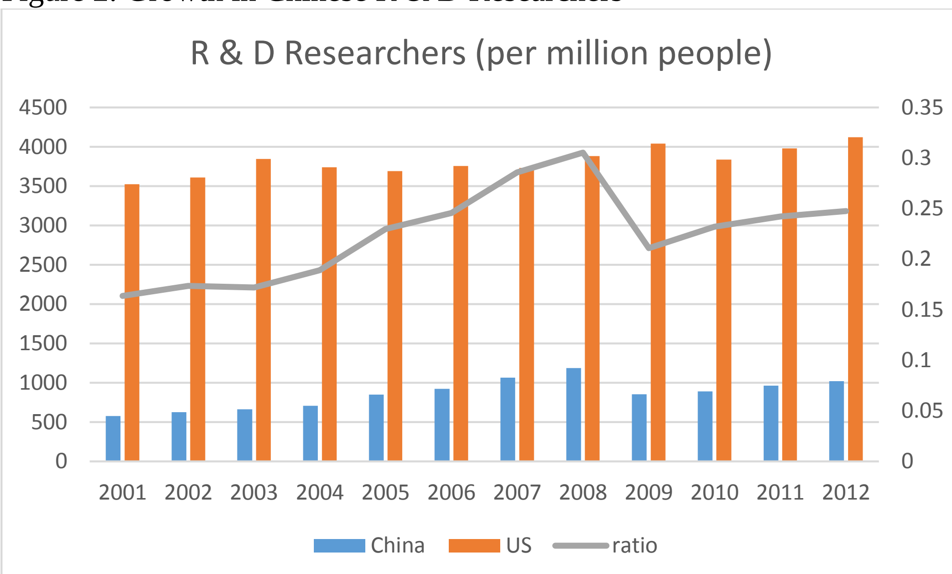
As noted earlier, Ph.D. trained scientists and engineers are often viewed as a valuable input to innovation and economic development. Most of the previous work on returnee decisions suggest along with concerns such as wages, family connections and cultural norms, the quality of the working environment matters (Fontes 2007). Over the past decade, China has enhanced the quality of its overall science and engineering infrastructure through investments. This has shown up in dramatic increases in research and development expenditures and in the growing number of science and engineering graduates. Figures 1 and 2 demonstrate this growth relative to the US. Much of this growth is driven by policy with the expressed objective of improving China's overall economic development and innovativeness.

Figure 1: Chinese Growth in R & D Expenditures 2001-2011



Local governments in China have been under great pressure to maintain high levels of economic growth, in part because their budget depend on it to obtain general budget funding from the central government. Not surprisingly this pressure has motivated local governments to consider policies that might attract returnees, particularly entrepreneurial returnees in high tech fields. In 2001, after graduating with a Ph.D. from the University of New South Wales and receiving Australian citizenship, Zhengrong Shi returned to China and founded a solar power company, SunTech. After failing to obtain subsidies from Shanghai we was able to extract a few benefits for a smaller close by local government Wu Xi. By 2005 SunTech was successful is issuing stock on the NYSE. By 2013 Zhengrong Shi had an estimated personal wealth of over $3 billion. This success led Wu Xi to establish the "530 Plan" which when initiated in 2006 aimed at attracting 30 leading returnees to Wu Xi over the next 5 years. Some of the features of the program included providing startup funds, working space and rent-free living arrangements for up to 3 years. By 2011 Wu Xi had provided over 1 billion is subsidies to returnees and attracted over 1200 returnees, most of who had doctoral degrees (http://www.china530.gov.cn/chinese)

Figure 2: Growth in Chinese R & D Researchers



The success of the "530 Plan" inspired other local government to emulate the practice. Shanghai created its "Thousand Talents Plan", Nanjing created its "321 Plan" and Shenzheng created the "Peafowl Plan (Zhang, Wang et al. 2011, Liu, Cao et al. 2013)."

Motivated by the local government program, in 2008 China's central government created the "Recruitment Program for Global experts. Also called the "Thousand Talents Plan," its expressed objective was to recruit experts that could make breakthroughs in key technologies or directly enhance China's high-tech industries and emerging disciplines. Returnees who enrolled were expected to assume leadership, professional or technical positions in universities, R & D institutes and serve on national R & D projects such as “863 Program” (National High Tech R & D), “973 Program” (National Key Basic Research Project). Like their local government counterparts the program supported living expenses for returnees and their families along with startup packages values at 1 million RMB. Employers were expect to also offer employment to spouses and children were guaranteed admission to schools. Typical salaries were based on previous salaries from overseas employment and through negotiations. By 2012 the plan had attracted over 2200 returnees.

The continued improvement in China’s underlying science and technology infrastructure certainly helps to set the stage for increase return rates not just from US based Ph.D. education but for individuals from all over, like Zhengrong Shi from Australia. The first local government program starts in 2006 which spurred other local governments, all motivated to show more and more economic growth. By 2008 China’s central government creates its own program to encourage returnees. While these program were not exclusively targeted at Ph.D. holders, many of the enrolled did have Ph.D.’s from foreign universities. While it may be purely coincidental, the initiation and growth in the number of these programs from the mid-2000s coincides with the graphical evidence that the actual increase in China’s growth in returnees begins around 2006. We expect that is at best a partial explanation as to why China appears to be one of the only places return rates are going up but it provides us with a starting point.

Conclusion

Over the past 50 years not only has the US higher education system's capacity for doctoral education grown it has serviced more and more non-US citizens. Today almost half of all US Ph.D. degrees are awarded to non-US citizens. These highly skilled graduates help to generate innovations that promote economic growth and productivity gains. Foreign governments like China have actively invested in their own science infrastructure and courted their citizens abroad who hold Ph.Ds. in order to generate more Ph.D. graduates and attract returnees (Li 2015, Li, Miao et al. 2015). This suggest there are potential public policy issues surround return rates for non-US citizens holding US based Ph.D. degrees.

We can see that the overall return rate for all non-US citizens earning a Ph.D. between 2001 and 2011 is approximately 23% and for the most part this rate has been declining by about 1% per year over that same time frame. This suggest that most foreign graduates stay in the US and that the trend seems to be reducing the overall likelihood a new graduate will return home. When this is analyzed by the top 10 foreign countries of origin and the seven major substantive degree fields this pattern persists. Some countries like Thailand, Taiwan, Korea, and Turkey have relatively high return rates while others like India and China have relatively low rates. In all but one of the sub-series that exhibit trends, the trend is down, return rates are in decline. Countries like Korea, Taiwan and Turkey – all with relatively high return rates – are experiencing a three to four percent drop per year in those rates. More typically, the decline in return rates is around 1% per year like the overall return rate. These trend suggest that the US's ability to attract high quality scientific and technical labor from abroad through is high education system will not only continue but improve. Such a trend will allow the US to continue its dominance in technological innovation.

The one exception is China. Chinese nationals who earn a US Ph.D. degree seem to have a growing likelihood of returning to China of around .6% per year since 2001 but this trend seems to have begun in the middle of the time period. This is also the best know case of a country that is attempting to increase its skilled stem workforce not only through improved investments in science infrastructure but also through programs designed to encourage high skilled citizens living abroad to return home. Unlike other countries China has made very large investments in science and technology infrastructure and incentive based policy to court return by scientist and engineers. If these policies are indeed altering perceptions about long term opportunities associated with return, China may begin be able to enhance its overall innovation system through an increased stem workforce trained abroad.

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Appendix –Graphical Displays of Return Rates with Simple Smoothing, Double Smoothing and Linear Trend Forecast

Figure A1, Overall Return Rate

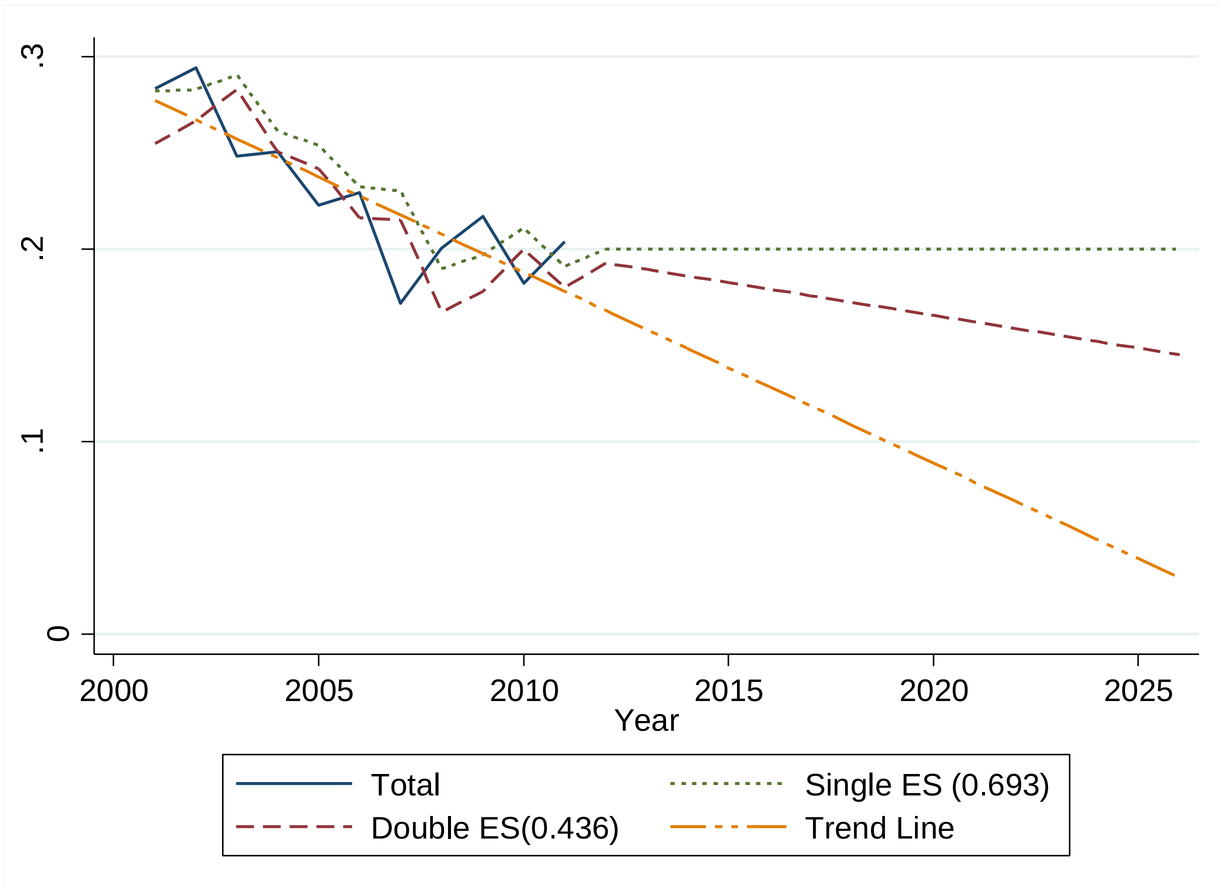
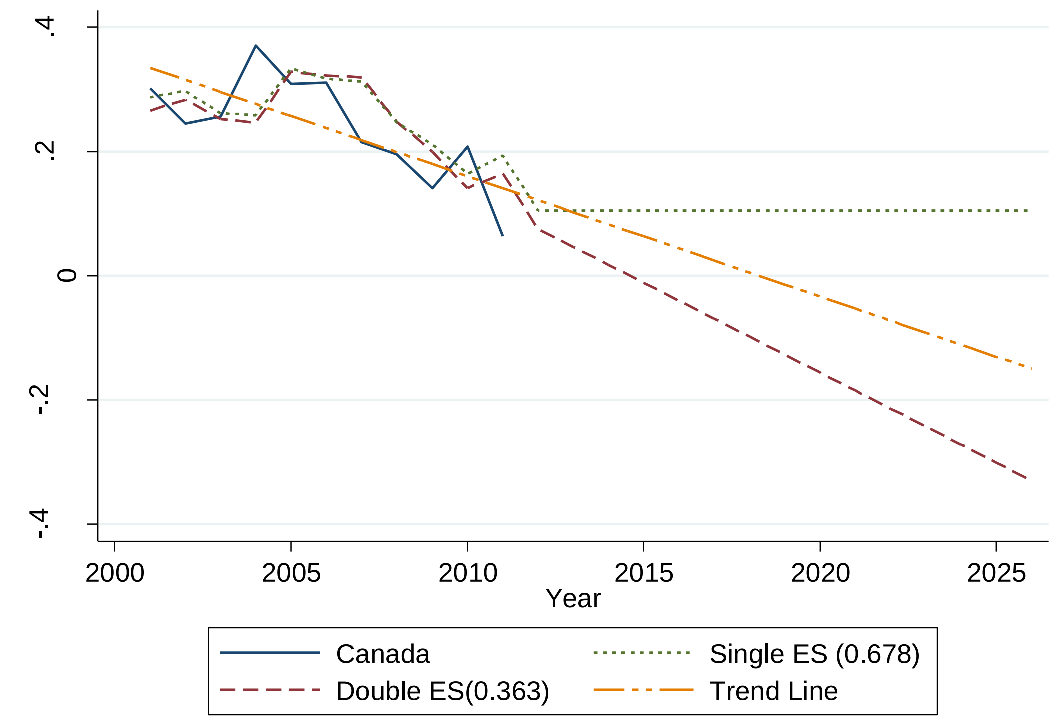
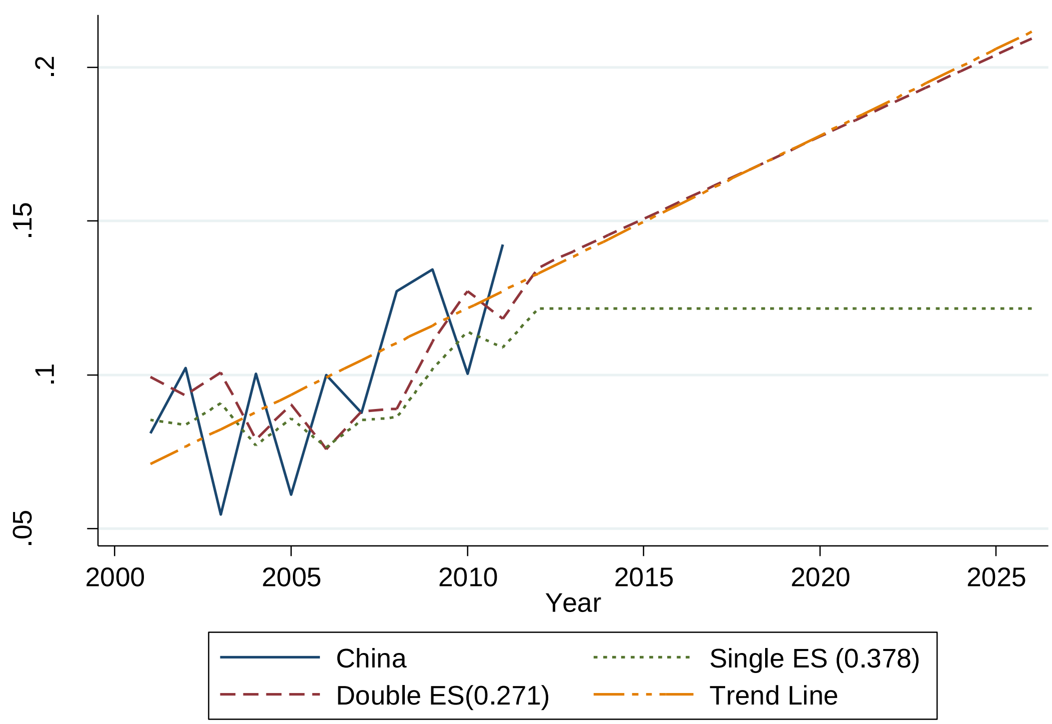
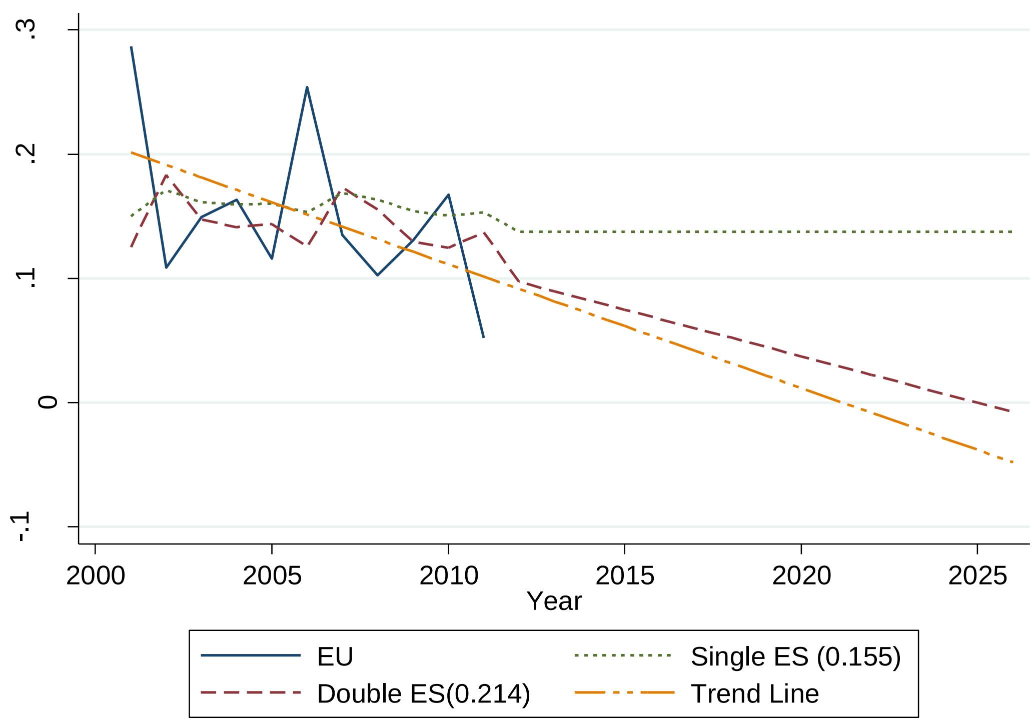


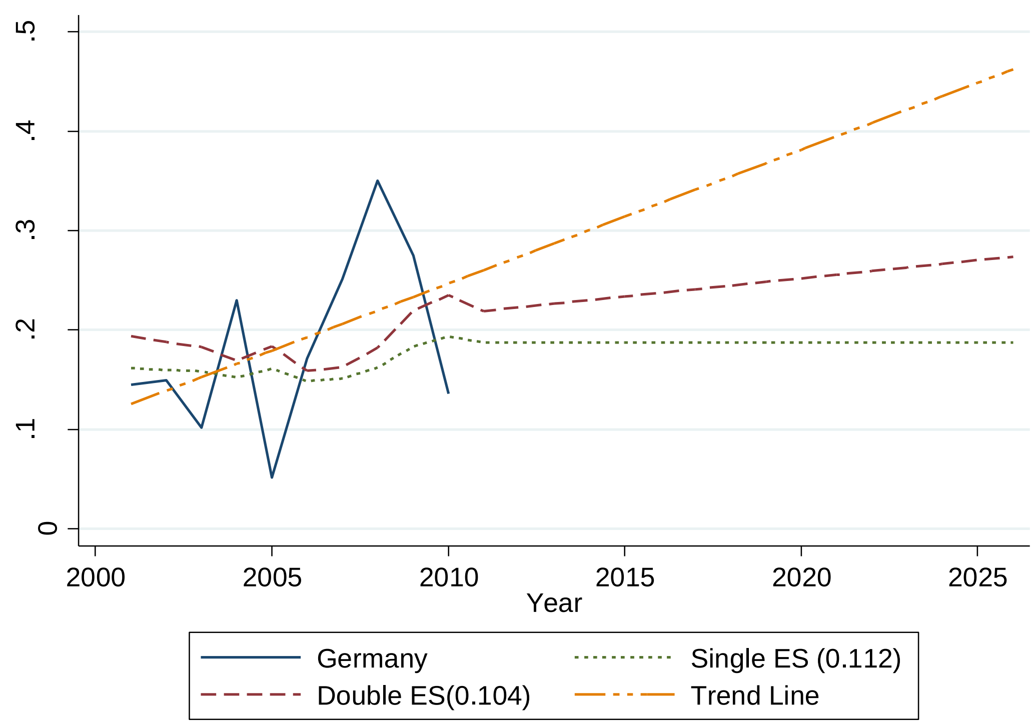
Figure A2. Return Rates by Country of Citizenship



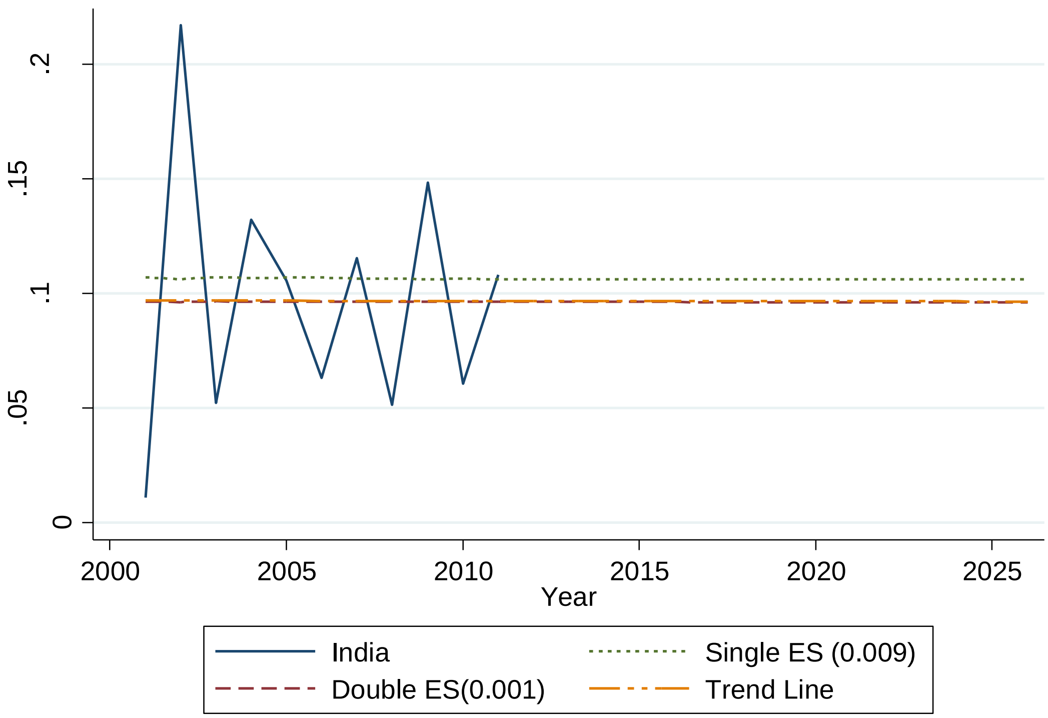


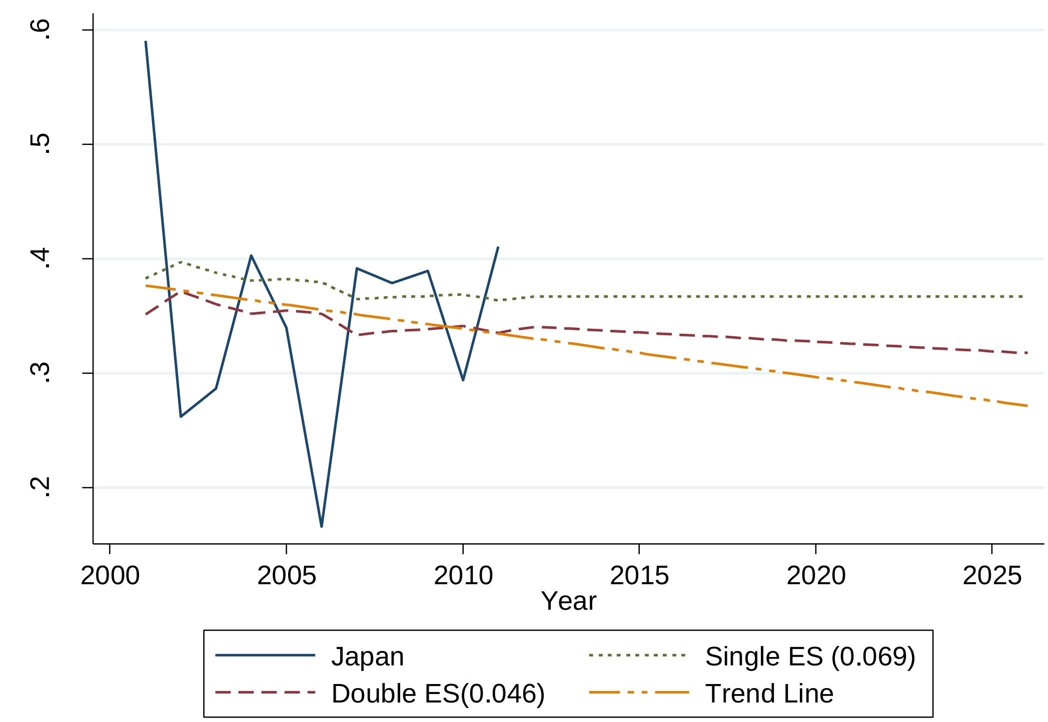


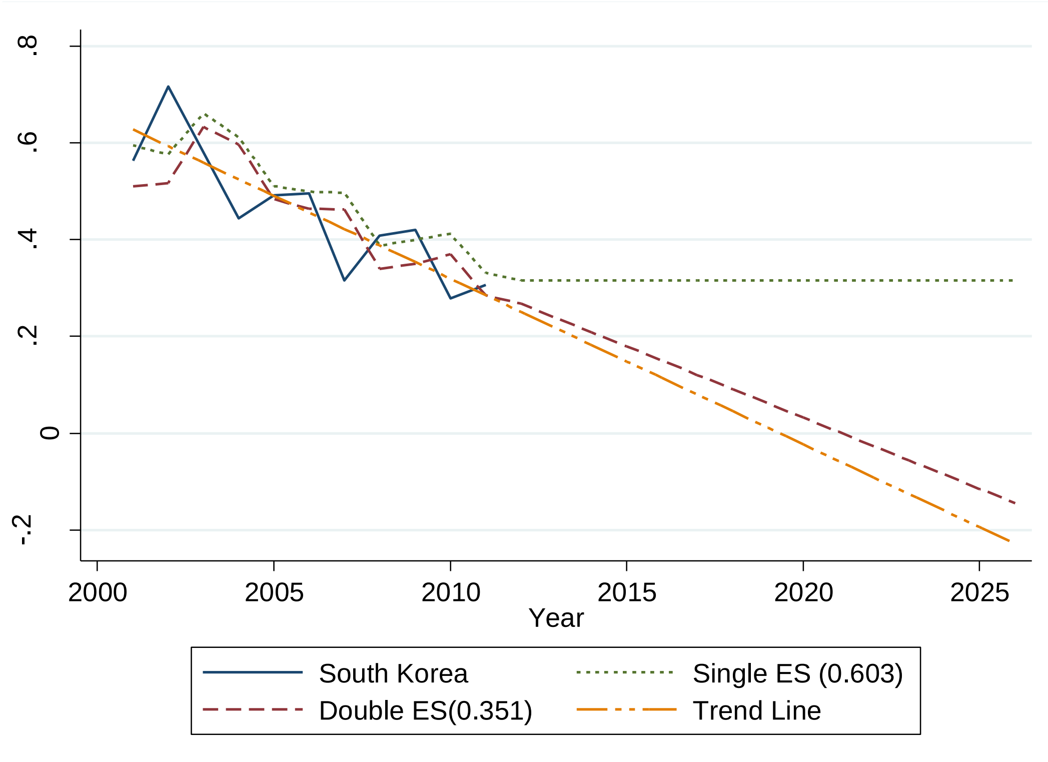
.3
.2
.1
0
-.1
2000
2005
2010
2015
2020
2025
Year
EU
Single ES (0.155)
Double ES(0.214)
Trend Line



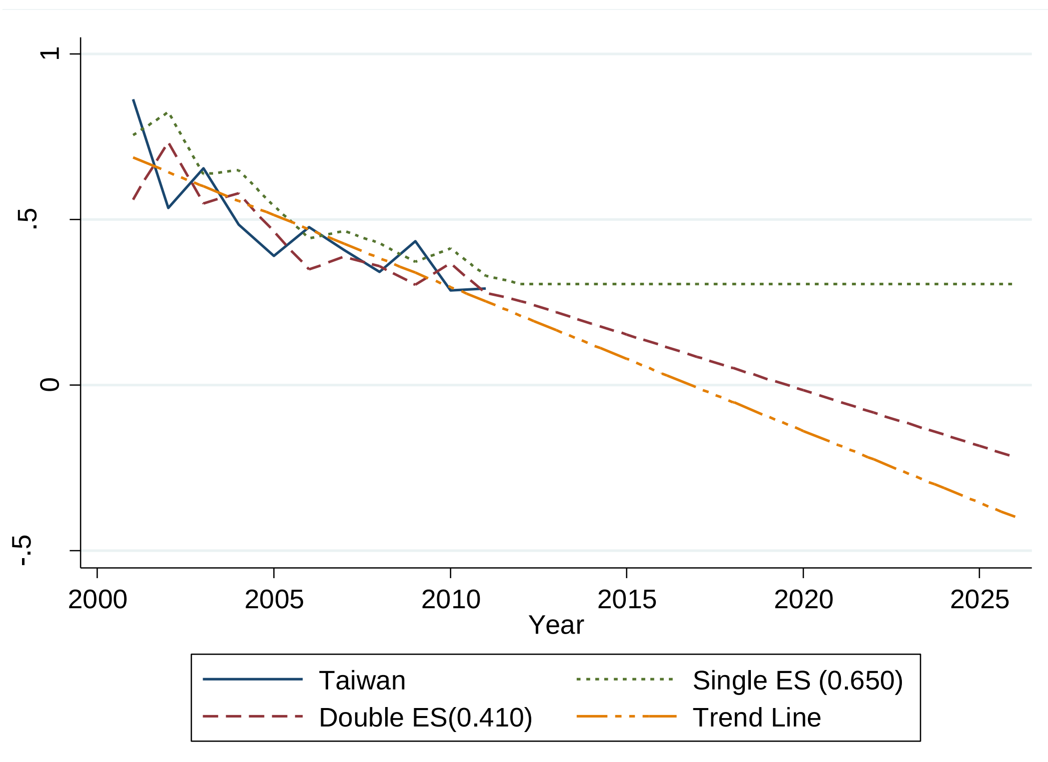
.5
.4
.3
.2
.1
0
2000
2005
2010
2015
2020
2025
Year
Germany
Single ES (0.112)
Double ES(0.104)
Trend Line


0
.05
.1
.15
.2
2000
2005
2010
2015
2020
2025
Year
India
Single ES (0.009)
Double ES(0.001)
Trend Line


.2
.3
.4
.5
.6
2000
2005
2010
2015
2020
2025
Year
Japan
Single ES (0.069)
Double ES(0.046)
Trend Line



.8
.6
.4
.2
0
-.2
2000
2005
2010
2015
2020
2025
Year
South Korea
Double ES(0.351)
Single ES (0.603)
Trend Line



1
.5
0
-.5
2000
2005
2010
2015
2020
2025
Year
Taiwan
Double ES(0.410)
Single ES (0.650)
Trend Line

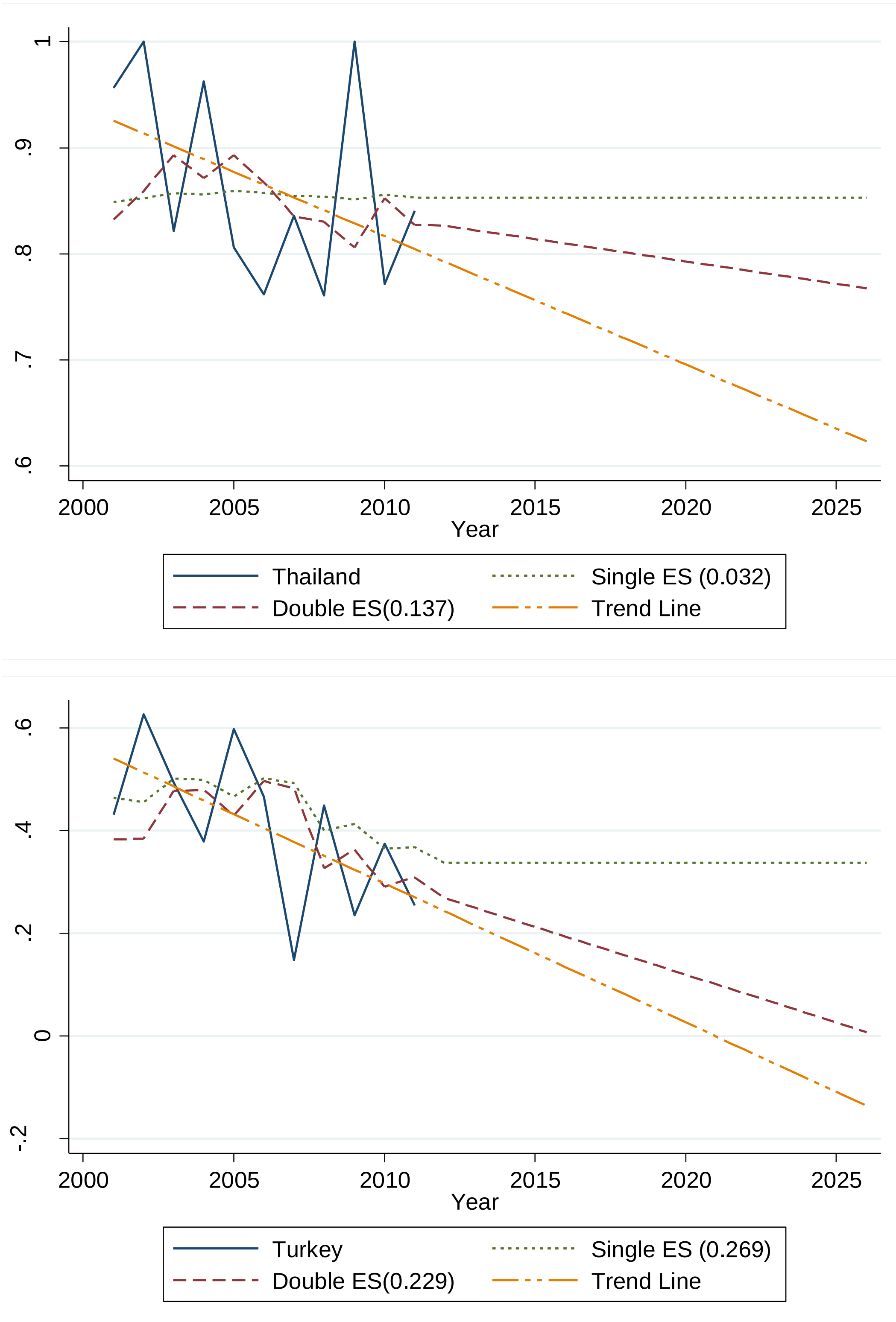
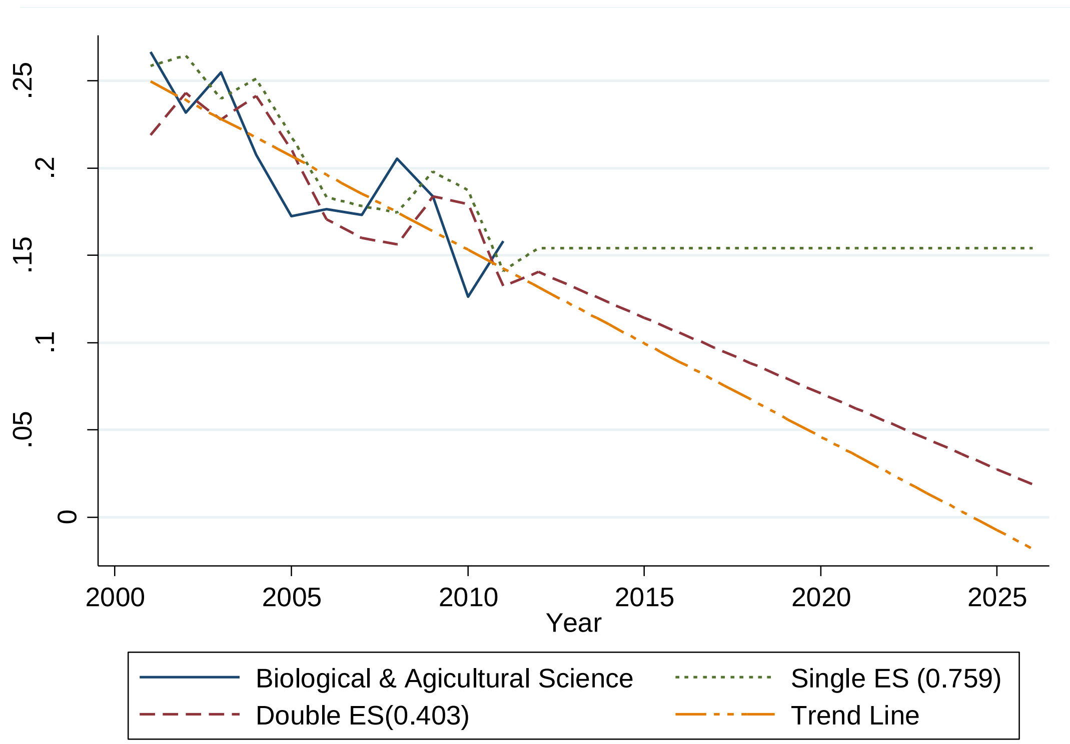
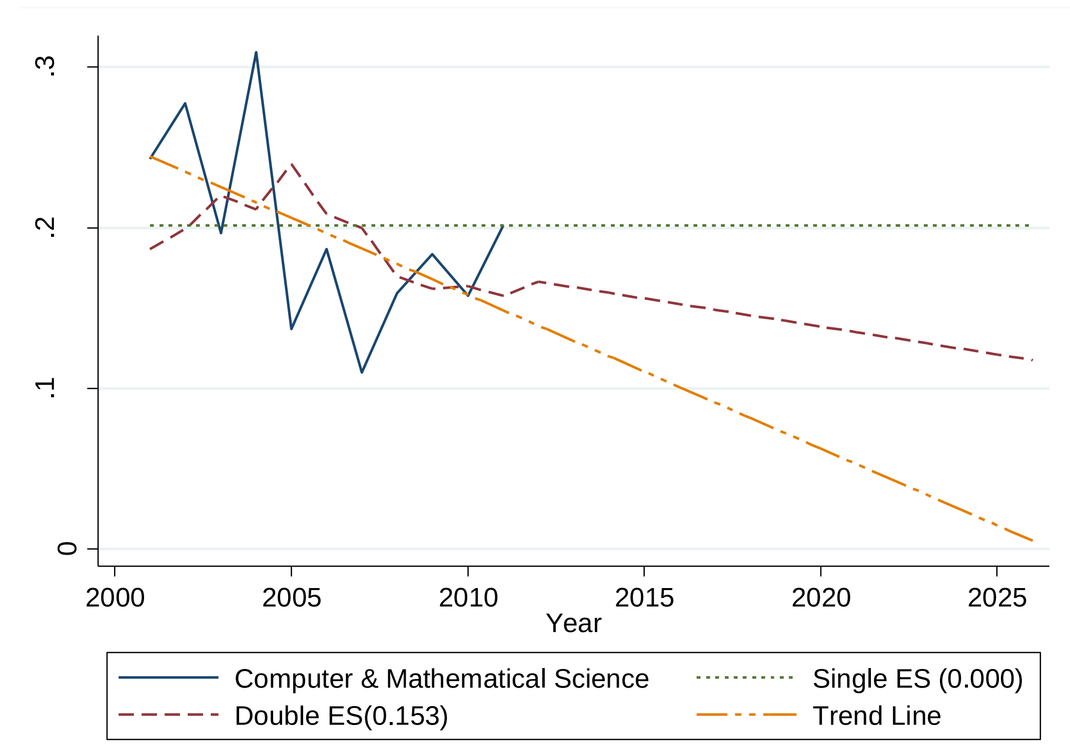
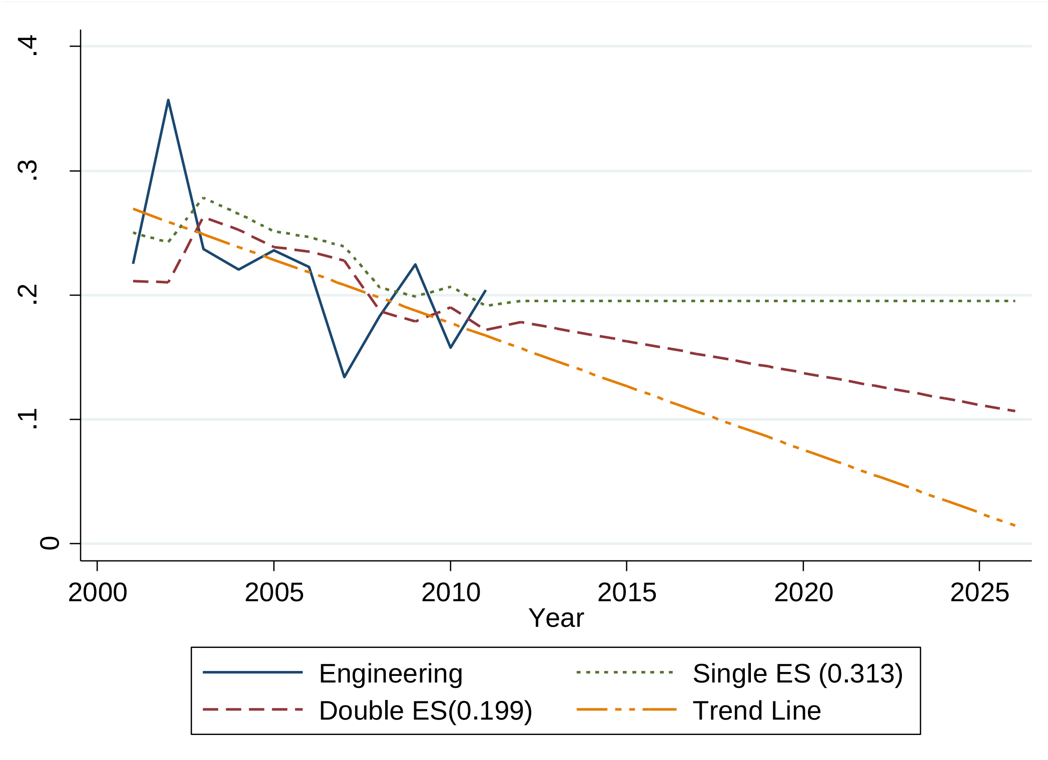
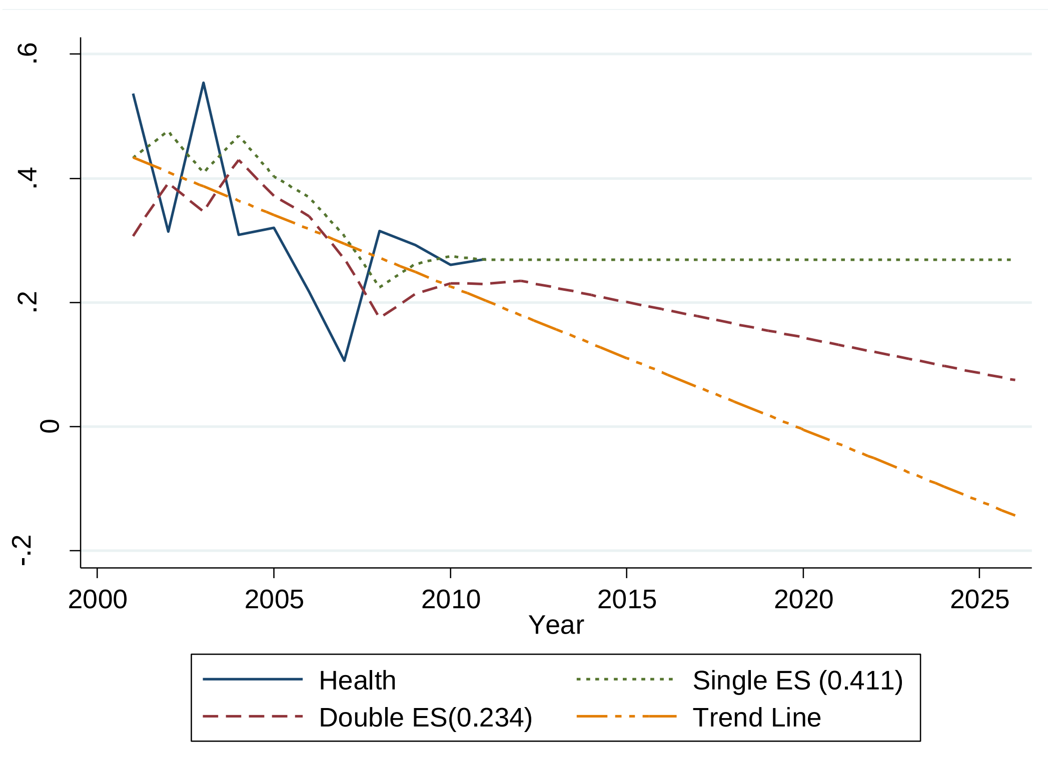


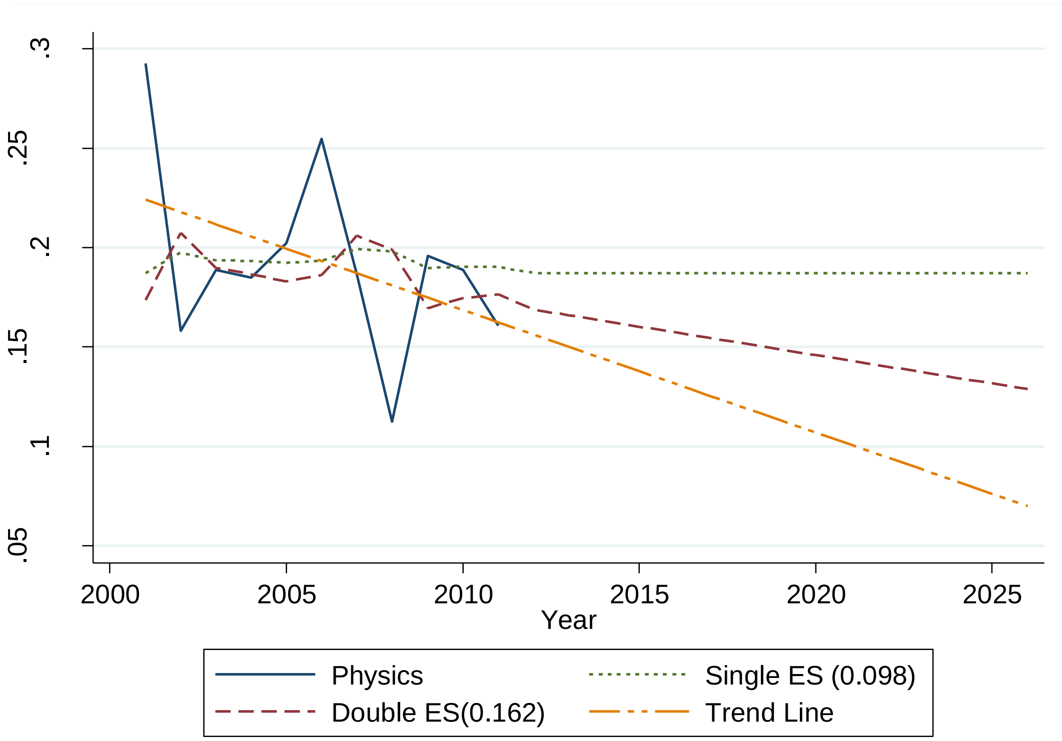
Figure A3. Return Rates by Major

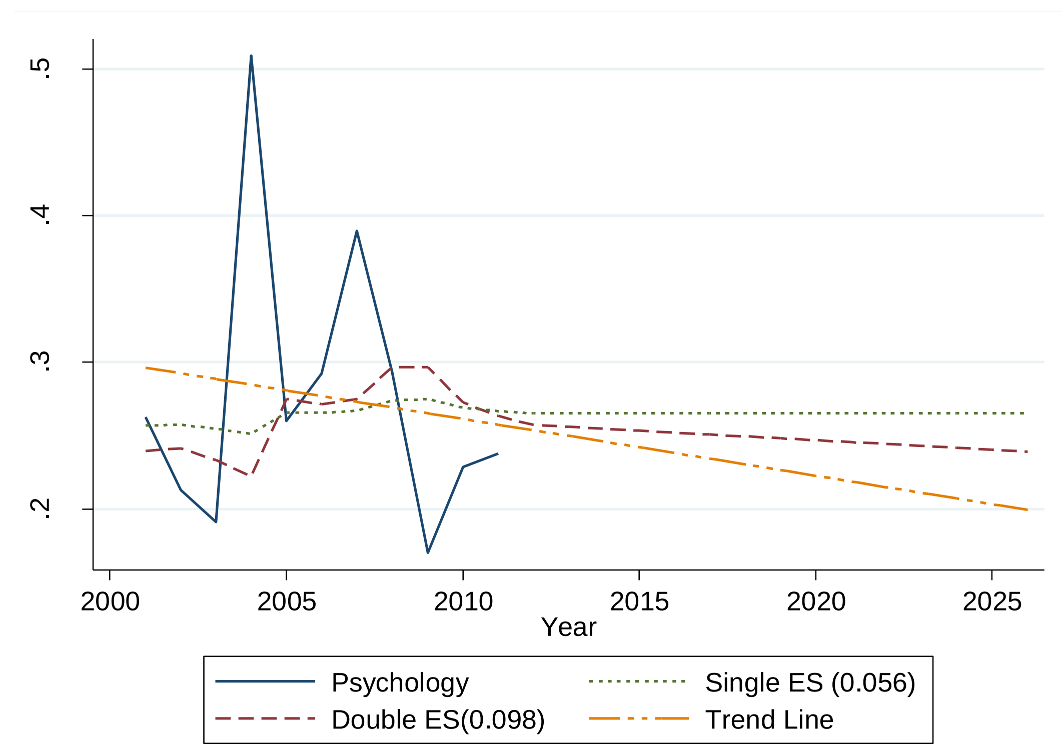

.25
.2
.15
.1
.05
0
2000
2005
2010
2015
2020
2025
Year
Biological & Agicultural Science
Single ES (0.759)
Double ES(0.403)
Trend Line

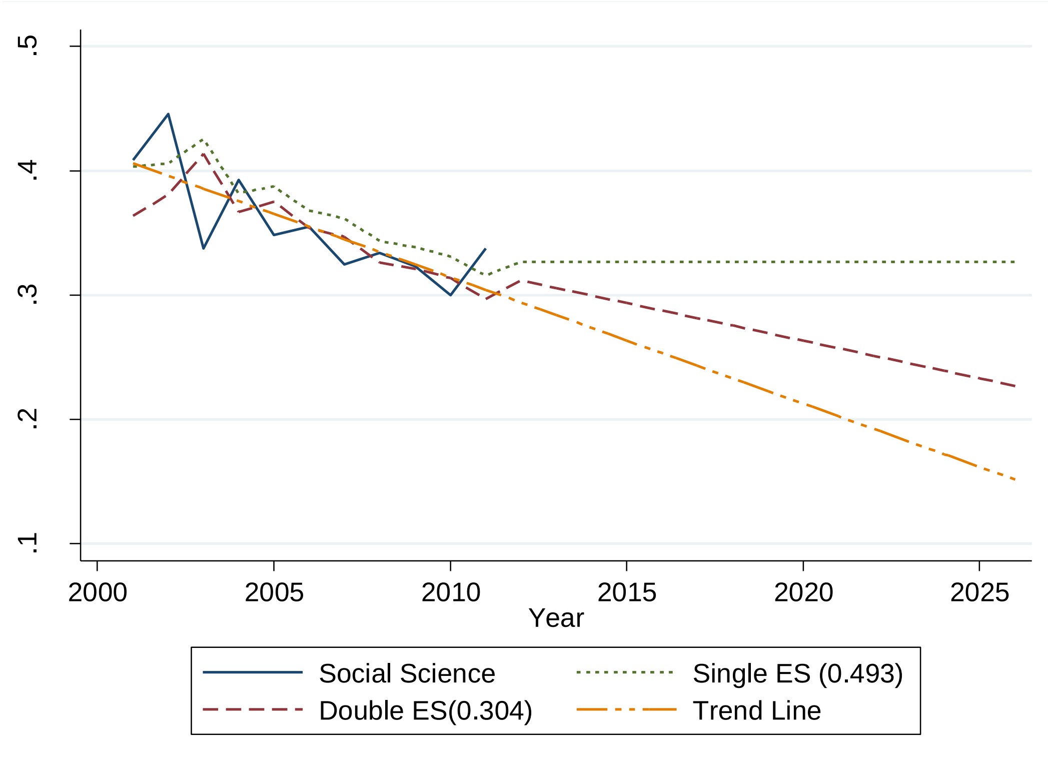

.3
.2
.1
0
2000
2005
2010
2015
2020
2025
Year
Computer & Mathematical Science
Single ES (0.000)
Double ES(0.153)
Trend Line


.4
.3
.2
.1
0
2000
2005
2010
2015
2020
2025
Year
Engineering
Single ES (0.313)
Double ES(0.199)
Trend Line


.6
.4
.2
0
-.2
2000
2005
2010
2015
2020
2025
Year
Health
Single ES (0.411)
Double ES(0.234)
Trend Line


.3
.25
.2
.15
.1
.05
2000
2005
2010
2015
2020
2025
Year
Physics
Single ES (0.098)
Double ES(0.162)
Trend Line


.5
.4
.3
.2
2000
2005
2010
2015
2020
2025
Year
Psychology
Single ES (0.056)
Double ES(0.098)
Trend Line



.5
.4
.3
.2
.1
2000
2005
2010
2015
2020
2025
Year
Social Science
Single ES (0.493)
Double ES(0.304)
Trend Line