Step4EU: *A Policy Brief*

Why Science Policy matters?…Looking at flows of doctorates in Portugal, 1970-2010[1]

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Summary

Science policies emphasizing the advanced qualification of human resources, together with democratizing access to science and internationalizing the science base, are shown to help build the conditions needed to drive brain gain over time. The analysis is based on the flows of doctorates in Portugal over 40 years, for the period 1970-2010, with the ultimate goal of helping to promote the absorptive capacity that emerging regions and countries worldwide need to acquire to learn how to use science for economic development. The data shows a notable process of brain gain by the end of this period and, above all, it provides a dynamic approach to the cumulative process of building knowledge-based societies. The results show the need to consider the co-evolution of brain gain, brain drain and brain circulation over time and space. In addition, they suggest the importance of certain major counter-intuitive policy instruments to facilitate the co-evolution of human capital formation and research capacity building. In the case of Portugal, these instruments have included a centralized program of research grants, research careers independent of traditional academic career tracks, and a diversified system of funding research units and institutions based on research assessments through international peer reviews.

1. Context and relevance

The growing importance of intangible resources to the social and economic development of modern societies has underlined the importance of enlarging the pool of talent, particularly at knowledge-based institutions, such as universities. In times of growing global uncertainty, scientific and academic institutions strive to build critical mass by attracting and retaining highly qualified people, resulting, above all, on increasing competition for talent worldwide. Doctorates are among the most sought after highly qualified human resources, and it is well known that scientific and economic powers throughout the world act as attracting magnets of talent from developing countries and emerging regions around the world. As a consequence, many EU regions suffer from brain-drain, with dire consequences to the building-up of their own scientific and higher education systems.

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Yet, this does not have to be so. We argue that science policies emphasizing the advanced qualification of human resources, together with institutional capacity building and the internationalization of the science base, can help creating the necessary conditions driving brain gain over time in many of those regions.

2. Key findings: the dynamics of the flux of doctorates in Portugal, 1970-2010

Our evidence comes from the analysis of the flux of doctorates in Portugal over the period 1970-2010, based on nominal data (Table 1). It shows a positive flow of doctorates in Portugal in 2010 (i.e., "brain gain" in the technical literature), after four decades of consecutive lagging behind in terms of scientific capacity. Out of a total 19,876 PhD holders that performed their PhD at a Portuguese university, only 669 were found to be working abroad (i.e., 3.4%), while 1,836 foreign PhDs were working in Portugal, of which 83% working in research and development activities.

Table 1 – Main flows of doctorates (PhDs) in Portugal over the last 40 years, 1970-2008

1. PhDs awarded by Portuguese universities between 1970 and 2008	**14,147**
1.1 % PhDs working in R&D-related activities in Portugal (2009)	86.8%
1.2 % PhDs working in non-R&D-related activities in Portugal or in other circumstances (e.g. retired)	7.0%
1.3 % PhDs working abroad (2009)	3.7%
1.4* % PhDs with no identified workplace	2.5%
2. PhDs awarded abroad and recognized by Portuguese universities between 1970 and 2008	**4,206**
Portuguese nationals	3491
Non-Portuguese nationals	313
2.1 % PhDs working in R&D-related activities in Portugal (2009)	76.3%
2.2 % PhDs working in non-R&D-related activities or in other circumstances (e.g. retired) in Portugal (2009)	13.3%
2.3 % PhDs working abroad (2009)	3.5%
2.4* % PhDs with no identified workplace	6.9%
3. Foreign PhDs with a PhD obtained abroad and not registered in Portugal or working in R&D in Portugal (2009)	**1,523**
Flow of doctorates:	
Number of foreign PhDs or Portuguese nationals with a PhD obtained abroad working in Portugal (2009)	**1,836**
3.1 % foreign PhDs working in R&D-related activities in Portugal (2009)	82.9%
3.2 % foreign PhDs working in non-R&D-related activities in Portugal (2009)	17.1%
4. Holders of PhDs awarded or recognized by Portuguese universities working abroad in 2009 (1.3 + 2.3)	**669**

* The maximum expected uncertainty of this analysis is associated with PhD holders with no identified workplace.

Source: GPEARI (http://www.gpeari.mctes.pt/index.php)

Portugal represents an interesting case study since it had the challenge to overcome a gap in scientific and technological development of decades, indeed centuries, to surpass the average

OECD level in terms of researchers per thousand people in the workforce by 2010. This was accomplished by public investment in science associated to policies facilitating the co-evolution of human capital formation and institutional capacity building, with the number of doctorates growing more than 74% between 2000 and 2010. In 1970, the number of new doctorates per year was below 100, to surpass 1000 by 2003, and 1600 by 2010, which highlights the relevance of time for attaining the necessary capacity to start attracting skilled human resources.

The process to attain brain-gain of doctorates requires time, commitment, and, often, counter-intuitive science policies (see Table 2). Until the mid-1980s the Portuguese higher education system did not have the capacity to train doctorates in general, and there was a lack of critical mass in many scientific areas. Thus, science policies continuously fostered advanced training abroad (See Figure 1), resulting in a continuous process of relative brain drain. But, after some two decades, from the 90´s, the mobility of human resources at doctoral level was clearly assumed as a policy strategy to create the foundations of scientific and academic basis in Portugal upon the return of the doctorates, as well as a means to internationalize the Portuguese scientific and academic communities. As a result, brain drain and brain circulation coexisted over time, although leading, many times, to academic inbreeding practices at the oldest universities.

Table 2 – Main periods analyzed in this paper for the development of science policy in Portugal (1970-2010)

Period	Mobility trend	GERD/GDP	Total researchers (PhDs)	S&T policy instruments
1970-1985	Early attempts at growth, with 50% PhDs abroad; few PhDs in universities (brain drain); high academic inbreeding	0.27%	5,736 (NA)	Creation of several universities in the mid-1970s (higher education policy); University and polytechnic career statutes
1986-1995	Striving to increase knowledge capacity; greater mobility to international scientific organizations (e.g. CERN); high academic inbreeding	0.48%	12,675 (NA)	infrastructure building, competitive R&D projects and individual fellowship program (doctoral and post-doctoral)
1996-2005	Doctoral and post-doctoral fellowship program, increased brain circulation	0.75%	29,761 (12,152)	Performance-based funding of research units, through national research assessments, including the creation of large Associate Laboratories, to foster research excellence through networks of academic research centers; research career status; promotion of scientific culture and the public understanding of science
2006-2010	Increasing capacity; research contracts (moving towards brain gain)	1.5%	75,073 (23,125)	Scientific employment though competitive research contracts; University Chairs; reform of university governance and assessment systems; international partnerships promoting thematic networks of research and advanced training; further promotion of the public understanding of science

Note: The calculation of GDP follows the European System of Accounts, ESA 2010 revision

Still, throughout time the percentage of academic staff holding a doctorate degree reached 68% in public universities by 2009, when it was only 48% by 2001. It is currently about 75% (Figure 2). A growth was also observed in the number of publications by total population, which reached 703 articles per million people in 2009, from 373 in 2004. In other words,

Portugal's science base in the fields of science, technology, engineering, and mathematics is becoming internationally competitive.

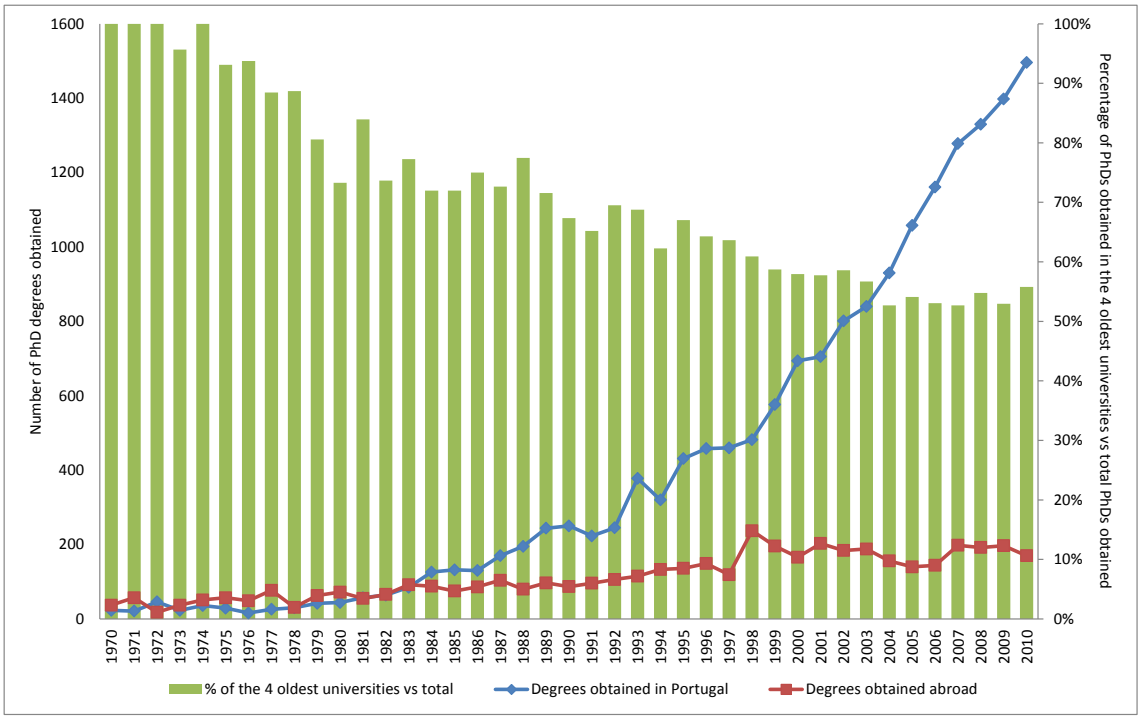

Figure 1 – Doctoral degrees concluded in Portugal and abroad, 1970-2010, and percentage of those obtained at the four oldest universities in Portugal (Porto, Coimbra, Lisbon and Technical Univ. of Lisbon); Source: GPEARI – MEC

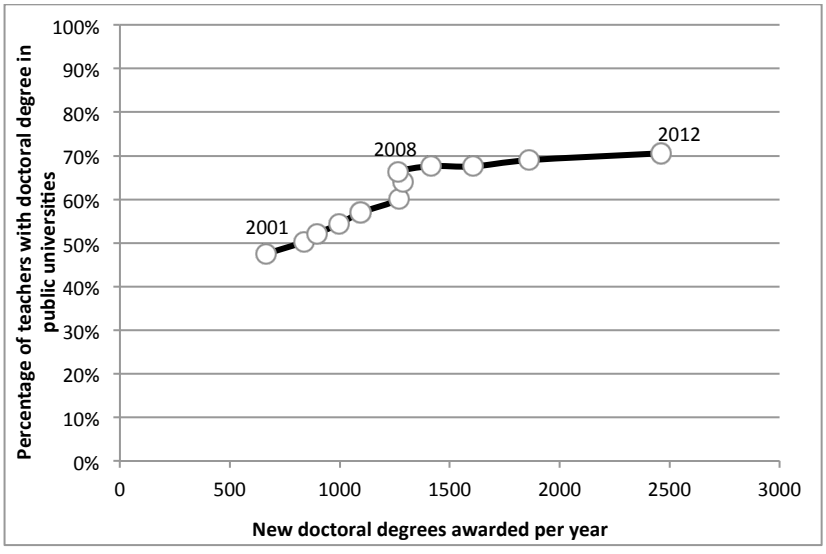

Figure 2 – Percentage of doctorate teachers in Public Universities versus the number of new doctorates per year, 2001-2012. Source: DGEEC

In the specific case of Portugal, it took almost four decades to achieve reasonable international levels of investment in science and technology and to overcome a situation of continuous

lagging behind the international scene. This is shown to be associated with patterns of relatively sluggish or fluctuating investments in R&D for many years, reaching unprecedented levels of development only after 2008. In general it has involved different science policy instruments, as documented in Table 3, although with emphasis on the advanced training of human resources. We argue other regions worldwide may accelerate this process, if adequate policy measures are systematically taken to facilitate the co-evolution identified in this policy brief.

Table 3 – Major science policy instruments used over time in Portugal (1970-2010)

Public policy instrument	Characterization/focus	Starting data/ Observations
Doctoral Fellowships	Centralized program oriented towards the advanced training of human resources, independently of university hierarchies	Late 1960s with JNICT; the number of fellowships and R&D projects increased substantially after 1986, through EU funds and particularly, after 1996, through FCT
Competitive funding program for R&D Projects	Promoting research activities and research teams at national and EU levels	
Post-doctoral fellowships	Promoting the internationalization and mobility of doctorates; fostering knowledge production and participation in international knowledge networks	Mid 1990s after the creation of FCT in 1996
Promotion of scientific culture	Science education in schools and the public understanding of science	Since 1996
Performance-based funding of research units, through national research assessments (every 3 to 4 years), with 3-year contracts	Promoting research capacity though institutional building, independently of university hierarchies. Facilitating the creation of independent research units and the concentration of doctorates in research units	Mid 1990s with the creation of FCT; first assessment only with Portuguese reviewers; all the others are international assessments
Associate Laboratories: performance-based funding of large research units and networks, based on national research assessments, with 10-year contracts	Association and networking of the better qualified R&D units in the assessment exercise; focus on critical mass and renewal of the researcher base.	Since 1999
International partnerships with leading universities and research institutes	Thematic research and advanced training networks, facilitating the internationalization of academic staff; increased R&D collaboration between Portuguese universities; Increasing the qualification of academic staff; academic exchange programs and pedagogical and scientific improvements	Since 2006
Post-doctoral research contracts program	Attraction of researchers nationally and internationally with a doctorate and some years of research experience; renewal of university academia	Since 2007
Sponsored Research Chairs	Attraction of foreign and Portuguese senior academics to Portuguese universities, co-sponsored by firms	Since 2007

As a result of the accumulation of public investment, three distinct but inter-related trends were observed by 2010. First, there has been a remarkable increase in overall business expenditure on R&D (BERD) and in industry's capacity to undertake research in collaboration with academic research centers. BERD rose from 425 million euros in 2005 to over 1.4 billion euros in 2010.

Second, the relative spread across the number of firms investing in R&D has grown considerably. The five most R&D-intensive firms account for only 30% of BERD, the top twenty for 59%, and the top hundred for some 80%. These figures suggest that Portuguese business R&D is not dependent on a few large companies. This is a good sign for the overall goal of

raising and sustaining the business sector's participation in the drive to increase the country's technological intensity. Nevertheless, analysis also suggests that large companies need to increase their R&D investment significantly if science-based job opportunities in the business sector are to increase. In addition, further specialization in the skills required by emerging areas is equally necessary if business competitiveness is to improve.

Third, there has been a considerable increase in academia's research capacity, with the number of PhD fellowships and post-doctoral research contracts more than doubling. Nevertheless, despite the impressive increase in investment in R&D in recent years, this still does not guarantee scientific maturity. Rather, given the development trajectory of Portugal's science system, it is more appropriate to regard investment as a further step in the recovery from a late awakening and its slow – and often intermittent – progress along the path to maturity.

It should be noted that the number of researchers grew in Portugal with relatively low levels of R&D funding per researcher (Table 4), but at a level attractive enough to foster brain-gain. Two further remarks should also be noted. First, despite reaching the same levels of investment as Spain, Italy or Ireland in 2010, Portugal's accumulated science investment over the past few decades is not even close to that of those countries. Building up the nation's scientific development to a position similar to the above countries requires a far larger and sustained investment in science, at a rate faster than in those countries, and over a long period.

Table 4 – Evolution of the number of researchers (headcount) and funding per researcher (in 1000 US dollars PPP of 2005), in a sample of OECD countries for 2001 and 2012

	S&T system			
	Total researchers (headcount)		Funding per researcher (1000 US$)	
	2001	2012	2001	2012
Czech Republic	29,216	47,650	73,217	97,372
Denmark	29,791	58,567	135,909	96,001
Estonia	4,803	7,634	24,616	70,817
Finland	47,534	56,704	102,163	107,175
France	217,173	356,469	176,710	127,536
Hungary	28,351	37,019	47,400	59,511
Iceland (2011)	3,231	3,270	80,146	88,614
Italy	100,442	157,960	173,690	132,718
Japan	792,699	887,067	142,659	150,941
Korea	178,937	401,724	126,531	151,578
Norway	34,506	46,747	87,205	90,555
Poland	89,596	103,627	31,965	60,627
Portugal	31,146	81,750	55,565	37,953
Slovakia	15,923	25,069	28,274	37,697
Slovenia	6,740	12,362	89,791	106,349
Spain	140,407	215,544	67,898	73,478
Turkey	67,190	155,133	47,198	60,346

Source: OECD

Second, despite the investments in S&T during the periods analyzed in this policy brief, Portugal is still far from the investment levels of other small and medium-sized European Union countries such as Belgium, Austria, Denmark or Finland. One indirect consequence of

these two features is Portugal's persistent "infantile status" in industry-science relationships and its present "immaturity" in both industry and academia in planning long-term joint ventures. This is affected by the structure of enterprises, as well as by the lack of large companies in sectors traditionally involved in advancing these ties in other industrialized countries.

3. Implications and Recommendations

A few counter-intuitive measures and scientific policy instruments were particularly relevant in the process of scientific development briefly discussed in this note for Portugal. Our research suggest the key role of a major, long-term public funded and centralized program of research grants, namely for doctoral and post-doctoral grants, upon independent national evaluations of individual proposals, in a way totally independent of any university or research institution. We argue this is particularly important to be implemented at earlier and middle stages of development of science and higher education systems to avoid the investment to be absorbed by hierarchically and change-adverse environments that characterize many universities in developing environments. In the case of Portugal, such instruments were complemented by public programs to fund research units based on multi-annual contracts established upon national research assessments, also totally independent of internal university hierarchies, aiming to build the necessary institutional capacity towards knowledge-based societies.

We emphasize that this is a long-term process, requiring different institutional speeds and types of multi-annual contracts and four main points should be emphasized, namely: i) the required accumulation over time of individual fellowships at doctoral and post-doctoral levels; ii) the nature of increasingly open competitions for individual fellowships, including the need to attract foreigners; iii) the need to evolve from fellowships to research contracts, at least at post-doctoral level and on a temporary basis; and iv) the need to consider some level of academic inbreeding in the oldest universities, in order to facilitate building local absorptive capacity.

In addition to the human resources component, our research clearly shows that the co-evolution of human capital formation and institutional building is critical to promote the absorptive capacity that emerging regions and countries worldwide need to acquire scientific and technological capacity. In this context, a key policy instrument in the Portuguese case was a public program to fund research units by multi-annual contracts based on national research assessments, totally independent of internal university hierarchies. This is again a long-term process, requiring different institutional speeds and types of multi-annual contracts.

A landmark in terms of institutional building in the Portuguese research landscape was the establishment of Associate Laboratories in November 2000, through long-term contracts with the Portuguese Science Foundation (ten-year as opposed to the three-year contracts with typical research units). By 2001, 15 of these laboratories were active, bringing together 31 research units and more than 2,200 researchers, of whom 880 were PhD holders. By 2009, the network of scientific institutions encompassed 510 research units and 25 laboratories. Overall,

institutional funding amounted to some 80 million euros, compared with 5 million euros a decade earlier.

In addition, the process of institutional building was oriented towards improving links between the research system and higher education institutions and private companies, while at the same time fostering institutional internationalization, as well as a greater internationalization of the science base at an individual level. This was particularly stimulated in the mid 80´s with the affiliation of Portugal to major international and European research organizations (as started with CERN, in 1985, and involving ESA in 2000, among many others) and was further achieved and considerably enlarged since 2006 by establishing selected partnerships with leading research universities and institutes worldwide (including strategic partnerships with MIT, Harvard, Carnegie Mellon and University of Texas at Austin, as well as with the Fraunhofer Society in Europe) in the form of relatively large consortia bringing together universities, R&D units, end users and companies.

Overall, our analysis shows that understanding aspects of time and space and processes associated with advanced training of human resources and institutional building helps to promote the absorptive capacity that regions and countries need to acquire in order to learn how to use science for economic development. In this developmental process, our data reveal that higher education institutions are the de facto main employers of PhDs and hence the advanced qualification of human resources needs to be considered in the context of full internationalization of their region/nation, in terms of facilitating the integration of those regions/nations in knowledge networks at the highest international level.

Further Readings

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