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# The impact of highly skilled emigrants on the origin country's innovation performance: the case of Greece



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## Abstract

**Purpose** – The study aims to investigate the impact of highly skilled emigration from Greece on the innovation performance of the Greek economy.

**Design/methodology/approach** – The study draws on a new, census-scale, database that includes all the Greek Ph.D. holders and on statistical information pooled from various secondary sources.

**Findings** – The mass emigration of highly educated Greek scientists that was exacerbated during the ten-year recession has had detrimental effects on Greece's innovation performance. Specifically, an increase in the number of highly skilled emigrants has a negative impact on scientific citations and on patent applications during the following year. An instrumental variable approach based on gravity model literature is employed to test the authors' findings. The potential effects of these findings and policy suggestions are also discussed.

**Originality/value** – The study enriches the academic and policy discussion on the science and technology–related consequences of brain drain on the origin country. This is the first study that focuses on Greece – the country which experienced the highest emigration rates within the EU during the severe ten-year economic crisis – and sheds light on the impact of skilled emigration on its innovation performance.

**Keywords** Highly skilled emigration, Innovation, Ph.D. holders, Brain drain, Greece

**Paper type** Research paper

## 1. Introduction

Human capital has long been recognised both as a key factor for economic development and as a means of diffusion of knowledge, technology and innovation (Grossman and Helpman, 1994; Deming, 2022). In turn, its geographical mobility has multi-level effects on both the origin and receiving countries. The early studies on skilled migration underlined the negative consequences of brain drain on the origin country's development and welfare and on the increasing global inequality (Docquier and Rapoport, 2012). Furthermore, brain drain can broaden the technological gap between high- and low-income countries and foster skilled labour shortages in the latter (Docquier, 2014; OECD, 2016). However, later studies challenged this pessimistic view by showing that origin countries may also reap multifaceted benefits stemming from remittances flows, capital formation, circular and/or return migration of entrepreneurs and researchers, and the important role that ethnic, social and co-inventor ties connecting an origin country and an advanced scientific diaspora abroad can play in knowledge diffusion, FDI and innovation activity (Saxenian, 2006; Beine *et al.*, 2008; Kerr, 2008; Docquier, 2014; Lissoni, 2018).

Given the importance of skilled migration for both the origin and receiving countries, the competition to attract the most talented labour force has been intensified and expanded not only

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among the receiving countries (Kerr *et al.*, 2016; Labrianidis and Sykas, 2021) but also among the countries of origin. The competition takes place in the form of policy initiatives that aim to construct, retain and strengthen scientific networks abroad (diaspora networks policies) (Baruffaldi and Landoni, 2012). An empirical manifestation of this is that, between 1990 and 2010, skilled migrants in the OECD area increased by almost 130%, reaching 28 million in 2010. At the same time, low-skilled migrants increased by only 40% (Kerr *et al.*, 2016).

Brain drain is not a new phenomenon for Greece. Its roots go back to the "70s, it displayed an increase during the 90s", while it was seriously exacerbated after the 2008 financial crisis when Greece witnessed one of the most severe brain drain among EU countries. The recession that hit Greece harder than any other EU country was accompanied by serious negative consequences such as the 25% reduction of the GDP during a five-year period (2010–2015), the sharp increase in youth unemployment, the shrinkage of the middle-class population and the downturn in living conditions (Vagianos *et al.*, 2017; OECD, 2018). All the above led to an unprecedented massive emigration of a skilled labour force (Labrianidis and Sykas, 2021). It has been estimated that, at the end of 2010, between 119,000 and 139,000 skilled migrants left the country (Labrianidis, 2011), while their number increased between 280,000 and 350,000 during the 2010–2015 time period (Labrianidis and Pratsinakis, 2016).

The recession magnified some of the structural deficiencies already existing in the Greek economy, and particularly the low demand for skilled labour, which is probably related to the low value of products and services that Greece mainly produces. As such, low demand for a highly skilled labour force may have aggravated the outflow of skilled individuals (Labrianidis, 2011). Indeed, while between 2011 and 2021, the EU-27 average rate of the ICT personnel in total employment was 3.7%, the same rate in Greece was 2.0% (own calculations from Eurostat, Statistical Database).

Despite the extent and the long duration of brain drain from Greece, there is limited research regarding its repercussions for the Greek economy. To some degree, this may be attributed to the serious lack of secondary data in general regarding the migratory phenomenon in Greece (Labrianidis and Sykas, 2021). Only recently, Oikonomou (2020) has shown that emigration from Greece resulted in the deepening and the protraction of the recession, while Bandeira *et al.* (2020) have found that fiscal austerity led to a 10% increase in the migration outflows.

Our study aims to fill the literature gap concerning the impact of skilled emigration on Greece and especially on its innovativeness, and enrich the scientific dialogue on the effects of skilled emigration from the origin country perspective. To the best of our knowledge, this study is the first that sheds light on the impact of skilled emigration on the innovation performance of Greece following the ten-year recession and the acute stigma that the Greek economy experienced as a result of this. Drawing on a totally new, census-based dataset that includes all the Greek Ph.D. holders combined with available secondary data, we show that skilled emigration from Greece has detrimental effects on its innovation performance. Specifically, a unit increase in the share of highly skilled emigrants is associated with a 35.6% decrease in patent applications and with a 5.2% decrease in the number of scientific citations that Greece receives during the following year.

The paper is organised as follows. In the next section we review the empirical literature that connects skilled emigration and origin country innovation. In section 3 we describe the methodology and the data used. In section 4 we discuss the results and we use an instrumental variable approach based on gravity model literature to test our findings. Section 5 concludes.

## 2. Literature review

A growing number of recent studies examine the effects of skilled immigration on the innovation performance of the receiving countries. The majority of them highlight the positive impact of skilled immigrants on innovative activity, scientific research, knowledge and technology diffusion, productivity, and job creation at the national, regional and firm level (Jensen, 2014; Bosetti *et al.*, 2015; Gagliardi, 2015; Kerr *et al.*, 2016; Fassio *et al.*, 2019). There are two basic avenues by which immigrants may foster innovation in the receiving countries. The first is their direct involvement in scientific research that may be transformed into innovative activity (e.g. patenting) (Jensen, 2014; Fassio *et al.*, 2019). The second arises from the positive consequences that cultural diversity may have for knowledge creation and spillovers, innovative learning, collective problem solving and therefore productivity (Ozgen *et al.*, 2011; Jensen, 2014; Bosetti *et al.*, 2015).

In parallel, however, there is a growing body of recent literature focusing on the contribution of skilled emigrants to the origin country's innovation performance. This mainly takes three forms: the international knowledge spillovers through the activation of ethnic networks, the FDIs, and the employment and entrepreneurial activities of those skilled individuals who have returned and/or circular emigrants (Breschi *et al.*, 2017; Lissoni, 2018).

Specifically, Kerr (2008) addresses the importance of ethnic scientific and entrepreneurial networks in the United States as a channel for technology transfer to their origin countries. In that respect, these networks can be seen as a "brain bank" which accumulates and diffuses technology to their homelands. Agrawal *et al.* (2011) show that, although on average, the emigration of Indian innovators limits the domestic knowledge base, the Indian diaspora abroad plays a crucial role in helping Indian inventors back home to gain access to foreign high-value inventions, and thus stimulate innovation in their origin country. Valette (2018) in a study of 20 OECD destination countries also stresses the importance of diaspora networks in transmitting new technologies from technologically advanced countries to low technology origin countries. According to Naghavi and Strozzi (2015), international migration fosters the flow of knowledge to developing origin countries, which can effectively be used by those countries having a sound intellectual property rights institutional base. Using industry-level data from 32 European countries, Fackler *et al.* (2020) find that emigrants have a positive impact on origin countries' innovation.

A series of studies point to the impact of skilled migration on cross-border knowledge and technology diffusion. Miguélez (2018) finds that skilled migrant networks favour cross-country co-inventorship and foster the internationalisation of inventive activity between high-income and developing countries. The significant role of immigrants/emigrants and their social ties in fostering co-inventorship between Spanish regions and foreign countries is also underlined by D'Ambrosio *et al.* (2019). Breschi *et al.* (2017) find that the patents of ethnic inventors residing in the United States receive higher citations by co-ethnic migrants ("diaspora" effect) in the case of Asian countries, a fact that underscores the strength of ethnic ties in transmitting technical knowledge. Choudhury and Kim (2019) analyse how Indian and Chinese inventors in the United States have contributed to the reuse and diffusion of contextual knowledge (i.e. knowledge previously locked within home regions) across borders.

Focusing on FDIs, Foley and Kerr (2013) find that there is a positive relationship between the share of a multinational firm's patents performed by inventors of a particular ethnicity and the investing activity of that firm in countries related to that ethnicity. Kugler and Rapoport (2007) show that current US FDI inflows to origin countries are positively associated with the past stock of skilled immigrants coming from these countries.

Saxenian (2006) analyses how Indian and Chinese circular and return migrants having work experience in Silicon Valley facilitated the transfer of knowledge, skills and innovative ideas back to their origin countries, while some of them invested in new business partnerships. Choudhury (2016) investigates the Indian R&D facilities of a US multinational enterprise and shows that local employees with returnee managers display higher innovative activity than those working under local managers. Jonkers and Cruz-Castro (2013), drawing on Argentinean returnee researchers, find that working experience abroad increases the propensity of international co-publishing as well as the propensity of publishing in highlyranked journals, thus benefiting both the receiving and origin country's research systems. Baruffaldi and Landoni (2012) examine foreign researchers working in Italy and Portugal and show that the propensity of return mobility and the scientific productivity are higher for those researchers that maintain ties with their origin countries. On the other hand, Agrawal *et al.* (2011) suggest that Indian returnees do not constitute a massive source of knowledge diffusion, while Gibson and McKenzie (2012) come to a similar conclusion regarding highly educated returnees in the case of five small economies.

As mentioned before, there is limited research regarding the effects of skilled emigration on the Greek economy and especially on its innovation performance. Hence, the first contribution of our study is that it enriches the literature on this under-researched topic for the Greek case. To the best of our knowledge, this study is the first that attempts to empirically estimate the impact of highly skilled emigration on the innovation performance of Greece. Secondly, it draws its conclusions from a unique national dataset that includes all the Greek Ph.D. holders, which allows us to investigate the impact of the highest educational level of emigrants on Greece's innovation. This is even more important taking into consideration that the relationship between Ph.D. holders, scientific research and innovation is inherently high and that only a few studies (e.g. Ozgen *et al.*, 2011; Gibson and McKenzie, 2012) focus on Ph.D. holders. Thirdly, our study contributes to the literature concerning the effects of skilled emigration from the origin country perspective.

The main hypothesis under research is that massive highly skilled emigration from Greece has detrimental effects on innovation performance of the Greek economy.

## 3. Data and methodology

In order to estimate the impact of skilled emigration on innovation performance of Greece, our empirical model relies upon the knowledge production function (Griliches, 1979) and uses highly skilled emigration as an input (see also Stuen *et al.*, 2012; Gagliardi, 2015; Bratti and Conti, 2018). It also uses two measures of innovative performance, that is the number of scientific citations and the number of patent applications (see also Bosetti *et al.*, 2015; Fackler *et al.*, 2020), however placing more emphasis on scientific citations (see below). The empirical specification we use is as follows:

$$lnIP_t = \beta_0 + \beta_1 R\&D_{t-1} + \beta_2 DC + \beta_3 FP_{t-1} + \beta_4 GP_{t-1} + \beta_5 HSM_{t-1} + \varepsilon_t \qquad (1)$$

Equation (1) implies that innovation performance (IP) is a function of resources allocated to R&D, as measured by R&D expenses and skilled human capital. Specifically, R&D is the total government budget allocations for R&D in PPP 2007 dollars. Skilled human capital has been classified into three categories (see Chellaraj *et al.*, 2008; Stuen *et al.*, 2012 for a similar treatment): FP is the percentage of active foreign population having obtained tertiary education (ISCED 5–8) to the total foreign population living in Greece. GP is the rate of tertiary education of the Greek population to the total Greek population. Both FP and GP are expected to have a positive impact on IP. Highly Skilled Migrants – HSM – is the main variable of our interest and it represents the stock of Greek Ph.D. holders living abroad as a share of the total stock of Greek Ph.D. holders.

The logic behind incorporating HSM into equation (1) is – as literature suggests – that highly skilled emigrants may have a positive impact both on the innovation performance of the receiving country (Bosetti *et al.*, 2015; Gagliardi, 2015; Kerr *et al.*, 2016; Fassio *et al.*, 2019), and, under certain circumstances (e.g. knowledge transfer, direct investment, networking, R&D collaboration, academic visitors, cooperative research projects), on the innovativeness of the origin country (Saxenian, 2006; Kerr, 2008; Agrawal *et al.*, 2011; Fackler *et al.*, 2020; Labrianidis *et al.*, 2021). In other words, HSM may be perceived as an active source of innovativeness both for the receiving and the origin country. Hence, a positive impact of HSM on IP may indicate a form of brain-circulation which can benefit innovative activity in Greece. However, in the absence of the above circumstances, it may be that HSM do not contribute to the innovativeness of the origin country or their contribution may be weak. If that is the case, then a possible negative impact of HSM on IP implies that brain drain from Greece may weaken its innovative capacity.

In fact, taking into consideration the massive exodus of HSM, not only limited to the crisis period but still ongoing, the positive self-selection of HSM and the lack of well-established brain-(re) gain policies in Greece (Labrianidis, 2011; Labrianidis and Sykas, 2021), it is reasonable to hypothesise that the loss of human capital of the highest educational level (Ph.D. holders) may have detrimental effects on innovation. Testing the above hypothesis is the main scope of our study.

Finally, DC is a dummy variable capturing the 10-year crisis (2009–2018) in Greece.

As mentioned above, the dependent variable (IP) uses two measures. The first is the natural logarithm of the total number of citations and the second is the natural logarithm of the total number of patent applications. Although we report results for both these variables, our main focus centres on scientific citations. This is for three main reasons.

Firstly, using patent applications as a proxy for innovative performance has been subject to intense criticism. The main criticism stems from the fact that not all innovations are transformed into patents (Griliches, 1990). Moreover, patents denote a narrow conception of knowledge that is only embodied in industrial applications. In contrast, intangible knowledge may also have a positive impact on innovation as it provides the ground on which new knowledge can be built (Bosetti *et al.*, 2015).

Secondly, it is well documented in the literature that, in the context of the Greek economy, there is weak cooperation between university scientific research and business. That is, the industrial use of scientific research is rather scanty (Foundation for Economic & Industrial Research, 2017). This fact is attributed both to the production of low-value-added products by Greek industries, resulting in low demand for a highly skilled labour force, and the low international profile of Greek universities [1] (Foundation for Economic & Industrial Research, 2017; Labrianidis and Sykas, 2021). Since the high level of human capital is rarely transformed into a productive resource, patent applications may not be an adequate measure to capture the impact of HSM on Greece's innovativeness, and, therefore, alternative or complementary innovation measures are needed. While this is our position herein, it should be noted that patent applications are widely adopted in the literature (Chellaraj *et al.*, 2008; Ozgen *et al.*, 2011; Bosetti *et al.*, 2015; Fassio *et al.*, 2019), as they are considered to be an important constituent of a country's innovative capacity and technological progress.

Thirdly, 55% of HSM in our survey are Academics and Researchers (see Table 3). Hence, their potential impact on innovation can be more accurately captured by the number of citations. Despite that, using the number of scientific citations as a measure of the innovation capacity of Greece helps us to better record those more intangible dimensions of knowledge production embedded in scientific work. More generally, the number of citations is a proxy of the basic knowledge quality produced in a country and its international impact (Stuen *et al.*, 2012; Bosetti *et al.*, 2015). Although they have some drawbacks in terms of comparability between countries, they constitute a reliable measure of innovation performance (European Commission, 2021).

In line with the literature, the independent variables are one year lagged in order to capture the time needed for a change in R&D resources to impact IP (Naghavi and Strozzi, 2015; Bosetti *et al.*, 2015; Bratti and Conti, 2018; Fassio *et al.*, 2019).

A serious obstacle related to migration research in the Greek case is the lack of official statistical information (Labrianidis, 2011; Labrianidis and Sykas, 2021). That is, data are time-limited, not detailed and there are many missing values at the regional level. Hence, equation (1) estimations are based on country aggregated annual data from 1995 to 2020 for patent applications and from 1996 to 2020 for the number of citations. The use of short-time series comprises the main limitation of our study, and therefore results should be interpreted with caution. However, as it is shown in the Cointegration Analysis (see Appendix A1 (see Tables A3 and A4 respectively)), our results, even within this limited time frame, are reliable.

In order to overcome the lack of detailed information, we pooled our data from various sources. Specifically, as mentioned above, the main focus being HSM, that is the stock of Greek Ph.D. holders living abroad, we made use of an entirely new database spanning a period of more than 30 years (1985–2020). The National Archive of Ph.D. Theses (henceforth N.A.Ph.D.) is the national registry collecting Ph.D. theses from all Higher Education Institutions in Greece as well as those Ph.D. degrees awarded to Greeks by foreign universities and certified by the Hellenic National Academic Recognition and Information Centre (Hellenic N.A.R.I.C.). For those Greek Ph.D. holders that had not submitted (at the time) their thesis to the N.A.Ph.D. database, an online open announcement was issued through social media – the idea was to attract as many as possible to participate in the survey.

The electronic survey was conducted between May and July 2020. Responsible organisations were the Greek National Documentation Centre (EKT), which is by law responsible for the collection, development and maintenance of the N.A.Ph.D., and the Regional Development and Planning Research Unit (R.D.P.R.U.) of the University of Macedonia. After the application of multiple data cleansing techniques, an electronic questionnaire was sent to 22,349 individuals. We opted for multivariate questions ranging from demographics, geographical and employment mobility to social and career satisfaction. Additionally, the questionnaire catered for the different employment statuses of the Ph.D. holders (employed, unemployed, retired, etc.). By the end of the survey (24/9/2020), a total number of 10,295 answers (46.1%) had been successfully completed and submitted [2].

In order to ensure time compatibility between the above dataset and the available secondary data used in our study (see below), we had to pose a time restriction on our sample. Subsequently, we limited our sample to the 1995–2020 period for patent applications and to 1996–2020 for the number of citations. This restriction led to a sub-sample of 998 Ph.D. holders living abroad, that is 9.7% of the total. These Ph.D. holders constitute the highly skilled emigrants used in our analysis. Figure S1 depicts the 30 countries where 98% of the HSM reside in 2020 (see “Supplementary figures” online, including Figures S2 and S3).

As stated earlier, we pooled our secondary data from various sources. Patent applications were derived from Eurostat’s statistical database and the European Patent Office. The number of citations was pooled from the SCImago Journal and Country Rank (2021) [3]. R&D data were gathered from OECD Main Science and Technology Indicators (2021). FP came from Eurostat statistical database. GP also came from Eurostat statistical database except for the 1995–2000, 2002 and 2003 time periods, for which there were missing values. Data for these years were pooled from OECD Education Data database. Summary statistics are depicted in Table 1.

| | Mean | Std. Dev |
|---|---|---|
| Patent applications (numbers) | 88.6 | 26.2 |
| Number of citations (numbers) | 284,919 | 123,749 |
| R&D (in constant USD PPP, 2007 = 100) | 106.5 | 39.5 |
| FP (%) | 77.1 | 2.7 |
| GP (%) | 24.1 | 6.1 |
| HSM (%) | 0.47 | 0.26 |

**Source(s):** Author’s own work

**Table 1.**
Summary statistics

## 4. Results and discussion

We estimate equation (1) using OLS method (Table 2).

The estimates confirm our hypothesis, that HSM have a negative impact on innovation performance of Greece, both in terms of number of citations and patent applications. In fact, HSM is the strongest variable that negatively affects IP. Before discussing in more depth the impact of HSM, we first comment on the other regressors.

Starting with R&D, its impact on patent applications is positive but not statistically significant, while, surprisingly, its impact on the number of citations is negative, though insignificant. This probably stems from collinearity that exists among R&D, FP, GP and HSM. However, when removing the GP variable, R&D has a positive and statistically significant effect both on patent applications and on the number of citations, while all the other variables are statistically insignificant (not shown in Table 2). A further possible explanation is that government expenditure in R&D does not necessarily turn into actual patent activity. As stated before, in the Greek case there is a poor connection between academic research and its productive use from the business sector.

As the DC variable shows, the number of patent applications during the economic crisis period was 24.2% lower compared to the pre-crisis period. It appears that economic recession had, among other things, a considerable negative impact on patent activity in Greece. However, the opposite was true regarding the number of citations. The number of citations was 62.4% higher than the pre-crisis period. This increase in the number of citations during the crisis years has been documented (and is in line with an increase in the number of publications) in the bi-annual national bibliometric reports [4] and should probably be attributed to the research capacity of the domestic research personnel whom, despite the hiring and financial restrictions placed upon them due to the crisis, managed to over-perform and turn out increasingly cited articles.

| Independent variables | Coefficients | Std. errors |
|---|---|---|
| *Dependent variable: patent applications* | | |
| Constant | 2.670 | 1.367 |
| R&D | 0.001 | 0.002 |
| DC | −0.277 | 0.086*** |
| FP | 0.000 | 0.016 |
| GP | 0.091 | 0.015*** |
| HSM | −1.033 | 0.283*** |
| Observations: 25 | | |
| $R$-squared: 0.721 | | |
| Durbin–Watson: 1.44 | | |
| *Dependent variable: Number of citations* | | |
| Constant | 5.570 | 2.051** |
| R&D | −0.002 | 0.004 |
| DC | 0.485 | 0.153*** |
| FP | 0.075 | 0.025*** |
| GP | 0.102 | 0.027*** |
| HSM | −2.962 | 0.574*** |
| Observations: 24 | | |
| $R$-squared: 0.775 | | |
| Durbin–Watson: 1.48 | | |

**Note(s)**: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Heteroscedasticity and Autocorrelation Corrected (HAC) standard errors have been used, which are consistent when there is suspicion of serial correlation
**Source(s):** Author's own work

**Table 2.** OLS estimates: the impact of highly skilled emigration on innovation

| Gender (%) | HSM | Non-HSM | Age groups (%) | HSM | Non-HSM | Family income (%) | HSM | Non-HSM |
|---|---|---|---|---|---|---|---|---|
| Males | 63.1 | 50.8 | Up to 29 | 0.6 | 0.2 | Very low | 2.2 | 2.0 |
| | | | 30–39 | 53.2 | 27.7 | Low | 8.8 | 7.0 |
| | | | 40–49 | 40.2 | 44.0 | Medium | 43.5 | 45.5 |
| | | | 50–59 | 5.5 | 21.8 | High | 28.7 | 27.4 |
| | | | 60–69 | 0.4 | 6.0 | Very high | 4.3 | 3.4 |
| | | | Over 70 | 0.1 | 0.3 | No answer | 12.5 | 14.7 |

| Post-doc degree (%) | HSM | Non-HSM | Profession (%) | HSM | Non-HSM | Staff position* (%) | HSM | Non-HSM |
|---|---|---|---|---|---|---|---|---|
| Yes | 18.6 | 8.3 | Professionals | 34.5 | 49.9 | No staff position | 12.3 | 26.3 |
| | | | Academics | 40.3 | 28.1 | Staff position | 22.0 | 35.2 |
| | | | Researchers | 15.0 | 5.1 | Staff position of high social prestige | 65.7 | 38.5 |
| | | | Managers | 9.5 | 15.2 | | | |
| | | | Other | 0.7 | 1.7 | | | |

**Source(s):** EKT/RDPRU Ph.D. holders survey
* Staff position refers to the classification of the importance of the employment position as reported by each respondent. A staff position is one that requires advanced skills, expertise, and/or supervisory responsibility
**Source(s):** Author's own work

**Table 3.**
Socio-economic, educational and professional characteristics of HSM

FP has an insignificant impact on patent applications, but a significant positive impact on the number of citations. In fact, a unit increase in FP is associated with a 7.8% increase in the number of citations. This is the first indication that the foreign population of tertiary education residing in Greece makes a positive contribution to an aspect of innovation performance of Greece. There is also a positive contribution of the tertiary educated Greek population on IP since a unit increase in GP is estimated to increase patent applications by 9.55% and the number of citations by 10.7%.

Focusing on HSM, which is the variable of main interest, a unit increase in HSM leads to a 35.6% decrease in patent applications and to a 5.2% decrease in the number of citations. Both these results point to a significantly negative effect of highly skilled emigration on the innovation performance of Greece [5].

A closer look at the socio-economic, educational and professional characteristics of HSM can offer a deeper insight into this finding (Table 3). Compared to non-HSM, that is Greek Ph.D. holders without migration experience, HSM are younger, have higher educational credentials (postdoc degree), are mainly academics and researchers, and hold staff positions of high social prestige. Hence, HSM represent a very high educational and professional class whose emigration denotes the loss of a valuable resource that could positively contribute to the innovation and, in consequence, to the development outcomes of Greece. This is in line with studies illustrating the higher scientific performance of migrant scientists compared to domestic ones (Franzoni *et al.*, 2014). Added to this, according to our database, 87.6% of HSM do not currently maintain any professional relationship with Greece. Also, 53.7% do not intend to return to Greece in the near future, although 46.3% have expressed their intention to return under specific circumstances, specifically if they find a job in their field of studies.

### *4.1 Instrumental variables*

A potential source of endogeneity may arise from the reverse causality between highly skilled migration and innovation. As Faggian and McCann (2009) have stressed, there is no dominant causality between innovation and skilled migration. That is, highly skilled migrants may contribute to a country's innovation performance and, simultaneously, may be attracted by that country's innovativeness. Or conversely, in our specification, highly skilled emigration may be positively associated with a weak innovative performance of Greece, which, simultaneously, may enhance highly skilled emigration.

In order to tackle this issue, we need an instrumental variable that influences HSM, but which does not have any direct effect on IP. An econometric strategy broadly applied in recent migration literature (Beine *et al.*, 2013; Naghavi and Strozzi, 2015; Valette, 2018) is used to produce predicted values of the stock of emigrants using exogenous variables in a gravity model related to bilateral migratory movements. These variables frequently appear in the gravity model literature of trade (Frankel and Romer, 1999). On the basis of the predicted values, a measure of HSM is constructed which is then used in 2SLS regression estimates.

Our version of the gravity model takes the following form:

$$LnMigr_{it} = a_0 Pop_{it} + a_1 Area_{it} + a_2 Ln\_Dist_i + a_3 Bord_i + a_4 Lang_i + a_5 Hist_i + y_t + e_{it} \quad (2)$$

where $Migr_{it}$ is the natural logarithm of the stock of Greek migrants in destination country $i$ in year $t$, Pop$it$ and Area$it$ are the population and Area of $i$ correspondingly, LnDist$i$ is the natural logarithm of distance between Greece and $i$, Bord$i$ is a dummy denoting whether Greece and $i$ have common borders, Lang$i$ is a dummy indicating whether Greek language is officially spoken by at least 9% of the population in $i$, and Hist$i$ is a dummy symbolising whether $i$ is one of the 10 countries with the highest rates of Greek immigrant inflows during the 20th century. This variable is used as an alternative to a Colony dummy that is commonly employed in the relevant literature (Naghavi and Strozzi, 2015; Valette, 2018), and denotes whether there is a colonial past between an origin and a destination country. Given that Greece has no colonial past, we added Hist$i$ dummy as an indicator of the historical migratory movements between Greece and the abovementioned 10 destination countries. Year fixed effect is captured by y$t$ and e$it$ is the error term.

Next, the predicted values obtained for each country in a specific year from the gravity estimations are aggregated to get the predicted stocks of Greek emigrants for each year. Thus, a time-series of predicted emigration stocks is constructed, which is used in 2SLS regressions.

Our gravity model estimates are based on a panel dataset including 50 countries where HSM resided for the 1995–2020 time period. Data on historical emigration stocks were drawn from OECD International Migration Database and UN Global Migration Database. In cases where there were missing data from these two basic sources for specific years, data were pooled from National Statistical Services. Population data come from UNCTAD statistics Data Centre, while area and destination data come from Worldometer and Globefeed portals. Gravity and first-stage regression results are presented in Appendix A2 (see Tables A1 and A2 respectively).

A one-year lagged IP has also been used as an instrument in order to capture the potential correlation between HSM and past values of IP (see Campbell and Mankiw, 1989 for a similar instrumental-variables approach).

Table 4 depicts the 2SLS regression estimates taking into account potential endogeneity. The coefficient of our main variable of interest, HSM, has the expected sign. HSM remains statistically significant in both regressions, although the estimations are larger in magnitude compared to OLS estimations. In other words, OLS estimations represent a lower bound for the 2SLS estimations. The values of the Hausman and Hansen J statistic point to the consistency of our instrumental variable estimators and the validity of our instruments respectively. Sargan test and Kleibergen–Paap rk LM statistic indicate the validity of the overidentifying and underidentifying restrictions respectively. The value of the first-stage

| Independent variables | Coefficients | Std. errors |
|---|---|---|
| *Dependent variable: patent applications* | | |
| Constant | 3.108 | 1.344** |
| R&D | −0.002 | 0.003 |
| DC | −0.564 | 0.238** |
| FP | −0.021 | 0.021 |
| GP | 0.204 | 0.073** |
| HSM | −3.105 | 1.423** |
| Observations: 25 | | |
| *R*-squared: 0.57 | | |
| First-stage F-statistic: 4.288 | | |
| Hausman Test: 11.894 | | |
| Sargan over-identification test: 0.074 | | |
| Kleibergen–Paap rk LM statistic: 7.596 | | |
| Hansen J statistic: 0.070 | | |
| *Dependent variable: Number of citations* | | |
| Constant | 6.035 | 2.931* |
| R&D | −0.006 | 0.006 |
| DC | 0.130 | 0.181 |
| FP | 0.049 | 0.038 |
| GP | 0.242 | 0.074*** |
| HSM | −5.562 | 1.284*** |
| Observations: 24 | | |
| *R*-squared: 0.71 | | |
| First-stage F-statistic: 17.090 | | |
| Hausman Test: 202.738 | | |
| Sargan over-identification test: 0.249 | | |
| Kleibergen–Paap rk LM statistic: 8.480 | | |
| Hansen J statistic: 0.709 | | |

**Note(s)**: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. T Heteroscedasticity and Autocorrelation Corrected (HAC) standard errors have been used, which are consistent when there is suspicion of serial correlation
**Source(s):** Author's own work

**Table 4.** 2SLS regressions: the impact of highly skilled emigration on innovation

F-statistic shows that our instruments are strong in the 2SLS regression that uses scientific citations as dependent variable, which, as we analysed above, is the dependent variable of our main focus, while they are not strong in the 2SLS regression where the dependent variable is patent applications [6].

## 5. Conclusion

This paper sheds light on the effects of highly skilled emigration on the country of origin innovation performance. To the best of our knowledge, this is the first study that addresses the impact of skilled emigration on the innovation performance of Greece. Drawing on a totally new database that includes all the Greek Ph.D. holders, this paper finds that the massive emigration of highly educated Greek scientists has detrimental effects on the innovation performance of Greece, and specifically on the number of scientific citations, which is the dependent variable that we mainly focus on, as well as on patent applications.

This stands as a serious stumbling block for any growth-related, nation-wide growth strategy. Taken together with the realisation that this negative relationship is found to be the case within the time frame of the decade-long economic crisis that the country underwent, makes this finding even more pronounced. The country lost a considerable share of its "knowledge procreators" at the time it lost its ground on a series of global macroeconomic indicators.

A growing body of literature focusing on the origin countries shows that these countries may reap considerable benefits from highly skilled emigration under certain conditions. Our study finds that highly skilled emigration may be detrimental for innovativeness of certain origin countries (e.g. Greece). It appears that the massive loss of valuable human resources carrying knowledge, new ideas and scientific discoveries may undermine the innovation capacity of those countries.

In the case of Greece, eliminating the abovementioned stumbling blocks calls for a number of parallel public policy steps. For one, a nation-wide growth strategy focusing on valorising science and technology outputs should be the norm. Hence, investing in education, placing a premium on industry-academia interactions and incentivising innovation activities through, e.g. tax incentives, less bureaucracy, export and networking services is such a policy step. In other words, public policies creating the industrial, research and policy conditions for increasing the demand for specialised knowledge labour within the country stand as a necessary prerequisite for retaining the local skilled human capital and regaining the lost human capital. These policies may also lead Greece towards a different development paradigm, namely the production of higher-value goods and services.

Furthermore, policies that aspire to activate diaspora networks and make the most of expatriates, while they remain abroad ("virtual return"), by establishing "bridges" with Greek industries, universities and professionals (for example, through joint research projects, co-publications, participation in conferences, lectures, mentoring activities and expert advice) could mitigate the negative consequences of their departure. In addition, policies aiming at attracting foreign highly skilled individuals and stimulating return of skilled emigrants (e.g. through tax incentives for investing in Greece, financial assistance for start-ups, productive use of their rich human and socio-cultural capital acquired abroad, support for emigrant families' resettlement) may also be beneficial. Sectoral policies, such as increasing labour market efficiency and improving tertiary education and research environments, may also have a positive impact in this direction, since they indirectly influence the decision to return.

In parallel, our findings call for an open discussion at the EU level about the potential negative effects of skilled emigration on small EU economies, which appear to be less able to retain scientists than larger economies (OECD, 2016; Labrianidis and Sykas, 2021). This could create a vicious cycle of skilled emigrant outflows and poor development. Therefore, closer cooperation between these EU member states in terms of harmonising labour market and educational policies, as well as coordinating recruitment efforts, may be more effective in attracting skilled labour than policies focused exclusively at the country level.

Our findings are based on patent applications and citations aggregates. Future research may focus on the impact of skilled emigration on the number of patent applications or granted patents, as well as citations, in specific disciplines such as STEM, chemistry, health and welfare, all of which play a significant role in a country's innovation performance. A deeper understanding of this issue may provide significant evidence for origin countries in order to shape policies that counterbalance the negative effects of skilled emigration on their innovativeness and growth potential.

## Notes

1. E.g. in 2021, Greece had the highest unemployment rates of tertiary graduates in EU-27, which was the case throughout the ten-year recession. Also, in 2011, it displayed the fourth lowest number of patent application per million inhabitants from the Higher education sector in EU-28 (Eurostat, Statistical Database). In addition, in 2015, Greece had the 9th lowest number of public-private co-publications per million of population in international scientific journals in EU-27, denoting weak knowledge flows between universities and private sector (Greek National Documentation Centre, 2016).

2. Given that EKT is both the official body for maintaining N.A.Ph.D. and a central RDI-related public authority with over 30.000 entities (people and organisations) receiving its produced material, the survey

conducted under the auspices of EKT had the broadest possible coverage. However, in order to obtain a more representative sample, the survey should be repeated in the future when more data is available.

3. Figures S2 and S3 depict the number of patent applications and the number of citations respectively (see "Supplementary figures" online).
4. https://metrics.ekt.gr/scientific-publications/publications.
5. As previously stated, the severe lack of statistical information at the regional level prevented us from relying our analysis on panel data. However, in Table S1 (see "Supplementary tables" online), we re-estimate Equation (1) in an attempt to use all available data at the regional level, namely 13 Regions in Greece for the 1999–2020 time period for patent applications and for the 2006–2020 time period for the number of citations. It should be noted that missing observations exceed 10% of the sample in both cases, which may seriously undermine the robustness of our results (Naghavi and Strozzi, 2015). Fixed effects regressions have been used hypothesising that individual characteristics of each Region affect the regressors. HSM coefficients are negative but not statistically significant, as shown in Table S1. It was not possible to apply our gravity model and proceed to TSLS estimations at the regional level due to a complete lack of data for specific variables, i.e. $Migr_{it}$.
6. We repeat our TSLS estimations in Table S2 (see "Supplementary tables" online) using a modified gravity model. We specifically added a dummy variable ($EU_i$) to our baseline gravity model to indicate whether a destination country $i$ is an EU member or not. The basic hypothesis is that the accession of various destination countries to EU and the subsequent freedom of movement may have increased Greek HSM outflows within the EU area. Table S3 (see "Supplementary tables" online) presents gravity model estimates. $EU_i$ variable is statistically insignificant. HSM variable estimates closely resemble our baseline TSLS estimates (Table 4).

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## Appendix 1: Cointegration Analysis

The use of aggregated time-series data casts doubts on the stationarity of our series. In our analysis, both GP and HSM variables have an upward trend over time due to probably unobserved factors. Since nonstationary series may produce spurious regressions, we have to further investigate this issue by proceeding to Cointegration Analysis. Applying augmented Dickey–Fuller unit root test to each variable we found that all variables are integrated of order one. We then use Johansen Cointegration Test (Johansen, 1988). Results of the Johansen Cointegration Test are presented in Table A1.

| Number of cointegrating equations | Trace statistic | $p$-value |
|---|---|---|
| *Patent applications* | | |
| $r = 0$ | 144.25 | 0.000*** |
| $r \leq 1$ | 87.324 | 0.000*** |
| $r \leq 2$ | 52.245 | 0.017** |
| *Number of citations* | | |
| $r = 0$ | 175.03 | 0.000*** |
| $r \leq 1$ | 113.04 | 0.000*** |
| $r \leq 2$ | 68.704 | 0.000** |

**Note(s)**: *$p$ < 0.10, **$p$ < 0.05, ***$p$ < 0.01
**Source(s):** Author's own work

**Table A1.** Johansen cointegration test

Trace statistics verifies the existence of cointegrating equations. This suggests that there are long-term relationships between the variables, indicating that the OLS estimations presented in Table 2 are consistent. Subsequently, we proceed to the estimation of long-run cointegrating equations, both for patent applications and number of citations (Table A2).

| | *Patent applications* | *Number of citations* |
|---|---|---|
| R&D | 0.020 (0.004) | 0.0002 (0.002) |
| DC | 1.595 (0.208) | 0.224 (0.092) |
| FP | 0.077 (0.020) | −0.010 (0.010) |
| GP | −0.263 (0.038) | −0.193 (0.0154) |
| HSM | 1.075 (0.295) | 2.323 (0.129) |
| Log-likelihood | −78,472 | −59,523 |

**Note(s):** Equations include intercept which is not shown. Standard errors are presented in parentheses
**Source(s):** Author's own work

**Table A2.** Long-run cointegration estimations

There are several differences between the long-run cointegration and OLS estimators presented in Table 2. Specifically, concerning patents applications, the impact of R&D, DC and FP are significantly positive, while that of GP is negative. As for the number of citations, the impact of R&D and FP are insignificantly negative, while the impact of GP is significantly negative. Surprisingly, the estimated coefficient of HSM, the variable of our main interest, is now estimated to be significantly positive in both the long-run cointegration estimations, denoting a positive effect of HSM on IP. Probably, these differences between the OLS and the long-run cointegration estimators can be explained by the combination of short time series used in our analysis and the presence of multicollinearity among R&D, FP, GP and HSM, since, as literature suggests, the trace test suffers from bias when applied in finite samples (Cheung and Lai, 1993), while Johansen estimators are sensitive to multicollinearity (Abeysinghe and Khay Boon, 1999). Given that, we can place greater emphasis on our initial estimations.

## Appendix 2: Gravity and first stage regressions

| Independent variables | Coefficients | Std. errors |
|---|---|---|
| *Dependent variable: Migr$_{it}$* | | |
| Constant | 5.979 | 1.586*** |
| Pop | −9.97738e-010 | 8,42729e-010 |
| Area | 7.46489e-07 | 6,91132e-08*** |
| Dist | 0.403 | 0.227* |
| Bord | 1.211 | 0.342*** |
| Lang | −0.587 | 0.596 |
| Hist | 2.745 | 0.157*** |
| Time Effects | Yes | |
| Observations: 416 | | |
| $R$-squared: 0.88 | | |

**Note(s):** *$p$ < 0.10, **$p$ < 0.05, ***$p$ < 0.01. Migr*it* and Dist are in natural logarithms
**Source(s):** Author's own work

**Table A3.**
Gravity regression

Historical emigration movements (*Hist*) appear to have the strongest impact on emigration stocks. Area (*Area*) and common borders (*Bord*) have also positive effect. The value of $R^2$ is high denoting a good explanatory power of our gravity specification.

| Independent variables | Coefficients | Std. errors |
|---|---|---|
| *Dependent variable: HSM* | | |
| Constant | −0.609 | 5.753 |
| R&D | −0.000 | 0.001 |
| DC | −0.150 | 0.051*** |
| FP | −0.004 | 0.010 |
| GP | 0.057 | 0.008*** |
| LnMigr | 0.002 | 0.011* |
| LnNumber of Patents at t−1 | −0.177 | 0.089 |
| Observations: 25 | | |
| $R$-squared: 0.91 | | |
| F: 29.4 | | |
| *Dependent variable: HSM* | | |
| Independent variables | Coefficients | Std. errors |
| Constant | −1.260 | 4.036 |
| R&D | −0.000 | 0.001 |
| DC | −0.012 | 0.484 |
| FP | 0.006 | 0.008 |
| GP | 0.049 | 0.006*** |
| LnMigr | 0.005 | 0.007 |
| LnNumber of Citations at t−1 | −0.205 | 0.043*** |
| Observations: 24 | | |
| $R$-squared: 0.94 | | |
| F: 54.5 | | |

**Note(s)**: The upper panel concerns patent applications, while the lower number of citations. HSM is lagged by one year. *$p$ < 0.10, **$p$ < 0.05, ***$p$ < 0.01. Heteroscedasticity and Autocorrelation Corrected (HAC) standard errors have been used which are consistent when there is suspicion of serial correlation
First stage $R$-squared is high in both panels, denoting a good explanatory power of our instruments
**Source(s):** Author's own work

**Table A4.**
First stage regressions: the impact of highly skilled emigration on innovation

**Supplementary material**
The supplementary material for this article can be found online.

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