Geography of doctoral education in the Netherlands: origin and current work location of recent PhDs from five Dutch universities

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Abstract

Human capital is indispensable for regional innovation and economic growth, and PhD graduates (PhDs) play an important role in these processes. This is the first study describing the geographic origin and current work location of PhDs from Dutch universities, which are located in a densely populated area with a high concentration of basic science and science-based industries. Our study shows that their country of origin is strongly related to the field of study, as engineering PhDs were born outside the Netherlands much more often than PhDs from other fields. Furthermore, we show that PhDs disproportionally come from the same region as where the PhD university is located. PhDs also frequently did their pre-PhD degree at the university where they obtained their PhD degree. Finally, a disproportionate number of PhDs stay in the PhD region to work, especially if they also did their pre-PhD degrees at the PhD university. The extent of PhDs staying in the PhD region varies by sector, with PhDs in the higher education sector staying in the PhD region more often than PhDs working in other sectors. This implies that the geographic concentration of PhDs in the region of the PhD university is mainly due to PhDs staying to work at the same university rather than employment opportunities in other (science-based) industries – a finding at odds with Dutch science policy, which promotes mobility in academia but also stresses the importance of the region in innovation by science-based industries.

Keywords

PhD graduates
CV analysis
Geography of science
Human capital
The Netherlands

Introduction

PhD graduates are a unique group of highly skilled workers trained in scholarship and science. Human capital is indispensable for regional innovation and regional economic growth, and scientific workers play a key role in this (Faggian and McCann 2009; Lawton Smith and Waters 2011). Human capital migration and regional growth are tightly linked in a positive feedback loop (Faggian and McCann 2009). In this loop, also called the "escalator model" (Fielding 1992), young workers migrate to attractive areas where they can develop their working career. As they are at an age at which they can develop their knowledge and skills, and increase their productivity, their migration contributes to economic growth. At later stages in life, many move out again to other regions in which they can enjoy higher levels of comfort. It is through such processes that concentration in certain regions develops.

Likewise, basic research, applied research, and experimental development are concentrated in specific regions (Bornmann and Waltman 2011; Breschi 2000; Ponds and Van Oort 2008), as are knowledge spillovers between basic research (conducted at universities and research institutes) on one hand, and applied research and experimental development on the other (typically conducted at private companies, and to a smaller extent at (semi-)public research institutes; e.g., Jaffe et al. 1993). Science policy in the Netherlands also aims for basic science to contribute to innovative capacity, and sees a special role for regional innovation systems in this process (Government of the Netherlands 2014: 48). At the same time, it also sees the importance of an international view and aims to promote the (international) mobility of academic researchers (Government of the Netherlands 2014: 64-65).

In the job mobility of individuals, several types of factors play a role, such as structural labor market factors, occupational labor market factors, organizational procedures and policies, work group-level factors, personal life factors, and personality and personal style differences (Feldman and Ng 2007). Interwoven with job mobility is geographic mobility: in quite a large number of cases, a change of job also implies a change of work location. Where a work organization is located, depends on a multitude of factors, such as access to markets, education, business climate, local physical infrastructure, and labor skills (Blair and Premus 1987). Looking more specifically at spin-off companies from public research organizations, important factors in location decisions are the presence of markets and of highly skilled labor (Egeln et al. 2004).

Geographic mobility for work purposes is thus the direct result of the actions of two parties: the work organization and the individual. As discussed above, these two parties also influence one another, as the availability of labor makes a region attractive to organizations, and the availability of jobs makes a region attractive to individuals. Furthermore, other parties, such as other organizations in the same sector, government institutions, and educational institutions play a role in geographic mobility decisions. For example, an organization may choose to locate itself close to other organizations in the same sector to profit from agglomeration benefits (Devereux et al. 2007). Local policies may influence the attractiveness of a region to individuals – it has become increasingly recognized that it is not only job availability that determines the attractiveness of a region, but that the whole "quality

of place" does (Servillo et al. 2012). And the presence of a university may increase the availability of highly skilled labor (Egeln et al. 2004). For PhD graduates (called PhDs in the remainder of the article), too, these mechanisms are likely to determine geographic mobility.

Despite these previous studies into the effects of geographic mobility on regional innovation and into the factors that determine the attractiveness of regions, there is virtually no knowledge on the geographic mobility of PhDs – notwithstanding the fact that PhDs make up a vital source of highly skilled knowledge workers. There have been some studies into the mobility of PhDs (including those not working in academic research), but it is difficult to obtain internationally comparable data, as the Organisation for Economic Co-operation and Development (OECD) also stated in its 2008 overview on the mobility of highly skilled people (OECD 2008). It points to heterogeneity in immigration data and the lack of a clear statistical definition of researchers as the causes for non-comparable data. Although these limitations should be borne in mind when analyzing the available data, the data suggest the expatriation rate is especially high for Ireland and New Zealand, while the most popular destination for highly skilled expatriates is the United States.

Next to international mobility, the national mobility of PhDs is an interesting issue. As for the United States, Stephan et al. (2004) found that of the recent science and engineering PhDs hired by firms in the top-25 metropolitan statistical areas (MSA), only a quarter had obtained their PhD degree in the same MSA, and only forty per cent of them had obtained it in the same state. Net inflow is highest in the Pacific and Northeast regions of the United States, whereas outflow is highest in the Midwest.

Data on the international and national mobility of PhDs are lacking for many other countries, including the Netherlands. At the same time, there have been studies on the national mobility of bachelor's and master's graduates in the Netherlands (Venhorst et al. 2010, 2011; Venhorst 2013). Venhorst (2013) investigated student and graduate mobility between NUTS1 regions. The NUTS classification is a hierarchical system to divide the EU territory. NUTS1 distinguishes four regions in the Netherlands: Northern, Western, Eastern and Southern. Venhorst showed that the majority of school leavers pursue college or university education in the same NUTS1 region as the one they already lived in, and that the majority of graduates find a job in the same region. As such, the study stresses the importance of "regional familiarity". At the same time, there is a net flow towards the west of the Netherlands, where economic activity is highest. The study also shows retention of graduates to be highest for the four biggest Dutch cities (all located in the western part of the country). Smaller cities in the west have retention rates that are roughly equal to similar-sized cities in other parts of the country. Finally, his study shows a net flow from rural to urban areas. One might expect similar migration patterns for PhDs, but this cannot be stated with any certainty for this vital demographic due to the lack of data.

In this study, we set out to study the mobility of recent PhDs from Dutch universities, as it provides knowledge on the migration patterns of highly skilled knowledge workers with a degree from universities in a densely populated area with high levels of scientific activity (Bornmann and Waltman 2011). We ask the questions: (1) which geographic mobility patterns do PhDs from Dutch universities follow, (2) to which extent are the geographic

mobility patterns congruent with current policies on job mobility and the knowledge economy, and (3) to which extent does geographic origin influence mobility after the PhD degree? Through these analyses we provide the first empirical evidence on the geography of doctoral education in the Netherlands.

The research questions are operationalized into the following analyses:

1. Where do PhDs from Dutch universities hail from, both in terms of:
    a. origin of birth, and
    b. educational origin?
2. Where do PhDs from Dutch universities work six to seven years after obtaining their PhD degree, and does this differ by sector of employment?
3. What is the relation between origin (both of birth and education) and the current work location?

Data and methods

Study sample

The sample of the current study consists of individuals who received a PhD degree from Utrecht University (a university with education and research in a broad range of fields), Delft University of Technology (engineering and technology), Wageningen University (an agricultural university), Erasmus University Rotterdam (focused on medicine and social sciences, especially economics and management) or Leiden University (a university with education and research in a broad range of fields) between April 2008 and March 2009 (see Sonneveld et al. [2010] and Waaijer [2017] for a more elaborate description of the sampling procedure). This sample was also used in a web-based survey on the labor market position, job choice, job satisfaction, and value of the PhD degree, which are described in other publications. However, it is important to note that in the current study, we did not use the survey data provided to us by the PhDs who responded to our survey, but publicly available data on *all* PhDs in the sample who obtained their PhD degree between April 2008 and March 2009.

The sample consists of 230 PhDs from the Delft, 315 from the Leiden, 268 from the Rotterdam, 418 from the Utrecht, and 174 from the Wageningen university (total: 1,405 PhDs). These five universities were chosen as together, they represent the whole range of scientific disciplines and form a representative sample of the fields of PhD graduations in the Netherlands (see end of next paragraph). The 2008-2009 period was chosen as we expected PhDs from this period to have settled into a post-PhD career and therefore, the location and sector of the job provide a relatively “stable” overview of the labor market situation of recent PhDs. This would not have been the case directly after the PhD, as we would expect the labor market situation of PhDs to be more variable. On the other end of the spectrum are PhDs who obtained their degree about ten to thirty years ago. However, such individuals would have been much more difficult to trace.

Data retrieval

For this study on the origin and current work place of PhDs, place of birth and past education were obtained through searching the universities' repositories for the PhDs' dissertations, which usually contain place of birth on the title page, and a short CV with educational information at the end of the dissertation. Information on the current job was obtained through online searches (a combination of consulting Google search, the professional online network LinkedIn, and the scientific databases Web of Science, Google Scholar, and Pubmed). Searches were conducted between March 2014 and January 2015. We consider a job to be "current" when we found information showing a person held that job in 2013 or later (including affiliations on research papers published from then onwards). When past education was not available from the dissertation (e.g., because a CV was missing), we attempted to determine the educational history through LinkedIn. We count all current jobs fractionally, e.g., if a person has two jobs listed on their online CV with different locations, the locations are counted with a weight of 0.5. Furthermore, for each PhD we recorded their field of PhD degree (engineering, humanities, medical and health sciences, natural sciences, or social sciences) using the dissertation and CV data. An overview of the fields by city of PhD degree is given in Table 1. This shows that the field distribution in our sample is a very good representation of the field distribution among PhDs from all Dutch universities (Rathenau Instituut 2016). In 2008, the natural sciences and engineering accounted for 42% of all PhD graduations in the Netherlands (cf. 41% in our sample), the medical sciences for 32% (cf. 34% in our sample), the social sciences for 19% (cf. 16% in our sample), and the humanities for 7% (cf. 7% in our sample).

Finally, we recorded the sector of employment for every job. We used two axes of delineation: activity in job (research and development [R&D, which includes basic research, applied research and experimental development], non-R&D, teaching, or health care) and type of organization (higher education, government, health care institution, research institute, for-profit organization or non-profit organization). Sector of employment is the result of crossing the activity in job and type of organization. Health care was defined as activities dealing directly with the diagnosis of, treatment of, and care for patients. One could argue it is a special case of non-R&D work, but as so many PhDs were involved in health care, we delineated it as a separate category. On the other end of the spectrum were the sectors that had few PhDs working in them, so reporting on the numbers of PhDs would not have been possible without the identification of individuals. Therefore, some sectors were merged. The sectors that are used throughout the paper are R&D at higher education, Other R&D (R&D conducted at other types of organizations), Outside R&D, Health care, and Teaching & Other. Like the locations, sectors are also counted fractionally. For example, if a PhD is an assistant professor at a university and performs both research and teaching according to their CV, that person is classified as working in R&D in higher education with a weight of 0.5 and in Teaching & Other with a weight of 0.5.

The classification of countries was performed according to the United Nations Geoscheme (United Nations Statistics Division 2013), with the exception that we classified overseas territories with the country they belong to. The 2010 NUTS3 (COROP) division provided by Statistics Netherlands on 1 January 2012 was used to classify the Dutch

municipalities listed in PhDs' CVs and online available data such as the place of birth, place of pre-PhD degree and current job(s) into the 40 NUTS3 regions (Statistics Netherlands 2013). Geographic data were plotted using the shapefile *Grenzen van de 40 COROP regio's (2015)* (source: Statistics Netherlands Data & TopGrenzen, CC-BY) with QGIS Desktop 2.0.1.

We used the Pearson's chi-squared test of independence to analyze the relation between categorical variables of interest. Logistic regression analysis was used to test whether the PhD university and field of PhD degree were related to birth origin.

Please note that numbers are reported and analyses performed as data were available. Therefore, *N*'s in each table vary by the availability of data on the variable(s) reported on. In total, we were able to retrieve the country of birth of 1,322 PhDs, the country of pre-PhD degree education of 1,331 PhDs, and the country of the current job of 1,251 PhDs (out of 1,405 PhDs studied in total).

Results

Origin: birth

First, we looked at the PhDs' origin of birth. A majority was born in the Netherlands (Table 2). The second largest group was PhDs born in other western European countries, followed by PhDs born in the Americas, Eastern Europe, Southern Europe, and Africa. However, there were large differences between universities. Almost three quarters of Rotterdam and Utrecht PhDs were born in the Netherlands, compared to 65% of Leiden, 62% of Wageningen and 45% of Delft PhDs. Conversely, Delft had more PhDs born in Eastern Europe and Southern Europe. Finally, the share of African PhDs was higher among Wageningen PhDs than among PhDs from other universities. The origins of birth differed statistically significantly between the universities, (X^2 (40, N=1,322]) = 1488.72, $p < 0.001$).

As Table 1 shows, the universities vary considerably with respect to the field of PhD degree, and it may be that this is what actually underlies the differences in origin. Therefore, we performed a logistic regression on having been born in the Netherlands (dependent dummy variable) by university and field of PhD degree (independent dummy variables; Nagelkerke pseudo-R^2 = 0.101). This showed that the university of PhD degree was not statistically significantly associated with being born in the Netherlands. Rather, it is the field that underlies the differences in origin, with PhDs in the medical and health field being much more likely to hail from the Netherlands than PhDs in engineering ($\exp(\beta) = 3.46$, $p = 0.014$). As Delft specializes in engineering, and Rotterdam in the medical sciences (Table 1), this explains the differences in origin.

Of the PhDs born in the Netherlands, we also assessed the NUTS3 regions they were born in. Figure 1 shows the shares of PhDs from the different NUTS3 regions controlled for the population shares living in those regions, e.g., a value of 2 would mean twice as many PhDs coming from a region than would be expected based on the population living there. This shows that especially Leiden PhDs disproportionally come from the areas around the city of PhD degree, but also Rotterdam and Utrecht PhDs do.

Origin: education

Next, we analyzed the educational origin of PhDs. We did this by determining the countries in which PhDs obtained their last (bachelor or master) degree before starting their PhD degree. Compared to the origin of birth, an even larger share hailed from the Netherlands in terms of educational origin: 75% in total compared to 65% who were born there (Table 3 cf. Table 2). This suggests that at least some foreign PhDs came to the Netherlands to pursue a bachelor or master degree, and then stuck there to also pursue a PhD degree. Again, there were differences between universities; Utrecht, Rotterdam and Leiden PhDs followed their pre-PhD education in the Netherlands more often than Wageningen and, especially, Delft PhDs (X^2 (40, N=1,331) = 1488.72, $p < 0.001$).

The "sticking" phenomenon is even clearer when looking at how many PhDs who followed their pre-PhD education in the Netherlands, did so at the same university where they obtained their PhD degree from. Of Delft PhDs, 70% did; this figure is 58% for Leiden, 41% for Rotterdam, 57% for Utrecht, and 74% for Wageningen (differences between universities statistically significant; [X^2 (4, N=1,000) = 1488.72, $p < 0.001$]). The figures reflect the specialization of the universities, Delft and Wageningen being much more specialized in certain research topics than Leiden, Rotterdam and Utrecht. The large shares of PhDs sticking to the university where they obtained their pre-PhD degree may also be explained by good master graduates being scouted by senior researchers and offered a PhD position, thereby staying at the university of their pre-PhD degree.

Current work location: all PhDs

In addition, the current work location of PhDs was analyzed. Table 4 shows the regions where PhDs work, with locations weighted by person. Again, this showed a large share of PhDs located in the Netherlands, ranging from 62% of Wageningen PhDs to 78% of Rotterdam PhDs (differences between universities statistically significant; [X^2 (40, N=1,251) = 84.98, $p < 0.001$]). Further relatively large labor markets for these PhDs are other western European countries (such as Belgium and Germany), the Americas and Northern Europe. The region of the current job was strongly associated with the sector of work. Compared to PhDs working in other sectors, quite many PhDs in higher education worked outside the Netherlands, especially in Northern Europe, Northern America, or in other regions (Table 5; [X^2 (12, N=1,251) = 1488.72, $p < 0.001$]). The share of PhDs working in the Netherlands was highest in health care: 91%.

Of the PhDs working in the Netherlands six to seven years after their PhD degree, we analyzed the regions in which they worked. This showed that many PhDs stayed to work in the region of the city where they received their PhD degree. Of Delft PhDs working in the Netherlands, 37% worked in the Delft & Westland region after their PhD degree; these figures are 29% for Leiden PhDs in the Leiden & Bollenstreek region, 47% for Rotterdam PhDs in the Greater Rijnmond region, 43% for Utrecht PhDs in the Utrecht region, and 38% for Wageningen PhDs in the Veluwe region (X^2 (4, N=856) = 13.73, p = 0.008). Again, we also controlled for the population density of the NUTS3 regions in question in order to obtain a fairer picture of the shares of PhDs working in a NUTS3 region compared to the share that could be expected.

This analysis confirmed the relative overrepresentation in the region of PhD degree (Fig. 2). The overrepresentation was strongest for Delft PhDs, followed by Leiden, Wageningen, Utrecht, and Rotterdam PhDs. Popular regions other than the region of PhD were Greater Amsterdam, Greater The Hague (but neither for Wageningen PhDs), Delft & Westland, Leiden & Bollenstreek, and Utrecht (Fig. 2). The latter regions were not only popular among those who obtained their PhD degree in that region, but also among PhDs from other cities. These regions probably attracted PhDs through their employment opportunities in science (Bornmann and Waltman 2011) and science-based industries (Ponds and Van Oort 2008).

Interestingly, some regions were not particularly popular. South East North Brabant, a region with high levels of technology-based industries due to the presence of Royal Philips Electronics NV (Ponds and Van Oort 2008), did not draw many PhDs, although especially Delft PhDs could have been expected to work there given the fact that they obtained their PhD degree from a university of technology (and the only university of technology in the studied sample).

Current work location: by sector of employment

In the previous section, we concluded that the number of PhDs working in the region of PhD degree is relatively high. We investigated whether this differed by sector of employment. Overall, the shares of PhDs working in the same region as where they obtained their PhD degree were higher among PhDs in "R&D in higher education" and "Teaching & Other" than among PhDs working in other sectors (Table 6; [X^2 (12, N=1,251) = 1488.72, p < 0.001]).

The relation between current work location and sector of employment differed between PhD universities. About seventy per cent of Delft PhDs in R&D in higher education, or teaching and other sectors, stayed in the Delft & Westland region, whereas these shares are much lower among PhDs doing "other R&D" (at a research institute, a for-profit company or a non-profit organization), working outside R&D or working in health care. The same pattern was observed for Wageningen. In Rotterdam, PhDs doing R&D in higher education or teaching stayed in the PhD region as well, but also PhDs in health care stayed to work there. In Utrecht, PhDs doing R&D in higher education or teaching also stayed often, but PhDs working in "other R&D" stuck to the region as well. Only Leiden was different when it came to PhDs in R&D in higher education; although many PhDs doing R&D in the higher education sector stayed in the Leiden & Bollenstreek region, quite many also flocked to other regions. In comparison, the Leiden & Bollenstreek region manages to attract a relatively high share of PhDs doing other R&D. Still, looking at the total, a significantly greater share of PhDs working in higher education, or teaching and other, stayed in the PhD degree region than PhDs working in other sectors. Thus, it is mostly the employment opportunities at the universities themselves that kept PhDs in the PhD degree region rather than other employment opportunities. This points to relatively high levels of "academic inbreeding", whereby academic researchers are employed by the same university as where they obtained their PhD degree from. For example, in the United States and the United Kingdom the percentage of

academic inbreeding among faculty is below 20% (Horta et al. 2010). On the other end of the spectrum, the figure is estimated to be 95% in Spain.

Relation between origins and current work location: origin of birth

Next, we looked at the relation between the origin of birth and educational origin on one hand, and current work location on the other. A comparison between birth locations and current work locations of PhDs shows more interesting patterns (Fig. 2 cf. Fig. 1). Delft and Wageningen drew PhDs from many different regions but retained many PhDs after the obtainment of the PhD degree. These mobility profiles probably reflect the high levels of specialization of these universities; to study agricultural sciences in the Netherlands, one must study in Wageningen and to study some specializations within engineering, one must study in Delft. In comparison, as also indicated in the paragraph on origin of birth, Leiden PhDs often hailed from the Leiden region itself or other regions in the west, but stayed in the Leiden region less often than the individuals who obtained their PhD degree in other cities. The NUTS3 mobility profiles of Rotterdam and Utrecht fall in-between the profiles of Delft and Wageningen on the one hand and Leiden on the other.

We also assessed whether brain gains or drains of PhDs took place, both at the national and at the regional level. To this end, we compared the inflow and outflow of PhDs from the Netherlands, and did the same for the NUTS3 region of the PhD degree city. This analysis shows that a considerable national brain gain only occurred for Delft, whereas the gain was much smaller for the other cities, especially for Leiden and Wageningen (Table 7). In addition, the results shed light on the dynamics of inflow and outflow. For Leiden and Wageningen, two cities with almost no net inflow, it was not the case that all PhDs born in the Netherlands stayed to work there after the PhD, and all foreign PhDs returned to their home country or moved to another country abroad. Rather, approximately 10% of PhDs from these cities were born outside the Netherlands and then stayed to work in the Netherlands, and another approximately 10% moved abroad while having been born in the Netherlands. Hence, the situation is more dynamic than the net brain gain would seem to show.

For NUTS3 regions, a much more pronounced brain gain was observed (Table 7). The main part of this inflow is due to PhDs who were born in the Netherlands (but outside the NUTS3 region of the PhD university) who stay to work in the PhD NUTS3 region. This implies that having a university in a NUTS3 region attracts highly educated individuals to that region, probably because these individuals stick to their PhD region.

Still, the number of individuals for whom no location of birth or current work location could be determined was quite high – higher than most national brain gains or drains. Therefore, we could not conclude with certainty whether any brain gain or drain occurred. However, it is likely that any trend in international mobility would be towards a brain drain: when tracing individuals online, we found that it was more difficult to trace the location of PhDs born outside Europe, and who are likely to have returned to their home countries, than it was to trace PhDs born in Europe. This was especially the case for individuals from countries with languages using non-Latin scripts. The names provided to us by the universities were in Latin script. If a PhD works in China and their employer’s website mentions their name in

Chinese, search engines would not pick up the Latin name, of course, thereby causing the country of the current job to be unknown.

Relation between origins and current work location: educational origin

Finally, we assessed the relationship between educational origin and current work location. As shown in the section on educational origin, a large share of PhDs completed their pre-PhD degrees at the PhD university. And as shown in the section on current work location, a disproportionate number of PhDs worked in the NUTS3 region of the PhD university. Are these observations related – do PhDs who completed their pre-PhD degree at the same university where they obtained their PhD degree also stay to work in the same NUTS3 region more often?

Indeed, they do: 34% of them stayed, compared to 29% of the PhDs completing a pre-PhD degree at another Dutch university, and 11% of PhDs completing that degree at a non-Dutch university (Table 8). An even greater difference was observed regarding working outside the Netherlands: 68% of PhDs completing their pre-PhD degree outside the Netherlands was also working outside the Netherlands six to seven years after obtaining the PhD degree. Differences between groups were statistically significant ([X^2 (4, N=1,405) = 1,488.72, $p < 0.001$]). In conclusion, persons who have been mobile in their educational past, i.e., moving to another country or region for doctoral education were more mobile afterwards as well.

Discussion and conclusions

To our knowledge, this is the first study of the "geography of doctoral education" in the Netherlands. As scientific workers play an important role in regional innovation systems, it is imperative that the mobility of these workers be analyzed (Lawton Smith & Waters, 2011).

Our study shows the birth origin, educational origin, and current work location of recent PhDs from five Dutch universities. The main findings are that the country of birth strongly depends on the field of PhD degree, with the university of technology in our sample attracting many more PhDs from other countries than universities active in other areas of study. This can be explained by the fact that at the time many PhDs in the sample would have started their undergraduate studies, there was a large shortage of students in the natural sciences and engineering in the Netherlands (Commissie Toekomst Natuur- en Technische Wetenschappen 1997). PhD candidates would then need to have been drawn from outside the Netherlands more than in other fields. The nature of the fields may play a role as well, with for example some specialties within medicine, such as social and family medicine, requiring PhD candidates to speak Dutch, whereas this would not be a requirement in physics.

The regional birth and educational origins also vary, with Leiden University especially attracting many of its PhDs from the same region. Particularly low levels of mobility are observed when assessing the educational origin of PhDs, many of which did their pre-PhD degrees at the same university as where they obtained their PhD degree from.

Furthermore, we found that a disproportionate share of PhDs works in the same region as where they obtained their PhD degree. This is especially the case for PhDs who also completed their pre-PhD degree at the PhD university, and especially for those working in R&D at higher education institutions or teaching. In the Netherlands, no NUTS3 region has more than one PhD degree-granting university located in it (except for the Greater Amsterdam region, which has two, but PhDs from these universities were not included in the sample). This means that the regional "stickiness" is mainly due to PhDs staying at the university where they obtained their PhD degree: "academic inbreeding" (except for a very minor share that moves jobs to a university of applied sciences in the same region). In comparison, PhDs stick to the same region less often if they work in other R&D or outside R&D. This points towards regional organizations and businesses not reaping the advantages of the geographic proximity to a university to full extent. Still, it is important to keep in mind that geographic job mobility is the result of both the work organization and the PhD, which in turn are influenced by other parties, such as educational institutions, government institutions and other organizations in the same sector. Therefore, it is likely that our findings on PhD job mobility patterns are also the result of a multifactorial process and not based on the actions of regional organizations and businesses alone.

On one hand, our results that a disproportionate share of PhDs works in the same region as where they obtained their PhD degree are hardly surprising, as they mirror the Venhorst's findings (2013) of limited mobility of Dutch bachelor's and master's graduates. On the other hand, PhD-holding scientists are highly encouraged to be (internationally) mobile (Government of the Netherlands 2014: 64-65). In this light, the total figure of PhDs staying in the PhD region is quite high. It appears to be much higher than in the United States, for example, where only a quarter of recent PhDs hired by firms received their PhD degree from a university in the same metropolitan area (Stephan et al. 2004). In addition, Stephan et al. investigated individuals who had just obtained their PhD degree (within the same year), whereas our sample consisted of less recent PhDs (six to seven years after the PhD degree). This indicates PhDs from our investigated Dutch universities are less mobile than their American counterparts.

However, the aim of the Dutch government, one of the actors in geographic mobility of PhDs, is to promote (international) mobility in academia, while promoting regional closeness in other sectors, especially high-technology industries and service companies. In view of this, our findings on regional mobility indicate that PhDs do the exact opposite of what Dutch science policy aims at: in academia, where mobility is promoted, they disproportionally keep working at the same university as where they obtained their PhD degree, but if they find a job in other sectors, they do go to other regions. Probably, businesses and other organizations in the NUTS3 regions of the universities could take more advantage of the fact that so many highly trained individuals are familiar with the region due to their time as PhD candidates there and attract them as employees. They are likely in a good position to do so; according to the respondents of Lawton Smith and Waters (2011) the second most important advantage of their current location (Cambridgeshire or Oxfordshire) was simply "It is home". To promote regional closeness even further, national and local government should consider the recommendations given in the article by Servillo et al.

(2012). Servillo and colleagues argue that the whole "quality of place" rather than only economic factors should be assessed when seeking to increase the regional attractiveness. In addition, they argue that local governments should not study which factors are important in regional attractiveness for multiple groups of people (e.g., expatriates, farmers and PhDs) but for PhDs *specifically*. By improving the factors important to PhDs, local governments can increase their attractiveness to PhDs.

A few reservations and limitations apply to our study. The findings imply PhD mobility patterns that are at odds with Dutch science policy, as this policy stresses high (international) geographic mobility of academic researchers but focuses on the local region when it comes to knowledge spillovers between universities and other sectors. Of course, this conclusion is quite simplistic. Our findings also show that *international* mobility is highest in academia. In addition, the PhDs staying to work at the PhD university may be involved in regional cooperation with local industry and other organizations and as such, contribute to regional innovation. Finally, PhDs who have moved to another NUTS3 region to work in the non-academic sector, can contribute to regional innovation in the other NUTS3 region.

Another reservation is that a large national brain gain is only observed for Delft: Delft University of Technology attracts more PhDs from abroad that stay to work in the Netherlands than PhDs born in the Netherlands go to work abroad after their PhD degree. Regional brain gains are observed for all universities. Still, there is a quite high number of PhDs for whom no birth location was known or whose current work location could not be traced, which means that no definitive conclusions on brain gains or drains can be drawn.

A limitation of this study is that it only looked at a confined set of PhDs from Dutch universities, both in terms of universities (five, four of which are located in the western, most densely populated area of the Netherlands) and time (PhD degree obtained between April 2008 and March 2009), of whom the work location in only 2014 or 2015 was determined. In future studies, the analysis could be expanded to include longitudinal data from statistical offices, for example using the Careers of Doctorate Holders Survey (Maas et al. 2014). Such an analysis could provide a more fine-grained analysis to track regional mobility of a greater set of PhDs, including more persons who obtained a PhD degree from a university in the northern, eastern, and southern parts of the Netherlands. This could show to what extent the South East North Brabant region retains PhDs of the Eindhoven University of Technology (southern part of the Netherlands), and to which extent the province of Groningen retains PhDs of the University of Groningen (northern part of the Netherlands), for example. Among bachelor's and master's graduates, there is net outflow from the northern, eastern, and southern parts of the Netherlands to the west (Venhorst 2013). For the sample of PhDs in our study, Greater Amsterdam is an important region to work in, especially for Leiden PhDs. Analyzing the mobility from University of Amsterdam and VU University Amsterdam PhDs would also be interesting – is the pull from the Greater Amsterdam region even greater for its own PhDs than for others?

Such an approach would also be useful to study regional flows of PhDs in other countries, which may play out differently. To our knowledge, such an analysis has only been conducted for the United States, and has shown significant outflows of PhDs trained in the

Midwest and inflows to the Pacific and northeastern regions of the United States, where innovative activities are concentrated (Stephan et al. 2004). Using fine-grained longitudinal data on the regional mobility of PhDs, the influence of doctoral education on regional innovation could be investigated. At the same time, the CDH does not include PhDs living abroad and would therefore not be suitable to analyze international mobility. In contrast, the current study, which employs CV analysis rather than registry data, is able to show patterns of international mobility of PhDs.

In conclusion, this study shows that regional familiarity plays an important role in the Netherlands in attracting persons to doctoral education, both in terms of origin of birth and of education. After graduation, employment opportunities in especially the higher education sector keep PhDs in the PhD region.

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Table 1. Field of PhD degree (PhD graduates Apr 2008-Sep 2009) by university (%)

Tables and figures

	PhD university					
	Delft	Leiden	Rotterdam	Utrecht	Wageningen	Total
Field of PhD degree			*%*			
Medical and health sciences	0	37	69	40	7	34
Natural sciences	0	30	0	32	70	25
Social sciences	4	17	29	19	14	16
Engineering	96	0	0	0	7	16
Humanities	0	17	2	9	2	7
Total	100	100	100	100	100	100
n	*220*	*315*	*267*	*403*	*174*	*1379*

n denotes the number of PhDs for whom the field of PhD degree could be established. Shares may not add up to 100 per cent because of rounding.

Table 2. Region of birth of PhD graduates Apr 2008-Sep 2009 by university (%)

	PhD university					
	Delft	Leiden	Rotterdam	Utrecht	Wageningen	Total
Region of birth			*%*			
Netherlands (NL)	45	65	73	73	62	65
Western Europe except NL	6	7	5	7	4	6
Americas	5	5	4	3	6	4
Eastern Europe	11	2	4	3	4	4
Southern Europe	9	4	2	3	3	4
Africa	4	5	3	2	7	4
Eastern Asia	7	4	3	1	3	3
Southern Asia	4	2	3	2	5	3
South-Eastern Asia	5	2	suppr.	2	3	3
Northern Europe	2	2	suppr.	3	suppr.	2
Other	3	2	suppr.	1	suppr.	2
Total	100	100	100	100	100	100
n	*217*	*311*	*244*	*384*	*166*	*1322*

'Other' category includes Australia and New Zealand, Caribbean, Central Asia, and Western Asia. *n* denotes the number of PhDs of whom the region of birth could be retrieved. Data suppressed if absolute numbers < 5 to avoid identification of individuals. Shares may not add up to 100 per cent because of rounding.

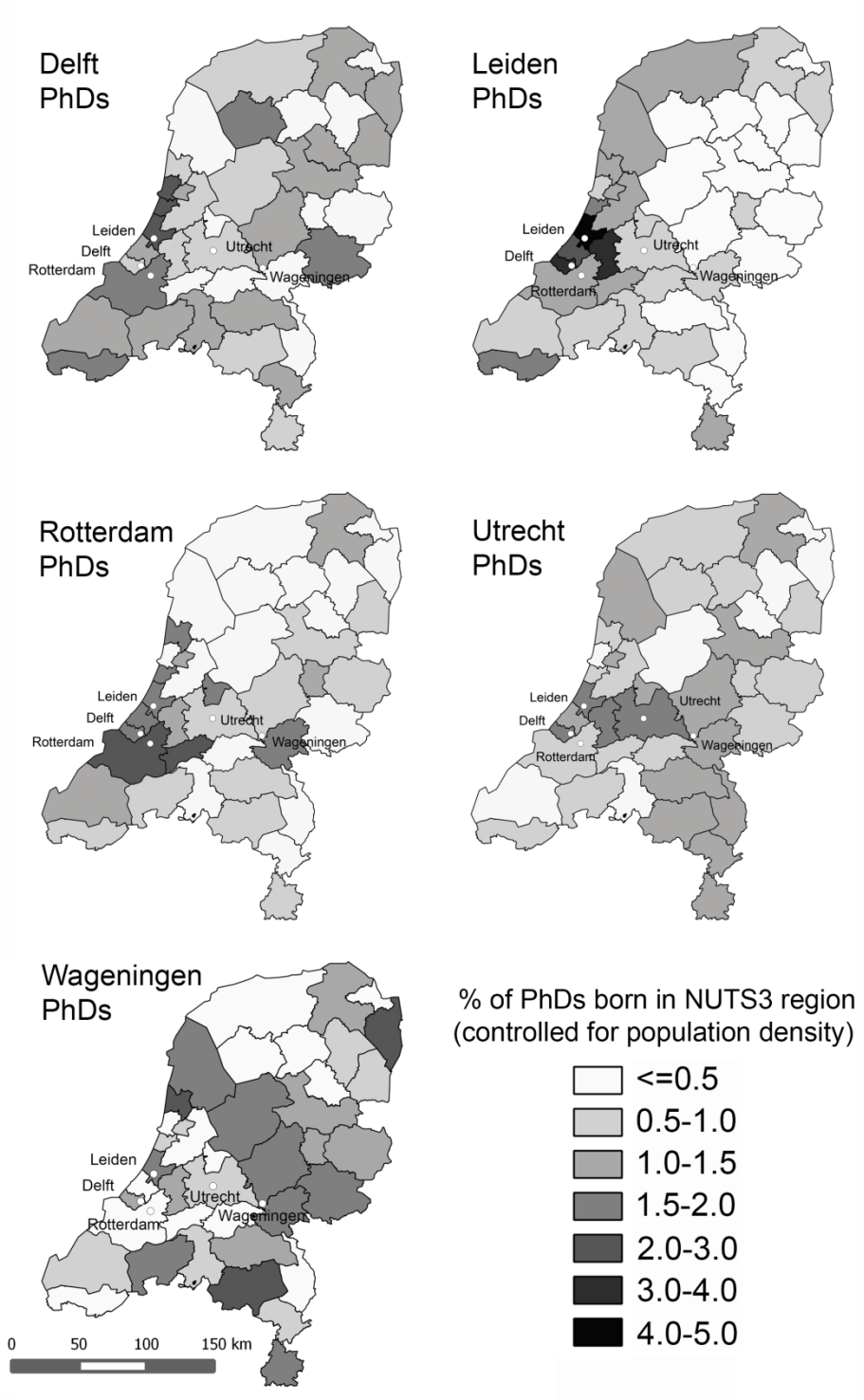

Figure 1. Origin of birth of PhD graduates (Apr 2008-Sep 2009) born in the Netherlands, by university.

The figure depicts the shares of PhDs born in Dutch NUTS3 regions (only for those born in the Netherlands) by PhD university, controlled for population density. A ratio of 1.0 means that the share of PhDs born in a NUTS3 region is equal to the share of the entire Dutch population living in that region.

Table 3. Region of pre-PhD education of PhD graduates (Apr 2008-Sep 2009) by university (%)

	PhD university					
	Delft	Leiden	Rotterdam	Utrecht	Wageningen	Total
Region pre-PhD education			*%*			
Netherlands (NL)	57	77	80	82	71	75
Western Europe except NL	6	6	7	6	5	6
Southern Europe	9	3	suppr.	3	3	4
Americas	4	4	3	3	3	3
Eastern Europe	10	suppr.	suppr.	1	4	3
Northern Europe	3	3	3	3	3	3
Southern Asia	3	suppr.	suppr.	suppr.	5	2
Eastern Asia	4	2	suppr.	suppr.	suppr.	2
South-Eastern Asia	3	suppr.	suppr.	suppr.	2	1
Africa	suppr.	2	suppr.	suppr.	suppr.	1
Other	suppr.	suppr.	suppr.	suppr.	suppr.	1
Total	100	100	100	100	100	100
n	*222*	*299*	*246*	*394*	*170*	*1331*

'Other' category includes Australia and New Zealand, Caribbean, Central Asia, and Western Asia. *n* denotes the number of PhDs for whom the region of pre-PhD education could be retrieved. Data suppressed if absolute numbers < 5 to avoid identification of individuals. Shares may not add up to 100 per cent because of rounding.

Table 4. Region of current job of PhD graduates (Apr 2008-Sep 2009) by university (%)

	PhD university					
	Delft	Leiden	Rotterdam	Utrecht	Wageningen	Total
Region current job			*%*			
Netherlands (NL)	65	67	78	75	62	70
Western Europe except NL	11	7	5	4	7	7
Americas	3	9	5	6	6	6
Northern Europe	4	6	6	5	4	5
Africa	suppr.	3	suppr.	2	8	2
Southern Europe	3	suppr.	suppr.	2	suppr.	2
Eastern Asia	suppr.	2	2	suppr.	suppr.	2
South-Eastern Asia	2	suppr.	suppr.	2	suppr.	2
Southern Asia	suppr.	suppr.	suppr.	suppr.	3	1
Eastern Europe	3	suppr.	suppr.	suppr.	suppr.	1
Other	suppr.	2	suppr.	1	suppr.	2
Total	100	100	100	100	100	100
n	*200.5*	*285.5*	*225.5*	*375.5*	*164*	*1251*

'Other' category includes Australia and New Zealand, Caribbean, Central Asia, and Western Asia. *n* denotes the number of PhDs for whom the region of the current job could be retrieved. Data suppressed if absolute numbers < 5 to avoid identification of individuals. Shares may not add up to 100 per cent because of rounding.

Table 5. Region of current job of PhD graduates (Apr 2008-Sep 2009) by sector of work (%)

	Sector of work				
	R&D at high ed	Other R&D	Health care	Outside R&D	Teaching & other
Region of current job			*%*		
Netherlands (NL)	59	71	91	74	70
Western Europe except NL	7	12	2	7	1
Northern Europe	9	3	3	4	4
Northern America	8	3	2	4	3
Other	18	11	2	11	22
Total	100	100	100	100	100
n	*411*	*260*	*186*	*282*	*112*

R&D at high ed: research or development at higher education (university or university of applied sciences). *n* denotes the number of PhDs for whom the region of the current job could be retrieved. Shares may not add up to 100 per cent because of rounding.

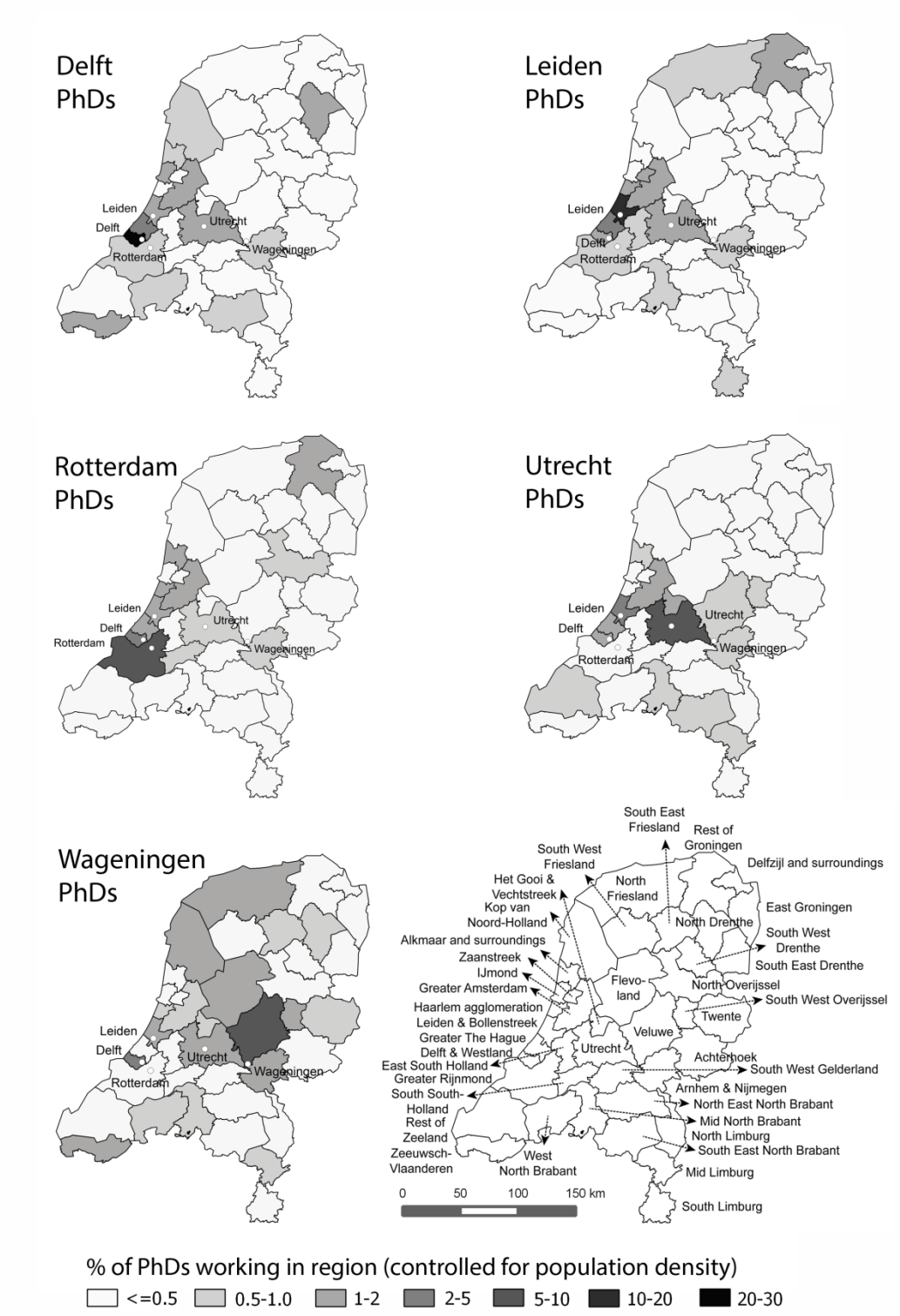

Figure 2. Current work location of PhD graduates (Apr 2008-Sep 2009) working in the Netherlands, by university.

The figure depicts the shares of PhDs working in Dutch NUTS3 region (only for those working in the Netherlands) by PhD degree university, controlled for population density. A ratio of 1.0 means that the share of PhDs working in a NUTS3 region is equal to the share of the entire Dutch population living in that region. Bottom right panel shows the Dutch NUTS3 regions.

Table 6. PhDs (Apr 2008-Sep 2009 and working in the Netherlands) working in NUTS3 region of PhD university, by university and sector of work (%)

	PhD university					
	Delft	Leiden	Rotterdam	Utrecht	Wageningen	Total
Sector of work			*%*			
R&D at HE	72	33	67	55	65	58
Other R&D	21	35	2	45	19	28
Outside R&D	20	10	15	29	21	20
Health care	0	33	58	32	0	42
Teaching & other	73	48	61	60	30	54

R&D at HE: research or development at higher education (university or university of applied sciences).

Table 7. National and regional (NUTS3) brain gains and drains of PhD graduates Apr 2008-Sep 2009, by university

	Delft	Leiden	Rotterdam	Utrecht	Wageningen
National inflow	51.00	29.75	27.00	38.50	18.00
National outflow	12.83	29.50	19.00	29.17	15.83
National brain gain/drain	38.17	0.25	8.00	9.33	2.17
Inflow to NUTS3 region of PhD university from other Dutch region	24.33	37.67	51.95	78.42	30.5
Inflow to NUTS3 region of PhD university from abroad	21.17	9.25	9.50	18.50	3.50
Outflow from NUTS3 region of PhD university	0.00	11.50	21.67	19.58	4.00
NUTS3 brain gain/drain	45.50	35.42	39.78	77.33	30.00
Total unknown birth locations	13.00	4.00	24.00	34.00	8.00
Total unknown work locations	27.50	28.50	41.50	42.50	10.00
Total unknown locations	40.50	32.50	65.50	76.50	18.00
n	*230*	*315*	*268*	*418*	*174*

National inflow is the number of PhDs born outside the Netherlands and working there in their current job(s); national outflow the number of PhDs born in the Netherlands and working outside the Netherlands in their current job(s). National brain gain/drain is the difference between the two figures. NUTS3 brain gains are calculated by adding the inflow to NUTS3 region of the PhD university from other Dutch regions and from abroad (both NUTS3 inflows), and subtracting the outflow from NUTS3 region of the PhD university. Please note that the numbers may not be whole numbers due to the fact that the jobs were weighted by person (e.g., if a PhD was born in the Netherlands and has one job in the Netherlands and two other jobs abroad, the national outflow would be 0.67). *n* denotes the total number of individuals in the sample by university of PhD degree. Also note that the numbers in the table do not add up to *n* as the PhDs who are not part of any inflow or outflow (e.g., PhDs born in the Netherlands and working there after the PhD degree) are not shown in the table.

Table 8. NUTS3 region of work of PhD graduates Apr 2008-Sep 2009 by type of pre-PhD degree university (%)

	Pre-PhD degree university			
	PhD university	Other Dutch university	Non-Dutch university	Total
Region of work		*%*		
NUTS3 region of pre-PhD university	34	29	11	27
Other Dutch NUTS3 region	46	57	21	43
Outside NL	20	14	68	30
Total	100	100	100	100
n	*516*	*373*	*290*	*1178*

n denotes the number of PhDs for whom the pre-PhD degree university and the region of the current job could be retrieved. Shares may not add up to 100 per cent because of rounding.